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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/183,734	03/14/2023	Mark J. Sarder	CET1090.104	4292
26629	7590	12/21/2023	EXAMINER	
ZIOLKOWSKI PATENT SOLUTIONS GROUP, SC (ZPS)			LATHERS, KEVIN ANTHONY	
136 S WISCONSIN ST			ART UNIT	
PORT WASHINGTON, WI 53074			PAPER NUMBER	
			3747	
DATE MAILED: 12/21/2023				

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. The United States Patent and Trademark Office (USPTO) collects the information in this record under authority of 35 U.S.C. 2. The USPTO's system of records is used to manage all applicant and owner information including name, citizenship, residence, post office address, and other information with respect to inventors and their legal representatives pertaining to the applicant's/owner's activities in connection with the invention for which a patent is sought or has been granted. The applicable Privacy Act System of Records Notice for the information collected in this form is COMMERCE/PAT-TM-7 Patent Application Files, available in the Federal Register at 78 FR 19243 (March 29, 2013).

<https://www.govinfo.gov/content/pkg/FR-2013-03-29/pdf/2013-07341.pdf>

Routine uses of the information in this record may include disclosure to:

- 1) law enforcement, in the event that the system of records indicates a violation or potential violation of law;
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- 4) the Department of Justice for determination of whether the Freedom of Information Act (FOIA) requires disclosure of the record;
- 5) a Member of Congress submitting a request involving an individual to whom the record pertains, when the individual has requested the Member's assistance with respect to the subject matter of the record;
- 6) a court, magistrate, or administrative tribunal, in the course of presenting evidence, including disclosures to opposing counsel in the course of settlement negotiations;
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- 8) another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c));
- 9) the Office of Personnel Management (OPM) for personnel research purposes; and
- 10) the Office of Management and Budget (OMB) for legislative coordination and clearance.

If you do not furnish the information requested on this form, the USPTO may not be able to process and/or examine your submission, which may result in termination of proceedings, abandonment of the application, and/or expiration of the patent.

Notice of Allowability	Application No. 18/183,734	Applicant(s) Sarder et al.	
	Examiner KEVIN A LATHERS	Art Unit 3747	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to terminal disclaimer filed 12/01/2023.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1-21. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some* c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. _____.

3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

* Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)	5. ☐ Examiner's Amendment/Comment
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.	6. ☒ Examiner's Statement of Reasons for Allowance
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.	7. ☐ Other _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.	

/KEVIN A LATHERS/ Primary Examiner, Art Unit 3747	
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DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Allowable Subject Matter

2. Claims 1-21 are allowed.

3. The following is an examiner's statement of reasons for allowance: The closest prior art fails to disclose or make obvious a dual fuel engine (i.e. an engine powered by two different fuels) which makes use of the specified fuel regulator system including an off-board fuel source, the system including a fuel lockout apparatus which can prevent a second fuel source from coupling to the fuel lines on the generator.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to KEVIN A LATHERS whose telephone number is (571)272-1050. The examiner can normally be reached M-F 10a-6p.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lindsay Low can be reached on 5712721196. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Art Unit: 3747

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: <https://patentcenter.uspto.gov>. Visit <https://www.uspto.gov/patents/apply/patent-center> for more information about Patent Center and <https://www.uspto.gov/patents/docx> for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/KEVIN A LATHERS/

Primary Examiner, Art Unit 3747

Search Notes 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

CPC - Searched*		
Symbol	Date	Examiner
F02D19/0673, 19/0647, 19/0605, 19/0613	09/24/2023	/K.L./

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
PE2E Search, EAST search, and Google search	09/24/2023	/K.L./
Applicant and inventor search	09/24/2023	/K.L./
PE2E Search	12/11/2023	/K.L./
Interference search	12/11/2023	/K.L./

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
F02D	19/0673, 19/0647, 19/0605, 19/0613	12/11/2023	/K.L./

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<i>Index of Claims</i> 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS										
☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47										
CLAIM		DATE								
Final	Original	09/24/2023	12/11/2023							
	1	✓	=							
	2	✓	=							
	3	✓	=							
	4	✓	=							
	5	✓	=							
	6	✓	=							
	7	✓	=							
	8	✓	=							
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	10	✓	=							
	11	✓	=							
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	14	✓	=							
	15	✓	=							
	16	✓	=							
	17	✓	=							
	18	✓	=							
	19	✓	=							
	20	✓	=							
	21		=							

Issue Classification 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

CPC						
Symbol					Type	Version
F02D	/	19	/	0613	F	2013-01-01
F02D	/	19	/	0605	I	2013-01-01
F02D	/	19	/	0647	I	2013-01-01
F02D	/	19	/	0673	I	2013-01-01
Y02T	/	10	/	30	A	2013-01-01

CPC Combination Sets					
Symbol				Type	Version
/	/				

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	21	
/KEVIN A LATHERS/ Primary Examiner, Art Unit 3747	11 December 2023	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	4A

<i>Issue Classification</i> 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

INTERNATIONAL CLASSIFICATION			
CLAIMED			
F02D19/06	/	19	/ 06

NON-CLAIMED			
/	/		

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	21	
/KEVIN A LATHERS/ Primary Examiner, Art Unit 3747 (Primary Examiner)	11 December 2023 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 4A

<i>Issue Classification</i> 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

☒ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47															
CLAIMS															
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		10		19										
	2		11		20										
	3		12		21										
	4		13												
	5		14												
	6		15												
	7		16												
	8		17												
	9		18												

NONE (Assistant Examiner) _____ (Date) _____		Total Claims Allowed: 21	
/KEVIN A LATHERS/ Primary Examiner, Art Unit 3747 (Primary Examiner) _____ (Date) 11 December 2023		O.G. Print Claim(s) 1	O.G. Print Figure 4A

PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	57	("3412258" "4287908" "4364370" "4416244" "4489699" "5555873" "5611312" "7954479" "9523497" "20070215223" "20100258099").pn.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:50 PM
L2	1402	F02D19/0613.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L3	2112	F02D19/0605.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L4	7150	F02D19/0647.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L5	435	F02D19/0673.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L6	6	(generator AND fuel AND regulator AND off-board AND stage AND line).clm.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:52 PM

PE2E SEARCH - Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
N1	1316	(L2 L3 L4 L5)	(US-PGPUB; USPAT)	OR	ON	ON	2023/12/11 03:46 PM
N2	4	(fuel ADJ lockout ADJ switch AND dual AND engine AND flow AND regulator AND valve).clm.	(US-PGPUB; USPAT)	OR	ON	ON	2023/12/11 03:46 PM

Bibliographic Data

Application No: 18/183,734

Foreign Priority claimed: ☐ Yes ☒ No

35 USC 119 (a-d) conditions met: ☐ Yes ☐ No ☐ Met After Allowance

Verified and Acknowledged: /KEVIN A LATHERS/

Examiner's Signature

Initials

Title: DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
03/14/2023	123	3747	
RULE			

APPLICANTS

Champion Power Equipment, Inc., Santa Fe Springs, CA, UNITED STATES

INVENTORS

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James J. Dehn, Brookfield, WI, UNITED STATES

Leigh Jenison, Hartland, WI, UNITED STATES

CONTINUING DATA

This application is a CON of 17937046 09/30/2022 PAT 11840970

17937046 is a CON of 16783455 02/06/2020 PAT 11492985

16783455 is a CON of 16191503 11/15/2018 PAT 11530654

16191503 is a CON of 14738060 06/12/2015 PAT 10221780

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

04/13/2023

** SMALL ENTITY **

STATE OR COUNTRY

UNITED STATES

ADDRESS

FILING FEE RECEIVED

\$664



ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
12/01/2023 05:38:57 PM Z ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Robyn Templin

PATENT CENTER # 63463318

FILING DATE 03/14/2023

CUSTOMER # 26629

FIRST NAMED INVENTOR Mark J. Sarder

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Jacob Fritz

Documents

TOTAL DOCUMENTS: 3

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
2023.12.01 Response.pdf	8	-	133 KB
2023.12.01 Response-A...pdf	(1-1) 1	Amendment/Request for Reconsideration-After Non-Final Rejection	101 KB
2023.12.01 Response-CLM.pdf	(2-6) 5	Claims	89 KB
2023.12.01 Response-REM.pdf	(7-8) 2	Applicant Arguments/Remarks Made in an Amendment	101 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
2023.12.01 Response.pdf	D8B0089945988ECB637FA134F2F4F611F5868ECA97301C99D3 74E12C06D53FED6848BB932E657A3CB996C9B72C5A2245C3C D440FCD0FAB8C9A64B198DE5A5945
2023.12.01 Response-A....pdf	B5F208850A06A5D3A978A1693AB30800374B764E94A3DB6D4A 0B6DAAE56F4306F61EAF53E16A5B79C7C6F094D7397A6584E 39BE3837FD6F7666BA7CF0499DD25
2023.12.01 Response-CLM.pdf	D123892E6EE7ACF24C2B89B0C933A278BB76EB5ED12C5AB5 5629D003C82D3E44BE6504AA24911C72C65B7B7F009C717904 93B1E3B7FEEB4325EB4876F9FB65A1
2023.12.01 Response-REM.pdf	6B00B4E7AA2D407504AD6532830ED2C630B72A18B654E83DF 9278DD54DA220FD21E264316FF85F009F66A9A78CACAE14B FFE8871F69B48452EBB943AB2AD47A

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Customer No. 26629
Confirmation No. 4292

Patent
Attorney Docket No. CET1090.104

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of : Sarder et al.
Serial No. : 18/183,734
Filed : March 14, 2023
For : DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE
Group Art No. : 3747
Examiner : Kevin A. Lathers

CERTIFICATION UNDER 37 C.F.R. §§1.8(a) AND 1.10

I hereby certify that, on the date shown below, this correspondence is being:

Mailing

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37 C.F.R. §1.8(a)

37 C.F.R. §1.10

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Transmission

☐ transmitted by facsimile to Fax No. 571-273-8300 addressed to Examiner Kevin A. Lathers at the Patent and Trademark Office.

☒ transmitted by Patent Center addressed to Examiner Kevin A. Lathers at the Patent and Trademark Office.

Date: December 1, 2023

Signature: /Robyn L. Templin/

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO OFFICE ACTION
MAILED SEPTEMBER 28, 2023

Dear Examiner Lathers:

Responsive to the Office Action mailed September 28, 2023, please consider the following
Remarks:

In the Claims

1. (Original) A mechanical fuel lockout switch for a dual fuel engine comprising:
a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line, the mechanical fuel valve configured to:
allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while in the first position, and
prevent communication between the first fuel source and the dual fuel engine while in the second position; and
a fuel lockout apparatus coupled to the mechanical fuel valve and configured to:
prevent the second fuel source from coupling to the second fuel line while the mechanical fuel valve is in the first position, and
permit the second fuel source to couple to the second fuel line while the mechanical fuel valve is in the second position.
2. (Original) The mechanical fuel lockout switch of claim 1 wherein the fuel lockout apparatus prevents actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.
3. (Original) The mechanical fuel lockout switch of claim 1 wherein the fuel lockout apparatus comprises a flange rigidly coupled to the mechanical fuel valve and configured to:
cover an inlet of the second fuel line while the mechanical fuel valve is in the first position, and
uncover the inlet of the second fuel line while the mechanical fuel valve is in the second position.
4. (Original) The mechanical fuel lockout switch of claim 3 wherein the mechanical fuel valve is configured to rotate between the first position and the second position and the flange is configured to rotate transversely across the inlet of the second fuel line.
5. (Original) The mechanical fuel lockout switch of claim 3 further comprising:

a first end of a quick-disconnect hose coupling attached to the inlet of the second fuel line; and

a second end of the quick-disconnect hose coupling configured to mate with the first end of the quick-disconnect hose coupling to couple the second fuel source to the second fuel line.

6. (Original) The mechanical fuel lockout switch of claim 1 wherein the mechanical fuel valve and the fuel lockout apparatus operate together to ensure that fuel from the first fuel source and fuel from the second fuel source are not simultaneously delivered to the dual fuel engine.

7. (Original) The mechanical fuel lockout switch of claim 6 wherein the mechanical fuel valve is configured to:

provide liquid fuel from a liquid fuel tank of the first fuel source to the dual fuel engine while in the first position, and

provide gaseous fuel from a pressurized fuel container of the second fuel source to the dual fuel engine while in the second position.

8. (Original) A mechanical fuel lockout switch for a dual fuel engine comprising:
a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line, the mechanical fuel valve configured to:

allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while the first position, and

prevent communication between the first fuel source and the dual fuel engine while in the second position; and

a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.

9. (Original) The mechanical fuel lockout switch of claim 8 wherein the fuel lockout apparatus comprises a flange rigidly coupled to the mechanical fuel valve and configured to:

cover an inlet of the second fuel line while the mechanical fuel valve is in the first position, and

uncover the inlet of the second fuel line while the mechanical fuel valve is in the second position.

10. (Original) The mechanical fuel lockout switch of claim 9 wherein the mechanical fuel valve is configured to rotate between the first position and the second position and the flange is configured to rotate transversely across the inlet of the second fuel line.

11. (Original) The mechanical fuel lockout switch of claim 9 further comprising:
a first end of a quick-disconnect hose coupling attached to the inlet of the second fuel line; and

a second end of the quick-disconnect hose coupling configured to mate with the first end of the quick-disconnect hose coupling to couple the second fuel source to the second fuel line.

12. (Original) The mechanical fuel lockout switch of claim 8 wherein the mechanical fuel valve and the fuel lockout apparatus operate together to ensure that fuel from the first fuel source and fuel from the second fuel source are not simultaneously delivered to the dual fuel engine.

13. (Original) The mechanical fuel lockout switch of claim 12 wherein the mechanical fuel valve is configured to:

provide liquid fuel from a liquid fuel tank of the first fuel source to the dual fuel engine while in the first position, and

provide gaseous fuel from a pressurized fuel container of the second fuel source to the dual fuel engine while in the second position.

14. (Original) A dual fuel generator and fuel delivery system comprising:
a dual fuel generator configured to operate on a liquid fuel supplied from a liquid fuel source through a liquid fuel line and a gaseous fuel supplied from a pressurized fuel source through a gaseous fuel line;

a fuel regulator system located off board the dual fuel generator, the fuel regulator system comprising:

a primary pressure regulator couplable to a service valve of the pressurized fuel source and configured to regulate the gaseous fuel supplied from the pressurized fuel source to a reduced pressure, and

a secondary pressure regulator couplable to the primary pressure regulator and configured to regulate the gaseous fuel supplied from the primary pressure regulator to a desired pressure for delivery through the gaseous fuel line to operate the dual fuel generator;

a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel generator from the liquid fuel source through the liquid fuel line and the pressurized fuel source through the gaseous fuel line, the mechanical fuel valve configured to open and close the liquid fuel line to selectively control fuel flow from the liquid fuel source to the dual fuel generator; and

a fuel lockout apparatus coupled to the mechanical fuel valve and configured to:
prevent the pressurized fuel source from coupling to the gaseous fuel line while the liquid fuel line is open, and

permit the pressurized fuel source to couple to the gaseous fuel line while the liquid fuel line is closed by the mechanical fuel valve.

15. (Original) The dual fuel generator and fuel delivery system of claim 14 wherein the fuel lockout apparatus is further configured to prevent the mechanical fuel valve from opening the liquid fuel line while the fuel regulator system is coupled to the gaseous fuel line.

16. (Original) The dual fuel generator and fuel delivery system of claim 14 wherein the fuel lockout apparatus comprises a fuel inlet cover that actuates with the mechanical fuel valve to cover an inlet of the gaseous fuel line while the liquid fuel line is open and to uncover the inlet of the gaseous fuel line when the liquid fuel line is closed.

17. (Original) The dual fuel generator and fuel delivery system of claim 14 further comprising:

a first end of a quick-connect hose coupling coupled to an outlet of the secondary pressure regulator; and

a second end of the quick-connect hose coupling coupled to an inlet of the gaseous fuel line and configured to mate with the first end of the quick-connect hose coupling to couple the secondary pressure regulator to the gaseous fuel line.

18. (Original) The dual fuel generator and fuel delivery system of claim 14 further comprising a regulator mounting device fixed to the pressurized fuel source; and
at least the secondary pressure regulator is mounted on the regulator mounting device.

19. (Original) The dual fuel generator and fuel delivery system of claim 18 wherein the primary pressure regulator is mounted on the regulator mounting device.

20. (Original) The dual fuel generator and fuel delivery system of claim 19 wherein the regulator mounting device is configured to attach onto a collar of a pressurized fuel container of the pressurized fuel source so that the primary and secondary pressure regulators are positioned adjacent each other along an outer periphery of the collar.

21. (Original) The dual fuel generator and fuel delivery system of claim 14 wherein:
the fuel regulator system comprises a dual stage pressure regulator; and
the primary and secondary pressure regulators are integral components of the dual stage pressure regulator.

REMARKS

Claims 1-21¹ are pending in the present application. In the Office Action mailed September 28, 2023, the Examiner provisionally rejected claims 1-21² on the ground of nonstatutory double patenting as being unpatentable over claims 1-52 of copending U.S. Application No. 17/937,046. *Office Action*, 09/28/2023, p. 3.

Responsive to the rejection, a properly executed eTerminal Disclaimer is being filed concurrently herewith to obviate the nonstatutory double patenting rejection. As such, Applicant respectfully requests withdrawal of the double patenting rejection of claims 1-21.

Therefore, in light of at least the foregoing, Applicant respectfully believes that the present application is in condition for allowance. As a result, Applicant respectfully requests timely issuance of a Notice of Allowance for claims 1-21.

Applicant appreciates the Examiner's consideration of these Remarks and cordially invites the Examiner to call the undersigned, should the Examiner consider any matters unresolved.

Respectfully submitted,

/Jacob M. Fritz/

Jacob M. Fritz
Registration No. 71,459
Phone 262-268-8100
jmf@zpatents.com

Dated: December 1, 2023
Attorney Docket No.: CET1090.104

P.O. ADDRESS:

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136 South Wisconsin Street
Port Washington, WI 53074
262-268-8100

¹ Page 1 of the Office Action incorrectly indicates that claims "1-20" are pending.

² The Office Action only indicates that the double patenting rejection applies to claims "1-20," but on October 31, 2023, the Examiner left a voicemail clarifying that the double patenting rejection applies to claim 21 as well.

General Authorization and Extension of Time

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§1.16-1.17, or credit any overpayment, to Deposit Account No. 50-2623. Should no proper payment be enclosed herewith, as by credit card authorization being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 50-2623. If any extensions of time are needed for timely acceptance of papers submitted herewith, Applicant hereby petitions for such extensions under 37 C.F.R. §1.136 and authorizes payment of any such extensions fees to Deposit Account No. 50-2623. Please consider this a general authorization to charge any fee that is due in this case, if not otherwise timely paid, to Deposit Account No. 50-2623.

/Jacob M. Fritz/

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Registration No. 71,459

Phone 262-268-8100

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Dated: December 1, 2023

Attorney Docket No.: CET1090.104

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PATENT AND TRADEMARK OFFICE**

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313 - 1450
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APPROVAL LETTER

APPLICATION #
18/183,734

FILING DATE
03/14/2023

APPLICANT/PATENT UNDER REEXAMINATION
Mark Sarder

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Electronic terminal disclaimer filed on 12/01/2023

☒ **Approved**

This patent is subject to a Terminal Disclaimer

Approved / Disapproved by: Electronic Terminal Disclaimer automatically approved



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ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
12/01/2023 05:25:34 PM Z ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Jacob Fritz

PATENT CENTER # 63462928

FILING DATE 03/14/2023

CUSTOMER # 26629

FIRST NAMED INVENTOR Mark J. Sarder

CORRESPONDENCE ADDRESS -

AUTHORIZED BY -

Documents

TOTAL DOCUMENTS: 2

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
petition-request.pdf	3	Terminal Disclaimer-Filed (Electronic)	49 KB
grantLetter.pdf	1	Terminal Disclaimer-Electronic- Approved	19 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
petition-request.pdf	5BA00D4B921774A930366CAFFDAA2E0CD5D990CF03BD8FBA D99BAD0C2602A55058E090AF68399077594CD64BEA8CAD974E

70DCF2A936B56D2C42ACDF07CBEF673

grantLetter.pdf

D3E20DF899B9EA0EA2F02E1CEAC5AF74F61DAEBF6E7AF471
EFF456B9356FE851ED3C20F4D3BFDE5383D6FEAAA15AEE6C
F7802F334D3EE332F4584A78355D78BD

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



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TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION

APPLICATION #
18183734

FILING DATE
03/14/2023

FIRST NAMED INVENTOR
Mark Sarder

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE



Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action



This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent interest
Champion Power Equipment, Inc.	100%
Total	100%

The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending reference Application Number(s)

Application #	Filing Date
17937046	09/30/2022

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent

granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of prior patent number(s)

Patent #

10221780

11530654

as the term of said prior patent is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the prior patent, "as the term of said prior patent is presently shortened by any terminal disclaimer," in the event that said prior patent later:

- expires for failure to pay a maintenance fee;
- is held unenforceable;
- is found invalid by a court of competent jurisdiction;
- is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
- has all claims canceled by a reexamination certificate;
- is reissued; or
- is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.



Terminal disclaimer fee under 37 CFR 1.20(d) included with Electronic Terminal Disclaimer request.

Applicant claims the following entity status:

Small

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I certify, in accordance with 37 CFR 1.4(d)(4) that I am: An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application

Signature	Name	Registration #
/Jacob M. Fritz/	Jacob Fritz	71459

* Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner). Form PTO/SB/96 may be used for making this certification. See MPEP 324.



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ELECTRONIC PAYMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
12/01/2023 05:25:34 PM Z ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Jacob Fritz

PATENT CENTER # 63462928

AUTHORIZED BY -

CUSTOMER # 26629

FILING DATE 03/14/2023

CORRESPONDENCE
ADDRESS -

FIRST NAMED
INVENTOR Mark J. Sarder

Payment Information

PAYMENT METHOD
CARD / 8631

PAYMENT TRANSACTION ID
E2023B1H26377233

PAYMENT AUTHORIZED BY
Jacob Fritz

FEE CODE	DESCRIPTION	ITEM PRICE(\$)	QUANTITY	ITEM TOTAL(\$)
2814	STATUTORY DISCLAIMER, INCLUDING TERMINAL DISCLAIMER	170.00	1	170.00
TOTAL AMOUNT:				\$170.00

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

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National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 18/183,734		Filing Date 03/14/2023		☐ To be Mailed		
ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO										
APPLICATION AS FILED - PART I										
		(Column 1)	(Column 2)							
FOR		NUMBER FILED	NUMBER EXTRA	RATE (\$)		FEE (\$)				
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A	N/A	N/A						
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A	N/A	N/A						
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A	N/A	N/A						
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =	*	x \$40 =						
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =	*	x \$ 192 =						
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).								
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))										
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL						
APPLICATION AS AMENDED - PART II										
		(Column 1)	(Column 2)	(Column 3)						
AMENDMENT	12/01/2023	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(i))	* 21	Minus	** 21	= 0	x \$40 =		0		
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0	x \$ 192 =		0		
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE		0		
		(Column 1)	(Column 2)	(Column 3)						
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)		
	Total (37 CFR 1.16(i))	*	Minus	**	=	x \$ 0 =				
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x \$ 0 =				
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))									
						TOTAL ADD'L FEE				
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.						PSS				
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".						/FIKIRTE A GEREMEW/				
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".										
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.										

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
18/183,734	03/14/2023	Mark J. Sarder	CET1090.104	4292
26629	7590	09/28/2023		
ZIOLKOWSKI PATENT SOLUTIONS GROUP, SC (ZPS)			EXAMINER	
136 S WISCONSIN ST			LATHERS, KEVIN ANTHONY	
PORT WASHINGTON, WI 53074				
			ART UNIT	PAPER NUMBER
			3747	
			NOTIFICATION DATE	DELIVERY MODE
			09/28/2023	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

info@zpatents.com
jmf@zpatents.com
lje@zpatents.com

Continuation of Disposition of Claims* 7) Claim(s) is/are rejected: /K.A.L/
Primary Examiner, Art Unit 37471-20

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Double Patenting

2. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the “right to exclude” granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159. See MPEP § 2146 *et seq.* for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The filing of a terminal disclaimer by itself is not a complete reply to a nonstatutory double patenting (NSDP) rejection. A complete reply requires that the terminal disclaimer be accompanied by a reply requesting reconsideration of the prior Office action. Even where the NSDP rejection is provisional the reply must be complete. See MPEP § 804, subsection I.B.1. For a reply to a non-final Office action, see 37 CFR 1.111(a). For a reply to final Office action, see 37 CFR 1.113(c). A request for reconsideration while not provided for in 37 CFR 1.113(c) may be filed after final for consideration. See MPEP §§ 706.07(e) and 714.13.

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit www.uspto.gov/patent/patents-forms. The actual filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to www.uspto.gov/patents/apply/applying-online/eterminal-disclaimer.

3. Claim 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-52 of copending Application No. 17/937,046 (reference application). Although the claims at issue are not identical, they are not patentably distinct from each other because the claims of the instant invention are fully disclosed within the claims of the copending application. It is noted that the independent claims pertain particularly to the fuel lockout switch of a dual fuel engine, including a mechanical fuel valve and fuel lockout apparatus, of claims 1 and 3-6 of the copending application.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Conclusion

4. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure: Pursifull et al (US 2011/0168133) discloses a dual fuel generator and its fuel delivery systems (Fig. 3, shown); and Sugimoto et al (US 2007/0137591) discloses a dual fuel engine delivery system (Fig. 1) which includes external fuel source power (¶ [0002]).

5. Any inquiry concerning this communication or earlier communications from the examiner should be directed to KEVIN A LATHERS whose telephone number is (571)272-1050. The examiner can normally be reached M-F 10a-6p.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lindsay Low can be reached on 5712721196. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of published or unpublished applications may be obtained from Patent Center. Unpublished application information in Patent Center is available to registered users. To file and manage patent submissions in Patent Center, visit: <https://patentcenter.uspto.gov>. Visit <https://www.uspto.gov/patents/apply/patent-center> for more information about Patent Center and <https://www.uspto.gov/patents/docx> for information about filing in DOCX format. For additional questions, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/KEVIN A LATHERS/
Primary Examiner, Art Unit 3747

<i>Notice of References Cited</i>	Application/Control No. 18/183,734		Applicant(s)/Patent Under Reexamination Sarder et al.	
	Examiner KEVIN A LATHERS		Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20110168133-A1	07-2011	Pursifull; Ross Dykstra	F02D19/0605	123/495
*	B	US-20070137591-A1	06-2007	Sugimoto; Yasuhiro	F02M21/06	123/527
	C					
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
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	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

<i>Search Notes</i> 	Application/Control No. 18/183,734	Applicant(s)/Patent Under Reexamination Sarder et al.
	Examiner KEVIN A LATHERS	Art Unit 3747

CPC - Searched*		
Symbol	Date	Examiner
F02D19/0673, 19/0647, 19/0605, 19/0613	09/24/2023	/K.L./

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
PE2E Search, EAST search, and Google search	09/24/2023	/K.L./
Applicant and inventor search	09/24/2023	/K.L./

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

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PE2E SEARCH - Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	British Equivalents	Time Stamp
L1	57	("3412258" "4287908" "4364370" "4416244" "4489699" "5555873" "5611312" "7954479" "9523497" "20070215223" "20100258099").pn.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:50 PM
L2	1402	F02D19/0613.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L3	2112	F02D19/0605.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L4	7150	F02D19/0647.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L5	435	F02D19/0673.cpc.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:51 PM
L6	6	(generator AND fuel AND regulator AND off-board AND stage AND line).clm.	(US-PGPUB; USPAT; USOCR; FIT (CN, FR, WO, JP, EP, KR); FPRS; EPO; JPO; DERWENT; IBM_TDB)	OR	ON	ON	2022/06/29 01:52 PM

PE2E SEARCH - Search History (Interference)

There are no Interference searches to show.



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
18/183,734	03/14/2023	Mark J. Sarder	CET1090.104

CONFIRMATION NO. 4292

26629
ZIOLKOWSKI PATENT SOLUTIONS GROUP, SC (ZPS)
136 S WISCONSIN ST
PORT WASHINGTON, WI 53074

PUBLICATION NOTICE



OC000000059854786

Date Mailed: 07/27/2023

Title:DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Publication No.US-2023-0235707-A1

Publication Date:07/27/2023

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently <https://portal.uspto.gov/pair/> PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
18/183,734	03/14/2023		704	CET1090.104	21	3

CONFIRMATION NO. 4292

26629

ZIOLKOWSKI PATENT SOLUTIONS GROUP, SC (ZPS)
136 S WISCONSIN ST
PORT WASHINGTON, WI 53074

FILING RECEIPT



0000000055996722

Date Mailed: 04/18/2023

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Mark J. Sarder, Waukesha, WI;
Aleko D. Sotiriades, Cedarburg, WI;
James J. Dehn, Brookfield, WI;
Leigh Jenison, Hartland, WI;

Applicant(s)

Champion Power Equipment, Inc., Santa Fe Springs, CA;

Power of Attorney: The patent practitioners associated with Customer Number 26629

Domestic Priority data as claimed by applicant

This application is a CON of 17/937,046 09/30/2022
which is a CON of 16/783,455 02/06/2020 PAT 11,492,985
which is a CON of 16/191,503 11/15/2018 PAT 11,530,654
which is a CON of 14/738,060 06/12/2015 PAT 10,221,780

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 04/13/2023

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 18/183,734**

Projected Publication Date: 07/27/2023

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

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Title 35, United States Code, Section 184
Title 37, Code of Federal Regulations, 5.11 & 5.15

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number
18/183,734

APPLICATION AS FILED - PART I

(Column 1)		(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	64		N/A	
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	280		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	320		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	21 minus 20 =	*	x 40 =	40	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x =	0			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	664		TOTAL	

APPLICATION AS AMENDED - PART II

(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
Total (37 CFR 1.16(i))	*	Minus **	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus ***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))						OR		
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						OR		
				TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)
Total (37 CFR 1.16(i))	*	Minus **	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus ***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))						OR		
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						OR		
				TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.



ELECTRONIC PAYMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
03/15/2023 01:51:53 PM ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Robyn Templin

PATENT CENTER # 61745235

AUTHORIZED BY Andrew Stark

CUSTOMER # 26629

FILING DATE -

CORRESPONDENCE
ADDRESS -

FIRST NAMED
INVENTOR Mark J. Sarder

Payment Information

PAYMENT METHOD
CARD / 4529

PAYMENT TRANSACTION ID
E20233ED52157202

PAYMENT AUTHORIZED BY
Robyn Templin

FEE CODE	DESCRIPTION	ITEM PRICE(\$)	QUANTITY	ITEM TOTAL(\$)
2202	EACH CLAIM IN EXCESS OF 20	40.00	1	40.00
TOTAL AMOUNT:				\$40.00

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National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. Petitioner MWE Investments, LLC, et al.
Exhibit 1003, Page 248

371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.



ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
03/15/2023 01:51:53 PM ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Robyn Templin

PATENT CENTER # 61745235

FILING DATE -

CUSTOMER # 26629

FIRST NAMED INVENTOR Mark J. Sarder

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Andrew Stark

Documents

TOTAL DOCUMENTS: 0

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
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Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
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New Applications Under 35 U.S.C. 111

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National Stage of an International Application under 35 U.S.C. 371

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Exhibit 1003, Page 250

371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	
Filing Date	
First Named Inventor	Mark J. Sarder
Title	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE
Art Unit	
Examiner Name	
Attorney Docket Number	CET1090.104

SIGNATURE of Applicant or Patent Practitioner

Signature	/Andrew C. Stark/	Date (Optional)	2023-03-14
Name	Andrew C. Stark	Registration Number	65742
Title (if Applicant is a juristic entity)	Patent Practitioner		
Applicant Name (if Applicant is a juristic entity)	Champion Power Equipment, Inc.		

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.



*Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**



ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
03/14/2023 05:13:59 PM ET

ATTORNEY DOCKET #
CET1090.104

Title of Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

Application Information

APPLICATION TYPE Utility - Nonprovisional Application
under 35 USC 111(a)

PATENT # -

CONFIRMATION # 4292

FILED BY Robyn Templin

PATENT CENTER # 61740290

FILING DATE -

CUSTOMER # 26629

FIRST NAMED
INVENTOR Mark J. Sarder

CORRESPONDENCE
ADDRESS -

AUTHORIZED BY Andrew Stark

Documents

TOTAL DOCUMENTS: 6

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
2023.03.14 ADS.pdf	9	Application Data Sheet	1196 KB
2023.03.14 Pat App- APP.TEXT.docx	26	Application body structured text document	50 KB
2023.03.14 Declaration.pdf	4	Oath or Declaration filed	1236 KB
2023.03.14 Drawings.pdf	5	Drawings-only black and white line drawings	3015 KB
2023.03.14 POA Transmittal.pdf	1	Power of Attorney	151 KB
2023.03.14 General POA.pdf	1	Power of Attorney	532 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
2023.03.14 ADS.pdf	2D383703CDD63A26BCBA27E93FD3B0AAABD631A22E23B9F6 EFD6172F2B256383A29C9E322588D96F5721005556370FFD85 6B9F4165F8B28A41CAC1118EF1AFBD
2023.03.14 Pat App- APP.TEXT.docx	0427F18590B362A544F6E3DF9F4EA54B3F1553A224B09C973F 37A14C95294B4D3DB651B228142595DDBE87AE18C9E37C115 E4C1BC8F35D48E3E7FE21E55597C6
2023.03.14 Declaration.pdf	775566D511699E66D2BAE31D262802794588C84CC180F4D26F 27D91ED5F242A25DCFB54490130BD56BBA46EFA1653B9BF8 317FD9A09251DDCD72F5E305084D0
2023.03.14 Drawings.pdf	DC66E7047F64747774BA69914C05097B8C010649F2D4C5F27E 85DCBD6BA012B9B496103726C3FE25673D990C85C1A3AA071 3C2E67474ED9994E81A717399A55A
2023.03.14 POA Transmittal.pdf	544A1E9D22A41E0D033C150FODFABEE725A441936991B2ED2 277AC66309D58BD6533570F08FFBF1D6F920896F9DAE6B0B3 73C5CFA3F69AFD820046604017050D
2023.03.14 General POA.pdf	EEE57956C00EA36439F3ECE88A916468E3E89FD7148120590B EA9FD6029EA56802800079ABA1694B6C5ACAAE418CC562026 80338D97979D157FAA73230CFFEB7

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New International Application Filed with the USPTO as a Receiving Office

Petitioner MWE Investments, LLC, et al.
Exhibit 1003, Page 254

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--------------------------	---

Inventor Information:

Inventor	1				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Mark	J.	Sarder		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Waukesha	State/Province	WI	Country of Residence	US

Mailing Address of Inventor:

Address 1	208 Oxford Rd				
Address 2					
City	Waukesha	State/Province	WI		
Postal Code	53186	Country	US		

Inventor	2				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Aleko	D.	Sotiriades		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Cedarburg	State/Province	WI	Country of Residence	US

Mailing Address of Inventor:

Address 1	W245 N5551 S Corp. Circle				
Address 2					
City	Sussex	State/Province	WI		
Postal Code	53089	Country	US		

Inventor	3				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	James	J.	Dehn		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					

Petitioner MWF Investments, LLC, et al

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

City	Brookfield	State/Province	WI	Country of Residence	US
------	------------	----------------	----	----------------------	----

Mailing Address of Inventor:

Address 1	W245 N5551 S Corp. Circle				
Address 2					
City	Sussex	State/Province	WI		
Postal Code	53089	Country	US		
Inventor	4				Remove
Legal Name					

Prefix	Given Name	Middle Name	Family Name	Suffix
	Leigh		Jenison	

Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Hartland	State/Province	WI	Country of Residence	US

Mailing Address of Inventor:

Address 1	W245 N5551 S Corp. Circle				
Address 2					
City	Sussex	State/Province	WI		
Postal Code	53089	Country	US		
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.					

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence information of this application.			
Customer Number	26629		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		
Attorney Docket Number	CET1090.104	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not be** the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	26629		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending	Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	17937046	2022-09-30

Application Data Sheet 37 CFR 1.76		Attorney Docket Number		CET1090.104	
		Application Number			
Title of Invention		DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE			

Prior Application Status		Patented		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
17937046	Continuation of	16783455	2020-02-06	11492985	2022-11-08

Prior Application Status		Patented		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
16783455	Continuation of	16191503	2018-11-15	11530654	2022-12-20

Prior Application Status		Patented		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
16191503	Continuation of	14738060	2015-06-12	10221780	2019-03-05

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.					
---	--	--	--	--	--

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove			
Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the Add button.			
--	--	--	--

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. ☐ NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.
--

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant	1	Remove
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. Clear		
☒ Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
Person to whom the inventor is obligated to assign.		Person who shows sufficient proprietary interest
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:		
Name of the Deceased or Legally Incapacitated Inventor:		
If the Applicant is an Organization check here. ☒		
Organization Name	Champion Power Equipment, Inc.	
Mailing Address Information For Applicant:		
Address 1	12039 Smith Avenue	
Address 2		
City	Santa Fe Springs	State/Province
Country	US	Postal Code
Phone Number		Fax Number
Email Address		
Additional Applicant Data may be generated within this form by selecting the Add button. Add		

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

Assignee	1			
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
				Remove
If the Assignee or Non-Applicant Assignee is an Organization check here.				☐
Prefix	Given Name	Middle Name	Family Name	Suffix
Mailing Address Information For Assignee including Non-Applicant Assignee:				
Address 1				
Address 2				
City		State/Province		
Country ⁱ		Postal Code		
Phone Number		Fax Number		
Email Address				
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.				Add

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Andrew C. Stark/		Date (YYYY-MM-DD)	2023-03-14
First Name	Andrew C.	Last Name	Stark	Registration Number
				65742
Additional Signature may be generated within this form by selecting the Add button.				Add

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.104
		Application Number	
Title of Invention	DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

- 1 The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
- 2 A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
- 3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
- 4 A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
- 5 A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
- 6 A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
- 7 A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
- 8 A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
- 9 A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

As the below named inventor, I hereby declare that:

This declaration
is directed to:



The attached application, or



United States application or PCT international application number _____
filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

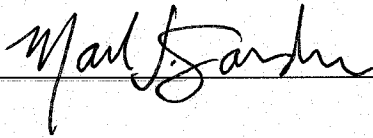
Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Mark J. Sarder

Date (Optional):

Signature:



Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

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This declaration
is directed to:



The attached application, or



United States application or PCT international application number _____
filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

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LEGAL NAME OF INVENTOR

Inventor: Aleko D. Sotiriades

Date (Optional): _____

Signature: _____

Aleko Sotiriades

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

As the below named inventor, I hereby declare that:

This declaration
is directed to:



The attached application, or



United States application or PCT international application number _____
filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

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LEGAL NAME OF INVENTOR

Inventor: James J. Dehn

Date (Optional): 6/12/2015

Signature:

James J. Dehn

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of
Invention

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

As the below named inventor, I hereby declare that:

This declaration ☒ The attached application, or
is directed to:

☐ United States application or PCT international application number _____
filed on _____

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

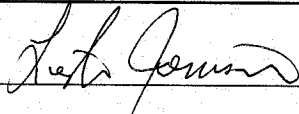
Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Leigh Jenison

Date (Optional): 6.12.2015

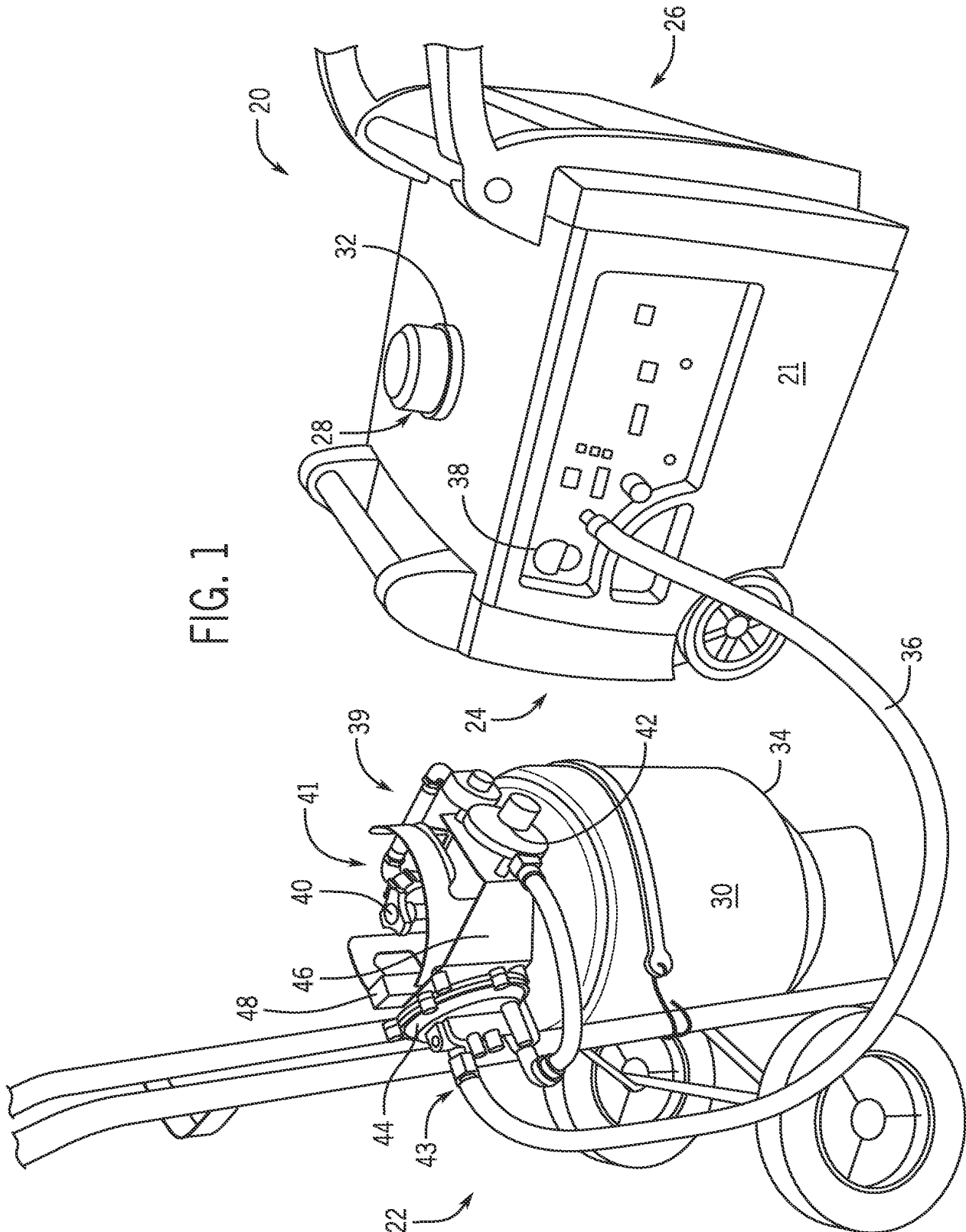
Signature:



Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.

1 / 5

FIG. 1



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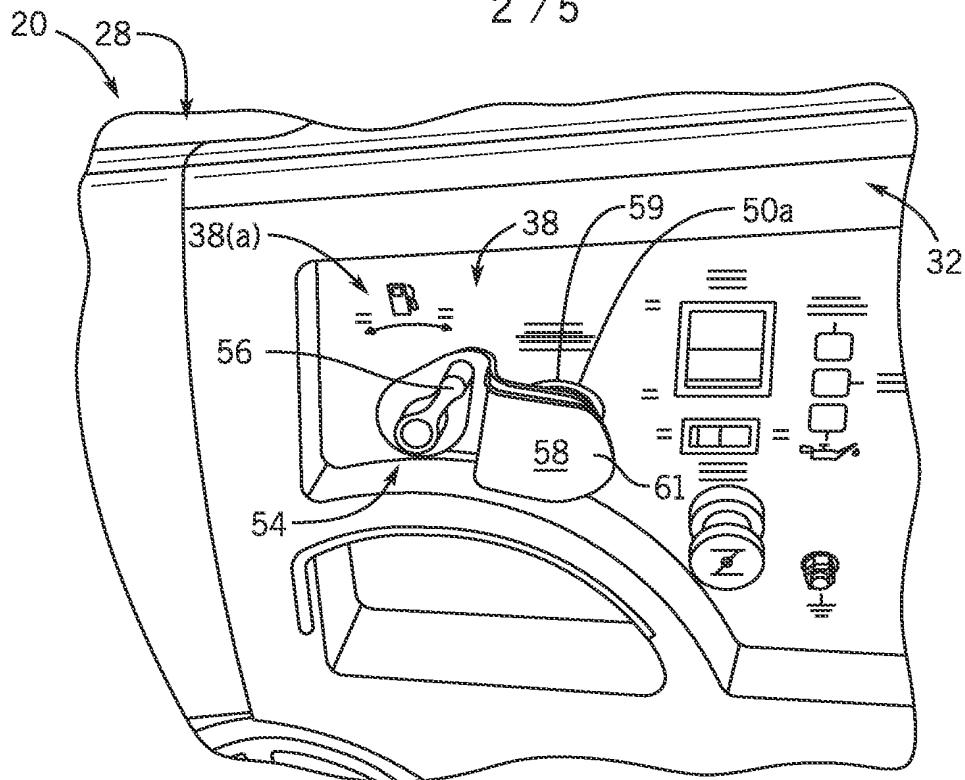


FIG. 2

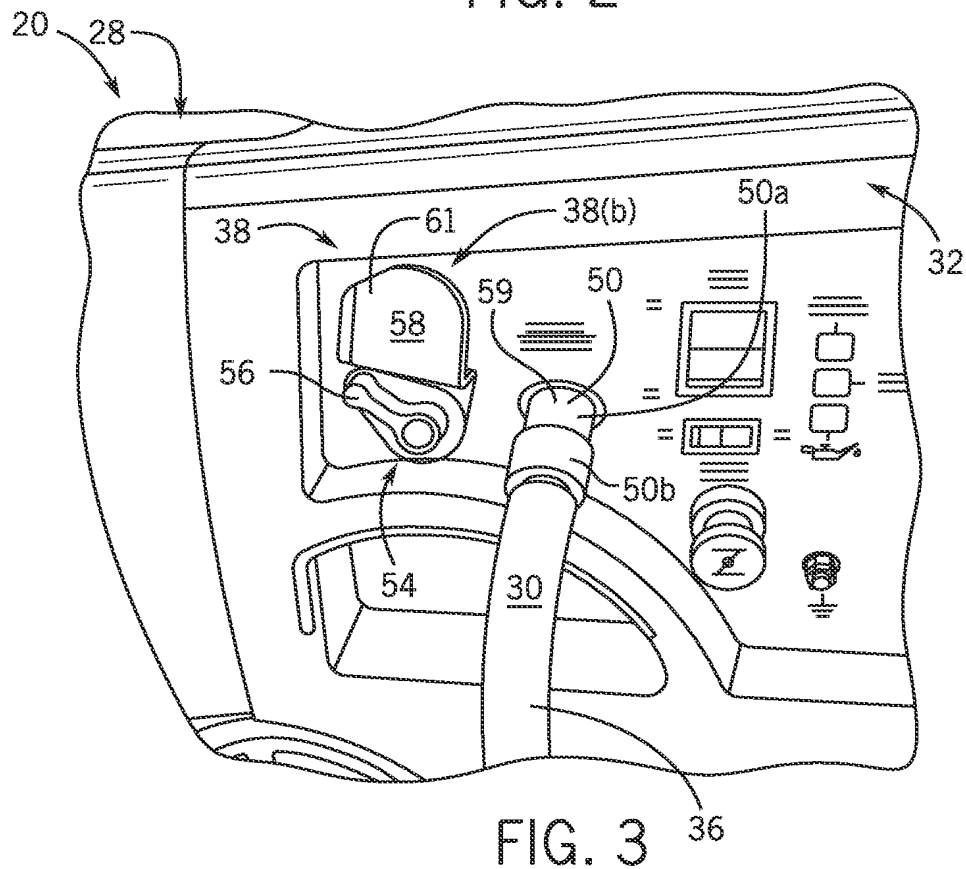


FIG. 3

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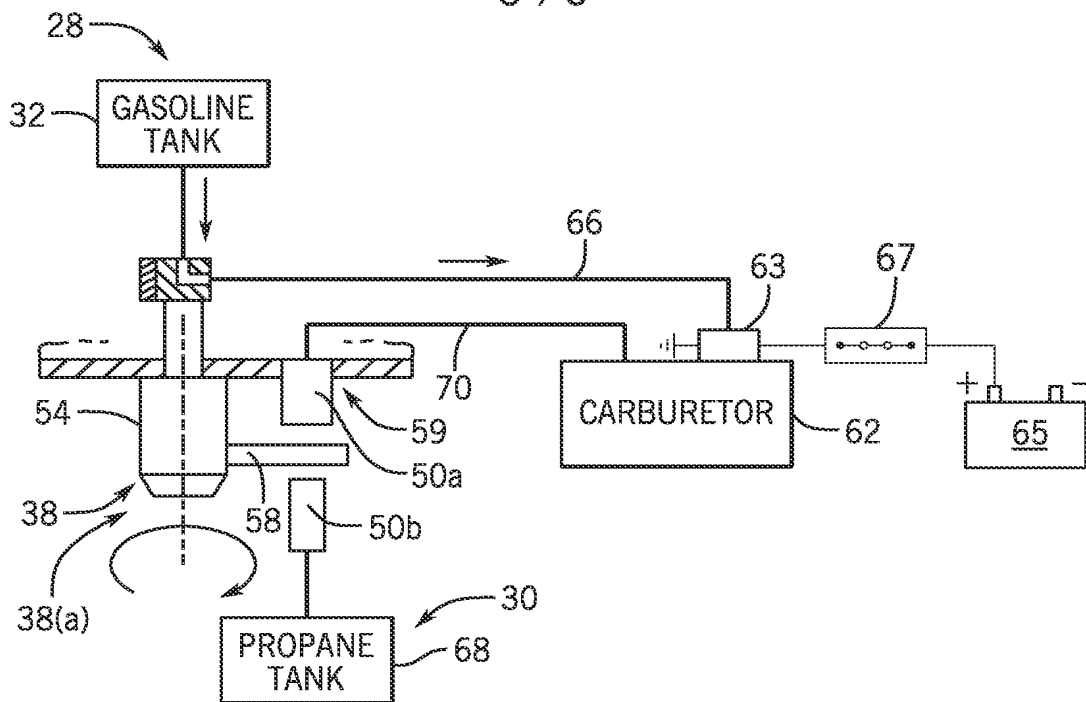


FIG. 4A

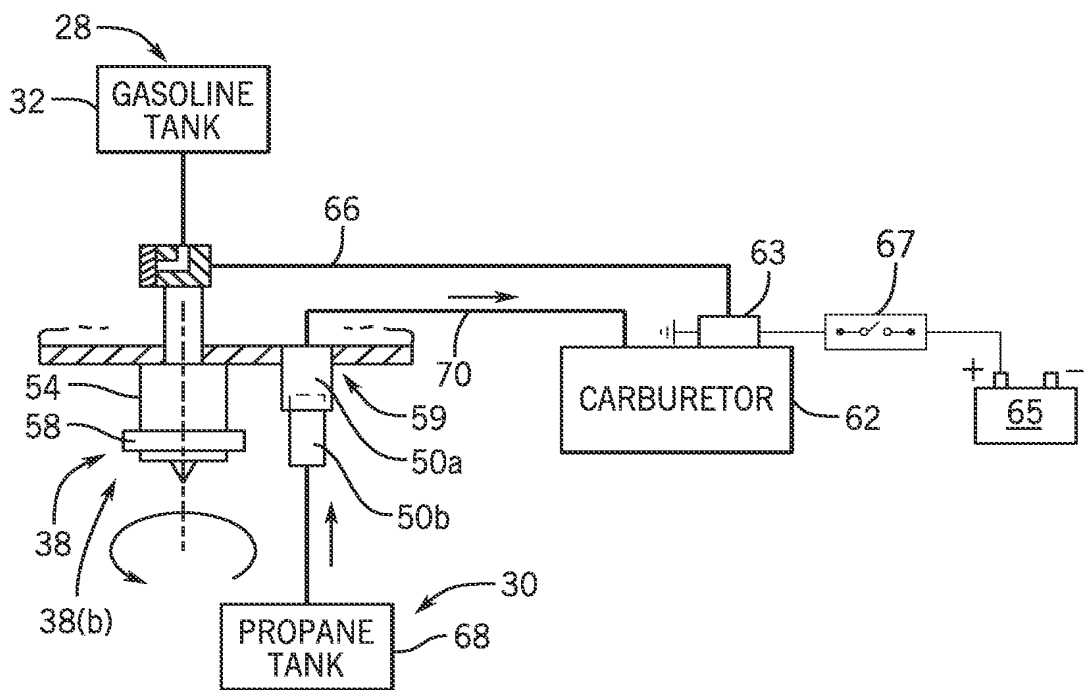


FIG. 4B

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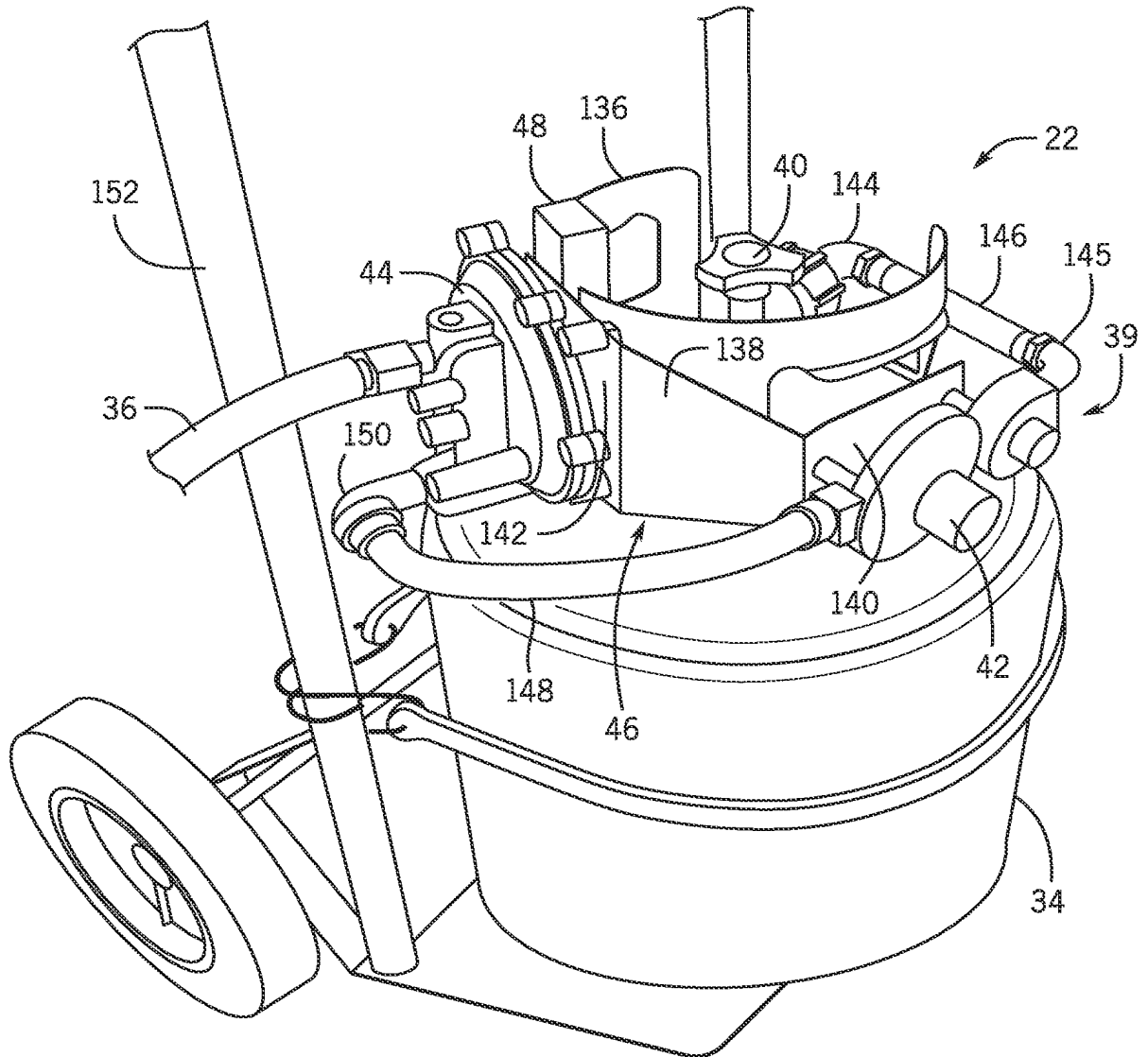


FIG. 5

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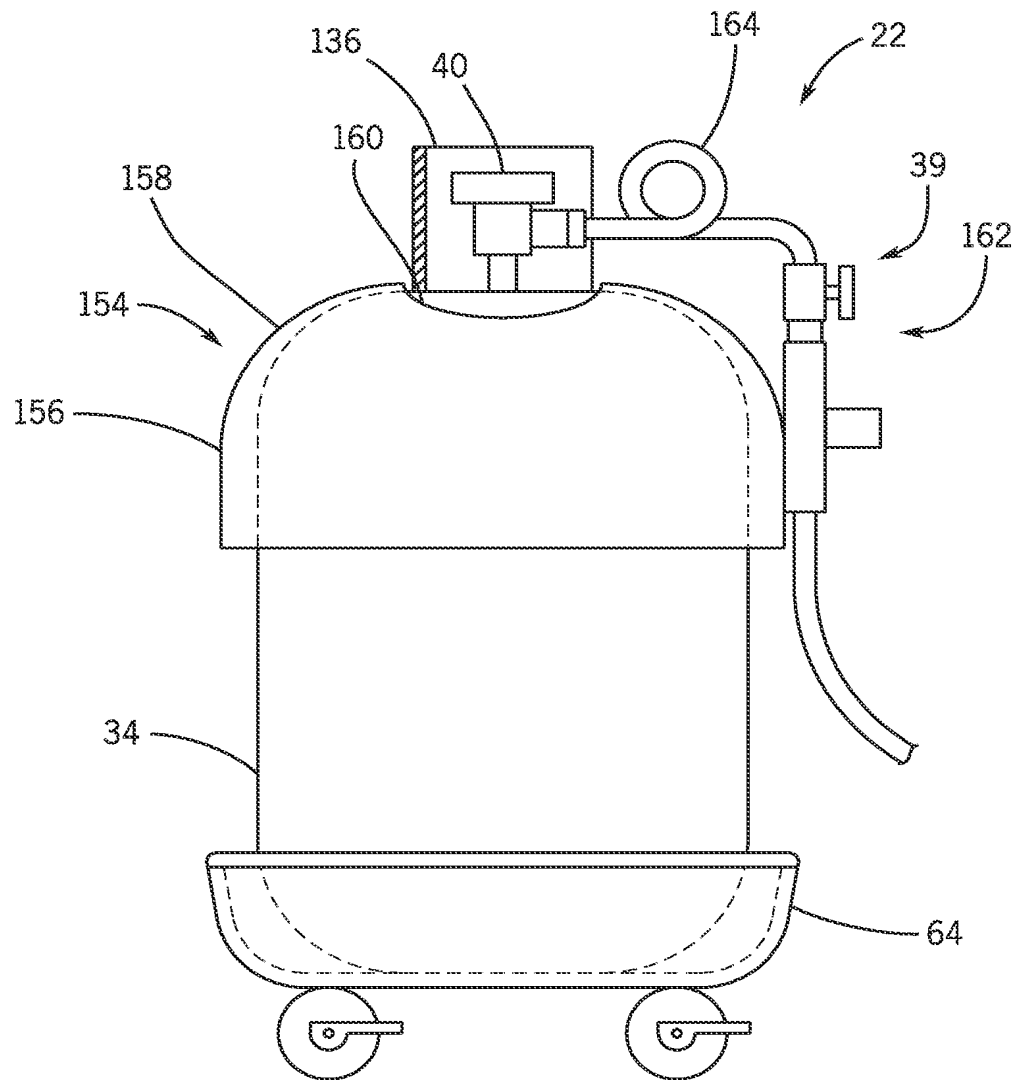


FIG. 6



ELECTRONIC PAYMENT RECEIPT

APPLICATION #
18/183,734

RECEIPT DATE / TIME
03/14/2023 05:13:59 PM ET

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CET1090.104

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DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

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FILING DATE -

CORRESPONDENCE
ADDRESS -

FIRST NAMED
INVENTOR Mark J. Sarder

Payment Information

PAYMENT METHOD
CARD / 4529

PAYMENT TRANSACTION ID
E20233DH16488073

PAYMENT AUTHORIZED BY
Robyn Templin

FEE CODE	DESCRIPTION	ITEM PRICE(\$)	QUANTITY	ITEM TOTAL(\$)
2111	UTILITY PATENT APPL. SEARCH FEE	280.00	1	280.00
4011	BASIC FILING FEE- UTILITY	64.00	1	64.00
2311	EXAMINATION OF ORIGINAL PATENT APPLICATION	320.00	1	320.00
TOTAL AMOUNT:				\$664.00

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If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

DUAL FUEL LOCKOUT SWITCH FOR GENERATOR ENGINE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation of, and claims priority to, U.S. Patent Application Serial No. 17/937,046, filed on September 30, 2022, which is a continuation of, and claims priority to, U.S. Patent Application Serial No. 16/783,455, filed on February 6, 2020, now U.S. Patent No. 11,492,985, which is a continuation of, and claims priority to, U.S. Patent Application Serial No. 16/191,503, filed on November 15, 2018, now U.S. Patent No. 11,530,654, which is a continuation of, and claims priority to, U.S. Patent Application Serial No. 14/738,060, filed on June 12, 2015, now U.S. Patent No. 10,221,780, the disclosures of which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] Embodiments of the invention relate generally to dual fuel generators, and more particularly, to an apparatus and method for delivering liquid fuel and gaseous fuel to a dual fuel generator.

[0003] Electric generators are frequently driven by internal combustion engines that use gasoline as a fuel source. Gasoline is a common fuel source for generators in a variety of applications. However, alternative fuel sources also provide a desirable fuel source. For instance, alternative fuels may provide a clean burning fuel that limits hazardous emissions. Alternative fuels may also be stored for long periods of time without degradation, whereas gasoline can degrade over a period of months leading to hard starting, rough running, and also lead to gum and varnish deposit left in the fuel system. In addition, generators that operate on alternative fuels may generate electricity when gasoline is not readily available. For instance, generators are frequently used when power outages in the utility grid result from severe weather. Unfortunately, gas stations may also be closed as a result of the power outage. Such a circumstance presents just one example where it would be advantageous to operate electrical generators on alternative fuels.

[0004] Certain generators are configured to operate as “dual fuel” generators, otherwise known as bi-fuel generators. These generators are driven by an internal combustion engine that is configured to operate on a liquid fuel for a period of operation and an alternative fuel for another period of operation. The alternative fuel source may exist in a gaseous state at normal temperature and pressure and can be any one of liquefied petroleum gas, compressed natural gas, hydrogen, or the like. Liquefied petroleum gas (LPG), often referred to as propane, exists in a gaseous state at normal temperature and pressure but can be conveniently stored under pressure in a liquid state. LPG may be a desirable fuel source for internal combustion engines because it can be stored for longer periods of time and contains fewer impurities than gasoline, resulting in smoother and cleaner operation, and often resulting in a longer lasting engine.

[0005] In order to provide the liquid and gaseous fuel to the engine, the dual fuel engine may have a first fuel line for liquid fuel and a second fuel line for gaseous fuel. A liquid fuel source and a gaseous fuel source may be coupled to the respective lines to provide fuel to the engine. However, a common problem with such configurations that couple two fuel sources to a single engine is the engine can experience overly rich air-fuel ratio when both fuels are simultaneously engaged during cross-over switching between the fuel sources. Further, such simultaneous delivery of fuel from the first fuel line and the second fuel line may make the engine hard to start or lead to unstable operating conditions.

[0006] Therefore, it would be desirable to design a dual fuel generator having a liquid fuel and gaseous fuel delivery system that overcomes the aforementioned detriments without substantially increasing the overall cost of the system.

BRIEF DESCRIPTION OF THE INVENTION

[0007] In accordance with one aspect of the invention, a mechanical fuel lockout switch for a dual fuel engine includes a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line. The mechanical fuel valve may be configured to allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while in the first position, and prevent communication between the first fuel source and the dual fuel engine while in the second position. The mechanical fuel lockout switch may also include a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent the second fuel source from coupling to the second fuel line while the mechanical fuel valve is in the first position, and permit the second fuel source to couple to the second fuel line while the mechanical fuel valve is in the second position.

[0008] In accordance with another aspect of the invention, a mechanical fuel lockout switch for a dual fuel engine includes a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line. The mechanical fuel valve may be configured to allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while the first position, and prevent communication between the first fuel source and the dual fuel engine while in the second position. The mechanical fuel lockout switch may also include a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.

[0009] In accordance with yet another aspect of the invention, a dual fuel generator and fuel delivery system includes a dual fuel generator configured to operate on a liquid fuel supplied from a liquid fuel source through a liquid fuel line and a gaseous fuel supplied from a pressurized fuel source through a gaseous fuel line, and a fuel regulator

system located off board the dual fuel generator. The fuel regulator system may include a primary pressure regulator couplable to a service valve of the pressurized fuel source and configured to regulate the gaseous fuel supplied from the pressurized fuel source to a reduced pressure, and a secondary pressure regulator couplable to the primary pressure regulator and configured to regulate the gaseous fuel supplied from the primary pressure regulator to a desired pressure for delivery through the gaseous fuel line to operate the dual fuel generator. The dual fuel generator and fuel delivery system may also include a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel generator from the liquid fuel source through the liquid fuel line and the pressurized fuel source through the gaseous fuel line, the mechanical fuel valve configured to open and close the liquid fuel line to selectively control fuel flow from the liquid fuel source to the dual fuel generator. A fuel lockout apparatus may couple to the mechanical fuel valve configured to prevent the pressurized fuel source from coupling to the gaseous fuel line while the liquid fuel line is open, and permit the pressurized fuel source to couple to the gaseous fuel line while the liquid fuel line is closed by the mechanical fuel valve.

[0010] Various other features and advantages will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The drawings illustrate preferred embodiments presently contemplated for carrying out the invention.

[0012] In the drawings:

[0013] FIG. 1 is a perspective view of a dual fuel generator coupled to a fuel delivery system, according to an embodiment of the invention.

[0014] FIG. 2 is a detail view of a portion of the generator of FIG. 1 about a mechanical fuel lockout switch with the switch in a first position, according to an embodiment of the invention.

[0015] FIG. 3 is a detail view similar to FIG. 2 and showing the mechanical fuel lockout switch in a second position, with an LPG supply line connected thereto, according to an embodiment of the invention.

[0016] FIG. 4A is a schematic diagram of a fuel system for the dual fuel generator of FIG. 1 showing a liquid fuel source in communication with a carburetor of the generator consistent with the first position of the switch as shown in FIG. 2, according to an embodiment of the invention.

[0017] FIG. 4B is a schematic diagram of the fuel system of FIG. 4A showing a gaseous fuel source in communication with a carburetor of the generator of FIG. 1 consistent with the second position of the switch as shown in FIG. 3, according to an embodiment of the invention.

[0018] FIG. 5 is a perspective view of a fuel delivery system for the dual fuel generator of FIG. 1, according to an embodiment of the invention.

[0019] FIG. 6 is a side view of a fuel delivery system for the dual fuel generator of FIG. 1, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0020] The operating environment of the invention is described with respect to a dual fuel generator. However, it will be appreciated by those skilled in the art that the invention is equally applicable for use with any dual fuel internal combustion engine. Moreover, the invention will be described with respect to a dual fuel generator configured to operate on a liquid fuel and a gaseous fuel. However, one skilled in the art will further appreciate that the invention is equally applicable for use with other fuel combinations for dual fuel generators and internal combustion engines.

[0021] Referring to FIG. 1, a dual fuel generator 20 is coupled to a fuel delivery system 22, in accordance with an embodiment of the invention. Dual fuel generator 20 includes an internal combustion engine (not shown) within housing 21 at one end 24, operatively connected to an alternator also enclosed in housing 21 at another end 26, by conventional means. Dual fuel generator 20 is configured to operate on different fuels via either a first fuel source 28 or a second fuel source 30. In an exemplary embodiment of the invention, first fuel source 28 is a liquid fuel and second fuel source 30 is a gaseous fuel. The liquid fuel may be gasoline and the gaseous fuel may be liquid petroleum gas (LPG). Each can selectively operate the generator as desired and controlled by an operator. For instance, generator 20 may operate on gasoline for a first period of operation and then switch to LPG for a second period of operation. However, it is contemplated that dual fuel generator 20 is configured to operate on fuels other than gasoline and LPG (e.g., natural gas, biodiesel, etc.), and thus the scope of the invention is not meant to be limited strictly to a dual fuel arrangement where first fuel source 28 provides gasoline and second fuel source 30 provides LPG.

[0022] In one embodiment of the invention, dual fuel generator 20 includes a gasoline tank 32 or, generally, a liquid fuel tank, located inside cover 21 onboard generator 20 to provide gasoline to the engine as first fuel source 28. Gasoline tank 32 connects to a first fuel line to provide gasoline to the carburetor to run the engine, as will later be described with reference to FIG. 4A and 4B. Generator 20 is also coupled to a pressurized fuel container 34, or a pressurized fuel source, located off board

generator 20 to provide LPG to the engine as second fuel source 30. Pressurized fuel container 34 is coupled to generator 20 with an LPG supply hose 36. LPG supply hose 36 is coupled to a second fuel line within generator 20 to provide LPG to the carburetor to run the engine. Dual fuel generator 20 includes a mechanical fuel lockout switch 38 for selecting a desired fuel to be provided to the engine. The mechanical fuel lockout switch 38 is actuated to select first fuel source 28 when in a first position, as shown in FIG. 2, and alternately to select second fuel source 30 when in a second position, as shown in FIG. 3.

[0023] Referring back to FIG. 1, in an exemplary embodiment, fuel 30 from pressurized fuel container 34 is regulated using a fuel regulator system 39 for delivery to the engine. Fuel regulator system 39 includes one or more pressure regulators that reduce and control the pressure of the fuel from pressurized fuel container 34 and delivers fuel at a desired pressure for operation of the engine. Fuel regulator system 39 has an inlet 41 operatively coupled to a service valve 40 of pressurized fuel container 34 and an outlet 43 coupled to LPG supply hose 36. Fuel regulator system 39 includes a primary pressure regulator 42 coupled to pressurized fuel container 34 and a secondary pressure regulator 44. Primary pressure regulator 42 protects downstream components from high pressure of pressurized fuel container 34. Primary pressure regulator 42 receives LPG through service valve 40 of pressurized fuel container 34 and reduces the pressure of the LPG to a first stage. In one embodiment of the invention, the first stage may be delivered directly to generator 20 at a pressure required for operation of the engine.

[0024] In an exemplary embodiment of the invention, fuel regulator system 39 includes secondary pressure regulator 44 coupled to the outlet of primary pressure regulator 42 in order to use standard “off-the-shelf” components. Typically, the primary pressure regulator is mounted on the LPG tank, while the secondary pressure regulator is mounted on the component using the fuel, such as an engine or grill. Here, since generator 20 can be used as a gasoline only generator, secondary pressure regulator 44 is mounted off-board the generator to reduce size and cost of the generator. Secondary pressure regulator 44 receives LPG from primary pressure regulator 42 and further

reduces the pressure of LPG to a second stage to be delivered to generator 20. In a system with two regulators, primary pressure regulator 42 regulates fuel received from pressurized fuel container 34 and reduces the pressure of the fuel to a level required for operation of secondary pressure regulator 44. Secondary pressure regulator 44 regulates fuel received from primary pressure regulator 42 and further reduces the pressure of the fuel to a level required for operation of generator 20. In addition, primary pressure regulator 42 may compensate for varying tank pressure as fuel is depleted while secondary pressure regulator 44 may compensate for varying demand from generator 20.

[0025] In accordance with an exemplary embodiment of the invention, fuel regulator system 39 includes both the primary and secondary regulators, or a custom single regulator, but in any case is located remotely, or off-board, from dual fuel generator 20. Fuel regulator system 39 may be directly mounted to pressurized fuel container 34 using a regulator mounting bracket 46. Regulator mounting bracket 46 has mounting locations for primary pressure regulator 42 and secondary pressure regulator 44. Regulator mounting bracket 46 also has a securing mechanism 48 to secure regulator mounting bracket 46 to pressurized fuel container 34.

[0026] In another embodiment of the invention, primary pressure regulator 42 is mounted on regulator mounting bracket 46 while secondary pressure regulator 44 could be mounted on or near generator 20. In yet another embodiment of the invention, a dual stage regulator may regulate the fuel received from pressurized fuel container 34 and deliver fuel at a pressure required for operation of generator 20. Such a dual stage regulator may regulate the fuel to the second stage within a single structure. The dual stage regulator may be mounted directly on fuel container 34.

[0027] Referring to FIG. 2, a detail view of a portion of generator 20 of FIG. 1 depicts mechanical fuel lockout switch 38 in a first position 38(a), in accordance with an embodiment of the invention. In this position, mechanical fuel lockout switch 38 provides gasoline flow from gasoline tank 32 to the engine while preventing connection of an LPG supply line to fuel inlet 59 of the second fuel line, as will later be discussed

in detail with reference to FIGS. 4A and 4B. Still referring to FIG. 2, mechanical fuel lockout switch 38 provides a combination liquid fuel shutoff valve and a gaseous fuel supply lockout that prevents simultaneous delivery of fuel to the engine from gasoline tank 32 and pressurized fuel container 34, FIG. 1. As such, mechanical fuel lockout switch 38 provides a fuel selector to ensure only the selected fuel is provided to dual fuel generator 20.

[0028] Mechanical fuel lockout switch 38, FIG. 2, includes mechanical fuel valve 54 actuatable between first position 38(a) as shown in FIG. 2 and second position 38(b) as shown in FIG. 3 to selectively control fuel flow to the dual fuel engine from first fuel source 28 through a first fuel line and second fuel source 30 through a second fuel line 36. Mechanical fuel lockout switch 38 may also include fuel lockout apparatus 58 coupled to mechanical fuel valve 54 to communicate fuel sources individually to generator 20. In one embodiment of the invention, fuel lockout apparatus 58 communicates first fuel source 28 to the engine by actuating mechanical fuel valve 54 to first position 38(a) to open the first fuel line as shown in FIG. 2, and communicates second fuel source 30 to the engine by actuating mechanical fuel valve 54 to second position 38(b) to open communication of the second fuel source 30 to the engine as shown in FIG. 3. Referring back to FIG. 2, when mechanical fuel valve 54 is in first position 38(a), fuel lockout apparatus 58 communicates first fuel source 28 to the dual fuel engine and prevents communication between the second fuel source and the dual fuel engine.

[0029] In an exemplary embodiment of the invention, mechanical fuel valve 54 controls the flow of LPG to the engine by actuating fuel lockout apparatus 58 to block or unblock fuel inlet 59 for the second fuel source. Mechanical fuel valve 54 is coupled to the first fuel line, as shown in FIGS. 4A and 4B, and therefore can control the flow of gasoline to the engine by opening and closing the first fuel line. When the mechanical fuel valve 54, FIG. 2, is in the first position 38(a), gasoline flows from the gasoline tank to the engine and the fuel lockout apparatus 58 blocks the fuel inlet 59. Accordingly, fuel lockout apparatus 58 prevents LPG flow to generator 20 when the mechanical fuel valve 54 is in first position 38(a) wherein the engine is operated on gasoline.

[0030] Mechanical fuel valve 54 includes a fuel valve handle 56 to control the opening and closing of the valve. Fuel valve handle 56 is movable between first position 38(a) as shown in FIG. 2 and second position 38(b) as shown in FIG. 3. Mechanical fuel valve 54 opens the first fuel line (to enable liquid fuel flow to the engine) when fuel valve handle 56 is in the first position, and mechanical fuel valve 54 closes the first fuel line (to prevent liquid fuel flow to the engine) when fuel valve handle 56 is in the second position. Thus, when fuel valve handle 56 is in first position 38(a) as shown in FIG. 2, mechanical fuel valve 54 opens the first fuel line and allows gasoline from gasoline tank 32 to flow to the engine.

[0031] Fuel valve handle 56 is coupled to fuel lockout apparatus 58. Fuel valve handle 56 actuates with fuel lockout apparatus 58 to prevent LPG flow to generator 20 when gasoline flow to the generator is enabled. Fuel lockout apparatus 58 is controlled by fuel valve handle 56 so that moving fuel valve handle 56 to the first position causes fuel lockout apparatus 58 to block fuel inlet 59 for LPG, and moving fuel valve handle 56 to the second position causes fuel lockout apparatus 58 to unblock fuel inlet 59 for LPG.

[0032] In an exemplary embodiment of the invention, fuel valve handle 56 rotates between the first position and the second position and fuel lockout apparatus 58 is rigidly coupled to the rotating handle. Fuel lockout apparatus 58 may include a fuel inlet cover 61, which may be a flange, coupled to fuel valve handle 56 so that fuel inlet cover 61 rotates with the handle. Fuel inlet cover 61 extends radially outward from fuel valve handle 56 and sweeps over fuel inlet 59 for LPG as fuel valve handle 56 rotates. That is, fuel inlet cover 61 rotates transversely across fuel inlet 59 and blocks access thereto. Accordingly, fuel inlet cover 61 prevents LPG flow to generator 20 when fuel valve handle 56 is in first position 38(a) to allow gasoline to run the engine.

[0033] Referring to FIG. 3, a detail view of a portion of generator 20 of FIG. 1 depicts mechanical fuel lockout switch 38 in a second position 38(b), in accordance with an embodiment of the invention. In this position, the mechanical fuel lockout switch 38 provides a disconnect to stop gasoline flow from gasoline tank 32 to the

engine while allowing connection of LPG supply hose 36 to fuel inlet 59 of the second fuel line. FIG. 3 further shows LPG supply hose 36 coupling second fuel source 30 to generator 20 to deliver LPG to run the generator.

[0034] Mechanical fuel lockout switch 38 includes mechanical fuel valve 54 coupled to fuel lockout apparatus 58 to prevent gasoline flow to generator 20 when LPG from the LPG service hose 36 is supplied to the engine. In one embodiment of the invention, actuation of mechanical fuel valve 54 to second position 38(b) causes fuel lockout apparatus 58 to allow communication of second fuel source 30 to the dual fuel engine, and interrupts the first fuel source 28 communication with the dual fuel engine. The position of fuel lockout apparatus 58 prevents the fuel valve handle 56 from moving to first position 38(a) (FIG. 2) while LPG supply hose 36 is connected to generator 20.

[0035] A quick-disconnect hose coupling 50, also referred to as a quick-connect hose coupling, connects LPG supply hose 36 to generator 20 so that LPG supply hose 36 may be quickly attached and detached from generator 20. Hose coupling 50 has a first end 50a mounted on the external surface of generator 20 and coupled to supply the second fuel to the engine. Hose coupling 50 has a second end 50b coupled to the outlet of LPG supply hose 36. Hose coupling 50 has a valve that opens when the couplings are engaged and closes when the couplings are disengaged. As such, quick-disconnect hose coupling 50 automatically opens when connected to enable fuel flow from LPG supply hose 36 to the engine. Hose coupling 50 automatically disconnects fluid communication when disconnected. Accordingly, when the supply hose is detached from generator 20, the coupling 50 is automatically closed so that fuel does not escape and unwanted air does not enter the fuel system.

[0036] In one embodiment, fuel inlet cover 61 is coupled to fuel valve handle 56 so that it is spaced apart from the surface of generator 20 to provide clearance for first end 50a of the quick-disconnect hose coupling 50 that protrudes from the surface of generator 20. As shown in FIG. 2, fuel inlet cover 61 blocks off first end 50a of the quick-disconnect hose coupling when fuel valve handle 56 is rotated to first position 38(a) to enable gasoline flow so that fuel inlet cover 61 prevents connection of LPG

supply hose 36 (FIG. 3) to generator 20. As shown in FIG. 3, fuel inlet cover 61 uncovers first end 50a of the quick-disconnect hose coupling 50 when fuel valve handle 56 is rotated to second position 38(b) to disable gasoline flow so that fuel inlet cover 61 permits connection of LPG supply hose 36 to generator 20.

[0037] To operate generator 20 on LPG, fuel valve handle 56 is turned to second position 38(b) to disable the flow of gasoline to the engine and to expose first end 50a of hose coupling 50 on generator 20. LPG supply hose 36 is then connected to generator 20 via hose coupling 50 to enable the flow of LPG to the engine. To operate generator 20 on gasoline, LPG supply hose 36 is disconnected from generator 20 via hose coupling 50 to disable the flow of LPG to the engine and to unblock fuel valve handle 56 from rotating to the first position. As shown in FIG. 2, fuel valve handle 56 is then turned to first position 38(a) to enable the flow of gasoline to generator 20.

[0038] Referring to FIG. 4A, a schematic diagram of a fuel system for a dual fuel engine shows mechanical fuel lockout switch 38 in first position 38(a) to provide communication between the first fuel source 28 and dual fuel carburetor 62, according to an embodiment of the invention. Mechanical fuel lockout switch 38 prevents communication between second fuel source 30 and dual fuel carburetor 62 when the switch is in first position 38(a). In one embodiment of the invention, first fuel source 28 includes a gasoline tank 32 to provide gasoline to carburetor 62 through a first fuel line 66, and second fuel source 30 includes a propane or LPG tank 68 to provide propane or LPG to carburetor 62 through a second fuel line 70. Accordingly, first fuel line 66 may be a liquid fuel line and second fuel line 70 may be a gaseous fuel line.

[0039] Mechanical fuel lockout switch 38 includes a mechanical fuel valve 54 actuatable between first position 38(a) as shown in FIG. 4A and second position 38(b) as shown in FIG. 4B to selectively control fuel flow to the dual fuel engine from first fuel source 28 through first fuel line 66 and second fuel source 30 through second fuel line 70. Referring back to FIG. 4A, mechanical fuel valve 54 selectively controls fuel flow through first fuel line 66 by opening the line when the mechanical fuel lockout switch 38 actuates to first position 38(a). Mechanical fuel valve 54 may be coupled to

fuel lockout apparatus 58 that actuates with mechanical fuel valve 54 to block and unblock fuel inlet 59 of second fuel line 70. First end 50a of the quick-disconnect hose coupling is located at fuel inlet 59 and a mating end 50b of the quick-disconnect hose coupling is coupled to the propane or LPG tank 68. Actuation of mechanical fuel valve 54 to first position 38(a) causes fuel lockout apparatus 58 to block fuel inlet 59 to prevent coupling the first end 50a and second end 50b of the quick-disconnect hose coupling together, and actuation of mechanical fuel valve 54 to another position causes fuel lockout apparatus 58 to unblock fuel inlet 59 to permit attaching first end 50a and second end 50b together.

[0040] In one embodiment of the invention, a fuel cut solenoid 63 couples to carburetor 62 to regulate liquid fuel flow into a main nozzle within the carburetor. Fuel cut solenoid 63 is advantageous to control liquid fuel flow downstream of a float bowl in the carburetor and can stop fuel flow to the engine immediately after ignition shutdown. As such, fuel cut solenoid 63 prevents the engine from drawing in fuel from the float bowl while the engine shuts off. Fuel cut solenoid 63 also traps fuel in the float bowl to eliminate delay in filling the bowl when starting the engine on liquid fuel, and prevents liquid fuel flow from the float bowl to the engine when starting on gaseous fuel.

[0041] Fuel cut solenoid 63 may regulate fuel flow through multiple fuel lines in carburetor 62 that provide fuel from the float bowl to the engine. For instance, carburetor 62 may have a main fuel line and an idle fuel line that receive fuel from the float bowl. Fuel cut solenoid 63 may control fuel flow through all of the fuel lines that receive fuel from the float bowl or may regulate only some of the fuel lines. As such, fuel cut solenoid 63 may block fuel flow through the main fuel line while small amounts of fuel can flow through the idle fuel line.

[0042] Fuel cut solenoid 63 preferably operates as a normally closed valve that opens when powered by a 12 volt battery 65, although fuel cut solenoid 63 may also be operated as a normally open valve. The normally closed valve is opened for gasoline mode to allow gasoline flow to the engine and closed for LPG mode to prevent gasoline

flow to the engine. Fuel cut solenoid 63 is operated by an electrical switch 67 which may be mechanically actuated and controlled by mechanical fuel lockout switch 38. As such, actuation of mechanical fuel lockout switch 38 to first position 38(a) closes electrical switch 67 to power and open fuel cut solenoid 63 as represented in FIG. 4A, and actuation of mechanical fuel lockout switch 38 to second position 38(b) opens electrical switch 67 to interrupt power and close fuel cut solenoid 63 as represented in FIG. 4B.

[0043] Referring to FIG. 4B, a schematic diagram of a fuel system for a dual fuel engine shows mechanical fuel lockout switch 38 in second position 38(b) to provide communication between second fuel source 30 and dual fuel carburetor 62, according to an embodiment of the invention. Mechanical fuel lockout switch 38 prevents communication between first fuel source 28 and dual fuel carburetor 62 when the switch is in second position 38(b). The dual fuel engine has a first fuel line 66 to provide fuel from first fuel source 28 to carburetor 62 and a second fuel line 70 to provide fuel from second fuel source 30 to carburetor 62.

[0044] Mechanical fuel lockout switch 38 includes mechanical fuel valve 54 that selectively controls fuel flow through first fuel line 66 by closing the line when mechanical fuel lockout switch 38 actuates to second position 38(b). Mechanical fuel lockout switch 38 may also include a mechanical lockout apparatus 58 to block and unblock fuel inlet 59 of the second fuel line 70. Fuel inlet 59 may include first end 50a of the quick-connect hose coupling mounted on the generator and coupled to second fuel line 70. Second end 50b of the quick-connect hose coupling is coupled to the outlet of second fuel source 30, and the first end 50a mates with second end 50b to quickly attach propane or LPG tank 68 to second fuel line 70. Fuel lockout apparatus 58 may also hold mechanical fuel lockout switch 38 in second position 38(b) when the propane or LPG tank 68 is coupled to the engine via the ends 50a, 50b of the quick-connect hose coupling.

[0045] Fuel cut solenoid 63 couples to carburetor 62 to regulate liquid fuel flow through the carburetor as described with respect to FIG. 4A. FIG. 4B shows electrical

switch 67 opened to interrupt power and close fuel cut solenoid 63 for LPG mode when mechanical fuel lockout switch 38 is in second position 38(b).

[0046] FIG. 4A and 4B depict an embodiment where mechanical fuel valve 54 operates along first fuel line 66 to provide a flow path for first fuel source 28 to carburetor 62 when the valve is in first position 38(a). That is, mechanical fuel valve 54 may control a single fuel line that runs through the valve while operating fuel lockout apparatus 58 to control fuel flow through second fuel line 70. Embodiments of the invention also contemplate mechanical fuel valve 54 configured to operate along second fuel line 70 to provide a flow path for second fuel source 30 to carburetor 62 when the valve is in second position 38(b). Mechanical fuel valve 54 may be configured to control multiple fuel lines that run through the valve according to embodiments of the invention.

[0047] Referring now to FIG. 5, a perspective view of fuel delivery system 22 for dual fuel generator 20 of FIG. 1 is shown, in accordance with an embodiment of the invention. Fuel delivery system 22 includes a mounting arrangement for fuel regulator system 39. The mounting arrangement includes regulator mounting bracket 46 for mounting fuel regulator system 39. Regulator mounting bracket 46 extends around the outer periphery of collar 136 on pressurized fuel container 34. Regulator mounting bracket 46 has securing mechanism 48 to secure to collar 136. In one embodiment, securing mechanism 48 is a rigid component that extends inward from regulator mounting bracket 46 with a slot for receiving collar 136 to hold regulator mounting bracket 46 to collar 136.

[0048] Regulator mounting bracket 46 provides mounting locations for pressure regulators. In one embodiment, regulator mounting bracket 46 is made of sheet metal bent in two locations to provide a central panel 138, a first outer panel 140, and a second outer panel 142 for mounting the regulators. The panels may be angled from each other such that regulator mounting bracket 46 fits around collar 136. Primary pressure regulator 42 mounts on first outer panel 140 and secondary pressure regulator 44 mounts on second outer panel 142. The panels are sized according to their respective

regulators. Accordingly, second outer panel 142 is larger than first outer panel 140 if secondary pressure regulator 44 is larger than primary pressure regulator 42. Panels 140, 142 have fasteners or openings to receive fasteners to couple respective regulators 42, 44 to the panels. Regulator mounting bracket 46 rests on top of pressurized fuel container 34 and engages the periphery of collar 136 to support fuel regulator system 39 on the container.

[0049] In one embodiment of the invention, primary pressure regulator 42 couples to two ninety degree elbows 144, 145 to reach around collar 136 in order to couple to service valve 40. The two elbows 144, 145 are joined by a hose or pipe 146 that leads from elbow 144 at service valve 40 to elbow 145 at the outer periphery of collar 136. The outlet of primary pressure regulator 42 couples to a hose 148 that extends to another ninety degree elbow 150 coupled to the inlet of secondary pressure regulator 44. Secondary pressure regulator 44 couples to LPG supply hose 36. Pressurized fuel container 34 may be strapped to a dolly 152.

[0050] Referring now to FIG. 6, a side view of another fuel delivery system 22 for dual fuel generator 20 of FIG. 1 is shown, in accordance with an embodiment of the invention. Fuel delivery system 22 includes a mounting arrangement for fuel regulator system 39. The mounting arrangement includes a regulator mounting structure 154 for mounting fuel regulator system 39 to pressurized fuel container 34. Regulator mounting structure 154 includes a cylinder 156 that surrounds the circumference of pressurized fuel container 34 to secure regulator mounting structure 154 radially along the circumference of pressurized fuel container 34. Cylinder 156 couples to a dome 158 to support cylinder 156 relative to the top of pressurized fuel container 34. Dome 158 has a central opening 160 through which collar 136 of pressurized fuel container 34 extends. Collar 136 of pressurized fuel container 34 extends through dome 158 so that service valve 40 is easily accessible from above regulator mounting structure 154 and so that dome 158 sits on pressurized fuel container 34 around collar 136.

[0051] Regulator mounting structure 154 supports pressure regulators around the outer circumference of cylinder 156. In some embodiments of the invention, a dual

stage pressure regulator 162 functions as both a primary pressure regulator and a secondary pressure regulator in a single integral component, and dual stage pressure regulator 162 may be mounted on regulator mounting structure 154. In other embodiments of the invention, primary pressure regulator 42 (FIG. 5) is mounted to service valve 40 while secondary pressure regulator 44 (FIG. 5) is mounted on regulator mounting structure 154. Alternatively, both primary pressure regulator 42 (FIG. 5) and secondary pressure regulator 44 (FIG. 5) may be mounted on regulator mounting structure 154.

[0052] Fuel regulator system 39 may be coupled to service valve 40 by a flexible connector called a pigtail 164. Pigtail 164 absorbs shock in the system from pressure surges and from movement of downstream components. Pigtail 164 can be looped to conserve space and therefore pressurized fuel container 34 is referred to as an LPG pig. Accordingly, regulator mounting structure 154 is referred to as a pig hat because it fits on the LPG pig. Pressurized fuel container 34 may be secured to a platform or mobile cart 64 for stability or transportation. In another embodiment, a regulator mounting device, including regulator mounting structure 154 or regulator mounting bracket 46 (FIG. 5), is secured directly to a platform or a mobile cart.

[0053] Beneficially, embodiments of the invention provide for a mechanical fuel lockout switch to ensure that two fuels are not simultaneously delivered to a dual fuel internal combustion engine. Embodiments of the invention also provide for a dual fuel generator with a remotely mounted gaseous fuel regulator system.

[0054] Therefore, according to one embodiment of the invention, a mechanical fuel lockout switch for a dual fuel engine includes a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line. The mechanical fuel valve may be configured to allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while in the first position, and prevent communication between the first fuel source and the dual fuel

engine while in the second position. The mechanical fuel lockout switch may also include a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent the second fuel source from coupling to the second fuel line while the mechanical fuel valve is in the first position, and permit the second fuel source to couple to the second fuel line while the mechanical fuel valve is in the second position.

[0055] According to another embodiment of the invention, a mechanical fuel lockout switch for a dual fuel engine includes a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line. The mechanical fuel valve may be configured to allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while the first position, and prevent communication between the first fuel source and the dual fuel engine while in the second position. The mechanical fuel lockout switch may also include a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.

[0056] According to yet another embodiment of the invention, a dual fuel generator and fuel delivery system includes a dual fuel generator configured to operate on a liquid fuel supplied from a liquid fuel source through a liquid fuel line and a gaseous fuel supplied from a pressurized fuel source through a gaseous fuel line, and a fuel regulator system located off board the dual fuel generator. The fuel regulator system may include a primary pressure regulator couplable to a service valve of the pressurized fuel source and configured to regulate the gaseous fuel supplied from the pressurized fuel source to a reduced pressure, and a secondary pressure regulator couplable to the primary pressure regulator and configured to regulate the gaseous fuel supplied from the primary pressure regulator to a desired pressure for delivery through the gaseous fuel line to operate the dual fuel generator. The dual fuel generator and fuel delivery system may also include a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel generator from the liquid fuel

source through the liquid fuel line and the pressurized fuel source through the gaseous fuel line, the mechanical fuel valve configured to open and close the liquid fuel line to selectively control fuel flow from the liquid fuel source to the dual fuel generator. A fuel lockout apparatus may couple to the mechanical fuel valve configured to prevent the pressurized fuel source from coupling to the gaseous fuel line while the liquid fuel line is open, and permit the pressurized fuel source to couple to the gaseous fuel line while the liquid fuel line is closed by the mechanical fuel valve.

[0057] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

CLAIMS

What is claimed is:

1. A mechanical fuel lockout switch for a dual fuel engine comprising:
a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line, the mechanical fuel valve configured to:
allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while in the first position, and
prevent communication between the first fuel source and the dual fuel engine while in the second position; and
a fuel lockout apparatus coupled to the mechanical fuel valve and configured to:
prevent the second fuel source from coupling to the second fuel line while the mechanical fuel valve is in the first position, and
permit the second fuel source to couple to the second fuel line while the mechanical fuel valve is in the second position.
2. The mechanical fuel lockout switch of claim 1 wherein the fuel lockout apparatus prevents actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.
3. The mechanical fuel lockout switch of claim 1 wherein the fuel lockout apparatus comprises a flange rigidly coupled to the mechanical fuel valve and configured to:
cover an inlet of the second fuel line while the mechanical fuel valve is in the first position, and
uncover the inlet of the second fuel line while the mechanical fuel valve is in the second position.

4. The mechanical fuel lockout switch of claim 3 wherein the mechanical fuel valve is configured to rotate between the first position and the second position and the flange is configured to rotate transversely across the inlet of the second fuel line.

5. The mechanical fuel lockout switch of claim 3 further comprising:
a first end of a quick-disconnect hose coupling attached to the inlet of the second fuel line; and

a second end of the quick-disconnect hose coupling configured to mate with the first end of the quick-disconnect hose coupling to couple the second fuel source to the second fuel line.

6. The mechanical fuel lockout switch of claim 1 wherein the mechanical fuel valve and the fuel lockout apparatus operate together to ensure that fuel from the first fuel source and fuel from the second fuel source are not simultaneously delivered to the dual fuel engine.

7. The mechanical fuel lockout switch of claim 6 wherein the mechanical fuel valve is configured to:

provide liquid fuel from a liquid fuel tank of the first fuel source to the dual fuel engine while in the first position, and

provide gaseous fuel from a pressurized fuel container of the second fuel source to the dual fuel engine while in the second position.

8. A mechanical fuel lockout switch for a dual fuel engine comprising:
a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line, the mechanical fuel valve configured to:

allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while the first position, and

prevent communication between the first fuel source and the dual fuel engine while in the second position; and

a fuel lockout apparatus coupled to the mechanical fuel valve and configured to prevent actuation of the mechanical fuel valve to the first position when the second fuel source is in communication with the dual fuel engine.

9. The mechanical fuel lockout switch of claim 8 wherein the fuel lockout apparatus comprises a flange rigidly coupled to the mechanical fuel valve and configured to:

cover an inlet of the second fuel line while the mechanical fuel valve is in the first position, and

uncover the inlet of the second fuel line while the mechanical fuel valve is in the second position.

10. The mechanical fuel lockout switch of claim 9 wherein the mechanical fuel valve is configured to rotate between the first position and the second position and the flange is configured to rotate transversely across the inlet of the second fuel line.

11. The mechanical fuel lockout switch of claim 9 further comprising:
a first end of a quick-disconnect hose coupling attached to the inlet of the second fuel line; and

a second end of the quick-disconnect hose coupling configured to mate with the first end of the quick-disconnect hose coupling to couple the second fuel source to the second fuel line.

12. The mechanical fuel lockout switch of claim 8 wherein the mechanical fuel valve and the fuel lockout apparatus operate together to ensure that fuel from the

first fuel source and fuel from the second fuel source are not simultaneously delivered to the dual fuel engine.

13. The mechanical fuel lockout switch of claim 12 wherein the mechanical fuel valve is configured to:

provide liquid fuel from a liquid fuel tank of the first fuel source to the dual fuel engine while in the first position, and

provide gaseous fuel from a pressurized fuel container of the second fuel source to the dual fuel engine while in the second position.

14. A dual fuel generator and fuel delivery system comprising:

a dual fuel generator configured to operate on a liquid fuel supplied from a liquid fuel source through a liquid fuel line and a gaseous fuel supplied from a pressurized fuel source through a gaseous fuel line;

a fuel regulator system located off board the dual fuel generator, the fuel regulator system comprising:

a primary pressure regulator couplable to a service valve of the pressurized fuel source and configured to regulate the gaseous fuel supplied from the pressurized fuel source to a reduced pressure, and

a secondary pressure regulator couplable to the primary pressure regulator and configured to regulate the gaseous fuel supplied from the primary pressure regulator to a desired pressure for delivery through the gaseous fuel line to operate the dual fuel generator;

a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel generator from the liquid fuel source through the liquid fuel line and the pressurized fuel source through the gaseous fuel line, the mechanical fuel valve configured to open and close the liquid fuel line to selectively control fuel flow from the liquid fuel source to the dual fuel generator; and

a fuel lockout apparatus coupled to the mechanical fuel valve and configured to:

prevent the pressurized fuel source from coupling to the gaseous fuel line while the liquid fuel line is open, and

permit the pressurized fuel source to couple to the gaseous fuel line while the liquid fuel line is closed by the mechanical fuel valve.

15. The dual fuel generator and fuel delivery system of claim 14 wherein the fuel lockout apparatus is further configured to prevent the mechanical fuel valve from opening the liquid fuel line while the fuel regulator system is coupled to the gaseous fuel line.

16. The dual fuel generator and fuel delivery system of claim 14 wherein the fuel lockout apparatus comprises a fuel inlet cover that actuates with the mechanical fuel valve to cover an inlet of the gaseous fuel line while the liquid fuel line is open and to uncover the inlet of the gaseous fuel line when the liquid fuel line is closed.

17. The dual fuel generator and fuel delivery system of claim 14 further comprising:

a first end of a quick-connect hose coupling coupled to an outlet of the secondary pressure regulator; and

a second end of the quick-connect hose coupling coupled to an inlet of the gaseous fuel line and configured to mate with the first end of the quick-connect hose coupling to couple the secondary pressure regulator to the gaseous fuel line.

18. The dual fuel generator and fuel delivery system of claim 14 further comprising a regulator mounting device fixed to the pressurized fuel source; and

at least the secondary pressure regulator is mounted on the regulator mounting device.

19. The dual fuel generator and fuel delivery system of claim 18 wherein the primary pressure regulator is mounted on the regulator mounting device.

20. The dual fuel generator and fuel delivery system of claim 19 wherein the regulator mounting device is configured to attach onto a collar of a pressurized fuel container of the pressurized fuel source so that the primary and secondary pressure regulators are positioned adjacent each other along an outer periphery of the collar.

21. The dual fuel generator and fuel delivery system of claim 14 wherein:
the fuel regulator system comprises a dual stage pressure regulator; and
the primary and secondary pressure regulators are integral components of the dual stage pressure regulator.

ABSTRACT

A mechanical fuel lockout switch for a dual fuel engine includes a mechanical fuel valve actuatable between a first position and a second position to selectively control fuel flow to the dual fuel engine from a first fuel source through a first fuel line and a second fuel source through a second fuel line. The mechanical fuel lockout switch may also include a fuel lockout apparatus coupled to the mechanical fuel valve. The mechanical fuel valve may be configured to allow communication between the first fuel source and the dual fuel engine and prevent communication between the second fuel source and the dual fuel engine while in the first position, and prevent communication between the first fuel source and the dual fuel engine while in the second position.

POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

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I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above:

26629

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Individual Name

Address

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Email

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):



Inventor or Joint Inventor (title not required below)



Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)



Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)



Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature

Date (Optional)

01-05-2019

Name

Dennis Trine

Title

Chief Executive Officer, Champion Power Equipment, Inc.

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.



Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. This information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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EXHIBIT 1003

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Summary/Highlights

Litigation Experience

- IPR/Patents: Completed eight cases in different areas of Mechanical Engineering systems including vehicles, engines, powertrains, heating ventilation air conditioning (HVAC) systems, buildings, ...
- ITC: Two cases in the area of Mechanical Engineering systems
- Depositions: 8 including serving plaintiff/complainant (3), defense/respondent (5)
- Expert Report/Declaration: 9 reports

Professional Work

- Registered Professional Engineer (PEng) in Alberta
- Academic: Professor, Associate Professor, Assistant Professor of Mechanical Engineering, 2012 – now
- Industry: Engine (3.5 years), Robotics (1 year) industries, HVAC (2.5 years)

Internal Combustion Engine Experience

- Have worked 25 years in the area of engine and engine control including dual fuel engines
- Have taught internal combustion engine courses many times since 2008 in different academic institutions in US and Canada
- Have supervised more 50 undergraduate and graduate students for the research in the area of engine and engine controls
- Have tested various dual fuel engines for different applications. These include small (< 0.5 liter) to large scale engines (e.g., 15 liter)
- Have studied engines running with a variety of fuels including but not limited to gasoline, diesel, ethanol, n-heptane, iso-octane, gaseous fuels (natural gas, butane, hydrogen, ...), and biofuels.
- Have worked with engines with carburetor, throttle body injection (TBI), port fuel injection (PFI), direct injection (DI) systems, and mixer systems for gaseous fuels
- Have studied various engine types including spark ignition, compression ignition, lean burn, low temperature combustion (HCCI, PPCI, RCCI) engines, and their exhaust aftertreatment systems
- Have led national level engine research programs in the US and Canada in the past 10 years
- Served on review panels for US Department of Energy Engine and Fuel Technology programs, and also rUS National Science Foundation (NSF) panels for grant proposals in the area of internal combustion engines design and controls
- Have been director of Energy Mechatronics Laboratory at Michigan Tech and University of Alberta for design and control of combustion engines

Professional Recognition

- Publications: 255 peer-reviewed publications including 113 journal papers, 138 peer-reviewed conference proceeding papers, and 4 book chapters. These publications center on mechanical engineering systems. Many of these publications are in the field of engines including dual fuel engines.
- Citations: Google Scholar shows total citations of 6204 from more than 80 different countries in Europe, Australia, Africa, Asia, North America, and South America; h-index: 41, i10-index: 144 (as of 2025-04-28).

- Reviews: Served on the United States NSF and DOE grant proposal review panels in the areas of mechanical engineering systems; Reviewer for international grant proposals from Canada, Croatia, France, Germany, and Netherlands; Reviewer for 24 international journals in the area of mechanical engineering systems.
- Editorship:
 - Technical Editor, ASME/IEEE Transactions on “Mechatronics”, 2025 -
 - Associate editor, American Society of Mechanical Engineers (ASME) Journal of Dynamic Systems, Measurement, and Controls, 2017 – 2023
 - Guest Editor for Special Issue on “Optimal Design and Operation of Energy Systems”, *Int. Journal of Optimal Control Applications and Methods* (Wiley Publisher), 2020 – 2022
 - Associate Editor, *Int. Journal of Powertrains* (Inderscience Publishers), 2014 – 2020
 - Guest Editor for two Special Issues on Advanced Powertrain Engineering, *Int. Journal of Powertrains*, 2016 – 2020
- Technical Committees (TC): Chair of Energy Systems TC in ASME-DSCD, 2018-2020; Chair of Automotive and Transportation Systems TC in ASME Dynamic Systems Control Division (DSCD), 2020-2022. The Automotive TC and Energy Systems TC have over 210 and 180 members respectively from academia, and industry from countries North America, Europe, Asia, and Australia. Secretary of ASME – DSCD Executive Committee, 2023 – now
- Funding/Grants: PI of over \$6M USD, co-PI of over \$9M USD, and \$591K USD equipment support from federal, provincial, industry, and international funding sources for proposals in the area of mechanical systems. These include highly competitive (success rate $\leq 15\%$) grants from US National Science Foundation, and US Department of Energy.
- Organizing International Technical Sessions: Organized/co-organized 78 invited technical sessions, special sessions, industry sessions in the area of modeling, estimation, optimization, and control of mechanical systems in ASME-DSCC, MECC, AIM, ACC, IEEE-CCTA, SAE and IFAC international conferences during 2012-2024.
- Chairing International Technical Sessions: Chaired/co-chaired 47 technical sessions in the area of modeling, diagnosis and control of mechanical systems in ASME-DSCC, ACC, MECC, SAE international conferences during 2012-2024.

Teaching

- Teaching Experience: Taught in mechanical engineering departments at three academic institutions from 2004 to 2025 as a primary instructor for more than 25 academic semesters and as a teaching assistant for eight academic semesters. The size of the classes ranged from 5 to 123 students for undergraduate and graduate level courses. These courses include Combustion Engines and Alternative Fuels, Thermodynamics, Fluid Mechanics, Energy Thermo-Fluids (ETF), Machine Learning Control, Model Predictive Control, etc.

Membership

- SAE (Society of Automotive Engineers), Member for about 20 years
- ASME (American Society of Mechanical Engineers), Member for about 13 years

Academic Appointments

University of Alberta - Department of Mechanical Engineering

Professor (2024 - now), Associate Professor (2019-2024), Canada

Director of Energy Mechatronics Lab (EML)

- Research interests: Energy Mechatronics, Combustion Engines, Vehicles, Thermodynamics, HVAC, Fuel Cells, Buildings

Michigan Tech. University - Department of Mechanical Engineering - Engineering Mechanics

Adjunct Professor (2020 - now), Research Associate Professor (2019-2020), Associate Professor (2017-2019), Assistant Professor (2012-2017), USA

University of California Berkeley - Department of Mechanical Engineering

Post-doctoral Scholar, 2010 – 2012, USA

Education

Ph.D. in Mechanical Engineering, University of Alberta, Edmonton, Canada, 2004 – 2009

Thesis: Modeling and Experimental Study of an HCCI Engine for Combustion Timing Control

M.Sc. in Mechanical Engineering (*Summa Cum Laude*), KNT University of Tech., Tehran, Iran, 2000 – 2003

Thesis: Dynamic Modeling of MPFI Engines for AFR Control during Cold Start and Warm up Conditions and Investigation of Factors Influencing Mixture Preparation and Pollutant Formation in these Conditions

B.Sc. in Mechanical Engineering (*Summa Cum Laude*), KNT University of Tech., Tehran, Iran, 1996 – 2000

Industry Experience

R&D Engineer, IPCO, Tehran, Iran, Mar. 2001 – Aug. 2004

Iran Khodro Powertrain Company (www.ip-co.com), the largest powertrain manufacturer in the Middle East

- Dynamic modeling of gasoline engines and longitudinal vehicle dynamics
- Calibration of engines and design of control strategies for CNG-gasoline engine control units
- On-vehicle testing of powertrain controllers
- Benchmarking of Peugeot 206 engine - a mutual project with FEV® carried out in Aachen, Germany

R&D Engineer, Advanced Robotics Automatic Systems (ARAS), Tehran, Iran, 2000 - 2001

Engineering Intern, Yekta Tahviah Arvand Air Conditioning Industries, Iran, 1998 - 2000

Consulting

- Law firms, Expert witness for patent/IP/ITC applications, 2018 – present
 - Ice Miller (Chicago, Indianapolis), DOAR (New York, NY): Expert witness for four Inter Partes Reviews (IPRs) cases in the area of internal combustion engines, 2025 - now
 - Kirkland & Ellis LLP (Chicago, Boston), DOAR (New York, NY): Expert witness for one International Trade Commission (ITC) case in the Mechanical Engineering area, Included one deposition, 2024
 - Fish & Richardson (Washington DC), DOAR (New York, NY): Expert witness for three IPRs in the Vehicles/Mechanical Engineering area, Included two depositions, 2020-2021
 - Maxwell Goss PLLC (Birmingham, MI): Expert witness for three IPRs in the area of Vehicles/Mechanical Engineering, Included two depositions, 2020
 - Latham & Watkins, LLP (Los Angeles, CA), DOAR (New York, NY): Expert witness for one International Trade Commission (ITC) case in the HVAC area, 2020
 - Finnegan, Henderson, Farabow, Garret & Dunner, LLP (Washington DC): Expert witness for two IPRs in the Vehicles/Mechanical Engineering area; Included three depositions, 2018 - 2019

Professional Affiliations

- American Society of Mechanical Engineers (ASME)
- Canadian Society of Mechanical Engineers (CSME)
- Society of Automotive Engineers (SAE)
- International Federation of Automatic Control (IFAC)
- Renewable Fuel Association (RFA)
- The Combustion Institute
- The New York Academy of Sciences (NYAS)

Professional Development

- Certificate of “Ingenuity - Innovation for Researchers” from THECIS (The Centre for Innovation Studies), a three-month course to advance understanding the use of innovation as a subject of both study and practice, 2008, AB, Canada.

Selected Awards

Research/Academic

- Transport Canada 2023 Technology Achievement Award Finalist, 2023
- Best Student Paper Award Finalists (top 6 papers), selected **three times** in 2012, 2013, 2016 ASME Dynamic System Control (DSC) Conferences, USA. Submissions to these conferences ranged from 233 to 406 papers.
- Best Paper Award, ASME Automotive and Transportation Systems Technical Committee – DSCC, 2015
- 2018 MARQUIS Who’s Who in the World (“top 3% of the professionals in the world”)
- Best Presentation in the Session, American Control Conference (ACC), 2012, 2015, 2016
- Best Presentation Award, SAE Int. Powertrain, Fuels & Lubricants Conference, Baltimore, MD, USA, 2016
- Research Excellence Fund, Michigan Tech University, 2013, 2014
- Best Paper Award, ASME Automotive and Transportation Systems Technical Committee – DSCC, 2012
- Canada NSERC (Natural Science and Engineering Research Council) Postdoctoral Fellowship, 2010 - 2012
- Andrew Stewart Memorial Graduate Prize, University of Alberta, 2009
- Prairie Mines & Royalty Ltd. Scholarship in Environments Engineering, University of Alberta, 2008
- THECIS - Ingenuity Scholarship, THECIS (The Center for Innovation Studies), Canada, 2008
- Queen Elizabeth II Graduate Scholarship - Doctoral Level, University of Alberta, 2008
- Lehigh Inland Cement Graduate Scholarship in Environmental Studies, University of Alberta, 2007
- Winning Team (first prize) of a Total of 66 Research Teams from 26 Canadian Universities, Canada Automotive21 High Qualified Personnel Competition, Windsor, Canada, June 11-13, 2007
- Chevron Graduate Scholarship in Natural Gas Engineering, University of Alberta, 2005
- Best Paper Award in 3rd International Conference on Internal Combustion Engines, Tehran, Iran, 2004
- Summa Cum Laude (ranked first among graduates) in both MSc Mech Eng – Powertrain (2003) and BSc Mech Eng – Thermofluids (2000), K. N. Toosi University of Technology, Tehran, Iran.

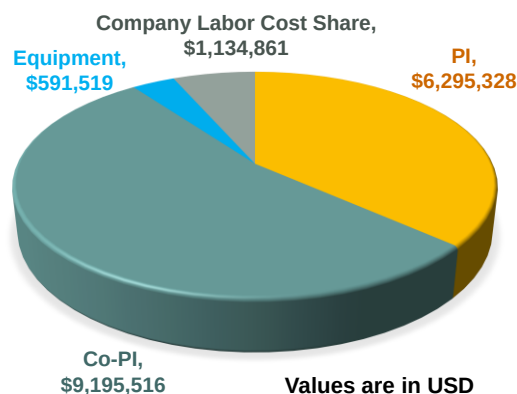
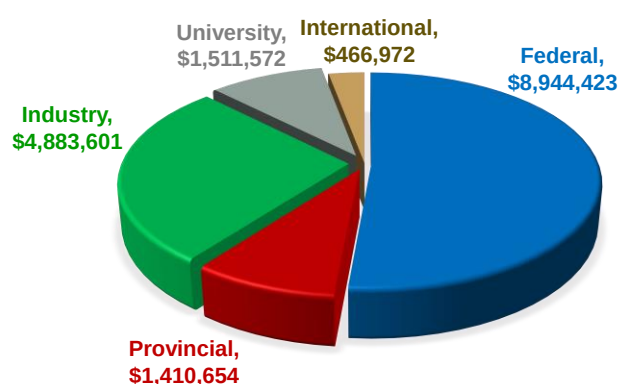
Teaching

- SAE Ralph R. Teetor Educational Award, 2016
- Provost's List, Top 10% instructors among over 1050 evaluated sections/instructors university-wide, Michigan Tech University, Selected **four times** in Fall 2015, Fall 2016, Fall 2017, Spring 2018
- Zita and John Rosen Teaching Excellence Award for Principal Instructor, University of Alberta, 2009
Only one award across the university is granted annually to give special recognition to a graduate student principal instructor who is an especially skilled and dedicated teacher.

Leadership and Service

- Province of Alberta Graduate Citizenship Award for Student Leadership, Canada, 2009
- Award for Outstanding Contribution for "Most Youth Reached" in National Let's Talk Science Program, Canada, 2007-2008
- Alan Wharmby Memorial Graduate Award in Mechanical Engineering, University of Alberta, 2008

Grants/Funding



Awarded

- 51- C. R. Koch, D. Gordon, M. Shahbakhti (co-PI), " Machine Learning Control for Hydrogen integration in Heavy-duty Engines ", 1,140,000 CAD, including 760,000 CAD from NSERC Alliance Grant and 340,000 CAD from Diesel Tech Industries (DTI) and 40,000 CAD from City of Edmonton, 2025 – 2029.
- 50- M. Shahbakhti (PI), C. R. Koch, " Alberta Zero-Emissions Fleet Fueling (AZEFF) ", 208,000 CAD, City of Edmonton via Emission Reduction Alberta (ERA), 2024 – 2027.
- 49- M. Shahbakhti (PI), C. R. Koch, " Hydrogen fueled combined heat and power (CHP) for commercial and residential buildings, and municipal applications ", 950,000 CAD, Alberta Innovates, 2024 – 2026.
- 48- M. Shahbakhti (PI), C. R. Koch, " Zero Emission Trucking Testbed ", 264,750 CAD, Alberta Motor Transport Association (AMTA), 2024 – 2028.
- 47- M. Shahbakhti (PI), C. R. Koch, A. Khajehoddin, " Machine Learning Control and Diagnostics of Solid Oxide Fuel Cell Stack to Optimize Performance and Minimize Degradation ", 1,450,887 CAD, including 898,887 CAD from NSERC Alliance Grant and 552,000 CAD from Cummins Inc., 2024 – 2027.
- 46- M. Shahbakhti (PI), G. McTaggart-Cowan (Simon Fraser Univ.), S. Munshi (Westport Inc.), " Assessment and Optimization of CleanTech Hydrogen-Fueled Commercial Vehicles for Zero Tailpipe Greenhouse Gas Emissions ", 265,000 CAD including 170,000 CAD from Mitacs Accelerate Program and 95,000 CAD from Westport Inc., 2024-2026.
- 45- M. Shahbakhti (PI), C. R. Koch, " Development of High-Performance Solid Oxide Fuel Cell Stack with Low

- Degradation Rate and Fault Tolerance for Commercial Applications", 363,600 CAD, University of Alberta Future Energy Systems (FES) – Canada First Research Excellence Fund, 2023 – 2026.
- 44- M. Shahbakhti (PI), C. R. Koch, J. Laverty " Intelligent and Sustainable Management Tool for UAlberta Fleet Vehicles: Operational Cost Reduction, GHG Reduction, and Campus Air Quality Improvement ", 128,942 CAD, Campus Sustainability Grant - University of Alberta, 2023 – 2025.
- 43- M. Shahbakhti (PI), C. R. Koch, " Hydrogen truck Performance Analysis and Technology Assessment ", 288,200 CAD, Alberta Motor Transport Association (AMTA), 2023 – 2026.
- 42- M. Shahbakhti (PI), C. R. Koch, " Performance Analysis of Alberta Zero Emissions Hydrogen Transit (AZEHT) Project Transit Buses ", 155,000 CAD, The Transition Accelerator, 2022 – 2025.
- 41- M. Shahbakhti (PI), C. R. Koch, " Scalable and Reconfigurable Powertrain Control Methods via Artificial Intelligence and Model Predictive Control ", 240,000 USD, Cummins Inc., 2022 – 2026.
- 40- C. R. Koch, V. Hosseini, M. Shahbakhti (co-PI), " Urban Transportation Emissions and GHGs; Technologies and Behavioral Shifts Towards Zero Emissions ", 498,750 CAD, Environment & Climate Change Canada, 2022 – 2027.
- 39- M. Shahbakhti (PI), C. R. Koch, " Fault Isolation of Solid Oxides Fuel Cell using Machine Learning ", 300,000 USD, Cummins Inc., 2021 – 2025.
- 38- A. Nouri, M. Shahbakhti (co-PI), " A Robust and Low-cost Technology for Risk Mitigation of Pathogenic Infection in HVAC Systems ", 733,000 CAD, including 373,000 CAD from NSERC Alliance Grant and 360,000 CAD from Engineered Air, 2022 – 2026.
- 37- M. Shahbakhti (PI), C. R. Koch, " Artificial Intelligence and Machine Learning for Engine Modeling and Virtual Field Calibration and Assessment of Heavy-Duty Engines ", 41,775 CAD, IAV GmbH, 2021 – 2022.
- 36- C. R. Koch, V. Hosseini, M. Shahbakhti (co-PI), " Blue hydrogen - Diesel Dual-Fuel Engine Technology Development for a Transition to a Hydrogen Economy ", 827,425 CAD, Alberta Innovates, 2021 – 2023.
- 35- M. Shahbakhti (PI), C. R. Koch, " Cooperative Truck Platooning System (CTPS) ", 245,936 CAD, Alberta Motor Transport Association (AMTA) – Transport Canada, 2021 – 2023.
- 34- M. Shahbakhti (PI), C. R. Koch, " Artificial Intelligence and Model Predictive Control Applications for Engine Control and Calibration ", 37,532 CAD, Cummins Inc., 2020 – 2022.
- 33- M. Shahbakhti (PI), G. McTaggart-Cowan (Simon Fraser Univ.), S. Munshi (Westport Inc.), " Optimum high-efficient hybrid electric natural gas powertrain designs towards economically viable low emission trucks", 179,750 CAD, NSERC Alliance Grant, 2021 – 2024.
- 32- M. Shahbakhti (PI), " Intelligent Control of Connected and Automated Vehicles and Powertrains for Cold Climates ", 273,000 CAD, NSERC Discovery Grant, 2020 – 2027.
- 31- M. Shahbakhti (PI), C. R. Koch, V. Hosseini, " Intelligent and Sustainable Management Tool for UAlberta Fleet Vehicles: Operational Cost Reduction, GHG Reduction, and Campus Air Quality Improvement ", 145,709 CAD, EMSO - University of Alberta, 2020 – 2022.
- 30- M. Shahbakhti (PI), C. R. Koch, " Artificial Intelligence and Machine Learning for Engine Modeling and Virtual Field Calibration and Assessment of Heavy-Duty Engines ", 76,904 CAD, IAV GmbH, 2019 – 2021.
- 29- M. Shahbakhti (PI), A. O. Vargas, C. R. Koch, V. Hosseini, " Urban Carrying Capacity under Cold Climate for Transportation Generated Air Pollution and Public Exposure ", 50,000 CAD, Social Sciences and Humanities Research Council of Canada (SSHRC) Grant, 2020 – 2021.
- 28- M. Shahbakhti (PI), " Exergy-Wise Predictive Control of Building and Automotive Energy Systems ", 27,000 CAD, NSERC Discovery Grant, 2019 – 2020.
- 27- J. Naber, M. Shahbakhti (co-PI), Y. Ra, J. Worm, S. Munshi (Westport Fuel Systems Inc.), " A Compression Ignition Mono-Fueled NG High-Efficiency, High-Output Engine for Medium and Heavy-Duty Applications ", 1,786,494 USD including 1,156,042 USD from US Department of Energy, 450,000 USD from Westport and 180,452 USD Michigan Tech cost share, 2019 – 2022.
- 26- J. Naber, Y. Ra, S.-Y. Lee, M. Shahbakhti (co-PI), J. Worm, " Co-optimized PPCI-SI Engine System Demonstrator to Improve Fuel Economy while Meeting LEV III Emissions ", 1,161,130 USD including 899,372 USD from US Department of Energy and 261,758 USD for MTU cost share, 2019 – 2022.
- 25- M. Shahbakhti (lead PI), J. Naber, J. Mohammadpour (Univ. of Georgia), A. Borhan (Cummins Inc.), " GOALI: Collaborative Research: Control-oriented Modeling and Predictive Control of High Efficiency Low-Emission Natural Gas Engines ", 561,422 USD including 499,976 USD from US National Science

Foundation and 61,446 USD from MTU, 2018 – 2021.

- 24- A. Barnard, M. Shahbakhti (co-PI), " Application of Carbon Nanotubes (CNT) for Heating Aftertreatment Systems in Vehicles ", 18,525 USD, Faurecia Automobile Company, 2018.
- 23- M. Shahbakhti (PI), D. Robinette J. Blough, " Improved Driveline Torque Shaping: Controls and Calibration ", 240,964 USD including 200,000 USD from Ford Motor Company and 40,964 USD for MTU cost share, 2018 – 2020.
- 22- J. Naber, M. Shahbakhti (co-PI), C. Morgan, " Development, Validation, and Integration Support for a Hardware-In-the-Loop (HIL) VD&PT Vehicle Model ", 59,600 USD, Hitachi America Ltd., 2018.
- 21- D. Robinette J. Blough, M. Shahbakhti (co-PI), " Improved Clunk Parameterization and Rig Development ", 240,964 USD including 200,000 USD from Ford Motor Company and 40,964 USD for MTU cost share, 2018 – 2020.
- 20- J. Naber, M. Shahbakhti (co-PI), " High Engine Speed Cranking and Individual Combustion Control for Reduced Cold Start Emissions ", 240,964 USD including 200,000 USD from Ford Motor Company and 40,964 USD for MTU cost share, 2018 – 2020.
- 19- M. Shahbakhti (PI), D. Robinette, J. Blough, " Driveline Torque Modeling and Estimation for Anti Jerk Control ", Ford Motor Company, 24,770 USD, 2017 – 2018.
- 18- M. Shahbakhti (PI), R. Robinett, " Micro Concentrated Solar Power (CSP) Contribution on the Management of an Electrical Grid Including Renewable Energy Sources ", Mohammadia School of Engineering via Morocco's Institut de Recherche en Energie Solaire et an Energies Nouvelles (IRESEN), 17,616 USD, 2017 – 2018.
- 17- J. Naber, D. Robinette, M. Shahbakhti (co-PI), K. Zhang, B. Chen, G. Cesiel (GM), " NEXTCAR: Connected and Automated Control for Vehicle Dynamics and Powertrain Operation on a Light-Duty Multi-Mode Hybrid Electric Vehicle ", US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E), 3,505,824 USD including 2,801,390 USD from DOE, 553,362 USD from GM cost share, 151,072 USD for MTU cost share, 2017 – 2020.
- 16- J. Naber, J. Blough, B. Chen, M. Shahbakhti (co-PI), " Sensor Evaluation and Fusion for Closed Loop Combustion Control for SI Engines ", Ford Motor Company, 165,000 USD, 2016 – 2017.
- 15- M. Shahbakhti (PI*), J. Naber, S. Munshi (Westport Innovations Inc. - Canada), " High BMEP and High Efficiency Micro-Pilot Ignition Natural Gas Engine ", 1,224,356 USD including 600,000 USD from US Department of Energy, 125,000 USD from Westport cash to MTU, 175,000 USD for MTU cost share, and 324,356 USD from Westport in-kind cost share, 2016 – 2019. [*Original PI but changed to Naber due to the final award requirement for foreign national approval.]
- 14- M. Shahbakhti (lead PI), K. Hedrick (UC Berkeley), K. Butts (Toyota), " GOALI: Collaborative Research: Easily Verifiable Controller Design ", 328,390 USD including 299,986 USD from US National Science Foundation (NSF), 28,404 USD from MTU cost share, 2014 – 2017.
- 13- J. Naber, M. Shahbakhti (co-PI), P. Dice, " Investigation of Ignition Performance of Hitachi Coils for PFI Natural Gas Fueled Engine on a Single Cylinder, Boosted, Spark Ignition Engine ", 42,500 USD, Hitachi North America, Feb. 2016 – Aug. 2016.
- 14- M. Shahbakhti (PI), " FPGA Software for Real-Time Powertrain Control Research and Education ", Xilinx® Design Software Tool, 1,099.00 USD, Xilinx Inc., Mar. 2016.
- 11- J. Naber, S.Y. Lee, M. Shahbakhti (co-PI), " Continuation of Engine Ignition Studies ", 115,000 USD, Ford Motor Company, 2015-2016.
- 10- J. Naber, M. Shahbakhti (co-PI), " Injector Evaluation and Characterization on Mahle Optical Single Cylinder DI SI Engine ", 63,477 USD, Nostrum Motors, 2015.
- 9- M. Shahbakhti (PI), R. Berkey, " Advancing Vehicle Education and Research through HIL Simulator and Student Competition Vehicle Support ", 25,000 USD, Denso North America, 2014-2015.
- 8- J. Naber, S.Y. Lee, M. Shahbakhti (co-PI), " Continuation of Ignition Studies ", 115,000 USD, Ford Motor Company, 2014-2015.
- 7- M. Shahbakhti (PI), " NI-based Automotive Hardware-in-the-Loop Setup Research", National Instruments, equipment 4,381 USD, 2015.
- 6- M. Shahbakhti (PI), " Optimal, Energy-Efficient Solutions for Integration of Buildings and Smart Grids ",

- 15,000 USD, Michigan Tech Research Excellence Fund, 2014-2015.
- 5- M. Shahbakhti (PI), " Research on Li-ion Battery in Hybrid Electric Powertrain Test Cell ", LG Chem Power Inc., equipment 11,100 USD, 2013.
 - 4- J. Naber, S.Y. Lee, M. Shahbakhti (co-PI), " Ignition Studies ", 95,752 USD, Ford Motor Company, 2013-2014.
 - 3- J. Naber, M. Shahbakhti (co-PI), " Optical Engine for Detailed Combustion Research ", equipment with value over 300,000 USD, Mahle Powertrain North America, 2013.
 - 2- M. Shahbakhti (PI), " REF-MG: Mentoring in Advanced Powertrain Control ", 9,000 USD, Michigan Tech Research Excellence Fund, 2013-2014.
 - 1- J. Worm, J. Naber, M. Shahbakhti (co-PI), 4-day course on " Torque-based Control of SI Engines ", 32,003 USD, DENSO North America Inc., Feb. 2013.

Invited Talks

- 37- M. Shahbakhti, " Data Analytics for Zero Emission Trucking Testbed ", Transport Canada, Deloitte, AMTA sponsored event on Accelerating Canada's Zero Emission Trucking Sector, Sep. 27, 2024, Edmonton, Alberta.
- 36- M. Shahbakhti, " Alberta Zero Emissions Truck Electrification Collaboration (AZETEC) ", Panellist on AMTA Industry Innovations EXPO, Sep. 26, 2024, Edmonton, Alberta.
- 35- M. Shahbakhti, " AI-based Modeling and Intelligent Management for a Fleet of Connected Vehicles ", Workshop, 27th IEEE International Conference on Intelligent Transportation Systems, Sep. 23, 2024, Edmonton, Alberta.
- 34- M. Shahbakhti, " Data Analytics and Control of Connected and Autonomous Vehicles (CAVs) ", Department of Mathematics and Computer Science, Data and Artificial Intelligence (DAI) Cluster Seminar, Technical University of Eindhoven (TU/e), Apr. 18, 2024, Eindhoven, Netherlands.
- 33- M. Shahbakhti, " Machine Learning for Monitoring and Control of Automotive Vehicles ", Eindhoven AI Systems Institute (EAIISI), EAIISI Lecture Series, Technical University of Eindhoven (TU/e), Apr. 17, 2024, Eindhoven, Netherlands.
- 32- M. Shahbakhti, " Machine Learning Modeling and Control of Automotive Powertrain and Vehicle Emissions ", TNO (Netherlands Organisation for Applied Scientific Research), Apr. 16, 2024, Helmond, Netherlands.
- 31- M. Shahbakhti, L. Jiang, " Truck Platooning on Canadian Public Roads in Winter Driving Conditions ", Transportation Association of Canada (TAC), Panelist for Technology Achievement Award, Jul. 27, 2023, Online session, Canada.
- 30- M. Shahbakhti, S. Lindwall, " Data & Movement Information for Cooperative Truck Platooning Systems Trial ", The Data Management (DAMA) Association, Apr. 28, 2022, Edmonton, Canada.
- 29- M. Shahbakhti, " Cooperative Truck Platooning Trials in Alberta ", SAE Alberta Section, Mar. 17, 2022, Edmonton, Canada.
- 28- M. Shahbakhti, J. Laverty, " Intelligent Management of University of Alberta Fleet Vehicles ", Panel on Sustainability Awareness: Campus as a Living Lab, University of Alberta, Oct. 26, 2021, Canada.
- 27- M. Shahbakhti, A. Osornio-Vargas, " Urban Carrying Capacity under Cold Climate for Transportation Generated Air Pollution and Public Exposure", Canada's Social Sciences and Humanities Research Council (SSHRC), Panellist and Online Forum/Talks and, Living within the Earth's Carrying Capacity Program, Panel on Healthy Communities, Apr. 7, 2021, Canada.
- 26- M. Shahbakhti, " Exergy-wise Control of Energy Systems: A Promising Paradigm to Enable Maximum Energy Conversion Efficiency in Systems ", Control Seminars Series, University of Michigan – Ann Arbor, Delivered online due to Covid travel restrictions, Nov. 13, 2020, Ann Arbor, MI, USA.
- 25- M. Shahbakhti, " Modeling and Predictive Control of Multi-Mode Combustion Engines along with Hybrid Electric Vehicles, and Energy Saving Opportunities in a Connected World", Mechanical Engineering Department, University of British Columbia, Jan. 30, 2020, Vancouver, BC, Canada.

- 24- M. Shahbakhti, " Energy Mechatronics: Enabling Smart Buildings and Intelligent Autonomous Vehicles in a Connected World ", School of Sustainable Energy Engineering, Simon Fraser University, Jan. 27, 2020, Vancouver, BC, Canada.
- 23- M. Shahbakhti, " Intelligent Control of Building and Automotive Energy Systems in a Connected World ", College of Engineering Seminar Series, University of Georgia, Oct. 5, 2018, Athens, GA, USA.
- 22- M. Shahbakhti, " Energy Mechatronics: Enabling Smart Buildings and Building-to-Grid Operation in a Connected World ", Mechanical Engineering Department, University of Alberta, July 6, 2018, Edmonton, AB, Canada.
- 21- M. Shahbakhti, " Modeling and Control of Building and Automotive Energy Systems in the New Era of Connected World ", Mechanical and Aerospace (MAE) Engineering Graduate Seminar Series, MAE Department, University of California - Davis, May 17, 2018, Davis, CA, USA.
- 20- M. Shahbakhti, " Intelligent Control of Buildings Integrated with Renewable Solae Energy Sources ", Guest lecture at Alternative Energy Enterprise, Michigan Technological University, Mar. 27, 2018, Houghton, MI, USA.
- 19- M. Shahbakhti, " Control of Advanced Hybrid Electric Vehicles ", Center for Automotive Research (CAR), Ohio State University, Sep. 5, 2017, Columbus, OH, USA.
- 18- M. Shahbakhti, " Ultra Low CO₂ Transportation Technologies via Energy Mechatronics ", Department of Automotive, Mechanical, and Manufacturing Engineering, University of Ontario Institute of Technology, Aug. 11, 2017, Oshawa, ON, Canada.
- 17- M. Shahbakhti, " Physics-based Control of Energy Systems Ranging from Smart Buildings and Power Grid to Smart Hybrid Electric Vehicles ", Waterloo Institute for Sustainable Energy, WISE Lecture Series, University of Waterloo, Aug. 02, 2017, Waterloo, ON, Canada.
- 16- M. Shahbakhti, " Multi-Physics Modeling and Model-based Control of Energy Systems ", University of Calgary, Mechanical Engineering Department, Jun. 23, 2017, Calgary, AB, Canada.
- 15- M. Shahbakhti, " Advanced Engine and Powertrain Research Towards Fuel-efficient Vehicles ", VolvoCars Company, Jun. 2, 2017, Gothenburg, Sweden.
- 14- M. Shahbakhti, A. Solouk, " Fuel Economy Benefits of Electrified Powertrains with Advanced Combustion Engines: Mild to Strong HEV Applications ", *2017 SIA Int. Powertrain Conference*, Jun. 7, 2017, Versailles, France.
- 13- B. Mahadevan, J. Johnson, M. Shahbakhti, " Simulation of Temperature and Particulate Matter Distribution and Pressure Drop of a Catalyzed Diesel Particulate Filter ", Cross Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Focus Group including a number of industry, government, and academic representatives, Teleconference Presentation, Mar. 22, 2017, USA.
- 12- M. Shahbakhti, D. Hanover, " Modeling and Control of Smart Buildings with Renewable Integrations ", Guest lecture at Alternative Energy Enterprise, Michigan Technological University, Mar. 14, 2017, Houghton, MI, USA.
- 11- M. Shahbakhti, " Control and Electrification of Multi-mode Low Temperature Combustion Engines ", University of Wisconsin-Madison, Mechanical Engineering Department, Feb. 27, 2017, Madison, WI, USA.
- 10- A. Solouk, M. Shahbakhti, " Potential of Low Temperature Combustion (LTC) Engine Technology for Range Extender Vehicles ", *2016 SAE Range Extenders for Electric Vehicles Symposium*, Nov. 2, 2016, Knoxville, TN, USA.
- 9- M. Shahbakhti, " Modeling and Control of Energy Systems ", Halla Visteon Climate Control Corp. (HVCC), Apr. 21, 2015, Van Buren Township, MI, USA.
- 8- M. Shahbakhti, " Model-based Control of a Low Temperature Combustion (LTC) Engine ", University of Wisconsin-Madison, Engine Research Center, May 23, 2013, Madison, WI, USA.
- 7- M. Shahbakhti, " Model-based Control of a Low Temperature Combustion (LTC) Engine ", GM R&D, October 16, 2013, Warren, MI, USA.

- 6- M. Shahbakhti, " Control Challenges and Opportunities for Advanced Automotive Combustion Engine Research ", 2013 IEEE Workshop on Open Problems and Challenges in Automotive Control, June 20, 2013, Washington DC, USA.
- 5- M. Shahbakhti, " LTC Engines: Opportunities, Challenges, and Solutions ", Michigan Tech University, Graduate Curriculum Seminar Series, Apr. 11, 2013, Houghton, MI, USA.
- 4- M. Shahbakhti, " Model-based Powertrain Controller Design and Verification ", University of Alberta, Apr. 20, 2012, Edmonton, Canada.
- 3- M. Shahbakhti, " Early Model-based Design and Verification of Powertrain Control System ", University of California - Merced, Feb. 8, 2012, Merced, CA, USA.
- 2- M. Shahbakhti, " Powertrain Research Seminar ", Cranfield University, Dec. 1, 2011, Cranfield, UK.
- 1- M. Shahbakhti, " Powertrain Modeling for Model-based Controller Design ", McMaster University, Jul. 14, 2011, Hamilton, Canada.

Media Appearances

- M. Shahbakhti, Interview by M. Cummings, " Alberta semi-automated truck convoys didn't save fuel but tech still has promise, researchers say ", Published in CBC (Canadian Broadcasting Corporation), May 3, 2024.
- M. Shahbakhti, Interview by I. Semeniuk, " At the top of the CN Tower, a rare study of winter air pollution is under way ", Published in The Globe and Mail, Feb. 11, 2024.

Professional Service

Technical Committees

- Secretary, Executive Committee (ExComm) of the ASME-Dynamic Systems and Control Division (DSCD), 2023 – present
- Elected chair (2020-2022), Elected vice-chair (2018-2020), Best Paper Award Committee Chair (2018-2021), Best Paper Award Committee Member (2022-2024), Elected Secretary (2016-2018), Lead session organizer (2014-2016), member (2010-present) of ASME-DSCD Automotive and Transportation Systems Technical Committee
- Elected chair (2018-2020), Elected vice-chair (2016-2018), Best Paper Award Committee Member (2016-2020,2023), secretary (2014-2016), publicity chair (2012-2014), and Fuels & Combustion thrust area leader (2012-2013), member (2012 – present) of ASME-DSCD Energy Systems Technical Committee
- Member of ASME-DSCD Mechatronic Technical Committee, 2011 – present
- Member of IEEE CSS Technical Committee on Automotive Controls, 2015 – present
- Member of SAE Technical Committee on New Engines, Components, Actuators and Sensors, 2016 – present

Editorships

- Editor
 - Technical Editor, ASME/IEEE Transactions on Mechatronics, 2025 – now
 - Guest Editor for Special Issue on “Optimal Design and Operation of Energy Systems”, *Int. Journal of Optimal Control Applications and Methods* (Wiley Publisher), 2020 – 2022

- Guest Editor for Special Issue on “Connected and Automated Vehicles”, *ASME Journal of Dynamic Systems, Measurement, and Control*, 2020 – 2021
- Guest Editor for Special Issue on “Enabling Green Mobility via Advanced Powertrain Engineering”, *Int. Journal of Powertrains (IJPT)*, 2019 – 2020
- Guest Editor for Special Issue on “Vehicle Powertrain Research”, *Int. Journal of Powertrains*, 2016-2017
- Guest Editor for *ASME Dynamic Systems and Control Division E-Newsletter* – Summer Issue, 2017
- Associate Editor
 - Associate Editor, *ASME Journal of Dynamic Systems, Measurement, and Control*, 2017 – 2023
 - Associate Editor, *Int. Journal of Powertrains* (Inderscience Publishers), 2014 – 2020
 - Associate Editor, 11th IFAC International Symposium on Advances in Automotive Control (AAC), Eindhoven, Netherlands, 2025
 - Associate Editor at large, 2024 IFAC Modeling, Estimation and Control Conference (MECC), Chicago, IL, USA, 2024
 - Associate Editor, Proceedings of 2022 IFAC International Symposium on Advances in Automotive Control, Columbus, OH, USA, 2022
 - Associate Editor, Proceedings of 2014 American Control Conference
 - Associate Editor, Proceedings of 2014 ASME Dynamic Systems Control Conference
- Editorial Board Member, *International Journal of Vehicle Autonomous Systems* (2020 – present), *International Journal of Automobiles and Automobile Technologies* (2020 – present), *International Journal of Powertrains* (2020 – present), *Energies* (2020 – present)

Reviewing/Refereeing Activities

Funding Agencies

- Panel for US Department of Energy (DOE) Vehicle Technologies - Fuels Technologies (FT) Program, Annual Merit Review and Peer Evaluation, Washington DC, 2013, 2014, 2018, 2020, 2021, 2022.
- Panel for US National Science Foundation (NSF), Reviewer for grant proposals, 2015, 2016, 2019, 2020, 2021.
- Panel for US Department of Energy (DOE), Reviewer for grant proposals, 2015, 2017, 2018.
- Grant proposals review, Mitacs (Canadian national research organization) Elevate Program, Accelerate Program, Canada, 2022, 2023, 2024.
- Panel for MTU REF Mentoring Grant Proposals, 2014.
- Grant proposal review, Poland National Science Centre (SHENG), 2018.
- Grant proposal review, Dutch Technology Foundation STW - NWO (Netherlands), 2016.
- Grant proposal review, IdEx Bordeaux (France), 2015.
- Grant proposal review, Luxembourg National Research Fund (Germany), 2014.
- Grant proposal review, Croatian Science Foundation, 2012, 2020.
- Grant proposal review, Shota Rustaveli National Science Foundation (USA), 2012.

National Institutions

- Review of the Research Program of the US DRIVE Partnership: Fifth Report (2017), 204 pages, Available online, US National Academies of Sciences, Engineering, Medicine, 2017.

Promotion & Tenure

- Promotion to Tenure application assessment, New Jersey Institute of Technology, USA, 2024.
- Promotion to Tenure application assessment, University of Massachusetts at Lowell, USA, 2024.
- Promotion to Tenure application assessment, Tennessee Tech Univ., USA, 2021.
- Promotion to Tenure application assessment, Carleton Univ., Canada, 2021.

Books/eLearning

- CRC Press, Review of a new book on engine controls, 2022.
- Elsevier Publishing, Review of a new book on nonlinear controls, 2020.
- Elsevier Publishing, Review of a new book on automotive powertrain testing, 2019.
- Springer International Publishing AG, Review of a new book on hybrid electric vehicle controls, 2017.
- IEEE eLearning Course, 2018.

Journals

- Automatica (Elsevier)
- Annual Reviews in Control (Elsevier)
- Journal of Dynamic Systems, Measurement, and Control (ASME)
- Applied Energy (Elsevier)
- Journal of the Energy Institute (Elsevier)
- Mechatronics (Elsevier)
- Int. Journal of Robust and Nonlinear Control (Wiley)
- Control Engineering Practice (Elsevier)
- IEEE/ASME Transactions on Mechatronics
- IEEE Transactions on Control Systems Technology
- IEEE Transactions on Industrial Electronics
- IEEE Transactions on Vehicular Technology
- IEEE Transactions on Intelligent Vehicles
- IEEE Transactions on Intelligent Transportation Systems
- IEEE Transactions on Transportation Electrification
- IEEE Systems Journal
- Transportation Research Part D: Transport and Environment (Elsevier)
- Journal of Mechanical Engineering Science - Proceedings of IMechE, Part C (SAGE)
- Int. Journal of Engine Research (SAGE)
- Int. Journal of Powertrains (Inderscience)
- International Journal of Vehicle Autonomous Systems (Inderscience)
- Journal of Automobile Engineering - Proceedings of IMechE, Part D (SAGE)
- SAE Int. Journal of Fuels and Lubricants
- Fuel (Elsevier)
- Journal of Petroleum Gas and Engineering (Academic Journals)

- Journal of Petroleum Technology and Alternative Fuels (Academic Journals)
- Combustion Science and Technology (Taylor & Francis)
- Journal of Heat Transfer Research (BegellHouse)
- Int. Journal of Vehicle Noise and Vibration (InderScience)

Conferences

- ASME: Dynamic Systems and Control Conference (DSCC); Internal Combustion Engine Conference
- CSME: Canadian Society of Mechanical Engineering International Congress
- SAE: World Congress; Powertrains, Fuels & Lubricants Conference
- IEEE/IFAC: American Control Conference; IFAC World Congress; IEEE Conference on Decision and Control; European Control Conference; Multi Conference on Systems and Control; IEEE Conference on Control Technology and Applications; Int. Symposium on Advances in Automotive Control

Chair/Co-chair Technical Sessions (47)

- Chair of the technical session " Batteries and Fuel Cells ", IFAC Modeling, Estimation and Control Conference (MECC), Oct. 27-30, 2024, Chicago, IL, USA.
- Co-chair of the technical session " Estimation and Control for Energy Storage Systems ", IFAC Modeling, Estimation and Control Conference (MECC), Oct. 27-30, 2024, Chicago, IL, USA.
- Chair of the workshop session on " Frontiers in AI-powered Optimization and Virtual Validation of Vehicle Systems and Fleet ", 27th IEEE International Conference on Intelligent Transportation Systems, Sep. 23, 2024, Edmonton, Alberta, Canada.
- Chair of the technical session on " RI: Machine Learning in Control ", American Control Conference, July 10, 2024, Toronto, ON, Canada.
- Co-chair of the technical session on " Machine Learning in Automotive Powertrains ", IFAC World Congress, July 13, 2023, Yokohama, Japan.
- Chair of the technical session on " Internal Combustion Engine & Gas-turbine Engine Combustion ", Combustion Institute/Canadian Section Spring Tech. Conference, May 16, 2023, Edmonton, AB, Canada.
- Chair of technical session " Rising Stars in Automotive and Transportation Systems ", IFAC Modeling, Estimation and Control Conference (MECC), Oct. 5, 2022, Jersey City, NJ, USA.
- Chair of three technical sessions in Transportation Symposium, Canadian Society of Mechanical Engineers (CSME) 2022 International Congress, Jun. 5-8, 2022, Edmonton, AB, Canada.
- Chair of the technical session on " Engine Combustion II ", Combustion Institute/Canadian Section (CI/CS) Spring Technical Conference, May 2022, Ottawa, ON, Canada.
- Co-chair of the technical session on " Energy Systems Modeling, Estimation and Control ", 2021 IFAC Modeling, Estimation, Control Conference (MECC), Oct. 2021, Austin, TX, USA.
- Co-chair of the special session on " Underrepresented Stories in Controls & Robotics Industry ", 2021 IFAC Modeling, Estimation, Control Conference (MECC), Oct. 2021, Austin, TX, USA.
- Track Chair of 2020 IEEE Connected and Automated Vehicles Symposium (CAVS), Oct. 2020, Victoria, BC, Canada.
- Chair of the session on " Control Methods for Automotive Applications ", IEEE Conference on Control Technology and Applications, Aug. 2020, Montreal, QC, Canada.
- Co-chair of the special session on " Automotive Applications 1 ", IEEE Conference on Control Technology and Applications, Aug. 2020, Montreal, QC, Canada.
- Chair of the session on " Control and Energy Management of Building Systems ", 2019 American Control Conference, Jul. 2019, Philadelphia, PA, USA.

- Co-chair of the special industry session on " Autonomous and Connected Vehicles ", 2019 American Control Conference, Jul. 2019, Philadelphia, PA, USA.
- Chair of the session on " Homogenous Charge Compression Ignition – Part II ", 2019 SAE World Congress, Apr. 2019, Detroit, MI, USA.
- Co-chair of the session on " Homogenous Charge Compression Ignition – Part I ", 2018 SAE World Congress, Apr. 2018, Detroit, MI, USA.
- Co-chair of the session on " Control of Smart Buildings and Microgrids ", 2017 ASME Dynamic Systems Control Conference, Oct. 2017, Tysons Corner, VA, USA.
- Co-chair of the session on " Sliding Mode Control ", 2017 ASME Dynamic Systems Control Conference, Oct. 2017, Tysons Corner, VA, USA.
- Co-chair of the session on " Control and Energy Management of Building Systems ", 2017 American Control Conference, May 2017, Seattle, WA, USA.
- Co-chair of the session on " IC Engine Modeling and Control ", 2017 American Control Conference, May 2017, Seattle, WA, USA.
- Co-chair of the session on " Modeling, Optimization, and Control of Engine Exhaust Systems ", 2017 American Control Conference, May 2017, Seattle, WA, USA.
- Co-chair of the session on " Homogenous Charge Compression Ignition – Part I ", 2017 SAE World Congress, Apr. 2017, Detroit, MI, USA.
- Chair of the session on " Modeling and Control of Automotive Systems ", 2016 ASME Dynamic System Controls Conference, Oct. 2016, Minneapolis, MN, USA.
- Chair of the session on " Modeling and Control of Combustion Engines ", 2016 ASME Dynamic System Controls Conference, Oct. 2016, Minneapolis, MN, USA.
- Co-chair of the session on " Homogenous Charge Compression Ignition – Part I ", 2016 SAE World Congress, Apr. 2016, Detroit, MI, USA.
- Chair of the session on " Homogenous Charge Compression Ignition – Part II ", 2016 SAE World Congress, Apr. 2016, Detroit, MI, USA.
- Chair of the session on " Modeling and Control of Electric and Hybrid Vehicles ", 2015 ASME Dynamic System Controls Conference, Oct. 2015, Columbus, OH, USA.
- Chair of the session on " Estimation and Control of Advanced Internal Combustion Engines ", 2015 American Control Conference, Jul. 2015, Chicago, IL, USA.
- Co-chair of the session on " Control of Autonomous Vehicles and Connected Vehicles ", 2015 American Control Conference, Jul. 2015, Chicago, IL, USA.
- Co-Chair of the session on " Control-Oriented Modeling of Advanced Internal Combustion Engines ", 2015 American Control Conference, Jul. 2015, Chicago, IL, USA.
- Co-chair of the session on " Modeling and Control of IC Engines ", 2014 ASME Dynamic System Control Conference, Oct. 2014, San Antonio, TX, USA.
- Co-chair of the session on " Dynamic Systems Modeling for the Design and Optimization of Vehicle Systems ", 2014 ASME Dynamic System Control Conference, Oct. 2014, San Antonio, TX, USA.
- Co-chair of the session on " Energy Storage: Transportation Applications ", 2014 ASME Dynamic System Control Conference, Oct. 2014, San Antonio, TX, USA.
- Chair of the session on " Modeling and Control of Advanced IC Engine Combustion ", 2014 American Control Conference, Jun. 2014, Portland, OR, USA.
- Co-chair of the session on " Model-based Estimation for Control and Diagnosis of Automotive systems ", 2014 American Control Conference, Jun. 2014, Portland, OR, USA.

- Co-chair of the session on " Modeling and Control of Advanced Transportation Systems ", 2014 American Control Conference, Jun. 2014, Portland, OR, USA.
- Chair of the session on "Control of Advanced Combustion Engines", 2013 ASME Dynamic System Control Conference, Oct. 2013, Palo Alto, CA, USA.
- Chair of the session on "Control Design Methods for Advanced Powertrain Systems and components", 2013 ASME Dynamic System Control Conference, Oct. 2013, Palo Alto, CA, USA.
- Co-chair of the session on "Automotive Control Systems", 2013 ASME Dynamic System Control Conference, Oct. 2013, Palo Alto, CA, USA.
- Chair of the session on "Modeling and Control of Advanced Combustion Systems", 2013 American Control Conference, Jun. 2013, Washington, DC, USA.
- Chair of the session on "Modeling, Estimation, and Control of Advanced Engine Sensing and Actuation", 2013 American Control Conference, Jun. 2013, Washington, DC, USA.
- Chair of the session on "Modeling and Model-Based Control of Advanced IC Engines", 2012 ASME Dynamic Systems and Control Conference, Oct. 2012, Fort Lauderdale, FL, USA.

Organizing Technical Sessions at Conferences (78 sessions)

- Co-organized two workshop sessions on " Frontiers in AI-powered Optimization and Virtual Validation of Vehicle Systems and Fleet ", 27th IEEE International Conference on Intelligent Transportation Systems, Sep. 23, 2024, Edmonton, Alberta, Canada.
- Co-organized a special industry session titled " Industrial Stories in Controls " at 2022 IFAC Modeling, Estimation, Control Conference (MECC), Jersey City, NJ, USA.
- Co-organized a technical session (PFL560) in the area of "Powertrain Actuators and Sensors" for 2022 SAE World Congress, Detroit, MI, USA.
- Co-organized a technical invited session in the area of Energy Systems Modeling, Estimation and Control at 2021 IFAC Modeling, Estimation, Control Conference (MECC), Austin, TX, USA.
- Co-organized a special session titled "Underrepresented Stories in Controls & Robotics Industry" at 2021 IFAC Modeling, Estimation, Control Conference (MECC), Austin, TX, USA.
- Co-organized a technical invited session in the area of Mechatronic Applications in Automotive Systems at 2020 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM).
- Co-organized a technical session (PFL560) in the area of "Powertrain Actuators and Sensors" for 2021 SAE World Congress, Detroit, MI, USA.
- Co-organized a technical invited session in the area of "robust and optimal control for building HVAC systems" at 2020 American Control Conference.
- Co-organized a special industry session titled "women in controls" at 2020 American Control Conference.
- Co-organized a special industry session on controls in autonomous vehicles at 2019 ASME Dynamic Systems and Control Conference.
- Co-organized a technical invited session in the area of modeling and control of thermal energy systems at 2019 ASME Dynamic Systems and Control Conference.
- Co-organized a technical invited session in the area of control and energy management of building systems at 2019 American Control Conference.
- Co-organized a special industry session in the area of connected and autonomous vehicles at 2019 American Control Conference.

- Co-organized two technical sessions in the area of combustion engines for 2019 SAE World Congress.
- Led and co-organized an invited session in the area of modeling and management of power and energy systems for 2018 ASME Dynamic Systems and Control Conference.
- Co-organized two technical sessions in the area of combustion engines for 2018 SAE World Congress.
- Co-organized one technical invited session in the area of control of smart buildings and microgrids for 2017 ASME Dynamic Systems and Control Conference.
- Co-organized one industry special session in the area of control research perspective in Automotive Industry for 2017 ASME Dynamic Systems and Control Conference.
- Led and co-organized eight technical invited sessions in the area of automotive systems for 2017 American Control Conference.
- Co-organized one technical invited session in the area of building energy systems for 2017 American Control Conference.
- Co-organized two technical sessions in the area of combustion engines for 2017 SAE World Congress.
- Led and co-organized three technical invited sessions in the area of Automotive and Transportation Systems for 2016 ASME Dynamic Systems and Control Conference.
- Led and co-organized five technical invited sessions in the area of automotive systems for 2016 American Control Conference.
- Co-organized two technical invited sessions in the area of building energy systems for 2016 American Control Conference.
- Co-organized two technical sessions in the powertrain area for 2016 SAE World Congress.
- Led and co-organized three technical invited sessions in division of Automotive and Transportation Systems (ATS) for 2015 ASME Dynamic Systems and Control Conference.
- Co-organized five technical invited sessions in the area of Automotive and Transportation Systems (ATS) for 2015 American Control Conference.
- Co-organized two technical sessions in the area of HCCI engines for 2015 SAE World Congress.
- Co-organized four technical invited sessions in the area of Automotive and Transportation Systems (ATS) and Energy Systems (ES) for 2014 ASME Dynamic Systems and Control Conference.
- Co-organized seven technical invited sessions in the areas of Automotive and Transportation Systems (ATS) and Energy Systems (ES) for 2014 American Control Conference.
- Co-organized six technical invited sessions in the area of Automotive and Transportation Systems (ATS) and Energy Systems (ES) for 2013 ASME Dynamic Systems and Control Conference.
- Co-organized five technical invited sessions in the areas of Automotive and Transportation Systems (ATS) and Energy Systems (ES) for 2013 American Control Conference.
- Co-organized three invited technical sessions in the area of Automotive and Transportation Systems (ATS) in 2012 ASME Dynamic Systems and Control Conference.
- Organized and coordinated a series of teaching seminars entitled " What Contributes to Successful Teaching in Engineering " in the Faculty of Engineering, University of Alberta, 2007-2008.

Conference Organizing Team

- Conference Finance Chair, IEEE Conference on Control Technology and Applications (CCTA), Vancouver, BC, Canada, 2026.

- Member of Technical Program Committee (TPC), 2025 International Conference on Intelligent Transportation and Future Mobility (ITFM 2025), Guangxi, Guilin, China, April 11-13, 2025.
- Conference International Program Co-Chair, IFAC Modeling, Estimation, and Control Conference (MECC), Chicago, IL, USA, 2024.
- Co-organized an open invited track on “Machine Learning in Automotive Powertrains” for IFAC World Congress, Yokohama, Japan, July 9-14, 2023.
- Conference Program Co-Chair, Combustion Institute/Canadian Section (CI/CS) Conference, Edmonton, AB, Canada, May 15-18, 2023.
- Conference International Program Committee Member, 10TH IFAC Symposium: Advances in Automotive Control, Columbus, Ohio, USA, August 28-31, 2022.
- Transportation Systems Symposium Co-chair, Canadian Society of Mechanical Engineers (CSME) International Congress, Edmonton, AB, Canada, June 5-8, 2022.
- Conference International Program Co-Chair, IFAC Modeling, Estimation, and Control Conference (MECC), Austin, TX, USA, Oct. 17-20, 2021.
- Member of Technical Program Committee (TPC), 2020 IEEE Connected and Automated Vehicles Symposium (CAVS), Victoria, Canada, 4-5 October, 2020.
- Member of Conference Scientific Committee, 2019 International Symposium on Automotive Science and Technology (ISASTECH), Ankara, Turkey, Sep. 5-6, 2019.
- Conference Program Co-Chair, 2019 International Conference on Advanced Vehicle Powertrains, Hefei, China, Aug. 25-27, 2019.
- Member of Program Committee, 2017 ASME Dynamic Systems and Control Conference, Tysons Corner, VA, USA, Oct. 11-13, 2017.
- Organizing Committee Chair, 2017 International Conference on Advanced Vehicle Powertrains, HangZhou, China, Sep. 25-27, 2017.
- Co-chaired and coordinated 2nd Annual Mechanical Engineering Graduate Symposium, over 180 participants from 8 different departments, University of Alberta, March 6, 2008.
- Member of organizing team for Combustion Institute/Canadian Section (CI/CS) spring technical conference, Banff, Alberta, Canada, May 14-16, 2007.

Workshops

- 12- R. Rezaei, F. Willems, M. Shahbakhti, H. Tadjine, workshop on " Frontiers in AI-powered Optimization and Virtual Validation of Vehicle Systems and Fleet ", 27th IEEE International Conference on Intelligent Transportation Systems, Sep. 23, 2024, Edmonton, Alberta, Canada.
- 11- A. Norouzi, C.R. Koch, M. Shahbakhti, workshop on “Machine Learning Control”, *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5, 2022, Edmonton, AB, Canada. [> 100 attendees]
- 10- M. Shahbakhti, H. Fathy, workshop (including 16 invited speakers) on “Connected and Automated Vehicles (CAVs)”, 2018 ASME Dynamic System and Control Conference, Atlanta, GA, USA, Sep. 30, 2018.
- 9- A. Scacchioli, M. Shahbakhti, workshop (including 6 invited speakers) on “From Data to Models and Decisions in Engineering Systems”, 2018 ASME Dynamic System and Control, Atlanta, GA, USA, Sep. 30, 2018.
- 8- M. Shahbakhti, K. Hedrick, K. Butts, half-day workshop on “Methods of Easily Verifiable Control Design”, American Control Conference, Boston, MA, USA, Jul. 5, 2016.
- 7- J. Worm, J. Naber, M. Shahbakhti, 4-day workshop on " Torque-based Control of SI Engines ", DENSO Inc., Southfield, MI, USA, Feb. 5-8, 2013.

- 5- M. Shahbakhti, N. Yusefi, " Automotive Engines and Power Transmission Systems ", Let's Talk Science Workshop, Edmonton, Canada, Mar. 14, 2008.
- 5- M. Shahbakhti, N. Yusefi, " Vortex in Rotational Flows ", Let's Talk Science Workshop, Edmonton, Canada, Mar. 14, 2008.
- 4- M. Shahbakhti, " HCCI Engines and Advanced Methods to Improve Emissions of Motor Vehicles ", 81th Annual GETCA Convention (Greater Edmonton Teachers Convention), Shaw conference center, Edmonton, Canada, Mar. 1-2, 2007.
- 3- M. Shahbakhti, " Vehicles' Emissions ", Heritage Youth Researcher Summer (HYRS) Teachers Workshop, University of Alberta, Jul. 25-26, 2006.
- 1- M. Shahbakhti, " Engineering Solutions for Automotive Emissions ", HYRS Teachers Workshop, University of Alberta, Aug. 8-10, 2005.
- 1- M. Shahbakhti, " Methods to Reduce Emissions of Vehicles during Cold Start and Warm up Conditions ", 3rd International Conference on Internal Combustion Engines (ICICE), Tehran, Iran, Feb. 19, 2004.

Publications (students under Shahbakhti's supervision/mentorship are indicated by “*”)



Publications cited in 83 countries [Google Scholar]

Book Chapters

- 4- A. R. Razmi*, Sh. Sharifi*, E. Gholamian, A. Arabkoohsar, M. Shahbakhti, " Green Hydrogen ", pages 574-620, Book title: Future Grid-Scale Energy Storage Solutions, Elsevier, ISBN 978-0-323-90786-6, 2023.
- 3- Sh. Sharifi*, A. R. Razmi*, M. H. Nabat, J. Liu, A. Arabkoohsar, M. Shahbakhti, " Power-to-X ", pages 621-646, Book title: Future Grid-Scale Energy Storage Solutions, Elsevier, ISBN 978-0-323-90786-6, 2023.
- 2- M. H. Nabat, A. R. Razmi*, Sh. Sharifi*, A. Arabkoohsar, M. Shahbakhti, " Liquid Air Energy Storage ", pages 345-408, Book title: Future Grid-Scale Energy Storage Solutions, Elsevier, ISBN 978-0-323-90786-6, 2023.

- 1- S. Batool*, J. D. Naber, M. Shahbakhti, " Multi-mode Low Temperature Combustion (LTC) and Mode Switching Control ", pages 43-93, Book title: Advanced Combustion for Sustainable Transport, Springer, ISBN 978-981-16-8417-3, 2022.

Selected Peer Reviewed Journal Papers

- 113- S. Moghadasi*, A. Yasami*, S. Munshi, G. McTaggart-Cowan, M. Shahbakhti, " Real-world Steep Drive Cycles and Gradeability Performance Analysis of Hybrid Electric and Conventional Class 8 Regional-haul Trucks ", *Energy*, Vol. 320, 24 pages, 2025.
- 112- A. Razmi*, A. R. Hanifi, M. Shahbakhti, " A Comparative Techno-Economic Analysis Between Solar-based Hydrogen Production by Methane Pyrolysis and Water Electrolysis Methods ", *Renewable Energy*, Vol. 242, pages 1-26, 2025.
- 111- Z. Salehi*, M. Tofigh*, A. Kharazmi, D. J. Smith, A. R. Hanifi, C. R. Koch, M. Shahbakhti, " Transfer Learning-based Deep Neural Network Model for Performance Prediction of Hydrogen-Fueled Solid Oxide Fuel Cells ", *Int. Journal of Hydrogen Energy*, Vol. 99, pages 102-111, 2025.
- 110- N. Balazadeh, S. Munshi, M. Shahbakhti, G. McTaggart-Cowan, " Predicting Transient Performance of a Heavy-Duty Gaseous-Fuelled Engine Using Combined Phenomenological and Machine Learning Models ", *Int. Journal of Engine Research*, 18 pages, 2024.
- 109- M. Tofigh*, A. Kharazmi, D. J. Smith, A. R. Hanifi, C. R. Koch, M. Shahbakhti, " Temporal Dilated Convolution and Nonlinear Autoregressive Network for Predicting Solid Oxide Fuel Cell Performance ", *Engineering Applications of Artificial Intelligence*, Vol. 136, 13 pages, 2024.
- 108- A. Ansari*, H. Abediasl*, M. Shahbakhti, " Ambient Temperature Effects on Energy Consumption and CO₂ Emissions of a Plug-in Hybrid Electric Vehicle ", *Energies*, Vol. 17, Issue 14, 21 pages, 2024, to appear.
- 107- M. Tofigh*, M. Fakouri Hasanabadi*, A. R. Hanifi, D. J. Smith, A. Kharazmi, C. R. Koch, M. Shahbakhti, " Control-oriented Modeling of a Solid Oxide Fuel Cell Affected by Redox Cycling using a Novel Deep Learning Approach ", *ASME Journal of Dynamic Systems, Measurement, and Control*, 13 pages, 2024, to appear.
- 106- S. Shahpouri*, D. Gordon, M. Shahbakhti, C. R. Koch, " Transient NO_x Emission Modeling of a Hydrogen-Diesel Engine Using Hybrid Machine Learning Methods ", *Int. Journal of Engine Research*, 21 pages, 2024, to appear.
- 105- A. Razmi*, A. R. Hanifi, M. Shahbakhti, " Thermodynamic and Economic Analysis of a Novel Concept for Methane Pyrolysis in Molten Salt Combined with Heliostat Solar Field ", *Energy*, Vol. 301, 17 pages, 2024.
- 104- M. Tofigh*, Z. Salehi*, A. Kharazmi, D. J. Smith, A. R. Hanifi, C. R. Koch, M. Shahbakhti, " Transient Modeling of a Solid Oxide Fuel Cell using an Efficient Deep Learning HY-CNN-NARX Paradigm ", *Journal of Power Sources*, Vol. 606, 15 pages, 2024.
- 103- S. Moghadasi*, Y. Long*, L. Jiang*, S. Munshi, G. McTaggart-Cowan, M. Shahbakhti, " Design and Performance Analysis of Hybrid Electric Class 8 Heavy-Duty Regional-haul Trucks with a Micro-Pilot Natural Gas Engine in Real-World Highway Driving Conditions ", *Journal of Energy Conversion and Management*, Vol. 309, 20 pages, 2024.
- 102- L. Jiang*, J. Kheyrollahi, C. R. Koch, M. Shahbakhti, " Cooperative Truck Platooning Trial on Canadian Public Roads under Commercial Operation in Winter Driving Conditions ", *IMEchE Part D – Journal of Automobile Engineering*, 13 pages, DOI:10.1177/09544070241245477, 2024.

- 101- S. Batool*, J. Naber, M. Shahbakhti, " Machine Learning Approaches for Identification of Heat Release Shapes in a Low Temperature Combustion Engine for Control Applications ", *Control Engineering Practice*, Vol. 144, 16 pages, 2024.
- 100- L. Jiang*, J. Kheyrollahi, C. R. Koch, M. Shahbakhti, " Performance Analysis of Cooperative Truck Platooning under Commercial Operation during Canadian Winter Season ", *SAE Int. Journal of Connected and Automated Vehicles*, Vol. 7, Issue 2, 16 pages, 2024.
- 99- A. Razmi*, Sh. Sharifi*, S. Vafaeenezhad, A. R. Hanifi, M. Shahbakhti, " Modeling and Microstructural Study of the Anode-support Solid Oxide Fuel Cells: Experimental and Thermodynamic Analyses", *Int. Journal of Hydrogen Energy*, Vol. 54, Pages 613-634, 2024.
- 98- N. Balazadeh Meresht, S. Moghadasi*, S. Munshi, M. Shahbakhti, G. McTaggart-Cowan, " Advances in Vehicle and Powertrain Efficiency of Long-haul Commercial Vehicles: A Review ", *Energies*, Vol. 16, Issue 19, 37 pages, 2023.
- 97- H. Abediasl*, N. Balazadeh Meresht, H. Alizadeh, M. Shahbakhti, C. R. Koch, V. Hosseini, "Road Transportation Emissions and Energy Consumption in Cold Climate Cities", *Urban Climate*, Vol. 52, 23 pages, 2023.
- 96- A. R. Razmi*, A. R. Hanifi, M. Shahbakhti, " A Green Hydrogen Production and Storage Concept based on Heliostat Solar Field and Solid Oxide Electrolyzer/Fuel Cells: Thermodynamic and Economic Analyses ", *Journal of Renewable Energy*, Vol. 215, 21 pages, 2023.
- 95- N. Samadi*, M. Shahbakhti, " Energy Efficiency and Optimization Strategies in a Building to Minimize Airborne Infection Risks ", *Energies*, Vol. 16, Issue 3, 28 pages, 2023.
- 94- H. Abediasl*, A. Ansari*, V. Hosseini, C. R. Koch, M. Shahbakhti, " Real-time Fuel Consumption Estimation using Machine Learning and On-board Diagnostics Data ", *IMEchE Part D: Journal of Automobile Engineering*, 15 pages, doi:10.1177/09544070231185609, 2023.
- 93- C. Reddy*, V. B. Vinhaes*, J. D. Naber, R. D. Robinett, M. Shahbakhti, " Exergy-Based Model Predictive Control of an Integrated Dual Fuel Engine and a Waste Heat Recovery System ", *Control Engineering Practice*, Vol. 135, 15 pages, 2023.
- 92- S. Shahpouri*, D. Gordon, C. Hayduk, R. Rezaei, C. R. Koch, M. Shahbakhti, " Hybrid Emission and Combustion Modeling of Hydrogen Fueled Engines ", *International Journal of Hydrogen Energy*, Vol. 48, Issue 62, pages 24037-24053, 2023.
- 91- P. Reddy*, M. Ravichandran, J. Doering, M. Shahbakhti, " Real-time Predictive Clunk Control using a Reference Governor ", *Control Engineering Practice*, Vol. 135, 15 pages, 2023.
- 90- A. Norouzi*, H. Heidarifar*, H. Borhan, M. Shahbakhti, C. R. Koch, " Integrating Machine Learning and Model Predictive Control for Automotive Applications: A Review and Future Directions ", *Engineering Applications of Artificial Intelligence*, Vol. 120, 31 pages, 2023.
- 89- X. Ma, M. Shahbakhti, T. Chigan, " Deep Learning based Distributed Meta-Learning for Fast and Accurate Online Adaptive Powertrain Fuel Consumption Modeling ", *IEEE Transactions on Vehicular Technology*, Vol. 72, Issue 6, pages 7251-7264, 2023.
- 88- A. Norouzi*, S. Shahpouri*, D. Gordon, M. Shahbakhti, C. R. Koch, " Safe Deep Reinforcement Learning in Diesel Engine Emission Control ", *Proc IMechE Part I: Journal of Systems and Control Engineering*, DOI: 10.1177/09596518231153445, 14 pages, 2023.
- 87- B. K. Irdmousa*, L. N. A. Basina*, J. D. Naber, J. Mohammadpour Velni, H. Borhan, M. Shahbakhti, " Control-oriented Data-driven and Physics-based Modeling of Maximum Pressure Rise Rate in Reactivity Controlled Compression Ignition Engines ", *SAE Int. Journal of Engines*, Vol. 16, Issue 6, 12 pages, 2023.
- 86- S. Shahpouri*, A. Norouzi*, C. Hayduk, A. Fandakov, R. Rezaei, C. R. Koch, M. Shahbakhti, " Laminar Flame Speed Modeling for Low Carbon Fuels Using Methods of Machine Learning ", *Fuel*, Vol. 333, Issue 1, 11 pages, 2023.

- 85- S. Batool*, J. D. Naber, M. Shahbakhti, " Closed-loop predictive control of a multi-mode engine including HCCI, PPCI and RCCI combustion modes ", *SAE International Journal of Fuels and Lubricants*, Vol. 16, Issue 1, 22 pages, 2023.
- 84- D. C. Gordon, A. Norouzi*, A. Winkler, J. McNally, E. Nuss, D. Abel, M. Shahbakhti, J. Andert, C. R. Koch, " End-to-End Deep Neural Network-based Nonlinear Model Predictive Control: Experimental Implementation on Diesel Engine Emission Control", *Energies*, Vol. 15, Issue 24, 24 pages, 2022.
- 83- A. Khameneian*, P. Dice, J. Duncan, M. Shahbakhti, J. D. Naber, C. Archer, P. Moilanen, C. Glugla, G. Huberts, " Dynamic Individual-Cylinder Analysis of a Gasoline Direct Injection Engine Emissions for Cold Crank-Start at Elevated Cranking Speed Conditions of a Hybrid Electric Vehicle ", *Control Engineering Practice*, Vol. 129, 15 pages, 2022.
- 82- A. Norouzi*, S. Shahpouri*, D. Gordon, A. Winkler, E. Nuss, D. Abel, J. Andert, M. Shahbakhti, C. R. Koch, " Deep Learning based Model Predictive Control for Compression Ignition Engines ", *Control Engineering Practice*, Vol. 127, 13 pages, 2022.
- 81- A. R. Razmi*, S. M. Alirahmi, M. H. Nabat, E. Assareh, M. Shahbakhti, " A Green Hydrogen Energy Storage Concept based on Parabolic Trough Collector and Proton Exchange Membrane Electrolyzer/Fuel Cell: Thermodynamic and Exergoeconomic Analyses with Multi-Objective Optimization ", *International Journal of Hydrogen Energy*, Vol. 47, Issue 62, Pages 26468-26489, 2022.
- 80- V. Bonfochi Vinhaes*, X. Yang*, G. McTaggart-Cowan, S. Munshi, M. Shahbakhti, J. Naber, " Development of a Medium-Duty Stoichiometric Diesel Micro-Pilot Natural Gas Engine ", *International Journal of Engine Research*, 14 pages, 2022. doi:10.1177/14680874221087954
- 79- O. Wine*, A. O. Vargas, S. Campbell, V. Hosseini, C. R. Koch, M. Shahbakhti, " Cold Climate Impact on Air Pollution Related Health Outcomes: A Scoping Review ", *International Journal of Environmental Research and Public Health*, Vol. 19, Issue 3, 17 pages, 2022.
- 78- V. Bonfochi Vinhaes*, G. McTaggart-Cowan, S. Munshi, M. Shahbakhti, J. D. Naber, " Experimental Studies of Low Load Limit in a Stoichiometric Micro-Pilot Diesel Natural Gas Engine ", *Energies*, Vol. 15, Issue 3, 18 pages, 2022.
- 77- M. Toub*, R. D. Robinett III, M. Shahbakhti, " Building-to-Grid Optimal Control of Integrated MicroCSP and Building HVAC System for Optimal Demand Response Programs", *Optimal Control Applications and Methods*, 19 pages, 2022.
- 76- S. Hemmati*, R. Yadav*, S. Kaushik*, D. Robinette, M. Shahbakhti, " Important Powertrain Dynamics for Developing Models for Control of Connected and Automated Electrified Vehicles ", *IMEchE Part D: Journal of Automobile Engineering*, 18 pages, 2022. doi:10.1177/09544070211070738
- 75- A. Khameneian*, B. Khoshbakht Irdmousa*, P. Dice, M. Shahbakhti, J. D. Naber, P. Moilanen, C. Archer, C. Glugla, G. Huberts, " A Dynamic Method to Analyze Cold Start First Cycles Engine-Out Emissions at Elevated Cranking Speed Conditions of a Hybrid Electric Vehicle Including a Gasoline Direct Injection Engine ", *SAE International Journal of Engines*, Journal Article Number 03-15-06-0044, Vol. 15, Issue 6, 21 pages, 2022.
- 74- C. Reddy*, V. Bonfochi Vinhaes*, J. D. Naber, R. D. Robinett III, M. Shahbakhti, " Model Predictive Control of a Dual Fuel Engine Integrated with Waste Heat Recovery used for Electric Power in Buildings", *Optimal Control Applications and Methods*, 20 pages, 2022.
- 73- A. Mohammad, R. Rezaei, C. Hayduk, T. O. Delebinski, S. Shahpouri*, M. Shahbakhti, " Physical-oriented and Machine Learning-based Emission Modeling in a Diesel Compression Ignition Engine: Dimensionality Reduction and Regression ", *Int. J. of Engine Research*, 15 pages, 2022.
- 72- P. Reddy*, M. Shahbakhti, M. Ravichandran, J. Doering, " Real-time Estimation of Backlash Size in Automotive Drivetrains ", *IEEE/ASME Transactions on Mechatronics*, 11 pages, 2022.

- 71- A. Khameneian*, X. Wang, P. Dice, J. D. Naber, M. Shahbakhti, C. Archer, P. Moilanen, C. Glugla, G. Huberts, " A Real-Time Control-Oriented Discrete Nonlinear Model Development for In-Cylinder Air Charge, Residual Gas and Temperature Prediction of a Gasoline Direct Injection Engine Using Cylinder, Intake and Exhaust Pressures ", *Control Eng. Practice*, Vol. 119, 21 pages, 2022.
- 70- M. Aliramezania, C. R. Koch, M. Shahbakhti, " Modeling, Diagnostics, Optimization, and Control of Internal Combustion Engines via Advanced Machine Learning Techniques: A Review and Future Directions ", *Progress in Energy and Combustion Science*, Vol. 88, 38 pages, 2022.
- 69- S. Shahpouri*, A. Norouzi*, C. Hayduk, R. Rezaei, M. Shahbakhti, C. R. Koch, " Hybrid Machine Learning Approaches and a Systematic Model Selection Process for Predicting Soot Emissions in Compression Ignition Engines ", *Energies*, Vol. 14, Issue 23, 25 pages, 2021.
- 68- A. Norouzi*, H. Heidarifar*, M. Shahbakhti, C. R. Koch, H. Borhan, " Model Predictive Control of Internal Combustion Engines: A Review and Future Directions ", *Energies*, Vol. 14, Issue 19, 40 pages, 2021.
- 67- S. A. Nadeem*, P. Reddy*, M. Shahbakhti, M. Ravichandran, J. Doering, " Model Predictive Control of an Automotive Driveline for Optimal Torque Delivery with Minimal Oscillations during Torque Converter Slipping Conditions ", *SAE International Journal of Passenger Cars: Mechanical Systems*, Paper No. 06-14-01-0004, Vol. 14, Issue 1, 16 pages, 2021.
- 66- M. Toub*, C. R. Reddy*, R.D. Robinett III, M. Shahbakhti, " Integration and Optimal Control of MicroCSP with Building HVAC Systems: Review and Future Directions ", *Energies*, Vol. 14, Issue 3, 42 pages, 2021.
- 65- S. Hemmati*, N. Doshi*, D. Hanover*, C. Morgan, M. Shahbakhti, " Integrated HVAC and Powertrain Thermal Energy Management for a Connected Hybrid Electric Vehicle ", *Applied Energy*, Vol. 283, 22 pages, 2021.
- 64- A. Paykani, A. Garcia Martinez, M. Shahbakhti, P. Rahnama, R. D. Reitz, " Reactivity Controlled Compression Ignition Engine: Pathways Towards Commercial Viability ", *Applied Energy*, Vol. 282, Part A, 23 pages, 2021.
- 63- S. Polat*, H. S. Yücesu, A. Uyumaz, K. Kannan*, M. Shahbakhti, " An Experimental Investigation on Combustion and Performance Characteristics of Supercharged HCCI Operation in Low Compression Ratio Engine Setting ", *Applied Thermal Engineering*, Vol. 180, 16 pages, Nov. 2020.
- 62- Y. Bao, J. Mohammadpour Velni, M. Shahbakhti, " Epistemic Uncertainty Quantification in State-space LPV Model Identification Using Bayesian Neural Networks ", *IEEE Control Systems Letters (L-CSS)*, Vol. 5, Issue 2, Pages 719-724, 2020.
- 61- X. Ma, M. Shahbakhti, T. Chigan, " Connected Vehicle based Distributed Meta-Learning for Online Adaptive Engine/Powertrain Fuel Consumption Modeling ", *IEEE Transactions on Vehicular Technology*, Vol. 69, Issue 9, Pages 9553-9565, 2020.
- 60- C. Reddy*, M. Shahbakhti, R. Robinett, M. Razmara*, " Exergy-wise Predictive Control Framework for Optimal Performance of MicroCSP Systems for HVAC Applications in Buildings ", *Energy Conversion and Management*, Vol. 210, 15 pages, 2020.
- 59- M. Toub*, C. Reddy*, M. Razmara*, M. Shahbakhti, R. Robinett, G. Aniba, " Model-Based Predictive Control for Optimal MicroCSP Operation Integrated with Building HVAC Systems ", *Energy Conversion and Management*, Vol. 199, 16 pages, 2019.
- 58- V. R. Chundru, B. S. Mahadevan*, J. H. Johnson, G. G. Parker, M. Shahbakhti, " Development of a 2D Model of a SCR Catalyst on a DPF ", *Emission Control Science and Technology*, Vol. 5, Issue 2, Pages 133-171, 2019.
- 57- E. Ansari*, T. Menucci, M. Shahbakhti, J. Naber, " Experimental Investigation into Effects of High Reactive Fuel on Combustion and Emission Characteristics of the Diesel - Natural Gas RCCI Engine ", *Applied Energy*, Vol. 239, Pages 948-956, 2019.
- 56- A. Raut*, B. Irdmousa*, M. Shahbakhti, " Dynamic Modeling and Model Predictive Control of an RCCI Engine ", *Control Engineering Practice*, Vol. 81, Pages 129-144, 2018.
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- 10- S. Sharifi Rad*, S. A. Jazayeri, M. Shahbakhti, " Simulation of Vehicle Dynamics and Design of an Auto-driver for ECE Driving Cycles ", *Proceeding of 4th International Conference on Internal Combustion Engines (ICICE)*, 9 pages, Nov. 16-17, 2005, Tehran, Iran.
- 9- M. Shahbakhti, S. A. Jazayeri, M. Ghafuri, A. R. Aslani, A. Sahraeian, S. Azadi, " A Novel Method to Estimate Parameters of the Wall-Wetting Fuel Model in MPFI Engines for Cold Start and Warm up Conditions ", *Proceeding of ASME Internal Combustion Engine Fall Technical Conference*, 12 pages, Oct. 24-27, 2004, Long Beach, CA, USA.
- 8- A. Sahraeian, M. Shahbakhti, A. R. Aslani, S. A. Jazayeri, S. Azadi, " Longitudinal Vehicle Dynamics Modeling on the Basis of Engine Modeling ", *Proceeding of SAE World Congress*, SAE Paper No. 2004-01-1620, 11 pages, Mar. 8-11, 2004, Detroit, USA.
- 7- A. R. Aslani, M. Shahbakhti, A. Sahraeian, S. M. Hoseinalipoor, S. A. Jazayeri, " Dynamic Modeling of a Port Fuel-Injected Engine with Sensitivity Analysis ", *Proceeding of SAE World Congress*, SAE Paper No. 2004-01-1771, 9 pages, Mar. 8-11, 2004, Detroit, USA.
- 6- M. Shahbakhti, S. A. Jazayeri, M. Ghafuri, A. R. Aslani, A. Sahraeian, S. Azadi, " Control Oriented Modeling of Mixture Formation in MPFI Engines to Predict Air-Fuel-Ratio in Transient Conditions ", *Proceeding of 3rd International Conference on Internal Combustion Engines (ICICE)*, 15 pages, Feb. 17-19, 2004, Tehran, Iran.
- 5- A. Sahraeian, M. Shahbakhti, A. R. Aslani, " Development and Use of a Vehicle Power-train Simulation for Fuel Economy and Performance Studies ", *Proceeding of 3rd International Conference on Internal Combustion Engines (ICICE)*, 11 pages, Feb. 17-19, 2004, Tehran, Iran.
- 4- A. R. Aslani, M. Shahbakhti, A. Sahraeian, S. M. Hoseinalipoor, " Control Oriented Modeling of Paykan Injection Engine ", *Proceeding of 3rd International Conference on Internal Combustion Engines (ICICE)*, 9 pages, Feb. 17-19, 2004, Tehran, Iran. (Best paper award)

- 3- M. Shahbakhti, S. A. Jazayeri, A. R. Aslani, M. Ghafari, S. Azadi, " Identification of Dynamic Fuel Parameters in PFI Engines for Different Thermal Conditions ", Proceeding of 7th International and 11th Annual Mechanical Engineering Conference, ISME, Vol. 2, pages 743-760, 2003, Mashhad, Iran.
- 2- M. Shahbakhti, A. Mohsenian rad, S. A. Jazayeri, S. Azadi, " An Investigation into the Effective Methods to Reduce Emissions of Passenger Cars During Cold Start and Warm up Conditions ", Proceeding of 7th International and 11th Annual Mechanical Engineering Conference, ISME, Vol. 2, pages 702-718, 2003, Mashhad, Iran.
- 1- A. R. Aslani, M. Shahbakhti, S. M. Hoseinalipoor, S. A. Jazayeri, A. Ohadi, S. Azadi, " Dynamic Modeling of a Port Fuel Injection Engine for Air/Fuel Ratio Determination ", Proceeding of 7th International and 11th Annual Mechanical Engineering Conference, ISME, Vol. 2, pages 773-785, 2003, Mashhad, Iran.

Submitted Conference Papers

- 1- L. Jiang*, S. Moghadasi*, M. Shahbakhti, " Energy Management of Large-Spacing Platooning with Hybrid Electric Trucks ", *IFAC Modeling, Estimation and Control Conference (MECC)*, 6 Pages, Oct. 5-8, 2025, Pittsburgh, PA, USA.

Abstract/Extended-abstract Refereed Conference Papers (6-9 page long conference papers)

- 16- H. Abediasl*, C.R. Koch, M. Shahbakhti, " Tailpipe Emissions of a Plug-in Hybrid Electric Vehicle in Cold Climate ", Proceeding of *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 14-16, 2025, Calgary, AB, Canada.
- 15- H. Mehnatkesh*, E. Sperling, J. Kheyrollahi, M. Shahbakhti, D. Gordon, and C.R. Koch, " Emission Analysis in Data-Driven Model Predictive Control of Hydrogen/Diesel Dual-Fuel Engines ", Proceeding of *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 13-16, 2024, Kingston, ON, Canada.
- 14- L. Jiang*, M. Shahbakhti, " Cooperative Truck Platooning on Canadian Public Roads during a Winter Season ", Proceeding of 28th IAVSD International Symposium on Dynamics of Vehicles on Roads and Tracks, 9 pages, Aug. 21-25, 2023, Ottawa, ON, Canada.
- 13- J. McNally*, D. Gordon, E. Sperling, M. Shahbakhti, C.R. Koch, " Performance and Emission Investigation of Hydrogen Diesel Dual Fuel Combustion ", Proceeding of *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 15-18, 2023, Edmonton, AB, Canada.
- 12- N. Balazadeh, G. McTaggart-Cowan, S. Munshi, M. Shahbakhti, " Evaluating the Transient Performance of a Direct Injection of a Natural Gas Engine using a Phenomenological Combustion Model ", Proceeding of *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 15-18, 2023, Edmonton, AB, Canada.
- 11- S. Shahpouri*, A. Norouzi*, C. Hayduk, R. Rezaei, C. R. Koch, M. Shahbakhti, " Modeling of a Single-Fuel Hydrogen Spark ignition and a Dual-Fuel Diesel-Hydrogen Engines ", Proceeding of *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 16-19, 2022, Ottawa, ON, Canada.
- 10- A. Solouk*, M. Shahbakhti, " Fuel Economy Benefits of Electrified Powertrains with Advanced Combustion Engines: Mild to Strong HEV Applications ", 7 pages, 2017 SIA Int. Powertrain Conference, Jun. 7-8, 2017, Versailles, France.
- 9- K. Ebrahimi, M. Shahbakhti, C. R. Koch, " Comparison of Butanol/n-Heptane to PRF Blended Fuels in HCCI Engines ", 2011 *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS11-34, 6 pages, May 8-11, 2011, Winnipeg, Canada.
- 8- A. Ghazimirsaid, M. Shahbakhti, C. R. Koch, " Ignition Timing Criteria for Partial Burn Operation in an HCCI Engine", 2011 *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS11-33, 6 pages, May 8-11, 2011, Winnipeg, Canada.
- 7- M. Shahbakhti, A. Ghazimirsaid, C. R. Koch, " Combustion Characteristics of Butanol/n-Heptane Blend Fuels in an HCCI Engine ", 2010 *Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS10-A018, 6 pages, May 9-12, 2010, Ottawa, Canada.

- 6- A. Ghazimirsaid, M. Shahbakhti, C. R. Koch, " Recognizing Partial Burn Operation in an HCCI Engine", *2010 Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS10-A017, 6 pages, May 9-12, 2010, Ottawa, Canada.
- 5- M. Shahbakhti, A. Ghazimirsaid, C. R. Koch, " The Effect of Operating Conditions on HCCI Exhaust Gas Temperature ", *Proceeding of Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS-A02, 6 pages, May 10-13, 2009, Montréal, Canada.
- 4- A. Ghazimirsaid, M. Shahbakhti, C. R. Koch, " Partial-Burn Crank Angle Limit Criteria Comparison on an Experimental HCCI Engine ", *Proceeding of Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, Paper No. CICS-A52, 6 pages, May 10-13, 2009, Montréal, Canada.
- 3- A. Ghazimirsaid, M. Shahbakhti, A. Audet, C. R. Koch, " HCCI Engine Cyclic Variation Characterization Using Both Chaotic and Statistical Approach ", *Proceeding of Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 12-14, 2008, Toronto, Canada.
- 2- M. Shahbakhti, R. Lupul, A. Audet, C. R. Koch, " Experimental Study of HCCI Cyclic Variations for Low-Octane PRF Fuel Blends ", *Proceeding of Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 13-16, 2007, Banff, Canada.
- 2- M. Shahbakhti, C. R. Koch, " Thermo-kinetic Combustion Modeling of an HCCI Engine to Analyze Ignition Timing for Control Applications ", *Proceeding of Combustion Institute-Canadian Section (CICS) Spring Technical Conference*, 6 pages, May 13-16, 2007, Banff, Canada.

Non-refereed Conference Papers

- 1- B. Chen, D. Robinette, M. Shahbakhti, K. Zhang, J. Naber, " Connected Vehicles and Powertrain Optimization ", *Invited article*, 9 pages, *ASME Dynamic System Control Magazine*, 2017.
- 2- J. K. Hedrick and M. Shahbakhti, " Model-based Verification of Automotive Control System Implementation ", *Keynote paper*, 8 pages, *Int. Conference on Advanced Vehicle Technologies and Integration (VTI)*, Jul. 16-19, 2012, Changchun, China.

Abstract-refereed Conference Presentations

- 23- M. Shahbakhti, B. Bahri, J. Rao, " Alberta Zero Emission Hydrogen Transit Bus Winter Performance Results in the Edmonton Region", *Canadian Hydrogen Convention*, Apr. 23-25, 2024, Edmonton, AB, Canada.
- 22- A. Ansari*, H. Abediasl*, M. Shahbakhti, " Effect of Cold Climate on Energy Consumption of a Plug-in Hybrid Electric Vehicle ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 21- L. Jiang*, J. Kheyrollahi, C. R. Koch, M. Shahbakhti, " Cooperative Truck Platooning Trials on Canadian Public Roads under a Commercial Operation in Winter Driving Conditions ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 20- D. C. Gordon, A. Norouzi*, S. Shahpouri*, M. Shahbakhti, C. R. Koch, " Deep Reinforcement Learning for Emission Control in Diesel Engines ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 19- Y. Long*, L. Jiang*, S. Moghadasi*, S. Munshi, G. McTaggart-Cowan, M. Shahbakhti, " Performance Analysis of a Heavy-Duty Hybrid Electric Truck with a MicroPilot Natural Gas Engine in Real-World Highway Driving Conditions ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 18- A. Norouzi*, S. Shahpouri*, D. C. Gordon, A. Winkler, E. Nuss, J. Andert, M. Shahbakhti, C. R. Koch, " Deep Learning and Nonlinear Model Predictive Control Integration for Compression Ignition Engine Emission Reduction ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.

- 17- N. Balazadeh, S. Munshi, M. Shahbakhti, G. McTaggart-Cowan, " High Efficiency Natural Gas Engine Modeling for Commercial Vehicle Studies ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 16- S. Shahpouri*, A. Norouzi, C. Hayduk, A. Fandakov, R. Rezaei, C. R. Koch, M. Shahbakhti, " Laminar Flame Speed Modeling of Hydrogen, Methanol, and Ammonia using Machine Learning ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 15- S. Shahpouri*, A. Norouzi, C. Hayduk, A. Fandakov, R. Rezaei, C. R. Koch, M. Shahbakhti, " Machine Learning Modeling of Soot Emissions in Diesel Engines ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 14- S. Moghadasi*, Y. Long*, S. Munshi, G. McTaggart-Cowan, M. Shahbakhti, " Investigation of Davis Dam Drive Cycle Application for Performance Assessment of Electrified and Conventional Long-Haul Trucks ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 13- H. Abediasl*, V. Hosseini, N. Balazadeh, C. R. Koch, M. Shahbakhti, " Impact of Cold Climate on Emissions and Fuel Consumption of Vehicles: Knowledge Gap Synthesis ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 12- J. McNally*, D. Gordon, A. Norouzi, M. Shahbakhti, C. R. Koch, " Experimental Study of Hydrogen Diesel Dual Fuel Engine Characterization ", *Canadian Society of Mechanical Engineers (CSME) 2022 International Congress*, Jun. 5-8, 2022, Edmonton, AB, Canada.
- 11- S. Batool*, J. D. Naber, M. Shahbakhti, " Machine Learning Approach for Identification of Heat Release Shapes in a Low Temperature Combustion Engine", *2022 SAE World Congress*, Apr. 5-7, 2022, Detroit, MI, USA.
- 10- A. Norouzi*, M. Shahbakhti, C.R. Koch, " Machine Learning-based Diesel Engine-out Emissions Model and Control Using the Learning-based Control Technique ", *2021 SAE World Congress*, Apr. 13-15, 2021, Detroit, MI, USA.
- 9- S.A. Nadeem*, P. Reddy*, M. Shahbakhti, M. Ravichandran, J. Doering, " Model Predictive Control of an Automotive Driveline for Optimal Torque Delivery with Minimal Oscillations during Torque Converter Slipping Conditions ", *2021 SAE World Congress*, Apr. 13-15, 2021, Detroit, MI, USA.
- 8- B. Khoshbakht*, A. Basina*, J. Valeni, H. Borhan, J. Naber, M. Shahbakhti, " Control-oriented Modeling of Maximum Pressure Rise Rate in RCCI Engines ", *2021 SAE World Congress*, Apr. 13-15, 2021, Detroit, MI, USA.
- 7- S. Batool*, J. Naber, M. Shahbakhti, " Closed-loop Predictive Control of a Multi-mode Engine Including HCCI, PPCI, and RCCI Combustion Modes ", *2021 SAE World Congress*, Apr. 13-15, 2021, Detroit, MI, USA.
- 6- S. Hemmati*, N. Doshi*, D. Hanover*, C. Morgan, M. Shahbakhti, " Integrated HVAC and Powertrain Control for a Connected Plug-in Hybrid Electric Vehicle ", *2019 SAE Thermal Management Systems Symposium (TMSS)*, Oct. 15-17, 2019, Plymouth, MI, USA.
- 5- B. S. Mahadevan*, J. H. Johnson, and M. Shahbakhti, " Development of a MPF Model with a Kalman Filter State Estimator for Simulation and Control of Particulate Matter Distribution of a CPF for Aftertreatment System Control Applications ", *2017 CLEERS (Cross-Cut Lean Exhaust Emissions Reduction Simulations) Workshop*, Oct. 3-5, 2017, Ann Arbor, MI, USA.
- 4- A. Solouk*, M. Shahbakhti, " Potential of Low Temperature Combustion (LTC) Engine Technology for Range Extender Vehicles ", *2016 SAE Range Extenders for Electric Vehicles Symposium*, Nov. 2-3, 2016, Knoxville, TN, USA.
- 3- M. Nazemi*, S. Polat*, M. Shahbakhti, "Advanced Combustion Model of LTC Engines", *2014 CONVERGE™ User Group Meeting*, Sept. 23-25, 2014, Madison, Wisconsin, USA.
- 2- M. Shahbakhti, K. Edelberg*, S. Pan*, A. Hansen*, J. Li*, J. K. Hedrick, " Model-Based Verification and Real-Time Validation of Automotive Controller Software ", *ASME Verification and Validation Symposium*, May 22-24, 2013, Las Vegas, NV, USA.

- 1- K. Edelberg*, M. Shahbakhti, J. K. Hedrick, " Modeling and Incorporation of Software Implementation Uncertainty to Realize Easily Verifiable Automotive Controllers ", *ASME Verification and Validation Symposium*, May 22-24, 2013, Las Vegas, NV, USA.

Technical Posters

- 9- B. Bahri*, M. Shahbakhti, AZEHT team, " Preliminary Winter Performance Results of AZEHT Project in Edmonton, Alberta ", Canadian Hydrogen Convention, April 25-27, 2023, Edmonton, AB, Canada.
- 8- J. McNally, E. Sperling, D. Gordon, J. Kheyrollahi, C.R. Koch, M. Shahbakhti, " Hydrogen-Diesel Dual-Fuel Combustion Testing ", Canadian Hydrogen Convention, April 25-27, 2023, Edmonton, AB, Canada.
- 7- N. Balazadeh Meresht, S. Munshi, M. Shahbakhti, G. Mctaggart-Cowan, " Predictive Combustion Modeling of HPDI Natural Gas Engine for Class-8 Commercial Vehicle Applications ", 39th International Symposium on Combustion, July 24-29, 2022, Vancouver, BC, Canada.
- 6- S. Vafaenezhad, A. R. Hanifi, M. Cuglietta, A. R. Razmi*, A. Khaled Elkashat*, M. Shahbakhti, P. Sarkar, T. H. Etsell, " High-Efficiency and Stable Solid Oxide Fuel Cells and Electrolysis Cells ", Canadian Hydrogen Convention, April 26-28, 2022, Edmonton, AB, Canada.
- 5- M. Mashkournia, A. Ghazimirsaid, J. Boddez, M. Shahbakhti, D. Achtymichuk, D. Handford, " Flexible Operation of HCCI Combustion Using Intelligent Control ", Canada Auto21 HQP Conference, May 26-28, 2009, Hamilton, ON, Canada.
- 4- S. Varnhagen, A. Audet, M. Shahbakhti, D. Handford, A. Ghazimirsaid, " Flexible Operation of HCCI Combustion Using Intelligent Control ", Canada Auto21 HQP Conference, Jun. 1-4, 2008, London, ON, Canada.
- 3- A. Audet, R. Lupul, M. Shahbakhti, V. Hosseini, A. Ghazimirsaid, P. Kongseereparp, X. Yao, " Electronic Control for VVT and HCCI Combustion ", Canada Auto21 HQP Conference, Jun. 11-13, 2007, Windsor, ON, Canada.
- 2- R. Chladny, R. Lupul, M. Shahbakhti, V. Hosseini, P. Kongseereparp, Y. Gao, " Electronic Control for VVT and HCCI Combustion ", Canada Auto21 HQP Conference, May 15-17, 2006, Barrie, ON, Canada.
- 1- R. Chladny, V. Hosseini, S. Chung, K. Frank, P. Kongseereparp, M. Shahbakhti, " Electronic Control for VVT and HCCI Combustion ", Canada Auto21 HQP Conference, May 10-12, 2005, Oshawa, ON, Canada.

Teaching/Mentoring Experience

New Course Development

Department of Mechanical Eng., University of Alberta

- MECE 442: Vehicle Propulsion Systems
- MECE 610: Machine Learning Control for Engineering Applications

Principal Instructor

Department of Mechanical Eng., University of Alberta

- MECE 442: *Vehicle Propulsion Systems*, 17 students, Winter 2025
- MECE 610: *Machine Learning Control for Engineering Applications*, 16 students, Fall 2024
- MECE 541: *Combustion Engines*, 21 students, Fall 2024
- MECE 541: *Combustion Engines*, 27 students, Winter 2024
- MECE 610: *Machine Learning Control for Engineering Applications*, 21 students, Fall 2023
- MECE 541: *Combustion Engines*, 28 students, Fall 2023
- MECE 442: *Vehicle Propulsion Systems*, 7 students, Winter 2023

- MECE 610: *Machine Learning Control for Engineering Applications*, 5 students, Fall 2022
- MECE 541: *Combustion Engines*, 44 students, Fall 2022 (student evaluation*: 4.6/5)
- MECE 541: *Combustion Engines*, 43 students, Winter 2022 (student evaluation*: 4.3/5)
- MECE 541: *Combustion Engines*, 36 students, Fall 2021 (student evaluation*: 4.6/5)
- MECE 340: *Applied Thermodynamics*, 70 students, 2021 (student evaluation*: 4.8/5)
- MECE 541: *Combustion Engines*, 14 students, Winter 2021 (student evaluation*: 4.9/5)
- MECE 340: *Applied Thermodynamics*, 74 students, Spring-Summer 2020 (student evaluation*: 4.9/5)

* The course rating system at the University of Alberta ranks responses to the USRI question 221 “Overall, this instructor was excellent” on a scale of 1 – 5, with 1 being “strongly disagree” and 5 being “strongly agree”.

Department of Mechanical Eng.-Eng. Mechanics, Michigan Tech. University

- MEEM 5295: *Advanced Propulsion for Hybrid Electric Vehicles*, 28 students, Spring 2019 (student evaluation: 4.64/5)
- MEEM 2201: *Energy-Thermal-Fluids I*, 80 students, Fall 2018 (student evaluation: 4.4/5)
- MEEM 5295: *Advanced Propulsion for Hybrid Electric Vehicles*, 45 students, Spring 2018 (student evaluation: 4.74/5)
- MEEM 2201: *Energy-Thermal-Fluids I*, 85 students, Fall 2017 (student evaluation: 4.61/5)
- MEEM 2201: *Energy-Thermal-Fluids I*, 85 students, Fall 2016 (student evaluation: 4.66/5)
- MEEM 5295: *Advanced Propulsion for Hybrid Electric Vehicles*, 37 students, Spring 2016
- MEEM 2201: *Energy-Thermal-Fluids I*, 96 students, Fall 2015 (student evaluation: 4.57/5)
- MEEM 2201: *Energy-Thermal-Fluids I*, 76 students, Spring 2015 (student evaluation: 4.35/5)
- MEEM 2200: *Thermodynamics*, Spring 2014, two sections, 85 students (student evaluation – ave. of two sections: 4.3/5)
- MEEM 2200: *Thermodynamics*, Spring 2013, 26 students (student evaluation: 4.36/5)
- MEEM 5990/6990 Special Topics (graduate courses):
 - *Optimal and Model Predictive Controls*, 7 students, Fall 2013
 - *Design, Instrumentation, Control of HEV-LTC Powertrain Setup*, 20 students, 2013-2016
 - *Experiment and Simulation of LTC Engine in HEV Powertrain*, 4 students, Spring 2013
 - *HCCI Engine Control*, 1 student, Fall 2012

Department of Mechanical Engineering, KNT University of Technology

- ME16-31: *Design of Combustion Engines*, Winter 2010, 28 students (student evaluation: 3.61/4)
- ME19-31: *Environmental Pollution Control*, Winter 2010, 32 students (student evaluation: 3.94/4)

Department of Mechanical Engineering, University of Alberta

- MECE 541: *Combustion Engines and Alternative Fuels*, Fall 2008, 28 students (student evaluation: 4.7/5)
- MECE 541: *Combustion Engines and Alternative Fuels*, Fall 2009, 50 students (student evaluation: 4.4/5)

Teaching Assistant

Department of Mechanical Engineering, University of Alberta

- MECE 420: *Feedback Control Design of Dynamic Systems*, Winter 2005, Winter 2006
- MECE 330: *Fluid Mechanics*, Fall 2004, Fall 2005, Fall 2006, Winter 2007, Winter 2008

- MECE 541: *Combustion Engines*, Winter 2009

Teaching Professional Development

- University Teaching Program, University of Alberta, 2004 - 2009
 - Completed 50 hours of formal classroom training which covers a wide range of theoretical teaching topics through seminars and workshops.

Supervising/Mentoring

- **Research Associates (3)**

- Dr. M. Cuglietta, Research Associate (100%), Simulation and design of Solid Oxides Fuel Cell stacks, University of Alberta, 2024 - present.
- Dr. P. Sarkar, Research Associate - Principal Advisor in Fuel Cell (100%), Design and fabrication of Solid Oxides Fuel Cell stack, University of Alberta, 2024 - present.
- Dr. A. Hanifi, Research Associate (100%), Solid Oxides Fuel Cell stack design and fabrication, University of Alberta, 2022 - present.

- **Postdoctoral Scholars (9)**

- Dr. A. Razmi, Postdoctoral Researcher (100%), Techno-Economic Analysis of Hydrogen Energy Solutions, University of Alberta, 2025 - present.
- Dr. S. A. Sobhi, Postdoctoral Researcher (100%), Data Analytics and Software Development, University of Alberta, 2024 - present.
- Dr. M. Fakouri Hasanabadi, Postdoctoral Researcher (100%), Design, Experimentation, and Analysis of Fuel Cell Stacks, University of Alberta, 2023 - present.
- Dr. M. Ezzat, Postdoctoral Researcher (100%), Modeling and Assessment of Hydrogen Fueled Heavy-Duty Vehicles, University of Alberta, 2022 - present.
- Dr. B. Bahri, Postdoctoral Researcher (100%), Analysis and Assessment of City of Edmonton and Strathcona County Fuel Cell, Electric, and Diesel Buses, University of Alberta, 2022 - present.
- Dr. S. Vafaeenezhad, Postdoctoral Researcher (60%; joint with C.R. Koch), Experimental study of Solid Oxides Fuel Cells, University of Alberta, 2022 - 2023.
- Dr. O. Wine, Postdoctoral Researcher (50%; joint with A. Osornio Vargas), Transportation Health Impact in Cold Climates, University of Alberta, 2020 - 2021.
- Dr. H. Solmaz, Postdoctoral Researcher (100%), Experimentation and Analysis of LTC Regimes in a Light-duty Engine, Michigan Tech University, 2015 - 2016.
- Dr. M. Razmara, Research Engineer (50%; joint with R. Robinett), Building-to-Grid Demand Response Optimization, Michigan Tech University, 2016 - 2017.

- **PhD Students (37)**

- **Thesis advising (26)**

- N. Fadaei Mobarhan, PhD thesis co-adviser (joint with A. Hakkaki-Fard), Modeling and analysis of solid oxides fuel cell operation, Laval University, 2024 - present.
- A. Shabani, PhD thesis adviser (40%; joint with A. Nouri), Analysis of airborne particles in HVAC channels for Covid-virus filter disinfection units, University of Alberta, 2022 - present.
- A. Vafamand, PhD thesis adviser (60%; joint with C.R. Koch), Machine learning control of battery electric systems, University of Alberta, 2022 - present.
- A. Salahi, PhD thesis adviser (40%; joint with C.R. Koch), Control of fuel cell systems, University of Alberta, 2022 - present.

- A. Mirzazadeh Akbarpoor, PhD thesis adviser (50%; joint with A. Nouri), Low-cost Technology for Risk Mitigation of Pathogenic Infection in HVAC Systems, University of Alberta, 2022 - present.
- A. Yasami, PhD thesis adviser (40%; joint with C.R. Koch), Intelligent fleet management using artificial intelligence, University of Alberta, 2022 - present.
- S. Moghadasi, PhD thesis adviser (100%), Optimization and modeling of natural gas fueled hybrid electric trucks, University of Alberta, 2021 - present.
- Z. Salehi, PhD thesis adviser (40%; joint with C.R. Koch), Diagnostics of solid oxide fuel cell degradation using methods of machine learning, University of Alberta, 2021 - present.
- M. Tofigh, PhD thesis adviser (60%; joint with C.R. Koch), Fault diagnostics of solid oxide fuel cell systems using methods of machine learning, University of Alberta, 2021 - present.
- L. Jiang, PhD thesis adviser (100%), Experimental analysis and control of platooning trucks, University of Alberta, 2021 - present.
- H. Abediasl, PhD thesis adviser (60%; joint with C.R. Koch), Optimization of university fleet vehicles to minimize GHG and energy consumption, University of Alberta, 2020 - present.
- A. Razmi, PhD thesis adviser (100%), Design and optimization of hydrogen fueled thermodynamic cycles, University of Alberta, 2020 - present.

Graduated (15):

- A. Razmi, PhD thesis adviser (100%), Design, Techno-Economic Assessment, and Comparison of Clean Hydrogen Production/Utilization Technologies Based on High-Temperature Solar Thermal Energy, University of Alberta, 2020 - 2025.
- B. Khoshbakht Irdmousa, PhD thesis adviser (40%; joint with J. Naber), Modeling and control of natural gas-diesel RCCI engines, Michigan Tech University, 2016 - 2023.
- S. Shahpouri, PhD thesis adviser (60%; joint with C.R. Koch), Machine learning for emission modeling of fossil-fueled and hydrogen-fueled internal combustion engines, University of Alberta, 2020 - 2023.
- S. Batool, PhD thesis adviser (60%; joint with J. Naber), Dynamic modeling and control of a multi-mode combustion engine, Michigan Tech University, 2018 - 2023.
- A. Norouzi Yengeje, PhD thesis adviser (40%; joint with C.R. Koch), Machine learning and deep learning for modeling and control of internal combustion engines, University of Alberta, 2020 - 2022.
- P. Reddy, PhD thesis adviser (80%; joint with D. Robinette), Design and real-time implementation of optimal model-based torque shaping automotive control systems, Michigan Tech University, 2018 - 2022.
- V. B. Vinhaes, PhD thesis adviser (50%; joint with J. Naber), Combustion development of a high efficiency micro pilot diesel natural gas engine, Michigan Tech University, 2016 - 2022.
- C. R. Reddy, PhD thesis adviser (70%; joint with R. Robinett III), Model predictive control of energy systems for heat and power applications, Michigan Tech University, 2017 - 2022.
- A. A. Khameneian, PhD thesis adviser (50%; joint with J. Naber), Model-based engine-out emissions analysis for a gasoline turbocharged direct injection spark-ignition engine in elevated HEV (hybrid electric vehicle) cranking speed, Michigan Tech University, 2016 - 2021.
- M. R. Amini, PhD thesis adviser (100%), Easily verifiable controller design with application to automotive powertrains, Michigan Tech University, 2013 - 2017.
- A. Solouk Mofrad, PhD thesis adviser (100%), Model-based control of hybrid electric powertrains integrated with LTC engines, Michigan Tech University, 2013 - 2017.
- B. Mahadevan, PhD thesis adviser (50%; joint with J. Johnson), Development of a Multi-Zone Catalyzed Particulate Filter Model and Kalman Filter Estimator for Simulation and Control of Particulate Matter Distribution of a CPF for Engine ECU Applications, 2014 - 2017.
- M. Razmara, PhD thesis adviser (60%; joint with R. Robinett III), Predictive control of power grid-connected energy systems based on energy and exergy metrics, Michigan Tech University, 2012 - 2016.

- M. Bidarvatan, PhD thesis adviser (100%), Physics-based modeling and control of powertrain systems integrated with low temperature combustion engines, Michigan Tech University, 2012 - 2015.
- B. Bahri, PhD thesis adviser (30%; joint with A.A. Aziz), Investigation of HCCI engines fueled with ethanol blends, University Technology Malaysia, 2010 - 2013.

Visiting students (7)

- Y. Long, Visiting PhD candidate from Wuhan University of Technology in China, Modeling a MicroPilot NG Engine and Integration into a Plug-in Hybrid Electric Truck, University of Alberta, May 2021 – April 2022.
- M. Toub, co-hosted by Prof. R. Robinett, Visiting PhD candidate from Mohammed V University in Morocco, Modeling and control of concentrated solar power (CSP) for building energy management and building-to-grid operation, Michigan Tech University, Sep. 2016 – 2018.
- P. Ahmadizadeh, Visiting PhD candidate from Iran University of Science and Technology, Two-mode power split hybrid electric powertrain, Michigan Tech University, Feb. 2016 – Oct. 2016.
- K. Poorghasemi, Visiting PhD candidate from Sahand University of Tech in Iran, RCCI engine combustion modeling, Michigan Tech University, Feb. - Aug. 2015.
- M. Baloo, co-hosted by Prof. S.Y. Lee, Visiting PhD candidate from Amir Kabir University of Tech in Iran, Experimental combustion diagnosis, Michigan Tech University, Sep. 2014 – Jan. 2015.
- S. Polat, Visiting PhD candidate from Gazi University in Turkey, Modeling and experimental study of an HCCI engine, Michigan Tech University, Jan. 2014 – Mar. 2015.
- M. Pčolka, co-hosted by Prof. R. Robinett, Visiting PhD candidate from Czech Tech University in Prague, Building energy controls, Michigan Tech University, Jan. 2013 – May 2013.

Mentoring (4)

- S. Hemmati, PhD student, Control of connected and automated hybrid electric vehicles, Michigan Tech University, 2018 - 2019.
- S. Pan, PhD candidate, Adaptive sliding controller design with robustness to implementation imprecision, University of California, Berkeley, 2012.
- R. Salehi, Visiting PhD candidate from Sharif University in Iran, Hybrid switching controller for cold start emission reduction, University of California, Berkeley, 2012.
- Y. Chen, Visiting PhD candidate from Jilin University in China, Control of engine emissions during cold start, University of California, Berkeley, 2010 - 2011.

• MSc Students (77)

Thesis advising (33)

- M. Moghtader, MSc thesis adviser (40%; joint with A. Nouri), Use of radiative heating for HVAC filter disinfection, University of Alberta, 2023 - present.
- E. Rasouli, MSc thesis adviser (40%; joint with A. Nouri), CFD modeling of airborne particles in HVAC channels for Covid-virus filter disinfection units, University of Alberta, 2022 - present.
- Y. Ma, MSc thesis adviser (100%), Modeling and analysis of City of Edmonton fuel cell transit buses, University of Alberta, 2022 - present.

Graduated (30):

- A. Ansari, MSc thesis adviser (100%), Fuel consumption estimation and analysis of the University of Alberta fleet vehicles, University of Alberta, 2020 - 2023.
- A. Khaled, MSc thesis adviser (100%), CFD modeling and analysis of anode supported solid oxide fuel cells, University of Alberta, 2021 - 2023.
- L. Yang, MSc thesis adviser (100%), Driving cycle and driver behavior analysis for University of Alberta fleet vehicles, University of Alberta, 2021 - 2023.

- H. Heidarifar, MSc thesis adviser (100%), Energy optimization of a residential building using occupancy prediction via sensor fusion and machine learning algorithms, University of Alberta, 2020 - 2023.
- N. Samadi, MSc thesis adviser (100%), Modeling and control of an HVAC system to minimize COVID-19 virus transmission, University of Alberta, 2020 - 2022.
- S. A. Nadeem, MS thesis main adviser (90%; joint with D. Robinette), Design of an anti-jerk controller for both locked and slipping torque converter conditions in a vehicle, Michigan Tech University, 2019 - 2020.
- R. Sitaraman, MS thesis main adviser (60%; joint with J. Naber), Identification of heat release shapes and combustion control of an LTC engine, Michigan Tech University, 2018 - 2020.
- R. Moharjan, MS thesis adviser (100%), Optimization of diesel engine and after-treatment system for a series hybrid forklift application, Michigan Tech University, 2018 - 2019.
- A. Basina, MS thesis adviser (100%), Modeling and control of maximum pressure rise rate in RCCI engines, Michigan Tech University, 2018 - 2019.
- N. Doshi, MS thesis main adviser (80%; joint with D. Robinette), Modeling of thermal dynamics in Chevrolet Volt GEN II hybrid electric vehicle for integrated powertrain and HVAC optimal operation through connectivity, Michigan Tech University, 2018 - 2019.
- K. Darokar, MS thesis main adviser (80%; joint with D. Robinette), Automotive driveline backlash state and size estimator design for anti-jerk control, Michigan Tech University, 2018 - 2019.
- P. Reddy, MS thesis main adviser (60%; joint with D. Robinette), Control oriented modeling of an automotive drivetrain for anti-jerk control, Michigan Tech University, 2017 - 2018.
- R. Yadav, MS thesis main adviser (70%; joint with D. Robinette), Modeling and analysis of energy consumption in Chevrolet Volt Gen II Hybrid Electric Vehicle, Michigan Tech University, 2017 - 2018.
- A. Abhay Raut, MS thesis adviser (100%), Model-based control of an RCCI engine, Michigan Tech University, 2016 - 2017.
- N. Kondipati, MSc thesis adviser (100%), Experimental Study, Modeling and Controller Design for an RCCI Engine, Michigan Tech University, 2015 - 2016.
- J. Arora, MSc thesis adviser (100%), Design of Real-Time Combustion Feedback System and Experimental Study of an RCCI Engine for Control, Michigan Tech University, 2015 - 2016.
- K. Kannan, MSc thesis adviser (100%), An Experimental Investigation of Low Temperature Combustion Regimes in a Light Duty Engine, Michigan Tech University, 2014 - 2016.
- J. Dobbs, MSc thesis adviser (100%), Model Predictive Control of Building Energy Management Systems in a Smart Grid Environment, Michigan Tech University, 2013 - 2015.
- K. Khodadadi, MSc thesis adviser (100%), Modeling and Control of Combustion Phasing of an RCCI Engine, Michigan Tech University, 2013 - 2015.
- M. R. Nazemi, MSc thesis adviser (100%), Modeling and Analysis of Reactivity Controlled Compression Ignition (RCCI) Engine Combustion, Michigan Tech University, 2013 - 2015.
- M. Paranjape, MSc thesis adviser (100%), Optimal Control of Building Energy with Smart Grid Interaction, Michigan Tech University, 2013 - 2014.
- H. Saigaonka, MSc thesis adviser (100%), An Investigation of Variable Valve Timing Effects on HCCI Engine Performance, Michigan Tech University, 2013 - 2014.
- D. Kothari, MSc thesis adviser (100%), Experimental Setup and Controller Design for an HCCI Engine, Michigan Tech University, 2013 - 2014.
- V. Thakkar, MSc thesis adviser (100%), Modeling and Experimental Setup of an HCCI Engine, Michigan Tech University, 2013 - 2014.

- A. Soloukmofrad, MS thesis adviser (50%; joint with M. Mahjoob), Modeling and control of a hybrid electric powertrain using an HCCI engine, University of Tehran, 2011 - 2013.
- M. Amini, MSc thesis co-adviser (50%; joint with A. Ghaffari), Model-based Control of Cold Start Hydrocarbon Emissions in SI Engines, KNT University, 2010 - 2012.
- M. Boodaghi, MSc thesis co-adviser (50%; joint with S.A. Jazayeri), Strategies of Misfire Detection in Gasoline-CNG Bi-fuel Engines, KNT University, 2010 - 2011.
- M. Marami, MSc thesis co-adviser (50%; joint with S.A. Jazayeri), Simulation of Oil Circuit in an SI Engine at Cold Start Transient Conditions, KNT University, 2010 - 2011.
- M. Dehghani, MSc thesis co-adviser (50%; joint with S.A. Jazayeri), Thermodynamic Modeling of HCCI Exhaust Temperature, KNT University, 2010 - 2011.
- M. Bidarvatan, MSc thesis co-adviser (50%; joint with S.A. Jazayeri), Control of Combustion Phasing in an HCCI Engine, KNT University, 2010 - 2011.

Technical report advising (11)

Graduated (11):

- K. Shah, MEng Capstone project adviser, Data collection and analysis of City of Edmonton buses to determine passenger comfort, University of Alberta, 2024.
- C. Niu, MEng Capstone project adviser, Alberta residential building's energy consumption simulation and optimization, University of Alberta, 2021 - 2022.
- Z. Luan, MEng Capstone project adviser, Performance analysis of alternative heavy-duty transit buses, University of Alberta, 2021 - 2022.
- M. Owais, MEng Capstone project adviser, Measurement and analysis of fuel consumption, wind velocity and angle from a class 8 truck, University of Alberta, 2021.
- P. Rakeshkumar, MEng Capstone project adviser, Real-time fuel consumption of university's vehicle fleet using on-board diagnostic (OBD) sensor, University of Alberta, 2021.
- S. Bhasme, MS technical report main adviser (co-adviser: Dr. Darrell Robinette), Modeling Chevy Vol Gen II supervisory controller in charge sustaining operation, Michigan Tech University, 2018 - 2019.
- V. B. Vinhaes, MS technical report co-adviser (50%), Combustion development of a high efficiency diesel micro pilot natural gas engine, Michigan Tech University, 2016 - 2018.
- K. Suresh, MS technical report main adviser (co-adviser: Dr. Darrell Robinette), Modeling and analysis of Chevy Volt Gen II hybrid vehicle in electric mode, Michigan Tech University, 2017 - 2018.
- P. Lakhani, MS technical report main adviser (co-adviser: Dr. Darrell Robinette), Modeling and analysis for driveline jerk control, Michigan Tech University, 2017 - 2018.
- A. Soloukmofrad, MS technical report adviser, Energy management of hybrid electric powertrains integrated with low temperature combustion engines, Michigan Tech University, 2013 - 2015.
- M. Razmara, MS technical report main adviser (co-adviser: Dr. Rush Robinett III), Model Predictive Control of Building HVAC Systems, Michigan Tech University, 2012 - 2014.

Mentoring (33)

- R. Khonsarian, Short term scholar, Modeling and control of connected and automated vehicles (CAVs), University of Alberta, 2019-2020.
- V. Prasaad Raghupathy, Short term scholar, Study and analysis of HVAC systems in Electric Vehicles, Michigan Tech University, 2019-2020.

- A. Mahapatra, Short term scholar, Simulation of CNT materials for three-way catalyst cold start heating, Michigan Tech University, 2019.
- R. Kamaraj, Short term scholar, Investigations into state-of-the-art hybrid electric vehicles powertrain configurations, Michigan Tech University, 2018.
- A. Somasundaram, Short term scholar, Modeling of mode switching control strategies of Chevy Volt II plug-in hybrid electric vehicle, Michigan Tech University, 2018.
- J. Tripp, Short term scholar, Modeling of powertrain and vehicle dynamics for Chevy Volt II, Michigan Tech University, 2017.
- M. Darji, Short term scholar, Electrification of high-efficiency engines, Michigan Tech University, 2017.
- K. C. Dhankani, Short term scholar, LPV modeling of an RCCI engine, Michigan Tech University, 2016.
- D. B. Lodaya, Short term scholar, Modeling and optimization of two-mode power split hybrid electric powertrain, Michigan Tech University, 2016.
- G. Ramanathan, D. Dhanraj, Short term scholars, Control of robot's electric motor for throwing ball and demonstration for MTU's Summer Youth Program, Michigan Tech University, 2016.
- J. Dwivedi, V. Ghadge, E. Malik, D. Dhanraj, Short term scholars, Calibration and torque control of 100-kW E-motor for hybrid electric powertrain test bed, Michigan Tech University, 2015 – 2016.
- R. R. Zakkam, H. Nutulapati, M. Cheruvathur, Short term scholars, Experimental setup for a LTC engine and hybrid electric powertrain, Michigan Tech University, 2014.
- F. Ahmed, G. Xiong, A. Ketkale, A. Kondra, A. Girase, and H. Su, Short term scholars, Experimental setup for low temperature combustion engine research, Michigan Tech University, 2013 - 2014.
- Z. Han, S. Viswanathan, Z. Huang, and N. Ghike, Short term scholars, Control of electric motor and Lithium-ion battery for HEV powertrain, Michigan Tech University, 2013 - 2014.
- B. Moridian, Short term scholar, Adaptive parameter/state estimation for building energy control, Michigan Tech University, 2012 - 2013.
- A. Hansen, Visiting M.Sc. student from Technische Universität Hamburg-Harburg, Discrete sliding mode control of automotive controllers, University of California, Berkeley, 2012.
- K. Edelberg, MSc student, Robust model-based controller design using implementation imprecision bounds, University of California, Berkeley, 2012.
- A. Cranmer, MSc student, Modeling HC tailpipe emissions from an SI engine, University of California, Berkeley, 2010 - 2011.
- S. Sharifirad, Visiting MSc student from KNT University, Automatic driver controller design for standard driving test cycles simulation, Iran Khodro Engine Research Center, 2003 - 2004.

- **BSc Students (34)**

- Thesis advising (8)**

- A. Solouk Mofrad, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), On-board diagnosis of catalytic converters in SI engines, KNT University, 2010.
 - A. Kazemi Taskoh, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Control strategies to reduce cold start and warm-up emissions from passenger cars, KNT University, 2010.
 - M. Aliramezani, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Control strategies of Anti-lock Braking Systems (ABS) in passenger cars, KNT University, 2010.
 - J. Rezaee, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Experimental study of an HCCI engine running with butanol blended fuels, KNT University, 2010.
 - A. Shahrokhshahi and H. Zamani, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Strategies to control/monitor evaporative emissions in passenger cars, KNT University, 2010.

- H. Jafarian, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Simulation of bearings of a SI engine using AVL-EXCITE software, KNT University, 2010.
- M. Amereh, BSc thesis co-adviser (50%; joint with S.A. Jazayeri), Numerical modeling of the flow under engine's hood of Samand vehicle using Fluent software, KNT University, 2010.

Co-op (6)

- C. D. Reyes, Co-op student, SOFC planar cell fabrication, University of Alberta, Winter 2025.
- K. Kunkle-Reed, Co-op student, Test setup design and fabrication for a fuel cell stack, University of Alberta, Winter-Summer 2025.
- J. Sathya Sai, Co-op student, Data collection and synchronization for analysis of two platooning trucks, University of Alberta, Fall 2021.
- S. Virk, Co-op student, Design of a vehicle data acquisition system for two platooning trucks, University of Alberta, Summer-Fall 2021.
- E. Stewart, Co-op student, co-supervised with Prof. Bob Koch, Vehicle OBD setup and data analysis for reducing vehicle fuel consumption from the UAlberta fleet vehicles, University of Alberta, Fall 2020.
- H. Holzer, Co-op student, co-supervised with Prof. Bob Koch, Vehicle OBD setup, University of Alberta, Summer 2020.

Mentoring (20)

- M. Khani, Short term scholar, Vehicles data processing and analysis, University of Alberta, 2024 - present.
- D. Hanover, Short term scholar, PV Panel modeling, HVAC modeling for an MTU building and a Chevy Volt Vehicle, Michigan Tech. University, 2015 – 2018.
- A. Krisztian, Short term scholar, Analysis of the experimental data from Chevy Volt Gen 2 vehicle, Michigan Tech. University, Summer 2017.
- R. P. Robles, Short term scholar, Sizing Analysis of Energy Storage Systems and Solar PV Panels for Commercial Buildings, Michigan Tech. University, 2016.
- S. Hedblom, Student project as part of The Honors Institute, Skiing's mechanical efficiency, Michigan Tech. University, 2015.
- T. Kovach, Short term scholar, Experimental study of building energy efficiency, Michigan Tech. University, 2014.
- A. Soneji, R. Bhasin, A. Neti, N. Neti, A. Hayashi, S. Bigdeli, S. Raghunathan, Mech. Eng. undergraduate students, Modeling, control and testing of a 2.4-liter Toyota engine and exhaust aftertreatment system, University of California, Berkeley, 2012.
- J. Li, and A. Cheng, Senior Mech. Eng. undergraduate students, Verification and hardware-in-the-loop testing of automotive controllers, University of California, Berkeley, 2012.
- M. Muller, P. Sang Cho, and R. Sze, Senior Mech. Eng. undergraduate students, Model analysis and control trajectory modification for reducing hydrocarbon emissions in SI engines, University of California, Berkeley, 2011.
- S. Varnhagen, NSERC summer student, HCCI experimental study, University of Alberta, 2008.
- K. Swan, NSERC summer student, HCCI combustion modeling, University of Alberta, 2006.

• Lab Engineers (3)

- L. Yamarte, Lab Engineer (100%), Fabrication of Solid Oxides Fuel Cells, University of Alberta, 2024 - present.
- S. Hanifi, Lab Engineer (100%), Experimentation, Testing, and Analysis of Solid Oxides Fuel Cells, University of Alberta, 2024 - present.

- Sh. Sharifi, Lab Engineer (60%), Fabrication, Testing, and Analysis of Solid Oxides Fuel Cells, University of Alberta, 2022 - 2023.

University/Community Service

Theses/Proposals (examination committee member)

PhD committees (30):

- Prasoon Garg, PhD thesis exam, “Intelligent Data-Driven Control Calibration For Automotive Powertrains”, Eindhoven University of Technology, 2024.
- Fan Wu, PhD thesis exam, “Traffic Management in Mixed Autonomy with CAVs: Sensing, Signal Optimization, and Trajectory Control”, University of Alberta, 2024.
- Ramin Fathian, PhD candidacy exam, “Evaluating the Prevalence of Shoulder Injury Among Manual Wheelchair Users”, University of Alberta, 2024.
- Wenkang Zhang, PhD thesis defense, “Scheduling of Remanufacturing Systems based on Metaheuristic Methods”, University of Alberta, 2023.
- Navid Balazadeh Meresht, PhD proposal exam, Simon Fraser University, 2023.
- David Gordon, PhD thesis defense, “Realtime Machine Learning based In-Cycle Control of Homogeneous Charge Compression Ignition”, University of Alberta, 2023.
- Ajay Singh, PhD thesis defense, “Deterministic Characteristics of Cyclic Combustion Dynamics of Conventional and Advanced Reciprocating Engines”, Indian Institute of Technology - Ropar, 2022.
- Wenkang Zhang, PhD candidacy exam, “Process Planning and Scheduling for a Flexible Job-shop-type Remanufacturing System based on Metaheuristic Methods”, University of Alberta, 2022.
- Sajad Vafaenezhad, PhD thesis defense, “Studying the Microstructure of electrodes for Low-Temperature Solid Oxide Fuel Cell and Electrolysis Applications”, University of Alberta, 2022.
- Fan Wu, PhD candidacy exam, “V2X Technology Supported Traffic Management System for Signalized Arterials”, University of Alberta, 2022.
- Mudasser Seraj, PhD thesis defense, “Mobility and Safety Implications of Automated Vehicles in Mixed Traffic by Recognizing Behavioral Variations of Drivers”, University of Alberta, 2021.
- Zhihao Zhao, PhD thesis defense, “High Injection Pressure Impinging Diesel Spray Characteristics and Subsequent Soot Formation in Reacting Conditions”, Michigan Tech University, 2021.
- Alireza Noamani, PhD candidacy exam, “Development of Wearable Technologies for Standing and Sitting Balance Evaluation”, University of Alberta, 2020.
- Jihoon Lim, PhD thesis defense, “Gain-scheduling and Preview Control of Selective Catalytic Reduction Systems in Diesel Engines”, The University of British Columbia (Vancouver), 2020.
- Xin Wang, PhD proposal and thesis defense, “A Study of Model-based Control Strategy for a Gasoline Turbocharged Direct Injection Spark Ignited Engine”, Michigan Tech University, 2015-2020.
- David Gordon, PhD candidacy exam, “Realtime Machine Learning based In-Cycle Control of Homogeneous Charge Compression Ignition for Combustion Stability and Emissions Improvement”, University of Alberta, 2020.
- Mudasser Seraj, PhD candidacy exam, “Mobility and Safety Implications of Automated Vehicles in Mixed Traffic by Recognizing Behavioral Variations of Drivers”, University of Alberta, 2019.
- Xin Ma, PhD proposal and thesis defense, “Connected Vehicle-Based Distributed Machine Learning for Adaptive Fuel Consumption and Eco-Driving”, University of Massachusetts at Lowell, 2016-2019.
- Mufaddel Dahodwala, PhD proposal and thesis defense “Experimental and Computational Investigation of Dual Fuel Diesel-Natural Gas RCCI Combustion in a Heavy-Duty Diesel Engine”, Michigan Tech University, 2016-2018.
- Zhihao Zhao, PhD proposal, “Study of High Injection Pressure Impinging Diesel Spray and Combustion Processes” Michigan Tech University, 2018.
- Mojtaba Bahramgiri, PhD oral exam, Michigan Tech University, 2018.

- Guna R. Bharati, PhD proposal, and thesis defense, “Hierarchical Optimization for Vehicle-to-Grid and Building-to-Grid Integration” Michigan Tech University, 2015-2017.
- Yanyu Wang, PhD proposal, and thesis defense, “The Interaction of Ignition and In-Cylinder Flow on Flame Kernel Development and Combustion Variability in an Optically Accessible Direct Injection Engine”, Michigan Tech University, 2014-2017.
- Ehsan Ansari, PhD proposal, and thesis defense, “Combustion, Emissions, and Performance Optimization in a DI/PFI-RCCI Diesel/Natural Gas Turbocharged Engine”, Michigan Tech University, 2014-2017.
- Bin Zhou, PhD proposal entitled “Hybrid Electric Vehicle Battery Aging Estimation and Optimization based on Energy Consumption Minimization Strategy”, Michigan Tech University, 2017.
- Amir Rezaei, PhD proposal, and thesis defense, “Optimal Energy Management Strategies for Hybrid Electric Vehicles”, Michigan Tech University, 2015-2017.
- Jiongkun Zhang, PhD proposal entitled “Experimental Characterization of Spark Ignited Direct Injection Gasoline Engine Injection Processes”, Michigan Tech University, 2015.
- Mufaddel Dohodwala, committee member for PhD qualifying exam, Michigan Tech University, 2014.
- Zhuyong Yang, committee member for PhD qualifying exam, Michigan Tech University, 2014.
- Eva Žáčková, PhD thesis entitled “Identification for Model Predictive Control under Closed-loop Conditions”, Czech Technical University, 2013.

MSc committees (31):

- Lap Quan Au-Yeung, MSc thesis entitled “Applications of Machine Learning in Drop Impact Dynamics and Drug Discovery”, University of Alberta, 2024.
- Lalitha Ganesh Prabhu Komaragiri, MSc thesis entitled “Study of Dynamics of Water Droplet Freezing”, University of Alberta, 2024.
- Jakub McNally, MSc thesis entitled “Hydrogen-Diesel Dual Fuel Combustion Characterization for an Internal Combustion Engine”, University of Alberta, 2023.
- Caitlyn Shum, MSc thesis entitled “Addressing Urban Climate Hazard Vulnerability in Canada through Building Retrofit Techniques and Strategies”, University of Alberta, 2023.
- Amir Hossein Ebrahimnezhad, MSc thesis entitled “Deep Learning in Autonomous UAV Pursuit”, University of Alberta, 2023.
- Michael E. Nicol-Seto, MSc thesis entitled “Investigation of a Drive Mechanism Modification to Increase Thermodynamic Power of a Low Temperature Differential Gamma Type Stirling Engine”, University of Alberta, 2021.
- Habiba Imam, MSc thesis entitled “Towards an Autonomous Robot-based Laser Cladding Repair Process: A Framework for Damage Detection, Localization and Path Planning”, University of Alberta, 2021.
- Aditya Kodkani, MSc thesis entitled “Numerical Analysis of a Hybrid Cooling Tower and its Plume”, University of Alberta, 2021.
- Ali Lotfi, MSc thesis entitled “Study of Light-duty Gasoline Vehicle Cold Climate NOx and Particulate Number Emissions in Real-world Driving Conditions”, University of Alberta, 2020.
- Ali Alizadeh, MSc thesis entitled “Assessment of Co-processing Hydrodeoxygenated Fast Pyrolysis Oil and Vacuum Gas Oil in a Fluid Catalytic Cracking Unit”, University of Alberta, 2020.
- Jason Philip Michaud, MSc thesis entitled “Low Temperature Difference Alpha-Type Stirling Engine for the Experimental Determination of Optimal Parameters to maximize Shaft Power”, University of Alberta, 2020.
- Mario Alberto Soriano Morales, MSc thesis entitled “Multi-Sensor Data Fusion and Reconfigurable Measurement System: A Machine Learning Approach”, University of Alberta, 2019.
- Muralidhar Nischal, MSc thesis entitled “Application of Sensor Fusion for SI Engine Diagnostics and Combustion Feedback”, Michigan Tech University, 2019.

- Anurag Kamal, MSc thesis entitled “Physical Modeling of Lithium-Ion Aging for Automotive Applications”, Michigan Tech University, 2018.
- Gaurav Bagwe, MSc technical report entitled “ Video Frame Reduction in Autonomous Vehicles ”, Michigan Tech University, 2018.
- Huanqing Wang, MSc thesis entitled “ Development of Dynamic Programming and Receding Horizon Control Strategies for GM Volt II Multi-mode Hybrid Electric Vehicle ”, Michigan Tech University, 2018.
- Kovid_Sachdeva, MSc technical report entitled “ Development of Optimal Operating Point maps and Mode Shift Strategy for Chevrolet Volt Gen II Plug-in Hybrid Electric Vehicle ”, Michigan Tech University, 2018.
- Kaushik Prabhu, MSc thesis entitled “ Sensor Fusion for Spark Ignited Engines ”, Michigan Tech University, 2018.
- Yash Borghate, MSc thesis entitled “ Cold Start Analysis and Modeling of a Direct-Injection Gasoline Engine ”, Michigan Tech University, 2018.
- Abhishek Jadav, MSc thesis entitled “Experimental and Modeling Study of Particulate Matter Oxidation under Loading Conditions for a SCR Catalyst on a Diesel Particulate Filter ”, Michigan Tech University, 2017.
- Sandesh S. Rao, MSc thesis entitled “An Experimental Investigation on the Effect of Dual Coil Ignition Discharges on Dilute Combustion in a Spark Ignition Engine ”, Michigan Tech University, 2017.
- Omkar Dilip Rane, MSc thesis entitled “Multi Resonant Feedback Control of Wave Energy Converters using Recursive Least Squares”, Michigan Tech University, 2017.
- Biswajit Barik, MSc thesis entitled “Designing a Real-time Velocity Predictor for Powertrain Optimization of Connected and Automated Vehicles”, Michigan Tech University, 2017.
- Reem Merchant, MSc thesis entitled “New Model to Predict Heat Transfer Coefficient for Flow Boiling in Microfin Tubes”, Michigan Tech University, 2016.
- Arya Yazdani, MSc thesis entitled “Air Charge Estimation for an SI Engine using In-cylinder Pressure Sensor”, Michigan Tech University, 2016.
- Rui Hu, MSc thesis entitled “State of Charge Balancing Droop Control”, Michigan Tech University, 2015.
- Prathamesh Chendvankar, MSc technical report entitled “1D Simulation of Direct Water Injection in a Spark Ignited Engine”, Michigan Tech University, 2015.
- Jiongkun Zhang, MSc technical report entitled “Optical Access Engine Setup and Validation”, Michigan Tech University, 2015.
- Ritam Misra, MSc thesis entitled “Impact of Plug-in Electric Vehicles and Wind Generators on Harmonic Distortion of Electric Distribution Systems”, Michigan Tech University, 2014.
- Zhe Huang, MSc technical report entitled “SVPWM Switching Pattern for Z-Source Inverter, Simulation and Application in HEV/EV Motor Drive”, Michigan Tech University, 2014.
- Dustin Loveland, MSc thesis entitled “Development of a Predictive Combustion Model of a Spark Ignited Engine with Gasoline Direct Injection, Variable Valve Timing, Duration and Lift Technologies”, Michigan Tech University, 2012.

University Service

- Member of University of Alberta's Institutional Advisory and Oversight Committee on Equity, Diversity and Inclusion (EDI), 2024 – present
- Member of the Association of Academic Staff of the University of Alberta (AASUA) Finance Committee, University of Alberta, 2020 – present

- Member of Review and Adjudication Committee for Killam/Notley Postdoctoral Fellowships, University of Alberta, 2025
- Member of AASUA Equity & Diversity Committee, University of Alberta, 2020 – present
- Member of Faculty Hiring Committee for Mechatronics position, Department of Mechanical Engineering, University of Alberta, 2023
- Member of University of Alberta District Energy System - Master Energy Plan Advisory Committee, 2022 – 2024
- Judge for Faculty of Engineering Graduate Research Symposium, University of Alberta, 2022, 2023
- Volunteer for the Engineering Booth at U of A Open House 2022, University of Alberta, 2022
- Co-adviser of Alternative Energy Enterprise (AEE), Michigan Tech. University, 2018 - 2019
- MTU Review Committee to Assess Participation into National APLU (Association of Public and Land-grant Universities) Program to Increase the Diversity of STEM Faculty, Michigan Tech. University, Fall 2017.
- Member of MEEM Department Seminar Committee, Michigan Tech. University, 2012 – 2016.
- Judge for MEEM Senior Capstone Design Critical Design Review, Michigan Tech. University, Spring 2017.
- Facilitator at the MEEM and Graduate School Orientation, Michigan Tech. University, 2016.
- Member of MEEM Department Faculty Development Committee, Michigan Tech. University, 2014.
- Judge for Undergraduate Research Expo, Michigan Tech. University, 2015.
- Review panel for Research Excellence Fund - Mentoring Grant Proposals, Michigan Tech. University, 2014.
- Judge in Graduate Research Colloquium (GRC), Michigan Tech. University, 2013, 2015.
- Faculty host for two of the MTU's Leading Scholar Award Finalists, Michigan Tech. University, 2012, 2013.

Community Service

- Led and co-organized a half-day workshop on “Controls and Robotics” in Michigan Tech’s Summer Youth Program -- ME: Design the Future, high school students in grades 9-12, Jul. 27, 2016.
- Mentoring FIRST® Robotics Competition Team on motor controller design, Houghton High School, 2016
- Judge in Western UP Science Fair, Houghton, MI, March 23, 2015.
- Judge in Canada-Wide Youth Science Fair, Ottawa, May 10-18, 2008.
- Member of University of Alberta Student Life Advisory Committee for graduate students, 2008-2009.
- Student representative of the University of Alberta graduate students in the Council of Faculty of Graduate Studies and Research (FGSR), 2007-2009.
- Member of University of Alberta Grant Selection Committee for graduate students, 2007-2008.
- Elected Vice-President Events of Mechanical Engineering Graduate Students Association (MEGSA), University of Alberta, 2007-2008.
- One of the main coordinators for 2008 GSA (Graduate Students Association) Universal Orientation for over 400 new graduate students recruited to the University of Alberta in September 2008.
- Judge in Edmonton Regional Science Fair, Northern Alberta Institute of Technology (NAIT), Edmonton, April 9, 2007.

EXHIBIT 1004

Oct. 24, 1933.

G. L. HOLZAPFEL

1,931,698

FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed March 30, 1931

Fig.1

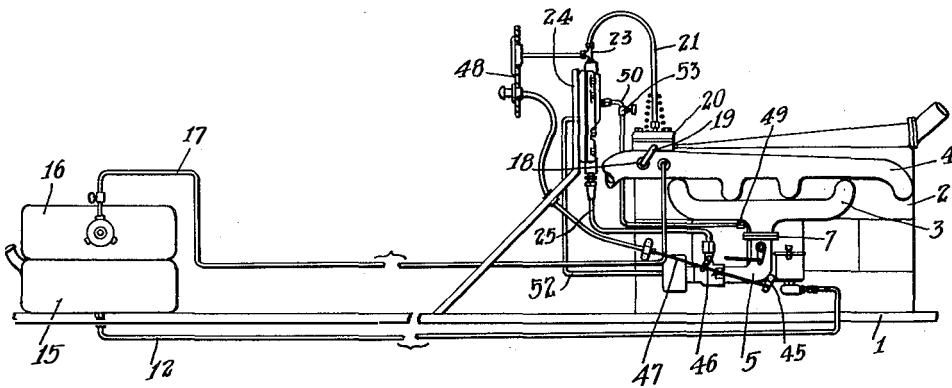


Fig. 2

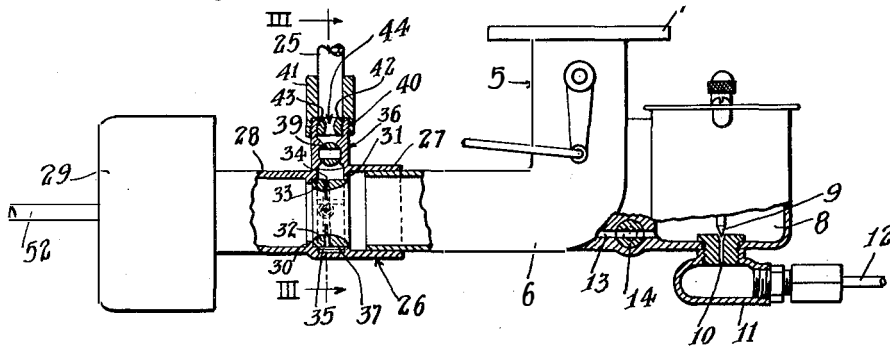
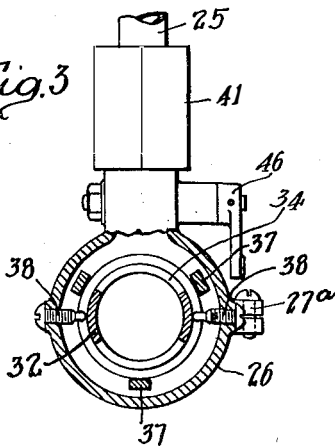


Fig. 3



Inventor:

George L. Holzappel

By

Lyon & Lyon

Attorneys

UNITED STATES PATENT OFFICE

1,931,698

FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINES

George L. Holzapfel, Palos Verdes Estates, Calif.,
 assignor to Richfield Oil Company of California,
 Los Angeles, Calif., a corporation of Delaware

Application March 30, 1931. Serial No. 526,175

4 Claims. (Cl. 261—16)

My invention relates to fuel systems for internal combustion engines, and has particular reference to a fuel system embodying the supplying of liquid fuel and gaseous fuel to an engine in alternation at will.

In the copending joint application of David E. Day and myself, Serial No. 494,328, filed November 8, 1930, a system of employing gaseous fuel for an internal combustion engine was disclosed in which a relatively cheap low grade gaseous fuel stored under pressure was passed through a pressure reducing valve to be introduced into a carbureter connected with an internal combustion engine so that gaseous fuel could be supplied to the engine at the desired pressure and mixed with air in the carbureter in the desired quantities to produce a proper combustible mixture for forming a fuel for the engine.

However, it frequently occurs that it is undesirable to rely upon the gaseous fuel as the sole source of supply for an internal combustion engine, particularly when such engine is employed for the purpose of driving a motor vehicle. It is, therefore, an object of this invention to provide a fuel system in which a gaseous fuel supply shall be auxiliary to the liquid fuel supply now commonly employed in connection with automobiles and similar vehicles.

Another object of the invention is to provide a fuel system in which the normal liquid fuel supply and carbureter therefor is combined with a gaseous fuel supply and a mixer therefor, the two fuel supplies being used in alternation to each other.

Another object of the invention is to provide a fuel system as set forth in the preceding paragraph in which the liquid fuel supply may be cut off and the gaseous fuel supply turned on, or vice versa so that when the liquid fuel is employed the gaseous fuel is disconnected and while the gaseous fuel is employed the liquid fuel is disconnected.

Another object of the invention is to provide a fuel system for supplying the gaseous fuel to an internal combustion engine in alternation with the normal liquid fuel supply and in which the gaseous fuel system may be readily connected to the existing liquid fuel carbureters now used on automobiles and similar vehicles.

Other objects and advantages will be apparent from a study of the following specification, read in connection with the accompanying drawing, wherein

Figure 1 is a diagrammatic view indicating the various elements of both the liquid and gaseous

fuel supplies in proper relation to an automobile engine;

Figure 2 is a detailed view of a carbureter such as generally employed for supplying liquid fuel to an engine, this view being partly in section 60 to illustrate the attachment of my gaseous fuel mixing device thereto; and

Figure 3 is a detailed, sectional view taken along line III—III of Fig. 2, illustrating the interior mechanism of the gaseous fuel mixer employed in practicing my invention.

Referring to the drawing, I have illustrated a portion of an automobile chassis 1, constituting the mounting for an internal combustion engine 2, such as is commonly employed in automobiles 70 and the like. The engine 2 is illustrated as being provided with an intake manifold 3 communicating with the intake ports of the various cylinders comprising the engine 2. An exhaust manifold 4 is illustrated as being connected to the inside ports of the cylinders constituting the engine.

Connected to the intake manifold 3 is a carbureter 5 of any suitable construction, such as those constructions now employed for the mixing of liquid fuel with air prior to injection of such mixture into the intake manifold of the engine.

The carbureter 5 is illustrated as comprising a bent tube 6, one end 7 of which is connected 85 to the intake manifold 3 and the other end of which constitutes an inlet opening through which air may be sucked for mixing with the fuel injected into the carbureter. The carbureter is equipped with a float chamber or fuel reservoir 90 8 which may be of any suitable construction to provide a supply of fuel at atmospheric pressure ready for injection into the tube 6 of the carbureter 5, the float chamber being provided with a float operated needle valve 9 which obstructs 95 the entrance of fuel into the chamber 8 by closing off the passage 10 communicating with an inlet connection 11 to which the fuel supply line 12 may be connected.

The float chamber 8 is illustrated as communicating with the bent tube portion of the carbureter as by means of a passage 13 communicating with both the float chamber 8 and the tube 6. A rotary valve 14 is preferably interposed in the passage 13 for the purpose of permitting this passage to be cut off, as will hereinafter be described.

A main liquid supply tank is illustrated at 15 having attached to the lower end thereof the fuel supply line 12 through which fuel from the tank 110

15 may be passed to the float chamber 8 of the carburetor.

The foregoing description of the liquid fuel system is in all essential respects identical with the fuel supply systems now in common use in connection with automobiles, and similar vehicles.

I propose to add an additional fuel supply system employing a normally gaseous fuel, this system comprising a fuel supply tank 16 in which normally gaseous fuel is compressed and thereby maintained in liquefied condition. From tank 16 there extends a suitable gaseous fuel supply tube 17 extending to the bottom of the tank 16, so as to draw off the liquid and not gas. The gaseous fuel supply tube 17 is preferably threaded through the exhaust manifold 4 of the engine 2, as is indicated at 18, so that the fuel passing therethrough will be heated by contact of the tube 17 with the hot exhaust gases coming from the engine. The tube 17 continues from the exhaust manifold 4 as by way of the short section of tubing 19 into a combined filter and heat exchanger 20 which further assists in heating the gaseous fuel. From the filter 20 the fuel inlet tube continues, as is indicated at 21, to the inlet connection 23 to a pressure reducing valve 24.

The pressure reducing valve 24 is illustrated and described in detail in my copending application Serial No. 491,468, filed October 27, 1930 which has since matured into Patent 1,912,479 dated June 6, 1933 and comprises a valve constructed to receive a gas under relatively high pressure and to permit gases to flow therefrom at a pressure equal to that of the air supply. In order to equalize these pressures, a pipe 52 connects the air cleaner 29 with the atmosphere side of the pressure equalizing valve 24.

The gaseous fuel supply through outlet tube 25 may be mixed with air and passed into the tube 6 of the carburetor 5 so that such air and gas mixture may pass into the intake manifold 3 of the engine 2 and thus constitute the combustible fuel for operating the engine 2.

The mixing device is illustrated as comprising an attachment which may be connected to the inlet end of the carburetor tube 6, this mixing device comprising a tubular member 26, one end 27 of which is provided with an internal diameter of such size as to telescopically engage the air inlet end of the carburetor tube 6 and may be clamped thereon as by means of clamping screw 27a. The opposite end 28 of the mixer 26 is illustrated as being of slightly reduced diameter so that its outside diameter corresponds substantially with the outside diameter of the inlet end of the tubular carburetor 6. By reason of this reduced diameter the air cleaner 29, which normally is telescopically engaged upon the inlet end of the carburetor 6, may be inserted in place upon the end 28 of my mixer.

Within the tubular mixer 26 is a pair of radial flanges 30 and 31 which extend inwardly to form a seat for a venturi 32. The flange 30 is preferably formed with a shoulder 33 thereon to act as a limit stop for the venturi 32 when the same is inserted into engagement with the flanges 30 and 31.

The venturi 32 comprises an annular ring which has one or more slots 34 extending radially therethrough. Between the flanges 30 and 31 is an annular space 35 surrounding the venturi 32. This annular space 35 communicates with a gas inlet stem 36 through which gaseous fuel may be passed into the annular space 35 and thence

through the slots 34 to the interior of the venturi 32. The annular space 35 between the flanges 30 and 31 may be bridged at a plurality of points by means of cross members 37 to assist in guiding the venturi 32 into its proper seating relation relative to the flanges when the same is to be inserted within the tubular mixer 26. The venturi 32 may be held in place when inserted as by means of one or more set screws 38 threaded radially into the mixer 26.

The gas inlet stem 36 is preferably provided with a cut off valve 39 which may be operated to either open the inlet passage 36 to the passage of gas therethrough, or to close the same so that gas cannot pass therethrough.

The upper end of the stem 36 is provided with external threads 40 for engagement with a suitable union nut 41 to secure the gas inlet pipe 25 thereto while the stem 36 may be additionally provided with internal threads 42 to permit a metering jet 43 to be threaded thereto to provide the desired size orifice 44 for metering or limiting the quantity of gas permitted to flow into the mixer 26.

Referring, particularly, to Figure 1, it will be observed that the operating levers 45 and 46 for the valves 14 and 39, respectively, are connected to a rod or wire 47 which extends to a point of convenient access to the operator of the vehicle such as, for example, the dashboard 48 so that the rod or wire 47 may be manipulated to simultaneously control both valves 14 and 39.

The operation of my device is as follows: When the engine 2 is to be started the valves 14 and 39 may be operated by the rod or wire 47 to the position opposite to that illustrated in Fig. 2. That is, the valve 14 is closed and the valve 39 is open so that under these conditions gaseous fuel will be supplied to the carburetor 5 and thus the engine may be started upon the gaseous fuel. For small loads, or low speeds, the engine may be operated continuously upon such gaseous fuel though as soon as the engine is started it may be switched over to the liquid fuel by manipulating the rod or wire 47. Operating the rod or wire 47 will reverse the valves 14 and 39 so that the gaseous fuel supply is cut off and the liquid fuel supply connected to feed the carburetor.

Either the liquid fuel contained in tank 16 which changes to gas on release of pressure or the higher boiling point gasoline fuel in tank 15 may be used for starting the motor, the object of applicant's invention being to obtain flexibility in the use of either type of fuel as conditions or supply may warrant. For example, on a cold morning, or with a cold motor, it would be preferable to use the low boiling point fuel in tank 16 to start the motor and thereafter when the motor is warmed up the fuel supply coming from tank 16 may, if desired, be shut off and the gasoline supply in tank 15 turned on, although the operation of the motor can be maintained on the fuel from tank 16 if desired. There is an advantage in starting a cold motor on the low boiling point fuel from tank 16 in that liquid fuel is not deposited on the cylinder walls to wash away the lubricating oil. Furthermore, the low boiling point fuel from tank 16 has higher anti-knock value than ordinary gasoline so that where a long run on full throttle is to be made, the motor may be supplied with fuel from the tank 16 and detonation or knocking prevented.

Upon opening the valve 39 gaseous fuel passing through the metering jet 43 will pass to the annular chamber 35 surrounding the venturi 32 and

will thence pass inwardly through the leads 34 to be mixed with the incoming air stream drawn into the inlet end of the carburetor 5 through the air cleaner 29.

5 By properly selecting the orifice 44 of the metering jet 43 and the slotted orifices 34 of the venturi 32, the desired quantity of gaseous fuel to be supplied relative to the quantity of air drawn into the carburetor may be adjusted to
10 provide a properly combustible mixture.

It will be observed that as the air is drawn through the venturi into the carburetor 5, the quantity of air so drawn will act on the venturi 32 to increase or decrease the quantity of gaseous
15 fuel supplied in proportion to the quantity of air drawn through so that the proper combustible mixture will be maintained at various speeds of operation of the engine.

For idling purposes, when operating on the gaseous fuel, an idler connection 49 may be connected into the intake manifold 3 of the engine 2, this connection being made as by means of a tube or pipe 50 to the low pressure side of the pressure
20 reducing valve 24. Thus at idling speeds a desirable quantity of fuel for idling may be furnished to the engine. The amount of fuel by-passed to the engine is regulated by the valve 53.

It will be observed that I have disclosed herein a system in which liquid fuel or gaseous fuel may be used in alternation with each other for supplying the required fuel to the engine. Hence the engine 2 may be supplied with high grade gaseous fuel for the greater portion of its operation and the liquid fuel may be used only when a supply
25 of gaseous fuel is undesirable.

If desired, the valves 14 and 39 may be operated so as to cut off partly both the liquid and the gaseous fuel, so that a progressive proportioning can be utilized whereby more or less liquid
30 or gaseous fuel can be utilized without disturbing the air fuel ratio of the mixture delivered to the engine.

While I have illustrated and described the preferred embodiment of my invention, I do not desire to be limited to any of the details shown or described herein, except as defined in the appended claims.

I claim:

1. In a fuel system for internal combustion engines, a liquid fuel supply, a gaseous fuel supply, a carburetor comprising an air passage
35 through which air may be passed into the intake

of the engine, a liquid fuel inlet communicating with the air passage of said carburetor for supplying liquid fuel to the air stream drawn through the carburetor, a cut off valve for cutting off the supply of liquid fuel to said carburetor, a gaseous
30 fuel inlet connected to and communicating with the air passage of said carburetor, said gaseous fuel inlet including a venturi through which said air stream may pass and having openings therein through which gaseous fuel may be drawn
35 through the venturi into the air stream, a valve interposed between said gaseous fuel inlet and said venturi, and means for simultaneously operating said valves to open one of said valves and close the other, and vice versa, to supply either
40 liquid or gaseous fuel to said carburetor.

2. In a fuel system for internal combustion engines having a carburetor, a source of gaseous fuel, means for introducing said gaseous fuel into said carburetor comprising a tube connectible to
45 the air inlet passage of said carburetor, a venturi in said tube having openings therein through which gaseous fuel may be passed into said tube, a gaseous fuel inlet communicating with the openings in said venturi, and a metering jet in
50 said gaseous fuel inlet for metering the quantity of fuel supplied therethrough.

3. An attachment for a standard liquid fuel carburetor having an air supply opening, which attachment comprises a tube connectible to the
55 air inlet passage of said carburetor, said tube having a Venturi passage therein for air drawn through said tube into the carburetor, with openings in the throat of the venturi through which gaseous fuel may flow into said tube and a gaseous
60 fuel inlet passage communicating with the openings in the throat of the venturi.

4. An attachment for a liquid fuel carburetor having an air inlet nipple with an air cleaner slidably engageable therewith, which attachment
65 comprises a tube dimensioned at one end to engage with the air inlet of the carburetor normally engaging with the air cleaner, and dimensioned at the opposite end to engage with the end of the air cleaner normally engaging with
70 the carburetor inlet, whereby said tube may be inserted as a unit between the air inlet passage of the carburetor and the air cleaner, said tube being provided with gaseous fuel inlet openings and an inlet port connected thereto for connection to a supply of gaseous fuel.

GEORGE L. HOLZAPFEL.

EXHIBIT 1005

LP-Gas Code Handbook



LP-Gas Code Handbook

EIGHTH EDITION

Edited by

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Principal Gases Engineer, NFPA

With the complete text of the 2008 edition of NFPA[®] 58, *Liquefied Petroleum Gas Code*



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Notice Concerning Code Interpretations: This eighth edition of *LP-Gas Code Handbook* is based on the 2008 edition of NFPA 58, *Liquefied Petroleum Gas Code*. All NFPA codes, standards, recommended practices, and guides are developed in accordance with the published procedures of the NFPA by technical committees comprised of volunteers drawn from a broad array of relevant interests. The handbook contains the complete text of NFPA 58 and any applicable Formal Interpretations issued by the Association. These documents are accompanied by explanatory commentary and other supplementary materials.

The commentary and supplementary materials in this handbook are not a part of the *Code* and do not constitute Formal Interpretations of the NFPA (which can be obtained only through requests processed by the responsible technical committees in accordance with the published procedures of the NFPA). The commentary and supplementary materials, therefore, solely reflect the personal opinions of the editor or other contributors and do not necessarily represent the official position of the NFPA or its technical committees.

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This handbook is dedicated to the people who led the NFPA Technical Committee on Liquefied Petroleum Gases from NFPA 58's first edition in 1932 to the present. In the early days the committee truly wrote the standard (it became a code in 1998), with NFPA staff taking a larger role beginning in 1956.

Those who chaired the committee in the past are recognized here for their foresight, dedication, and vision, which shaped the Code into the complete document it is today.

H. E. Newell*, National Board of Fire Underwriters, 1932–1955

Franklin R. Featherston*, Liquefied Petroleum Gas Association, 1956–1967

H. V. Keepers*, Fire Prevention & Engineering Bureau of Texas, 1968–1975

Connor L. Adams*, City of Miami Bldg. Dept., 1976–1996

E. E. (Al) Linder, Watsonville, CA, 1997–2004

NFPA 58 would not be *the* internationally recognized propane code were it not for the work of these dedicated people. Their contributions are appreciated.

*deceased

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Preface

The eighth edition of the *LP-Gas Code Handbook* continues the tradition begun by Wilbur L. Walls, editor of the first edition in 1986. The handbook provides commentary that brings the legalistic language of the code to life. The code must be written using a technically clear, usable, and enforceable style. It cannot include the guidance and explanations that the Technical Committee on Liquefied Petroleum Gases would like to include.

The purpose of this handbook is to assist you, the enforcer or user of NFPA 58, *Liquefied Petroleum Gas Code*. The commentary and supplements provide guidance, recommendations, and common practices for the use of LP-Gas as a fuel.

The 2008 edition of the code contains several important changes, including the following:

1. Revised table of container appurtenance requirements
2. New section on patio heaters
3. New requirements for notification prior to transfer of liquid LP-Gas from rail cars to tank cars without intermediate storage
4. New requirements for operation of small LP-Gas pipeline vapor systems with 10 to 99 users (such as might be located at a mobile home park) that is consistent with U. S. Department of Transportation requirements

An NFPA code handbook is never complete. In order to stay current, it must change as technology and code requirements change. Users will find that problems they encounter may not be addressed fully in the handbook commentary, tables, illustrations, or photographs, or that the commentary appears incomplete when applied to real problems. Therefore, the editor invites suggestions, examples, new illustrations, and photographs from all readers for use in the next edition.

History of NFPA 58

NFPA standards concerned with gases date from 1900, only four years after the establishment of NFPA itself. The first standards were concerned with acetylene, which was actually used in those days as a household cooking, lighting, and heating fuel, and with manufactured, or “city,” gas derived from coal and oil.

The NFPA Technical Committee on Gases developed the early standards. By 1924, the use of liquefied petroleum gas (LP-Gas), primarily as a cooking and heating fuel in rural areas, had become common, and the need for a national fire safety standard was recognized. The LP-Gas for these systems was stored in compressed gas cylinders. Because of their cylindrical shape, the LP-Gas they contained was widely referred to simply as “bottled gas,” an identification rather lacking in specificity (acetylene was also a “bottled gas”) but one still used today.

In 1927, the Committee on Gases secured NFPA approval of the first NFPA standard on LP-Gas, a four-page document with a title — *Regulations for the Installation and Operation of Compressed Gas Systems Other than Acetylene for Lighting and Heating* — that comprised a fair proportion of the text of the standard itself. The standard covered only systems in which

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EXHIBIT P.1 Early Magazine Advertisements for Acetylene Lighting and Cooking.



the LP-Gas was stored in cylinders fabricated to regulations of the U.S. Interstate Commerce Commission (ICC), today known as the U.S. Department of Transportation (DOT).

In those days, NFPA published its standards only in the Proceedings of the Annual Meeting at which the standards were adopted. To make them more available to users, the National Board of Fire Underwriters (NBFU), now known as the American Insurance Association, obtained NFPA permission to publish many of them in pamphlet form. These were identified as standards of the NBFU "as recommended by the NFPA." In those days, NFPA did not identify many of its standards by number. However, the NBFU did, and the standard was thus designated NBFU 52. Amended editions of the standard were adopted in 1928, 1933, and 1937.

Because the LP-Gas "bottles" had to be refilled (in those days, only at a plant built for that purpose), which required the use of a much larger container for plant storage, new specifications had to be developed. In addition, major consumers found a container larger than an ICC cylinder to be advantageous. These larger containers required different design and siting criteria.

In 1931, NFPA tentatively adopted *Regulations for the Design, Installation and Construction of Containers and Pertinent Equipment for the Storage and Handling of Liquefied Petroleum Gases*, which was officially adopted at the next NFPA meeting in 1932. This standard covered the larger containers, which are the ASME containers of today. Also published by the NBFU, under the designation NBFU 58, this standard had 14 pages, 10 more than NBFU 52.

At the 1931 Annual Meeting, committee chairman Harry E. Newell of the NBFU noted in his report that the proposed standard had been prepared by a joint subcommittee of the Committee on Gases and the Committee on Flammable Liquids. He attributed this to the fact that "it was difficult to decide whether liquefied petroleum gases were flammable liquids or gases." Even today, confusion exists on this score. Some municipal ordinances, undoubtedly of considerable vintage, equate them, and many communities have failed to adopt LP-Gas regulations under the erroneous impression that their flammable liquid regulations apply to LP-Gas.

For many years, the Committee on Gases was composed of 11 to 20 members. In 1932, there were 15 members, representing the Associated Factory Mutual Fire Insurance Compa-

nies, American Gas Association, Board of Fire Underwriters of Allegheny County, Western Factory Insurance Association, Conference of Special Risk Underwriters, Manufacturing Chemists Association, Boston Board of Fire Underwriters, International Acetylene Association, Underwriters Laboratories Inc., Compressed Gas Manufacturers Association, American Petroleum Institute, Railway Fire Protection Association, and the U.S. National Bureau of Standards, as well as the NBFU. With 6 of the 15 members, including the chairman, representing the insurance industry, the standard could be presumed to be rather conservative and thus lacked the balance of interests that is required under today's NFPA procedures.

The extreme versatility of "gas in a bottle" soon led to more and more complex uses, and the Committee on Gases was hard-pressed to keep up. Amended editions of the 1931 standard were adopted in 1934, 1937, 1938, and 1939.

In 1935, a standard on LP-Gas cargo vehicles, whose use had become widespread in the early 1930s, was adopted and published by NBFU as NBFU 59. In 1937, a standard was adopted to regulate the use of LP-Gas as a fuel to power vehicles, a practice that had become prevalent by the mid-1930s. In 1938, however, this became a part of the ASME Code container standard (NBFU 58).

By now, it was apparent that the various standards contained considerable duplicate material and could be combined into a single standard. This was done in 1940. The resulting 47-page standard (in the NBFU 58 pamphlet version) combined the 1937 edition of NBFU 52 and the 1939 editions of NBFU 58 and 59. This single standard also replaced the *Liquefied Petroleum Gas Code*, which was adopted in 1937 in response to a request by regulatory and insurance interests to provide container siting and basic fabrication criteria that were not as detailed as those found in the existing standards. This code ultimately proved inadequate from the industry's point of view, and it was withdrawn when the combined standard was introduced. The 1943 edition of the standard was the first edition to be designated NFPA 58. The first pamphlet edition of NFPA 58 was published in 1950.

The dates of each edition of NFPA 58 are given in the "Origin and Development" section of each edition. To date, there have been 31 editions since the 1940 edition, an average of about one every two years. From 1950 to 1961, in fact, a new edition was adopted each year. This is a very high rate, and it placed an impossible burden upon its usefulness as a public safety regulatory instrument. Since 1961, new editions have been adopted about every three years, except for the 2008 edition, which took four years due to controversy, which resulted in a last-minute deletion of proposed coverage of cabinet heaters.

The Committee on Gases itself developed NFPA 58 until 1956. By that time, the number and variety of NFPA standards covering various gases had grown so large that the size of the committee was becoming difficult to manage. The solution was to establish a number of smaller committees, known as sectional committees, composed of experts on the different gas applications. The developmental and interpretative responsibilities for NFPA 58 were thus assigned to the Sectional Committee on Liquefied Petroleum Gases. However, the sectional committee could only recommend amendments, Formal Interpretations, or Tentative Interim Amendments (TIAs) for adoption by the Committee on Gases.

Because the sectional committee lacked authority, its membership essentially duplicated that of the Committee on Gases, and the purpose of the sectional committee was defeated. It was also becoming evident that the Committee on Gases seldom overturned a sectional committee recommendation.

In 1966, the sectional committees — there were four at the time — were organized into three full-fledged technical committees, and the Committee on Gases ceased to exist. NFPA 58 thus became the complete responsibility of the Technical Committee on Liquefied Petroleum Gas.

From 1940 to 1969, NFPA 58 consisted of a chapter entitled Basic Rules, followed by a number of chapters entitled Divisions and by appendixes. The Introduction and Basic Rules included all material common to all applications, such as scope statements, retroactivity, definitions, odorization, approval requirements, container fabrication, siting, design criteria for

pipings, valves, hoses and fittings, filling levels, and ignition source controls. The eight divisions amplified and sometimes modified the basic provisions for specific applications, some on the basis of kinds of containers and others on the basis of the environment in which the system was used.

As a new application was developed, it was essentially treated as a package and added as a new division, which was easier to do and allowed for the timely inclusion in the standard of new applications. The problem with this approach was that similar hazards were being treated differently, and the basic rules were becoming less and less basic.

In the late 1960s, the Technology and Standards Committee of the National Propane Gas Association (NPGA) undertook the development of a format that would provide consistency in hazard evaluation, would reduce the extent to which particular interests would have to study the entire standard, and would make the format more like that used in other NFPA standards.

In the current format, **Chapters 1 through 4** include only material truly relevant to all applications.

Chapters 5 and 6 address the fundamental breakdown of interest that experience has shown exists between manufacturers of equipment and those who assemble this equipment into systems and actually install them. Fire experience clearly reveals that incidents are nearly always due to failure to comply with one or more provisions and that many of these failures are the result of confusion between manufacturers and installers as to who should do what. To help reduce this confusion, **Chapter 5** is aimed at the equipment manufacturer and **Chapter 6** at the installer.

The same experience has also shown that the great majority of nonappliance-related accidents occur when LP-Gas liquid is being transferred from one container to another. An essential aspect of such operations is the presence and performance of a person or persons conducting the transfer operation: An accident generally involves human behavior, as well as equipment. **Chapter 7** addresses LP-Gas liquid transfer.

Chapter 8, Storage of Cylinders Awaiting Use, Resale, or Exchange, and **Chapter 9**, Vehicular Transportation of LP-Gas, retain the old format of Divisions V and III.

Chapter 10 was essentially new in the 1972 edition. Earlier editions had not considered the role of the structural behavior of a room or building in an explosion.

Chapter 11 was created in the 1992 edition by relocating the coverage of engine fuel systems from Chapter 6 to this chapter.

Drawn largely from NFPA 59 and NFPA 59A, **Chapter 12** was added in the 1989 edition to provide requirements for the new coverage of refrigerated storage containers.

Coverage of marine shipping and receiving was relocated from Chapter 4 to create Chapter 13 in the 1992 edition.

Chapter 14, Operations and Maintenance, was added in the 2001 edition. It contains only operations and maintenance requirements that were new in the 2001 edition. In the current edition, a new section was added, Small LP-Gas Systems, covering vapor systems of 10 to 99 users connected to a common supply system. These requirements essentially duplicate requirements in U. S. Federal Law applicable to these pipeline systems. The intent is to make them more easily available to operators of these relatively small systems, which may be located in mobile home parks, campgrounds, and housing developments.

Chapter 15 was added in the 1998 edition. It consists of tables used to size propane vapor piping. The tables were extracted from NFPA 54, *National Fuel Gas Code*. The chapter was added because some pipe sizing in buildings is now included in the scope of NFPA 58, because it was deleted from NFPA 54 in the 1996 edition.

While the 1972 edition went a long way toward bringing the format of NFPA 58 into line with other NFPA standards, it still did not properly segregate mandatory and nonmandatory provisions, and it used a different paragraph numbering system. These differences were corrected in the 1983 edition.

Experience with the format of the 1972 edition and with subsequent editions indicates that it has led to improved comprehension and application. However, it is more difficult to re-

view existing provisions to see if a new application is in fact already covered than it is to start from scratch. Furthermore, there is always pressure to include all provisions applicable to a new and “hot” application in one place. This temptation must be resisted lest the standard evolve into the conflicting and cumbersome document it once was.

The administration of the committees responsible for NFPA 58 has been remarkably stable over its history. Harry E. Newell of the NBFU was chairman from 1932 until 1956, when he retired from NBFU. As an indication of the respect the committee and NFPA had for him, the position of honorary chairman was created for him, the only time this position has existed. He served in this capacity until 1958.

Newell’s dedication was even more remarkable in that he also performed the chores of committee secretary, albeit anonymously. It wasn’t until 1954 that NFPA was able to assign a staff member, Clark F. Jones, as committee secretary. Jones served in this post until his untimely death in 1962. Wilbur L. Walls succeeded him in September 1962. Walls was the committee secretary until his retirement from NFPA in 1984. In May 1985, Theodore C. Lemoff became the NFPA staff secretary.

Franklin R. Fetherston succeeded Newell as chairman of the Committee on Gases in 1956. Initially representing the Liquefied Petroleum Gas Association (now the National Propane Gas Association), he later represented the Compressed Gas Association until he retired in 1966. During Fetherston’s tenure, the Sectional Committee on Liquefied Petroleum Gases was chaired by Harold L. DeCamp of the Fire Insurance Rating Organization of New Jersey from 1956 to 1964, and by Myron Snell of the Hartford Accident and Indemnity Company from 1964 to 1966.

Hugh V. Keepers of the Fire Prevention and Engineering Bureau of Texas became the first chairman of the current committee in 1966 and served for 10 years until his retirement. He was followed by Connor Adams of the City of Miami, who served as chair from 1975 to 1996. The immediate past chairman, E. E. (Al) Linder, a safety consultant and former propane company employee, took over the reins in 1996 and served through the 2004 edition. He was replaced by Frank Mortimer of Federated Mutual Insurance Company.

Acknowledgments

A book that compiles the history, intent, and application of an NFPA standard, as the *LP-Gas Code Handbook* does, is the work of many contributors, many of whom are members of the Technical Committee on Liquefied Petroleum Gases, and all of whom work with LP-Gas daily. The foundation for this sixth edition was laid by the three authors who contributed to the first edition in 1986: Wilbur L. Walls, who represented, at the time, the expertise of NFPA on flammable gases; Walter H. Johnson, who possessed a broad knowledge of the LP-Gas industry from the industry association viewpoint; and H. Emerson Thomas, who offered his perspective as one of the founders of the propane industry in the United States.

The preparation of this eighth edition was enhanced by the contributions of Bruce Swiecicki, Senior Technical Advisor for the National Propane Gas Association. Bruce, as the contributing editor, provided draft commentary on the entire code and made many important contributions. He is a registered professional engineer in Illinois and has an M.S. in Mechanical Engineering from the University of Illinois. Bruce has been a member of the Technical Committee on Liquefied Petroleum Gases since 1994, and his efforts on this publication are appreciated.

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This handbook is built on the foundation laid by the Technical Committee on Liquefied Petroleum Gases, which writes NFPA 58. The editor appreciates the work the committee members do in carefully considering each proposal and comment and the discussions on other topics, which is the basis of the book.

I would also like to again thank Wilbur Walls, NFPA gases engineer emeritus, who, though retired, volunteered his time and energy to assist me when I joined NFPA and took over responsibility for the NFPA gases project. Bill continues to be a valuable resource for the historical questions that arise.

I also appreciate the efforts of the NFPA staff who made this book possible. Particular thanks go to Josiane Domenici, permissions editor, Marla Marek, copy editor, Irene Herlihy, developmental and project editor, and Debra Rose, product manager.

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Bruce Swiecicki has worked 14 years at the National Propane Gas Association as vice president of technical services and now as senior technical advisor. His work experience includes 10 years at Building Officials and Code Administrators, International, where he was senior staff engineer. He has been a member of the Technical Committee on Liquefied Petroleum Gases since 1994 and a member of several other NFPA committees as well as other codes and standards organizations. Bruce holds bachelor's and master's degrees in mechanical engineering from the University of Illinois and is a registered professional engineer in the state of Illinois.

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About the Editor

After graduating from the City College of New York with a Bachelor of Engineering (Chemical) degree, Theodore C. Lemoff was employed in the chemical and petrochemical industry by Proctor and Gamble Company, Sun Chemical Corporation, and Badger Engineers, Inc., in various engineering positions. He joined NFPA in 1985 and currently serves as NFPA's principal gases engineer. He serves as the NFPA staff liaison to the National Fuel Gas Code Committee, and he is also responsible for other NFPA standards on flammable gases.

In addition to being the editor of the *LP-Gas Code Handbook*, Lemoff is the editor of the *National Fuel Gas Code Handbook* and co-author of the *NFPA Pocket Guide to Fuel Gas Storage and Use*.

Lemoff represents NFPA on the ASME Code for Pressure Piping Committee (National Interest Review Group) (B31), the pipeline safety advisory committee of the U.S. Department of Transportation, and the IAPMO Mechanical and Plumbing Code Committees.

Lemoff is a registered professional engineer in the Commonwealth of Massachusetts and is a member of the American Institute of Chemical Engineers and Society of Fire Protection Engineers, the American Society of Plumbing Engineers, and the International Association of Plumbing and Mechanical Officials.

PART ONE

NFPA[®] 58, *Liquefied Petroleum Gas Code,* with Commentary

Part One of this handbook includes the complete text of the 2008 edition of NFPA 58, *Liquefied Petroleum Gas Code*, which is made up of 15 mandatory chapters and 12 nonmandatory annexes. Working within the framework of NFPA's consensus codes- and standards-making process, the Technical Committee on Liquefied Petroleum Gases prepared the mandatory provisions found in Chapters 1 through 15.

The Technical Committee on Liquefied Petroleum Gases also developed the material found in the annexes of the code. The annex material is designed to assist users in interpreting the mandatory code provisions. It is not considered part of the requirements of the code; it is advisory or informational in nature. An asterisk (*) following a code paragraph number indicates that advisory annex material pertaining to that paragraph appears in Annex A. For the reader's convenience, in this handbook Annex A material has been repositioned to appear immediately following its base paragraph in the body of the code text.

The explanatory commentary in this handbook was prepared by the handbook editor, with the assistance of those persons mentioned in the acknowledgments, and is intended to provide the reader with an understanding of the provisions of the code and to serve as a resource and reference for implementing the provisions of or enforcing the code. It is not a substitute for the actual wording of the code or the text of the many codes and standards that are incorporated by reference. The commentary immediately follows the code text it discusses and is set in blue type for easy identification.

This edition of the handbook includes a frequently asked questions feature. The marginal FAQs are based on the questions most commonly asked of the NFPA 58 staff. The handbook also features a tool designed to help users easily identify important new or revised elements in the code. New or revised material is identified with a "new" icon in the margin of the book next to that material.

Definitions

CHAPTER 3

Since the 2004 edition, all definitions that apply to subjects covered throughout the code have been located in Chapter 3.

The sections in Chapter 3 are outlined as follows:

- General (See Section 3.1.)
- NFPA Official Definitions, which apply to all NFPA codes and standards (See Section 3.2.)
- General Definitions, which apply to NFPA 58 only (See Section 3.3.)

3.1 General

The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

Generally, if terms used in the code are not defined in Chapter 3, then *Merriam-Webster's Collegiate Dictionary* [1] is the source for common usage.

3.2 NFPA Official Definitions

Section 3.2 contains definitions that are used in other NFPA documents and are not specifically related to the propane industry. NFPA attempts to make all of its documents consistent with respect to terms used to describe the enforcement authority and approval process.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

Equipment, materials, or services can be listed, approved, or both. *Listed*, defined in 3.2.5, means that the item has been reviewed by an independent testing organization that evaluates products and continues to evaluate their production. Listed products are included in "lists" maintained by the testing agency. *Approved*, as defined in 3.2.1, means that the equipment, material, or services have been accepted by the authority having jurisdiction. Listed products

◀ FAQ

What is the difference between the terms *listed* and *approved*?

must comply with standards, while approved products may or may not comply with standards.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase “authority having jurisdiction,” or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

FAQ ►
What is the meaning of “authority having jurisdiction” as used in NFPA 58?

An authority having jurisdiction is a governmental agency responsible for protecting the public welfare through its activities to enforce the codes and standards that have been enacted into law. The propane industry can be regulated through a number of governmental agencies, including the state or local fire marshal’s office, the state or local building department, or the federal or state department of transportation. Notably, many enforcement agencies, including the U.S. Occupational Safety and Health Administration, promulgate rules that reference earlier editions of NFPA 58 than the 2008 edition. As noted in **A.3.2.2**, nongovernmental bodies can be the authority having jurisdiction by virtue of the conditions of a private contract (e.g., an insurance policy).

Each propane retail marketing business should become familiar with which authorities have jurisdiction over each operation of its business. The following are examples of authorities having jurisdiction for different parts of a propane business:

- Bulk plant — Fire marshal or fire chief
- Vehicles — State vehicle bureau or state police
- Residential installations — Building or gas official

3.2.3* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

A.3.2.3 Code. The decision to designate a standard as a “code” is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

FAQ ►
What information should be on a label?

A product is labeled to indicate that a third-party, independent agency has either conducted testing or otherwise evaluated the performance or the design of a product or system. The label indicates the name of the evaluating organization (such as Underwriters Laboratories Inc. or CSA-America) as well as the manufacturer’s name or trademark and the model number and/or serial number and should list the applicable standard under which the product or equipment was evaluated or tested.

3.2.5* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

A.3.2.5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

The AHJs customarily accept or even require (depending on whether or not NFPA 58 requires) the use of listed equipment whenever it is available. In the United States and Canada, the major LP-Gas equipment listing agencies customarily recognized as such by the authorities having jurisdiction are Underwriters Laboratories Inc., Underwriters' Laboratories of Canada, FM Global, CSA-International, and others. Many other organizations perform such services, however, and equipment listed by them is acceptable provided that the organization is acceptable to the authority having jurisdiction.

A point of some confusion is that not all the above organizations use the term *listed*. For example, CSA-America uses the term *certified* and FM Global uses the term *approved*. The terms *certified* and *approved* are synonymous with the term *listed* in this definition.

3.3 General Definitions

3.3.1 Actuated Liquid Withdrawal Excess-Flow Valve. An excess-flow valve for liquid withdrawal applications that remains in a closed position until actuated by a pipe nipple or adapter, as recommended by the manufacturer, and that is used with a shutoff valve attached to the actuator.

The definition of *actuated liquid withdrawal excess-flow valve* was added in the 1995 edition. These valves are required in ASME containers of 125 gal to 2000 gal (0.5 m³ to 7.6 m³) water capacity manufactured after July 1, 1961. The valve is designed to eliminate the need to roll a container on its side to remove liquid from it. Since the early 1960s, at least three manufacturers have made valves that accomplish the requirements related to this definition under the names of Check-Lok® and Check-Mate®. Prior to the 1995 edition, this specific function valve had no name or definition. The term *actuated* is used to indicate that the valve remains closed until the insertion of the mating connection opens it.

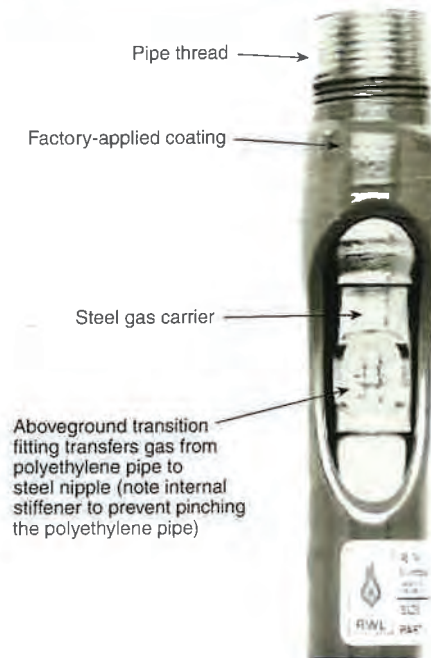
3.3.2 Anodeless Riser. A transition assembly where polyethylene or polyamide pipe or tubing is permitted to be installed underground and is terminated above ground outside of a building.

An anodeless riser is a piping component that connects to polyethylene (or polyamide) pipe under ground and terminates in a metal threaded connection above ground (see [Exhibit 3.1](#)). It is anodeless because it provides no metallic surface that contacts the soil, thereby protecting the riser against corrosion. Typically, anodeless risers are manufactured of steel-encased polyethylene liners. The steel is coated with an epoxy covering that protects the inner components. (See [6.9.4.3](#).)

3.3.3 ANSI. American National Standards Institute.

The American National Standards Institute (ANSI) is a private, nonprofit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment

EXHIBIT 3.1 *Cutaway View of Riser Assembly. (Courtesy of R.W. Lyall & Company, Inc.)*



system. ANSI does not develop its own standards but sanctions those prepared by committees and organizations that are ANSI members and that use procedures approved by ANSI.

NFPA is recognized as a standards-developing organization under ANSI and issues codes and standards with the ANSI designation because its regulations are accepted by ANSI.

3.3.4 API. American Petroleum Institute.

The American Petroleum Institute (API) is a trade association composed largely of U.S. oil companies. Many oil companies produce and distribute LP-Gas because it is a byproduct of the refining of crude oil as well as the processing of natural gas. API also develops standards that can be useful for those involved in the LP-Gas industry.

3.3.5 API-ASME Container (or Tank). A container constructed in accordance with the pressure vessel code jointly developed by the American Petroleum Institute and the American Society of Mechanical Engineers.

Until 1961 a joint API-ASME code was used for designing propane tanks. A small number of these vessels are still in service, and they remain acceptable for service. After the joint code was discontinued, API addressed the refining industry's need for large storage vessels, while ASME addressed pressure vessels for all applications.

3.3.6 ASME. American Society of Mechanical Engineers.

The American Society of Mechanical Engineers (ASME) is a membership organization of mechanical engineers.

3.3.7 ASME Code. The American Society of Mechanical Engineers Boiler and Pressure Vessel Code.

3.3.8 ASME Container. A container constructed in accordance with the ASME Code.

3.3.9 ASTM. American Society for Testing and Materials.

The American Society for Testing and Materials (ASTM) promulgates the largest body of private-sector standards in the United States. As is evident in 2.3.5, many ASTM standards that address piping and castings are adopted by mandatory reference in NFPA 58.

3.3.10* Bulk Plant. A facility where the primary function is to store LP-Gas prior to further distribution. LP-Gas is received by cargo tank vehicle, railroad tank car, or pipeline, and then distributed by portable container (package) delivery, by cargo tank vehicle, or through gas piping.

A.3.3.10 Bulk Plant. Bulk plants receive gas through a variety of methods, such as railroad tank car, transport, cargo tank vehicle, gas piping, or watercraft. These plants are generally utilized for domestic, commercial, agricultural, institutional, and industrial applications, or for the storage of product awaiting delivery to the end user. A facility that transfers LP-Gas from railroad tank cars from a private track directly into cargo tank vehicles is also in this category. Such plants could have container-filling and truck loading/unloading facilities on the premises. Normally, no persons other than the plant management or plant employees have access to these facilities.

As defined in 3.3.10, bulk plants are facilities where LP-Gas is stored before it is delivered to the end-use customer. Frequent liquid transfer operations take place at bulk plants. These include cylinder filling, transport truck unloading, rail tank car unloading, and bobtail (retail bulk delivery truck) filling. See Exhibit 3.2 for an example of a typical bulk plant. Exhibit 3.3 shows a larger bulk plant with the capability to unload LP-Gas from rail cars. See also F.I. 58-04-3.

3.3.11 Cargo Tank. A container that is used to transport LP-Gas as liquid cargo and either is mounted on a conventional truck chassis or is an integral part of a cargo transporting vehicle.

Cargo tanks are typically installed on truck chassis (cargo tank motor vehicles), which are built to comply with DOT requirements (MC-330 and MC-331 specifications) [2,3]. Cargo tank vehicles include bobtails (see Exhibit 3.4) and transports (see Exhibit 3.5). Cargo tanks differ from DOT containers, which are “portable” and are transported on trucks.

3.3.12 CGA. The Compressed Gas Association.

In 1913, a nonprofit service organization was incorporated in New York as the Compressed Gas Manufacturers' Association to promote, develop, represent, and coordinate technical and standardization activities in the compressed gas industries in the interest of safety and effi-

◀ **FAQ**

What is meant by the term *bulk plant*?



EXHIBIT 3.2 Aerial View of a Bulk Plant. (Courtesy of Revere Gas and Appliance)

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EXHIBIT 3.3 Large Bulk Plant. (Courtesy of Eastern Propane Corp.)



Formal Interpretation
NFPA 58
Liquefied Petroleum Gas Code
2008 Edition

Reference: 3.3.10

F.I. No.: 58-04-3

Question: Is it the intent of the Committee, based on the definition provided in 3.3.10 of NFPA 58, that a building, at a bulk plant, containing cylinders for distribution or buildings at bulk plants where LP-Gas cylinders are filled, is part of the bulk plant?

Answer: Yes

Issue Edition: 2004

Reference: 3.3.10

Issue Date: November 30, 2005

Effective Date: December 19, 2005

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ciency. Today, among the Compressed Gas Association's (CGA's) members are companies and individuals producing compressed, liquefied, and cryogenic gases and their containers (including cargo containers), container appurtenances, and other system components.

From its inception, a major activity of CGA has been the development of standards through the efforts of more than 40 technical committees. The 1932 edition of what is now NFPA 58 was based on a draft prepared by CGA's Test and Specification Committee in 1930 and 1931. (See "History of NFPA 58" in the **Preface**.) Much of this work has now passed on



EXHIBIT 3.4 Bobtail. (Courtesy of CENEX, a brand name of CHS Inc.)



EXHIBIT 3.5 Transport Vehicle. (Courtesy of Mississippi Tank Co.)

to the National Propane Gas Association (NPGA). CGA continues to provide valuable technical assistance to the NFPA Technical Committee on Liquefied Petroleum Gases.

3.3.13 Container. Any vessel, including cylinders, tanks, portable tanks, and cargo tanks, used for the transporting or storing of LP-Gases.

As noted in the definition of *container*, there are several different pressure containers used to store and transport LP-Gas, and each must comply with specific fabrication requirements. The word *container* is a generic description in NFPA 58 for pressure vessels that store LP-Gases and is used by itself in the code whenever it is not necessary to cite a specific type. A container may be either a DOT cylinder or an ASME tank.

3.3.14 Container Appurtenances. Devices installed in container openings for safety, control, or operating purposes.

3.3.15 Container Assembly. An assembly consisting of the container and fittings for all container openings such as shutoff valves, excess-flow valves, liquid level gauging devices, pressure relief devices, and protective housings.

3.3.16 Cylinder. A container designed, constructed, tested, and marked in accordance with U.S. Department of Transportation specifications, Title 49, Code of Federal Regulations, or in accordance with a valid DOT exemption.



The definition of *cylinder* was revised in the 2008 edition to include the stipulation that the cylinder be designed, tested, and marked to comply with DOT requirements, in addition to the previous requirement that the cylinder be constructed in accordance with DOT requirements. Therefore, a container is not a cylinder unless it complies with all DOT requirements.

3.3.17 Design Certification. The process by which a product is evaluated and tested by an independent laboratory to affirm that the product design complies with specific requirements.

3.3.18 Diameter. The length of a straight line passing through the center of a circle, terminating at the periphery.

3.3.19 Direct Gas-Fired Tank Heater. A gas-fired device that applies hot gas from the heater combustion chamber directly to a portion of the container surface in contact with LP-Gas liquid.

3.3.20 Dispensing Station. Fixed equipment in which LP-Gas is stored and dispensed into portable containers.

The definition of *dispensing station* was extracted from NFPA 30A, *Code for Motor Fuel Dispensing Facilities and Repair Garages*, 2003 edition [4], and first appeared in the 1992 edition of NFPA 58.

The fundamental feature differentiating vehicle fuel dispensers and dispensing stations from bulk plants or industrial plants is that persons other than management or employees have access to the vehicle fuel dispensing facility. The distinct provisions for dispensing fuel into portable containers are included in [Section 6.24](#).

Dispensing stations include cylinder refilling facilities, which are open to the public; cylinder refueling facilities at recreational vehicle parks; facilities at hardware, equipment rental, and sporting goods stores for filling gas grill cylinders; and facilities at marinas. Refueling of industrial truck cylinders could be at a bulk plant where exchange cylinders are refilled or at an industrial plant where either exchange cylinders or containers mounted on the industrial truck are refilled.

3.3.21 DOT. U.S. Department of Transportation.

3.3.22 Filling.

All LP-Gas containers have a maximum permitted filling limit to prevent the container from becoming “liquid full” if the temperature of the gas rises. If a container becomes “liquid full,” gas can be released into the atmosphere, possibly resulting in a fire or explosion if a source of ignition is present. If liquid LP-Gas is released through a pressure relief valve, it will expand to 270 times its liquid volume. Two fundamental methods are allowed for filling LP-Gas containers — *volumetric* and *weight*.

3.3.22.1 Volumetric Method Filling. Filling a container to not more than the maximum permitted liquid volume.

The volumetric method filling limits the volume of liquid LP-Gas to 80 percent for cylinders and smaller ASME containers, or to a level determined by the density and temperature of the liquid LP-Gas for ASME containers over 1200 gal (4.5 m³) (see [7.4.3](#)). Volumetric filling is typically performed using a fixed maximum liquid level gauge, which comprises a dip tube protruding into the container and a knurled nut or slotted screw that opens the dip tube to the atmosphere. When the liquid LP-Gas level contacts the bottom of the dip tube, liquid is transported out of the cylinder and vaporizes outside the cylinder at the lower pressure of the atmosphere. The act of vaporization causes moisture in the surrounding air to condense and appear as a white fog. The appearance of this fog indicates that the container has been filled to its maximum limit.

3.3.22.2 Weight Method Filling. Filling containers to not more than the maximum permitted filling limit by weighing the LP-Gas in the container.

The weight method for filling cylinders is used for smaller size cylinders and limits the amount of liquid propane gas to 42 percent of the water capacity (in pounds) marked on the cylinder. Using the weight filling method for cylinders requires the use of a scale to measure the weight of the gas in the container.

3.3.23* Fire Protection. Fire protection for the purposes of this code shall be defined in the broad sense to include fire prevention, fire detection, and fire suppression.

A.3.3.23 Fire Protection. *Fire prevention* covers measures directed at avoiding the inception of fire or the escalation of an incident following the accidental or inadvertent release of LP-Gas. Such measures could include product control equipment and the insulation, mounding, or burial of containers.

Fire detection covers equipment that detects the presence of fire or heat either to initiate automated operation of the product control or other process equipment or to initiate local or remote alarms.

Fire suppression covers means of supplying water or other agents providing for fire control, exposure protection, or fire extinguishment.

The definition of *fire protection* was added to the code in 2004 to clarify the intent of the term as it relates to the provisions contained in **Section 6.25**, Fire Protection. Fire protection systems can include methods for fire prevention, fire detection, or fire suppression. Methods of fire prevention include requirements that are specified in the code, such as restricting the separation distance between propane containers and combustible materials or tanks containing flammable liquids. Fire detection methods may be traditional systems, such as smoke or heat detectors, but they may also be systems specifically required by the code, such as thermal activation links for internal valves and emergency shutoff valves. Fire suppression systems are traditionally recognized as being active systems, such as water spray or deluge systems. However, “passive” systems, such as insulating, burying, or mounding containers, also fall into this category.

3.3.24 Fixed Piping System. Piping, valves, and fittings permanently installed in a location to connect the source of the LP-Gas to the utilization equipment.

3.3.25 Flexible Connector. A short [not exceeding 60 in. (1.52 m) overall length] piping system component that is fabricated from a flexible material and equipped with connections at both ends.

The definition of *flexible connector* was revised in the 2008 edition, and new subdefinitions were added for related connectors to allow the user to discern between different materials used for flexible connectors.

The definition of *flexible connector* recognizes an increase in the permitted length up to 60 in. because flexible connectors are necessarily longer than 36 in. in order to achieve the necessary separation between the containers and the appliances they connect to. Previously, the 36 in. maximum was insufficient to maintain the 36 in. separation required by the code. Flexible connectors in permanent installations are restricted to flexible metallic connectors for durability.

3.3.25.1 Flexible Hose Connector. A component fabricated from LP-Gas hose that meets the requirements of UL 569, *Standard for Pigtails and Flexible Hose Connectors for LP-Gas*, or the following requirements of UL 21, *Standard for LP-Gas Hose*: (1) The tube or lining of a hose shall be made from a material compatible with LP-Gas. (2) The hose reinforcement shall be of cotton, synthetic fibers, or corrosion-resistant material such as stainless steel, or any combination thereof, evenly applied over the tube.

3.3.25.2 Flexible Metallic Connector. A component fabricated from flexible metal such as stainless steel wire braid or soft copper tubing.

Flexible hose connectors or flexible metallic connectors are allowed for portable and exchange cylinders. This construction is successfully used in many applications, including recreational vehicles. Flexible hose connectors up to 60 in. in length would only be used for portable exchange cylinders. Flexible hose connectors and flexible metallic connectors longer than 36 in. are successfully being used in areas subject to seismic forces for piping system flexibility. The additional length avoids overstressing the connector in order to maintain required separation distances between the appliance and the container.

The use of stainless steel wire braid hose is an accepted practice for motor fuel supply lines. The stainless steel reinforced tube provides extra protection for the tube assembly within the flexible hose connector.

3.3.26 Gallon. U.S. Standard. 1 U.S. gal = 0.833 Imperial gal = 231 in.³ = 3.785 L.

3.3.27 Gas. Liquefied petroleum gas in either the liquid or vapor state. The more specific terms *liquid LP-Gas* or *vapor LP-Gas* are used for clarity.

3.3.28* Gas–Air Mixer. A device or a system of piping and controls that mixes LP-Gas vapor with air to produce a mixed gas of a lower heating value than the LP-Gas.

A.3.3.28 Gas–Air Mixer. A gas–air mixture normally is used in industrial or commercial facilities as a substitute for another fuel gas.

Gas–air mixers are used to provide substitute fuel gas in natural gas systems. They are commonly referred to as “peak shaving” installations where the economics of the system make the temporary or permanent use of diluted LP-Gas more economically attractive than using natural gas.

3.3.29 Gauge.



3.3.29.1 Fixed Liquid Level Gauge. A liquid level indicator that uses a positive shutoff vent valve to indicate that the liquid level in a container being filled has reached the point at which the indicator communicates with the liquid level in the container.

3.3.29.2 Fixed Maximum Liquid Level Gauge. A fixed liquid level gauge that indicates the liquid level at which the container is filled to its maximum permitted filling limit.

An *outage gauge* is a common term for a fixed maximum liquid level gauge. A *10 percent gauge* is a common term for a fixed maximum liquid level gauge located at the 90 percent fill level of a container (leaving 10 percent empty space). A *20 percent gauge* is a common term for a fixed maximum liquid level gauge located at the 80 percent fill level of a container (leaving 20 percent empty space). **Exhibit 3.6** shows the components of a fixed maximum liquid level gauge.

3.3.29.3 Float Gauge. A gauge constructed with an element installed inside the container that floats on the liquid surface and transmits its position to a device outside the container to indicate the liquid level.

3.3.29.4 Magnetic Gauge. See **3.3.29.3**, Float Gauge.

A magnetic gauge is a type of float gauge that relies on a magnetized coupling to display the liquid level in the container. With a magnetic gauge, there is no possible leakage of LP-Gas through a seal since there is no penetration of the container wall.

3.3.29.5 Rotary Gauge. A variable liquid level gauge consisting of a small positive shutoff vent valve located at the outside end of a tube that has a bent end inside the container and can be manually rotated to determine the liquid level in the container. It is equipped with a pointer and an outside dial to indicate the liquid level.

A rotary gauge is a manually operated gauge that is used in both stationary and mobile storage containers. It comprises a vent to the atmosphere (a small tube with a valve) that is normally closed and a tube within the container that is manually rotated from outside. The gauge is operated by locating the tube in its uppermost position and opening the valve. A small stream of LP-Gas vapor is released, which is not visible. The tube is rotated until the stream turns white, indicating that liquid is being released, and the position of the gauge is read from the scale. For a more accurate reading, the tube rotation is continued, and the point at which the stream turns clear again is noted. The two measurements are averaged, compensating for any bending of the tube in the container.

3.3.29.6* Slip Tube Gauge. A variable liquid level gauge in which a relatively small positive shutoff valve is located at the outside end of a straight tube, normally installed vertically, that communicates with the container interior.

A.3.3.29.6 Slip Tube Gauge. The installation fitting for the tube is designed so that the tube can be slipped in and out of the container and so that the liquid level at the inner end of the tube can be determined by observing when the shutoff valve vents liquid.

EXHIBIT 3.6 Fixed Maximum Liquid Level Gauge.



3.3.29.7 Variable Liquid Level Gauge. A device that indicates the liquid level in a container throughout a range of levels.

3.3.30 GPA. Gas Processors Association.

3.3.31 ICC. U.S. Interstate Commerce Commission.

3.3.32 Ignition Source. See 3.3.67, Sources of Ignition.

3.3.33 Industrial Occupancy. Includes factories that manufacture products of all kinds and properties devoted to operations such as processing, assembling, mixing, packaging, finishing or decorating, and repairing.

Industrial occupancies may sometimes have large LP-Gas storage on hand. In that respect, an industrial occupancy may be similar to a retail bulk plant. The primary difference between the two is that a retail bulk plant typically has many more liquid transfer operations.

This definition is taken from *NFPA 5000*[®], *Building Construction and Safety Code*[®] [5], and is also used in *NFPA 101*[®], *Life Safety Code*[®] [6].

3.3.34 kPa. Absolute pressure in kilo-Pascals.

3.3.35 kPag. Gauge pressure in kilo-Pascals.

3.3.36 Liquefied Petroleum Gas (LP-Gas). Any material having a vapor pressure not exceeding that allowed for commercial propane that is composed predominantly of the following hydrocarbons, either by themselves or as mixtures: propane, propylene, butane (normal butane or isobutane), and butylenes.

LP-Gas can comprise any of a number of different hydrocarbons, but within the scope of NFPA 58, it is limited to a material with a vapor pressure for commercial propane. ASTM D 1835, *Standard Specification for Liquefied Petroleum Gases* [7], defines the vapor pressure for commercial propane to be 208 psig at 100°F (1.43 MPa at 38°C). By the same standard, commercial propane must be “predominantly propane,” while HD-5 propane grade must be at least 90 percent propane.

3.3.37* Low Emission Transfer. Establishes a maximum fugitive emissions standard for certain product transfer operations. Low emission transfer specifications might be employed to comply with environmental regulations or to determine certain minimum distance requirements.

A.3.3.37 Low Emission Transfer. Specifications for low emission transfer might be employed to comply with environmental regulations or to determine certain minimum distance requirements.

Low emission transfer is a method of transferring LP-Gas into containers with significantly reduced emission of hydrocarbon vapors. It is accomplished with specialized dispensing nozzles and corresponding transfer fittings that limit the amount of vapor released to the atmosphere to 4 cc (0.24 in.³) of product (liquid equivalent).

3.3.38 LP-Gas System. An assembly consisting of one or more containers with a means for conveying LP-Gas from a container to dispensing or consuming devices that incorporates components that control the quantity, flow, pressure, and physical state (liquid or vapor) of the LP-Gas.

LP-Gas systems include LP-Gas transfer facilities such as bulk plants.

3.3.39 Maximum Allowable Working Pressure (MAWP). The maximum pressure at which a pressure vessel is to operate as described by the ASME *Boiler and Pressure Vessel Code*.

◀ FAQ

Is propane the same as LP-Gas?



3.3.40 Minimum Design Metal Temperature (MDMT). As described by the ASME *Boiler and Pressure Vessel Code*.

3.3.41 Mobile Container. A container that is permanently mounted on a vehicle and connected for uses other than supplying engine fuel.

The term *mobile container* defines permanently mounted, non-engine fuel containers on vehicles, such as recreational and catering vehicles. [Exhibit 3.7](#) shows a mobile container designed for use in recreational vehicles. The definition does not include cargo tank motor vehicles.

EXHIBIT 3.7 *Recreational Vehicle Propane Tank.*
(Courtesy of Manchester Tank)



3.3.42 Mounded Container. An ASME container designed for underground service installed above the minimum depth required for underground service and covered with earth, sand, or other material, or an ASME container designed for aboveground service installed above grade and covered with earth, sand, or other material.

Mounded containers are aboveground or partially aboveground containers covered with earth, sand, or other material so that the container itself is not visible. Mounding provides protection from exterior flame impingement.

3.3.43* Movable Fuel Storage Tender. A container equipped with wheels (including a farm cart) not in excess of 1200 gal (4.5 m³) water capacity that is moved from one location to another.

A farm cart is shown in [Exhibit 9.12](#).

A.3.3.43 Movable Fuel Storage Tender. Movable fuel storage tenders or farm carts are basically non-highway vehicles but can occasionally be moved over public roads or highways for short distances to supply fuel for farm tractors, construction machinery, and similar equipment.

3.3.44 MPa. Absolute pressure in mega-Pascals.

3.3.45 MPag. Gauge pressure in mega-Pascals.

3.3.46 Multipurpose Passenger Vehicle. A motor vehicle with motive power, with the exception of a trailer, designed to carry 10 or fewer persons that is constructed on a truck chassis or with special features for occasional off-road operations.

The definition of *multipurpose passenger vehicle* is needed because the term, as used in [Chapter 11](#), is not self-evident. A label affixed to the vehicle in accordance with U.S. federal regulations identifies a multipurpose passenger vehicle.

3.3.47 NFPA. National Fire Protection Association.

3.3.48 NPGA. National Propane Gas Association.

The National Propane Gas Association (NPGA), originally the National Bottled Gas Association and later the National LP-Gas Association, is the national association for the liquefied petroleum gas industry. NPGA members include producers of LP-Gas, wholesale and retail marketers, gas appliance and equipment manufacturers and distributors, tank and cylinder fabricators, transport firms, and others. NPGA has 3500 members throughout the United States and 228 other countries.

One of the primary reasons for the association's establishment in 1931 was to afford all interested segments of the industry full opportunity to aid in making the rules that safeguard it. The NPGA was first affiliated with the Compressed Gas Manufacturers' Association (now the Compressed Gas Association), the only technical association in existence that could manage the problems involving gases in cylinders, the primary method of handling LP-Gases at that time.

Today, the NPGA is a separate and distinct organization that carries on its own technical activities through its technical committees. One of these committees, the Technology and Standards Committee, has engineering and technical representation from all segments of the industry. In addition, there are advisory members representing other related industry associations, testing laboratories, regulatory officials, insurance organizations, and others that greatly assist the technical committee in its standards development work. The technical committee initiates many recommendations for new provisions and amendments of existing provisions in NFPA 58 as industry-sponsored recommendations. The NFPA Technical Committee on Liquefied Petroleum Gases, which reflects a broader interest, in turn considers these recommendations. Because the NPGA Technology and Standards Committee has at its disposal a large amount of technical talent, the NFPA Technical Committee on Liquefied Petroleum Gases has at times referred matters to this group for initial study and recommendations.

3.3.49 Overfilling Prevention Device (OPD). A safety device that is designed to provide an automatic means to prevent the filling of a container in excess of the maximum permitted filling limit.

The definition of *overfilling prevention device (OPD)* was added in the 1998 edition to describe a device that is required in cylinders with a propane capacity of 4 lb (2 kg) through 40 lb (18 kg) and in engine fuel containers fabricated after January 1, 1984. There are different designs in use, but all of them shut off flow into the container when the liquid within reaches a specific level. (See 5.7.3 and 11.4.1.13 for requirements for overfilling prevention devices.) Exhibit 3.8 shows an OPD.

3.3.50 Overpressure Shutoff Device. A device that shuts off the flow of LP-Gas vapor when the outlet pressure of the regulator reaches a predetermined maximum allowable pressure.

NFPA 58 requires protection against excessive vapor pressure in propane piping systems in buildings. This protection is in the form of an overpressure shutoff device, which is usually incorporated into pressure regulators used in vapor distribution systems. The outlet pressure of a first-stage pressure regulator is 10.0 psig (69 kPag), and a second-stage pressure is 11 in. water column (2.7 kPag). Regulators require a feature (which can be an overpressure shutoff device) to prevent the pressure at the discharge of the second-stage regulator from exceeding 2.0 psig (14 kPag). [See 5.8.1.2(1) and its related commentary.]

3.3.51 Permanent Installation. See 3.3.71, Stationary Installation.

3.3.52 Permitted. Allowed or acceptable, and not requiring a permit (a document granting permission) to be secured.



The definition of *permitted* is new to the 2008 code and is intended to clarify a misconception regarding the issuance of formal permits. The term, as used in NFPA 58, does not require or imply a need for a permit from a local or state official. It means that something is permissible according to NFPA 58.

EXHIBIT 3.8 *Overfilling Prevention Device. (Courtesy of Cavagna North America, Inc.)*



3.3.53 Piping Systems. Pipe, tubing, hose, and flexible rubber or metallic hose connectors with valves and fittings made into complete systems for conveying LP-Gas from one point to another in either the liquid or the vapor state at various pressures.

3.3.54 Point of Transfer. The location where connections and disconnections are made or where LP-Gas is vented to the atmosphere in the course of transfer operations.

Point of transfer is a term used to identify the location of the temporary connection between a liquid transfer supply tank, such as a bobtail or a dispenser tank, and the storage container that is being filled. (See [Exhibit 3.9](#).) This connection establishes the point from which clearance must be maintained to sources of ignition and other equipment. It was introduced in the 1972 edition of NFPA 58.

3.3.55* Portable Container. A container designed to be moved readily, as opposed to a container designed for stationary installations.

A.3.3.55 Portable Container. Portable containers, designed for transportation, include *cylinders*, *cargo tanks*, and *portable tanks*, which are defined separately in this code. Containers that are designed to be readily moved from one location of use to another but that are substantially empty of product are *portable storage containers* and are also defined separately in this code.

3.3.56* Portable Storage Container. A container that is designed and constructed to be moved over a highway from one usage location to another.

A.3.3.56 Portable Storage Container. Portable storage containers have legs or other supports attached or are mounted on running gear (such as trailer or semitrailer chassis), with suitable supports that can be of the fold-down type. Such supports allow them to be placed on a reasonably firm and level surface. For large-volume, limited-duration product usage (such

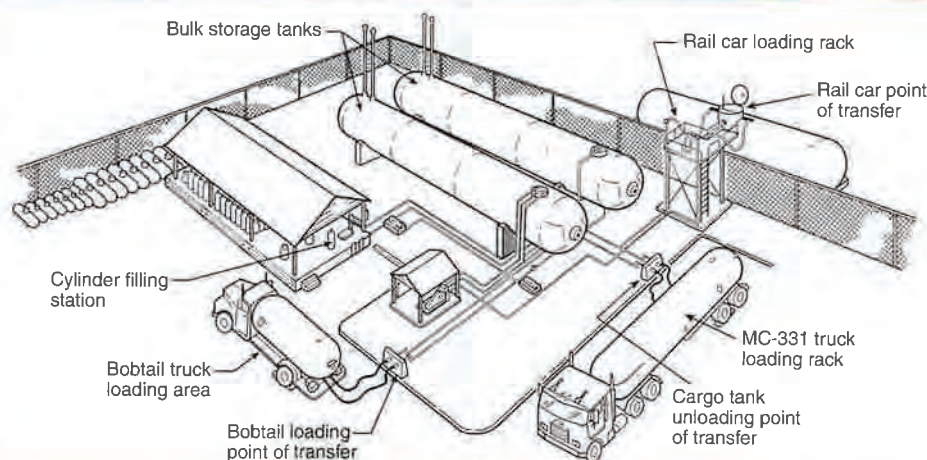


EXHIBIT 3.9 *Points of Transfer at a Propane Bulk Plant. (Courtesy of National Propane Gas Association)*

as at construction sites and normally for 12 months or less), portable storage containers serve as permanently installed stationary containers.

3.3.57 Portable Tank (or Skid Tank). A container of more than 1000 lb (454 kg) water capacity that is equipped with protected container appurtenances, is used to transport LP-Gas, and is designed and fabricated with permanently mounted skids or runners or is fabricated and installed within a full framework.

The definition of *portable tank* was revised in the 2008 edition to ensure that it is consistent with the terminology used by DOT in Title 49 of the Code of Federal Regulations. A portable tank differs from a portable storage container in that the portable tank complies with DOT requirements and can be shipped entirely filled with LP-Gas. However, a portable storage container is an ASME container but not an approved DOT shipping container and therefore must be transported with no more than 5 percent liquid within it.

3.3.58 Pressure Relief Device. A device designed to open to prevent a rise of internal pressure in excess of a specified value due to emergency or abnormal conditions.

All cylinders and ASME containers used for LP-Gas are equipped with pressure relief devices. These are designed to prevent failure of the container due to overpressurization. Overpressurization may occur when the container becomes “liquid full,” due to the heating of the container by a fire or, in some cases, if the container has been overfilled. Although opening of the pressure relief device will prevent the container from failure due to overpressure, the released flammable LP-Gas may also present a hazard.

In addition to containers, pressure relief devices are used in segments of hose or piping where liquid can be trapped between shutoff valves.

3.3.59 psi. Pounds per square inch.

3.3.60 psia. Pounds per square inch, absolute.

3.3.61 psig. Pounds per square inch gauge.

Units of pressure measurement used in the code are pounds per square inch (psi) and Pascals (Pa). When metric units of measurement were added to the code in the 1980s, pressure measurements were converted into Pascals (and kilo-pascals and mega-pascals because the Pascal is a small unit). Pressure measurements are usually given in one of two forms, either gauge or absolute. *Absolute pressure* is the pressure of the gas in the container plus the atmospheric



FAQ

What is the difference between a portable storage container and a portable tank?

FAQ

When is a pressure relief device likely to activate?

FAQ

What is the difference between gauge pressure and absolute pressure?

pressure. *Gauge pressure* is the absolute pressure of a gas minus the local atmospheric pressure, or the pressure one would read on an accurate gauge connected to a tank. A pressure gauge at sea level will read 0, even though a pressure of 14.7 psi is present. Traditionally, pressure in tanks and piping systems is expressed in gauge pressure.

3.3.62 Quick Connectors. Fittings used to connect hose assemblies to piping and valves without the use of tools.

Quick connectors are used to connect transfer hose to piping and valves for loading and unloading cargo tank vehicles or railroad tank cars. They can also be used as connectors on swivel-type transfer piping. Quick connectors are also used in other LP-Gas systems, such as those used for engine fuel refueling and cylinder filling, connecting cylinders to gas-fired barbecue grills, and connecting gas systems between two sections of mobile homes.

3.3.63 Refrigerated LP-Gas. LP-Gas that is maintained as a liquid at temperatures below ambient temperature to reduce the storage pressure including fully refrigerated LP-Gas at pressures near atmospheric pressure but not exceeding 15 psig (103 kPag) and semi-refrigerated LP-Gas at pressures above 15 psig (103 kPag).

Refrigerated LP-Gas is just what the term implies — LP-Gas that has been refrigerated or cooled. When the gas is propane, the liquid is typically at a temperature of about -40°F (-40°C). At that temperature propane is a liquid that exerts no pressure on its container, thus providing a way to store propane in a nonpressurized (and usually insulated) container, which is less expensive than a pressure vessel. The economics are such that refrigerated storage is normally used for very large containers (1,000,000 gal is not unusual), and refrigerated LP-Gas storage is normally found at pipeline and marine terminals and occasionally at larger storage facilities.

3.3.64 Regulator.

The various types of regulators defined in NFPA 58 are shown in Exhibits 3.10 to 3.13 and listed in Commentary Table 3.1.

3.3.64.1* Automatic Changeover Regulator. An integral two-stage regulator that combines two high-pressure regulators and a second-stage regulator into a single unit designed for use with multiple cylinder installations.

A.3.3.64.1 Automatic Changeover Regulator. An automatic changeover regulator incorporates two inlet connections and a service-reserve indicator. The system automatically changes the LP-Gas vapor withdrawal from the designated service cylinder(s) when depleted to the designated reserve cylinder(s) without interruption of service. The service reserve indicator gives a visual indication of the cylinder(s) that is supplying the system.



EXHIBIT 3.10 Automatic Changeover Regulator. (Courtesy of Sherwood, Harsco Gas & Fluid Control Group.)

EXHIBIT 3.11 Cutaway of First-Stage Regulator. (Courtesy of Engineered Controls International, Inc.)



COMMENTARY TABLE 3.1 Regulators

Type	Location	Description or Use
Automatic changeover (Exhibit 3.10)	Outdoor	Changes service cylinder to reserve cylinder automatically
First stage (Exhibit 3.11)	Outdoor	Reduces tank pressure to 10 psig or less
High pressure	Outdoor	Reduces tank pressure to lower pressure above 1 psig
Integral 2 psi service	Outdoor	Reduces tank pressure in two stages to 2 psig
Integral two-stage (Exhibit 3.12)	Outdoor	Reduces tank pressure in two stages to 11 in. w.c.
Line pressure	Indoor	Reduces 2 psig inlet pressure to 11 in. w.c.
Second-stage (Exhibit 3.13)	Outdoor/indoor*	Reduces first-stage pressure to 11 in. w.c.
Single-stage	Outdoor	Reduces tank pressure to 11 in. w.c.
2 psi service	Outdoor	Reduces first-stage pressure to 2 psig
2 psi system	Outdoor/indoor**	Reduces first-stage pressure to 2 psig

* Regulator vent is piped to outdoors.

** Only the line pressure regulator is installed indoors.

3.3.64.2 First-Stage Regulator. A pressure regulator for LP-Gas vapor service designed to reduce pressure from the container to 10.0 psig (69 kPag) or less.

3.3.64.3 High-Pressure Regulator. A pressure regulator for LP-Gas liquid or vapor service designed to reduce pressure from the container to a lower pressure in excess of 1.0 psig (6.9 kPag).

3.3.64.4 Integral 2 psi Service Regulator. A pressure regulator for LP-Gas vapor service that combines a high-pressure regulator and a 2 psi service regulator into a single unit.

3.3.64.5 Integral Two-Stage Regulator. A pressure regulator for LP-Gas vapor service that combines a high-pressure regulator and a second-stage regulator into a single unit.

3.3.64.6 Line Pressure Regulator. A pressure regulator in accordance with the *Standard for Line Pressure Regulators*, ANSI Z-21.80/CSA 6.22, with no integral overpressure protection device for LP-Gas vapor service designed for installation inside a building to reduce a nominal 2 psig inlet pressure to 14 in. w.c. (4.0 kPa) or less.

3.3.64.7 Second-Stage Regulator. A pressure regulator for LP-Gas vapor service designed to reduce first-stage regulator outlet pressure to 14 in. w.c. (4.0 kPag) or less.

3.3.64.8 Single-Stage Regulator. A pressure regulator for LP-Gas vapor service designed to reduce pressure from the container to 1.0 psig (6.9 kPag) or less.

3.3.64.9 2 psi Regulator System. An LP-Gas vapor delivery system that combines a first-stage regulator, a 2 psi (14 kPag) service regulator, and a line pressure regulator(s).

3.3.64.10 2 psi Service Regulator. A pressure regulator for LP-Gas vapor service designed to reduce first-stage regulator outlet pressure to a nominal 2 psig (14 kPag).

3.3.64.11 Two-Stage Regulator System. An LP-Gas vapor delivery system that combines a first-stage regulator and a second-stage regulator(s), or utilizes a separate integral two-stage regulator.

3.3.65 Service Head Adapter. A transition fitting for use with polyethylene or polyamide pipe or tubing that is recommended by the manufacturer for field assembly and installation at the aboveground termination end of an anodeless riser.

A service head adapter is a fitting that connects plastic pipe or tubing inserted inside a non-pressure-containing steel jacket to steel piping.



EXHIBIT 3.12 Integral Two-Stage Regulator. (Courtesy of Engineered Controls International, Inc.)



EXHIBIT 3.13 Second-Stage Regulator. (Courtesy of Engineered Controls International, Inc.)

3.3.66 Skid Tank. See 3.3.57, Portable Tank.

3.3.67 Sources of Ignition. Devices or equipment that, because of their modes of use or operation, are capable of providing sufficient thermal energy to ignite flammable LP-Gas vapor–air mixtures when introduced into such a mixture or when such a mixture comes into contact with them, and that will permit propagation of flame away from them.

Although the code has addressed the control of ignition sources since its inception, this definition for *sources of ignition* was added in the 1979 edition. The definition became necessary because of the existence of electrical devices and equipment that could ignite a flammable LP-Gas–air mixture under certain conditions. In addition, the definition clarifies that other devices might produce ignition but would not permit a flame to propagate away from them, in which case they are not a hazard. Examples of such devices include certain Class I, Division 1, Group D electrical equipment in which devices are installed in enclosures using gap flame-quenching principles and devices or enclosures equipped with flame arresters.

Some sources of ignition are as follows:

- Devices or equipment — such as gas- or oil-burning appliances, torches, matches, and lighters — producing, or capable of producing, flame
- Devices or equipment — such as motors, generators, switches, lights, and wiring and welding machines — producing, or capable of producing, electrical arcs or sparks of sufficient energy (Devices or equipment listed for Class I, Group D locations are not sources of ignition when properly used and maintained in the classified areas prescribed in this code.)
- Devices or equipment having, or capable of having, surfaces at temperatures exceeding 700°F (371°C)
- Devices or equipment — such as grinders, metal saws, chipping hammers, and flint lighters — producing, or capable of producing, mechanical (struck) sparks of sufficient energy (Unpowered hand tools used only by one individual at a time and for their intended purposes are not considered sources of ignition.)
- Cigarettes and other smoking materials
- Gravity or mechanical air intakes and exhaust terminals of ventilation systems for structures housing the ignition sources described, because they constitute a readily communicating pathway (These include air intakes and exhaust terminals for gas- or oil-burning appliances such as those for direct-vent appliances, and air intakes and exhaust terminals for air conditioners.)

Operating spark-ignition internal combustion engines do not appear, based on experience, to be an ignition source. However, they have been an ignition source during the act of being started. Operating diesel engines have been identified as the ignition source in fire reports, usually as the result of burning carbon being blown out of their exhausts. Such engines tend to speed up when LP-Gas is drawn into their intake manifolds.

3.3.68* Special Protection. A means of limiting the temperature of an LP-Gas container for purposes of minimizing the possibility of failure of the container as the result of fire exposure.

A.3.3.68 Special Protection. Where required in this code, special protection consists of one of the following:

- (1) Applied insulating coating
- (2) Mounding
- (3) Burial
- (4) Water spray fixed systems
- (5) Fixed monitor nozzles that meet the criteria specified in this code
- (6) Any means listed for this purpose

See [Section 6.25](#) for more information on fire protection and special protection.

In the late 1960s and early 1970s, the propane industry in the United States experienced a number of BLEVEs (Boiling Liquid Expanding Vapor Explosions) of LP-Gas railroad tank cars (some following derailments). Most of these incidents were caused by container failure from overheating of the container metal (steel) through contact with flames from flammable or combustible materials released from other cars. These incidents were accompanied by fire fighter fatalities.

Although this hazard was beyond the scope of NFPA 58, these accidents resulted in widespread fear of all large LP-Gas containers among the fire service and the public. Notable in this respect was an increasing reluctance by fire fighters to approach an LP-Gas container exposed to fire in order to limit the container temperature by the application of water from hose streams. Because this procedure was, and is, a fundamental and universal BLEVE prevention tactic, the NFPA Technical Committee on Liquefied Petroleum Gases and the industry were concerned that a reduction in its use would increase the frequency and severity of BLEVEs.

A joint task force of the NFPA technical committee and the NPGA's Technology and Standards Committee (augmented by representatives of railroad and DOT groups studying the tank car problem) concluded that additional provisions were needed to reduce the chances for BLEVEs caused by fire exposure. As a result, the following two provisions were first included in the 1976 edition of NFPA 58.

1. The first provision was for the installation and use of emergency shutoff valves as described in [Section 6.10](#). These valves were considered important enough to require retroactive installation in all of the larger facilities as prescribed in [Section 6.10](#).
2. The second provision was for special protection as stipulated in [6.25.5](#). It is noted, however, that the need for this protection is predicated on the results of a required fire safety analysis.

The six modes of special protection cited in [A.3.3.68](#) represent those currently recognized and for which standards exist. However, the definition is broad enough to recognize other means, provided those means are listed for the purpose.

3.3.69 Standard Cubic Foot (SCF). The volume of gas in cubic feet at the standard atmospheric conditions at 60°F (15.6°C) and 14.7 psia (101 kPa).

3.3.70 SCFM. Standard cubic feet per minute. [1901, 2003]

3.3.71 Stationary Installation (Permanent Installation). An installation of LP-Gas containers, piping, and equipment for indefinite use at a particular location; an installation not normally expected to change in status, condition, or location.

3.3.72 UL. Underwriters Laboratories Inc.

Founded in 1894, Underwriters Laboratories Inc. (UL) was chartered as a not-for-profit, independent organization performing testing for public safety. The organization maintains laboratories for the examination and testing of devices, systems, and materials to determine their relation to life, fire, casualty hazards, and crime prevention.

UL-listed materials within the scope of NFPA 58 are included in the following UL Product Directories: *Hazardous Location Equipment* [8]; *Marine Products* [9]; *Automotive, Burglary Protection, and Mechanical Equipment* [10]; and *Flammable and Combustible Liquids & Gases Equipment* [11].

Where NFPA 58 requires listing of a product, any listing agency acceptable to the authority having jurisdiction can be used.

3.3.73 Universal Cylinder. A cylinder that can be connected for service in either the vertical or the horizontal position, so that the fixed maximum liquid level gauge, pressure relief device, and withdrawal appurtenances function properly in either position.



FAQ

Is UL the only agency that can test and list products, devices, and systems for use within the scope of NFPA 58?



EXHIBIT 3.14 Universal Cylinder. (Courtesy of Worthington Cylinder Corp.)

A universal cylinder is shown in **Exhibit 3.14**.

3.3.74 Valve.

3.3.74.1 Emergency Shutoff Valve. A shutoff valve incorporating thermal and manual means of closing that also provides for remote means of closing.

3.3.74.2 Excess-Flow Valve (or Excess-Flow Check Valve). A valve designed to close when the liquid or vapor passing through it exceeds a prescribed flow rate.

3.3.74.3 Internal Excess-Flow Valve. An excess-flow valve constructed and installed so that damage to valve parts exterior to the container does not prevent closing of the valve.

3.3.74.4* Internal Valve. A container primary shutoff valve having the following features: (1) The seat and seat disc remain inside the container so that damage to parts exterior to the container or mating flange does not prevent effective sealing of the valve; (2) The valve is designed for the addition of a means for remote closure and is also designed for automatic shutoff when the flow through the valve exceeds its maximum rated flow capacity or when pump actuation differential pressure drops to a predetermined point.

A.3.3.74.4 Internal Valve. An internal valve has provision for the addition of a means of remote closure. An internal valve closes when flow through the valve exceeds its rated excess-flow capacity or when pump actuation differential pressure drops to a predetermined point.

An internal valve is a valve that is installed in ASME container openings. It is typically installed in the liquid inlet/outlet of propane containers of 4000 gal (15.1 m³) and larger, but can also be used to protect openings used for vapor inlet and outlet. An internal valve allows flow to be stopped remotely in the event of failure in the piping system. Remote operation can be by a mechanical, pneumatic, or electrical means. Internal valves are required in all new installations of containers larger than 4000 gal (15.1 m³) and must be installed on all existing containers larger than 4000 gal (15.1 m³) by July 1, 2011 (see **5.7.4.2**).

By halting the flow of gas, a fire or the potential fuel for a fire is eliminated. In addition, internal valves can be operated at their installed locations, and they have an excess flow valve incorporated into them to stop the flow should it exceed the rating of the valve. **Exhibit 3.15** shows an internal valve.

3.3.74.5 Pressure Relief Valve. A type of pressure relief device designed to both open and close to maintain internal fluid pressure.

3.3.74.5.1* External Pressure Relief Valve. A pressure relief valve that is used on older domestic containers, on pressure relief valve manifolds, and for piping protection where all the working parts are located entirely outside the container or piping.

EXHIBIT 3.15 Internal Valve. (Courtesy of Engineered Controls International, Inc.)



A.3.3.74.5.1 External Pressure Relief Valve. See Figure A.3.3.74.5.1.

3.3.74.5.2* Flush-Type Full Internal Pressure Relief Valve. An internal pressure relief valve in which the wrenching section is also within the container connection, not including a small portion due to pipe thread tolerances on makeup.

A.3.3.74.5.2 Flush-Type Full Internal Pressure Relief Valve. See Figure A.3.3.74.5.2.

3.3.74.5.3* Full Internal Pressure Relief Valve. A pressure relief valve, for engine fuel and mobile container use, in which all working parts are recessed within the container connection, and the spring and guiding mechanism are not exposed to the atmosphere.

A.3.3.74.5.3 Full Internal Pressure Relief Valve. See Figure A.3.3.74.5.3.

3.3.74.5.4* Internal Spring-Type Pressure Relief Valve. A pressure relief valve, for use on ASME stationary containers, that has a low profile and is similar to a full internal relief valve except the wrenching pads and seating section are above the container connection. The adjusting spring and the stem are below the seat and are not exposed to the atmosphere.

A.3.3.74.5.4 Internal Spring-Type Pressure Relief Valve. See Figure A.3.3.74.5.4.

3.3.75 Vaporizer. A device, other than a container, that receives LP-Gas in liquid form and adds sufficient heat to convert the liquid to a gaseous state.

Vaporizers are heat exchangers that transfer heat to convert LP-Gas liquid to vapor, just as boilers convert water into steam. The heat provided to a vaporizer converts the liquid to a gaseous state in pipes, coils, or chambers within the vaporizer. There are several styles of listed vaporizers that perform this function. Section 5.21 provides detailed requirements for different vaporizer styles.

Exhibit 3.16 shows principal features and operating characteristics of a typical vaporizer installation. Liquid flows from the bottom of the tank into the direct-fired vaporizer (shown on the left). A float controls the liquid level in the vaporizer. Flames provide heat to the liquid through the shell. Vapor travels from the upper part of the vaporizer to a tee where it goes to the equipment. Excess pressure is returned to the tank through the optional vapor line. If the tank pressure is high enough, it will supply the load, and the vaporizer will no longer be required to operate.

3.3.75.1 Direct-Fired Vaporizer. A vaporizer in which heat furnished by a flame is directly applied to some form of heat exchange surface in contact with the liquid LP-Gas to be vaporized. This classification includes submerged-combustion vaporizers.

Direct-fired vaporizers convert liquid propane into propane vapor, just as boilers convert water into steam. In a direct-fired vaporizer the flame is directed on piping or a vessel containing liquid propane. This differs from an indirect vaporizer where the liquid propane is vaporized in a coil immersed in a heated fluid (see 3.3.75.3).

Submerged combustion vaporizers are vaporizers in which a flame is directed into a non-flammable fluid, usually water, which surrounds pipe coils containing liquid propane. This type of vaporizer is usually used for very large vaporizing loads. Although they do not meet the definition of direct-fired vaporizers in 3.3.75.1, for purposes of this code, submerged combustion vaporizers may be treated as direct-fired.

3.3.75.2 Electric Vaporizer. A vaporizer that uses electricity as a source of heat.

Because electric vaporizers can be designed so that they are not a source of ignition (unlike a vaporizer using fuel-fired burners), they can be installed differently and thus need to be defined separately. Electric vaporizers are separated into two types — direct immersion, described in 3.3.75.2.1, and indirect, described in 3.3.75.2.2.

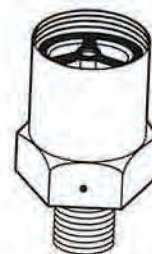


FIGURE A.3.3.74.5.1
External Pressure Relief Valve.

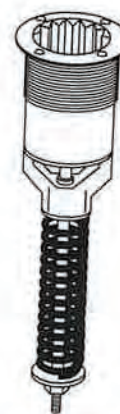


FIGURE A.3.3.74.5.2
Flush-Type Full Internal Pressure Relief Valve.



FIGURE A.3.3.74.5.3 Full Internal Pressure Relief Valve.



FIGURE A.3.3.74.5.4
Internal Spring-Type
Pressure Relief Valve.

3.3.75.2.1 Direct Immersion Electric Vaporizer. A vaporizer wherein an electric element is immersed directly in the LP-Gas liquid and vapor.

3.3.75.2.2 Indirect Electric Vaporizer. An immersion-type vaporizer wherein the electric element heats an interface solution in which the LP-Gas heat exchanger is immersed or heats an intermediate heat sink.

3.3.75.3 Indirect (or Indirect-Fired) Vaporizer. A vaporizer in which heat furnished by steam, hot water, the ground, surrounding air, or other heating medium is applied to a vaporizing chamber or to tubing, pipe coils, or other heat exchange surface containing the liquid LP-Gas to be vaporized; the heating of the medium used is at a point remote from the vaporizer.

3.3.75.4 Waterbath (or Immersion-Type) Vaporizer. A vaporizer in which a vaporizing chamber, tubing, pipe coils, or other heat exchange surface containing liquid LP-Gas to be vaporized is immersed in a temperature-controlled bath of water, water-glycol combination, or other noncombustible heat transfer medium that is heated by an immersion heater not in contact with the LP-Gas heat exchange surface.

A waterbath vaporizer is shown in Exhibit 3.17.

3.3.76 Vaporizing Burner (Self-Vaporizing Liquid Burner). A burner that also vaporizes liquid LP-Gas prior to burning it.

3.3.77 Vehicle Fuel Dispenser. A device or system designed to transfer and measure LP-Gas into engine fuel and mobile containers on vehicles.

3.3.78 Volumetric Loading. See 3.3.22.1, Volumetric Method Filling.

3.3.79 Water Capacity. The amount of water at 60°F (16°C) required to fill a container.

The water capacity of a container is the maximum amount of water the container can hold at 60°F (15.6°C). The water capacity (full of water) is expressed in pounds (kilograms) for cylinders and gallons (cubic meters) for ASME containers.

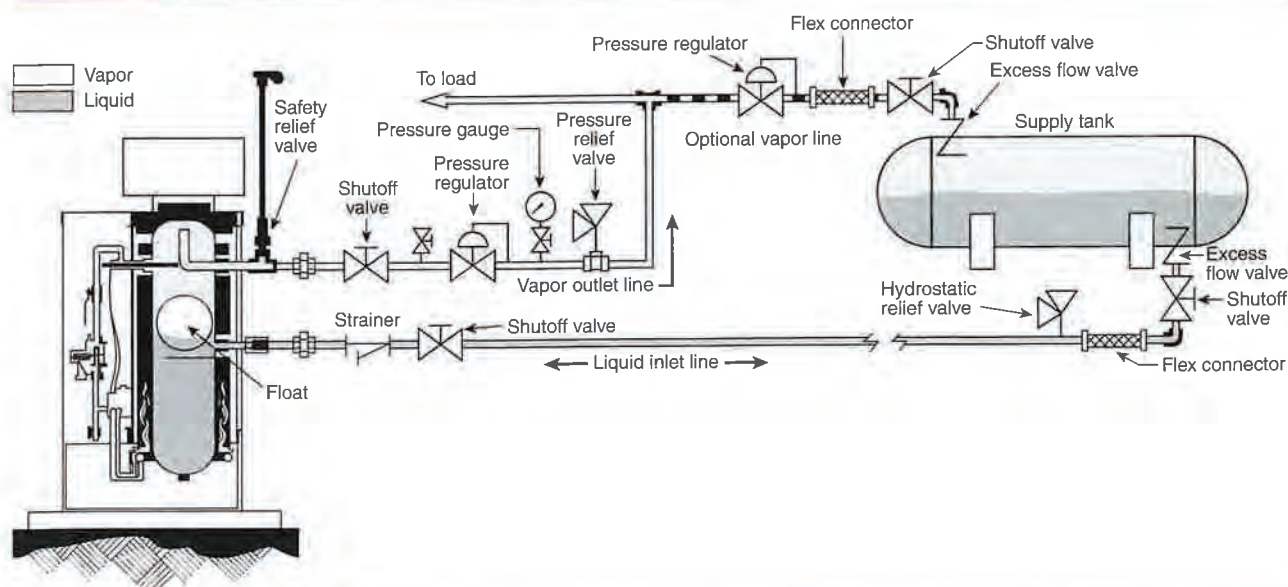


EXHIBIT 3.16 Typical Vaporizer Installation. (Courtesy of Ransome Manufacturing)

The water capacity is different from the propane capacity of a container. Water capacity is measured with the container 100 percent full, whereas the maximum permitted filling limit allowed for propane is typically set at 80 percent of the water capacity, although there are exceptions to this practice as described in [Chapter 7](#). For example, the typical 1000 gal (3.8 m³) water capacity ASME container is allowed to hold about 800 gal (3.0 m³) of propane (80 percent). However, a 30,000 gal (114 m³) container can be filled to 25,800 gal (86 percent at 40°F) of propane because its large size minimizes extreme swings in the temperature of the product (and therefore expansion and contraction are minimized) due to daytime solar heating and night cooling.

The maximum propane capacity of a cylinder is also based on its water capacity, but since the water capacity is given in pounds, the multiplying factor for propane is 42 percent because propane is about half the density of water. If the water capacity of a cylinder is marked as being 48 lb (36 kg), the propane capacity is 42 percent of 48 lb (36 kg), or about 20 lb (9 kg).

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EXHIBIT 3.17 Waterbath Vaporizer. (Courtesy of Ransome Manufacturing)

General Requirements

CHAPTER 4

Chapter 4 covers general requirements that apply to the entire code. In the 2001 and previous editions of the code, these requirements were included in [Chapter 1](#). The sections in Chapter 4 cover the following:

- Acceptance of Equipment and Systems (See [Section 4.1](#).)
- LP-Gas Odorization (See [Section 4.2](#).)
- Notification of Installations (See [Section 4.3](#).)
- Qualification of Personnel (See [Section 4.4](#).)
- Ammonia Contamination (See [Section 4.5](#).)
- Minimum Requirements (See [Section 4.6](#).)

4.1 Acceptance of Equipment and Systems

4.1.1 Systems or components assembled to make up systems shall be approved as specified in [Table 4.1.1](#).

Approval of systems using cylinders applies to the following:

- The cylinder itself, which must meet DOT specifications and have the dates of manufacture and retest (if done) stamped in the collar, as shown in [Exhibit 5.13](#) (See [Annex C](#) for information on requalification of cylinders.)

TABLE 4.1.1 Containers

Containers Used	Capacity, Water		Approval Applies to . . .
	gal	m ³	
Cylinders	<120	0.445	Container valves and connectors Manifold valve assemblies Regulators and pressure relief devices
ASME containers	≤2000	≤7.6	Container system* including regulator, or container assembly* and regulator separately
ASME containers	>2000	>7.6	Container valves Container excess-flow valves, backflow check valves, or alternate means of providing this protection such as remotely controlled internal valves Container gauging devices Regulators and container pressure relief devices

*Where necessary to alter or repair such systems or assemblies in the field in order to provide for different operating pressures, change from vapor to liquid withdrawal, or the like, such changes shall be permitted to be made by the use of approved components.

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- Cylinder valves, which must comply with DOT regulations, which reference CGA V-1, *Standard Compressed Gas Cylinder Valve Outlet and Inlet Connections* [1]
- Cylinder connectors, manifold valve assemblies, regulators, and pressure relief devices, which must be approved

The approval of systems using ASME containers of 2000 gal (7.6 m³) or less includes one of the following:

- The container, which must be designed, fabricated, and marked in accordance with the *ASME Boiler and Pressure Vessel Code* [2], and its appurtenances, which may be approved as a unit
- The container, which may be approved separately, in which case the container appurtenances and pressure regulator must also be approved separately

The approval of systems using ASME containers of more than 2000 gal (7.6 m³) includes the following:

- Container valves
- All other container appurtenances, as listed in [Table 4.1.1](#), and the pressure regulator(s)

Larger systems using ASME containers with capacities greater than 2000 gal (7.6 m³) capacity are not approved as a system. Instead, the individual parts are approved. The reason is that there are many variations on how a container may be used, and approval of the entire unit as a system would be very difficult, possibly requiring many different approvals to cover all possible applications.

4.1.2 Where necessary to alter or repair containers or container assemblies in the field, such changes shall be made using approved components.

4.1.3 Acceptance applies to the complete system or to the individual components of which it is comprised as specified in [Table 4.1.1](#).

4.2 LP-Gas Odorization

4.2.1* All LP-Gases shall be odorized prior to delivery to a bulk plant by the addition of a warning agent of such character that the gases are detectable, by a distinct odor, to a concentration in air of not over one-fifth the lower limit of flammability.

A.4.2.1 It is recognized that no odorant will be completely effective as a warning agent in every circumstance.

It is recommended that odorants be qualified as to compliance with [4.2.1](#) by tests or experience. Where qualifying is by tests, such tests should be certified by an approved laboratory not associated with the odorant manufacturer. Experience has shown that ethyl mercaptan in the ratio of 1.0 lb (0.45 kg) per 10,000 gal (37.9 m³) of liquid LP-Gas has been recognized as an effective odorant. Other odorants and quantities meeting the provisions of [4.2.1](#) can be used. Research on odorants has shown that thiophane (tetrahydrothiophene) in a ratio of at least 6.4 lb (2.9 kg) per 10,000 gal (37.9 m³) of liquid LP-Gas might satisfy the requirements of [4.2.1](#).

NOTE: Odorant research includes *A New Look at Odorization Levels for Propane Gas*, BERC/RI-77/1, United States Energy Research and Development Administration, Technical Information Center, September 1977.

FAQ ►
Why is ethyl mercaptan a good choice for an odorant in propane?

The note to [A.4.2.1](#) provides additional information on the important subject of odorization. It must be remembered that the code requires the gas to have an odor that serves as a “distinctive” warning agent, but it does not specify the type of odorant or the quantity of odorant. While specific recommendations for odorization levels are made in [A.4.2.1](#), LP-Gas is re-

quired to be odorized prior to delivery to a bulk plant or other bulk storage where a bulk plant is bypassed in the chain of distribution. There are several odorants that have been tested through many research projects, but ethyl mercaptan remains as the odorant of choice for its distinctive smell and its chemical and physical properties, which match up well with those of propane. (See the commentary following A.4.2.3.)

4.2.2 Odorization shall not be required if it is harmful in the use or further processing of the LP-Gas or if such odorization will serve no useful purpose as a warning agent in such further use or processing.



LP-Gas used as a feedstock in the manufacture of petrochemicals and for use as an aerosol filling are two examples of situations in which the gas is not required to be odorized. Another potentially large application of propane in the future may be the fuel cell. Fuel cells convert hydrocarbon fuels to electricity through a chemical process. LP-Gas is being considered as a potential fuel for this application, but the sulfur added in the form of odorant to the gas may present a problem for the fuel cell stack and can possibly damage it. Therefore, it may be necessary to strip the odorant and sulfur from LP-Gas prior to introducing it to the fuel cell. This procedure, however, would most likely have to be done on site and as part of the fuel conversion process to remain in compliance with the code requirement for odorant to serve as a warning agent.

4.2.3* If odorization is required, the presence of the odorant shall be determined by sniff-testing or other means, and the results shall be documented as follows:

- (1) When LP-Gas is delivered to a bulk plant
- (2) When shipments of LP-Gas bypass the bulk plant

A.4.2.3 Another method of determining the presence of odorant is the stain tube test. This method involves using a small hand-held pump to draw a sample across a filled glass tube and reading the length of color change. For additional information, see GPA Standard 2188, *Tentative Method for the Determination of Ethyl Mercaptan in LP-Gas Using Length of Stain Tubes*, and CAN/CGSB-3.0 No. 18.5, *Test for Ethyl Mercaptan Odorant in Propane, Field Method*. At the time of the preparation of this code, additional analytical methods were under development.

LP-Gas is stored in pressure vessels, or containers, that contain both liquid LP-Gas and vapor. The pressure in the container depends on the temperature of the LP-Gas in the container, with higher pressure at higher temperature. (See **Annex B** for pressure-temperature charts.) When this pressure is reduced (e.g., by vapor being drawn out of the container to supply an appliance) the liquid in the container begins to boil, producing additional vapor to raise the pressure back to equilibrium. In the process of this boiling, the temperature of the liquid is reduced as it vaporizes, which in turn reduces the equilibrium vapor pressure. This temperature reduction is sometimes seen as ice forming on the outside of a container on a humid day.

The odorant used with propane is ethyl mercaptan, which is a liquefied flammable gas that is mixed with the liquid propane and which, in turn, boils with the propane. The boiling point of ethyl mercaptan is higher than that of propane [95°F (35°C) for ethyl mercaptan versus -44°F (-42°C) for propane], which means that as propane is first withdrawn from a full cylinder with ethyl mercaptan more propane will boil than ethyl mercaptan. The result is that 15 to 25 percent of the amount of ethyl mercaptan in the liquid (depending on the temperature of the propane) is found in the vapor. More ethyl mercaptan than propane is left in the container, and the concentration of ethyl mercaptan in the vapor increases as more propane is vaporized and will exceed the concentration added to the liquid near the end of vapor withdrawal. The amount of ethyl mercaptan added to the propane takes this fact into account. A sufficient amount of odorant is in the gas phase, throughout the entire useful temperature range to meet code requirements.

◀ FAQ

How does the odorant in LP-Gas get into the vapor?

Determining the presence of an odorant in LP-Gas is important and is required by the code to be done on each shipment to a bulk plant. Shipments that bypass a bulk plant and are delivered directly to the end user must also be tested. Sniff testing, in which a human with a normal sense of smell verifies the odor, is common practice. In some cases, however, an evaluation method with a quantifiable result may be desired.

The odorization of gas started as early as 1880 in Europe, where it was used to prevent injuries or fatalities resulting from escaping gas. The first reported odorant used was ethyl mercaptan, a prevalent compound still used to odorize LP-Gas. Ethyl mercaptan has a characteristic smell that has been described as garlic or rotten eggs. Regardless of dosage levels, it is impossible to warn 100 percent of the population of gas leaks by the use of odorant systems. Some individuals may simply not be able to discern the odor. Others may have their sense of smell temporarily impaired due to a cold, sickness, or other condition. Odorization is a valuable practice, because it does serve as a useful warning in the vast majority of cases. In a study conducted by inserting a “scratch and sniff” card in its magazine, *National Geographic* reported that gas was one of the most recognized odors [3].

Odorization for bottled propane and LP-Gases began in the late 1920s and early 1930s in the United States. Around this same time, the companies that sold LP-Gases into home-use markets began using odorants. The work of the Bureau of Mines [4], which was funded by the American Gas Association, and research conducted by those companies developing this new market showed that ethyl mercaptan was the best odorant for propane because of its volatility, odor properties, and chemical properties. The concentration of ethyl mercaptan required was also determined by research and calculation during this same period.

Ethyl mercaptan and later thiophane (tetrahydrothiophene or THT) were used at a rate of at least 1.0 lb per 10,000 gal (0.45 kg per 37.9 m³) until the late 1970s, when an industry group funded a study at the Bartlesville Energy Research Center [5]. The main action resulting from this study was an increase in the amount of THT from 1.0 lb per 10,000 gal (0.45 kg per 37.9 m³) to 6.4 lb per 10,000 gal (2.9 kg per 37.9 m³) of propane (0.012 kg/m³ to 7.7 kg/m³). This study measured values for the distribution coefficients of ethyl mercaptan and THT from propane at a variety of temperatures. Because THT has a much higher boiling point than ethyl mercaptan, its odor is not as striking as that of ethyl mercaptan. For this reason and because of its cost, THT is not used in the U.S. propane market.

Further research funded by companies that were part of the propane industry — the Gas Processors Association (GPA), the Canadian Propane Gas Association (CPGA), and the National Propane Gas Association (NPGA) — and by the Consumer Product Safety Commission (CPSC) indicated that there was a potential problem with “odor fade” in the use of ethyl mercaptan in propane. The GPA, CPGA, and the NPGA funded another series of tests, which evaluated alternative odorants for use in propane. This study and the results of the summation of industry research were synthesized into a document issued by the Joint Industry Task Force on Propane Odorization [6]. This group verified that ethyl mercaptan was the best choice for propane odorization.

A result of an engineering study funded by the CPSC was the incorporation of 4.2.3 into NFPA 58 [7]. This requirement stipulates that the presence of odorant in LP-Gas should be determined and also documented. Although the code requires only that the presence of odorant be verified, there are laboratory methods and field test methods that may be used to determine the amount of odorant present in the gas. The note to A.4.2.3 contains information regarding “length-of-stain” tube tests, which were developed by the GPA and by the CPGA, as part of the activity of the Joint Industry Task Force on Propane Odorization. In the stain tube test, a sample of the propane is drawn through a glass tube (see Exhibit 4.1), which changes color in the presence of ethyl mercaptan or other mercaptan. The length of the changed color indicates the concentration of the odorant.

The odorant level can also be determined through the use of an instrument called an Odorator®, which is shown in Exhibit 4.2. The Odorator mixes odorized gas with air in vary-



EXHIBIT 4.1 Stain Tubes and Pump. (Courtesy of Sensidyne, Inc., www.Sensidyne.com)



EXHIBIT 4.2 Odorator®. (Courtesy of Heath Consultants Incorporated)

ing amounts, as the operator sniffs the gas. When the odor is detected, the operator presses a button and reads the concentration of the odorant.

Another method used to verify the odorant concentration is by the gas chromatographic analysis of a liquid propane sample. This laboratory method takes more time and is complicated by sampling and shipping issues. A knowledgeable chemist, familiar with the properties of propane and odorants, should be consulted before taking samples of propane for gas chromatographic analysis.

Those interested in odorization are encouraged to review the latest available work in the field. (See “Additional Readings on Odorization,” a list of published papers and magazine articles on the subject at the end of this chapter. The additional readings cover odorization of both natural gas and propane.)

4.3 Notification of Installations

4.3.1 Stationary Installations.

Plans for stationary installations utilizing storage containers of over 2000 gal (7.6 m³) individual water capacity, or with aggregate water capacity exceeding 4000 gal (15.1 m³), and all rooftop installations of ASME containers shall be submitted to the authority having jurisdiction by the person or company that either installs or contracts to have the containers installed before the installation is started. [See also 6.19.11.1(F).]

Plans should be submitted to the authority having jurisdiction (AHJ), which is usually a fire department. In the absence of specific requirements from the AHJ, plans should include a site plan showing key distances and references to the code, along with information regarding key equipment (i.e., container specifications, investigation of reused equipment, etc.). Subsection 6.25.3 also requires a written fire safety analysis to be submitted for installations that have an aggregate water capacity of more than 4000 gal (15.1 m³) subject to exposure from a single fire in heavily populated or congested areas. (See Supplement 1, Guidelines for Fire Safety

FAQ ►
Why are plans only required to be submitted for installations of containers of over 2000 gal individual water capacity or 4000 gal aggregate water capacity?

Analysis, and the *Fire Safety Analysis Manual for LP-Gas Storage Facilities* [8] for more information.)

Installations smaller than 2000 gal individual / 4000 gal aggregate do not require plans to be submitted because they are relatively simple and standard installation procedures are used. Smaller installations include most one- and two-family homes and typical smaller commercial services that use DOT cylinders and/or ASME 500 gal or 1000 gal capacity containers. Some authorities, however, do require approval of these small installations in heavily populated or congested areas. In such instances, the authorities will either amend 4.3.1 or adopt specific wording in the document that requires approval.



4.3.2 Temporary Installations.

The authority having jurisdiction shall be notified of temporary (not to exceed 12 months) installations of the container sizes covered in 4.3.1 before the installation is started.

Subsection 4.3.2 recognizes that some installations are of a temporary nature. These temporary installations of the sizes covered in 4.3.1 must be brought to the attention of the AHJ prior to installation so that the fire service can be made aware of them. Such notice is important for emergency response planning. Temporary installations are found at construction sites if temporary heating is needed. They are also found at fairs, where they are used for heating tents and cooking, and at other similar locations.

FAQ ►
What happens after the 12-month period for a temporary installation has passed?

Twelve months is now the maximum period for temporary installations. This change in the 2008 edition resolves a conflict that existed in the 2004 edition, where temporary installations were defined as 6 months in one section and 12 months in another. Twelve months was chosen because many construction projects use propane for heating during the construction phase, which often takes longer than 6 months to complete. However, it is not unusual for a new permit application to be submitted after the 12-month period has expired, due to the fact that the job may be ongoing. Under such circumstances, the authority would conduct a review of the submittal as if it were a new temporary installation.

Specific requirements for containers in all temporary services are found in 5.2.7.2 and 6.6.5.

Installations that are removed and then reinstalled in the same specific location might not be considered temporary. For example, a 5-month installation at a cabin used only in the winter might not be considered temporary beyond the first year if the installation is removed after the heating season. However, many summertime fairs require propane for cooking, and these installations are made and removed after a few days in the same location year after year. These are temporary installations and must be approved by the AHJ every year. The AHJ is responsible for determining the nature of all such installations.



4.3.3 Notification of intent for transfer of LP-Gas directly from railcar to cargo tank shall be submitted to the authority having jurisdiction before the first transfer. The authority having jurisdiction shall have the authority to require inspection of the site or equipment for such transfer prior to the initial transfer.

Subsection 4.3.3 has been added to the 2008 edition. It requires anyone planning to transfer LP-Gas directly from a railcar to a cargo tank to notify the authority having jurisdiction of the installation. The authority having jurisdiction can require that the system be inspected before the first transfer. This requirement applies to both transfers from a railcar to a cargo tank vehicle at rail sidings and to such transfers at a bulk plant. The intent of this requirement is not to discourage such transfers, as long as all the required safety equipment is in place, but to ensure that the authorities having jurisdiction are aware of them.

While not specifically stated in the code, in an emergency situation where the transfer must be done promptly, such as a derailment, notification should be as soon as practical following the incident, which may be the following day or the following business day.

4.4* Qualification of Personnel

Persons who transfer liquid LP-Gas, who are employed to transport LP-Gas, or whose primary duties fall within the scope of this code shall be trained in proper handling procedures. Refresher training shall be provided at least every 3 years. The training shall be documented.

A.4.4 The term *refresher* indicates that the periodic training could be less intensive than the original training, whose primary purpose is to reinforce initial training rather than repeat it.

A requirement for training in proper handling and operation procedures has been included in NFPA 58 since the first edition in 1932. This requirement has been revised over the last decade, as shown in **Commentary Table 4.1**.

COMMENTARY TABLE 4.1 Changes in Qualification of Personnel Requirement

<i>Edition Year</i>	<i>Nature of Change</i>
1992	Each employee required to carry written certification of his or her job qualifications issued by the training agent or to carry a written document issued by the authority having jurisdiction identifying the functions each employee is authorized to perform
1995	Training required to be documented, but employee no longer required to carry proof of training
1998	Required training limited to those — Who transfer liquid LP-Gas — Who are employed to transport LP-Gas — Whose primary duties fall within the scope of NFPA 58
2001	Refresher training required every three years added

The evolution of the requirements of **Section 4.4** shows how difficult it can be to convey the intent of any technical committee. The change in 1992 that required documentation of training was well received by all parties as a way to verify that training was being conducted. The requirement to carry proof of training, however, was not well received, except in areas that had state licensing requirements in place. Because it merely duplicated employee and company records, the requirement was removed in 1995.

Questions regarding who should be trained led to the 1998 revision, which excluded those who handle cylinders as an incidental part of their jobs from being trained in the hazards of LP-Gas. For example, drivers of propane-powered industrial trucks who exchange fuel cylinders and clerks at retail stores who exchange empty propane cylinders for full ones are exempt from the training requirements. By the same token, office workers in a propane plant are not required to be trained to fill cylinders if that operation is not associated with their job.

The 2001 requirement for refresher training every three years recognizes that ongoing reinforcement of training is needed, especially for tasks that are not normally part of the job function, but that the employee may be called on to do. For example, a bobtail driver may occasionally be called on to fill cylinders at a dispensing station at the propane company's plant. The driver clearly must have been trained on filling stationary tanks, but must also be trained to fill cylinders.

Complete retraining of all employees on a three-year cycle is not required. Refresher training should cover the normal job functions the employee is expected to perform, any new equipment and procedures introduced since the last training, and the operating procedures established by the company. Note that **Chapter 14**, Operations and Maintenance, requires each LP-Gas bulk plant and industrial plant to have an operating plan and a maintenance plan. Training should follow the procedures in these plans.

◀ FAQ

Are all employees of a propane company required to be trained to handle LP-Gas?

4.5* Ammonia Contamination

A.4.5 To test for the presence of ammonia, allow a moderate vapor stream of the product to be tested to escape from the container. A rotary, slip tube, or fixed level gauge is a convenient vapor source. Wet a piece of red litmus paper by pouring distilled water over it while holding it with clean tweezers. Hold the wet litmus paper in the vapor stream from the container for 30 seconds. The appearance of any blue color on the litmus paper indicates that ammonia is present in the product.

NOTE: Because the red litmus paper will turn blue when exposed to any basic (alkaline) solution, care is required in making the test and interpreting the results. Tap water, saliva, perspiration, or hands that have been in contact with water having a pH greater than 7, or with any alkaline solution, will give erroneous results.

NOTE: For additional information on the nature of this problem and conducting the test, see NPGA Safety Bulletin 122, *Recommendations for Prevention of Ammonia Contamination of LP-Gas*, published by the National Propane Gas Association.

Because anhydrous ammonia and LP-Gas are liquefied gases that have about the same vapor pressure characteristics at the same temperature, the same transportation and storage equipment can be used for either ammonia or LP-Gas. In warmer months, when the demand for LP-Gas for heating falls, LP-Gas tanks are commonly used for ammonia in agricultural areas where ammonia is used as a fertilizer. When switching from ammonia back to LP-Gas service, the tank must be cleaned properly. If not cleaned properly, serious consequences can result.

Specifically, brass fittings are commonly used on tanks in LP-Gas service, particularly on consumers' and dealers' containers. Ammonia can cause these brass fittings to fail while in service through a process known as stress corrosion cracking. If ammonia gets into an LP-Gas distribution system, the ammonia will spread through the system and may damage any brass fittings it contacts.

The maximum concentrations of ammonia that can be tolerated in LP-Gas have been determined through a research project, "A Study of Cleaning Methods for LP-Gas Transports," conducted by Battelle Memorial Institute of Columbus, Ohio [9]. This research indicates that the red litmus paper test for ammonia in LP-Gas, if performed properly, is a much better indicator than simply trying to detect the absence of ammonia odor, and it will ensure that tolerable limits are not exceeded. Litmus paper will detect ammonia to a concentration of 1 to 2 parts per million. This procedure is referenced only in **A.4.5** because the test is not mandated for ammonia but rather is informative material for the user. Other test methods can be used, and it is the responsibility of the user to verify that any alternative method will be equally effective in identifying ammonia concentrations that will cause corrosion.

4.5.1 LP-Gas stored or used in systems within the scope of this code shall contain less ammonia than the quantity required to turn the color of red litmus paper to blue.

4.5.2 The initial fill of LP-Gas in a transportation or storage system that has been converted from ammonia to LP-Gas service shall be tested for ammonia contamination prior to being used or transferred from that system.

Testing for ammonia is not required to be performed prior to or after every transfer of LP-Gas from one container to another. **Subsection 4.5.2** does require, however, that a test be performed on the LP-Gas transferred into a container that has just undergone a change in service from ammonia to LP-Gas.

4.6* Minimum Requirements

For any purpose or application addressed within the scope of this code, where the minimum requirements of the code are met, additional features or components of equipment not prohibited by the code shall be permitted to be used.

A.4.6 The installation of safety-enhancing equipment that is not otherwise required by the code is permitted by the code. This includes any device that performs a safety-related function even though the device is designed or named to perform a required function. For example, an emergency shutoff valve (ESV) is installed in a location where it is not required to provide all the safety functions of an ESV. Even though the installer uses it to provide a specific feature that can be common to all ESVs, the code would still not require compliance with all of the ESV provisions — for example, the closing requirements described in 5.12.4.

Section 4.6 was added to the 2004 edition. It is intended to permit the installation and use of equipment that is not specifically required by the code, even if that particular piece of equipment, which may be commonly used within a specific system, is not installed with the other components of that system. For example, if an installation were made using an emergency shutoff valve where the code did not necessarily require one to be installed, the installation could be made without requiring a thermal element to be installed to operate the valve in the event of a fire.

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LP-Gas Equipment and Appliances

CHAPTER 5

Chapter 5 provides the information necessary for the design, manufacture, marking, and performance requirements for individual LP-Gas components or complete systems, with the exception of cargo tank vehicles, which are covered in Chapter 9, and engine fuel systems, which are covered in Chapter 11.

The chapter is organized by numbering many of the sections to align with the sections in Chapter 6, Installation of LP-Gas Systems. This organization makes it easy to go from product to installation requirements, because they will carry similar numbering. For example, Section 5.9, Piping (Including Hose), Fittings, and Valves, contains the requirements for all piping materials, and Section 6.9, Piping Systems, contains requirements for the installation of piping systems. Because of the alignment of subject matter, a number of sections in Chapter 5 are reserved (not used).

Chapter 5 includes detailed information and requirements for the following topics:

- Containers — cylinders and ASME containers (See Section 5.2.)
- Container appurtenances, such as pressure relief devices, regulators, pressure regulators, overfilling prevention devices, container connections, and various gauges (See Section 5.7.)
- Pressure regulators and regulator vents (See Section 5.8.)
- Piping (including hose), fittings, and valves (See Section 5.9.)
- Valves other than container valves (See Section 5.12.)
- Hydrostatic relief valves (See Section 5.13.)
- Equipment, such as pumps, compressors, meters, engines, and sight flow indicators (See Section 5.17.)
- Appliances (See Section 5.20.)
- Vaporizers, tank heaters, vaporizing burners, and gas-air mixers (See Section 5.21.)

5.1* Scope

This chapter applies to individual components and components shop-fabricated into sub-assemblies, container assemblies, and complete container systems.

A.5.1 The field assembly of components, subassemblies, container assemblies, or complete container systems into complete LP-Gas systems is addressed in Chapter 6. (See 3.3.38, *LP-Gas System*.)

5.2 Containers

5.2.1 General.

5.2.1.1* Containers shall be designed, fabricated, tested, and marked (or stamped) in accordance with the regulations of the U.S. Department of Transportation (DOT); the ASME *Boiler and Pressure Vessel Code*, Section VIII, "Rules for the Construction of Unfired Pressure

Vessels”; or the API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, except for UG-125 through UG-136.

DOT has approved a new type of cylinder for use in the United States — a composite cylinder fabricated from reinforced fiberglass. Only composite cylinders fabricated under a DOT special permit can be used. They have a 15-year service life and must be requalified every 5 years. These cylinders can be used for all applications not prohibited by NFPA 58, such as outdoor gas grills, industrial trucks, and other applications not located in buildings.

(A) Adherence to applicable ASME Code case interpretations and addenda that have been adopted and published by ASME 180 calendar days prior to the effective date of this code shall be considered as compliant with the ASME Code.

The text of 5.2.1.1(A) was revised in the 2001 edition of NFPA 58 to ensure that the NFPA Technical Committee on Liquefied Petroleum Gases had an opportunity to review any “code case” amendments to the ASME *Boiler and Pressure Vessel Code* [1] before being accepted in NFPA 58. According to ASME procedures, a code case (similar to a Tentative Interim Amendment) is effective when issued by the ASME committee.

(B) Containers fabricated to earlier editions of regulations, rules, or codes listed in 5.2.1.1 and of the Interstate Commerce Commission (ICC) *Rules for Construction of Unfired Pressure Vessels*, prior to April 1, 1967, shall be permitted to be continued to be used in accordance with Section 1.4.

The intent and application of 5.2.1.1(B) are often misinterpreted with regard to containers that were built to the API-ASME Code (specification U-200 and U-201) and pre-1949 editions of the ASME Code (specification U-68 and U-69). Because these ASME containers have a very long service life when properly maintained, many remain in use and are sometimes relocated and reinstalled. However, not all containers built to these older editions of the ASME Code can be continued in use and reinstalled, regardless of their condition. Before it is filled, a container must be found suitable for continued use, as required in 7.2.2, which states:

7.2.2 Filling and Evacuating of Containers.

7.2.2.1 Transfer of LP-Gas to and from a container shall be accomplished only by qualified individuals trained in proper handling and operating procedures meeting the requirements of Section 4.4 and in emergency response procedures.

7.2.2.2 When noncompliance with Section 5.2 and Section 5.7 is found, the container owner and user shall be notified in writing.

7.2.2.3 Injection of compressed air, oxygen, or any oxidizing gas into containers to transfer LP-Gas liquid shall be prohibited.

7.2.2.4 When evacuating a container owned by others, the qualified person(s) performing the transfer shall not inject any material other than LP-Gas into the container.

7.2.2.5* Valve outlets on cylinders of 108 lb (49 kg) water capacity [nominal 45 lb (20 kg) propane capacity] or less shall be equipped with a redundant pressure-tight seal or a listed quick-connect coupling. Where seals are used, they shall be in place whenever the cylinder is not connected for use.

7.2.2.6 Nonrefillable (disposable) and new unused cylinders shall not be required to be equipped with valve outlet seals.

7.2.2.7 Containers shall be filled only after determination that they comply with the design, fabrication, inspection, marking, and requalification provisions of this code.

7.2.2.8 “Single trip,” “nonrefillable,” or “disposable” cylinders shall not be refilled with LP-Gas.

7.2.2.9 Containers shall comply with the following with regard to service or design pressure requirements:

- (1) The service pressure marked on the cylinder shall be not less than 80 percent of the vapor pressure of the LP-Gas for which the cylinder is designed at 130°F (54.4°C).

- (2) The maximum allowable working pressure for ASME containers shall be in accordance with [Table 5.2.4.2](#).

7.2.2.10 Transfer of refrigerated product shall be made only into systems that are designed to accept refrigerated product.

7.2.2.11 A container shall not be filled if the container assembly does not meet the requirements for continued service.

7.2.2.12 Transfer hoses larger than $\frac{1}{2}$ in. (12 mm) internal diameter shall not be used for making connections to individual cylinders being filled indoors.

A.5.2.1.1 Prior to April 1, 1967, regulations of the U.S. Department of Transportation were promulgated by the Interstate Commerce Commission. In Canada, the regulations of the Canadian Transport Commission apply and are available from the Canadian Transport Commission, Union Station, Ottawa, Canada.

Construction of containers to the API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, has not been authorized after July 1, 1961.

The requirements for the construction of pressure vessels used to store LP-Gases are referenced in [5.2.1.1](#). (Requirements for nonpressurized refrigerated containers are located in [Chapter 12](#), Refrigerated Containers.) The referenced codes provide a level of safety such that the NFPA Technical Committee on Liquefied Petroleum Gases has not needed to develop its own requirements for pressure vessels for LP-Gas. In referencing the ASME *Boiler and Pressure Vessel Code* [1], the committee has made an exception to sections UG-125 through UG-136, which cover pressure relief devices. The requirements for pressure relief devices in the ASME *Boiler and Pressure Vessel Code* are more conservative than those in UL 132, *Standard on Safety Relief Valves for Anhydrous Ammonia and LP-Gas* [2], which requires larger pressure relief valves.

Pressurized LP-Gas containers in the United States, Canada, and other countries served by marketers based in the United States and Canada comply with [5.2.1.1](#). Many other countries that use NFPA 58 have their own container requirements. In the event that a container constructed to a different standard, such as one used in a foreign country, is to be filled in a jurisdiction that enforces NFPA 58, approval to fill that container must be obtained from the authority having jurisdiction. For cylinders, the authority having jurisdiction is the U. S. Department of Transportation (DOT), and approval to fill is not likely to be given. Given the relatively low cost of cylinders, it is easier to purchase a new cylinder than to petition DOT for a variance. Small foreign vessels and campers that travel internationally provide a source of cylinders built to specifications of other countries. Cylinders manufactured to other than DOT specifications can be used in the United States, but cannot be refilled.

If the container is a pressure vessel, the authority having jurisdiction is the state in which the container is installed. Because most states adopt and enforce the ASME *Boiler and Pressure Vessel Code* [1], the state boiler agency must be contacted. For example, when packaged propane equipment is imported with propane tanks, the authority having jurisdiction should be contacted to determine how to proceed. The following paragraphs provide more detailed information on the specific types of containers used in the LP-Gas industry.

U.S. Department of Transportation (DOT) Cylinders. DOT cylinders first used for LP-Gas were built to specifications of the Interstate Commerce Commission (ICC). DOT restricts cylinders to 1000 lb (454 kg) water capacity or less. Prior to 1967, ICC specifications were used, but they have not been used for many years. The current basic cylinders for reusable service are DOT 4BA-240 (steel construction) and DOT 4E (aluminum construction) cylinders, specifications for which are found in 49 CFR 178.50 [3] and 49 CFR 178.68 [4], respectively. Disposable cylinders, such as hand torch cylinders, have different DOT specifications.

The regulations for DOT cylinders [and similar cylinders built to Transport Canada (TC) specifications] are concerned with transportation, whereas much of NFPA 58 is concerned

◀ FAQ

Is it permissible to use containers that have been fabricated and marked in accordance with regulations in foreign countries?

with container usage and storage. Several DOT/TC cylinders are shown in Exhibits 5.1 and 5.2. Nevertheless, there are compelling reasons why NFPA 58 must recognize these cylinders as storage containers. Because DOT specifications are developed for transportation applications only, the NFPA technical committee continuously monitors DOT and TC standards to ensure that the standards are adequate for the applications covered by NFPA 58. For example, the committee did not permit the use of 4E (aluminum) cylinder for several years, until the cylinder's use and storage safety were demonstrated by tests and experience.

All DOT/TC cylinders are portable and designed to be transported when filled with product. Cylinders hold from 1 lb to 420 lb (0.5 kg to 191 kg) of propane. (See Exhibit 5.3.) Cylinders can be moved with reasonable ease by an individual or by vehicles that are equipped with lifting devices that can transport the larger portable cylinders.

Cylinders are filled at the location where they are installed or used. It is common to see 100 lb (45 kg) cylinders "permanently" installed at residential and commercial locations being filled on site. When the cylinder is permanently installed, the standard cylinder valve is replaced with a multipurpose valve so that the cylinder can be refilled without disconnecting the piping.

Commentary Table 5.1 lists types of popular cylinders, their applications, water and propane capacities, and specification numbers. The information listed in Commentary Table 5.1 is especially useful because the capacity of cylinders is rated by weight, in pounds (kilograms), and their spacing is determined by the volumetric capacity, in gallons (cubic meters), by Table 6.3.1. Commentary Table 5.1 allows conversions from pounds to gallons so that the proper spacing distances can be easily determined.

A DOT cylinder must be marked with certain information, usually on the cylinder itself or on its collar, as shown in Exhibit 5.4. This information is especially vital in determining the suitability of the cylinder for continued service, as indicated by the requalification date.

EXHIBIT 5.1 DOT/TC Cylinders. Top: Typical Industrial Truck Motor (Engines) Fuel Cylinders; Bottom: Typical Stationary and Portable Cylinders for Residential and Commercial Uses. (Courtesy of Manchester Tank)





EXHIBIT 5.2 DOT/TC Cylinders. (Courtesy of Manchester Tank)

Industrial/Commercial	Consumer	Industrial Truck/Fork Lift
Description/Size Openings A. Safety relief valve 1 in. B. NPT float gauge 1 in. C. Fill valve .75 in. D. Vapor service valve .75 in. E. Multi-valve .75 in.		Description A. Universal float gauge B. Liquid service valve C. Safety relief valve D. Fixed liquid level E. Vapor service (plugged) F. Liquid fill port (plugged)
420 lb LP-Gas cap. 100 gal Tare wt. 289 lb/131 kg Water cap. 1000 lb/454 kg DOT-4BW240	20 lb 5 gal 18 lb/8.2 kg 47.7 lb/21.6 kg DOT-4BA240	20 lb 5 gal 26.5 lb/12 kg 47.7 lb/21.6 kg DOT-4BA240
200 lb 47 gal 150 lb/71 kg 474 lb/215 kg DOT-4BW240	6 lb 1.5 gal 9.2 lb/4.1 kg 15.5 lb/7 kg DOT-4BA260	33-1/2 lb 8 gal 34.5 lb/15.5 kg 80 lb/36.3 kg DOT-4BW240
100 lb 23 gal 72 lb/32.6 kg 240 lb/108 kg DOT-4BW240		43-1/2 lb 10 gal 40 lb/18 kg 103.6 lb/47 kg DOT-4BW240

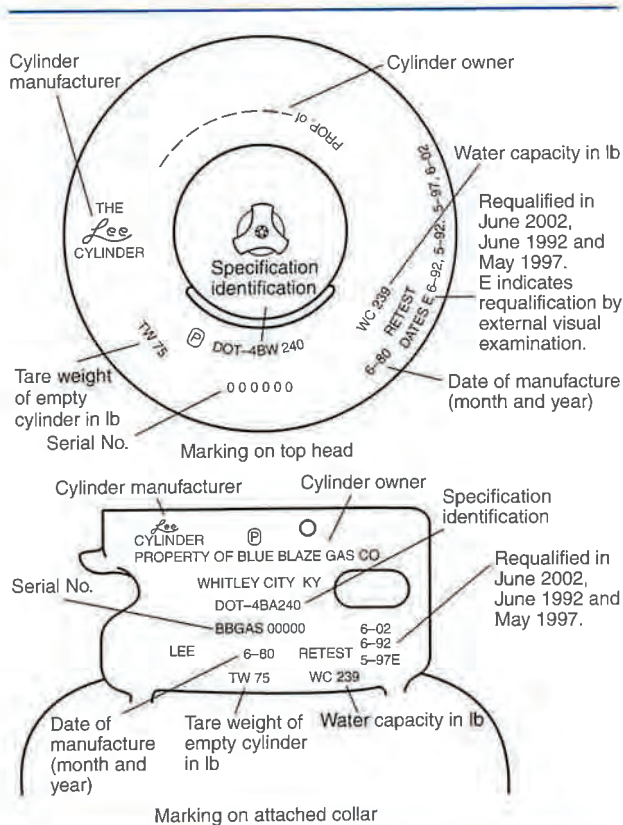
EXHIBIT 5.3 Dimensions and Capacities of Typical DOT Cylinders. (Courtesy of Worthington Cylinder Corp.)

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COMMENTARY TABLE 5.1 DOT/TC Cylinder Applications

Type of Service	Typical Use	Propane Capacity			Water Capacity			Common DOT Mfg. Code
		Pounds	Kilograms	Gallons	Pounds	Kilograms	Gallons	
Stationary	Homes, business	420	191	99	1000	454	119	4B, 4BA, 4BW
Stationary	Homes, business	300	136	71	715	324	86	4B, 4BA, 4BW
Stationary	Homes, business	200	91	47	477	216	57	4B, 4BA, 4BW
Stationary	Homes, business	150	68	35	357	162	43	4B
Exchange	Homes, business	100	45	24	239	108	29	4B, 4BA, 4BW
Exchange	Homes, business	60	27	14	144	65	17	4B, 4BA, 4BW
Engine fuel	Forklift	43.5	19.7	10	104	47	12	4B, 4BA, 4BW, 4E
Engine fuel	Forklift	33.5	15.2	8	80	36	9.6	4B, 4BA, 4BW, 4E
Engine fuel	Forklift	20	9	4.7	48	22	5.7	4B, 4BA, 4BW, 4E
Engine fuel	Forklift	14	6.4	3.3	34	15.4	4.1	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	40	18	9.5	95	43	11	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	30	13.6	7.1	72	32.7	8.6	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles	25	11.3	5.9	59.5	27	7.1	4B, 4BA, 4BW
Portable	Rec. vehicles, grills	20	9	4.7	48	22	5.7	4B, 4BA, 4BW, 4E
Portable	Rec. vehicles, and small appliances	10	4.5	2.4	23.8	10.8	2.8	4B, 4BA, 4BW, 4E
Portable	Indoors, trailers	5	2.3	1.2	12	5.4	1.4	4B, 4BA, 4BW, 4E
Portable	Torches, RV	0.93	0.42	0.2	2.2	1	0.3	39 (disposable), 4B240 (refillable)

EXHIBIT 5.4 Typical DOT Cylinder Marking. (Courtesy of National Propane Gas Association)



ASME Containers. ASME containers, often referred to as bulk containers, are unfired pressure vessels built to the ASME Code, Section VIII, Division 1 or 2. Division 1 is a “prescriptive” approach to container design that lays out the requirements in “cookbook” fashion. Division 2 is a “performance” approach that allows the designer more latitude in the choice of materials, but requires a more extensive analysis to demonstrate compliance. ASME Code containers are usually found in stationary installations but can also be mounted on trucks for use as a cargo tank motor vehicle. (See [Exhibit 5.5](#).)



EXHIBIT 5.5 Small ASME Container Commonly Used in Residential and Commercial Applications. (Courtesy of Trinity Containers)

Prior to World War I, the first LP-Gas bulk containers in use were riveted, but keeping these containers leak-free around the rivets and the seams was difficult. Forge-welded containers came into use after World War I as the technology became available in the United States. In the 1930s, the current-style fusion-welded pressure vessels were used. At that time, the ASME Code specifications were U-68 and U-69. These specifications had a design margin (safety factor) of 5 to 1 — the ratio of the theoretical burst pressure to the design operating pressure. The normal working pressure of U-68 and U-69 containers was 200 psig (1.4 MPag). At that time, NFPA 58 allowed the pressure relief valve setting to be 125 percent of the working pressure, or 250 psig (1.7 MPag). Pressure relief valves prevent the excessive buildup of pressure in the containers in case of overfilling, or excessive heating of the propane due to fire impingement on the container.

ASME specifications U-200 and U-201, which were developed in conjunction with the American Petroleum Institute (API), were also applied prior to 1949. ASME specifications U-200 and U-201 were known as the API-ASME Code. These API-ASME Code specifications applied to containers that were restricted in use to installations such as refineries, gas processing plants, and tank farms.

In 1949, ASME adopted the current ASME Code precept with a design margin (safety factor) of 4 to 1. At that time, the requirement for the pressure relief valve setting was changed to the working pressure of a container, 250 psig minimum (1.7 MPag minimum) for propane. In effect, the 4 to 1 safety factor and the previous 5 to 1 safety factor are comparable, with the same ultimate burst pressure, as 250×4 and 200×5 both equal 1000. Many pre-1949, 200 psig (1.4 MPag) ASME tanks are still in service.

In the mid-1990s, the ASME Code design margin (safety factor) was further reduced from 4 to 1 to 3.5 to 1. The ASME Boiler and Pressure Vessel Code Committee took this action because of the improvement in both material quality control and welding technology since the 1950s. The design margin in pressure vessel design anticipates minor defects in materials (thickness variation, imperfections, and inclusions in the metal) as well as less than perfect welding. Because both materials and welding have improved since the 1950s, it was determined that the design margin was excessive and was reduced. This reduction does not

decrease safety in pressure vessels designed to the ASME Code. [See Annexes C and D for further descriptions of DOT (ICC) and ASME containers.]

Commentary Table 5.2 shows popular ASME container sizes, their applications, and their water and propane capacities. The table also lists the capacities, in pounds, of smaller size containers for easy comparison to cylinder capacities. It is important to note that the ranges given for LP-Gas capacity in the table are not all at the same reference temperature. For example, the LP-Gas capacity for a bulk plant tank of 12,000 gal (45.4 m³) is shown to be 10,800 gal (41 m³), which is 90 percent of the container water capacity. However, 7.4.3.2(B), and referenced Table 7.4.2.3(b), only permit volumetric filling to 90 percent when the propane is at a temperature of 70°F (21°C). Therefore, it is important to realize that the capacities shown in **Commentary Table 5.2** are those at assumed propane temperatures.

Intermodal Containers. Intermodal containers, as shown in Exhibit 5.6, are shipping containers larger than cylinders that are mounted within a frame for shipment on railroads, trucks, and ships. The containers are similar to dry shipping containers. The United Nations accepts intermodal containers for international shipping. These containers must meet DOT specifications and ASME Code requirements. LP-Gas is shipped via intermodal containers to islands and inland areas that are accessible only by rivers or other bodies of water.

Container Ownership. Usually, the LP-Gas marketer leases residential and commercial LP-Gas containers to the customer. However, NFPA 58 does not prevent consumers from purchasing their own containers. Industrial and other large users are more likely to own their containers. When residential consumers and industrial LP-Gas users own their containers, they are responsible for complying with the code requirements concerning container maintenance. The propane supplier is responsible for taking reasonable steps to verify that a container is fit for service before filling it and should not fill a container that is unfit for service. This applies equally to a 20 lb (9.1 kg) gas grill cylinder, a 500 gal (1.9 m³) ASME container at a residence, and a 30,000 gal (14 m³) ASME container at an industrial facility.

5.2.1.2 Containers that have been involved in a fire and show no distortion shall be requalified for continued service before being used or reinstalled.

COMMENTARY TABLE 5.2 Typical Stationary ASME Container Applications

Service	Water Capacity		LP-Gas Capacity		
	Gallons	Liters or Cubic Meters	Gallons*	Liters or Cubic Meters	Pounds
Domestic	100	379 L	80	301 L	338
Domestic	125	473 L	100	379 L	423
Domestic	150	568 L	120	454 L	508
Domestic	250	946 L	200	757 L	848
Domestic	325	1230 L	260	984 L	
Domestic	500	1893 L	400	1514 L	
Domestic	1,000	3.8 m ³	800	3 m ³	
Industrial/agricultural/commercial	1,000–5,000	3.8–19 m ³	800–4,500	3–17 m ³	
Service stations	1,000–6,500	3.8–24.6 m ³	800–5,850	3–22 m ³	
Bulk plant or standby storage	12,000–18,000	45.4–68 m ³	10,800–16,200	41–61 m ³	
Bulk plant or standby storage	20,000–30,000	76–114 m ³	18,000–27,000	45.4–102 m ³	
Bulk plant or standby storage	30,000–60,000	114–227 m ³	27,000–54,000	102–204 m ³	
Bulk plant or standby storage	60,000–120,000	227–454 m ³	48,000–96,000	182–364 m ³	

*Based on propane specific gravity of 0.508 at 70°F (21°C). Actual filling level depends on the specific gravity and temperature of the propane.



EXHIBIT 5.6 Intermodal Container. (Courtesy of Permugas)

(A) Cylinders shall be requalified by a manufacturer of that type of cylinder or by a repair facility approved by DOT.

(B) ASME or API-ASME containers shall be retested using the hydrostatic test procedure applicable at the time of the original fabrication.

Older containers can continue to be used when evidence of design or construction flaws, or dents, pits, and corrosion, is not evident. When these containers were built, they incorporated the latest technology in design, metallurgy, and fabrication techniques. Although technology has improved significantly over the years, there is no evidence that older containers are less safe now than when they were built, as long as they have been properly maintained.

Other nondestructive test methods may be considered as alternatives to the hydrostatic test required in 5.2.1.2(B). The following methods are listed in the ASME *Boiler and Pressure Vessel Code* [1] and may be useful for finding flaws in the container that would prevent it from being placed back into service after a fire:

- Radiography
- Ultrasonics
- Magnetic particle
- Liquid penetrants
- Visual inspection
- Leak testing
- Electromagnetic testing
- Acoustic emission

It is important to remember that the ASME Code is a construction code, and not a maintenance or an inspection code, and other codes (e.g., DOT, NFPA 58) may allow or require hydrostatic pressure testing as a nondestructive test when needed. While a hydrostatic pressure test is considered nondestructive, it can result in damage to the pressure vessel if a significant flaw is detected. The person performing such tests must be familiar both with the code requirements used to construct the container and with the test methods used to test the container.

(C) All container appurtenances shall be replaced.

(D) DOT 4E specification (aluminum) cylinders and composite cylinders involved in a fire shall be permanently removed from service.

If a cylinder has been subjected to fire, the metal shell, which is usually steel or aluminum, can be weakened, and the cylinder must be requalified by a properly qualified repair facility authorized by DOT (in the United States) or TC (in Canada). When an ASME container has been subjected to fire, it must be retested using the hydrostatic test procedure applicable at the time the container was originally made. The testing is required because the fire heat can alter the properties of the steel, reducing its ability to contain pressure. Container appurtenances must also be replaced after a container has been exposed to fire.

Paragraph 5.2.1.2(D) was not located here in the 2004 edition, where it was paragraph 5.2.3.2. It was moved to this more appropriate location in the 2008 edition. DOT 4E aluminum cylinders may not be returned to service after a fire because even exposure to moderately high temperatures can affect the structural properties of aluminum and severely decrease its tensile strength.

Exhibit 5.7 shows a container that has been exposed to fire.

EXHIBIT 5.7 ASME Container Damaged by Fire.
(Courtesy of Independent Propane Co., Pine, CO)



5.2.1.3 ASME paragraph U-68 or U-69 containers shall be permitted to be continued in use, installed, reinstalled, or placed back into service. Installation of containers shall be in accordance with all provisions listed in this code. (See Section 5.2, Table 5.2.4.2 and Table 5.7.2.4(A), and Annex D.)

FAQ ►
Can ASME containers constructed to U-68 and U-69 requirements be installed into a new service?

The requirement in 5.2.1.3 clearly and specifically states ASME paragraph U-68 or U-69 containers may be continued in service and reinstalled. This addition to the 1995 edition of NFPA 58 was intended to clarify the NFPA technical committee's opposition to one state's interpretation of the code that would not permit ASME containers built under ASME U-68 and U-69 to be reinstalled. [See the commentary following 5.2.1.1(B) for more information on ASME U-68 and U-69.]

5.2.1.4 Containers that show excessive denting, bulging, gouging, or corrosion shall be removed from service.

All containers that show excessive dents, bulges, gouges, or corrosion must be removed from service because these defects can reduce the pressure capability of the container. Once removed from service, the container should be scrapped, or repaired using methods that are in accordance with the code of manufacture.

5.2.1.5 Repairs or alteration of a container shall comply with the regulations, rules, or code under which the container was fabricated. Repairs or alteration to ASME containers shall be in accordance with the *National Board Inspection Code*.

5.2.1.6 Field welding shall be permitted only on saddle plates, lugs, pads, or brackets that are attached to the container by the container manufacturer.

The heat of welding directly to the container can affect the strength of the material and change its characteristics so that it may no longer meet the requirements of the ASME *Boiler and Pressure Vessel Code* [1]. Such heating can set up localized stresses that can reduce the material's strength. Repairs to pressure vessels must meet the requirements of the *National Board Inspection Code* (NBIC) [5], and must be performed by a repair organization accredited by the National Board and authorized to utilize the "R" code symbol stamp. Following a repair and final inspection by a National Board Commissioned Inspector, the repair organization will affix a "Repair" nameplate to the pressure vessel that is similar to the ASME nameplate. The requirements in the NBIC were developed to maintain the integrity of the pressure vessel after it has been placed in service. (See [Exhibit 5.8](#).)

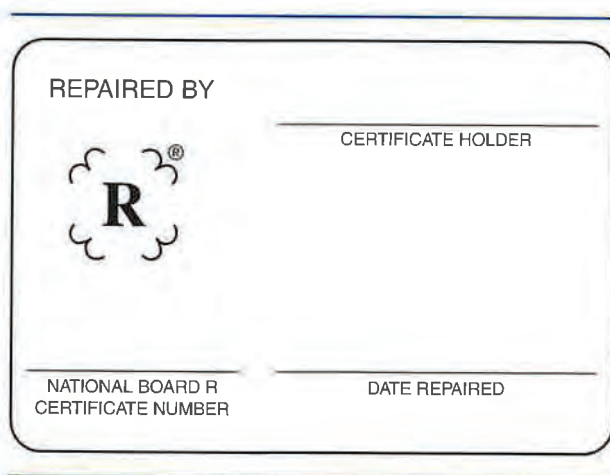


EXHIBIT 5.8 National Board "R" Stamp. (This material is taken from the National Board Inspection Code and is reprinted with permission of the National Board of Boiler and Pressure Vessel Inspectors.)

5.2.1.7 Containers for general use shall not have individual water capacities greater than 120,000 gal (454 m³).

Containers installed for general use and in dispensing stations are limited in size per [5.2.1.7](#). However, the number of containers in general use is not limited. The term *general use*, which is not defined in the code, refers to installations where LP-Gas is being stored for an end use application, such as for use as a fuel. Thus an LP-Gas bulk plant, where most employees can be expected to be aware of the proper procedures for handling LP-Gas, is not general use, whereas a container used as an alternate fuel supply at a manufacturing plant, whose product is not related to LP-Gas, would be considered to be general use.

5.2.1.8 Containers in dispensing stations not located in LP-Gas bulk plants, industrial plants, or industrial applications shall have an aggregate water capacity not greater than 30,000 gal (114 m³).

The 30,000 gal (114 m³) water capacity limit on total storage in dispensing stations provides a limit on storage capacity at locations where only cylinders are filled or LP-Gas is dispensed.

5.2.1.9 Heating or cooling coils shall not be installed inside storage containers.

Internal container components, such as heating and cooling coils, can be inspected only when the container is emptied, purged, and declared safe for entry. It is possible that a container's components may not be inspected during the container's normal life of service. If not inspected, corrosion or other container component failure will not be observed. If heating or cooling coils installed inside the storage container leak, the gas could enter the piping of the

heating or cooling system, because the LP-Gas pressure is normally higher than the pressure in the internal coil. Leakage into the system could result in a pressure that could rupture or create leaks in the heating or cooling system. Even if a break does not occur, a flammable product will be present in the heating or cooling system that could escape near an ignition source.

5.2.2 Cylinders.

5.2.2.1* Cylinders shall be continued in service and transported in accordance with DOT regulations.

A.5.2.2.1 See CGA Publication C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, or C-6.3, *Guidelines for Visual Inspection and Requalification of Low Pressure Aluminum Compressed Gas Cylinders*, for further information regarding cylinder inspection.

5.2.2.2 A cylinder with an expired requalification date shall not be refilled until it is requalified by the methods prescribed in DOT regulations.

An important safety provision of NFPA 58 is that all LP-Gas containers be safe before they are filled. Cylinders that are built to DOT requirements can be filled for 12 years from the date of manufacture and subsequently must be recertified periodically. Until the 2004 edition, the question of recertification of cylinders that were used outside of the scope of DOT (not in transportation) was not completely clear. This issue has been resolved by 5.2.2.2 and 5.2.3, which address cylinders that are filled on site and not subject to DOT regulation.

There are three different methods by which to requalify a cylinder:

Requalification Method	Time Before Next Recertification
Water-jacket hydrostatic test method	12 years
Modified hydrostatic	7 years
Visual	5 years

Refer to Annex C for a detailed description of these methods.

Requalification of cylinders under DOT regulations using the visual method could have been done by anyone up until August 8, 2002, when DOT issued Final Rule HM-220D, which requires registration of requalifiers using the visual method. The rule requires facilities or individuals that requalify cylinders to register with DOT in order to obtain a requalifier identification number (RIN). Registration of a business facility covers individual employees at the facility. The following also applies to cylinder requalification using the visual method:

- Beginning May 31, 2004, only facilities that held an RIN were permitted to requalify cylinders by external visual inspection.
- Inspections must have been performed in accordance with CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders* [6], and/or C-6.3, *Guidelines for Visual Inspection and Requalification of Low Pressure Aluminum Compressed Gas Cylinders* [7].
- Cylinders passing requalification by external visual inspection must be marked as described below
- Cylinder markings must be made by stamping, engraving, scribing, or any other method that produces a legible, durable mark. Interpretations obtained from DOT allow the mark to be on a “durable pressure adhesive label.”
- Each facility that requalifies cylinders must maintain records at the facility where the requalification is performed.

The requirement for an RIN applies only to those who requalify cylinders for use “in transportation” and does not apply to those who visually inspect stationary cylinders per the procedures in 5.2.3.

The following is reprinted from 49 CFR Part 180.213 [8]:

49 CFR Part 180 — CONTINUING QUALIFICATION AND MAINTENANCE OF PACK-
AGINGS

Subpart C — Qualification, Maintenance and Use of Cylinders
180.213 Recertification markings.

(a) *General.* Each cylinder or UN pressure receptacle recertified in accordance with this subpart with acceptable results must be marked as specified in this section. Required specification markings may not be altered or removed.

(b) *Placement of markings.* Each cylinder must be plainly and permanently marked on the metal of the cylinder as permitted by the applicable specification. Unless authorized by the cylinder specification, marking on the cylinder sidewall is prohibited.

(1) Recertification and required specification markings must be legible so as to be readily visible at all times. Illegible specification markings may be remarked on the cylinder as provided by the original specification. Recertification markings may be placed on any portion of the upper end of the cylinder excluding the sidewall, as provided in this section. Recertification and required specification markings that are illegible may be reproduced on a metal plate and attached as provided by the original specification.

(2) Previous recertification markings may not be obliterated, except that, when the space originally provided for recertification dates becomes filled, additional dates may be added as follows:

(i) All preceding recertification dates may be removed by peening provided that—

(A) Permission is obtained from the cylinder owner;

(B) The minimum wall thickness is maintained in accordance with manufacturing specifications for the cylinder; and

(C) the original manufacturing test date is not removed.

(ii) When the cylinder is fitted with a footing, additional dates may be marked on the external surface of the footing.

(c) *Recertification marking method.* The depth of recertification markings may not be greater than specified in the applicable specification. The markings must be made by stamping, engraving, scribing or other method that produces a legible, durable mark.

[NOTE: Although DOT has not published a rulemaking to this effect, it has stated in letters to the propane industry that a “durable pressure adhesive label is acceptable” to be used to mark the cylinder]

(1) and (2) [not applicable to propane cylinders]

(3) For a composite cylinder, the recertification markings must be applied on a pressure sensitive label, securely affixed in a manner prescribed by the cylinder manufacturer, near the original manufacturer’s label. Stamping of the composite surface is not authorized.

(d) *Recertification markings.* Each cylinder successfully passing recertification must be marked with the RIN set in a square pattern, between the month and year of the recertification date. The first character of the RIN must appear in the upper left corner of the square pattern; the second in the upper right; the third in the lower right, and the fourth in the lower left.

Example: A cylinder recertified in September 2006, and approved by a person who has been issued RIN “A123”, would be marked plainly and permanently into the metal of the cylinder in accordance with location requirements of the cylinder specification or on a metal plate permanently secured to the cylinder in accordance with paragraph (b) of this section. An example of the markings prescribed in this paragraph (d) is as follows:

A1

9

06 X

32

◀ FAQ

How must the recertifier identification number be applied to a cylinder?

Where:

“9” is the month of requalification,

“A123” is the RIN,

“06” is the year of requalification, and

“X” represents the symbols described in paragraphs (f)(2) through (f)(9) of this section.

(1) Upon a written request, variation from the marking requirement may be approved by the Associate Administrator.

(2) *Exception.* A cylinder subject to the requirements of §173.301(l) of this subchapter may not be marked with a RIN.

(e) *Size of markings.* The size of the markings must be at least 6.35 mm (1/4 in.) high, except RIN characters must be at least 3.18 mm (1/8 in.) high.

(f) *Marking illustrations.* Examples of required requalification markings for DOT specification and special permit cylinders are illustrated as follows:

(1) For designation of the 5-year volumetric expansion test, 10-year volumetric expansion test for UN cylinders and cylinders conforming to §180.209(f) and (h), or 12-year volumetric expansion test for fire extinguishers conforming to §173.309(b) of this subchapter and cylinders conforming to §180.209(e) and 180.209(g), the marking is as illustrated in paragraph (d) of this section.

(2) and (3) [not applicable to propane cylinders]

(4) For designation of the proof pressure test, the marking is as illustrated in paragraph (d) of this section, except that the “X” is replaced with the letter “S”.

(5) For designation of the 5-year external visual inspection for cylinders conforming to Sec. 180.209(g), the marking is as illustrated in paragraph (d) of this section, except that the “X” is replaced with the letter “E”.

(5) through (9) [not applicable to visual requalification of propane cylinders]

DOT initially underestimated the number of companies that would be registering as cylinder requalifiers and ran out of four-digit numbers to assign. A seven-digit numbering system was started. Facilities using the seven-digit number must display it, along with the date of inspection, using one of the following formats:

V100001	0907	V100001 0907
0907	V100001	

5.2.3 Cylinders Filled on Site.

DOT cylinders in stationary service that are filled on site and therefore are not under the jurisdiction of DOT either shall be requalified in accordance with DOT requirements or shall be visually inspected within 12 years of the date of manufacture and within every 5 years thereafter, in accordance with 5.2.3.1 through 5.2.3.3.

FAQ ►
Are all cylinders, whether or not they are under DOT jurisdiction, required to be requalified in accordance with DOT procedures?

Subsection 5.2.3 was added to the 2004 edition of the code. It addresses the need to inspect stationary cylinders and provides a method to recertify cylinders filled on site. Cylinders not “in transportation” are not subject to DOT regulations for recertification; however, they are required to be recertified by NFPA 58. Cylinders “in transportation” include cylinders transported by common carriers (trucking companies); by someone in the LP-Gas business; or by those who use them as a material of trade, such as a caterer or a roofer using propane fuel.

The need for this requirement, which differs from DOT regulations, stems from the difficulty involved in recertifying cylinders filled on site without disconnecting piping, emptying the cylinder, and inspecting and weighing the cylinder, as required by DOT regulations. Weighing is deleted here, because the committee was advised that CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders* [6] (which is referenced by DOT), was being revised to drop the re-weighing requirement, and the committee saw

potential safety disadvantages to the additional gas transfers that emptying the cylinder would require.

The need for the new requirement was recognized prior to the processing of the 2004 edition with TIA (01-1), which was issued in 2002 on the 2001 edition. The TIA delayed the implementation of the requalifications until July 1, 2004, for cylinders of 100 lb and larger that are filled on site. The delay resulted from the recognition of the burden to propane marketers and their customers, because all cylinders that needed recertification would have been required to be pulled from the field immediately for requalification.

5.2.3.1 Any cylinder that fails one or more of the criteria in **5.2.3.3** shall not be refilled or continued in service until the condition is corrected.

5.2.3.2 Personnel shall be trained and qualified to perform inspections. Training shall be documented in accordance with **Section 4.4**.

Per **5.2.3.2**, training received by persons visually inspecting stationary cylinders filled on site must be documented. As with any documentation required by the code, training documentation should be placed in the employee's file so that it can be located if needed.

5.2.3.3 Visual inspection shall be performed in accordance with the following:

- (1) The cylinder is checked for exposure to fire, dents, cuts, digs, gouges, and corrosion according to CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, except that paragraph 4.2.1.1(1) of that standard (which requires tare weight verification) shall not be part of the required inspection criteria.
- (2) The cylinder protective collar (where utilized) and the foot ring are intact and are firmly attached.
- (3) The cylinder is painted or coated to minimize corrosion.
- (4) The cylinder pressure relief valve indicates no visible damage, corrosion of operating components, or obstructions.
- (5) There is no leakage from the cylinder or its appurtenances that is detectable without the use of instruments.
- (6) The cylinder is installed on a firm foundation and is not in contact with the soil.
- (7) A cylinder that passes the visual examination shall be marked with the month and year of the examination followed by the letter "E" (example: 10-01E, indicating requalification in October 2001 by the external inspection method).
- (8) The results of the visual inspection shall be documented, and a record of the inspection shall be retained for a 5-year period.

The procedures for visual inspection listed in **5.2.3.3** are simple and will identify cylinder defects and conditions that require correction. Several are taken from CGA C-6 [6], the standard for visually inspecting steel cylinders.

In **5.2.3.3(3)**, the phrase "retard corrosion" was revised to read "minimize corrosion." The technical committee intends that the painting or coating prevent excessive corrosion from occurring.

Paragraph 5.2.3.3(5) states that using an electronic or other gas detection device is not required.

Paragraph 5.2.3.3(6) addresses an important installation requirement, namely, that the cylinder be installed on a firm foundation, not in contact with the soil. "Firm" is not defined but in the context of the usage, it is intended to require the foundation to remain substantially intact and level while it supports the cylinder.

The marking requirements of **5.2.3.3(7)** are similar to those used for cylinders that are requalified. An important difference is that a requalifier identification number is not required to be marked on the cylinder.

Paragraph 5.2.3.3(8) provides a definite five-year term for retaining the records of all inspected cylinders.

5.2.4 Container Service Pressure.



5.2.4.1 The service pressure of cylinders shall be in accordance with the appropriate regulations published under 49 CFR, “Transportation.”

See **Annex C**, Design, Construction, and Requalification of DOT (ICC) Cylinders, for information on the DOT requirements for cylinder design and fabrication.

5.2.4.2 The maximum allowable working pressure (MAWP) for ASME containers shall be in accordance with Table 5.2.4.2.

FAQ ►

Can a container having a maximum allowable working pressure of 200 psi be used in propane service?

Table 5.2.4.2 provides minimum MAWP for ASME containers in LP-Gas service. Most containers require a MAWP of 250 psig (1.7 MPag). The higher pressure of 312 psig (2.2 MPag) [125 percent of 250 psig (1.7 MPag)] is now required for all engine fuel container installations, including automobiles, industrial trucks, buses, recreational vehicles, school buses, and multipurpose passenger vehicles.

Note that containers constructed to the ASME *Boiler and Pressure Vessel Code* [1] up to the 1946 edition, and paragraphs U-68 and U-69 in the 1949 edition, are permitted to be used even though the MAWP is 200 psi. The reason for this allowance is due to the design margin (safety factor) of 5 that was used to design those containers. The recognized benefits of modern technologies and material science have resulted in a reduced design margin for the current ASME *Boiler and Pressure Vessel Code*.

5.2.4.3 In addition to the applicable provisions for horizontal ASME containers, vertical ASME containers over 125 gal (0.5 m³) water capacity shall comply with 5.2.4.3(A) through 5.2.4.3(E).

(A) Containers shall be designed to be self-supporting without the use of guy wires and shall be designed to withstand the wind, seismic (earthquake) forces, and hydrostatic test loads anticipated at the site.



(B) Maximum allowable working pressure (see **Table 5.2.4.2**) shall be the pressure at the top head with allowance made for increased pressure on lower shell sections and bottom head due to the static pressure of the product.

TABLE 5.2.4.2 Maximum Vapor Pressures and MAWP

Maximum Vapor Pressure in psig (MPag)		MAWP Pressure in psig (MPag)					
		Current ASME Code ^a		Earlier Codes			
				API-ASME		ASME ^b	
At 100°F	At 37.8°C	psig	MPag	psig	MPag	psig	MPag
80	0.6	100	0.7	100	0.7	80	0.6
100	0.7	125	0.9	125	0.9	100	0.7
125	0.9	156	1.1	156	1.1	125	0.9
150	1.0	187	1.3	187	1.3	150	1.0
175	1.2	219	1.5	219	1.5	175	1.2
215	1.5	250	1.7 ^c	250	1.7 ^c	200	1.4
215	1.5	312	2.2 ^c	312	2.2 ^c	—	—

Note: See Annex D for information on earlier ASME or API-ASME codes.

^aASME Code, 1949 edition, paragraphs U-200 and U-201 and all later editions (see D.2.1.5).

^bAll ASME codes up to the 1946 edition and paragraphs U-68 and U-69 of the 1949 edition (see D.2.1.5).

^cSee 6.23.3.1(A), 6.23.3.1(C), and 6.23.3.1(D) for required maximum allowable working pressure (MAWP) for ASME engine fuel and mobile containers.

(C) Wind loading on containers shall be based on wind pressures on the projected area at various height zones above ground in accordance with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Wind speeds shall be based on a mean occurrence interval of 100 years.

(D) Seismic loading on containers shall be in accordance with ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. A seismic analysis of the proposed installation shall be made that meets the approval of the authority having jurisdiction.

(E) Shop-fabricated containers shall be fabricated with lifting lugs or other means to lift the container.

Where a container is installed in a vertical rather than a horizontal position, the loading dynamics of the container differ. The methods of support for the vertical container must be designed to account for the increased possibility of toppling the taller container in high wind and seismic conditions. These methods of support are addressed further in 5.2.7.1.

Paragraph 5.2.4.3(B) was changed editorially to employ terms that are commonly used in the ASME *Boiler and Pressure Vessel Code* [1]. The intent remains the same — that is, to require a container to be designed with a maximum allowable working pressure sufficient to encompass all of the pressures present at the bottom of the container.

Paragraph 5.2.4.3(E) requires lifting lugs, but does not require the lugs to carry a specific weight. It must be assumed that the lifting lugs are not adequate to carry the entire weight of the container when filled with LP-Gas or water, so additional support, such as a strapping system, must be used to lift ASME tanks that contain product.

5.2.4.4* ASME engine fuel and mobile containers shall have a MAWP of 312 psig (2.2 MPag) or higher.

A.5.2.4.4 ASME mobile fuel containers constructed prior to April 1, 2001, were required to have a maximum allowable working pressure (MAWP) of 250 psig (1.7 MPag).



The maximum allowable working pressure (MAWP) for engine fuel and mobile containers was changed from 250 psig (1.7 MPag) to 312 psig (2.2 MPag) or higher in the 2004 edition in order to resolve a conflict with NFPA 1192, *Standard on Recreational Vehicles* [9], which required the higher design pressure. The following two safety benefits resulted from this change:

1. The higher design pressure provides a stronger container, which could be important in a vehicle accident.
2. The higher design pressure reduces the remote possibility of pressure relief valve opening in the event of high internal vehicle temperature.

5.2.4.5 Cylinders shall be designed and constructed for at least a 240 psig (1.6 MPag) service pressure.

5.2.5 ASME Container Openings.

5.2.5.1 ASME containers shall be equipped with openings for the service for which the container is to be used.

NFPA 58 does not limit the number of container openings because a properly installed plug, cap, or blind flange will provide an effective seal to maintain the integrity of the container.

5.2.5.2 The openings required by 5.2.5.1 shall be located either in the shell, in the heads, or in a manhole cover.

5.2.5.3* ASME containers of more than 30 gal (0.1 m³) through 2000 gal (7.6 m³) water capacity that are designed to be filled volumetrically shall be equipped for filling into the vapor space.

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FAQ ►
Why is it desirable to fill into the vapor space of the container rather than the liquid space?

A.5.2.5.3 Prior to December 1, 1963, ASME containers greater than 30 gal (0.11 m³) water capacity, up to and including 2000 gal (76 m³) water capacity, were not required to be equipped for filling into the vapor space of the container.

Filling only into the vapor space, but not into the liquid space, more rapidly achieves equilibrium between the vapor and the liquid in the container. Lower container pressure results when filling into the vapor space, compared to filling into the liquid space. Filling only into the vapor space allows containers to be filled more rapidly, because the pump does not have to overcome a greater pressure in the container.

5.2.5.4* ASME containers of 125 gal (0.5 m³) through 2000 gal (7.6 m³) water capacity shall be provided with an opening for an actuated liquid withdrawal excess-flow valve with a connection not smaller than 3/4 in. national pipe thread.



A.5.2.5.4 Containers fabricated on or before July 1, 1961, are exempt from this requirement.

An actuated liquid withdrawal excess-flow valve is defined in **Chapter 3** as follows:

3.3.1 Actuated Liquid Withdrawal Excess-Flow Valve. An excess-flow valve for liquid withdrawal applications that remains in a closed position until actuated by a pipe nipple or adapter, as recommended by the manufacturer, and that is used with a shutoff valve attached to the actuator.

This valve (see **Exhibit 5.9**), which is required by **5.2.5.4**, is needed to remove liquid from ASME containers before they are transported to another location. The DOT regulations require that such tanks can only be transported when the liquid volume is 5 percent or less of the water capacity of the tank. However, a special permit was issued by DOT in 2006 (see Special Permit No. 13341) that allows the transportation of ASME containers with more than 5 percent liquid volume in the container, subject to several limitations. The special permit may be obtained at the following website: http://hazmat.dot.gov/sp_app/special_permits/spec_perm_index.htm

The actuated liquid withdrawal excess-flow valve is more commonly known by the trade names Chek-Lok®, Checkmate®, and SafEvac®, as well as by liquid withdrawal valve with excess flow. An actuated liquid withdrawal valve is operated by removing the valve cap and threading a pipe nipple or adapter (available from the manufacturer) into the valve. As the nipple or adapter turns, the valve opens, liquid flows through the valve until the flow exceeds the excess flow, and the valve closes. (See **Exhibit 5.10**.) A manual valve is then installed to the pipe nipple or adapter, and the valve is closed. A small bypass allows a small amount of vapor to bypass the excess-flow valve, and pressure increases on the outlet side of the adapter. When pressure on both sides of the excess flow disc is about equal, the excess flow valve opens with an audible “click.” The liquid can then be removed.

EXHIBIT 5.9 Actuated Liquid Withdrawal Excess-Flow Valve; Old Style (Left) and Current Style (Center and Right). (Courtesy of Engineered Controls International, Inc.)



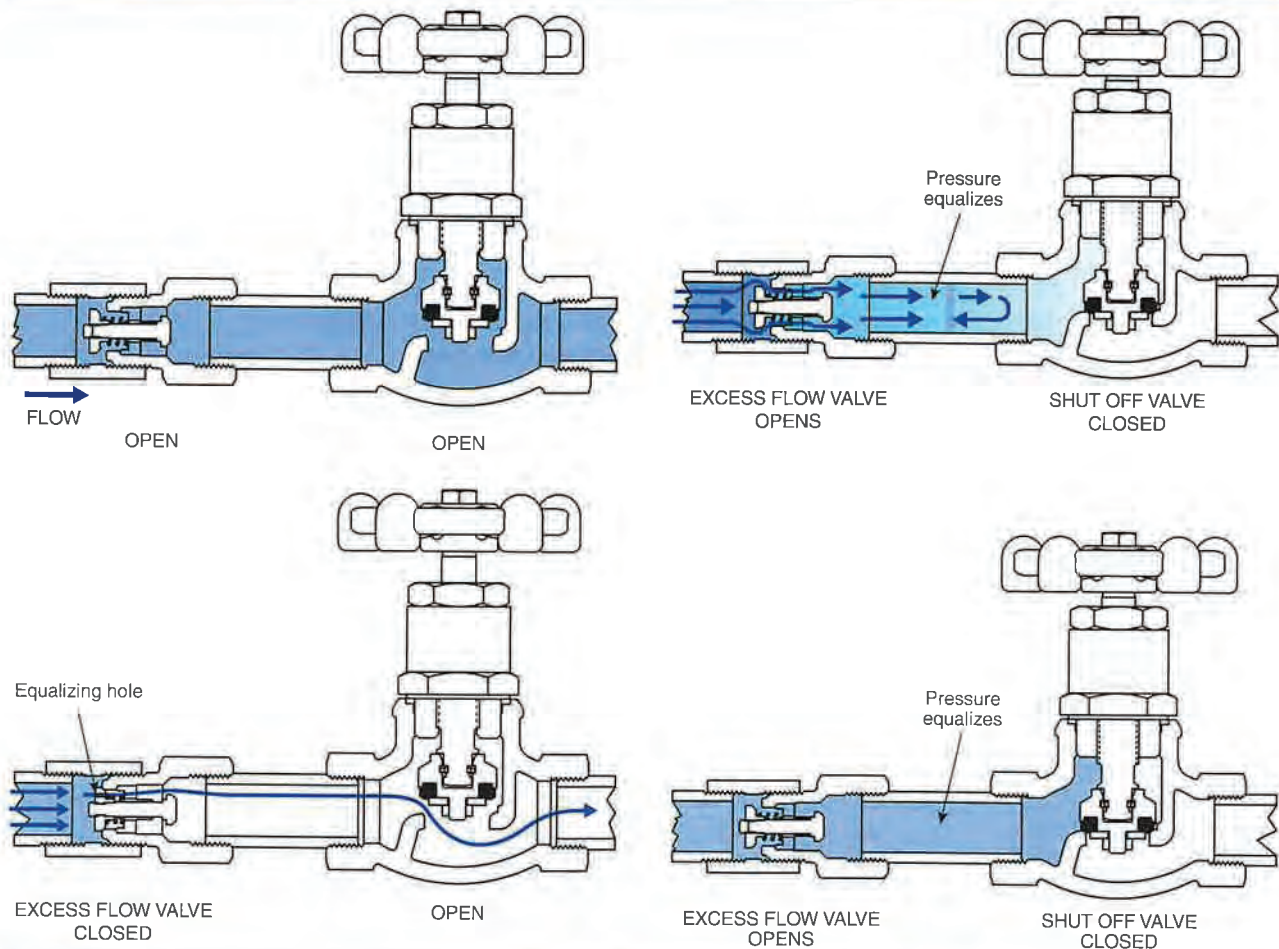


EXHIBIT 5.10 Operation of an Actuated Liquid Withdrawal Excess-Flow Valve. (Courtesy of Fisher Controls Intl, LLC)

Section A of Exhibit 5.10 shows an excess-flow valve in the open position, with a manually operated shutoff valve connected also in the open position. The flow through the excess-flow valve is less than the rate that will close the valve. Section B shows an excess-flow valve in the closed position, because the flow has exceeded the rate that will close the excess-flow valve. Note that a small amount of propane, shown as a blue line, continues to flow through the closed excess-flow valve through a designed bypass, such as a small hole drilled in the valve. The manually operated valve remains in the open position. Section C shows the shut-off valve closed, which has allowed the bypass flow to begin to pressurize the space between the shutoff valve and the excess-flow valve. The spring tension retains the excess-flow valve in the closed position. Section D shows the shutoff valve closed, which has allowed the bypass flow to fully to pressurize the space between the shutoff valve and the excess flow valve. With equal pressure (force) on both sides of the excess flow valve, the spring tension opens the excess flow valve. The shutoff valve can now be opened (slowly) to restart the flow.

In 5.7.4.1(B) and 5.7.4.1(D), the code recognizes that the valves are usually intended for only occasional use and that the valve manufacturer may or may not recommend them for continuous use.

Can an actuated liquid withdrawal excess-flow valve be used on a permanent basis to convert a container to liquid withdrawal service?

◀ FAQ

5.7.4.1(B) Containers of 125 gal through 4000 gal (0.5 m³ through 15.2 m³) water capacity shall be provided with an actuated liquid withdrawal excess-flow valve with a connection not smaller than 3/4-in. national pipe thread.

5.7.4.1(D) The actuated liquid withdrawal excess flow valve shall not be connected for continuous use unless the valve is recommended by the manufacturer for such service.

To the editor's knowledge, the major valve manufacturers recommend that the old-style actuated liquid withdrawal excess-flow valves shown in [Exhibit 5.9](#) (left) should not be used for continuous liquid withdrawal operations. The new-style valves, shown in [Exhibit 5.9](#) (center and right), are more robust, and according to the editor's information, the manufacturers do recommend these new, listed valves for continuous service. To be sure, check with the valve manufacturer.

There is a difference between [5.2.5.4](#) and [5.7.4.1\(B\)](#). The latter paragraph was changed in the 2001 edition to recognize that residential customers' tanks sometimes exceed 2000 gal (7.6 m³), and therefore the assumed upper limit for vapor service residential customers was increased to 4000 gal (15 m³). Tanks larger than 4000 gal (15 m³) were treated as a bulk plant or dispenser tank, for the purposes of establishing the requirements for appurtenances in [5.7.4.1](#). This difference is minor, as there are relatively few containers in the size range greater than 2000 gal (7.6 m³) up to 4000 gal (15 m³).

5.2.5.5* ASME containers of more than 2000 gal (7.6 m³) water capacity shall have an opening for a pressure gauge.



A.5.2.5.5 See [5.7.8.6](#) for the pressure gauge requirement.

Knowledge of the pressure in larger containers is useful, especially during liquid transfer operations. When installing a pressure gauge, reference should be made to [5.7.6.2](#), which reminds the user of an important safety feature requiring either a maximum opening of a No. 54 drill size between the container and the pressure gauge or installation of an excess-flow check valve. This safety feature prevents discharge of significant amounts of LP-Gas in case the pressure gauge is broken off. In the 2008 edition, Annex A text was added that refers to the requirement for pressure gauges in [5.7.8.6](#).

5.2.5.6 ASME containers in storage or use shall have pressure relief valve connections that have direct communication with the vapor space of the container.

(A) If the pressure relief valve is located in a well inside the ASME container with piping to the vapor space, the design of the well and piping shall have a flow capacity equal to or greater than that of the pressure relief valve.

(B) If the pressure relief valve is located in a protecting enclosure, the enclosure shall be designed to minimize corrosion and to allow inspection.

(C) If the pressure relief valve is located in any position other than the uppermost point of the ASME container, the connection shall be internally piped to the uppermost point practical in the vapor space of the container.

FAQ ►

Why is it important that the relief valve be in communication with the vapor space of a container?

By discharging vapor through the relief valve, the total quantity of LP-Gas escaping to the atmosphere is reduced, compared to discharging liquid, and the pressure within the container is reduced more quickly. Because of the high liquid-to-vapor expansion ratio of LP-Gas (270 to 1 for propane), a liquid discharge through the relief valve represents a much greater quantity of gas discharging into the atmosphere. If vapor is discharged, the pressure is reduced inside the container and the remaining liquid boils, cooling the liquid and thus reducing the pressure in the container. If liquid is discharged, the following results:

- Vaporization occurs outside the container.
- There is no cooling effect from vaporization inside the container.
- Container pressure is higher.

These factors are significant if the valve is discharging as a result of fire exposure.

The relief valve must either be located at the uppermost point of the container or be internally piped to the uppermost point practical in the vapor space of the container. This provision recognizes that some containers used for engine fuel and recreational vehicle applications have been manufactured with the relief valve located just above the 80 percent liquid level. The provision that the relief valve be piped to the uppermost point practical in the container recognizes that, in some containers — for example, portable lift truck cylinders that are stored vertically and used horizontally — the relief valve inlet cannot be located at the uppermost point for use in both positions.

5.2.5.7* ASME containers to be filled on a volumetric basis shall be fabricated so that they can be equipped with a fixed maximum liquid level gauge(s) that is capable of indicating the maximum permitted filling level(s) in accordance with **7.4.2.3**.

A.5.2.5.7 Containers fabricated on or before December 31, 1965, are exempt from this requirement.

Variable liquid level gauges indicate liquid level over most of the container's capacity range but are not completely reliable. The float may develop a leak, the float arm may sag over time, the mechanism may bind, or the gauge may otherwise indicate an inaccurate reading. Therefore, a fixed maximum liquid level gauge is required by **5.2.5.7** to be used to accurately fill the container.

5.2.6 Portable Container Appurtenance Physical Damage Protection.

5.2.6.1 Cylinders of 1000 lb (454 kg) water capacity [nominal 420 lb (191 kg) propane capacity] or less shall incorporate protection against physical damage to cylinder appurtenances and immediate connections to such appurtenances when not in use by either of the following means:

- (1) A ventilated cap
- (2) A ventilated collar

The cap or collar described in **5.2.6.1** and shown in **Exhibit 5.11** is required to provide physical protection for the valves and any other appurtenances connected to the cylinder.



Cylinders are portable and normally are transported from their normal use point to a filling point; there are inevitable occurrences where the cylinder is involved in a transportation incident, falls over, or is dropped. If a removable cap is used, it must be in place prior to moving the cylinder. The cap also provides a lifting point for the cylinder. The valve must never be used for lifting a cylinder. Ventilation openings are required to permit discharge from the pressure relief valve to dissipate.

5.2.6.2 Protection of appurtenances of portable containers, skid tanks, and tanks for use as cargo tanks of more than 1000 lb (454 kg) water capacity [nominal 420 lb (191 kg) propane capacity] shall comply with **5.2.6.2(A)** through **5.2.6.2(C)**.

(A) Appurtenance protection from physical damage shall be provided by recessing, by protective housings, or by location on the vehicle.

(B) Appurtenance protection shall comply with the provisions under which the containers are fabricated.



(C) Appurtenance protection shall be secured to the container in accordance with the ASME code under which the container was designed and built.

Paragraph **5.2.6.2(C)** was revised in the 2008 edition with regard to the design of appurtenance protection to refer to the code under which the container was built, instead of specifying the safety factors to be used. As the appurtenance protection is usually installed by the container manufacturer or assembler of a portable tank unit, it is reasonable to assume that the fabricator has access to the container construction code.

5.2.7 Containers with Attached Supports.

5.2.7.1 Vertical ASME containers of over 125 gal (0.5 m³) water capacity for use in permanent installations in stationary service shall be designed with steel supports that allow the container to be mounted on and fastened to concrete foundations or supports.

(A) Steel supports shall be designed to make the container self-supporting without guy wires and to withstand the wind and seismic (earthquake) forces anticipated at the site.

(B) Steel supports shall be protected against fire exposure with a material having a fire resistance rating of at least 2 hours.

(C) Continuous steel skirts having only one opening of 18 in. (460 mm) or less in diameter shall have 2-hour fire protection applied to the outside of the skirt.

Vertical containers, as shown in **Exhibit 5.12**, are used where space is not available for horizontal containers. Because the failure of a vertical tank's structural supports can result in severe damage to the container when it falls, there are special fire protection requirements for the supports. The two-hour fire resistance rating is obtained by using a protective material that has been tested to the requirements of ASTM E-119, *Standard Test Methods for Fire Tests of Building Construction and Materials* [10], a standard used to determine the fire resistance rating of structural elements. Vertical tanks are most often located at propane vehicle refueling stations where space is usually at a premium. Larger vertical tanks have also been installed where land cost is very high, such as near New York City.

Paragraph **5.2.7.1(C)** addresses vertical tanks equipped with continuous steel skirts, which are not normally found at propane dispensing locations, but are more common in refineries. Their use is permitted where the skirt is protected with fire resistance-rated insulation on its exterior.

5.2.7.2 ASME containers to be used as portable storage containers, including movable fuel storage tenders and farm carts for temporary stationary service (normally not more than 12 months duration at any location), shall comply with **5.2.7.2(A)** through **5.2.7.2(D)**.



EXHIBIT 5.12 Vertical Container.

Notification of temporary installations is required by 4.3.2, and notification is required for all installations of 12 months or less. (See the commentary following 4.3.2 for additional information.)

(A) The legs or supports, or the lugs for the attachment of legs or supports, shall be secured to the container in accordance with the ASME code under which the container was designed and built.



(B) The attachment of a container to either a trailer or semi-trailer running gear, or the attachments to the container to make it a vehicle, so that the unit can be moved by a conventional over-the-road tractor, shall comply with the DOT requirements for cargo tank service.



(C) The unit shall be approved for stationary use.



(D) Movable fuel storage tenders, including farm carts, shall be secured to the trailer support structure for the service involved.



Paragraph 5.2.7.2 was revised in the 2008 edition to reference the ASME *Boiler and Pressure Vessel Code* [1], rather than to extract selected parts. Significant changes are as follows:

1. Former subparagraphs 5.2.7.2(A) and (B) are combined into (A), as they both covered the attachment of legs or supports, and reference to the specific safety factor of 4 is deleted and replaced with a reference to the ASME *Boiler and Pressure Vessel Code*.
2. Subparagraph 5.2.7.2(B), formerly (C), was revised by deletion of the last sentence, which had provided a design basis for a stress calculation. This topic is covered in the DOT regulations, and the technical committee believes that DOT is in a better position to regulate design of container attachments.
3. Subparagraph 5.2.7.2(D) is not new, but was relocated from 5.2.7.4 as it deals with the subject of securing a container to its supports.

See Exhibit 9.12 in Chapter 9 for a photo of a farm cart.



5.2.7.3 Portable tank design and construction of a full framework, skids, or lugs for the attachment of skids, and protection of fittings shall be in accordance with DOT portable tank specifications. The bottom of the skids shall be not less than 2 in. (50 mm) or more than 12 in. (300 mm) below the outside bottom of the tank shell.

Section 5.2.7.3 was revised to insert the words “full framework” into the text. This change makes the code consistent with Title 49 of the Code of Federal Regulations.

5.2.8 Container Marking.

5.2.8.1 Cylinders shall be marked as provided in the regulations, rules, or code under which they are fabricated.

(A) Where LP-Gas and one or more other compressed gases are to be stored or used in the same area, the cylinders shall be marked “Flammable” and either “LP-GAS,” “Propane,” or “Butane,” or shall be marked in accordance with the requirements of 49 CFR, “Transportation.”

(B) When being transported, cylinders shall be marked and labeled in accordance with 49 CFR, “Transportation.”

By referencing the code of fabrication for marking requirements, NFPA 58 defers to the requirements of other codes. ASME containers require a nameplate with all required markings, while DOT cylinders require stamping in the head and other markings.

The requirements of DOT regulations can be difficult to understand. Markings and labeling of cylinders have specific meanings within the context of the DOT, as the following two paragraphs explain.

Labels. Hazardous materials labels are normally printed on or affixed to cylinders containing hazardous materials. They are color- and symbol-coded to afford easy and immediate recognition of the existing hazards. Cylinders containing propane require the label to appear as a diamond with a red background and at least 3.9 in.², unless the neck ring listed in CGA-Pamphlet 7 shown in Exhibit 5.13 is used. The “2” represents the hazard class, which is “compressed gas.” Sometimes the number “2.1” will appear instead of “2.” The “2.1” represents the hazard class division and denotes “flammable gas.”

Markings. Markings are printed on or affixed to packages of hazardous materials such as propane cylinders to convey additional information about the hazardous material being transported. Cylinders that contain hazardous materials must be marked with the proper name of the material (either “Liquefied Petroleum Gas” or “Propane” and the shipping identification number, usually “1075” but may also be “1978”).

5.2.8.2* Cylinders shall be marked with the following information:

- (1) The water capacity of the cylinder in pounds
- (2) The tare weight of the cylinder in pounds, fitted for service



EXHIBIT 5.13 DOT
Flammable Gas Label (Red).

A.5.2.8.2 The tare weight is the cylinder weight plus the weight of all permanently attached valves and other fittings but does not include the weight of protecting devices that are removed in order to load the cylinder.

Exhibit 5.14 illustrates a typical DOT cylinder marking. Note that the cylinder manufacturer's name, serial number, DT specification number, tare weight, and water capacity are shown. The date of manufacture and the retest date are of special importance. NFPA 58 prohibits the refilling of a cylinder if the requalification or inspection date of the cylinder has passed.



EXHIBIT 5.14 DOT Cylinder Marking. (Tank courtesy of Worthington Cylinder Corp.)

5.2.8.3* The markings specified for ASME containers shall be on a stainless steel metal nameplate attached to the container, located to remain visible after the container is installed.

(A) The nameplate shall be attached in such a way as to minimize corrosion of the nameplate or its fastening means and not contribute to corrosion of the container.

(B) Where the container is buried, mounded, insulated, or otherwise covered so the nameplate is obscured, the information contained on the nameplate shall be duplicated and installed on adjacent piping or on a structure in a clearly visible location.

(C) ASME containers shall be marked with the following information:

- (1) Service for which the container is designed (for example, underground, aboveground, or both)
- (2) Name and address of container supplier or trade name of container
- (3) Water capacity of container in pounds or U.S. gallons
- (4) MAWP in pounds per square inch
- (5) The wording "This container shall not contain a product that has a vapor pressure in excess of ___ psig at 100°F" (See [Table 5.2.4.2.](#))
- (6) Outside surface area in square feet
- (7) Year of manufacture
- (8) Shell thickness and head thickness
- (9) OL (overall length), OD (outside diameter), HD (head design)
- (10) Manufacturer's serial number
- (11) ASME Code symbol

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- (12) Minimum design metal temperature ____°F at MAWP ____ psi
 (13) Type of construction “W”
 (14) Degree of radiography “RT-____”

A.5.2.8.3 Head design refers to the shape of the head. Shapes include hemispherical, semi-ellipsoidal, and others. (Refer to the API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases for more information.)

The container nameplate, as shown in Exhibit 5.15, must be stainless steel and must be attached to the container in order to eliminate the possibility of corrosion to the nameplate, fasteners, or the container. Container corrosion can occur if water is trapped between the nameplate and the container. The nameplate is usually attached to the container using a continuous stainless steel weld around the nameplate. Because the ASME Code requires the nameplate to be attached to a container (otherwise the container does not meet the ASME Code), the need for this provision is consistent with the long service life of propane containers. This requirement exceeds the ASME Code requirements, which do not specify how the nameplate is attached. This provision is not in conflict with the ASME Code, but it is important to be aware of the provision if ordering a propane container from a fabricator that does not normally fabricate propane containers.

EXHIBIT 5.15 Optional Container Listing on Container Nameplate. (Courtesy of Trinity Containers, LLC)

S.N./NAT'L BD. 			
CERTIFIED BY			
TRINITY CONTAINERS, LLC		DALLAS, TX	
MAWP: 250 PSIG @ 125°F			
MDMT: -20°F @ 250 PSIG			
	YEAR BUILT		37.42"
			O.S. DIA.
W RT	HEMI	500	1,892.5
	HEAD D.R.	NOM W.G.	LITERS
4	0.218"	0.185"	118"
	SHELL THK	HEAD THK	LENGTH
UG	98	89% =	
TYPE	OSSA, S.F.	DIP TUBE	
CRN			
CANADIAN REGISTRATION NUMBER			
THIS CONTAINER SHALL NOT CONTAIN A PRODUCT HAVING A VAPOR PRESSURE IN EXCESS OF 215 PSIG AT 100°F			
NPI		1711290191 rC	

FAQ ►

Can a container without a nameplate be used in LP-Gas service?

Nameplates provide the operating parameters used in the design of the container and information on the materials used. If the nameplate is missing, the container cannot be used as a pressure vessel. It may be possible to obtain a replacement nameplate, if the manufacturer is still in business, and records of the container construction are available.

The provisions for buried or mounded tanks in 5.2.8.3(B) require that duplicate nameplate information be provided in a visible location if the original nameplate is obscured. This additional marking permits verification of the container nameplate information without digging up an underground container, which could damage the container; the protective coating; or a cathodic protection system, if one is used.

The information required by 5.2.8.3(C)(12) through 5.2.8.3(C)(14) was revised in the 2004 edition and was inserted to make the requirements of NFPA 58 consistent with the manufacturers' requirements in the ASME *Boiler and Pressure Vessel Code* [1]. Containers manufactured prior to this edition of NFPA 58 are not required to display this new information on the nameplate.

5.2.8.4 Warning labels shall meet the following requirements:

- (1) Warning labels shall be applied to all cylinders of 100 lb (45.4 kg) propane capacity or less that are not filled on site.
- (2) Warning labels shall include information on the potential hazards of LP-Gas.



The requirements in 5.2.8.4 recognize the need to provide warning to users who are not familiar with the properties and potential hazards of propane. A variety of labels address various container sizes and uses. Exhibits 5.16 and 5.17 show examples of different types of warning labels. This requirement was clarified in the 2008 edition by deleting "LP-Gas capacity" and substituting "propane capacity" as propane and butane, which are both LP-Gases, have different densities and therefore different weights for a full cylinder of the same volume. The term *filled on site* means filled at the usage site and typically applies to cylinders permanently installed at buildings that are filled by a propane delivery truck (bobtail). Cylinders that are filled on site do not require a warning label because the consumer does not handle or install the cylinder.

Warning labels are only required on portable cylinders of 100 lb propane capacity (45.4 kg water capacity) and less, because these are the containers that are most likely to be used by consumers of gas who may not be familiar with the hazards associated with LP-Gas. Larger cylinders are assumed to be handled only by propane companies, although there are probably a few exceptions.

The code does not specify the text of a label. The label must include information on the potential hazards of LP-Gas as well as other information. Many labels include a warning that the cylinder must not be brought into buildings. This is true for most cylinders, but not all. In accordance with Section 6.19 certain cylinders can be brought into buildings. A warning stating that the cylinder may not be brought into buildings should not be placed on such

FAQ

What kind of warning label is needed on a propane tank?

DANGER - FLAMMABLE GAS UNDER PRESSURE - LEAKING LP-GAS CAN CAUSE A FIRE OR EXPLOSION IF IGNITED-CONTACT LP-GAS SUPPLIER FOR REPAIRS OR DISPOSAL OF THIS CYLINDER OR UNUSED LP-GAS - FOR OUTDOOR USE ONLY - DO NOT USE OR STORE CYLINDER IN A BUILDING, GARAGE OR ENCLOSED AREA*

Customer Warning:

- Know the odor of LP-gas. Under certain circumstances, you may not be able to smell the odor. If you hear or smell leaking LP-gas, immediately get everyone away from the cylinder and call the fire department.
- Caution your LP-gas supplier to:
 - purge the cylinder of trapped air prior to first filling
 - check the cylinder's liquid level date
 - be certain not to overfill the cylinder
- LP-gas is heavier than air and can settle in low places while dissipating.
- Contact with the liquid contents of the cylinder will cause freeze burns to skin.
- Do not allow children to tamper or play with the cylinder.
- When the cylinder is not connected for use, keep the valve turned off. If your cylinder valve looks like Figure 1 and is of 45 lb LP-gas capacity or less, it must also be plugged.
- Do not use, store or transport cylinder where it could be exposed to high temperatures. Relief valves can open allowing a large amount of flammable gas to escape.
- When transporting, keep cylinder secured in an upright position with cylinder valve turned off. If the cylinder is of 45 lb LP-gas capacity or less and looks like Figure 1, it must also be plugged.
- Self-contained outdoor cooking appliances must be limited to one cylinder of 22 pounds LP-gas capacity or less.

When Connecting for Use:

- Use only in compliance with applicable codes.
- Read and follow appliance manufacturer's instructions.
- If the regulator has a male threaded coupling nut, it has left handed threads and must be tightened by turning counter clockwise (Figure 1).
- If regulator has a plug-in connection, pull valve sleeve back, insert fully and release valve sleeve (Figure 2). If the regulator has a female threaded coupling nut and the cylinder valve has large outside threads, tighten the coupling nut by turning clockwise (Figure 3).
- Turn off all valves on appliance.
- Do not check for gas leaks with match or open flame.
- Apply soapy water to all areas marked X and open valve. If bubbles appear, close valve and have an LP-gas service person make needed repairs. Also check appliance valves and connections for leakage before lighting appliance.
- Light appliance(s) following manufacturer's instructions.
- When appliance(s) is not in use, keep cylinder valve closed.

DO NOT REMOVE, DEFACE OR OBLITERATE THIS LABEL

***EXCEPT AS AUTHORIZED BY NFPA 58**

FIG. 1

POL TYPE

FIG. 2

SPRING-LOADED SLEEVE

FIG. 3

OCC TYPE

PROPANE

LIQUEFIED PETROLEUM GAS UN 1075

PERSONAL PROTECTION

- Extremely flammable Gas
- Heavier than Air
- Simple Asphyxiant
- Customized to warn of its presence
- Contact with Liquid will cause Freezing of Tissue
- PEL 1000 PPM
- Store container outside and keep cool (under 130 F.)

CONSULT CORRESPONDING MSDS FOR FURTHER INFORMATION AND INSTRUCTIONS

APPLY TO ALL PORTABLE CONTAINERS USED BY COMMERCIAL CUSTOMERS

Do not attempt repairs - Call your LP-Gas Dealer

Turn off container valve when not in use.

This LP tank is equipped with a safety relief valve. Do not place inside any enclosed or heated area.

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EXHIBIT 5.16 Sample Warning Label Intended for Gas Grill Cylinders. (Courtesy of Screen Graphics of Florida)

EXHIBIT 5.17 Sample Warning Label Intended for Use on Cylinders in Commercial or Industrial Service. (Courtesy of Screen Graphics of Florida)



cylinders. Although this may seem obvious, problems have arisen when inspectors have found cylinders that are permitted by [Section 6.19](#) to be used in buildings that have labels stating that they must not be used in buildings. This situation occurs because the most common size of propane cylinders is 20 lb, and their most common use is with gas grills. Cylinder manufacturers usually provide a warning label that anticipates use of the cylinder with gas grills, unless otherwise specified.

FAQ ►

Can the warning label required for cylinders of 100 lb or less be applied on an enclosure holding the cylinder or on another cylinder cover?

The code does not specify the form of the label, only that it be applied to the cylinder. Applied means “to put on.” Therefore, the label can be glued to the container or be attached by a mechanical means such as a plastic strip. If the label is not on the cylinder, but on an enclosure holding the cylinder, or on a cylinder cover or other container, it has not been applied to the cylinder and does not meet the requirement of [5.2.8.4](#). Therefore, if a decorative cover or plastic sleeve is used to cover a cylinder, the required label must be on the cylinder, and can also be on the cover or sleeve.



5.2.8.5 All containers that contain unodorized LP-Gas products shall be marked NOT ODORIZED. The marking shall have a contrasting background surrounded by a rectangular border in red letters and red border in the sizes shown in [Table 5.2.8.5](#). The markings shall be on both ends or on both sides of a container or on both sides and the rear of cargo tanks.

TABLE 5.2.8.5 NOT ODORIZED Label Size

Water Capacity		Letter Height		Border Width	
gal	L	in.	cm	in.	cm
499 and over	1881 and over	4.0	10.0	1/2	1.3
49 to 498	184 to 1880	1.5	3.7	3/16	0.8
2.6 to 48	10 to 183	3/4	1.8	1/4	0.6
1 to 2.5	4 to 9	3/8	1.0	1/16	0.2

FAQ ►

Are any special precautions needed when storing LP-Gas that has not been odorized?

The marking NOT ODORIZED on ASME containers of unodorized propane provides important information to emergency responders. (See [Exhibit 5.18](#).) The lack of odorant in a storage container adds to the potential hazard that both users and emergency responders face. By providing a visible marking, everyone working around stationary containers holding unodorized LP-Gas is made aware of the absence of odorant. If leakage is suspected, alternate sensing devices can be used to locate the leak.



EXHIBIT 5.18 ASME Containers Marked NOT ODORIZED.

Paragraph 5.2.8.5 was revised in the 2008 edition of the code to expand its applicability to not only ASME containers, but cylinders as well. Table 5.2.8.5 was added in recognition that 2 in. letters would not fit on smaller containers.

Unodorized propane is also likely to be found at refineries, import terminals, pipeline terminals, and other similar locations. Odorant is normally added to bulk shipments of propane leaving these facilities.

Odorized LP-Gas cannot be used in a few applications; for example, where propane is used as a chemical feedstock and the odorant could poison a catalyst; where butane is used as a foaming gas in the manufacture of styrene trays used to package meats for retail display; or where butane is used as a propellant in filling aerosol cans.

5.3 Reserved

5.4 Reserved

5.5 Reserved

5.6 Reserved

5.7 Container Appurtenances and Regulators



In the early days of distribution of bulk quantities of LP-Gas to an ASME container located on the consumer's premises, each container assembly of 1200 gal (4.5 m³) [and subsequently 2000 gal (7.6 m³)] water capacity or less had to be tested and listed, or inspected and approved, by the authority having jurisdiction. Each appurtenance and regulator on larger containers also had to be listed. Many LP-Gas distributing companies and container fabricators had their own systems listed by Underwriters Laboratories Inc. (UL). Today, the individual appurtenances are tested and listed and either shop-installed by container fabricators or field-installed. Section 5.7 addresses criteria for such appurtenances, which are used as a basis for testing laboratories, manufacturers, and installers.

5.7.1 Materials.



5.7.1.1 Container appurtenances and regulators shall be fabricated of materials that are compatible with LP-Gas and shall be resistant to the action of LP-Gas under service conditions. The following materials shall not be used:

- (1) Gray cast iron
- (2) Nonmetallic materials, for bonnets or bodies of valves or regulators

FAQ ►

Can cast iron be used as a material to construct an appurtenance for an ASME container?

Gray cast iron is prohibited because cast iron can be subject to cracking and failing from mechanical shock and from severe thermal shock under fire conditions. The requirement for using metallic materials for the bodies of valves and regulators ensures that exposure of the device to the elements, a fire, or mechanical abuse will result in a reasonable expectation that the device will continue to function without creating a safety hazard. Although there have been considerable improvements in the temperature and pressure capabilities of plastic materials, these materials still do not approach the melting or softening point of metals.

5.7.1.2* Pressure-containing metal parts of appurtenances shall have a minimum melting point of 1500°F (816°C), except for the following:

- (1) Fusible elements
- (2) Approved or listed variable liquid level gauges used in containers of 3500 gal (13.2 m³) water capacity or less

A.5.7.1.2 Materials with melting points exceeding 1500°F (816°C) include steel, ductile (nodular) iron, malleable iron, or brass, as follows:

- (1) Ductile iron should meet the requirements of ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*, or equivalent and malleable iron should meet the requirements of ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings*, or equivalent.
- (2) Approved or listed variable liquid level gauges used in containers of 3500 gal (13.2 m³) water capacity or less are exempt from the minimum melting point requirement.
- (3) Cast-iron should not be used.
- (4) Nonmetallic materials should not be used for bonnets or bodies of valves or regulators.

The melting-point criteria for metal parts of appurtenances in 5.7.1.2 are intended to provide a degree of structural integrity in the event of exposure to fire and the application of water for fire control. However, appurtenance configuration, mass, and location on the container affect the degree of hazard to the appurtenance. Paragraph 5.7.1.2(2) for liquid level gauges on smaller containers reflects this consideration.

Note that metal used for pressure-containing parts is required to have a melting point of at least 1500°F (816°C). Most metals and alloys become structurally unusable at temperatures approaching one-third to one-half their Fahrenheit melting points, making materials with melting points below 1500°F (816°C) a potential safety concern should the appurtenance be exposed to fire.



5.7.1.3 Container appurtenances shall have a service pressure of at least 250 psig (1.7 MPag).

5.7.1.4 Gaskets used to retain LP-Gas in containers shall be resistant to the action of LP-Gas.

(A) Gaskets shall be made of metal or other material confined in metal having a melting point over 1500°F (816°C) or shall be protected against fire exposure.

(B) When a flange is opened, the gasket shall be replaced.

(C) Aluminum O-rings and spiral wound metal gaskets shall be permitted.

(D) Gaskets for use with approved or listed liquid level gauges for installation on a container of 3500 gal (13.2 m³) water capacity or less shall be exempt from the minimum melting point requirement.

LP-Gas systems must be able to maintain their integrity when subjected to fire. Therefore, the requirements in 5.7.1.4 that gaskets maintain their integrity when subjected to a temperature of 1500°F (816°C) limits their use to those materials that have the best chance of maintaining their integrity in a fire. Other gasket materials, such as Teflon® and rubber, are permitted only when the flange containing the gasket is protected against fire exposure. This protection, although not specified, must safeguard the gasket from temperatures that would degrade it in a reasonably expected fire condition. A thermal insulating material that would not be degraded in a fire situation can be used.

When a flange is opened, the gasket can be damaged, and the damage may not be visible to the person opening the flange. Therefore, gasket replacement is required.

Aluminum O-rings and spiral-wound metal gaskets are permitted because of long and successful experience with this equipment, which has been listed for many years.

5.7.2 Pressure Relief Devices.

(See [Section 5.13](#) for hydrostatic relief valves.)

[Subsection 5.7.2](#) applies to pressure relief devices that relieve vapor only. Hydrostatic relief valves, which release liquid, are not addressed here, but are addressed in [Section 5.13](#).

5.7.2.1 ASME containers shall be equipped with one or more pressure relief valves that are designed to relieve vapor.

The requirement in [5.7.2.1](#) restates a key safety requirement, namely, that one or more pressure relief valves are required on all ASME containers. The number of valves is not important, as long as adequate relief capacity (flow) is provided. Pressure relief valves open when the pressure in the container reaches the rated pressure of the relief valve. The valves are required to be in communication with the vapor space of the container so that they release vapor, not liquid LP-Gas.

5.7.2.2 Cylinders shall be equipped with pressure relief valves as required by DOT regulations.

In the 2004 edition of the code, a requirement that appeared in previous editions stating that the start-to-discharge pressure for spring-loaded pressure relief valves used to protect cylinders must be between 75 percent and 100 percent of the minimum required test pressure for the cylinder was deleted. Although no longer included in the code, this provision is still a requirement because the DOT regulations specify the relief valve setting through a reference to CGA S-1.1 *Pressure Relief Device Standards, Part I—Cylinders for Compressed Gases* [11]. The NFPA Technical Committee on Liquefied Petroleum Gases simply felt that it was inappropriate to re-state this requirement. Because cylinder pressure relief valves are provided with cylinders, the requirement is for the cylinder manufacturer, rather than the propane user, and is not needed in NFPA 58.

Most propane cylinders have a service pressure of 240 psig (1.6 MPa). Therefore, DOT requires the test pressure for these cylinders to be at least 480 psig (3.3 MPa). Based on the requirement in CGA S-1.1, the start-to-discharge setting for pressure relief valves in these cylinders would be between 360 psig (2.5 MPa) and 480 psig (3.3 MPa). In actual practice, many of these relief valves are set at 375 psig (2.6 MPa).

5.7.2.3 DOT nonrefillable metal containers shall be equipped with a pressure relief device(s) or system(s) that prevents propulsion of the container when the container is exposed to fire.

DOT regulations in 49 CFR 173.301(f) require that cylinders in butane and propane service be equipped with one or more pressure relief devices selected and tested in accordance with

CGA S-1.1, *Pressure Relief Device Standards* [11]. A pressure relief valve (see [Exhibit 5.19](#)) is always required, and a fusible plug can be installed in addition to the pressure relief valve. The pressure relief device system must be capable of preventing rupture of the normally charged cylinder when the cylinder is subjected to a bonfire fire test conducted in accordance with CGA C-14, *Methods for Hydrostatic Testing of Compressed Gas Cylinders* [12].

DOT-specification 2P and 2Q nonrefillable metal containers are used primarily for aerosol products. The 2P and 2Q containers have also been used with LP-Gas, specifically butane, for portable butane-fired appliances and for refilling butane cigarette lighters.

In [5.7.2.2](#), all cylinders are required to have relief devices. In accordance with 49 CFR 173.304(d)(3)(ii) [13], DOT 2P and 2Q nonrefillable metal containers are authorized for LP-Gas. However, depending on the pressure and the quantity of gas, cylinders may not be required to be equipped with a relief device. The LP-Gas committee believes, however, that any container for LP-Gas must contain a relief device or system to help prevent failure or propulsion of the container. Small LP-Gas cylinders can be very dangerous in warehouse fires because they have been known to “rocket” and spread the fire laterally. Sprinkler systems are not always able to contain warehouse fires that involve aerosol containers, resulting in the loss of the structure. Requiring cylinders to have relief devices prevents such incidents involving butane containers. There are at least two ways to prevent “rocketing” of cylinders exposed to fire, as follows:

- A designed point of weakness in the cylinder that forces the failure mode by over-pressure and causes the partial separation of the bottom or top of the cylinder (This method results in the gas being released quickly over a large area with little propelling force. Some butane 2P and 2Q containers being sold for use with portable cooking stoves contain a weakness point at one seam that provides pressure relief without rocketing. See [Exhibit 5.20](#), in

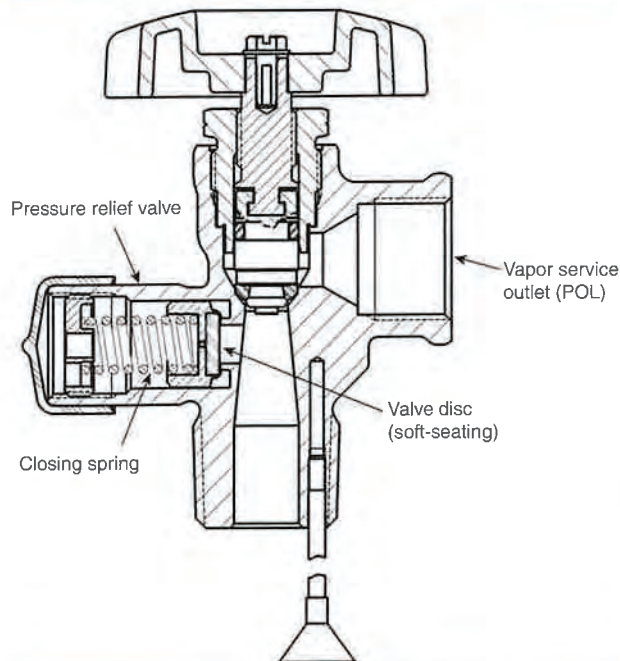


EXHIBIT 5.19 Pressure Relief Valve on DOT/TC Cylinder. On these cylinders, the relief valve is part of a fitting that includes the manual shutoff valve. (Courtesy of Engineered Controls International, Inc.)



EXHIBIT 5.20 Indentations on the Upper Rim Seal of a Listed Butane Cylinder.

which small dents at the top seam of a butane cylinder can be seen. These weakness points provide the pressure relief.

- An inert, porous fill in the cylinder that slows the release of gas in the event of cylinder failure

5.7.2.4 ASME containers for LP-Gas shall be equipped with direct spring-loaded pressure relief valves conforming with applicable requirements of UL 132, *Standard on Safety Relief Valves for Anhydrous Ammonia and LP-Gas*, or other equivalent pressure relief valve standards.

(A) The start-to-leak setting of such pressure relief valves, in relation to the pressure rating of the container, shall be in accordance with **Table 5.7.2.4(A)**.

The provision in **5.7.2.4** specifically states that spring-loaded pressure relief valves must comply with UL 132, *Standard on Safety Relief Valves for Anhydrous Ammonia and LP-Gas* [2], or its equivalent. UL 132 is essentially an exception to the mandatory reference to the ASME Code in 5.2.1.1, which states in part:

Containers shall be designed, fabricated, tested, and marked (or stamped) in accordance with the regulations of the . . . *ASME Boiler and Pressure Vessel Code*, Section VIII, "Rules for the Construction of Unfired Pressure Vessels," . . . except for UG-125 through UG-136.

This exception recognizes differences between the ASME Code and UL 132. The difference between the pressure relief valve requirement of the *ASME Boiler and Pressure Vessel Code* [1] and UL 132 is that ASME requires a larger pressure relief valve because of its more conservative testing method, which requires larger pressure relief valves than those required by UL 132.

Exhibit 5.21 shows a pressure relief valve that is used with a relief valve manifold for a large ASME container and **Exhibit 5.21** shows an external pressure relief valve for an older, small ASME container. The manifold allows the pressure relief valves to be removed individually for testing or replacement without emptying the container of propane.

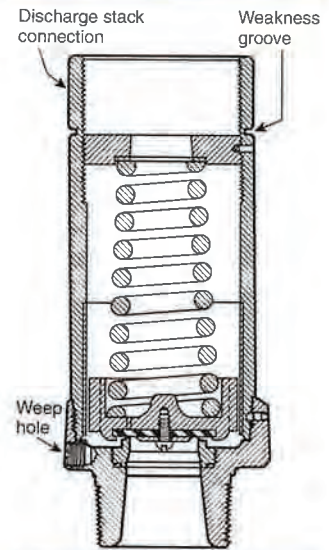


EXHIBIT 5.21 External-Type Pressure Relief Valve for Large Stationary ASME Container for Use with a Relief Valve Manifold. (Courtesy of Engineered Controls International, Inc.)

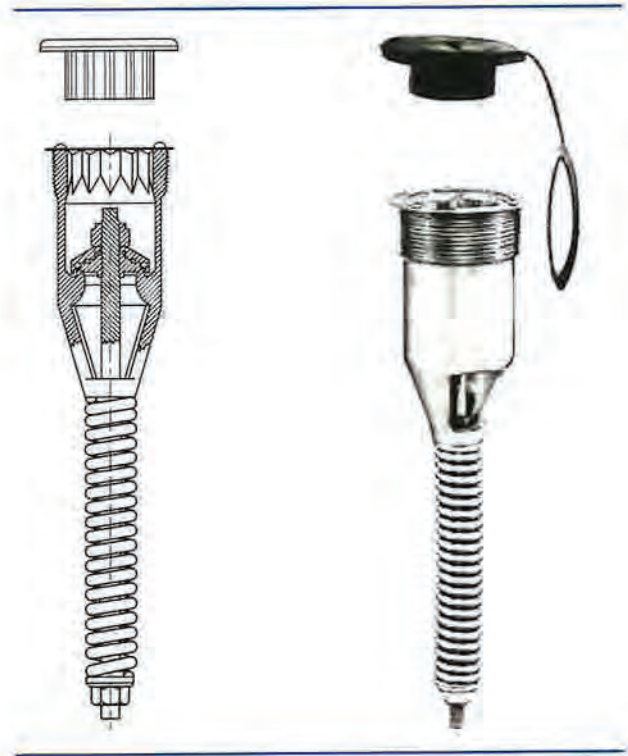


EXHIBIT 5.22 External-Type Pressure Relief Valve for Older, Small ASME Container. (Courtesy of Engineered Controls International, Inc.)

A difference still exists between the ASME Code and other standards — the official capacity of the valves. The ASME Code requires 10 percent derating of the average test capacities of three samples to determine the official capacity of the valve. NFPA 58 and UL 132 do not require such derating.

Reference is made to “direct spring-loaded pressure relief valves” to describe accurately the type of relief valve desired on ASME containers used in installations covered by NFPA 58. Various types of direct spring-loaded pressure relief valves exist, such as flush-type internal pressure relief valves used on cargo containers and full internal-type pressure relief valves for engine fuel containers. (See [Exhibit 5.23](#) and [11.4.1.7](#).) More complex types, such as pilot-operated pressure relief valves, are not needed, are unlikely to receive adequate maintenance, and could result in undesirable frequent premature operation in facilities covered by NFPA 58. Pilot-operated pressure relief valves can only be used on containers larger than 40,000 gal because of their excellent history of use on these larger containers. Simpler devices also exist; for example, burst discs that fail catastrophically at the relief set pressure and cannot reclose. Burst discs are not permitted because the entire contents of the container would be released if the disc opens.

EXHIBIT 5.23 *Flush-Type Internal Pressure Relief Valve Used on Cargo Containers. All working parts are within the container or below the container shell. Stacks are not used. (Courtesy of Fisher Controls Intl, LLC)*



(B) Containers of 40,000 gal (151 m³) or more water capacity shall be equipped with either a spring-loaded pressure relief valve or a pilot-operated pressure relief valve, as follows:

- (1) The pilot-operated relief valve shall be combined with and controlled by a self-actuated, direct, spring-loaded pilot valve that complies with [Table 5.7.2.4\(A\)](#).
- (2) The use of a pilot-operated pressure relief valve shall be approved.
- (3) Pilot-operated pressure relief valves shall be inspected and maintained by persons with training and experience and shall be tested for operation at intervals not exceeding 5 years.

The requirement in [5.7.2.4\(B\)](#) recognizes that direct spring-loaded pressure relief valves may not be available in the larger sizes required by larger containers. Large installations that use 40,000 gal (151 m³) storage containers are more likely to comply with the testing and training conditions specified in [5.7.2.4\(B\)\(3\)](#).

TABLE 5.7.2.4(A) Start-to-Leak Pressure Settings of Pressure Relief Valves in Relation to Container Pressure Rating

Containers	Minimum	Maximum
All ASME codes prior to the 1949 edition, and the 1949 edition, paragraphs U-68 and U-69	110%	125%*
ASME Code, 1949 edition, paragraphs U-200 and U-201, and all ASME codes later than 1949	100%	100%*

* Manufacturers of pressure relief valves are allowed a plus tolerance not exceeding 10 percent of the set pressure marked on the valve.

Exhibit 5.24 shows a pilot-operated relief valve typically used on very large containers. **Exhibits 5.25** and **5.26** show a pilot-operated relief valve in the closed and open (relieving) position, respectively. In the closed position, pressure from the pressure relief valve inlet at the bottom of the valve is transmitted through the tube to the pilot at the right. The pressure is below the set pressure and is transmitted to the top of the pressure relief valve piston. Because the area of the piston at the top is larger than the area of the piston at the bottom, the force is down, holding the valve closed.

In **Exhibit 5.26**, the pressure has exceeded the set pressure, and the pilot piston moves up, releasing the pressure through the pilot discharge (shown at the left of the pilot). This reduces the pressure to the top of the piston, and it moves up very quickly.

5.7.2.5 The minimum rate of discharge of pressure relief valves installed in ASME containers shall be in accordance with **Table 5.7.2.5** or shall be calculated using the following formula:

$$F = 53.632 \times A^{0.82}$$

where:

A = total outside surface area of container in ft^2

F = flow rate in SCFM air



EXHIBIT 5.24 Pilot-Operated Relief Valve. (Courtesy of Anderson Greenwood)

FAQ

What is a “pilot-operated” pressure relief valve?

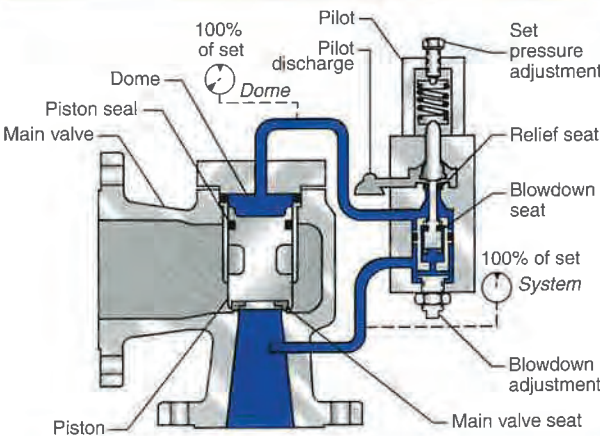


EXHIBIT 5.25 Pilot-Operated Relief Valve in the Closed Position. (Courtesy of Anderson Greenwood)

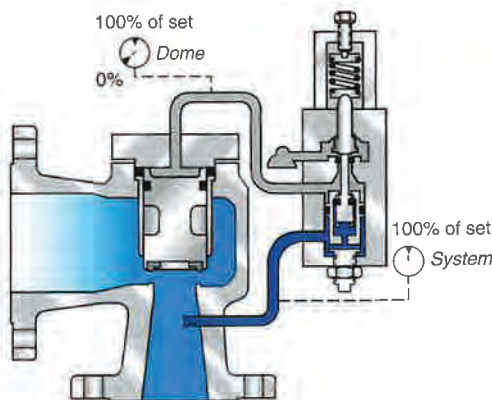


EXHIBIT 5.26 Pilot-Operated Relief Valve in the Open Position. (Courtesy of Anderson Greenwood)

TABLE 5.7.2.5 Pressure Relief Valve Flow Capacity as a Function of Container Surface Area

Surface Area (ft ²)	Flow Rate (SCFM)	Surface Area (ft ²)	Flow Rate (SCFM)	Surface Area (ft ²)	Flow Rate (SCFM)
≤20	626	170	3620	600	10,170
25	751	175	3700	650	10,860
30	872	180	3790	700	11,550
35	990	185	3880	750	12,220
40	1100	190	3960	800	12,880
45	1220	195	4050	850	13,540
50	1330	200	4130	900	14,190
55	1430	210	4300	950	14,830
60	1540	220	4470	1000	15,470
65	1640	230	4630	1050	16,100
70	1750	240	4800	1100	16,720
75	1850	250	4960	1150	17,350
80	1950	260	5130	1200	17,960
85	2050	270	5290	1250	18,570
90	2150	280	5450	1300	19,180
95	2240	290	5610	1350	19,780
100	2340	300	5760	1400	20,380
105	2440	310	5920	1450	20,980
110	2530	320	6080	1500	21,570
115	2630	330	6230	1550	22,160
120	2720	340	6390	1600	22,740
125	2810	350	6540	1650	23,320
130	2900	360	6690	1700	23,900
135	2990	370	6840	1750	24,470
140	3080	380	7000	1800	25,050
145	3170	390	7150	1850	25,620
150	3260	400	7300	1900	26,180
155	3350	450	8040	1950	26,750
160	3440	500	8760	2000	27,310
165	3530	550	9470	—	—

For SI units, 1 SCFM = 0.0283 m³/min.

Note: Flow rate in SCFM air.

Although a pressure relief valve can function for other reasons (hydrostatic pressure buildup due to overfilling, for example), the minimum relieving capacity required is based on fire exposure. In the fire exposure scenario, the calculation of relief valve capacity assumes that the container is exposed to fire on the entire surface area and the vaporization rate is calculated from the heat transfer from the fire into the container over the entire surface area of the container. CGA publications describe the factors involved.

The equation in 5.7.2.5 is used to calculate the required relief valve rating based on the flow of air through the relief valve. The flow of air is used rather than the flow of propane for two reasons. First, it is simple and less expensive for valve manufacturers to test their products using air rather than propane. Using air eliminates the need to introduce a flammable gas into manufacturing facilities that otherwise do not need propane as a test gas, and helps keep the cost of producing valves down. Furthermore, using air prevents propane release into the atmosphere. Second, the valves can be used for other services such as ammonia and other gases. Conversions are available for the flow of air to the flow of propane, ammonia, and other gases. Table 5.7.2.5 provides the minimum airflow rate required for pressure relief valves based on the surface area of ASME containers. Although there is no advantage to testing relief valves with propane, testing with propane is not prohibited.

Exhibit 5.27 shows ASME container relief valve manifolds. The container shown requires three relief valves. The manifold contains four. By operating the hand wheel or lever, an internal valve is rotated to isolate any one of the four relief valves so that it can be removed for testing, maintenance, or replacement.

5.7.2.6 Relief valves for aboveground ASME containers shall relieve at not less than the flow rate specified in 5.7.2.5 before the pressure exceeds 120 percent of the minimum permitted start-to-leak pressure setting of the device. This does not include the 10 percent tolerance in Table 5.7.2.4(A).

Pressure relief valves for ASME containers that are fabricated to current codes must begin to open at no less than 100 percent of the container design pressure, which is usually 250 psig (1.7 MPag). A tolerance of 10 percent is allowed per Table 5.7.2.4(A); therefore, the valve can begin to open between 250 psig and 275 psig (1.7 MPag and 1.9 MPag). Making pressure relief valves that begin to open at exactly 250 psig (1.7 MPag) would be very expensive, even if it could be done in mass production. The tolerance is allowed to exceed the design pressure

◀ FAQ

Why does Table 5.7.2.4(A) permit a tolerance on the pressure settings of relief valves?

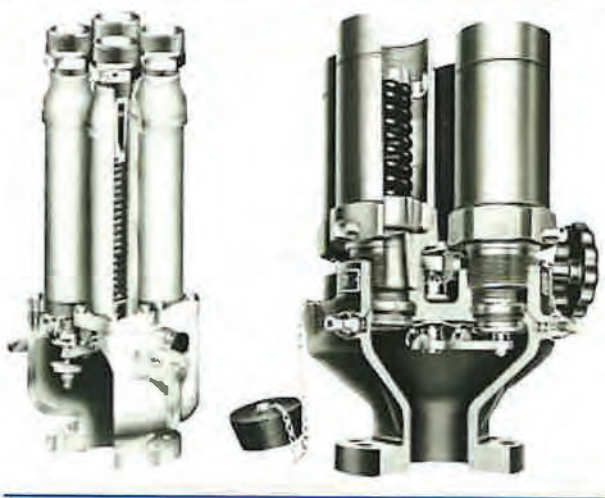


EXHIBIT 5.27 ASME Container Relief Valve Manifolds. [Courtesy of Fisher Controls Intl, LLC (left) and Engineered Controls International, Inc. (right)]

of the ASME container to prevent unneeded release of propane into the atmosphere. Allowing the ASME container to reach a pressure of 10 percent above its design pressure is recognized by the ASME *Boiler and Pressure Vessel Code*, and is not a threat to safety. Remember that the ASME containers are now built with a design margin (formerly called safety factor) of 3.5 to 1, so the container should maintain its integrity to a pressure of 875 psig (6.0 MPa), assuming no excessive corrosion, dents, pits, or other imperfections are present.

5.7.2.7 The flow capacity of pressure relief valves installed on underground or mounded containers shall be permitted to be reduced to 30 percent of the flow specified in [Table 5.7.2.5](#).

Because underground containers cannot be exposed to fire in the same manner as an above-ground container, their required pressure relief valve capacities are 30 percent of those specified in [Table 5.7.2.5](#).

If a container designed for underground installation is installed aboveground, the relief valve must be properly sized for aboveground service. The editor is aware of a case in which local laws were revised to relocate all underground fuel tanks (including propane) aboveground, based on concerns about potential gasoline and other liquid fuel contamination of groundwater. This law resulted in the relocation of propane containers above ground. (Note that propane is exempt from the EPA requirements for leaking underground storage tanks because it is not a toxic substance.) Propane containers for underground service are usually painted with black paint as part of their protective coating. Since black is a highly absorptive color when exposed to sunlight or another radiative source, installing these tanks above ground may result in occasional relief valve operation. Therefore, if an underground propane container is relocated above ground, the pressure relief valve must be resized in accordance with the requirements for aboveground containers.

5.7.2.8 Each pressure relief valve shall be plainly and permanently marked with the following:

- 
- (1) The pressure in psig at which the valve is set to start-to-leak
 - (2) Rated relieving capacity in SCFM air

The definition of *SCFM* has been added to the code and can be found in [3.3.70](#). Also see [3.3.69](#) for the definition of *standard cubic foot*.

- (3) The manufacturer's name and catalog number

5.7.2.9 Shutoff valves shall not be installed between pressure relief devices and the container unless a listed pressure relief valve manifold meeting the requirements of [6.7.2.9](#) is used.

5.7.2.10 Pressure relief valves shall be designed to minimize the possibility of tampering.

Most pressure relief valves used on propane containers have nonadjustable internal springs that prevent tampering. Some older containers may have pressure relief valves that do not have tamper-proof adjustable springs. If the pressure setting on these valves is in doubt, the valves should be tested.

5.7.2.11 Externally set or adjusted valves shall be provided with an approved means of sealing the adjustment.

5.7.2.12 Where used on aboveground ASME containers of 1200 gal (4.5 m³) or less water capacity in addition to spring-loaded pressure relief valves, fusible plugs shall be in accordance with the following:

- (1) Have a yield point between 208°F and 220°F (98°C and 104°C)
- (2) Have a total discharge area not exceeding 0.25 in.² (1.6 cm²)
- (3) Communicate directly with the vapor space of the container

Note that fusible plugs are allowed to be used in some instances for additional pressure relief capacity for smaller tanks, but they cannot replace spring-loaded pressure relief valves. (See the commentary following 5.7.2.3.)

5.7.2.13 All cylinders used in industrial truck service (including forklift truck cylinders) shall have the cylinder's pressure relief valve replaced by a new or unused valve within 12 years of the date of manufacture of the cylinders and every 10 years thereafter.

Pressure relief valves on cylinders used in industrial truck service are exposed to the truck's operating environment in industrial facilities where foreign material may enter the relief valve. This condition could prevent normal operation of the pressure relief valve. Industrial truck maintenance procedures should include a periodic visual inspection so that any accumulated foreign material can be removed, and to ensure that a relief valve protective cover has been installed over the relief valve outlet.

Paragraph 5.7.2.13 requires that the pressure relief valve be replaced within 12 years of the date of manufacture of the cylinder and every 10 years thereafter. The first replacement coincides with the first required requalification of the cylinder, which is also 12 years after the date of manufacture. Thereafter, the containers are normally recertified by a visual inspection every 5 years, and the relief valve is replaced on each second requalification. This replacement should be marked on the cylinder. Markings are not permitted on the body of the cylinder, but can be made on the cylinder's collar, which is not a pressure-containing part.

5.7.3 Overfilling Prevention Devices.

Overfilling of cylinders can result in the release of liquid propane through the relief valve. An overfilled propane cylinder that is heated can lead to expansion of the liquid propane in the cylinder. If the liquid expands to the point where it fills the cylinder, the pressure is relieved through the cylinder's pressure relief valve, a very dangerous situation.

The vast majority of propane cylinders in use today are small cylinders in the range of 4 lb through 40 lb (1.8 kg through 18 kg) propane capacity. These cylinders are used with propane barbecue grills (i.e., gas grills) and other outdoor appliances (e.g., camping equipment, patio heaters, and mosquito traps) and for providing energy for space heating, water heating, and cooking in recreational vehicles.

In response to the problem of overfilled cylinders, the 1998 edition of NFPA 58 first required new small portable cylinders to be equipped with an overfilling prevention device (OPD) (see Exhibit 3.8). There are some exceptions to this requirement that are detailed in 5.7.3.5. In addition to new cylinders, all existing cylinders were required to be retrofitted in accordance with 5.7.3.2 by April 1, 2001. It is important to note that the OPD is not the primary means by which the proper cylinder fill level is to be determined. The OPD is intended to serve as a secondary safety measure to the primary means of filling a cylinder by weight or by volume, as described in Chapter 7.

At the time of writing this edition of the handbook, OPDs have been required for 8 years for new cylinders and 4 years for all cylinders. While the retrofitting of OPDs has not been adopted by all states, a significant number of cylinders have OPDs. Data analyzed by the NFPA Fire Analysis Department issued in April 2006, shown in Exhibit 5.28, show that the number of home structure fires involving gas grills has been cut in half since the new requirement took effect in 1998. According to NFPA, the number of gas grill home structure fires decreased from 1200 in 1997 to 600 in 2002. By contrast, the number of home structure fires involving charcoal grills remained steady during that same period (see Exhibit 5.28).

5.7.3.1 Cylinders with 4 lb (1.8 kg) through 40 lb (18 kg) propane capacity for vapor service shall be equipped or fitted with a listed overfilling prevention device that complies with UL 2227, *Overfilling Prevention Devices*, and a fixed maximum liquid level gauge. These devices shall be permitted to be a part of the container valve assembly.

FAQ

Why are relief valves on cylinders used in industrial truck service required to be changed periodically, although other relief valves are not?

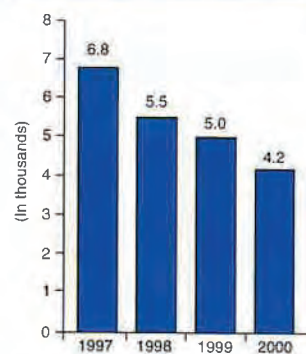


EXHIBIT 5.28 U.S. Structure Fires Involving Gas Grills, 1997–2003 (Source: NFPA Fire Analysis Department).



Portable cylinders in the 4 lb to 40 lb (1.8 kg to 18 kg) propane capacity range are those that are most likely to be overfilled. The fixed maximum liquid level gauge has been used for many years to determine that the cylinder is properly filled by the volumetric method. In [Exhibit 5.29](#), note the plastic dip tube to the right of the lower part of the valve. When the screw seen on the valve body is turned, it opens a valve from the bottom of the dip tube through the valve body to the atmosphere. The OPD, which is the lower part of the valve assembly, is a secondary safety device that prevents overfilling. Note that the OPD is required only for cylinders used in vapor service, not those used in liquid service.

EXHIBIT 5.29 *Cylinder Valve with Overfilling Prevention Device. Note the triangle-shaped hand wheel, which identifies the OPD valve. In addition to the unique hand wheel, the valve is also stamped "OPD." (Courtesy of Sherwood, Harsco Gas & Fluid Control Group)*



In the 2008 edition, the code now requires all OPD valves to be listed to UL 2227 [14]. Prior to this edition, OPD valves were still required to be listed, but there was no reference to a standard.

5.7.3.2* Cylinders requalified after September 30, 1998, shall be equipped with a listed overfilling prevention device and a fixed maximum liquid level gauge, sized in accordance with [7.4.3.2\(A\)](#) or [Table 5.7.3.2](#), prior to being filled.

Paragraph 5.7.3.2 is one of the few retrofit provisions that are contained in NFPA 58. The matter of requiring overfilling protection on cylinders is so significant that the industry decided to require even existing cylinders to be retrofitted with OPD valves when they were due for requalification. Refer to the commentary on [5.7.3](#) for information on the reduction in home fires since the introduction of OPDs.

A.5.7.3.2 Example: When the dip tube length marked on the cylinder is 3.8 in. (97 mm) use a 4.0 in. (102 mm) dip tube for the retrofit.

If the dip tube length is not marked on the cylinder, contact the manufacturer for the recommended dip tube length.

5.7.3.3 No cylinder shall be filled unless it is equipped with an overfilling prevention device and a fixed maximum liquid level gauge. The length of the fixed maximum liquid level gauge dip tube shall be in accordance with [7.4.3.2\(A\)](#) or [Table 5.7.3.2](#).

TABLE 5.7.3.2 Recommended Dip Tube Lengths for Various Cylinders

Propane Cylinder Size (lb)	Material	Cylinder I.D. (in.)	Cylinder Water Capacity (lb)	Dip Tube Lengths for Various Cylinders (in.)
4.25	Steel	8.9	10.2	2.2
5	Steel	7.8	11.9	3.0
6	Steel	7.5	15.5	3.2
10	Steel	8.9	26.1	3.6
11	Steel	8.9	26.2	3.6
11	Steel	12.0	26.2	3.0
11.5	Steel	12.0	27.3	3.2
20	Steel	12.0	47.6	4.0
25	Steel	12.0	59.7	4.8
30	Steel	12.0	71.5	4.8
40	Steel	12.0	95.3	6.5
6	Aluminum	6.0	15.0	4.8
10	Aluminum	10.0	23.6	4.0
20	Aluminum	12.0	47.6	4.8
30	Aluminum	12.0	71.5	6.0
40	Aluminum	12.0	95.2	7.0

For SI units, 1 lb = 0.454 kg; 1 in. = 25 mm.

Note: This table indicates the approximate fixed maximum liquid level gauge dip tube lengths to be used for retrofitting cylinders with valves incorporating an overfilling prevention device. This table does not cover every cylinder design or configuration. If the dip tube length that is marked on the cylinder does not appear in Table 5.7.3.2, use the next longer dip tube shown in the table.

5.7.3.4 Cylinders required to have an overfilling prevention device installed shall be equipped with either a CGA connection number 791 or a CGA connection number 810 as described in CGA V-1, *Standard Compressed Gas Cylinder Valve Outlet and Inlet Connections*.

Paragraph 5.7.3.4 restricts the type of cylinder valve that can be used with an overfilling prevention device. (See CGA V-1, *Standard Compressed Gas Cylinder Valve Outlet and Inlet Connections*. [15]) The CGA designation numbers refer to two specific connection designs, both of which were developed for use with outdoor cooking gas appliances such as grills [see **Exhibit 5.29**, which shows a CGA 791 connection (Type I) with matching nut]. The performance requirements for each CGA designation require the cylinder connection device to provide three important safety attributes:

1. A “positive seal,” which will not permit gas to flow from the cylinder to the appliance unless the connection is properly made
2. An excess flow feature, which will stop the flow of gas should a hose separation occur downstream of the cylinder connection
3. A thermal link that will shut gas flow from the cylinder if the temperature of the link reaches 300°–400°F (150°–205°C), which would occur if there was a fire in close proximity to the connection

5.7.3.5 The following types of cylinders shall be exempt from the requirements of **5.7.3.1** through **5.7.3.4** for installing a listed overfilling prevention device:

◀ FAQ

Why can only certain types of cylinder connections be used with cylinders having OPD valves?

FAQ ►
Are cylinders used for floor buffer machines required to be fitted with an OPD before they are filled?

- (1) Cylinders used in industrial truck service and cylinders identified and used for industrial welding and cutting gases

Industrial truck cylinders used in liquid service are exempt from the OPD requirement per 5.7.3.5(1), and now so are industrial truck cylinders in vapor service. It is important to note that cylinders used in engine fuel service on vehicles, including floor buffer machines, are also exempt from the OPD requirements, per 5.7.4.1(E). This exception to the OPD requirement for cylinders used in industrial truck service and industrial welding and cutting recognizes the different characteristics of these cylinders, which have a higher level of quality control during the filling process and are therefore not subject to the same threats of overfilling that has occurred in grill cylinders.

- Cylinders used in industrial truck service are universal cylinders that can be filled or used in either the horizontal or the vertical position. They are exempt from the OPD requirements because an OPD is not available for universal cylinders [see 5.7.4.1(E)].
- Cylinders used with floor maintenance machines are usually equipped for vapor withdrawal and are exempt from the OPD requirement because of the higher flow required, which cannot be met with some OPD valves.
- Cylinders used in industrial and welding cutting gas service are exempt from the OPD requirement due to the higher gas flow required in cutting and welding, which cannot be met with some OPD valves.

- (2) Cylinders manufactured prior to October 1, 1998, and designed for use in the horizontal position and where an overfilling prevention device is not available

Horizontal cylinders manufactured prior to October 1, 1998, are exempt from the OPD requirement because the connections for these cylinders are located on the head, which is on the side when the cylinder is in use. Horizontal cylinders manufactured after October 1, 1998, incorporated an OPD valve. The design of an OPD for a horizontal cylinder is different and more complicated than an OPD for a vertical cylinder, because each horizontal cylinder requires an opening in the head to accommodate the OPD. It would be prohibitively costly to empty, purge, and weld a new connection to a horizontal cylinder manufactured before the OPD was required. In addition, several styles of horizontal cylinders are no longer made, and replacement cylinders may not fit in the compartments of boats, recreational vehicles, and trailers that accommodate them. Because fewer horizontal cylinders are made, they are more expensive than gas grill cylinders — as much as 10 times more in some cases. This combination of hardships created by the unavailability of replacement cylinders in usable sizes, the high cost of such cylinders, and the relatively small number of horizontal cylinders in use led to their exemption from the OPD requirement.

5.7.3.6 Exempted horizontal cylinders shall be marked with a label to indicate that they are not equipped with an overfilling prevention device.

Note that horizontal cylinders not equipped with an OPD are required be marked so that the filler is aware that the cylinder is not equipped with an OPD and that extra care must be taken not to overfill the cylinder. The code does not state who is responsible for adding the label to cylinders not equipped with an OPD. Anyone — the cylinder owner, the filler, or any other party — can add this label, after determining that an OPD is not required for the cylinder (see 5.7.3.5).



5.7.4 Container Valves and Other Appurtenances.

5.7.4.1 Containers of 2000 gal (7.6 m³) water capacity or less shall be fitted with valves and other appurtenances in accordance with Table 5.7.4.1. Shutoff, filler, check, and excess-flow valves shall comply with ANSI/UL 125, *Standard for Valves for Anhydrous Ammonia and LP-*

TABLE 5.7.4.1 *Container Connection and Appurtenance Requirements for Containers Used in Other Than Bulk Plants and Industrial Plants*

Part	Appurtenance	1	2	3
		<i>Cylinders 2 Through 420 lb Propane Capacity</i>	<i>Stationary ASME Containers ≤ 4000 gal Water Capacity³</i>	<i>DOT and ASME Engine Fuel and Mobile Containers</i>
A	Vapor shutoff valve ¹	R (CGA 555 outlet prohibited)	R	R with internal excess-flow valve
B	Liquid shutoff valve ¹	R with CGA 555 outlet and internal excess flow shutoff	R with internal excess flow shutoff	R with internal excess-flow valve
D	Pressure relief valve	R (see 5.7.2.2)	R ² [see 5.7.4.1(A)]	R (full internal or flush-type full internal pressure relief valve)
E	Fixed maximum liquid level gauge	R (filled by volume) R (filled by weight, ≤ 40 lb and > 100 lb) [see 5.7.4.1(H)]	R	R
F	Overfilling prevention device	R (4 thru 40 lb) (see 5.7.3)	NR	R (ASME only) (see 5.7.4.1(E))
G	Actuated liquid withdrawal excess flow valve	NR	R (≥ 125 gal) [see 5.7.4.1(B) through 5.7.4.1(D)]	NR
H	Float gauge	NR	R (> 124 gal only)	NR
I	Double backflow check filler valve	R (≥ 100 lb filled on site)	R	R (ASME only)

R: Required. NR: Not required.

¹Where installed.

²Aboveground ASME containers, internal spring-type pressure relief valves only.

³All ASME container capacities are water capacity.

Gas (Other than Safety Relief), except that shutoff valves used on DOT cylinders shall comply with UL 1769, *Cylinder Valves*. Containers of 2001 gal through 4000 gal (7.6 m³ through 15.1 m³) water capacity in bulk plant and industrial plant service shall be fitted with valves and other appurtenances in accordance with Table 5.7.4.2. Containers of 2001 gal through 4000 gal (7.6 m³ through 15.1 m³) water capacity in other than bulk plant and industrial plant service shall be in accordance with Table 5.7.4.1.

Paragraph 5.7.4.1 draws distinctions between the size of containers and the type of service for which they are used. The code assumes that containers 2000 gal (7.6 m³) and under are not used in bulk plant operations. In addition, a distinction is made between containers 4000 gal (15.2 m³) or less used in bulk plant service and those that are not. This distinction is due to

the fact that bulk plant equipment is subject to many more liquid transfer operations than a typical residential or commercial customer facility. For that reason, the product control and appurtenance requirements in [Table 5.7.4.2](#) (covering containers installed in bulk plants and industrial plants) are more rigorous than those appearing in [Table 5.7.4.1](#). Industrial plants have historically been grouped with bulk plants, and [Table 5.7.4.2](#) continues that tradition because the quantities of LP-Gas stored are similar.

[Paragraph 5.7.4.1](#) was revised in the 2008 edition of the code to require the specific valves listed to comply with ANSI/UL 125, *Standard for Valves for Anhydrous Ammonia and LP-Gas (Other than Safety Relief)* [16], and to require cylinder valves to comply with UL 1769, *Cylinder Valves* [17]. These standards had not been referenced in the code prior to this edition.

[Table 5.7.4.1](#) was completely revised in the 2008 edition to provide performance requirements only and not to attempt to cover all possible combinations, which makes it easier to use. The table now has columns for cylinders, 2 through 240 lb, ASME containers through 4000 gal, and engine fuel/mobile containers, compared to six types of containers previously. It also has nine appurtenances (rows), compared to fourteen previously. The former table had blank cells, which sometimes led to confusion as to the meaning of a blank cell. In this edition, all cells clearly state “R” for “required” or “NR” for “not required.” Of course, anything that is not required can be used if desired.

(A) The requirement for internal spring-type pressure relief valves that are shown in [Table 5.7.4.1](#) for stationary ASME containers up to and including 4000 gal (15.2 m³) water capacity shall not apply to underground containers where external pressure relief valves are permitted or to containers that were originally equipped with external pressure relief valves.

Internal pressure relief valves are designed so that the entire valve mechanism is inside the container. In the event of a vehicle impacting a container, the pressure relief valve cannot be broken off, thus preventing the release of the container contents. Underground containers have used external pressure relief valves, because the valve is in the container dome, which is below ground level, and is therefore protected from being broken by vehicle impact.

(B) Containers of 125 gal through 4000 gal (0.5 m³ through 15.2 m³) water capacity shall be provided with an actuated liquid withdrawal excess-flow valve with a connection not smaller than 3/4 in. national pipe thread.

(C) An actuated liquid withdrawal excess-flow valve shall not be required on container connections equipped for liquid withdrawal with a positive shutoff valve that is located as close to the container as practical in combination with an excess-flow valve installed in the container connection.

A positive shutoff valve and an excess-flow valve in the container provide the same function as an actuated liquid withdrawal excess-flow valve. The term *positive shutoff valve* means a valve where the operation of the handle, wheel, or lever directly opens or closes the flow path.

(D) The actuated liquid withdrawal excess-flow valve shall not be connected for continuous use unless the valve is recommended by the manufacturer for such service.

Refer to the commentary following [5.2.5.4](#) for information on continuous service of actuated liquid withdrawal excess-flow valves.

(E) An overfilling prevention device shall not be required for engine fuel cylinders used on industrial (and forklift) trucks powered by LP-Gas or for engine fuel cylinders used on vehicles (including floor maintenance machines) having LP-Gas-powered engines mounted on them.

Refer to the commentary following [5.7.3.5\(1\)](#) for an explanation of why overfilling prevention devices are not required for these vehicle applications.

(F) Excess-flow protection shall not be required for manual shutoff valves for vapor service where an approved regulator is directly attached or attached with a flexible connector to the outlet of the manual shutoff valve for vapor service and the controlling orifice between the container contents and the shutoff valve outlet does not exceed 5/16 in. (8 mm) in diameter.

Paragraph 5.7.4.1(F) requires that unless an excess-flow valve is installed downstream of the container shutoff valve, a pressure regulator (either high pressure, first-stage, or integral two-stage) must be attached to the service valve or to a flexible connector emanating from the service valve. The 5/16 in. controlling orifice must be located within the shutoff valve itself. This paragraph serves as an alternative to the requirement for an excess-flow valve because it provides a “passive” restriction to the flow of gas should the line become severed downstream of the regulator, due to the restrictive orifice and pressure regulator.

(G) Overfilling prevention devices shall be required on cylinders having 4 lb through 40 lb (1.8 kg through 18 kg) propane capacity for vapor service. (See 5.7.3.)

See the commentary following 5.7.3 for an explanation of why overfilling prevention devices are only required on cylinders in the 4 lb to 40 lb range.

(H) Cylinders greater than 40 lb through 100 lb (18 kg through 45 kg) propane capacity filled by volume shall have a fixed maximum liquid level gauge.

FAQ

Why is an excess-flow valve not required when a regulator with 5/16 in. flow orifice is connected to a container?

The text was revised in the 2008 edition to make the fixed maximum liquid level gauge mandatory only for cylinders with capacities greater than 100 lb that are filled by volume. The technical committee was made aware that it is common practice of many companies where cylinders are exchanged, to fill all cylinders by the weight method, making the fixed maximum liquid level gauge unneeded. The requirement also recognizes that in the fuel gas distribution business, it is common to fill cylinders with capacities of greater than 40 lb through 100 lb by volume, especially at sites where the cylinder remains at the point of use.

5.7.4.2 ASME containers over 4000 gal (15.2 m³) water capacity shall be equipped in accordance with 5.7.4.2(A) through 5.7.4.2(G) and Table 5.7.4.2.

The provisions in 5.7.4.2(A) through (G) are identical to the requirements shown in Table 5.7.4.2. The technical committee duplicated this information in the table because many users find it an easier format to understand.

Paragraph 5.7.4.2 was intended to address containers used in bulk plant and industrial installations. It recognizes that the internal valve incorporates all of the safety features that are available, including providing protection for the container opening in the event the valve is sheared off; thermal protection that would automatically close the valve if it is subjected to fire; and excess-flow protection and remote shutoff capability.

However, the code also recognizes that many existing installations provide similar protection and, therefore, does permit certain alternatives to be used instead of an internal valve. Those alternatives are described in 5.7.4.2(A) through (I).

Internal valves are categorized according to the means by which they are operated. See Exhibits 5.30, 5.31, 5.32, and 5.33 for examples of the different types of internal valves.

(A) Vapor withdrawal openings shall be equipped with either of the following:

- (1) A positive shutoff valve located as close to the container as practical in combination with an excess-flow valve installed in the container
- (2) An internal valve

The requirements for container appurtenance protection reflect the hazard presented by failure downstream of the connection. Vapor withdrawal lines carry much less propane than liquid withdrawal lines of the same size. Internal valves are not required but are allowed. An excess-flow valve will close in the event the piping system is compromised and the flow exceeds the design flow of the excess-flow valve. It is important to remember that excess-flow



FAQ

Are there any differences between the requirements in 5.7.4.2 and those in Table 5.7.4.2?

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TABLE 5.7.4.2 *Connection and Appurtenance Requirements for New and Existing Container Installations in Bulk Plants and Industrial Plants*

Service	2001 gal Through 4000 gal W.C. ^a	Greater Than 4000 gal W.C. ^a	Requirements for Containers of Greater Than 4000 gal W.C. With and Without Internal Valves ^b	
			Without Existing Internal Valves (by 7/1/11)	With Existing Internal Valves
Vapor inlet	Option A or Option B or Option C Option C	Option A or Option B or Option C	See Note	See Note
Vapor outlet	Option B or Option C	Option B or Option C	See Note	See Note
Liquid inlet	Option A or Option B or Option C	Option D or Option E	Option D or Option E or Option F or Option G	RT
Liquid outlet	Option B or Option C	Option E	Option E or Option H	RT

Option A: Positive shutoff valve installed as close as practical to a backflow check valve installed in the container.

Option B: Positive shutoff valve installed as close as practical to an excess-flow valve installed in the container and sized in accordance with 5.7.8.1(H).

Option C: Internal valve installed in the container or an excess-flow valve in accordance with 5.7.4.2(I).

Option D: Positive shutoff valve installed as close as practical to a backflow check valve designed for the intended application and installed in the container.

Option E: Internal valve installed in the container equipped for remote closure and automatic shutoff using thermal (fire) activation within 5 ft (1.5 m) of valve or an excess-flow valve in accordance with 5.7.4.2(I).

Option F: Emergency shutoff valve equipped for remote closure and automatic shutoff using thermal (fire) activation installed in the line upstream as close as practical to an existing positive shutoff valve/excess-flow valve combination.

Option G: Backflow check valve designed for the intended application and installed in the line upstream as close as practical to the existing positive shutoff valve/excess-flow valve combination.

Option H: Emergency shutoff valve equipped for remote closure and automatic shutoff using thermal (fire) activation, installed in the line downstream as close as practical to an existing positive shutoff valve/excess-flow valve combination.

RT: Equipping an existing internal valve for remote closure and automatic shutoff using thermal (fire) actuation within 5 ft (1.5 m) of the internal valve.

Note: Vapor connections on containers installed prior to the effective date of the 2001 edition of NFPA 58 are not required to be modified.

^aApplicable to installations constructed on or after the effective date of this code.

^bApplicable to installations constructed prior to the effective date of this code.

valves can not provide complete safety, as the flow from a container is a function of the pressure in the container, which is temperature dependent. On colder days, container pressure may not be sufficient to develop a flow that will close the excess-flow valve. Excess-flow valves may also not close if the pipe area is reduced by breakage that restricts flow.

(B) Liquid withdrawal openings in new installations shall be equipped with an internal valve that is fitted for remote closure and automatic shutoff using thermal (fire) actuation where the thermal element is located within 5 ft (1.5 m) of the internal valve.

Liquid withdrawal lines present a greater potential hazard than vapor withdrawal lines, and the requirement for the container appurtenance is more stringent. An internal valve is required.

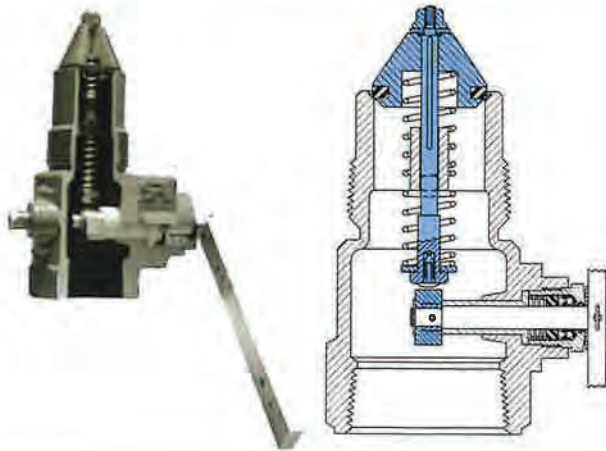


EXHIBIT 5.30 Lever Operated Internal Valve for Threaded Installation. (Courtesy of Engineered Controls International, Inc.)

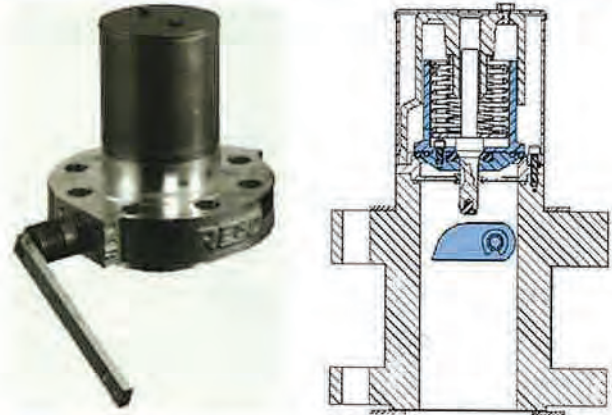


EXHIBIT 5.31 Lever Operated Internal Valve for Flanged Installation. (Courtesy of Engineered Controls International, Inc.)

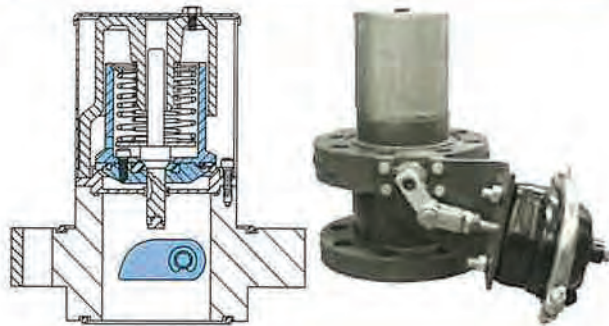


EXHIBIT 5.32 Pneumatically Operated Internal Valve. (Courtesy of Engineered Controls International, Inc.)

(C) Liquid withdrawal openings in existing installations where the container is equipped with an internal valve that is not fitted for remote closure and automatic shutoff using thermal (fire) actuation shall be equipped for remote and thermal closure by July 1, 2003.

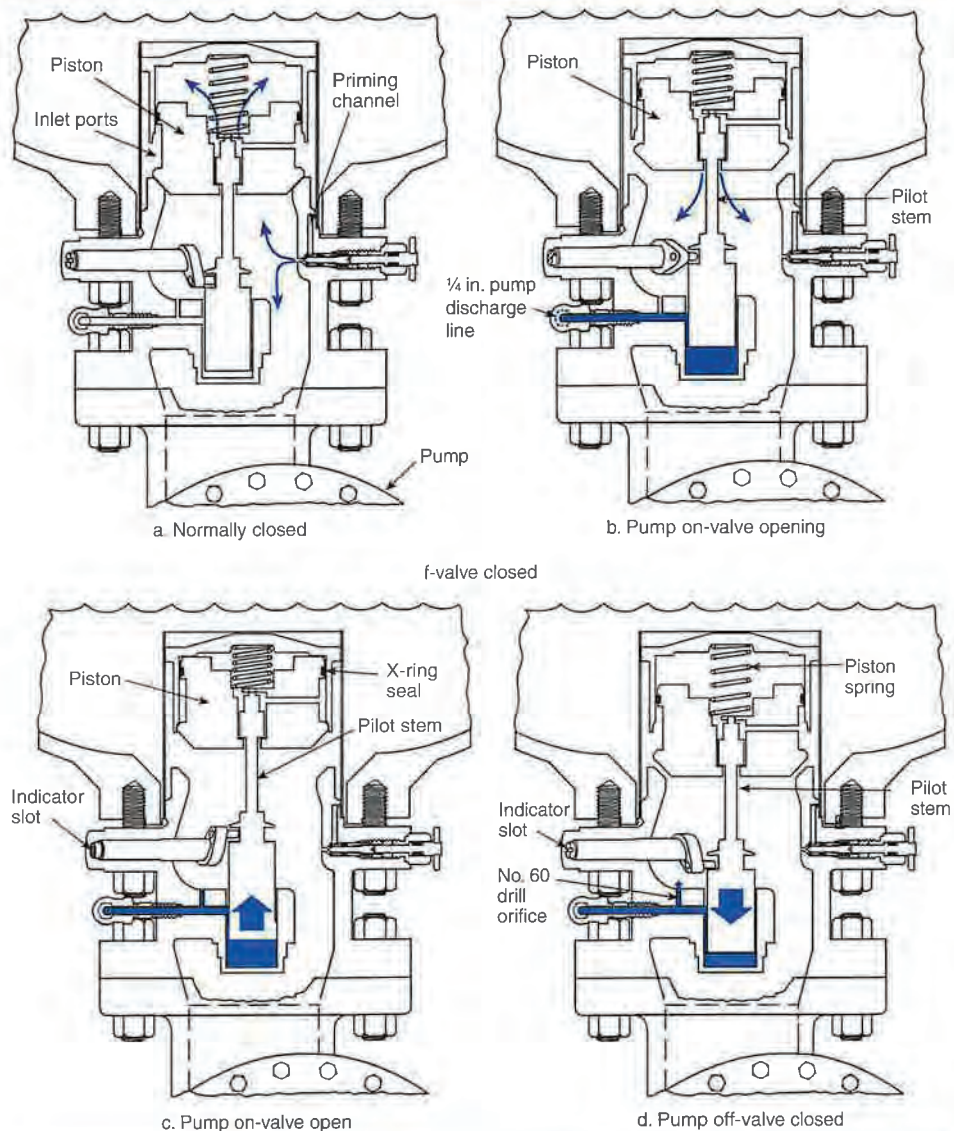
Although the July 1, 2003, date has passed, it is kept in the code to provide guidance to jurisdictions that may not yet have adopted the 2004 edition. This date is also prior to the retrofit date that appears in 5.7.4.2(D) because of the relative ease by which compliance with this paragraph can be achieved. Since the internal valve is already present in the tank, only the remote closure and thermal activation features need be installed.

(D) Liquid withdrawal openings in existing installations shall be equipped with either of the following by July 1, 2011:

- (1) An internal valve that is fitted for remote closure and automatic shutoff using thermal (fire) actuation where the thermal element is located within 5 ft (1.5 m) of the internal valve
- (2) An emergency shutoff valve that is installed in the line downstream as close as practical to a positive shutoff valve in combination with an excess-flow valve installed in the container

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EXHIBIT 5.33 Operation of a Pump Pressure-Operated Internal Valve. (Courtesy of Engineered Controls International, Inc.)



A substantial amount of time for compliance is given for this retrofit provision for existing installations. To add an internal valve, the container must be emptied of all product to remove the existing valve from the container. Seals and gaskets may be made of materials having low melting points that could potentially be affected when exposed to heat. The maximum 5 ft distance for the location of the thermal element is intended to keep the activation element close to the valve itself, to avoid heat affecting the ability of the valve to retain product while in the “open” position.

(E) Vapor inlet openings shall be equipped with either of the following:

- (1) A positive shutoff valve that is located as close to the container as practical in combination with either a backflow check valve or excess-flow valve installed in the container
- (2) An internal valve

The container appurtenance requirement for vapor withdrawal openings is the same as vapor inlet openings, because the potential consequences are the same.

(F) Liquid inlet openings in new installations shall be equipped with either of the following:

- (1) An internal valve that is fitted for remote closure and automatic shutoff using thermal (fire) actuation where the thermal element is located within 5 ft (1.5 m) of the internal valve
- (2) A positive shutoff valve that is located as close to the container as practical in combination with a backflow check valve that is designed for the intended application and is installed in the container

The container appurtenance requirements for liquid inlet openings in new installations allow either an internal valve or a positive shutoff valve and a check valve in the container. A check valve will allow flow only in one direction and will allow propane to enter the container, but not to leave. Check valves are not perfect, but experience with them has been better than with excess-flow valves, as their operation will occur over a much wider flow range than an excess-flow valve. Note that 6.12.9 requires that check valves used as container appurtenances be checked for proper operation annually

See 5.7.4.2(H) for requirements effective in 2011 for container appurtenances for all containers.

(G) Liquid inlet openings in existing installations where the container is equipped with an internal valve that is not fitted for remote closure and automatic shutoff using thermal (fire) actuation shall be equipped for remote and thermal closure by July 1, 2003.

Internal valves are required by NFPA 58 to provide a higher level of safety than provided by excess-flow valves, but they do so only when someone is present to operate the internal valve. The remote operating point must be installed properly. Installation distances are provided in 6.11.4. The requirement for installation by July 1, 2003, was added in the 2001 edition to require that remote operating stations be installed for all internal valves.

(H) Liquid inlet openings in existing installations shall be equipped with any of the following by July 1, 2011:

- (1) An internal valve that is fitted for remote closure and automatic shutoff using thermal (fire) actuation where the thermal element is located within 5 ft (1.5 m) of the internal valve
- (2) An emergency shutoff valve that is installed in the line upstream as close as practical to a positive shutoff valve in combination with an excess-flow valve installed in the container
- (3) A positive shutoff valve that is located as close to the container as practical in combination with a backflow check valve that is designed for the intended application and is installed in the container
- (4) A backflow check valve that is designed for the intended application and is installed in the line upstream as close as practical to a positive shutoff valve in combination with an excess-flow valve installed in the container

Note that these requirements are retroactive to all existing containers on July 1, 2011. This date was selected when the requirement was added in the 2001 edition to allow a 10-year period to modify all existing containers.

The options for liquid inlet openings are as follows:

- An internal valve
- An internal check valve with a positive shutoff valve
- An internal check valve with a positive shutoff valve and an external excess-flow valve
- An internal excess-flow valve with a positive shutoff valve and an external check valve.

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These requirements are similar to those for liquid withdrawal openings, with the addition of another option, a check valve. Check valves can be used only on inlet openings because they will not allow liquid both into and out of a container.

(I) Container openings that are not compatible with internal valves shall be permitted to utilize both an excess-flow valve installed in the container and a valve complying with API 607, *Fire Test for Soft-Seated Quarter Turn Ball Valves*, with the following features:

- (1) The valve shall be activated either hydraulically or pneumatically and shall fail in the closed position.
- (2) The valve shall be equipped for remote closure and thermal actuation with a thermal element located within 5 ft (1.5 m) of the valve.

This provision was introduced in the 2004 edition of the code because the Technical Committee on Liquefied Petroleum Gases recognized that internal valves are not available in larger sizes to fit 3 in. or larger container openings. These larger sizes would be found typically on high-volume commercial or industrial installations and propane terminals. The option of an internal excess-flow valve with an external valve meeting API 607, *Fire Test for Soft-Seated Quarter Turn Ball Valves* [18], provides a similar level of safety. See [Exhibit 5.34](#) for an API 607 valve.

EXHIBIT 5.34 Tank Valve Complying with API 607.
(Courtesy of Superior Energy Systems)



5.7.4.3 Appurtenances used on inlet and outlet connections of containers larger than 2000 gal through 4000 gal (7.6 m³ through 15.1 m³) water capacity shall be in accordance with [Table 5.7.4.1](#). Appurtenance requirements for inlet and outlet connections of containers in bulk plant and industrial plant service shall be in accordance with [Table 5.7.4.2](#).

FAQ ►

Why are containers between 2000 and 4000 gal water capacity required to comply with different provisions, depending on whether they are used in residential/commercial service or bulk plant/industrial service?

Containers falling within the size range of greater than 2000 through 4000 gal water capacity are required to comply with either [Table 5.7.4.1](#) or [Table 5.7.4.2](#), depending on how they are being used. Because of more frequent liquid transfers to and from containers in bulk plant service, these containers must comply with [Table 5.7.4.2](#) for the installation of internal valves or specified alternatives, rather than the less stringent requirements in [Table 5.7.4.1](#).

5.7.4.4 ASME containers over 4000 gal (15.2 m³) water capacity shall also be equipped with the following appurtenances:

- (1) An internal spring-type, flush-type full internal, or external pressure relief valve (*see Annex E*)
- (2) A fixed maximum liquid level gauge
- (3) A float gauge, rotary gauge, slip tube gauge, or a combination of these gauges

- (4) A pressure gauge
- (5) A temperature gauge

Since containers used in bulk plant and industrial service are not within the scope of [Table 5.7.4.1](#), the requirements listed in 5.7.4.4 specify the types of appurtenances that must be installed on containers greater than 4000 gal water capacity.

5.7.4.5 The appurtenances specified in [Table 5.7.4.1](#) and [5.7.4.3](#) shall comply with the following:

- (1) Manual shutoff valves shall be designed to provide positive closure under service conditions.

The term *positive closure* means the valve should be leak-free across its seat, throughout its entire working pressure range.

- (2) Excess-flow check valves shall be designed to close automatically at the rated flows of vapor or liquid specified by the manufacturer.
- (3) Excess-flow valves shall be designed with a bypass that shall not exceed a No. 60 drill size opening to allow equalization of pressure.
- (4) Excess-flow valves of less than 1/2 in. (1.3 cm) NPT shall have a bypass that limits propane vapor flow to 10 scf/hr at 100 psig (690 kPag).

An excess-flow check valve remains in the open position until the flow of liquid or vapor passing through the valve exceeds its designed closing flow rate. The small bypass is a hole or “nick” in the valve seat disc that allows a very small amount of LP-Gas to “leak.” This feature is not required for all excess-flow valves, but is required for excess-flow valves in LP-Gas service. This leak is the means by which the valve is reopened, because excess-flow valves do not have a manual means of opening (no valve handle). To reopen a closed excess-flow valve, a valve downstream of the excess-flow valve is closed, and the leakage accumulates between the excess-flow valve and the closed manual valve, increasing the pressure downstream of the excess-flow valve. When the pressure on the downstream side is about equal to the pressure on the upstream side, the valve is no longer held closed and opens with an audible “click.” (See [Exhibits 5.35](#), [5.36](#), and [5.37](#).)

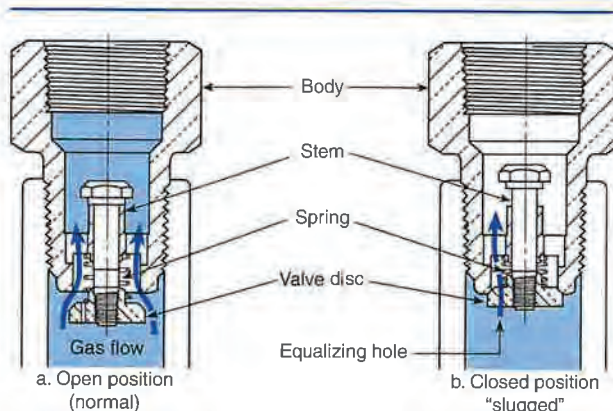


EXHIBIT 5.35 Operation of Excess-Flow Check Valve. After the spring-loaded excess-flow valve has closed due to excessive flow above the manufacturer's flow rating, the closing of the downstream valve will allow pressure on both sides of the excess-flow check mechanism to equalize through the equalizing hole and the spring loading will cause the excess-flow check to reopen. (Courtesy of Fisher Controls Intl, LLC)

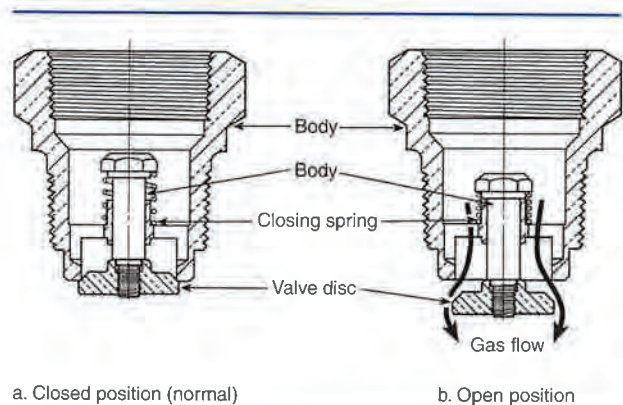


EXHIBIT 5.36 Operation of Backflow Check Valve. (Courtesy of Fisher Controls Intl, LLC)

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EXHIBIT 5.37 Various Excess-Flow Check Valves. (Courtesy of Fisher Controls Intl, LLC)

Some other characteristics that apply to all excess-flow valves include the following:

- Excess-flow valves are designed to close automatically at the rated flow of vapor or liquid specified by the manufacturer. If there is only a partially broken hose or piping system and it does not allow the specified rated flow for closure, the excess-flow valve will not close.
 - If the temperature of the liquid is extremely low, there may not be enough pressure in the container to reach the required differential pressure to close the valve even if there is complete breakage of the hose or piping system.
- (5) Backflow check valves shall be of the spring-loaded or weight-loaded type with in-line or swing operation and shall close when the flow is either stopped or reversed.
 - (6) Internal valves (*see 3.3.74.4, Internal Valve*), either manually or remotely operated and designed to remain closed except during operating periods, shall be considered positive shutoff valves.

The code specifically states that an internal valve is considered to be a “positive shutoff valve.” When it is closed, no flow is passing through the valve. If an internal valve is left open and no flow occurs, it is not a positive shutoff valve, and the installation of another valve may be needed.

Installers should be aware that an internal valve does provide positive shutoff in both flow directions. Consider an internal valve installed in the liquid outlet of a container. When closed, the internal valve will not allow flow out of the container, but can allow flow into the container where more than one container is connected to a common manifold, especially in a container that has been taken out of service and depressurized. In such installations, a gate or globe valve should be installed with the internal valve.

5.7.5 Liquid Level Gauging Devices.

5.7.5.1 Liquid level gauging devices shall be installed on all containers filled by volume.

5.7.5.2 The gauging devices shall be either fixed maximum liquid level gauges or variable gauges of the slip tube, rotary, or float type (or combinations of such gauges).

5.7.5.3* Every container designed to be filled on a volumetric basis shall be equipped with a fixed maximum liquid level gauge(s) to indicate the maximum filling level(s) for the service(s) in which the container is to be filled or used (*see 7.4.3.3*).

A.5.7.5.3 Containers fabricated on or before December 1, 1965, were exempt from this requirement.

5.7.5.4 ASME containers shall have permanently attached to the container adjacent to the fixed maximum liquid level gauge, or on the container nameplate, markings showing the percentage of capacity that is indicated by that gauge.

5.7.5.5 Cylinders shall have the letters DT stamped on them followed by the vertical distance (to the nearest tenth of an inch) measured from the top of the boss or coupling into which the gauge, or the cylinder valve of which it is a part, is installed to the end of the dip tube.

5.7.5.6 Cylinders equipped with a fixed maximum liquid level gauge where the dip tube is not welded to the inside of the cylinder shall be permanently marked adjacent to the gauge.

(A) Cylinders designed to be filled in one position shall be marked as follows:

- (1) The marking shall be the letters DT followed by the dip tube length to the nearest tenth of an inch.
- (2) The dip tube length shall be measured from the top center of the cylinder boss or coupling where the gauge is installed to the maximum permitted filling level.

(B) Universal-type cylinders, where the dip tube is not welded to the inside of the cylinder and that are permitted to be filled in either the vertical or horizontal position, shall be marked as follows:

- (1) Vertical filling: With the letters VDT followed by the vertical distance (to the nearest tenth of an inch) measured from the top center of the coupling where the gauge is installed to the maximum permitted filling level
- (2) Horizontal filling: With the letters HDT followed by the vertical distance (to the nearest tenth of an inch) measured from the centerline of the coupling opening into which the gauge is installed, that is located at the maximum filling level in the horizontal position, to the inside top of the cylinder

Universal cylinders are commonly used in the recreational vehicle industry and also in the forklift truck industry, because they allow filling to take place while the cylinder is still in its installed position. When filled in the horizontal position, a universal cylinder must be oriented correctly around its circumference in order to properly fill the cylinder.

5.7.5.7 Cargo tanks and ASME containers utilizing multiple fixed liquid level gauges shall have the loading percentage (to the nearest 2/10 percent) stamped adjacent to each gauge.

Liquid level gauges are needed on all containers that are filled volumetrically to enable proper filling. The two types of liquid level gauges are

- Fixed, which measure only one level in the container
- Variable, which measure and indicate all liquid levels in the container

Two types of variable gauges commonly used in LP-Gas service are the rotary type and the float type, as shown in Exhibits 5.38 and 5.39. Because variable gauges can be inaccurate, it is necessary to have a fixed maximum liquid level gauge installed in all containers for calibration purposes. The fixed maximum liquid level gauge is used to determine maximum filling levels if the variable gauge is inoperative and to calibrate the variable gauges to prevent inadvertent overfilling.

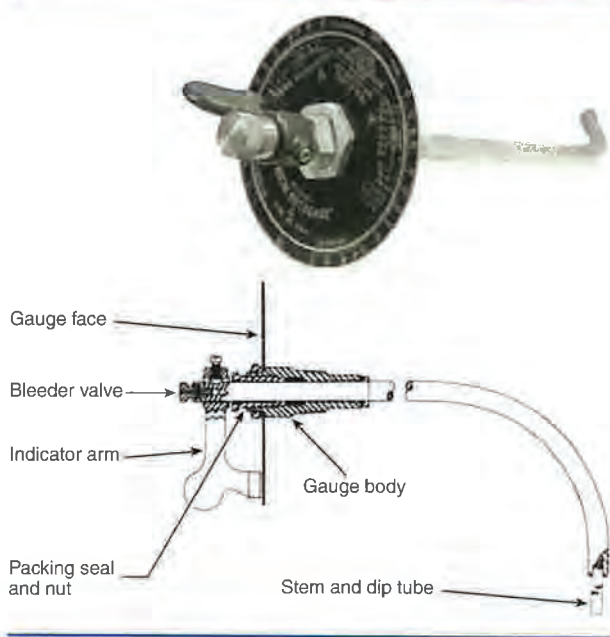


EXHIBIT 5.38 Rotary Type of Variable Liquid Level Gauge. (Courtesy of Engineered Controls International, Inc.)



EXHIBIT 5.39 Float Type of Variable Liquid Level Gauge (Top) and Dial Faces (Bottom). (Courtesy of Gas Equipment Co., Inc. and Rochester Gauges, Inc.)

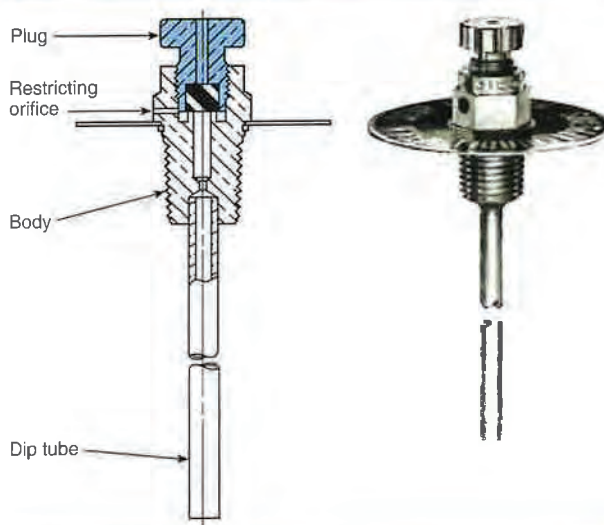
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EXHIBIT 5.41 Multiple Valve for 100 lb to 200 lb (45 kg to 91 kg) Cylinder with Fixed Maximum Liquid Level Gauge (Dip Tube) and Separate Inlet and Outlet Connections. (Courtesy of Sherwood, Harsco Gas & Fluid Control Group)

Fixed maximum liquid level gauges incorporate dip tubes at the 80 percent liquid level of the container. **Exhibit 5.40** shows a schematic drawing and a photograph of a fixed maximum liquid level gauge. The marking on the disk in the photograph reads, “STOP FILLING WHEN LIQUID APPEARS.” **Exhibit 5.43** shows a multiple function container valve assembly that incorporates a fixed maximum liquid level gauge. The dip tube is connected to a valve that allows a small amount of vapor or liquid to be discharged to the atmosphere when opened. The gauge discharge is invisible if vapor is emitted, but a white fog of condensed water vapor is created in the air by the refrigeration effect caused by the vaporizing liquid when it is discharged into the atmosphere.

EXHIBIT 5.40 Fixed Maximum Liquid Level Gauge. [Courtesy of Fisher Controls Intl, LLC (left) and Engineered Controls International, Inc. (right)]



The location of fixed maximum liquid level gauges in different containers is shown in **Exhibit 5.42**. Paragraphs 5.7.5.4 through 5.7.5.7 provide marking requirements for containers equipped with fixed maximum liquid level gauges to readily indicate the length of the dip tube or the percentage fill indicated by the fixed level gauge.

5.7.5.8 Variable liquid level gauges shall comply with the following:

- (1) Variable liquid level gauges installed on containers over 2000 gal (7.6 m³) water capacity shall be marked with the maximum liquid level, in inches, metric units, or percent of capacity of the container where they are to be installed.
- (2) Markings shall indicate the maximum liquid level at liquid temperatures from 20°F to 130°F (−6.7°C to 54.4°C) and in increments not greater than 20°F (11°C) for propane, for 50/50 butane–propane mixtures, and for butane.
- (3) Markings indicating the various liquid levels from empty to full shall be shown on the system nameplate, on the gauging device, or on both.
- (4) Dials of magnetic float gauges or rotary gauges shall indicate whether they are for cylindrical or spherical containers and whether they are for aboveground or underground service.
- (5) The dials of gauges for use only on aboveground containers of over 1200 gal (4.5 m³) water capacity shall be so marked.

Variable liquid level gauges are normally found on larger containers with capacities over 2000 gal (7.6 m³) (see **Exhibit 5.43**), and must be marked so that they can be easily read. Markings are required for propane, butane, and 50 percent propane/50 percent butane mix as these are

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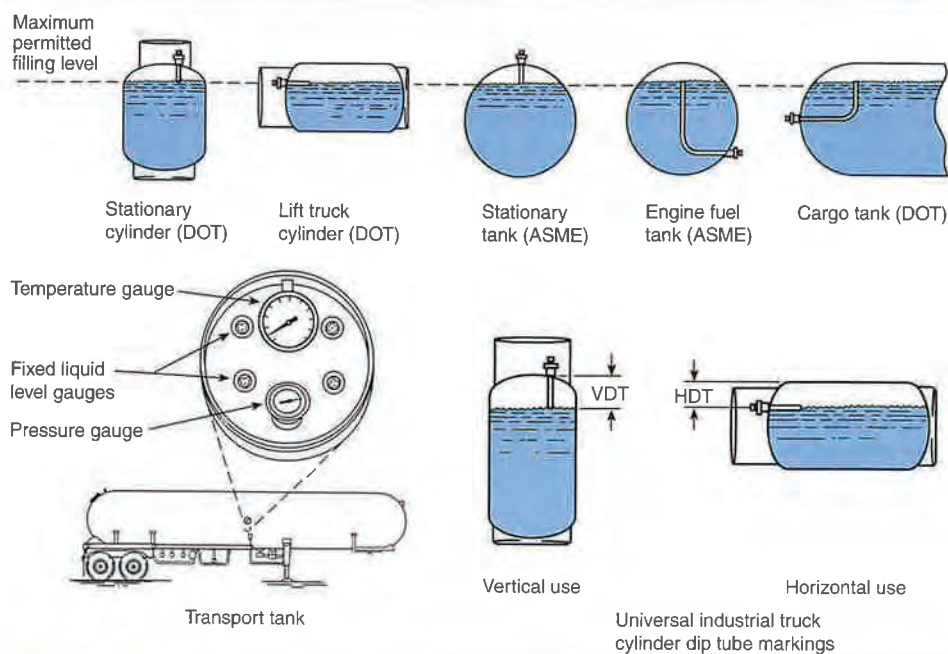


EXHIBIT 5.42 Locations of Fixed Liquid Level Gauges. (Courtesy of Mississippi Tank Company)



EXHIBIT 5.43 Variable Liquid Level Gauge. (Courtesy of Eastern Propane Corp.)

used. The gauge scale must also provide for the variation in density from 20°F to 130°F (–7°C to 54°C), in increments no larger than 20°F (11°C) so that the container can be properly filled at any temperature within this range. Because the shape of the container (cylindrical or spherical) affects the gauge reading, the type of container for which the gauge is calibrated must be indicated.

5.7.5.9 Variable liquid level gauges shall comply with the provisions of 7.4.3.2(B) if they are used for filling containers.

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5.7.5.10 Gauging devices requiring bleeding of product to the atmosphere, such as fixed liquid level, rotary tube, and slip tube gauges, shall be designed so that the bleed valve maximum opening to the atmosphere is not larger than a No. 54 drill size.

A No. 54 drill size allows a very small amount of vapor or liquid flow and should not create a hazardous condition if the gauge is opened briefly.

5.7.6 Pressure Gauges.

5.7.6.1 Pressure gauges shall be attached directly to the container opening or to a valve or fitting that is directly attached to the container opening.

5.7.6.2 If the cross-sectional area of the opening into the container described in **5.7.6.1** is greater than that of a No. 54 drill size, an excess-flow check valve shall be provided for the container connection.

Pressure gauges are connected to container openings and because they extend outward, they can be easily broken off. Pressure gauges must be protected to minimize leakage in the event of accidental breakage. If a break should occur, the leakage is minimized by restricting the opening to the size of a No. 54 drill (see the commentary following **5.7.5.10**) or by installing an excess-flow valve, which will close automatically if excessive flow passes through it.

5.7.7 Other Container Connections.



5.7.7.1 Other container openings shall be equipped with any of the following:

- (1) A positive shutoff valve in combination with either an excess-flow check valve or a backflow check valve
- (2) An internal valve
- (3) A backflow check valve
- (4) An actuated liquid withdrawal excess-flow valve, normally closed and plugged, with provision to allow for external actuation
- (5) A plug, blind flange, or plugged companion flange



5.7.7.2 Any of the valves listed in **5.7.7.1**(1), (2), or (3) that are not connected for service shall be plugged or capped.

5.7.8 Container Appurtenance Installation.

5.7.8.1 All container openings except those used for pressure relief devices, liquid level gauging devices, pressure gauges, double check filler valves, combination backflow check and excess-flow vapor return valves, actuated liquid withdrawal excess-flow valves, and plugged openings shall be equipped with internal valves or with positive shutoff valves and either excess-flow or backflow check valves.

(A) Valves in ASME containers, where excess-flow or backflow check valves are installed between the LP-Gas in the container and the shutoff valves, shall be installed either inside the container or at a point immediately outside where the line enters or leaves the container.

An excess-flow valve is used where flow is in either direction through a given connection. A backflow check valve can be used where flow is intended only into a container and where outflow must be prevented. It is preferable (and required in most cases) to have an excess-flow valve or backflow check valve installed inside the container so that if the piping outside of the container breaks, the safety device will not be adversely affected.

(B) If excess-flow and backflow check valves are installed outside the container, installation shall be made so that any strain beyond the excess-flow or backflow check valves will not cause breakage between the container and the valve.

(C) All connections that are listed in the ASME Manufacturers' Data Report for the container shall be considered part of the container.

(D) If an excess-flow valve is required for cylinders other than for mobile or engine fuel service, it shall be permitted to be located at the outlet of the cylinder shutoff valve.

Cylinders in mobile and engine fuel service are more prone to damage by the very nature of the service they are in. To reduce the possibility of an excess-flow valve being sheared or otherwise disabled on these cylinders, the code requires them to be installed within the container or immediately outside the container in accordance with 5.7.8.1(A) and (B).

(E) Shutoff valves shall be located as close to the container as practical.

(F) Shutoff valves shall be readily accessible for operation and maintenance under normal and emergency conditions.

(G) Shutoff valves either shall be located in a readily accessible position less than 6 ft (1.8 m) above ground level, or shall have extension handles, stairs, ladders, or platforms for access, or shall be equipped for remote operation.

(H) The connection or line that leads to or from any individual opening shall have a flow capacity greater than the rated flow of the excess-flow valve protecting the opening.

An excess-flow valve will shut off the flow of product only if the flow rate is in excess of the valve's flow rating. The sizing of excess-flow valves is critical to their performance. The valves must be sized above the normal design flow rating of the system, but also below the maximum flow capacity of the piping system. The flow of gas in a system can exceed the normal flow, especially during startup when there is no pressure in the system. This condition can cause the excess-flow valve to close when container valves are opened. One solution to this problem is to specify an excess-flow valve with a higher flow rating, but the flow selected must never exceed the maximum design flow capacity of the system. Finding an excess-flow valve with a higher capacity and lower than the maximum system capacity can be difficult, because excess-flow valves are only available with a limited number of flow ratings. The best solution to the problem may be to partially open the valve to avoid pressure spikes until the system reaches operating pressure.

Excess-flow valves are especially effective to control product after hose or piping systems have totally separated. If a partial break in a line occurs that will not allow a flow up to the rated capacity, the excess-flow valve will not close. Many designers and operators believe that an excess-flow valve provides 100 percent protection in case of a pipe break, but this is true only if the break will permit enough flow to operate the excess-flow valve. Because container pressure is a function of temperature, pressure in and flow from a container will be lower at lower temperatures. For this reason, it is well known that excess-flow valves cannot provide 100 percent assurance of stopping product flow. This problem became evident after an incident involving the unintended release of liquid during unloading of a transport truck. Other means of stopping flow in the event of this unintended discharge are now required by DOT for cargo tank vehicles, and by NFPA 58 (internal valves) for larger container installations. Bobtails must have a remote means of closure of the container liquid withdrawal valve within 20 seconds of unintended release of the liquid. This closure is most commonly accomplished with the use of a radio remote shutoff button carried by the operator. Transports require a "passive" shutdown device, which is one that operates without human intervention. Additional information on this subject can be obtained from DOT.

It is also important to size the piping downstream of the excess-flow valve so that it does not restrict the flow of product and thereby prevent the excess-flow valve from closing. If the pipe size is reduced in a branch pipe, the excess-flow valve in the main line will probably not close if the branch pipe is broken, because the flow will probably be less than the closing flow of the excess-flow valve in the main line. Branch lines that are reduced in size from the main

◀ FAQ

Why are excess-flow valves installed in cylinders used in mobile and engine fuel service not permitted to be installed at the outlet of the cylinder shutoff valve?

line must be equipped with a separate excess-flow valve that is sized for the smaller flows in the branch line.

5.7.8.2 Valves, regulators, gauges, and other container appurtenances shall be protected against physical damage.

Paragraph 5.7.8.2 does not intend that appurtenances must be provided with covers or other protection for all installations. The requirement is intended to apply to those installations where extraordinary circumstances may present the threat of physical damage to appurtenances. For example, an installation where material handling is routinely performed above or immediately adjacent to the container may present the need for additional protection.

5.7.8.3 Valves and other appurtenances that are part of the assembly of portable multicylinder systems shall be arranged so that replacement of cylinders can be made without shutting off the flow of gas in the system.

Paragraph 5.7.8.3 recognizes that where practical, locating the components in a system so that the system need not be shut off to replace cylinders will avoid the necessity of performing a leak check as required by the NFPA 54, *National Fuel Gas Code* [19], after an interruption of service has occurred.

5.7.8.4 Connections to ASME containers installed underground shall be located within a substantial dome, housing, or manhole and shall have a cover.

(A) Underground containers shall be installed so that all connections for hose and any opening through which there can be a flow from pressure relief devices or pressure regulator vents are located above the normal maximum water table.

(B) Such manholes or housings shall be ventilated.

(C) The area of ventilation openings shall equal or exceed the combined discharge areas of the pressure relief devices and other vent lines that discharge into the manhole or housing.

The housing around appurtenances on underground containers is subject to the accumulation of water and debris. Provisions must be in place to permit the proper operation of safety systems for the installation.

5.7.8.5 Container inlet and outlet connections on ASME containers of more than 2000 gal (7.6 m³) water capacity shall be labeled to designate whether they communicate with the vapor or liquid space.

(A) Labels shall be permitted to be on valves.

(B) Connections for pressure relief devices, liquid level gauging devices, and pressure gauges shall not be required to be labeled.

Note that **Exhibit 5.44** shows a typical method of identifying liquid and vapor lines at a bulk plant. Not only is the piping system identified by a label, but the liquid and vapor pipes are color-coded as well. The requirements of **5.7.8.5** can help avoid an incident due to the misidentification of a pipe or valve.

5.7.8.6 Every ASME storage container of more than 2000 gal (7.6 m³) water capacity shall be provided with a pressure gauge.



5.8 Regulators and Regulator Vents

5.8.1 Regulators.

An LP-Gas pressure regulator, commonly referred to simply as a regulator, is designed to control propane vapor pressure. Propane appliances in buildings typically operate at 11 in. w.c.



EXHIBIT 5.44 ASME Container with Labeled and Color-Coded Connections. (Courtesy of Propane Education and Research Council)

(2.7 kPa) (about 1/2 psi), so the vapor pressure of the propane in the container must be reduced to a much lower pressure for the appliance to operate safely. Regulators also incorporate devices designed to prevent excessive pressure from reaching appliances installed in buildings. Regulators are the key to the safe use of propane in buildings. [Exhibit 3.11](#) shows a first-stage regulator for vapor service. [Exhibit 3.13](#) shows a second-stage regulator. Although these regulators look very similar, they operate at different pressures. [Exhibits 5.45](#) and [5.46](#) illustrate how regulators work. The regulator also incorporates a pressure relief function, which is illustrated in [Exhibit 5.46](#).

Since the 1995 edition, two-stage pressure regulation systems have been required for most fixed propane installations in buildings. The regulators used in two-stage regulator systems are designed to reduce propane container pressure to an intermediate pressure of 10 psig (69 kPag), and then further reduce pressure to 11 in. w.c. (2.7 kPag). This is accomplished with the use of two separate regulators (first- and second-stage), or with one single unit, an integral two-stage regulator.

See [Exhibit 5.47](#), where the second stage is the large regulator and the first stage is bolted on at the right. The second-stage bonnet with the vent pointing to the left can be seen above the two pressure taps, which are used for reading first-stage and second-stage regulator outlet pressures. The first-stage regulator is at the threaded inlet with the vent pointing down.

5.8.1.1 Single-stage regulators shall have a maximum outlet pressure setting of 1.0 psig (7 kPag) and shall be equipped with one of the following (*see 6.8.1.5 for required protection from the elements*):

- (1) An integral pressure relief valve on the outlet pressure side having a start-to-discharge pressure setting within the limits specified in UL 144, *Standard for LP-Gas Regulators*.
- (2) An integral overpressure shutoff device that shuts off the flow of LP-Gas vapor when the outlet pressure of the regulator reaches the overpressure limits specified in UL 144, *Standard for LP-Gas Regulators*. Such a device shall not open to permit flow of gas until it has been manually reset.

Single-stage regulators are permitted in limited applications. (See [6.8.1.9](#) for applications in which single-stage regulation is permitted.) The design requirements required by [5.8.1.1\(2\)](#) are intended for the regulator manufacturer and not for the user.

5.8.1.2 Second-stage regulators and integral two-stage regulators shall have a maximum outlet pressure setting of 14 in. w.c. (4.0 kPag) and shall be equipped with one of the following (*see 6.8.1.5 for required protection from the elements*):

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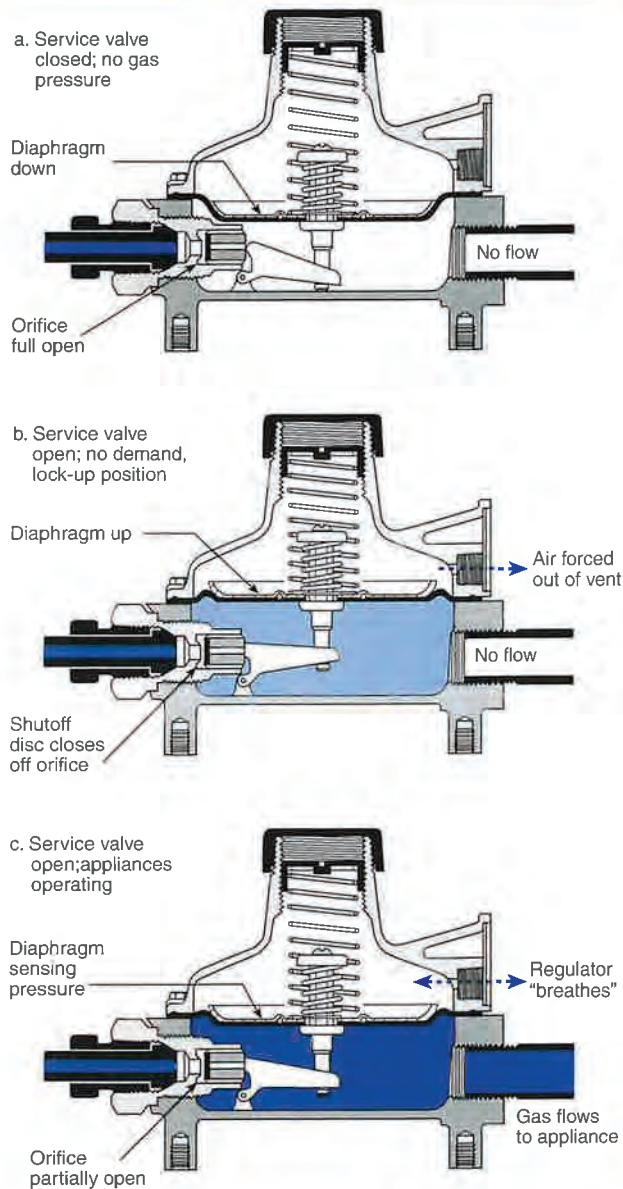


EXHIBIT 5.45 Regulator Operation. (Courtesy of National Propane Gas Association)

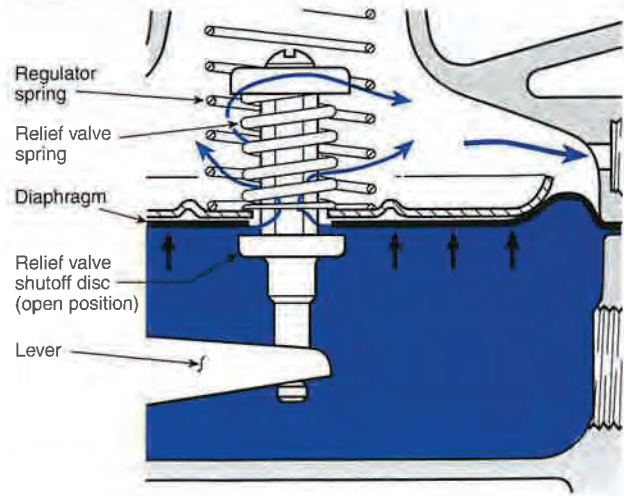


EXHIBIT 5.46 Operation of Regulator Relief Valve. (Courtesy of National Propane Gas Association)

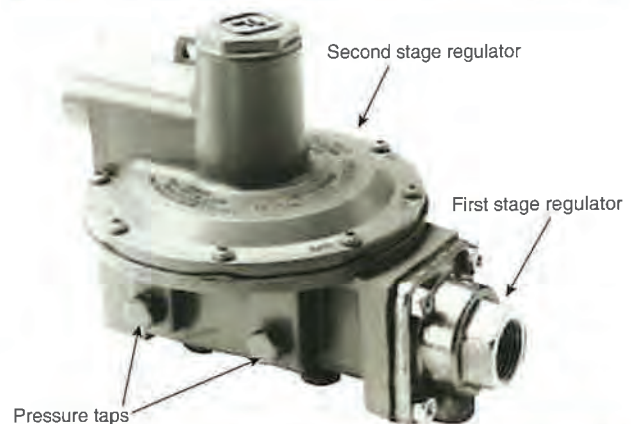


EXHIBIT 5.47 Integral Two-Stage Regulator. (Courtesy of Fisher Controls Intl, LLC)

- (1) An integral pressure relief valve on the outlet pressure side having a start-to-discharge pressure setting within the limits specified in UL 144, *Standard for LP-Gas Regulators*. This relief device shall limit the outlet pressure of the second-stage regulator to 2.0 psig (14 kPag) when the regulator seat disc is removed and the inlet pressure to the regulator is 10.0 psig (69 kPag) or less, as specified in UL 144.
- (2) An integral overpressure shutoff device that shuts off the flow of LP-Gas vapor when the outlet pressure of the regulator reaches the overpressure limits specified in UL 144, *Standard for LP-Gas Regulators*. Such a device shall not open to permit flow of gas until it has been manually reset.

The requirements in 5.8.1.1(1) and 5.8.1.1(2) and 5.8.1.2(1) and 5.8.1.2(2) are intended to prevent overpressure in building piping systems. Overpressure can force flames to protrude beyond an appliance and ignite nearby combustibles or otherwise give unsafe, inefficient combustion performance. Prevention of overpressure in the system begins by mandating two-stage regulation in most applications in buildings and by mandating the first-stage outlet pressure to be set at 10 psig (15 kPag) or less. Second-stage regulators must be designed to limit pressure in the building piping to 2 psig. This is accomplished by making the second-stage regulator relief capacity large enough to prevent pressure from exceeding 2 psig in the event of failure to control the flow of gas. The 2 psig limit is also in UL 144, *Standard for LP-Gas Regulators* [20], for second-stage pressure regulators. The seat is the resilient sealing component in the regulator. This 2 psig overpressure criterion was chosen because it should not cause appliance controls to fail. Appliance control standards require that they not leak when exposed to 2 psig.

Overpressure in piping systems can result from the failure of a regulator component or, in some cases, from blockage of the regulator vent in the regulator housing. Components that can fail include all the components of the regulator: seats, diaphragms, linkages, and other mechanical elements. Although a failure of one of these components may occur, it is not likely to happen. Insect nests built in the screen or opening, or freezing water may cause blockage of a regulator vent. Outdoor installation of regulators must comply with 6.8.1.5, which states in part that they be “designed, installed, or protected so their operation will not be affected by the elements.” Regulators constructed and tested in accordance with UL 144 have a test for vent blockage caused by freezing rain and require a vent screen to prevent insect blockage to protect the regulators. Unusual weather conditions can cause ice buildup of such thickness that it is beyond the testing mandated by UL 144. For example, one highly unusual storm in Cape May, New Jersey, in March 1984, reportedly resulted in ice thickness of about one inch.

The maximum discharge pressure from a second-stage regulator is limited to a 14 in. (4.0 kPag) water column. To the editor’s knowledge, no regulators are available in the United States with an integral overpressure shutoff device for use in LP-Gas systems. The drawback of overpressure shutoff devices, in addition to their higher manufacturing cost, is that once the gas flow is shut off, it must be manually reset. The system thus experiences an “interruption of service,” which then requires a leak check to be performed (per NFPA 54). Currently, all regulators use an integral full-capacity relief valve that prevents the outlet pressure from exceeding 2 psig (3 kPag), even with total regulator seat failure.

- (3) Regulators with a rated capacity of more than 500,000 Btu/hr (147 kW/hr) shall be permitted to have a separate overpressure protection device complying with 5.9.2 of NFPA 54, *National Fuel Gas Code* (ANSI Z223.1). The overpressure protection device shall limit the outlet pressure of the regulator to 2.0 psig (14 kPag) when the regulator seat disc is removed and the inlet pressure to the regulator is 10 psig (69 kPag) or less.

Regulators with capacities over 500,000 Btu/hr (147 kW/hr) are exempt from the required integral overpressure protection provisions because, with an engineered system, one can use a special separate overprotection device that is addressed in NFPA 54. Information on sizing independent pressure relief valves is located in Supplement 3, Paragraphs 5.9.2 through 5.9.8 of NFPA 54, *National Fuel Gas Code*, state the following:

5.9.2 Devices.

5.9.2.1 Pressure relieving or pressure limiting devices shall be one of the following:

- (1) Spring-loaded relief device
- (2) Pilot-loaded back pressure regulator used as a relief valve so designed that failure of the pilot system or external control piping will cause the regulator relief valve to open
- (3) A monitoring regulator installed in series with the service or line pressure regulator

- (4) A series regulator installed upstream from the service or line regulator and set to continuously limit the pressure on the inlet of the service or line regulator to the maximum working pressure of the downstream piping system
- (5) An automatic shutoff device installed in series with the service or line pressure regulator and set to shut off when the pressure on the downstream piping system reaches the maximum working pressure or some other predetermined pressure less than the maximum working pressure. This device shall be designed so that it will remain closed until manually reset.
- (6) A liquid seal relief device that can be set to open accurately and consistently at the desired pressure

5.9.2.2 The devices in **5.9.2.1** shall be installed either as an integral part of the service or line pressure regulator or as separate units. Where separate pressure relieving or pressure limiting devices are installed, they shall comply with **5.9.3** through **5.9.8**.

5.9.3 Construction and Installation. All pressure relieving or pressure limiting devices shall meet the following requirements:

- (1) Be constructed of materials so that the operation of the device will not be impaired by corrosion of external parts by the atmosphere or of internal parts by the gas.
- (2) Be designed and installed so they can be operated to determine whether the valve is free. The devices shall also be designed and installed so they can be tested to determine the pressure at which they will operate and be examined for leakage when in the closed position.

5.9.4 External Control Piping. External control piping shall be protected from falling objects, excavations, or other causes of damage and shall be designed and installed so that damage to any control piping shall not render both the regulator and the overpressure protective device inoperative.

5.9.5 Setting. Each pressure limiting or pressure relieving device shall be set so that the pressure shall not exceed a safe level beyond the maximum allowable working pressure for the piping and appliances connected.

5.9.6 Unauthorized Operation. Precautions shall be taken to prevent unauthorized operation of any shutoff valve that will make a pressure relieving valve or pressure limiting device inoperative. The following are acceptable methods for complying with this provision:

- (1) Lock the valve in the open position. Instruct authorized personnel in the importance of leaving the shutoff valve open and of being present while the shutoff valve is closed so that it can be locked in the open position before leaving the premises.
- (2) Install duplicate relief valves, each having adequate capacity to protect the system, and arrange the isolating valves or three-way valve so that only one safety device can be rendered inoperative at a time.

5.9.7 Vents.

5.9.7.1 The discharge stacks, vents, or outlet parts of all pressure relieving and pressure limiting devices shall be located so that gas is safely discharged to the outdoors. Discharge stacks or vents shall be designed to prevent the entry of water, insects, or other foreign material that could cause blockage.

5.9.7.2 The discharge stack or vent line shall be at least the same size as the outlet of the pressure relieving device.

5.9.8 Size of Fittings, Pipe, and Openings. The fittings, pipe, and openings located between the system to be protected and the pressure relieving device shall be sized to prevent hammering of the valve and to prevent impairment of relief capacity. [NFPA 54, 2006]

5.8.1.3 Integral two-stage regulators shall be provided with a means to determine the outlet pressure of the high-pressure regulator portion of the integral two-stage regulator.

Integral two-stage regulators, as shown in **Exhibit 3.12** — sometimes called “piggyback” regulators — consist of first-stage and second-stage regulators in the same body. They are sold and installed as one unit. To determine outlet pressure of the first-stage regulator portion, a plugged opening with a restrictive orifice for a pressure gauge or a permanently installed pressure-indicating device is included with the integral two-stage regulator.

5.8.1.4 Automatic changeover regulators shall be exempt from the requirement in **5.8.1.3**.



5.8.1.5 Integral two-stage regulators shall not incorporate an integral pressure relief valve in the high-pressure regulator portion of the unit.

5.8.1.6 First-stage regulators shall incorporate an integral pressure relief valve having a start-to-discharge setting within the limits specified in UL 144, *Standard for LP-Gas Regulators*.

5.8.1.7 First-stage regulators with a rated capacity of more than 500,000 Btu/hr (147 kW/hr) shall be permitted to have a separate pressure relief valve.



5.8.1.8 High-pressure regulators with a rated capacity of more than 500,000 Btu/hr (147 kW/hr) where permitted to be used in two-stage systems shall incorporate an integral pressure relief valve or shall have a separate relief valve.

Regulators larger than 500,000 Btu/hr (147 kW/hr) can have a separate pressure relief valve or a separate overpressure shutoff device. Information on sizing independent pressure relief valves is located in Supplement 3.

5.8.1.9 First-stage regulators shall have an outlet pressure setting up to 10.0 psig (69 kPag) in accordance with UL 144, *Standard for LP-Gas Regulators*.

5.8.1.10 Regulators shall be designed so as to drain all condensate from the regulator spring case when the vent is directed down vertically.

5.8.1.11 Two-psi service regulators shall be equipped with one of the following:

- (1) An integral pressure relief valve on the outlet pressure side having a start-to-discharge pressure setting within the limits specified in UL 144, *Standard for LP-Gas Regulators*. This relief device shall limit the outlet pressure of the 2 psi (14 kPa) service regulator to 5.0 psi (34.5 kPa) when the regulator seat disc is removed and inlet pressure to the regulator is 10.0 psi (69 kPa) or as specified in UL 144.
- (2) An integral overpressure shutoff device that shuts off the flow of LP-Gas vapor when the outlet pressure of the regulator reaches the overpressure limits specified in UL 144, *Standard for LP-Gas Regulators*. Such a device shall not open to permit flow of gas until it has been manually reset.

The requirement in **5.8.1.11** preserves the overpressure protection limits to interior piping and appliances that have already been established in the code where 2 psi systems are used. Two psi (14 kPa) systems have the advantage over 11 in. w. c. systems in larger piping systems because smaller piping can be used. This difference can result in lower material costs. In addition, corrugated stainless steel tubing commonly is used with 2 psi (14 kPa) systems. This material is not rigid, so it offers the advantages of design flexibility, fewer fittings and joints, and a substantial decrease in installation time.

Two psi (14 kPa) systems are three-stage regulator systems comprised of a 10 psi (69 kPa) regulator at the container, a 2 psi (14 kPa) regulator at the outside of the building, and a line pressure regulator located in the building and near the appliance. NFPA 58 covers the first- and second-stage regulators. NFPA 54, *National Fuel Gas Code* [19], covers the line pressure regulator.

5.8.2 Pressure Regulators. (Reserved)

5.8.3* Pipe for Regulator Venting.

A.5.8.3 UL 651, *Schedule 40 or 80 Rigid PVC Conduit*, listed rigid PVC electrical conduit has been designed, manufactured, and tested for use in a wide variety of operating conditions, including low temperatures and exposure to sunlight and outdoor weather. UL 651 conduit is widely available and can be purchased in hardware and electrical supply stores, where it is usually sold as electrical conduit.

5.8.3.1 Pipe or tubing used to vent regulators shall be one of the following:

- (1) Metal pipe and tubing in accordance with **5.9.3**
- (2) PVC meeting the requirements of UL 651, *Schedule 40 or 80 Rigid PVC Conduit*

FAQ ►

Can plastic pipe or tubing be used to vent regulators? If so, what type of plastic pipe or tubing is permitted?

Permitting the use of PVC in the requirements for regulator venting was added in the 2001 edition to provide an alternative to the pressure piping materials listed in the code for regulator relief valve vent piping. It is noted that PVC complying with UL 651, *Schedule 40 and 80 Rigid PVC Conduit* [21], is tested and listed for outdoor use. The PVC electrical conduit is also ultraviolet-resistant and does not crack at subzero temperatures. These properties provide advantages over steel pipe, which will probably corrode over time if installed outdoors.

5.8.3.2 Other PVC piping materials and polyethylene and polyamide pipe and tubing shall not be permitted to be used to vent regulators.

5.9 Piping (Including Hose), Fittings, and Valves

The term *piping*, as used in NFPA 58, includes pipe, tubing, hose, and fittings used in the piping system. Minimum requirements for this equipment are given in **Section 5.9** for use by manufacturers in producing piping system components. Guidelines, both for testing laboratories to list equipment for possible acceptance by authorities having jurisdiction and for users to select proper materials when making a piping installation, are also included. The requirements for valves used in a piping system are located in **Section 5.12**.

5.9.1 General.

5.9.1.1 Material specifications for pipe, tubing, pipe and tubing fittings, valves (including hydrostatic relief valves), hose, hose connections, and flexible connectors shall be in accordance with **Section 5.9**.

5.9.1.2 Piping, pipe and tubing fittings, and valves used to supply utilization equipment within the scope of NFPA 54, *National Fuel Gas Code*, shall comply with that code.

Most LP-Gas building piping systems downstream of the second-stage regulator are subject to the provisions of NFPA 54. Therefore, reference should be made to NFPA 54 to determine whether the particular installation (primarily a permanent building piping system) is subject to that code.

Where an LP-Gas system serves a building, piping between the container and the second-stage regulator is within the scope of NFPA 58 and piping downstream of the second-stage regulator is within the scope of NFPA 54. However, LP-Gas piping in buildings for agricultural applications — for example, brooders, dehydrators, dryers, and irrigation equipment — falls under NFPA 58 even when those buildings are served by fixed piping because NFPA 54 excludes piping serving farm equipment. [See 1.1.1.2(2) in NFPA 54.] Coverage by NFPA 58 is necessary because natural gas mains rarely serve farms, and NFPA 54 has specifically excluded farm equipment. Other piping systems beyond the second-stage regulator in applications not usually served by natural gas mains are covered under NFPA 58. These systems include piping systems serving railroad switch heaters and heaters that keep microwave antennae free of ice.

5.9.1.3 Pipe and tubing shall comply with one of the following requirements:

- (1) Pipe and tubing shall comply with **5.9.3**.
- (2) Pipe and tubing shall be recommended for that service by the manufacturer and shall be approved.

5.9.1.4 Piping that can contain liquid LP-Gas and that can be isolated by valving and that requires hydrostatic relief valves, as specified under **Section 6.13**, shall have an operating pressure of 350 psig (2.4 MPag) or a pressure that is equivalent to the maximum discharge pressure of any pump or other source feeding the piping system if it is greater than 350 psig (2.4 MPag).

Liquid piping that can be isolated by valves can experience high pressures if the liquid is heated. Although **Section 6.11** requires a hydrostatic pressure relief valve to prevent pipe failure, a higher pipe design pressure of 350 psig (2.4 MPag) is specified. There is no potential threat to the integrity of a piping designed to 350 psig (2.4 MPag) with a pressure relief valve setting up to 400 psig (2.8 MPag).

5.9.2 Reserved.

5.9.3 Pipe and Tubing.

5.9.3.1 Pipe shall be wrought iron or steel (black or galvanized), brass, copper, polyamide, or polyethylene and shall comply with the following:

- (1) Wrought iron: ASME B36.10M, *Welded and Seamless Wrought Steel Pipe*
- (2) Steel pipe: ASTM A 53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless*
- (3) Steel pipe: ASTM A 106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*
- (4) Brass pipe: ASTM B 43, *Standard Specification for Seamless Red Brass Pipe, Standard Sizes*
- (5) Copper pipe: ASTM B 42, *Standard Specification for Seamless Copper Pipe, Standard Sizes*
- (6) Polyamide and polyethylene pipe: ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings*, and shall be recommended by the manufacturer for use with LP-Gas

5.9.3.2 Tubing shall be steel, stainless steel, brass, copper, polyamide, or polyethylene (*see 6.9.4*) and shall comply with the following:

- (1) Steel tubing: ASTM A 539, *Standard Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas Fuel Oil Lines*
- (2) Brass tubing: ASTM B 135, *Standard Specification for Seamless Brass Tube*
- (3) Copper tubing:
 - (a) Type K or L: ASTM B 88, *Standard Specification for Seamless Copper Water Tube*
 - (b) ASTM B 280, *Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service*
- (4) Polyamide and polyethylene tubing: ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings*, and shall be recommended by the manufacturer for use with LP-Gas
- (5) Corrugated stainless steel tubing: ANSI/CSA 6.26 (LC1), *Interior Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing*

Provisions for plastic pipe and tubing were first incorporated in the 1979 edition of the code. Pipe and tubing were limited to polyethylene (PE) meeting certain ASTM standards and recommended for propane service by the manufacturer. Since the 2004 edition, the code now permits the use of polyamide (PA, or nylon) pipe and tubing as well. The technical committee reviewed data on the performance of PA with respect to temperature and pressure ratings and resistance to LP-Gas, and determined that PA is suitable to be used for LP-Gas applications.

In practice, it is not anticipated that nylon tubing will be widely used, because it is more costly than PE.

5.9.4 Fittings for Metallic Pipe and Tubing.

Fittings shall be steel, brass, copper, malleable iron, or ductile (nodular) iron.

Subsection 5.9.4 provides the material requirements for pipe and tubing fittings. The pressure limitations for piping materials were reorganized into table format in the 2001 edition, making the requirements easier to locate (see **Table 5.9.4.1**). No changes were made to the requirements themselves.

5.9.4.1 Pipe fittings shall have a minimum pressure rating as specified in **Table 5.9.4.1** and shall comply with the following:

- (1) Cast-iron pipe fittings shall not be used.
- (2) Brazing filler material shall have a melting point that exceeds 1000°F (538°C).

TABLE 5.9.4.1 Service Pressure Rating of Pipe, Tubing Fittings, and Valves

Service	Minimum Pressure
Higher than container pressure	350 psig (2.4 MPa), or the MAWP, whichever is higher, or 400 psig (2.8 MPa) WOG rating
LP-Gas liquid, or vapor at operating pressure over 125 psig and at or below container pressure	250 psig (1.7 MPa)
LP-Gas vapor at operating pressure of 125 psig (0.9 MPa) or less	125 psig (0.9 MPa)

Brazing is an acceptable method of joining fittings to pipe and, more commonly, to tubing when the filler alloy has a melting point in excess of 1000°F (538°C). Nearly all brazes meet this requirement, because a braze is defined as a metal alloy with a melting point above 850°F (454°C). Any filler metal with a lower melting point is defined as solder. The lower melting point prohibits soldering as a method of joining LP-Gas fittings to pipe and tubing. The 1000°F (538°C) minimum temperature is intended to ensure the integrity of a gas piping system when exposed to fire.

Although brazing alloys are not specified in this code, NFPA 54 states that brazing alloys must not contain more than 0.05 percent phosphorus because this can lead to a deterioration of the joint. The editor is advised that all brazing materials available at the time of publication meet this phosphorus level requirement.

5.9.4.2 Metal tube fittings shall have a minimum pressure rating as specified in **Table 5.9.4.1**.

Paragraph 5.9.4.2 is silent on the fabrication and use of flared fittings. Flared fittings are fabricated when installed in the field and do not require approval.

5.9.5* Fittings for Polyethylene and Polyamide Pipe and Tubing.

Joints in polyamide and polyethylene pipe and polyethylene tubing shall be made by heat fusion, by compression-type mechanical fittings, or by factory-assembled transition fittings.

A.5.9.5 Persons joining PE pipe should be trained under the applicable joining procedure established by the manufacturer, including the following:

- (1) Appropriate training in the use of joining procedures
- (2) Making a specimen joint from pipe sections joined according to the procedures
- (3) Visually examining these joints during and after assembly

PE joints in PE and PA pipe and tubing can be made by heat fusion and by compression-type mechanical fittings meeting ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings* [22]. Factory-assembled transition fittings may also be used. The use of PE pipe and tubing is limited to vapor (no liquid) and must not exceed 30 psig (208 kPag). The system can only be installed outside and underground.

Fusion joints are made by inserting the ends of either PE or PA tubing sections into a fitting, and then heating the fitting using a special electrically heated tool or by butting the tubing ends in a heating tool and forcing the hot ends together. These methods are used widely for PE tubing in natural gas service, where the vast majority of this piping material is used. An installer using this equipment must be trained, certified, and experienced in its use in order to make leak-free joints.

Fittings that do not require special heating tools include the following:

- Fittings made of nonmetallic thermoplastic materials, other than PE, that comply with ASTM D 2513 [22] for selection of materials
- PE or PA compression-type mechanical fittings to join PE piping materials
- Risers that provide the transition from PE or PA pipe under ground to metallic pipe above ground. [See 5.9.5(E) for information on risers.]

(A) Polyethylene pipe shall not be joined by a threaded or miter joint.

(B) Polyamide and polyethylene fusion fittings shall be recommended by the manufacturer for use with LP-Gas and shall conform to one of the following:

- (1) ASTM D 2683, *Standard Specification for Socket-Type Polyethylene (PE) Fittings for Outside Diameter Controlled Polyethylene Pipe*
- (2) ASTM D 3261, *Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing*
- (3) ASTM F 1055, *Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing*
- (4) ASTM F 1733, *Standard Specification for Butt Heat Fusion Polyamide (PA) Plastic Fitting for Polyamide (PA) Plastic Pipe and Tubing*

(C) Installation instructions specific to the type and grade of polyethylene being joined shall be provided with heat fusion fittings.

(D)* Mechanical fittings shall comply with Category 1 of ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings*, and the following:

- (1) Mechanical joints shall be tested and recommended by the manufacturer for use with polyethylene pipe and tubing.

An example of a mechanical fitting is shown in Exhibit 5.48.

- (2) Compression-type mechanical fittings shall include a rigid internal tubular stiffener, other than a split tubular stiffener, to support the pipe.
- (3) Gasket material in the fitting shall be resistant to the action of LP-Gas and shall be compatible with the polyamide or polyethylene pipe material.

Prior to the 1992 edition of NFPA 58, the use of PE and PA piping in LP-Gas service was not allowed except by approval from the authority having jurisdiction. The use of PE piping was

EXHIBIT 5.48 *Mechanical Fitting for PE Tubing.*
(Courtesy of Elster Perfection)



restricted because compression-type mechanical fittings were prohibited until the publication of the 1992 edition of NFPA 58. Thus, there was no legal way to transition from PE pipe to steel pipe, because transition fittings were considered to be compression-type fittings. Since 1992, with the allowed use of compression-type mechanical fittings, the underground use of PE tubing in LP-Gas piping systems has grown at a very rapid rate. In the 2004 edition, the use of PA in addition to PE pipe and tubing was added.

The use of compression-type mechanical fittings provides a more practical joining method for propane system installers, because only a few inexpensive special tools are required and training and certification of the installers are easily accomplished. Compression-type mechanical fittings must comply with Category 1 of ASTM D 2513 [22], be tested and recommended for use with LP-Gas by the fitting manufacturer, and be installed in accordance with the fitting manufacturer's instructions. All installers must be trained appropriately, and the training must be documented. These qualifications are consistent with **Section 4.4**, Qualification of Personnel. (See **Formal Interpretation 92-1**.)

An important change made in the 2004 edition was recognition of the use of compression-type mechanical fittings on PE piping above 2 in. pipe size. This change was made because it was recognized that larger-size PE and PA pipe have been successfully joined with compression fittings in the natural gas industry.

A.5.9.5(D) 49 CFR 192.281(e) states the following:

Mechanical joints — Each compression-type mechanical joint on plastic pipe must comply with the following:

- (1) The gasket material in the coupling must be compatible with the plastic.
- (2) A rigid internal tubing stiffener, other than a split tubular stiffener, must be used in conjunction with the coupling.

49 CFR 192.283(b) states the following:

Mechanical joints — Before any written procedure established under 192.273(b) is used for plastic making mechanical plastic pipe joints that are designed to withstand tensile forces, the procedure must be qualified by subjecting five specimen joints made according to the procedure to the following tensile test:

Formal Interpretation

NFPA 58

**Liquefied Petroleum Gas Code
2008 Edition**

Reference: 5.9.5

FI 92-1

Question: Was it the intention of the Technical Committee on Liquefied Petroleum Gases, when they adopted 5.8.5 in the 1992 edition of NFPA 58, to restrict the choice of any, or all, of the materials that might be utilized in the several components that comprise the total assembly of mechanical joints to those specifically “listed” or mentioned in the ASTM Standard D2513-90.

Answer: No.

It was not the intent of the committee in 5.8.5 to specify materials of construction. Materials of construction of mechanical fittings are covered in 5.8.4 where it was the committee’s intent to limit fittings to be constructed of materials listed in ASTM D2513, except for gasket materials, which are covered in 5.8.5.

In 1-2.4, Alternate Materials and Provisions, the committee provides a method of use of alternate materials when supported by sufficient evidence acceptable to the authority having jurisdiction.

Issue Edition: 1992

Reference: 2-4.4(c)(2)

Issue Date: January 15, 1993

Effective Date: February 3, 1993

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- (1) Use an apparatus for the test as specified in ASTM D 638, *Standard Test Method for Tensile Properties of Plastics* (except for conditioning).
- (2) The specimen must be of such length that the distance between the grips of the apparatus and the end of the stiffener does not affect the joint strength.
- (3) The speed of testing is 5.0 mm (0.2 in.) per minute, plus or minus 25 percent.
- (4) Pipe specimens less than 102 mm (4 in.) in diameter are qualified if the pipe yields to an elongation less than 25 percent or failure initiates outside the joint area.
- (5) Pipe specimens 102 mm (4 in.) and larger in diameter shall be pulled until the pipe is subjected to a tensile stress equal to or greater than the maximum thermal stress that would be produced by a temperature change of 55°C (100°F) or until the pipe is pulled from the fitting. If the pipe pulls from the fitting, the lowest value of the five test results or the manufacturer’s rating, whichever is lower, must be used in the design calculations for stress.
- (6) Each specimen that fails at the grips must be retested using new pipe.
- (7) Results obtained pertain only to the outside diameter and material of the pipe tested, except where testing of a heavier wall pipe is used to qualify pipe of the same material but with a lesser wall thickness.



EXHIBIT 5.49 *Factory-Assembled Risers. (Courtesy of R. W. Lyall & Company, Inc.)*

(E) Anodeless risers shall comply with the following:

- (1) The metal-gas carrying portion of the anodeless riser after the transition shall have a wall thickness equal to Schedule 40 pipe.
- (2) Factory-assembled anodeless risers shall be recommended for LP-Gas use and shall be leak tested by the manufacturer in accordance with written procedures.
- (3) Field-assembled anodeless risers with service head adapters shall be equipped with moisture seals and shall be recommended for LP-Gas use by the manufacturer and shall be design certified to meet the requirements of Category 1 of ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings*; U.S. Department of Transportation, 49 CFR 192.281(e), “Transportation”; and 6.9.4.3 and 6.9.4.4.
- (4) The manufacturer shall provide the user qualified installation instructions as prescribed by U.S. Department of Transportation, 49 CFR 192.283(b).

In the 1995 edition, the provision was added to permit the use of assembled anodeless risers, which are piping system components used to transition between underground PE and PA piping systems and aboveground metallic piping systems. Risers have been in use in the natural gas service for many years.

The term *anodeless*, used in conjunction with riser, indicates that the riser is designed to retard corrosion without the use of a sacrificial anode. Sacrificial anodes are used with underground propane containers. Risers are protected from corroding by a factory-applied, epoxy-based painted coating.

The two types of risers permitted are described as follows:

- A factory-assembled riser that requires only connection to the PE or PA pipe or tubing under ground and to metallic piping above ground. (See Exhibit 5.49.)
- A field-assembled riser with a flexible metallic or metallic casing incorporating the transition from the PE or PA pipe or tubing to the metal piping above ground. This transition is to be made in the field. The riser consists of a transition fitting (see Exhibit 5.49) and a prefabricated, pre-bent steel riser casing or a flexible metal riser casing. The PE or PA pipe or tubing is inserted up through the casing until it exits the upper end. The transition fitting is installed on the top of the casing, completing the connection from belowground PE or PA to aboveground steel pipe. The transition fitting must be located above ground to minimize corrosion to the steel pipe threads. A metallic or flexible metallic casing protects the PE pipe or tubing, and a moisture seal is installed at the lower end of the casing to prevent water from entering the riser. This type riser is an exception to the rule that PE or PA be used only below ground, but safety is not compromised because the PE or PA is encased with flexible metal or steel pipe and thus protected from mechanical and environmental damage.

5.9.6 Hose, Quick Connectors, Hose Connections, and Flexible Connectors.

5.9.6.1 Hose, hose connections, and flexible connectors (see 3.3.25, *Flexible Connector*) shall be fabricated of materials that are resistant to the action of LP-Gas both as liquid and vapor.

This new requirement in 5.9.6.1 recognizes that the hose used to transfer propane to and from containers and propane trucks includes materials that can be dissolved by propane. Each time propane is moved through a hose, a small amount of these soluble hose materials can be added to the propane. This requirement is intended to reduce the potential for hose products to contaminate LP-Gas.



5.9.6.2 When wire braid is used for reinforcement, it shall be of corrosion-resistant material such as stainless steel.

Carbon steel is not permitted to be used for wire braid reinforcement for hose. This prohibition is based on experience with hose that weakened as the carbon steel wire braid corroded.

5.9.6.3 Hose and quick connectors shall be approved.

5.9.6.4 Hose, hose connections, and flexible connectors used for conveying LP-Gas liquid or vapor at pressures in excess of 5 psig (34 kPag), and as provided in Section 6.19 regardless of the pressure, shall comply with 5.9.6.4(A) through 5.9.6.4(D).

(A) Hose shall be designed for a working pressure of 350 psig (2.4 MPa) with a safety factor of 5 to 1 and shall be continuously marked with LP-GAS, PROPANE, 350 PSI WORKING PRESSURE, and with the manufacturer's name or trademark.

The provisions of 5.9.6.4(A) for hose, hose connections, and flexible connectors apply only to those involved with pressures in excess of 5 psig (34 kPag). Requiring continuous marking permits identification of short pieces of hose used as connectors. In the 2008 edition, the word *propane* was substituted for *LP-Gas* to carry out the intent for international industry identification.

(B) Hose assemblies, after the application of couplings, shall have a design capability of not less than 700 psig (4.8 MPa).

The words *design capability* have been carefully chosen to convey the committee's intent that hose assemblies be capable of withstanding the anticipated pressure and that testing is an option. If testing is done, such assemblies must be pressure-tested at 120 percent of the maximum working pressure of the hose, which is required to be at least 350 psig (2.4 MPa).

(C) If a pressure test is performed, such assemblies shall be pressure tested at 120 percent of the maximum working pressure [350 psig (2.4 MPa) minimum] of the hose.

Note that pressure testing of hose is not required. Because the maximum hose working pressure is 350 psig (2.4 MPa), this optional testing is done at 420 psig (2.9 MPa).

(D) Hose assemblies shall be leak tested at the time of installation at not less than the operating pressure of the system in which they are installed.

5.9.6.5 Hoses at a pressure of 5 psig (34 kPag) or less in agricultural buildings not normally occupied by the public shall be designed for the working pressure of the system and shall be constructed of material resistant to the action of LP-Gas.

Paragraph 5.9.6.5 is an exception to the requirements of 5.9.6.4 for hose used in agricultural applications operating at a maximum pressure of 5 psig.

5.9.6.6 Hoses or flexible connectors used to supply LP-Gas to utilization equipment or appliances shall be installed in accordance with the provisions of 6.9.6 and 6.20.3.

5.10 Reserved

5.11 Internal Valves. (Reserved)

5.12 Valves Other Than Container Valves

5.12.1 Pressure-containing metal parts of valves shall be of steel, ductile (nodular) iron, malleable iron, or brass.

(A) Ductile iron shall meet the requirements of ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*, or equivalent.

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(B) Malleable iron shall meet the requirements of ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings*, or equivalent.

(C) All materials used, including valve seat discs, packing, seals, and diaphragms, shall be resistant to the action of LP-Gas under service conditions.

FAQ ►
What is meant by “resistant to the action of LP-Gas” in 5.12.1(C)?

The requirement in 5.12.1(C) uses language that is found in other areas of the code (e.g., 5.7.1.1, 5.7.1.4, and 5.9.6.1) to establish performance criteria for materials. The material must be resistant to LP-Gas such that it will not degrade, decompose, warp, or otherwise deteriorate to the point that it can no longer serve its intended function safely. Although this “criterion” is certainly subjective, the code relies upon product and material standards to establish more quantifiable performance criteria. For example, ANSI/UL125, *Standard for Valves for Anhydrous Ammonia and LP-Gas (Other than Safety Relief)* [16], provides testing criteria to establish the resistance of materials used in valves to the action of LP-Gas. Product standards of this type include tests intended for newly produced products and not to verify that products in use are suitable for continued use. Good judgment should be used in the selection of tests.

5.12.2 Valves shall have a service pressure rating as specified in Table 5.9.4.1.

5.12.3 Manual shutoff valves, emergency shutoff valves, excess-flow check valves, and backflow check valves used in piping systems shall comply with the provisions for container valves.

5.12.4 Emergency shutoff valves shall be approved and shall incorporate all of the following means of closing:

- (1) Automatic shutoff through thermal (fire) actuation
- (2) Manual shutoff from a remote location
- (3) Manual shutoff at the installed location

The emergency shutoff valve (ESV) is a key valve in the protection of liquid transfer operations at bulk plants and industrial plants. An ESV is shown in Exhibit 5.50. The installation requirements for these emergency shutoff valves are located in Section 6.12. The actuating means for remote shutoff is not specified. Electrical, mechanical, and pneumatic systems are all used. Many systems use a pneumatic valve with a plastic gas tubing system in which the tubing itself acts as a fusible element. When the tubing melts due to high temperatures (from a fire), it releases the pressure holding the valve open, and the flow of fuel is stopped. Regardless of whether continuous tubing or a discrete fusible element is used, thermal activation must be located within 5 ft of the point established in 6.12.6. If the ESV is closed remotely by a cable attachment, it is recommended that the remote closing feature of the ESV be operated occasionally to verify proper operation, especially in winter. Cables can become disabled if they lie in water that freezes. Also, the entire system must be tested at least annually. (See 6.12.9.)

See Formal Interpretation 58-01-3 for more information.

EXHIBIT 5.50 Two Emergency Cutoff Valves. [Courtesy of Fisher Controls Intl, LLC (left) and Engineered Controls International, Inc. (right)]



Formal Interpretation

NFPA 58

Liquefied Petroleum Gas Code

2008 Edition

Reference: 5.12.4

F.I. No.: 58-01-3

Question No. 1: Is it the intent of NFPA 58 to prohibit the installation and use of valves or other hardware not specifically required or described in the Code?

Answer: No.

Question No. 2: If a valve marketed as an “emergency shutoff valve” is installed in a location where it is not required to be, is the valve required to comply with all of the closing requirements described in Section 5.10.4?

Answer: No.

Question No. 3: Is it the intent of NFPA 58 for an emergency shutoff valve to be used as a container appurtenance?

Answer: No.

Issue Edition: 2001

Reference: 2.3.3.2 & 3.3.3.6

Issue Date: November 7, 2001

Effective Date: November 27, 2001

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5.12.5 Where fusible elements are used, they shall have a melting point not exceeding 250°F (121°C).

5.12.6 Valves in polyethylene piping systems shall be manufactured from thermoplastic materials listed in ASTM D 2513, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings*, that have been shown to be resistant to the action of LP-Gas and comply with ASTM D 2513. Valves in polyamide piping systems shall be manufactured from polyamide material as defined in ASTM D 2513. Metallic valves in polyethylene and polyamide piping systems shall be protected to minimize corrosion in accordance with [Section 6.16](#).

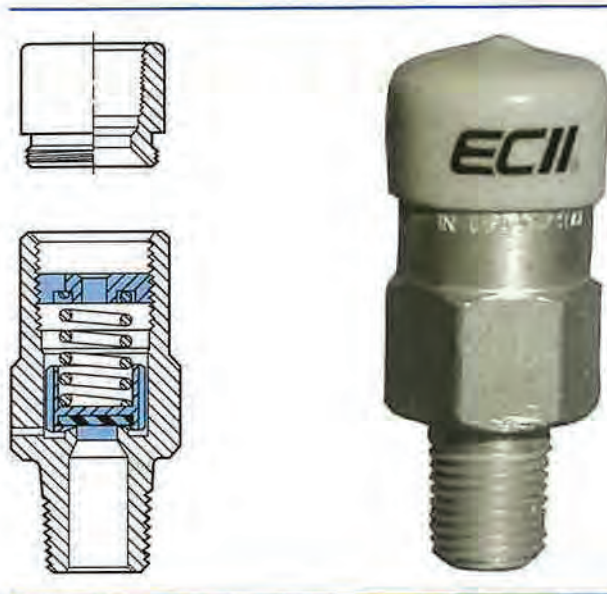
5.12.7 Valves shall be recommended for LP-Gas service by the manufacturer.

5.13 Hydrostatic Relief Valves

5.13.1 Hydrostatic relief valves designed to relieve the hydrostatic pressure that can develop in sections of liquid piping between closed shutoff valves shall have pressure settings not less than 400 psig (2.8 MPag) or more than 500 psig (3.5 MPag) unless installed in systems designed to operate above 350 psig (2.4 MPag).

A hydrostatic pressure relief valve is shown in [Exhibit 5.51](#). It is usually a small valve, because there is no capacity requirement for a hydrostatic relief valve, and it is usually equipped with a 1/4 in. male National Pipe Thread (MNPT) inlet connection. Hydrostatic pressure

EXHIBIT 5.51 Hydrostatic Relief Valve. (Courtesy of Engineered Controls International, Inc.)



FAQ ►
Why are hydrostatic relief valves required to be set at a higher activation pressure than pressure relief valves?

relief valves are required by **Section 6.13** to be installed in sections of piping that can be isolated between positive shutoff valves or other devices that stop liquid flow.

Hydrostatic pressure relief devices have a set point between 400 psig and 500 psig (2.8 MPag and 3.5 MPag) for piping systems with a design pressure of 350 psig (2.4 MPag). This pressure difference (400 psig vs. 350 psig) does not pose a problem for the piping because 350 psig (2.4 MPag) represents the maximum operating pressure at the maximum operating temperature of the piping. Because the actual operating temperature of LP-Gas systems is much less than the maximum temperature, the system is capable of withstanding much higher pressures.

It is significant to note that piping systems are designed for an operating pressure of 350 psig, whereas ASME containers are usually designed for a maximum working pressure of 250 psig. This lower value is why pressure relief valves for ASME containers are rated at 250 psig.

5.13.2 Hydrostatic relief valves for use in systems designed to operate above 350 psig (2.4 MPag) shall have settings not less than 110 percent or more than 125 percent of the system design pressure.

If the design pressure of the piping system exceeds 350 psig (2.4 MPag), hydrostatic relief valves must be set to operate between 110 percent and 125 percent of the system design pressure, because it is not practical to specify the hydrostatic pressure relief valve to operate exactly at the system design pressure of the piping. The hydrostatic pressure relief valve minimum is set to operate above the piping system pressure to minimize unnecessary operation, and the maximum is well below piping system burst pressure. The design pressure of propane piping systems can be higher than 350 psig if a positive displacement pump with a discharge pressure in excess of 350 psig is used. Such pumps are not normally used in the United States and Canada, but are used in other parts of the world.

5.14 Reserved

5.15 Reserved

5.16 Reserved

5.17 Equipment

Section 5.17 provides requirements for propane equipment, such as pumps, compressors, vaporizers, regulators, and other devices used to regulate, transfer, or vaporize propane.

5.17.1 General.

5.17.1.1 This section shall apply to pressure-containing metal parts of LP-Gas equipment.

5.17.1.2 The service pressure rating of equipment shall be in accordance with **Table 5.17.1.2**.

TABLE 5.17.1.2 Service Pressure Rating

Fluid	Pressure	Equipment Design Pressure
LP-Gas vapor	≤20 psig (≤138 kPag)	Maximum anticipated pressure
	20–125 psig (138 kPag–0.9 MPag)	125 psig (0.9 MPag)
	> 125 psig (>0.9 MPag)	250 psig (1.7 MPag) or the anticipated pressure, whichever is higher
LP-Gas liquid	≤250 psig (≤1.7 MPag)	250 psig (1.7 MPag)
	> 250 psig (>1.7 MPag)	350 psig (2.4 MPag) or the anticipated pressure, whichever is higher

5.17.1.3 Equipment shall be fabricated of materials that are compatible with LP-Gas under service conditions and shall be in accordance with **Table 5.17.1.3**.



(A) Pressure-containing metal parts shall be made from the following materials:

- (1) Steel
- (2) Ductile (nodular) iron (ASTM A 395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*, or ASTM A 536, *Standard Specification for Ductile Iron Castings*, Grade 60-40-18 or 65-45-12)
- (3) Malleable iron (ASTM A 47, *Standard Specification for Ferritic Malleable Iron Castings*)
- (4) Higher strength gray iron (ASTM A 48, *Standard Specification for Gray Iron Castings*, Class 40B)
- (5) Brass
- (6) Materials equivalent to **5.17.1.3(A)(1)** through **5.17.1.3(A)(5)** in melting point, corrosion resistance, toughness, and strength

(B) Cast-iron shall not be used as a material of construction for strainers or flow indicators.

(C) Aluminum shall be used only for cylinders, gaskets, regulators, approved meters, and indirect electric vaporizers.



An expanded list of components and equipment that are permitted to be fabricated of aluminum is new in the 2008 edition. The technical committee acknowledges the widespread use and performance history of aluminum in these listed and unlisted products.

(D) Zinc shall be used for approved regulators only, complying with ASTM B 86, *Standard Specification for Zinc-Alloy Die Casting*.



(E) Nonmetallic materials shall not be used for upper or lower casings of regulators.

TABLE 5.17.1.3 *Materials for Equipment Used in LP-Gas Service*

<i>Equipment Material</i>	<i>Service Condition</i>
Steel	
Ductile (nodular) iron (ASTM A 395, <i>Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures</i> , or ASTM A 536, <i>Standard Specification for Ductile Iron Castings</i> , Grade 60–40–18 or 65–45–12)	Pressure containing metal parts
Malleable iron (ASTM A 47, <i>Standard Specification for Ferritic Malleable Iron Castings</i>)	
Higher strength gray iron (ASTM A 48, <i>Standard Specification for Gray Iron Castings</i> , Class 40B)	
Brass	
Materials equivalent to 5.17.1.3(A)(1) through 5.17.1.3(A)(5) in melting point, corrosion resistance, toughness, and strength	
Cast iron	Not to be used as a material of construction for strainers or flow indicators
Aluminum	For approved meters, approved regulators, and indirect vaporizers
Zinc (ASTM B 86, <i>Standard Specification for Zinc-Alloy Die Casting</i>)	For approved regulators
Nonmetallic materials	Not to be used for upper or lower casings of regulators.

Materials used in equipment components must be suitable for use with LP-Gas. Equipment should not be purchased until the manufacturer has verified its suitability.

Restrictions on the use of cast iron in 5.17.1.3(B) reflect its tendency to crack under low temperature conditions and under fire control conditions when heated and suddenly cooled (for example, by water). The use of metals, such as aluminum and zinc, which melt at less than 1000°F (538.8°C), is restricted to situations in which their failure will not constitute an undue hazard. The prohibition of plastic for use in regulator casings reflects a concern for the material melting during fire conditions, allowing gas to flow freely and feed the fire.

The 2008 edition was revised to restrict the use of zinc to be used only in pressure regulators. Previously, the use of zinc in regulators was required to comply with ASTM B 86, *Standard Specification for Zinc-Alloy Die Casting* [23], but other uses were not specifically prohibited. The restriction was imposed because of the low melting point of zinc, which is 787°F (by comparison, the melting point of copper is 1984° F). The use of zinc in regulators is allowed because of a long history of safe use.

5.17.2 Pumps.

Pumps shall be designed for LP-Gas service.

It is important that pumps be designed and built for use with LP-Gas. There are many types of pumps, and some of these may not work satisfactorily in propane service. If necessary, the pump manufacturer can be contacted to determine if the pump is recommended for propane

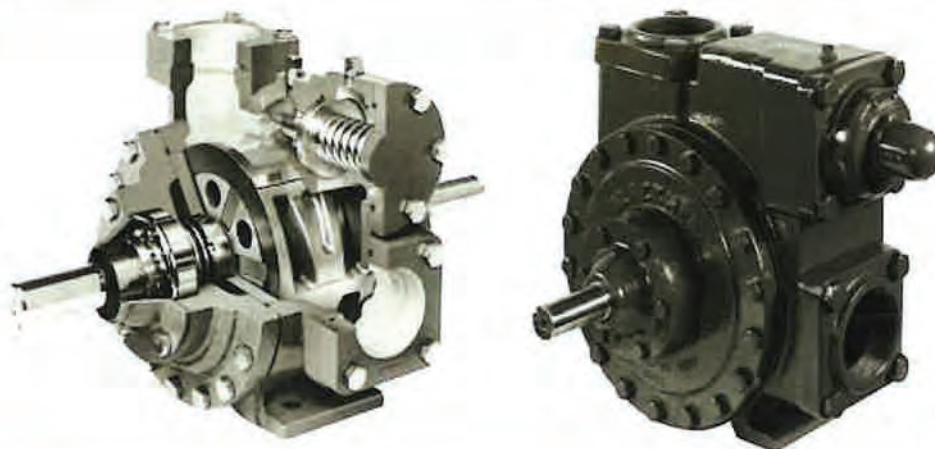


EXHIBIT 5.52 Sliding Vane Positive Displacement Pump. The cutaway is shown at left. (Courtesy of Blackmer, A Dover Company)

service and if it is capable of a discharge pressure higher than 350 psig (2.4 MPa). If the latter is the case, provisions must be made either to limit the pressure to 350 psig (2.4 MPa) or to design the system for the higher pressure.

Because pumps deliver a liquefied gas that will vaporize if the pressure drops even slightly, LP-Gas pumps are either positive displacement pumps or special types of centrifugal pumps, such as regenerative turbine pumps. (See Exhibits 5.52 through 5.55.) Standard centrifugal pumps may “vapor lock” easily and thus are ineffective. There are other types of pumps that can be used effectively for LP-Gas service, but they are not currently used in the United States. If required, such a pump can be used by referring to the Equivalency section (Section 1.5), and providing documentation to the authority having jurisdiction that the pump provides equivalent safety to those designed for LP-Gas service.

Prior to the 1998 edition, the discharge pressure of propane pumps was limited to 350 psig (2.4 MPa). This limitation was based on practice in the U.S. propane industry, in which the pumps used did not exceed this pressure. A proposal was made to delete the restriction based both on the use of pumps with higher discharge pressures in Mexico and other countries, and on the fact that this restriction was not based on safety, but reflected practice. Pumps

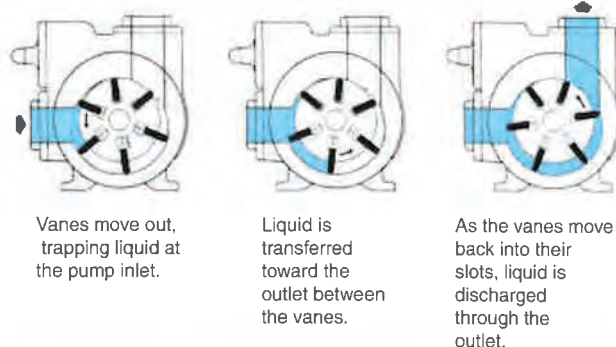


EXHIBIT 5.53 Operation of Sliding Vane Pump. (Courtesy of Blackmer, A Dover Company)

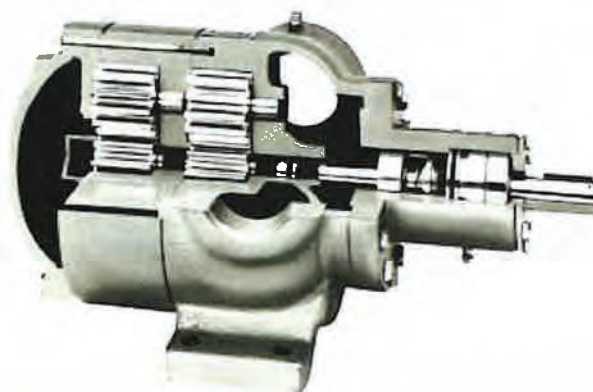


EXHIBIT 5.54 Gear Pump. (Courtesy of Smith Precision Products Company, Inc.)

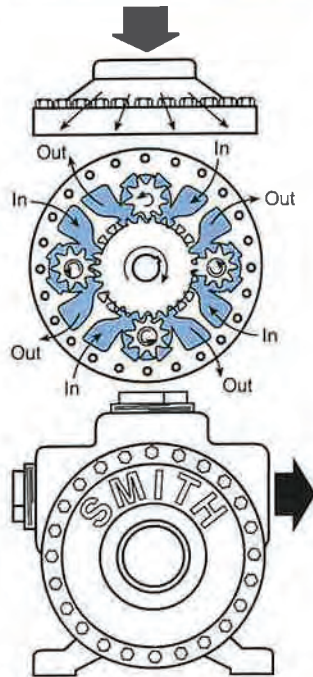


EXHIBIT 5.55 Operation of Gear Pump. (Courtesy of Smith Precision Products Company, Inc.)

EXHIBIT 5.56 Compressor with Protection Devices. (Courtesy of Blackmer, A Dover Company)

and piping systems can be safely designed and operated at pressures above 350 psig (2.4 MPag).

5.17.3 Compressors.

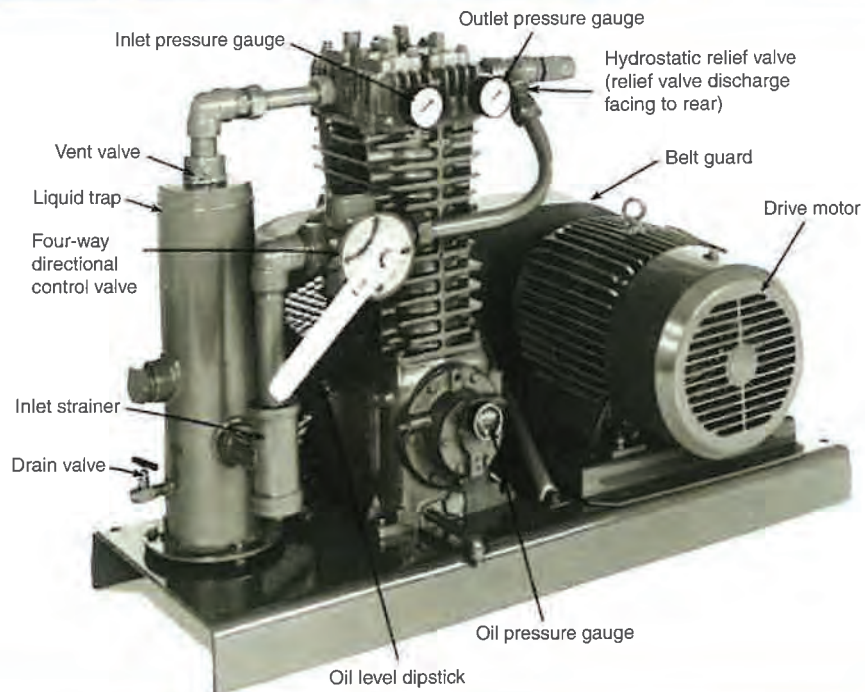
5.17.3.1 Compressors shall be designed for LP-Gas service.

Care should be taken in selecting compressors designed for LP-Gas service. Compressors designed for noncombustible gases may not provide the required leak protection for flammable LP-Gases.

Compressors are used to transfer liquid by pumping vapor from the receiving storage containers into the supply transport truck or railcar that is supplying the LP-Gas. Increasing pressure in the vapor space of the supply container while at the same time lowering the pressure in the receiving container forces liquid from the supply tank to the receiving container. This type of loading or unloading operation is preferred when it is impractical or impossible to use liquid pumps, such as when unloading railroad tank cars. Tank cars have all fittings installed at the top in the protective tank car dome. The use of pumps is impractical because of the extended length of piping to the bottom of the tank car plus the additional hose and piping to the pump suction, which results in pump cavitation and reduced capacity. When compressors are used to unload railroad tank cars, it is common practice to reverse the vapor flow from the compressor with a three-way valve after all liquid is removed from the tank car and recover a large amount of the remaining vapor in the tank car. Normally, this vapor recovery continues until the pressure in the tank car is about 30 psig (207 kPag). Refer to [Exhibit 7.7](#) for an illustration of liquid transfer using a compressor.

5.17.3.2 Compressors shall be constructed or shall be equipped with auxiliary devices to limit the suction pressure to the maximum for which the compressor is designed.

[Exhibit 5.56](#) shows a compressor complete with motor and all accessories.



5.17.3.3 Compressors shall be constructed or shall be equipped with auxiliary devices to prevent the entrance of LP-Gas liquid into the compressor suction.

Because all liquids, including liquid LP-Gas, are noncompressible, liquid must not be allowed to enter an operating compressor. If it does, the compressor will probably be damaged and may fail. A number of compressors manufactured for LP-Gas service include relief devices built into the cylinder head to prevent destruction of the compressor in case small amounts of liquid are allowed to enter. Continuously operating relief devices, however, eventually will damage the compressor.

Several float-operated devices, as shown in **Exhibit 5.57**, are designed to prevent liquid from entering the compressor. The liquid trap shown on the left is a standard trap with a mechanical float assembly and drain valve. The trap in the center shows an automatic liquid trap with one NEMA 7 liquid-level switch for compressor shutdown and drain valve. The trap on the right is an ASME Code-stamped automatic liquid trap with two NEMA 7 liquid-level switches for compressor shutdown and alarm. The trap shown on the right is equipped with a relief valve, pressure gauge, demister pad, and drain valve. Some manufacturers use these types of liquid traps, others simply use a large receiver as a liquid trap on the suction side of the compressor.

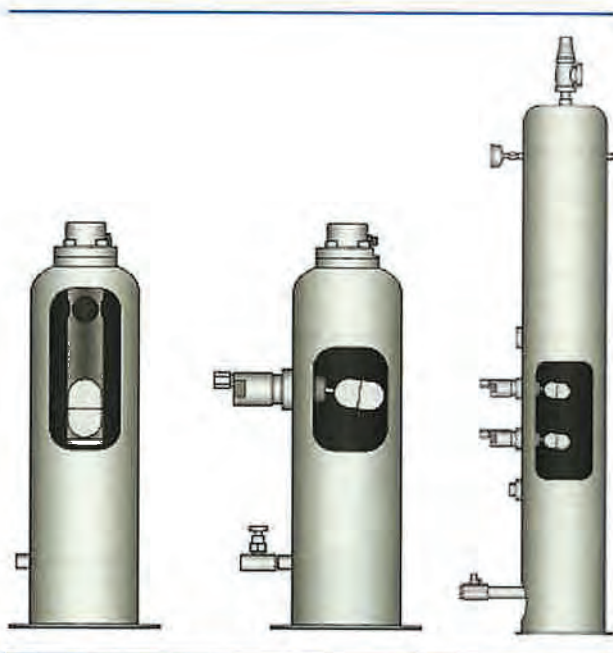


EXHIBIT 5.57 Compressor Liquid Traps. (Courtesy of Corken, Inc.)

5.17.3.4 Portable compressors used with temporary connections shall not require means to prevent liquid entrance into the compressor suction.

Portable compressors are exempt from the requirement to prevent liquid LP-Gas from entering a compressor, because the temporary connections used are empty at the time they are connected and thus usually prevent liquid from entering the compressor. Also, portable units are operated under continuous surveillance by an operator.

5.17.4 Reserved.

5.17.5 Meters.

5.17.5.1 Vapor meters of the tin or brass case type of soldered construction shall not be used at pressures in excess of 1 psig (7 kPag).

Meters are designed for either vapor or liquid service. Vapor meters are commonly used where one propane container serves more than one customer in vapor service (e.g., in an apartment house or mobile home park, or where vapor service to an industry or farm is provided from a tank where a propane company loads bobtails). Liquid meters are commonly used on bobtails, at bulk plants, at dispensing stations, and on transports that deliver to large accounts.

There are several meter technologies in propane use, including positive displacement meters, turbine meters, mass meters, and ultrasonic meters.

- Positive displacement meters are intended for liquid service. They operate by forcing the liquid to travel through metering chambers that have a precise, known volume. The number of times the chambers are filled and emptied is counted, resulting in a direct volume measurement.
- Turbine meters can be designed for either (but not both) vapor or liquid service. The flowing product rotates blades within the known volume turbine meter body. The number of times the blades rotate is counted, resulting in a direct volume measurement.
- Mass meters can be designed for either (but not both) vapor or liquid service. As the flowing product passes through vibrating tubes, the phase of the vibration changes in direct proportion to the mass of the flowing product. This permits a direct mass measurement utilizing the coriolis effect principle.
- Ultrasonic meters can be designed for either (but not both) vapor or liquid service. Ultrasonic pulses are transmitted through the flow, and the difference in propagation between various transmission paths is used to calculate the average flow velocity across a known volume section of pipe or meter. This permits a direct volume measurement.

About three-quarters of the states require that meters and registers used to deliver product to paying customers (other than contract sales) be controlled under the states' weights and measures programs. Specifically, this requires

1. "Type approval" to National Institute of Standards and Technology (NIST) Handbook 44 [24] by the National Type Evaluation Program (NTEP), operated by the National Conference on Weights and Measures (NCWM)
2. Field calibration in the final installation by a person or agency approved by the state.

Several positive displacement meters and a few mass flow meters are type-approved for LP-Gas delivery. A master meter is often used for field calibration. Some states require the use of a prover, a precisely calibrated container, to calibrate the meter. Meters tested for type approval and on the initial field testing must have errors within ± 0.6 percent. Subsequent meter errors must be within ± 1.0 percent. Under NTEP rules, vehicle-mounted metering systems must be equipped with a delivery ticket printer and all meters must have a provision for sealing such that an adjustment to the measuring element cannot be made without breaking the security seal.

The meter shown in [Exhibit 5.58](#) is a positive displacement liquid meter. Note the differential backpressure valve located at the right (downstream), which is required by [6.24.3.5](#). The item to the left (upstream) is the vapor eliminator, which, working with the differential backpressure valve, prevents anything but liquid from being measured and delivered. The measuring chamber is between these units and has a register, or display of the quantity delivered, mounted above it.

5.17.5.2 Vapor meters of the die cast or iron case type shall be permitted to be used at any pressure equal to or less than the working pressure for which they are designed and marked.



5.17.5.3 Liquid meters shall be installed so that the meter housing is not subject to excessive strains from the connecting piping. If not provided in the piping design, flexible connectors that do not exceed 36 in. (1 m) in overall length shall be permitted to be used.