

Beschreibung

[0001] Die vorliegende Erfindung betrifft eine Mehrwege-Ventilanordnung zur Verwendung als Kraftstofftank-Umschaltventil zwischen zwei Kraftstofftanks und einem Motor in einem Kraftfahrzeug, mit zweimal zwei Tankanschlüssen jeweils für Vorlauf und Rücklauf und zwei Motoranschlüssen für Vorlauf und Rücklauf sowie mit einer Ventileinrichtung derart, dass die Vorlauf-Tankanschlüsse alternativ oder gemeinsam mit dem Vorlauf-Motoranschluss und die Rücklauf-Tankanschlüsse alternativ oder gemeinsam mit dem Rücklauf-Motoranschluss verbindbar sind.

Stand der Technik

[0002] In bestimmten Regionen der Erde, beispielsweise in den U.S.A., werden im Fernverkehr mit Lastkraftwagen große Strecken zwischen Gebieten mit hohen Durchschnittstemperaturen und Gebieten mit sehr niedrigen Temperaturen zurückgelegt. Da LKW's üblicherweise mit Diesel-Kraftstoff betrieben werden, tritt dabei das Problem auf, dass "Normal-Diesel" bei etwa -15°C einfriert. Deshalb müssen Diesel-Fahrzeuge bei niedrigeren Temperaturen mit einem anderen, speziellen Kraftstoff betrieben werden, dem sogenannten "Arktic-Diesel", der auch bei Temperaturen bis -40°C noch flüssig bleibt. Arktic-Diesel ist allerdings um ca. 10 % bis 15 % teurer als Normal-Diesel und verursacht zudem auch einen um etwa 10 % bis 15 % höheren Kraftstoff Verbrauch. Deshalb soll vermieden werden, das Fahrzeug nur, d. h. auch in wärmeren Regionen, mit Arktic-Diesel zu betreiben. Allerdings ist es nicht praktikabel und auch nicht rentabel, das gesamte Kraftstoffsystem mit Tanks und Leitungen bei einem Wechsel zwischen warmen und kalten Regionen umzustellen, d. h. vollständig zu entleeren und neu zu befüllen.

[0003] Schwere LKW's sind heute üblicherweise mit (mindestens) zwei Kraftstofftanks ausgerüstet. Daraus ergibt sich die Möglichkeit, je nach Einsatzfall die Tanks mit gleicher oder unterschiedlicher Kraftstoffart zu betanken. Mit Hilfe einer Ventilanordnung der eingangs beschriebenen Art können dann die Tanks einzeln oder gemeinsam mit dem Motor verbunden werden.

[0004] Eine bekannte Ventilanordnung der genannten, gattungsgemäßen Art ist als Mehrfachventil aus Metall ausgebildet und besteht aus vielen miteinander verschraubten Einzelteilen, und zwar aus vier 2/2-Wege-Ventilen, die über zwei T-Verteiler verbunden sind. Jedes Einzelventil ist als Kugelventil ausgebildet und wird mechanisch über Zug/Schub-Stangen bedient. Dabei treten einige bedeutende Nachteile auf:

- lange Betätigungswege der Hebel-Gestänge (150 bis 160 mm)
- hohes Gewicht (ca. 2, 5 kg)

- verschraubte Anschlüsse sind nicht oder nur schwer richtungsverstellbar (bezüglich der Verlaufsrichtung von angeschlossenen Leitungen)
- hoher Material- und Montageaufwand
- hohe Betätigungskraft
- nur direkte manuelle Betätigung möglich, wozu der Fahrer anhalten und das Führerhaus verlassen muß.

Aufgabenstellung

[0005] Der vorliegenden Erfindung liegt die Aufgabe zugrunde, eine zur Vermeidung der beschriebenen Nachteile verbesserte Mehrwege-Ventilanordnung der genannten Art zu schaffen, die sich insbesondere durch reduzierten Material- und Montageaufwand, geringes Gewicht und geringe Betätigungskraft mit der daraus resultierenden Möglichkeit einer automatischen (Fern-) Betätigung auszeichnet.

[0006] Erfindungsgemäß wird dies durch die Merkmale des Anspruchs 1 erreicht. Vorteilhafte Ausgestaltungen der Erfindung sind in den abhängigen Ansprüchen enthalten.

[0007] Demnach besteht die Ventileinrichtung erfindungsgemäß aus (mindestens) zwei schaltungstechnisch bezüglich der vorhandenen Anschlüsse symmetrischen Teilventilen, die insbesondere als 4/2-Wege-Ventile beliebiger Bauart, bevorzugt aber als Schieberventile ausgebildet sind. Somit handelt es sich vorzugsweise um ein Doppel-Schieberventil mit zwei zusammenwirkenden Schieberventilen. Dies stellt eine kostengünstige Lösung dar, die mit minimalem Aufwand alle Funktionen der bekannten Ventilanordnung erfüllt, dabei aber aus sehr wenigen Einzelkomponenten besteht. Daraus resultiert auch ein geringer Herstellungs- und Montageaufwand. Der Einsatz von Schieberventilen ist auch bezüglich der Durchflusseigenschaften sehr vorteilhaft, weil große Strömungsquerschnitte realisiert werden können. So müssen keine Dichtungen umströmt werden, so dass die Strömungsquerschnitte innerhalb der Ventilanordnung sogar um etwa 20 % größer sein können, als in den angeschlossenen Leitungen, und dies sogar ohne größere Einbaumaße der Ventilanordnung. Die zur Betätigung notwendigen Schaltwege können kleiner als 30 mm gehalten werden.

[0008] Die Betätigungskräfte sind derart gering, dass auch ein Schalten mit automatischen Mitteln, insbesondere elektromagnetisch oder pneumatisch, möglich ist. Zudem kann gegenüber der bekannten Ausführung eine Gewichtsreduzierung von mindestens 50 % (bei manueller Betätigung) bzw. von mindestens 20 % (bei automatischer Betätigung) erreicht werden. Schließlich können alle Anschlüsse auf recht einfache Weise, insbesondere durch Verwendung von Steckverbindungen, richtungseinstellbar, ausgelegt sein.

[0009] Jedes Teilventil weist zwei Tankanschlüsse für Vor- und Rücklauf und zwei Motoranschlüsse für Vor- und Rücklauf auf, wobei die Vorlauf-Motoranschlüsse der Teilventile miteinander zu einem gemeinsamen Vorlauf-Motoranschluss sowie die Rücklauf-Motoranschlüsse der Teilventile miteinander zu einem gemeinsamen Rücklauf-Motoranschluss verbunden sind.

[0010] Es sei an dieser Stelle bemerkt, dass das bevorzugte Doppel-Schieberventil grundsätzlich auch unabhängig von der speziellen Anwendung eingesetzt werden kann, und zwar als 6/3- bzw. 6/4-Wege-Ventil.

Ausführungsbeispiel

[0011] Anhand von in der Zeichnung veranschaulichten, bevorzugten Ausführungsbeispielen soll die Erfindung genauer erläutert werden. Dabei zeigen:

[0012] Fig. 1 eine Perspektivansicht einer erfindungsgemäßen Ventilanordnung (ohne endseitige Deckelelemente),

[0013] Fig. 2 eine Seitenansicht der Ventilanordnung in Pfeilrichtung II gemäß Fig. 1,

[0014] Fig. 3 einen Axialschnitt in der Ebene III-III gemäß Fig. 2,

[0015] Fig. 4 einen weiteren Axialschnitt in der zur Ansicht nach Fig. 3 senkrechten Schnittebene IV-IV gemäß Fig. 3,

[0016] Fig. 5 eine Ausschnittvergrößerung des Bereichs V in Fig. 4,

[0017] Fig. 6 eine vergrößerte Ansicht eines Deckelelementes in Pfeilrichtung VI gemäß Fig. 7,

[0018] Fig. 7 einen Schnitt in der Ebene VII-VII in Fig. 6,

[0019] Fig. 8 eine teilweise geschnittene Seitenansicht eines Einzelteils, und zwar eines Schiebers, der erfindungsgemäßen Ventilanordnung,

[0020] Fig. 9 einen Querschnitt in der Ebene IX-IX gemäß Fig. 8,

[0021] Fig. 10 bis Fig. 13 Darstellungen analog zu Fig. 3 in verschiedenen Schaltstellungen der erfindungsgemäßen Ventilanordnung,

[0022] Fig. 14 eine Seitenansicht der Ventilanordnung in einer vorteilhaften Ausgestaltung mit einer Druckmittel-Betätigungseinrichtung,

[0023] Fig. 15 einen Axialschnitt in der Ebene

XV-XV in Fig. 14,

[0024] Fig. 16 eine vergrößerte Darstellung des Bereichs XVI der Betätigungseinrichtung in Fig. 15,

[0025] Fig. 17 eine vergrößerte Axialschnittansicht eines Einzelteils, und zwar eines Betätigungskolbens, der Betätigungseinrichtung gemäß Fig. 15 bzw. Fig. 16,

[0026] Fig. 18 eine Stirnansicht des Betätigungskolbens in Pfeilrichtung XVIII gemäß Fig. 17,

[0027] Fig. 19 eine Seitenansicht in Pfeilrichtung XIX in Fig. 18,

[0028] Fig. 20 einen weiteren Axialschnitt in der Ebene XX-XX in Fig. 18,

[0029] Fig. 21 eine weitere Ansicht eines Deckelelementes in einer gegenüber Fig. 6 alternativen Ausführung,

[0030] Fig. 22 einen Teilschnitt der Ventilanordnung entsprechend der Schnittlinie XII-XII in Fig. 15 mit zusätzlicher Darstellung von Anschlußsteckern und

[0031] Fig. 23 ein vereinfachtes Schaltbild der erfindungsgemäßen Ventilanordnung als Umschaltventil zwischen zwei Kraftstofftanks und einem Motor, beispielhaft in einer Schaltstellung wie in Fig. 13.

[0032] In den verschiedenen Figuren der Zeichnung sind gleiche Teile stets mit den gleichen Bezugszeichen versehen.

[0033] Wie sich zunächst aus Fig. 23 ergibt, wird eine erfindungsgemäße Mehrwege-Ventilanordnung 1 insbesondere als Kraftstofftank-Umschaltventil zwischen zwei Kraftstofftanks A und B und einem nur schematisch angedeuteten Motor M in einem Kraftfahrzeug (LKW) eingesetzt. Die Ventilanordnung 1 weist dazu zweimal zwei Tankanschlüsse A1, A2 für den Tank A und B1, B2 für den Tank B auf, wobei die Anschlüsse A1 und B1 als Vorlauf-Tankanschlüsse für je eine vom Tank A bzw. B zur Ventilanordnung 1 führende Tank-Saugleitung 2, 4 und die Anschlüsse A2 und B2 als Rücklauf-Tankanschlüsse für je eine zurück in Richtung Tank A bzw. B führende Rücklaufleitung 6, 8 fungieren. Ferner weist die Ventilanordnung 1 zwei Motoranschlüsse M1 und M2 auf, wobei der Anschluss M1 als Vorlauf-Motoranschluss für eine zum Motor M führende Vorlaufleitung 10 und der Anschluss M2 als Rücklauf-Motoranschluss für eine vom Motor M kommende Rücklaufleitung 12 vorgesehen sind. Die Ventilanordnung 1 weist weiterhin eine Ventileinrichtung derart auf, dass die Vorlauf-Tankanschlüsse A1, B1 alternativ oder gemeinsam mit dem Vorlauf-Motoranschluss M1 und die Rücklauf-Tankanschlüsse A2, B2 alternativ oder ge-

meinsam mit dem Rücklauf-Motoranschluss M2 verbindbar sind. Dadurch kann alternativ entweder der Tank A oder der Tank B mit dem Motor verbunden werden, oder es können beide Tanks A und B parallel mit dem Motor verbunden werden. Vorzugsweise ist noch eine vierte Schaltstellung vorgesehen, wobei beide Tanks A und B vom Motor M getrennt, d. h. abgesperrt sind. Diese vierte Schaltstellung (siehe [Fig. 10](#)) kann beispielsweise – durch eine geeignete Steuerung betätigt – den Kraftstoff zwangsweise absperren, um als Wegfahrsperrung zu dienen oder als Sicherheitsventil bei einem Unfall einen ungewollten Kraftstoffaustritt aus beschädigten Leitungen oder Aggregaten zu verhindern. In [Fig. 23](#) ist beispielhaft die Schaltstellung dargestellt, wobei der Tank B mit dem Motor M verbunden ist, während der andere Tank A abgesperrt ist. Zu den anderen Schaltstellungen wird bereits an dieser Stelle auf die [Fig. 10](#) bis [Fig. 13](#) verwiesen.

[0034] Erfindungsgemäß besteht nun die Ventileinrichtung 1 aus zwei zusammenwirkenden, Mehrwege-Teilventilen V1, V2, insbesondere Schieberventilen 14 und 16. Jedes Teilventil V1, V2 bzw. Schieberventil 14, 16 ist als 4/2-Wege-Ventil ausgebildet und weist zwei der Tankanschlüsse, und zwar einerseits A1 und A2 und andererseits B1 und B2, für Vor- und Rücklauf auf. Die Motoranschlüsse M1 und M2 sind mit beiden Schieberventilen 14, 16 verbunden. Daraus resultiert insgesamt ein Aufbau als 6/3- oder 6/4-Wege-Ventil mit sechs Anschlüssen und mindestens drei, vorzugsweise vier Schaltstellungen.

[0035] Jedes Schieberventil 14, 16 weist ein Ventilgehäuse 18 und einen in einem länglichen, zylinderartigen Schieberraum 20 innerhalb des Ventilgehäuses 18 in Richtung einer Schieberachse 22 kolbenartig zwischen (mindestens) zwei Schaltstellungen längsverschiebbaren Schieber 24 auf (vgl. hierzu auch die gesonderte Darstellung in [Fig. 8](#)). Jeder Schieberaum 20 weist an axial, d. h. in Richtung der Schieberachse 22 versetzten Stellen vier Steueröffnungen 26 auf, die jeweils mit einem der Tankanschlüsse A1, A2 bzw. B1, B2 bzw. einem der Motoranschlüsse M1 bzw. M2 verbunden sind. Je nach Stellung der Schieber 24 können die Steueröffnungen 26 paarweise verbunden oder gegeneinander abgesperrt werden.

[0036] In der bevorzugten Ausführung sind die zwei Schieberventile 14, 16 direkt benachbart und bezüglich ihrer Schieberachsen 22 parallel zueinander angeordnet. In weiterer vorteilhafter Ausgestaltung sind dabei die beiden Ventilgehäuse 18 zu einem monolithisch einstückigen Gehäuse-Formteil 28 zusammengefasst. Dieses Formteil 28 ist insbesondere als Kunststoff-Spritzteil oder als Druckgussteil beispielsweise aus Aluminium oder Zink ausgebildet. Auch dies trägt zu einer wirtschaftlichen Herstellung bei. Grundsätzlich kann aber das Formteil 28 auch aus

Vollmaterial durch eine spanende Bearbeitung hergestellt werden.

[0037] Das einstückige Gehäuse-Formteil 28 mit den beiden Ventilgehäusen 18 ist bezüglich einer mittigen Symmetrieebene 30 spiegelsymmetrisch ausgebildet. Dabei erstrecken sich die Tankanschlüsse A1, A2 und B1 und B2 jeweils mit zur Symmetrieebene 30 paralleler oder senkrechter Verlaufsrichtung von dieser weg nach außen. Die Motoranschlüsse M1, M2 sind mittig mit einer der Symmetrieebene 30 entsprechenden Verlaufsrichtung angeordnet. Somit liegen die Motoranschlüsse M1, M2 mittig zwischen den beiden Schieberventilen 14, 16. Jeder Motoranschluss M1, M2 geht in einen Kanal über, der zur Bildung der zugehörigen Steueröffnungen 26 die Schieberräume 20 beider Schieberventile 14, 16 anschnidet. Dadurch sind auf einfache Weise die Motoranschlüsse M1, M2 mit beiden Schieberventilen 14 und 16 verbunden.

[0038] Jeder Schieber 24 weist an axial beabstandeten Stellen Umfangsdichtungen 32 auf, die mit inneren Dichtflächen des jeweiligen Ventilgehäuses 18 zusammenwirken. Dabei besteht jeder Schieber 24 – siehe insbesondere [Fig. 8](#) – aus einem zentrischen, axialen Kern 36 und mehreren, in der dargestellten Ausführung vier, radialen tellerartigen Ventilscheiben 38 sowie einem einseitig aus dem jeweiligen Ventilgehäuse 18 nach außen geführten Betätigungsende 40. Jede Ventilscheibe 38 trägt auf ihrem Außenumfang vorzugsweise in einer Ringnut 42 eine der Umfangsdichtungen 32. Die Umfangsdichtungen 32 können von elastischen O-Ringen gebildet sein. Gemäß [Fig. 8](#) ist es vorteilhaft, wenn die Ventilscheiben 38 im Bereich radial zwischen dem Kern 36 und dem äußeren Umfang axiale Hinterschnidungen 44 aufweisen. Bei einer bevorzugten Herstellung der Schieber 24 als einstückige Kunststoff-Formteile werden durch die Hinterschnidungen 44 vorteilhafterweise Materialanhäufungen und damit ein Verzug vermieden. Diese Hinterschnidungen 44 werden bei der Fertigung durch eine sogenannte Springkerntechnik entformt.

[0039] In weiterer vorteilhafter Ausgestaltung der Erfindung ist hierbei vorgesehen, dass die Umfangsdichtungen 32 bezüglich ihrer Außendurchmesser D1, D2, D3 (siehe hierzu [Fig. 8](#)) sowie die Dichtflächen 34 bezüglich ihrer Innendurchmesser D'1, D'2 und D'3 (siehe [Fig. 4](#)) in Anpassung aneinander derart ausgelegt sind, dass jede Umfangsdichtung 32, die sich bei einem Schaltvorgang axial über den Bereich einer der Steueröffnungen 26 hinweg bewegt (im dargestellten Beispiel sind dies die Dichtungen 32b und 32d; siehe [Fig. 4](#) und [Fig. 8](#)), in ihrem sich axial über die jeweilige Steueröffnungen 26 hinweg erstreckenden Bewegungsbereich radial im Wesentlichen unverpresst ist und erst in einem jeweils axial zwischen zwei voneinander zu trennenden Steueröffnungen 26 liegenden Dichtbereich radial verpresst

wird. Durch diese vorteilhafte Maßnahme wird vermieden, dass eine der Umfangsdichtungen **32** bei ihrer Bewegung über eine seitlich in den Schieberaum **20** mündende Steueröffnung **26** hinweg beschädigt werden könnte, denn in einem verpressten Zustand könnte sich die Dichtung in die Steueröffnung **26** hinein ausdehnen und bei der weiteren Bewegung am Öffnungsrand hängenbleiben und so beschädigt werden. Dies wird durch die erfindungsgemäße Maßnahme vermieden. Konkret ist bei der bevorzugten Ausführung vorgesehen, dass der Schieberaum **20** jedes Ventilgehäuses **18** ausgehend von einem für das Betätigungsende **40** des Schiebers **24** offenen Ende **46** mehrere axial über konische Übergänge **48** ineinander übergehende, im Wesentlichen zylindrische Dichtflächen **34a** bis **c** aufweist, deren Innendurchmesser D'1 bis D'3 sich sukzessive über die konischen Übergänge **48** verkleinern (siehe nochmals Fig. 4). Es sei bemerkt, dass die Dichtflächen **34** auch jeweils schwach konisch, d. h. mit einem kleinen Konuswinkel $\leq 1^\circ$, ausgebildet sein können. Dies ermöglicht eine vereinfachte Entformbarkeit bei der Herstellung als Spritz- oder Druckgussteil. Die Auslegung der Durchmesser muss dabei in Relation zu den zugehörigen Umfangsdichtungen natürlich so sein, dass jede Umfangsdichtung **32** in ihrer Dichtstellung im Bereich der zugehörigen Dichtfläche **34** eine sichere Abdichtung gewährleistet. Was den Schieber **24** betrifft (siehe Fig. 8), so weist die – ausgehend vom Betätigungsende **40** – erste Umfangsdichtung **32a** einen Durchmesser D1 auf, der an den Innendurchmesser D'1 der ersten Dichtfläche **34a** so angepasst ist, dass diese Umfangsdichtung **32a** zur Abdichtung verpresst ist. Damit dient diese erste Umfangsdichtung **32a** zur ständigen Abdichtung des Schieberaums **20** nach außen in Richtung des offenen Endes **46**. Die nächste, zweite Umfangsdichtung **32b** weist demgegenüber einen reduzierten Durchmesser D2 auf, so dass diese zweite Umfangsdichtung **32b** im Bereich der ersten Dichtfläche **34a** nicht oder zumindest nicht vollständig radial verpresst ist. Dadurch kann sie sich über den Bereich der ersten Steueröffnung **26** hinweg schadlos bewegen. Im Anschluss daran wird diese zweite Umfangsdichtung **32b** über den konischen Übergang **48** radial verpresst, bis sie dann dichtend auf der zweiten Dichtfläche **34b** mit dem Innendurchmesser D'2 anliegt. In analoger Weise verhält sich dies auch mit der dritten und vierten Umfangsdichtung **32**. So liegt die dritte Umfangsdichtung **32c** in jeder Stellung radial verpresst und dadurch dichtend an der Dichtfläche **34b** an. Ihr Durchmesser D2 entspricht demgemäß etwa dem Innendurchmesser D'2. Die vierte und letzte Umfangsdichtung **32d** weist einen weiter reduzierten Durchmesser D3 auf, so dass sie folglich im Bereich dieser Dichtfläche **34b** mit dem Innendurchmesser D'2 nicht oder nur unwesentlich radial verpresst ist. Sie kann sich dadurch über den Bereich der weiteren Steueröffnung **26** schadlos hinweg bewegen und wird dann über den weiteren konischen Übergang **48**

radial verpresst, und zwar entsprechend dem Innendurchmesser D'3 der sich anschließenden Dichtfläche **34c**.

[0040] Es ist zweckmäßig, wenn die Ventilgehäuse **18** an ihren offenen Enden **46** mit einem Deckelelement **50** verschlossen bzw. verschließbar sind. Vorzugsweise dient das Deckelelement **50** auch zur Führung des Betätigungsendes **40** des jeweiligen Schiebers **24**. Dazu weist das Deckelelement **50** jeweils eine Führungsöffnung **52** mit einer dem Querschnitt des Kerns **36** bzw. eines zusätzlichen Führungsabschnittes **54** entsprechenden Öffnungskontur auf. Im dargestellten Beispiel handelt es sich um einen von der Kreisform abweichenden, insbesondere etwa kreuzförmigen Querschnitt, siehe insbesondere Fig. 6, so dass auch eine Führung gegen Verdrehen um die Schieberachse **22** erreicht wird. Durch eine spezielle, insbesondere gegeneinander „verdrehte“ Anordnung der Führungsöffnungen **52** (vgl. Fig. 6 und Fig. 21) wird eine definierte Einbaulage der Schieber **24** zur Korrektur von eventuellen, herstellungsbedingten Formabweichungen im Gehäuse **18** erreicht. Hierzu kann der Schieber **24** in der Form dem Gehäuse und dessen Formabweichung angepasst werden. Es ist dabei zudem vorteilhaft, wenn die einzelnen Deckelelemente **50** der beiden Ventilgehäuse **18** über einen Verbindungsabschnitt **56** zu einem einstückigen Teil, insbesondere einem einstückigen Kunststoff-Formteil, zusammengefasst sind.

[0041] In weiterer bevorzugter Ausgestaltung ist jeder Schieber **24** in jeder von zwei Schaltstellungen insbesondere über Rastmittel **58** kraftformschlüssig fixiert. Wie sich insbesondere aus Fig. 5 ergibt, kann als Rastmittel **58** jeweils ein Rastarm **60** im Bereich der Führungsöffnung **52** des Deckelelementes **50** vorgesehen sein, der mit einer Rastnase jeweils in eine Rastausnehmung **62** des Schiebers **24** bzw. des Führungsabschnittes **54** eingreift.

[0042] Wie nur in Fig. 3 stark schematisch angedeutet ist, ist es weiterhin vorteilhaft, wenn zur Schmutzabdichtung zwischen dem Betätigungsende **40** jedes Schiebers **24** und dem Ventilgehäuse **18** bzw. dem damit verbundenen Deckelelement **50** eine faltenbalgartig längenvariable Hülle **64** angeordnet ist.

[0043] In den Ausführungen gemäß Fig. 1 bis Fig. 13 sind die Schieber **24** manuell, insbesondere über nicht dargestellte mechanische Verbindungen, wie Gestänge oder Seilzüge, betätigbar.

[0044] Alternativ oder auch zusätzlich kann eine Betätigungseinrichtung **66** zur motorischen, insbesondere pneumatischen oder hydraulischen oder elektromagnetischen Betätigung der Schieber **24** vorgesehen sein.

[0045] Hierzu wird auf das Ausführungsbeispiel gemäß Fig. 14 bis Fig. 16 verwiesen, wobei die Ventilgehäuse **18** auf der Seite der Betätigungsenden **40** der Schieber **24** – vorzugsweise zusätzlich zu dem Deckelelement **50** – mit jeweils einem Zylindergehäuse **68** verbunden sind. Die Schieber-Betätigungsenden **40** sind mit jeweils einem in dem Zylindergehäuse **68** geführten Betätigungskolben **70** verbunden. Jedes Zylindergehäuse **68** weist einen Steuerdruckanschluß S1 bzw. S2 auf. Dadurch kann der jeweilige Betätigungskolben **70** auf der Seite eines Arbeitsraums **71** mit einem Druckmittel beaufschlagt werden, um den zugehörigen Schieber **24** insbesondere gegen die Rückstellkraft einer Rückstellfeder **72** zu verschieben. Vorzugsweise ist dabei jeder Betätigungskolben **70** über Rastmittel **74** mit dem Betätigungsende **40** des zugehörigen Schiebers **24** verbunden. Hierzu wird auch auf die gesonderten Darstellungen des Betätigungskolbens **70** in Fig. 17 bis Fig. 20 hingewiesen. Um auf der dem Arbeitsraum **71** gegenüberliegenden Seite des Betätigungskolbens **70** bei der Druck-Betätigung innerhalb des Zylindergehäuses **68** einen Überdruck zu vermeiden bzw. abzubauen, weist das/jedes Zylindergehäuse **68** in diesem Bereich (mindestens) eine Lüftungsöffnung **67** auf, die vorzugsweise außen von einer membranventilartigen, ringbandförmigen Schmutzdichtung **69** überdeckt ist (siehe insbesondere Fig. 16).

[0046] Weiterhin ist es vorteilhaft, wenn die beiden Zylindergehäuse **68** der Betätigungseinrichtung **66** zu einem einstückigen Formteil zusammengefasst sind. Dieses Zylinder-Formteil wird bevorzugt im Bereich von seitlichen Montageansätzen **75** mit dem Gehäuse-Formteil **28** verschraubt, und zwar unter Zwischenlage des einteiligen Deckelelementes **50**. Dieses weist dann gemäß Fig. 21 korrespondierende Montageansätze **75** mit Schraubenlöchern **76** auf. Zur Positionierung und Montagehilfe sind bevorzugt im Anlagebereich zwischen der Betätigungseinrichtung **66** und dem Deckelelement **50** sowie zwischen letzterem und dem Gehäuse **18** bzw. dem Gehäuse-Formteil **28** Positionsansätze **77** vorgesehen, die in korrespondierende Öffnungen eingreifen (siehe insbesondere Fig. 16). Durch eine unterschiedliche Anordnung und/oder Form, z.B. unterschiedliche Durchmesser, der Positionseinsätze **77** können die Teile nur korrekt und lagerichtig miteinander verbunden werden, so dass vorteilhafterweise eine Fehlmontage praktisch ausgeschlossen ist.

[0047] Bei der Alternative gemäß Fig. 2 bis Fig. 13 ist das Deckelelement **50** gemäß Fig. 6 über Rastmittel **78** mit den Ventilgehäusen **18** bzw. dem Gehäuse-Formteil **28** verrastbar.

[0048] Dabei kann auch die Betätigungseinrichtung **66** über Rastmittel befestigt werden (nicht dargestellt).

[0049] Es ist weiterhin zweckmäßig, wenn alle vorgesehenen Anschlüsse A1/2, B1/2, M1/2 und S1/2 als Kupplungsteile zum insbesondere richtungsvariablen Steckanschluss von Leitungen ausgebildet sind. Hierzu wird auf Fig. 22 verwiesen, wonach jeder Anschluss als muffenartige Aufnahmeöffnung **80** zum Einstecken eines Steckerteils **82** ausgebildet ist. Dabei sind zudem geeignete Arretiermittel **84** zum lösbaren Arretieren des eingesteckten Steckerteils **82** vorgesehen. Im dargestellten Beispiel weist jeder Anschluss im Mündungsbereich der Aufnahmeöffnung **80** einen radial nach außen ragenden Umfangsrand **86** auf, der im eingesteckten Zustand von äußeren, sich axial erstreckenden Rastarmen **88** des jeweiligen Steckerteils **82** rastend übergriffen wird. Zum Lösen können die Rastarme **88** radial nach außen gespreizt werden. Vorteil dieser Anschlussart ist, dass die Verlaufsrichtung der angeschlossenen Leitung (selbst nicht dargestellt) variabel ist, weil sich die Steckerteile **82** relativ zu den Anschlüssen verdrehen lassen. Im dargestellten Beispiel gemäß Fig. 22 weist jedes Steckerteil **82** zum Leitungsanschluss einen üblichen Anschlussdorn **90** auf.

[0050] Die Bestandteile der erfindungsgemäßen Ventilanordnung **1**, und zwar insbesondere die Ventilgehäuse **18** bzw. das einstückige Gehäuse-Formteil **28**, die Schieber **24** und vorzugsweise auch die Deckelelemente **50** und optional die Zylindergehäuse **68** und die Betätigungskolben **70**, bestehen vorzugsweise aus dem gleichen Material, und zwar insbesondere aus einem faserverstärkten Kunststoff, wie PA12-GF50. Dieses bevorzugte Material weist eine geringe Wasseraufnahme auf und eignet sich gut zur Anwendung mit Kraftstoffen, insbesondere Diesel. Durch Verwendung von gleichen Materialien für die Bestandteile werden Undichtigkeiten, die durch thermische Dehnung entstehen könnten, vermieden.

[0051] Das Gehäuse-Formteil **28** weist zur Montagebefestigung an einem nicht dargestellten Träger in einem Kraftfahrzeug mindestens zwei, bevorzugt drei außen angeformte Befestigungselemente **92** auf, die insbesondere derart gegenüber den Bereichen der Dichtflächen **34** axial und/oder radial versetzt angeordnet sind, dass bei der Montage ein Verzug des Formteils und daraus resultierende Formveränderungen im Bereich der Dichtflächen **34** weitgehend ausgeschlossen sind. Dies gewährleistet eine gute Funktionsfähigkeit und dauerhafte Dichtwirkung im Bereich der Umfangsdichtungen **32** und Dichtflächen **34**.

[0052] Die Funktion der erfindungsgemäßen Ventilanordnung **1** dürfte durch die obigen Erläuterungen des konstruktiven Aufbaus bereits hinreichend klar sein. Ergänzend wird auf die Darstellungen in den Fig. 10 bis Fig. 13 verwiesen. In Fig. 10 ist eine optionale Absperrstellung dargestellt, in der alle vorhandenen Anschlüsse voneinander getrennt sind.

Fig. 11 zeigt die Ventilstellung zur Verbindung des Tanks A mit dem Motor M, indem A1 mit M1 und A2 mit M2 verbunden sind. Der Tank B ist vom Motor M abgesperrt. Die umgekehrte Schaltstellung ist in **Fig. 13** dargestellt, wobei der Tank A abgesperrt und der Tank B mit dem Motor M verbunden ist. Schließlich zeigt **Fig. 12** eine Stellung, in der beide Tanks A und B mit dem Motor M verbunden sind. Diese Schaltstellung ist vorgesehen für den Fall, dass beide Tanks mit dem selben Kraftstoff befüllt sind.

[0053] Die Absperrstellung gemäß **Fig. 10** kann als Prüfstellung zur Dichtheitsprüfung vorgesehen sein. Dabei bilden sich im Ventil zwei Prüfkammern, die über die beiden Motoranschlüsse M1 und M2 mit einem Prüfdruck beaufschlagt werden können. Diese Prüfkammern werden von den Umfangsdichtungen **32** der Schieber **24** gedichtet. Im Falle eines gemessenen Druckabfalls des Prüfdruckes kann auf eine beschädigte oder gar fehlende Umfangsdichtung geschlossen werden.

[0054] Durch die beschriebene Ausgestaltung der Ventilanordnung **1** bzw. der beiden Schieberventile **14**, **16** werden Vor- und Rücklauf eines Tanks stets nur gemeinsam geschaltet. Dadurch sind Vertauschungen ausgeschlossen.

[0055] Es sei nochmals bemerkt, dass ein Schieberventil **14** bzw. **16** der beschriebenen Art bzw. ein Doppel-Schieberventil der bevorzugten Art auch unabhängig von der beschriebenen, speziellen Anwendung als Tank-Umschaltventil als allgemeines 4/2-bzw. 6/3- oder 6/4-Wege-Ventil verwendet werden kann.

[0056] Im Übrigen ist die Erfindung ohnehin nicht auf die beschriebenen Ausführungsbeispiele beschränkt, sondern erstreckt sich auch auf gleichwirkende Ausführungen. Ferner ist die Erfindung bislang auch noch nicht auf die im jeweils unabhängigen Anspruch definierte Merkmalskombination beschränkt, sondern kann auch durch jede beliebige andere Kombination von bestimmten Merkmalen aller insgesamt offenbarten Einzelmerkmalen definiert sein. Dies bedeutet, daß grundsätzlich praktisch jedes Einzelmerkmal des jeweils unabhängigen Anspruchs weggelassen bzw. durch mindestens ein an anderer Stelle der Anmeldung offenbartes Einzelmerkmal ersetzt werden kann. Insofern sind die Ansprüche lediglich als ein erster Formulierungsversuch für eine Erfindung zu verstehen.

Patentansprüche

1. Mehrwege-Ventilanordnung (**1**) zur Verwendung als Kraftstofftank-Umschaltventil zwischen mindestens zwei Kraftstofftanks (A, B) und einem Motor (M) in einem Kraftfahrzeug, mit mindestens zweimal zwei Tankanschlüssen (A1, A2; B1, B2). jeweils für

Vorlauf und Rücklauf und zwei Motoranschlüssen (M1, M2) für Vorlauf und Rücklauf sowie mit einer Ventileinrichtung derart, dass die Vorlauf-Tankanschlüsse (A1, B1) alternativ oder gemeinsam mit dem Vorlauf-Motoranschluss (M1) und die Rücklauf-Tankanschlüsse (A2, B2) alternativ oder gemeinsam mit dem Rücklauf-Motoranschluss (M2) verbindbar sind, **dadurch gekennzeichnet**, dass die Ventileinrichtung aus mindestens zwei zusammenwirkenden, schalttechnisch symmetrischen Mehrwege-Teilventilen (V1, V2), insbesondere 4/2-Wege-Ventilen, besteht.

2. Ventilanordnung nach Anspruch 1, dadurch gekennzeichnet, dass die Teilventile (V1, V2) als zusammenwirkende Schieberventile (**14**, **16**) ausgebildet sind.

3. Ventilanordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet, dass jedes Teilventil (V1, V2) zwei Tankanschlüsse (A1 und A2 bzw. B1 und B2) für Vor- und Rücklauf und zwei Motoranschlüsse für Vor- und Rücklauf aufweist, wobei die Vorlauf-Motoranschlüsse der Teilventile (V1, V2) miteinander zu einem gemeinsamen Vorlauf-Motoranschluss (M1) sowie die Rücklauf-Motoranschlüsse der Teilventile (V1, V2) miteinander zu einem gemeinsamen Rücklauf-Motoranschluss (M2) verbunden sind.

4. Ventilanordnung nach Anspruch 2 oder 3, dadurch gekennzeichnet, dass jedes Schieberventil (**14**, **16**) ein Ventilgehäuse (**18**) und einen in einem zylinderartigen Schieberraum (**20**) innerhalb des Ventilgehäuses (**18**) in Richtung einer Schieberachse (**22**) kolbenartig zwischen mindestens zwei Schaltstellungen längsverschiebbaren Schieber (**24**) aufweist, wobei jeder Schieberraum (**20**) an axial versetzten Stellen vier Steueröffnungen (**26**) aufweist, die jeweils mit einem der Tankanschlüsse (A1, A2 bzw. B1, B2) bzw. einem der Motoranschlüsse (M1 bzw. M2) verbunden sind.

5. Ventilanordnung nach einem der Ansprüche 2 bis 4, dadurch gekennzeichnet, dass die Schieberventile (**14**, **16**) direkt benachbart und bezüglich ihrer Schieberachsen (**22**) parallel zueinander angeordnet sind.

6. Ventilanordnung nach Anspruch 4 oder 5, dadurch gekennzeichnet, dass die Ventilgehäuse (**18**) der Schieberventile (**14**, **16**) zu einem monolithisch einstückigen Formteil (**28**) zusammengefasst sind.

7. Ventilanordnung nach Anspruch 6, dadurch gekennzeichnet, dass das Formteil (**28**) als Kunststoff-Spritzteil oder als Druckgussteil z.B. aus Aluminium oder Zink oder als spanend bearbeitetes Metall- oder Kunststoffteil ausgebildet ist.

8. Ventilanordnung nach einem der Ansprüche 4

bis 7, dadurch gekennzeichnet, dass die Ventilgehäuse (18) bezüglich einer mittigen Symmetrieebene (30) spiegelsymmetrisch ausgebildet sind, wobei sich die Tankanschlüsse (A1, A2; B1, B2) jeweils mit zur Symmetrieebene (30) senkrechter oder paralleler Verlaufsrichtung von dieser weg nach außen erstrecken, und wobei die Motoranschlüsse (M1, M2) mittig mit einer der Symmetrieebene (30) entsprechenden Verlaufsrichtung angeordnet sind.

9. Ventilanordnung nach Anspruch 8, dadurch gekennzeichnet, dass jeder Motoranschluss (M1, M2) einen Kanal aufweist, der zur Bildung der zugehörigen Steueröffnungen (26) die Schieberräume (20) beider Schieberventile (14, 16) anschneidet.

10. Ventilanordnung nach einem der Ansprüche 4 bis 9, dadurch gekennzeichnet, dass jeder Schieber (24) axial beabstandete Umfangsdichtungen (32a–d) aufweist, die mit inneren Dichtflächen (34) des jeweiligen Ventilgehäuses (18) zusammenwirken.

11. Ventilanordnung nach Anspruch 10, dadurch gekennzeichnet, dass jeder Schieber (24) aus einem zentrischen, axialen Kern (36) und mehreren, insbesondere vier, radialen, tellerartigen Ventilscheiben (38) sowie einem einseitig aus dem Ventilgehäuse (18) nach außen geführten Betätigungsende (40) besteht, wobei jede Ventilscheibe (38) auf ihrem Außenumfang in einer Ringnut (42) eine der Umfangsdichtungen (32a–d) trägt.

12. Ventilanordnung nach Anspruch 10 oder 11, dadurch gekennzeichnet, dass die Umfangsdichtungen (32a–d) bezüglich ihrer Außendurchmesser (D1–D3) sowie die Dichtflächen (34a–c) bezüglich ihrer Innendurchmesser (D'1–D'3) in Anpassung aneinander derart ausgelegt sind, dass jede Umfangsdichtung (32b, d), die sich bei einem Schaltvorgang axial über den Bereich einer der Steueröffnungen (26) bewegt, in ihrem sich axial über die Steueröffnung (26) hinweg erstreckenden Bewegungsbereich radial unverpresst und erst in einem jeweils axial zwischen zwei Steueröffnungen (26) liegenden Dichtbereich radial verpresst ist.

13. Ventilanordnung nach Anspruch 12, dadurch gekennzeichnet, dass der Schieberraum (20) jedes Ventilgehäuses (18) ausgehend von einem offenen Ende (46) mehrere axial über konische Übergänge (48) ineinander übergehende, zylindrische oder schwach konische Dichtflächen (34a–c) aufweist, deren Innendurchmesser (D'1 bis D'3) sich sukzessive über die konischen Übergänge (48) verkleinern.

14. Ventilanordnung nach einem der Ansprüche 4 bis 13, dadurch gekennzeichnet, dass die Ventilgehäuse (18) an ihren offenen Enden (46) mit einem Deckelelement (50) verschließbar sind, wobei vor-

zugsweise das Deckelelement (50) auch zur Führung des Betätigungsendes (40) des jeweiligen Schiebers (24) dient.

15. Ventilanordnung nach Anspruch 14, dadurch gekennzeichnet, dass das Deckelelement (50) jeweils eine Führungsöffnung (52) für einen Führungsabschnitt (54) des jeweiligen Schiebers (24) aufweist, wobei vorzugsweise eine bestimmte Drehlage mit Sicherung gegen Verdrehen der Schieber (24) vorgegeben ist.

16. Ventilanordnung nach einem der Ansprüche 4 bis 15, dadurch gekennzeichnet, dass jeder Schieber (24) in jeder von zwei Schaltstellungen insbesondere über Rastmittel (58) kraftformschlüssig fixiert ist.

17. Ventilanordnung nach einem der Ansprüche 4 bis 16, dadurch gekennzeichnet, dass zur Schmutzabdichtung zwischen dem Betätigungsende (40) jedes Schiebers (24) und dem Ventilgehäuse (18) bzw. dem damit verbundenen Deckelelement (50) eine faltenbalgartige Hülle (64) angeordnet ist.

18. Ventilanordnung nach einem der Ansprüche 4 bis 17, gekennzeichnet durch eine den Schiebern (24) zugeordnete Betätigungseinrichtung (66) zur manuellen oder motorischen, insbesondere pneumatischen oder hydraulischen oder elektromagnetischen Betätigung der Schieber (24).

19. Ventilanordnung nach einem der Ansprüche 3 bis 18, dadurch gekennzeichnet, dass die Ventilgehäuse (18) auf der Seite der Betätigungsenden (40) der Schieber (24) mit jeweils einem Zylindergehäuse (68) sowie die Schieber-Betätigungsenden (40) mit jeweils einem Betätigungskolben (70) verbunden bzw. verbindbar sind, wobei jedes Zylindergehäuse (68) einen zur Druckbeaufschlagung des Betätigungskolbens (70) in einen Arbeitsraum (71) mündenden Steuerdruckanschluss (S1, S2) aufweist.

20. Ventilanordnung nach Anspruch 19, dadurch gekennzeichnet, dass jedes Zylindergehäuse (68) auf der dem Arbeitsraum (71) gegenüberliegenden Seite des Betätigungskolbens (70) mindestens eine vorzugsweise mit einer ventilartigen Schmutzdichtung (69) ausgestattete Lüftungsöffnung (67) aufweist.

21. Ventilanordnung nach einem der Ansprüche 1 bis 20, dadurch gekennzeichnet, dass alle vorgesehenen Anschlüsse (A, B, M, S) als Kupplungsteile zum Steckanschluss von Leitungen ausgebildet sind, wobei vorzugsweise jeder Anschluss als muffenartige Aufnahmeöffnung (80) zum Einstecken eines Steckerteils (82) ausgebildet ist und Arretiermittel (84) zum lösbaren Arretieren des eingesteckten Steckerteils (82) vorgesehen sind.

22. Ventilanordnung nach einem der Ansprüche 4 bis 21, dadurch gekennzeichnet, dass die Ventilgehäuse (18) bzw. das einstückige Formteil (28) und die Schieber (24) aus dem gleichen Material bestehen, insbesondere aus einem faserverstärkten Kunststoff, wie PA12-GF50.

23. Ventilanordnung nach einem der Ansprüche 4 bis 22, dadurch gekennzeichnet, dass die Ventilgehäuse (18) bzw. das Gehäuse-Formteil (28) mindestens zwei, insbesondere drei Befestigungselemente (92) aufweisen/aufweist, die insbesondere derart außerhalb der Bereiche der Dichtflächen (34) angeordnet sind, dass bei der Montage und/oder beim Herstellprozess verzugsbedingte Verformungen im Bereich der Dichtflächen (34) vermieden werden.

24. Ventilanordnung nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, dass im Verbindungsbereich zwischen dem Deckelelement (50) und dem Ventilgehäuse (18) bzw. dem Gehäuse-Formteil (28) und/oder im Verbindungsbereich zwischen der Betätigungseinrichtung (66) und dem Deckelelement (50) in korrespondierende Öffnungen eingreifende Positionsansätze (77) insbesondere derart vorgesehen sind, dass nur eine korrekte, lage-richtige Montage möglich ist.

25. Schieberventil (14, 16) insbesondere für eine Ventilanordnung (1) nach einem der Ansprüche 1 bis 24, bestehend aus einem Ventilgehäuse (18) und einem in einem zylinderartigen Schieberaum (20) innerhalb des Ventilgehäuses (18) in Richtung einer Schieberachse (22) kolbenartig zwischen mindestens zwei Schaltstellungen längsverschiebbaren Schieber (24), der axial beabstandete Umfangsdichtungen (32) aufweist, die mit inneren Dichtflächen (34) des Schieberraums (20) zusammenwirken, um in den Schieberaum (20) mündende Steueröffnungen (26) und damit verbundene Anschlüsse (A1, A2, B1, B2, M1, M2) entweder zumindest paarweise zu verbinden oder gegeneinander abzusperrern, dadurch gekennzeichnet, dass die Umfangsdichtungen (32a-d) bezüglich ihrer Außendurchmesser (D1-D3) sowie die Dichtflächen (34a-c) bezüglich ihrer Innendurchmesser (D'1-D'3) in Anpassung aneinander derart ausgelegt sind, dass jede sich bei einem Schaltvorgang axial über eine der Steueröffnungen (26) hinweg bewegende Umfangsdichtung (32b, d) in ihrem sich über die Steueröffnung (26) hinweg erstreckenden Bewegungsbereich radial unverpresst und erst in einem jeweils axial zwischen zwei Steueröffnungen (26) liegenden Dichtbereich radial verpresst ist.

26. Schieberventil nach Anspruch 25, dadurch gekennzeichnet, dass der Schieberaum (20) des insbesondere als einstückiges Formteil ausgebildeten Ventilgehäuses (18) ausgehend von einem offenen Ende (46) mehrere axial über konische Übergänge

(48) ineinander übergehende, zylindrische oder schwach konische Dichtflächen (34a-c) aufweist, deren Innendurchmesser (D'1 bis D'3) sich sukzessive über die konischen Übergänge (48) verkleinern.

27. Schieberventil-Anordnung, gekennzeichnet durch zwei direkt benachbart und bezüglich ihrer Schieberachsen (22) parallel zueinander angeordnete Schieberventile (14, 16) nach Anspruch 25 oder 26.

28. Schieberventil-Anordnung nach Anspruch 27, dadurch gekennzeichnet, dass die beiden Ventilgehäuse (18) der Schieberventile (14, 16) zu einem monolithisch einstückigen Formteil (28), insbesondere einem Kunststoff-Spritzteil oder einem Druckgussteil z.B. aus Aluminium oder Zink oder einem spanend bearbeiteten Metall- oder Kunststoffteil, zusammengefasst sind.

29. Schieberventil-Anordnung nach Anspruch 27 oder 28, dadurch gekennzeichnet, dass die Ventilgehäuse (18) bezüglich einer mittigen Symmetrieebene (30) spiegelsymmetrisch ausgebildet sind, wobei sich je zwei separate Anschlüsse (A1, A2; B1, B2) jeweils mit zur Symmetrieebene (30) senkrechter oder paralleler Verlaufsrichtung von dieser weg nach außen erstrecken, und wobei zwei gemeinsame Anschlüsse (M1, M2) mittig mit einer der Symmetrieebene (30) entsprechenden Verlaufsrichtung angeordnet sind.

30. Schieberventil nach Anspruch 25 oder 26 oder Anordnung nach einem der Ansprüche 27 bis 29, gekennzeichnet durch mindestens ein weiteres Merkmal der Ansprüche 1 bis 24.

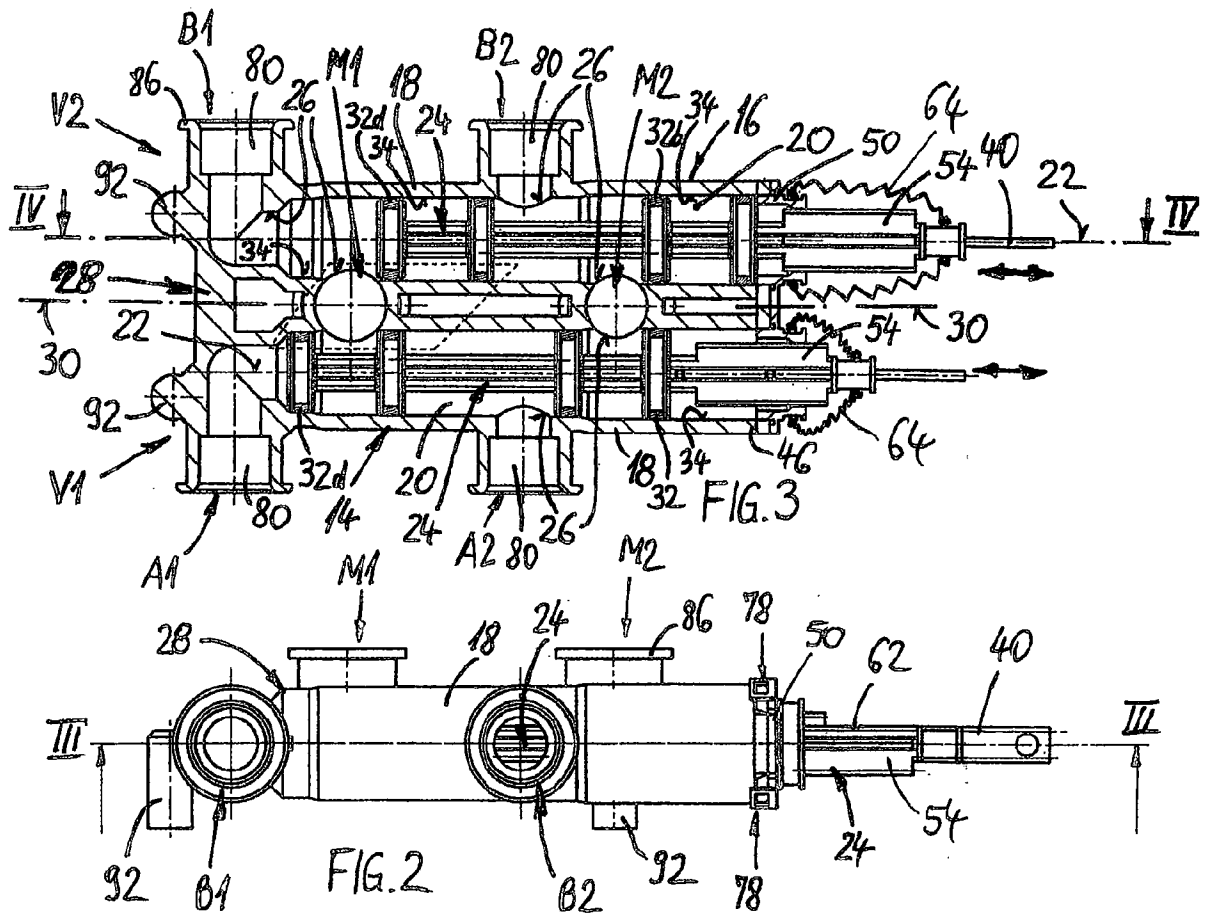
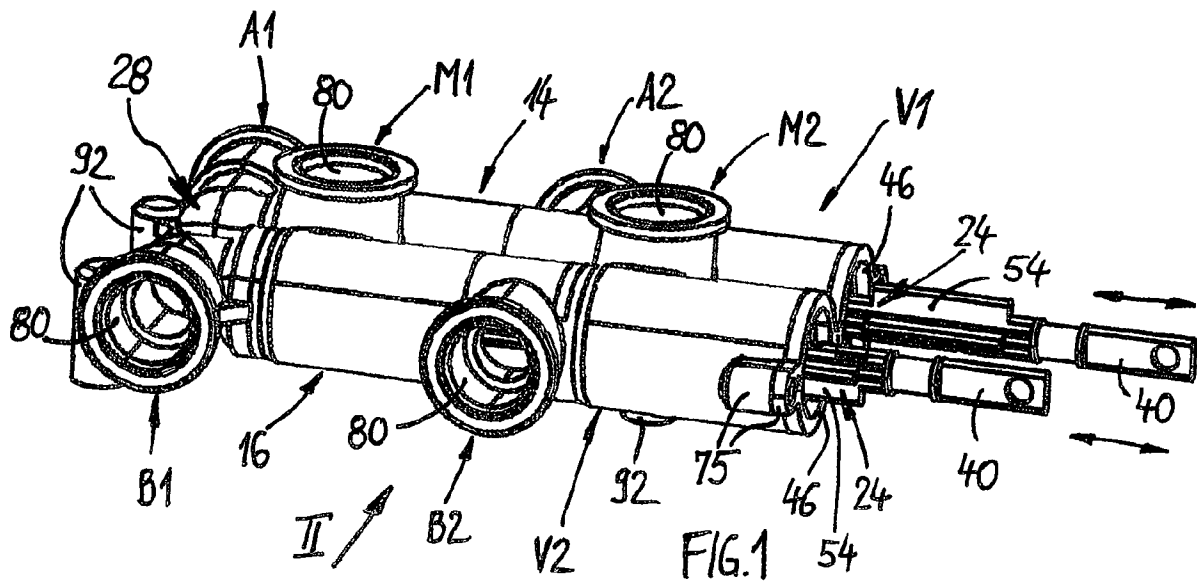
31. Ventilgehäuse (18) für eine Ventilanordnung (1) nach einem der Ansprüche 1 bis 24 oder für ein Schieberventil (14, 16) nach Anspruch 25 oder 26 oder 30.

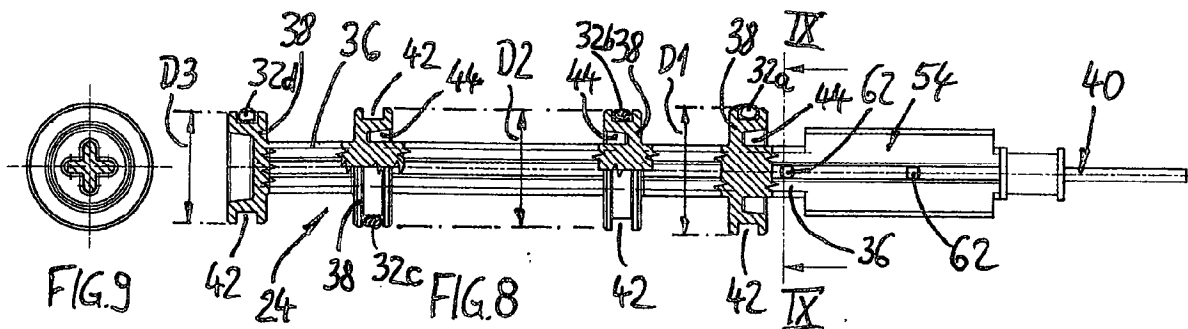
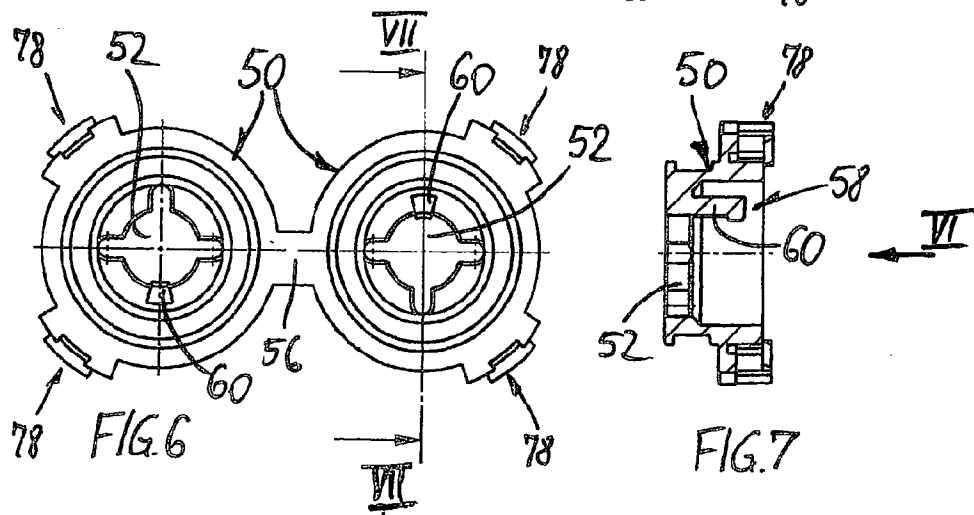
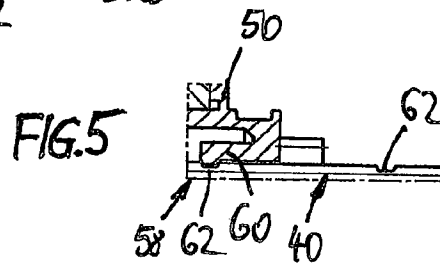
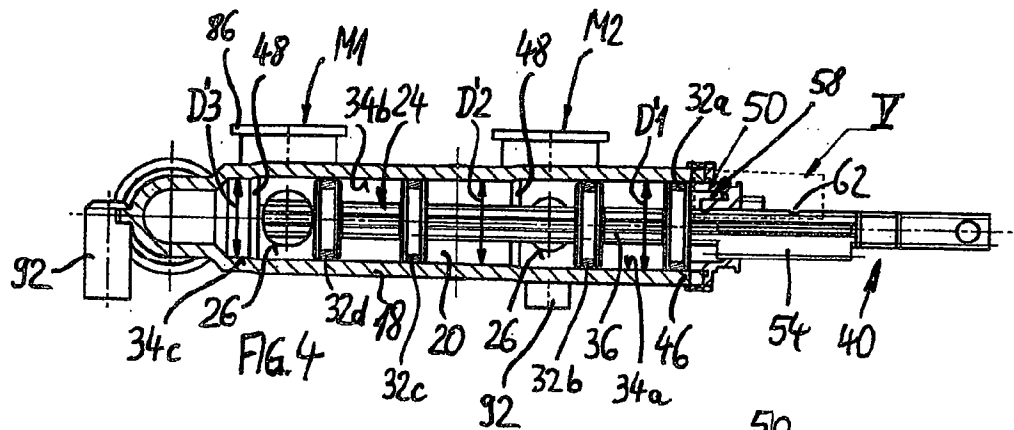
32. Gehäuse-Formteil (28) für eine Ventilanordnung (1) nach einem der Ansprüche 1 bis 24 oder für eine Schieberventil-Anordnung nach einem der Ansprüche 27 bis 30.

33. Schieber (24) für eine Ventilanordnung (1) nach einem der Ansprüche 1 bis 24 oder für ein Schieberventil (14, 16) nach Anspruch 25, 26 oder 30 oder für eine Schieberventil-Anordnung nach einem der Ansprüche 27 bis 30.

Es folgen 6 Blatt Zeichnungen

Anhängende Zeichnungen





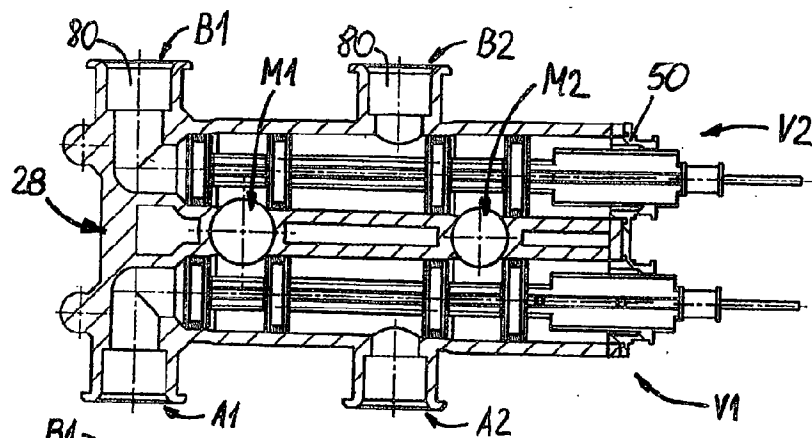


FIG. 10

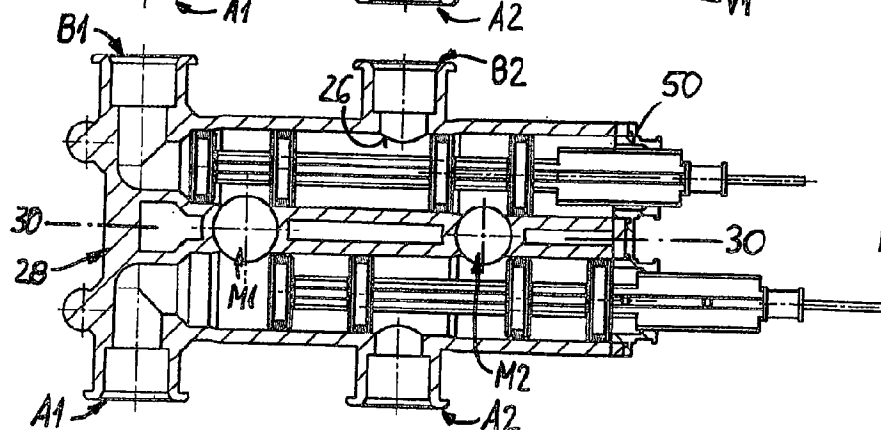


FIG. 11

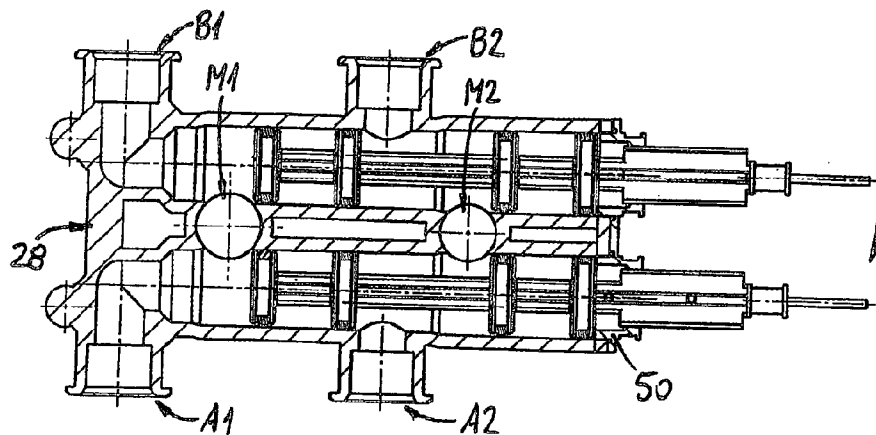


FIG. 12

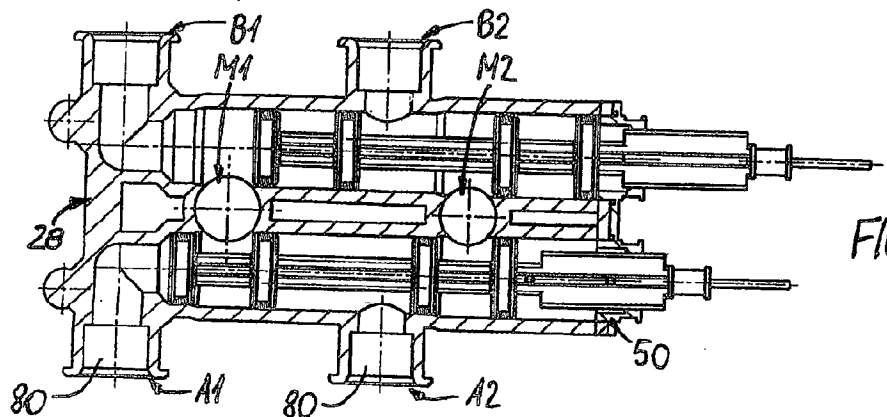
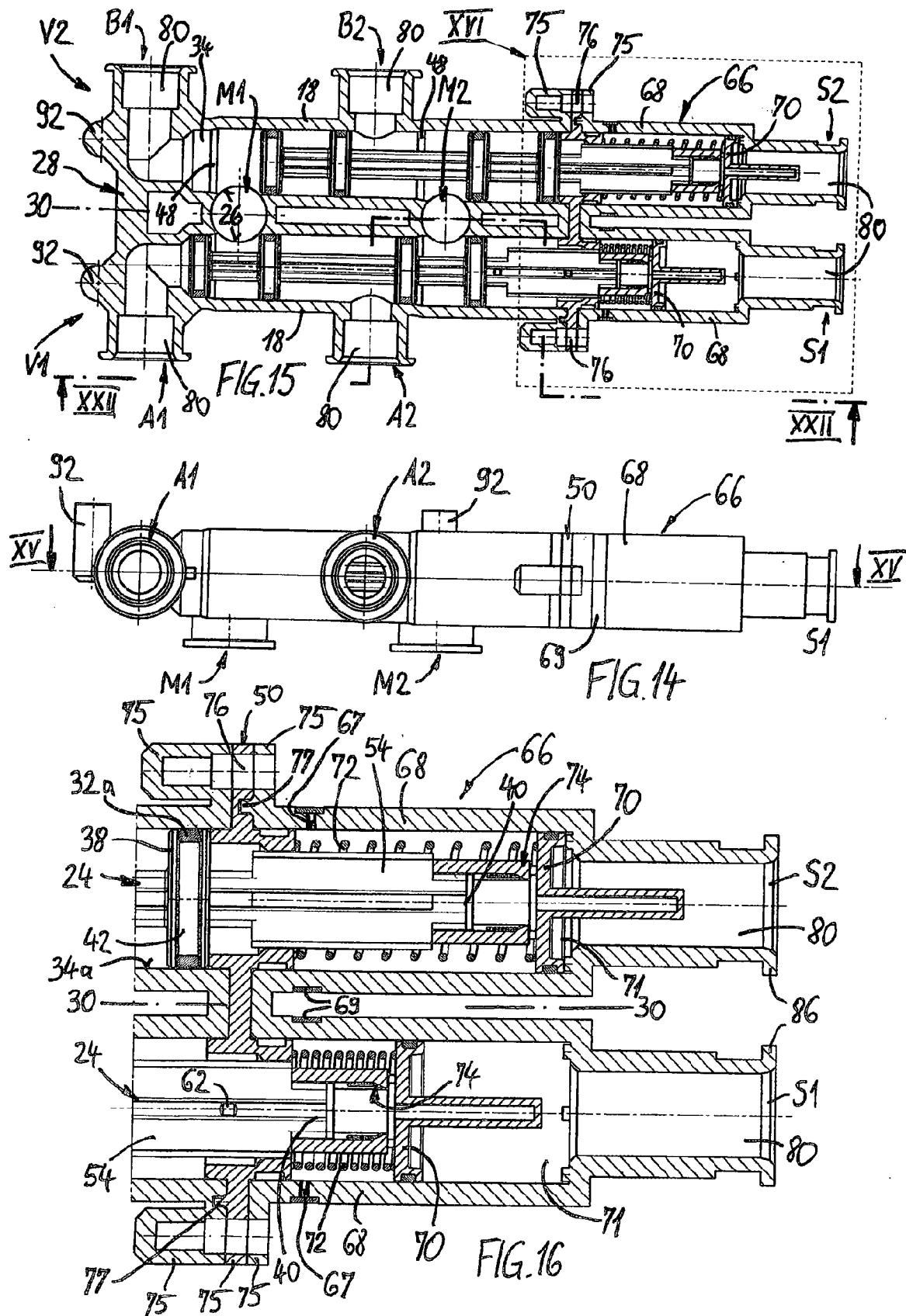
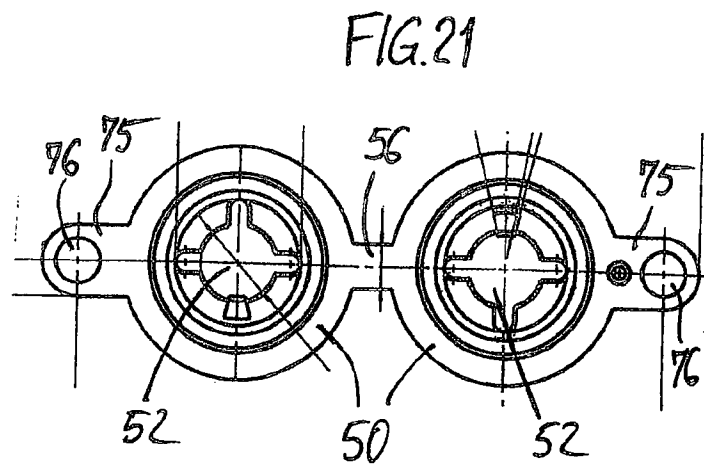
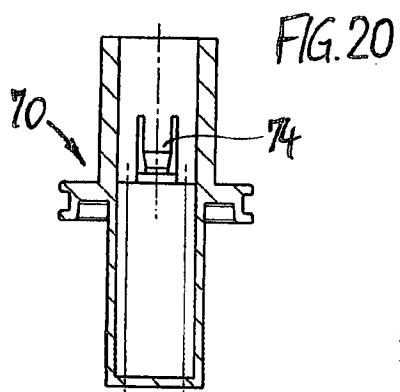
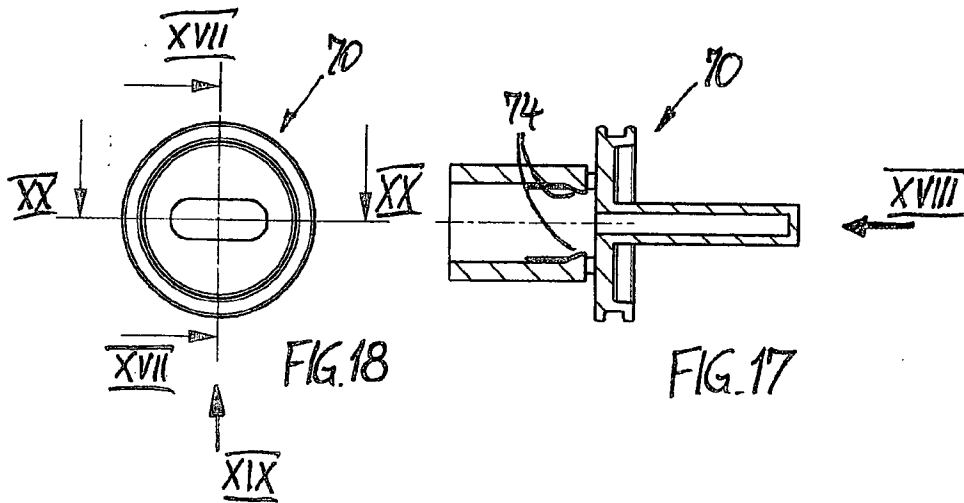
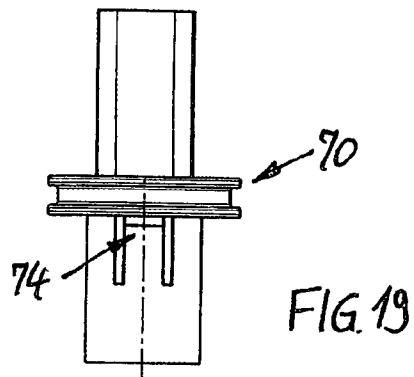
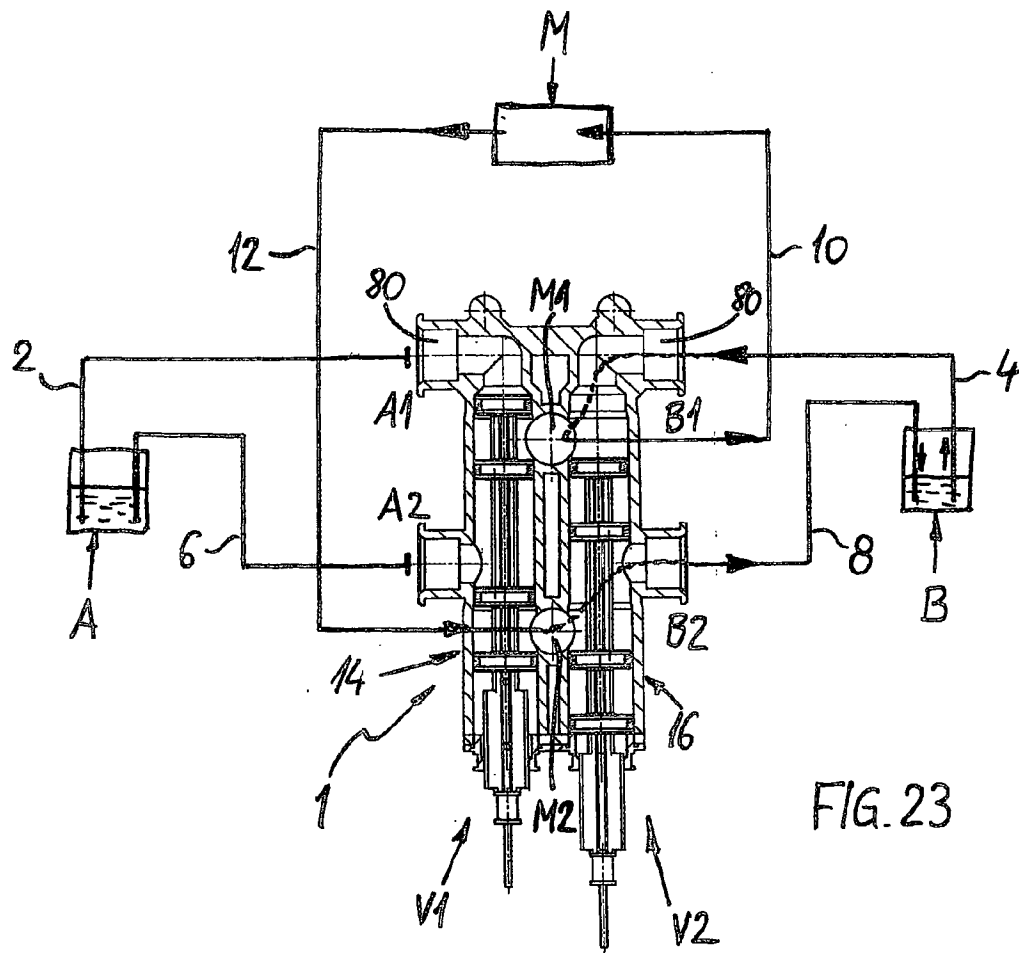
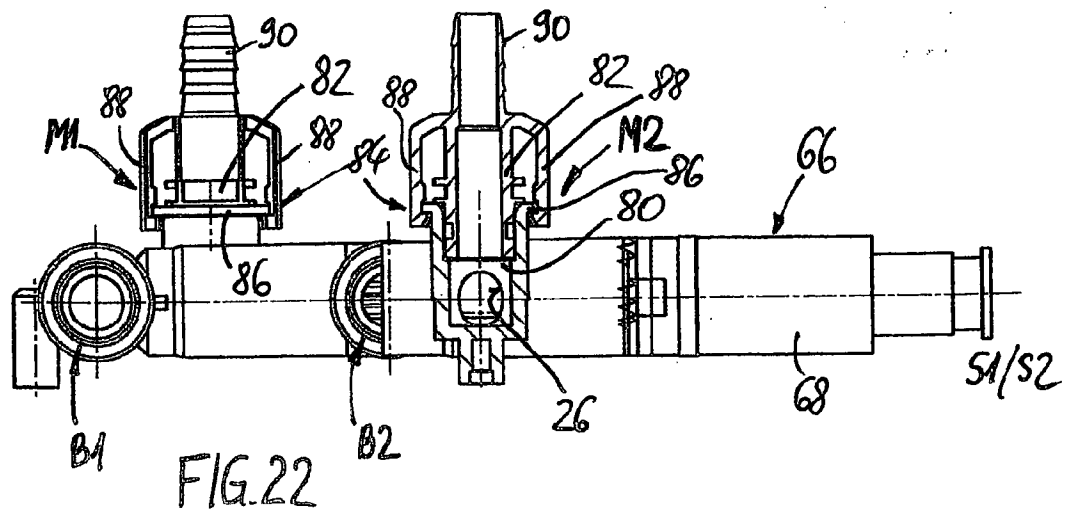


FIG. 13









UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/946,438	06/22/2020	Kendall J. Collie	CET1090.076

CONFIRMATION NO. 5786

PUBLICATION NOTICE



OC000000120511895

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

Title:BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF

Publication No.US-2020-0318578-A1

Publication Date:10/08/2020

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.

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

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 16/946,438	
APPLICATION AS FILED - PART I							
(Column 1)		(Column 2)		SMALL ENTITY		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	75		N/A	
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	330		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	380		N/A	
TOTAL CLAIMS (37 CFR 1.16(j))	19	minus 20 = *	x 50 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2	minus 3 = *	x 230 =	0.00			
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).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
			TOTAL	785		TOTAL	
* If the difference in column 1 is less than zero, enter "0" in column 2.							
APPLICATION AS AMENDED - PART II							
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY	
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)
	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	
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)
	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.							



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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
16/946,438	06/22/2020	3747	785	CET1090.076	19	2

CONFIRMATION NO. 5786

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

FILING RECEIPT



0000000118172207

Date Mailed: 07/06/2020

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)

Kendall J. Collie, Anaheim Hills, CA;
Mark J. Sarder, Waukesha, WI;
Aleko D. Sotiriades, Cedarburg, WI;
James J. Dehn, Brookfield, WI;
Leigh A. Jenison, Hartland, WI;
Hiroaki Sato, Brookfield, 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 14/925,441 10/28/2015 PAT 10697398
which is a CIP of 14/738,060 06/12/2015 PAT 10221780

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: 07/01/2020

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/946,438**

Projected Publication Date: 10/08/2020

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF

Preliminary Class

123

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

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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.

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Application Number	
Filing Date	
First Named Inventor	Kendall J. Collie
Title	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
Art Unit	
Examiner Name	
Attorney Docket Number	CET1090.076

SIGNATURE of Applicant or Patent Practitioner

Signature	/Kevin R. Rosin/	Date (Optional)	2020-06-22
Name	Kevin R. Rosin	Registration Number	55584
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.

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ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
16/946,438

RECEIPT DATE / TIME
06/22/2020 02:52:10 PM ET

ATTORNEY DOCKET #
CET1090.076

Title of Invention

BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF

Application Information

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

PATENT # -

CONFIRMATION # 5786

FILED BY Robyn Templin

PATENT CENTER # 60042042

FILING DATE -

CUSTOMER # 26629

FIRST NAMED
INVENTOR Kendali Collie

CORRESPONDENCE
ADDRESS -

AUTHORIZED BY Kevin Rosin

Documents

TOTAL DOCUMENTS: 6

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
2020.06.22 ADS.pdf	10	Application Data Sheet	1198 KB
2020.06.22 Declaration.pdf	6	Oath or Declaration filed	2162 KB
2020.06.22 General POA.pdf	1	Power of Attorney	532 KB
2020.06.22 Drawings.pdf	12	Drawings-only black and white line drawings	2823 KB
2020.06.22 POA Transmittal.pdf	1	Power of Attorney	187 KB
2020.06.22 Pat App- APP.TEXT.docx	40	Application body structured text document	70 KB

Warning: Text decorations have been removed

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
2020.06.22 ADS.pdf	F64B0663BCC6C06C9F4E8B3CC34BEBF7827BE483A88395F6 D4D52A655E3A35AED5585F718308920A1E126C64D77BD978E 5964B6856B41A81F68790B4B64193C4
2020.06.22 Declaration.pdf	44481B77E2D1CA4EE20793AF65254D2ED6B2B1977819578CA 3965AF706AA6CA916D8D22D79FAB808EE66B562DAB1D24AB A31F6C798666217543220C8134498FE
2020.06.22 General POA.pdf	EEE57956C00EA36439F3ECE88A916468E3E89FD7148120590B EA9FD6029EA56802800079ABA1694B6C5ACAAE418CC562026 80338D97979D157FAA73230CFFEB7
2020.06.22 Drawings.pdf	2CA2E6DE33E504CC390BE98BD3E81AF37DD9DC396DD46DF D570ADB8BF75E563493D135C396F919BDF4EC4E6F7676FDD2 CFE6C716240B6B7D610DBD262BFC8D56
2020.06.22 POA Transmittal.pdf	6C56ECC01EDB3A9D98255AF24AF43E1142F76C457A5A7D033 74E58813CE4F76240FFAEA70A93BCA631B6147FED1DAFB4D8 304A3BC72DAEE983F5399D2044425F
2020.06.22 Pat App- APP.TEXT.docx	D311296ED4C293DD26B35371451761333744B080E7CF2139AD 1A0D241E9AD75C737F47F53778CF2419ADF373D57574788602 62A59ECE02E05F25A76D328D2426

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ELECTRONIC PAYMENT RECEIPT

APPLICATION #
16/946,438

RECEIPT DATE / TIME
06/22/2020 02:52:10 PM ET

ATTORNEY DOCKET #
CET1090.076

Title of Invention

BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF

Application Information

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

PATENT # -

CONFIRMATION # 5786

FILED BY Robyn Templin

PATENT CENTER # 60042042

AUTHORIZED BY Kevin Rosin

CUSTOMER # 26629

FILING DATE -

CORRESPONDENCE
ADDRESS -

FIRST NAMED
INVENTOR Kendall Collie

Payment Information

PAYMENT METHOD
CARD / 4529

PAYMENT TRANSACTION ID
E20206LE54437567

PAYMENT AUTHORIZED BY
Robyn Templin

FEE CODE	DESCRIPTION	ITEM PRICE(\$)	QUANTITY	ITEM TOTAL(\$)
2111	UTILITY PATENT APPL. SEARCH FEE	330.00	1	330.00
4011	BASIC FILING FEE- UTILITY	75.00	1	75.00
2311	EXAMINATION OF ORIGINAL PATENT APPLICATION	380.00	1	380.00
TOTAL AMOUNT:				\$785.00

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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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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		
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	
	Kendall	J.	Collie		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Anaheim Hills	State/Province	CA	Country of Residence	US

Mailing Address of Inventor:

Address 1	751 S Weir Canyon Rd, Suite 157 PMB 391				
Address 2					
City	Anaheim Hills	State/Province	CA		
Postal Code	92809	Country	US		

Inventor	2				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	3				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					

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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

Mailing Address of Inventor:

Address 1	W245 N5551 Corporate 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	
	James	J.	Dehn		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Brookfield	State/Province	WI	Country of Residence	US

Mailing Address of Inventor:

Address 1	W245 N5551 Corporate Circle				
Address 2					
City	Sussex	State/Province	WI		
Postal Code	53089	Country	US		
Inventor	5				Remove
Legal Name					

Prefix	Given Name	Middle Name	Family Name	Suffix	
	Leigh	A.	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 Corporate Circle				
Address 2					
City	Sussex	State/Province	WI		
Postal Code	53089	Country	US		
Inventor	6				Remove
Legal Name					

Prefix	Given Name	Middle Name	Family Name	Suffix	
	Hiroaki		Sato		
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service					
City	Brookfield	State/Province	WI	Country of Residence	US

Application Data Sheet 37 CFR 1.76		Attorney Docket Number		CET1090.076	
		Application Number			
Title of Invention		BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF			
Mailing Address of Inventor:					
Address 1		W245 N5551 Corporate 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.					Add

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Customer Number	26629		
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Application Information:

Title of the Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		
Attorney Docket Number	CET1090.076	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

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.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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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		

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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	14925441	2015-10-28		
Prior Application Status	Patented	Remove			
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
14925441	Continuation in part of	14738060	2015-06-12	10221781	2019-03-05
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.					Add

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).

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

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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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	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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:

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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.				
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If the Assignee or Non-Applicant Assignee is an Organization check here.				☐
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Mailing Address Information For Assignee including Non-Applicant Assignee:				
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Signature:

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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	/Kevin R. Rosin/		Date (YYYY-MM-DD)	2020-06-22
First Name	Kevin R.	Last Name	Rosin	Registration Number
				55584
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CET1090.076
		Application Number	
Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF		

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.**

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- 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.
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- 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.
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BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation of, and claims priority to U.S. Patent Application Serial No. 14/925,441, filed October 28, 2015, which is a continuation-in-part of, and claims priority to, U.S. Patent Application Serial No. 14/738,060, filed June 12, 2015, now Issued U.S. Patent 10,221,780, issued March 5, 2019, 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 or 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 is

generally a gaseous fuel that 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. 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. Further, a float bowl in the carburetor that must first fill or empty prior to changeover causes delay in cross-over switching between the fuel sources.

[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 dual fuel engine includes an engine operable on a gaseous fuel and a liquid fuel. A carburetor attaches to an intake of the engine to mix air and fuel and connect to a gaseous fuel source and a liquid fuel source. The dual fuel engine also includes a switch to change operation of the engine between gaseous fuel and liquid fuel, and a liquid fuel cut-off attaches to the carburetor to interrupt liquid fuel upon actuation of the switch from liquid fuel to gaseous fuel.

[0008] In accordance with another aspect of the invention, a batteryless dual fuel generator includes a housing containing a pull start engine coupled to drive an alternator. The engine is operable on a gaseous fuel and a liquid fuel and includes a carburetor attached to an intake of the engine. The carburetor has a throat to mix fuel with air, a float bowl, and a fuel passage to provide liquid fuel from the float bowl to the throat. The generator may also include a switch to select engine operation on either the liquid fuel or the gaseous fuel and a fuel shutoff attached to the carburetor to close the fuel passage upon selection of engine operation to gaseous fuel.

[0009] In accordance with yet another aspect of the invention, a carburetor having a fuel shutoff includes a carburetor with a float bowl, a throat, and a fuel passage to provide fuel from the float bowl to the throat. A fuel shutoff couples to the carburetor which may have a first end in the carburetor that actuates to close the fuel passage and a second end external to the carburetor to actuate the first end. The fuel shutoff may operate within the carburetor such that the fuel shutoff actuates free from linear motion when opening and closing the fuel passage.

[0010] In accordance with yet another aspect of the invention, a method of assembling a dual fuel engine includes providing an engine operable on a gaseous fuel and a liquid fuel and attaching a carburetor to an intake of the engine to supply the fuels to the engine. The carburetor includes a throat to mix gaseous fuel with air and liquid fuel with air, a float bowl, and a fuel passage to provide liquid fuel from the float bowl to the throat. The fuels may be supplied to the carburetor by a gaseous fuel source coupled to the throat and a liquid fuel source coupled to the float bowl. The method

also includes coupling a switch to the engine to change operation of the engine between gaseous fuel and liquid fuel, and attaching a liquid fuel cut-off to the carburetor to close the fuel passage upon actuation of the switch from liquid fuel to gaseous fuel.

[0011] Various other features and advantages will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The drawings illustrate preferred embodiments presently contemplated for carrying out the invention.

[0013] In the drawings:

[0014] FIG. 1 is a perspective view of a dual fuel generator coupled to a fuel delivery system, according to an embodiment of the invention.

[0015] 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.

[0016] 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.

[0017] 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 electro-mechanical embodiment of the invention.

[0018] 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 electro-mechanical embodiment of the invention.

[0019] FIG. 5 is a perspective view of a dual fuel carburetor having a manual fuel shutoff system and coupled to a first fuel line and a second fuel line, according to a mechanical embodiment of the invention.

[0020] FIG. 6 is cross-sectional view of the carburetor of FIG. 5 taken along line 6-6 of FIG. 5 through a fuel passage that provides fuel from a float bowl to a throat of the carburetor, according to an embodiment of the invention.

[0021] FIG. 7A is a partial sectional view of the float bowl of FIG. 6 with a manual fuel shutoff system in an open position, according to an embodiment of the invention.

[0022] FIG. 7B is a detailed partial sectional view of the float bowl with a manual fuel shutoff of FIG. 7A taken along line 7B-7B of FIG. 7A, according to an embodiment of the invention.

[0023] FIG. 8 is a partial sectional view similar to FIG. 7A and showing the manual fuel shutoff system in a closed position, according to an embodiment of the invention.

[0024] FIG. 9 is a perspective view of a shaft for the manual fuel shutoff system of FIG. 5, according to an embodiment of the invention.

[0025] FIG. 10 is a side view of a valve member for the manual fuel shutoff system of FIG. 5, according to an embodiment of the invention.

[0026] FIG. 11 is a perspective view of the carburetor of FIG. 5 with the manual fuel shutoff system exploded from a float bowl of the carburetor.

[0027] FIG. 12 is a flow chart showing steps in fabricating a manual fuel shutoff system for a carburetor, according to an embodiment of the invention.

[0028] FIG. 13 is a magnetic fuel shutoff system for a carburetor, according to a magnetic-mechanical embodiment of the invention.

[0029] FIG. 14 is a wiring diagram of a microcontroller receiving input signals and operating engine components, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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.

[0038] Mechanical fuel lockout switch 38, FIG. 2, includes mechanical fuel valve 54 actuateable 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.

[0039] 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 a liquid fuel valve, 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.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] 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, 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.

[0044] 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 supply 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.

[0045] 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. Each end 50a, 50b has a gaseous fuel 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.

[0046] 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.

[0047] 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.

[0048] Referring to FIG. 4A, a schematic diagram of a fuel system for a dual fuel engine 60 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 can include 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.

[0049] Mechanical fuel lockout switch 38 changes the fuel source for engine 60 between liquid fuel and gaseous fuel. Mechanical fuel lockout switch 38 includes a mechanical fuel valve 54 actuateable 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 60 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.

[0050] A liquid fuel cut-off 72 couples to carburetor 62 to regulate liquid fuel flow through the carburetor. Liquid fuel cut-off 72 can stop liquid fuel flow to engine 60 to prevent an overly rich air-fuel ratio when operating engine 60 on gaseous fuel. Liquid fuel cut-off 72 may attach to carburetor 62 to interrupt liquid fuel upon actuation of mechanical fuel lockout switch 38 from liquid fuel to gaseous fuel. As such, liquid fuel cut-off 72 can prevent engine flooding by stopping liquid fuel flow when starting on gaseous fuel. Liquid fuel cut-off 72 is manually operated in some embodiments of the invention and electrically operated in other embodiments of the invention.

[0051] In one embodiment of the invention, liquid fuel cut-off 72 comprises a fuel cut solenoid 74, also referred to as a carburetor cutoff solenoid, that operates within carburetor 62 as a solenoid valve to control liquid fuel flow to engine 60. Fuel cut solenoid 74 actuates between an open position to provide liquid fuel to engine 60 and a closed position to stop liquid fuel to the engine. Fuel cut solenoid 74 can operate as a normally open solenoid valve so that power is not required to open the solenoid during liquid fuel operation. As such, fuel cut solenoid 74 is powered and moved to a closed position to stop liquid fuel flow to engine 60 during gaseous fuel operation. Alternatively, fuel cut solenoid 74 may be operated as a normally closed valve that is powered to open for liquid fuel operation.

[0052] Fuel cut solenoid 74 is preferably powered by a magneto 76, alternator, engine flywheel with a charge winding, or other electrical power generator having a charge winding or coil 78. Charging coil 78 allows operation of fuel cut solenoid 74 in a batteryless engine. In a batteryless dual fuel generator, the charging coil 78 may be integral to an alternator driven by the batteryless engine. Engine 60 may be a pull-start engine having a recoil starter 80. During engine startup, recoil starter 80 cranks the engine with a manual pull by a user that causes magneto 76 to supply electrical power to fuel cut solenoid 74. While a fuel cut solenoid 74 in a normally open mode does not require any initial electrical power for starting engine 60 on liquid fuel, charging coil 78 powers the solenoid to stop liquid fuel flow during startup on gaseous fuel. Alternatively, charging coil 78 can power a fuel cut solenoid 74 operating in a normally closed mode to open and provide liquid fuel to engine 60 during startup on liquid fuel.

[0053] Charging coil 78 has an output voltage generally proportional to engine speed and therefore charge coil 78 will produce a range of voltages over the range of engine operating speeds. For example, if charging coil 78 produces 12 VAC at 3600 rpm, it may only produce 1 VAC at 300 rpm which would be insufficient voltage during startup to power a solenoid that requires 12 volts. An alternator typically used to power 12 volt accessories, such as a battery, at engine speeds will need increased output voltage to provide sufficient voltage for operation of fuel cut solenoid 74 at low recoil start speeds. In addition, the output voltage of a charging coil may vary if the alternator or magneto 76 also powers accessories. Accordingly, the output voltage of a charging coil should be verified by running engine 60 through the full range of operating speeds before increasing the output voltage.

[0054] Additional turns can be added to a charging coil in the alternator or magneto 76 to increase the output voltage and provide sufficient voltage to activate fuel cut solenoid 74 at manual start speeds. Typical alternators or magnetos may have limited room within stator laminations for additional turns, but low current requirements of fuel cut solenoid 74 allows substitution of smaller gage wire. Alternatively, solenoid windings on fuel cut solenoid 74 can be modified to operate at lower voltages for recoil

starting. However, adding coil turns to a charge winding provides an inexpensive modification and allows use of standard 12 volt solenoids.

[0055] To protect electrical systems, a voltage regulator 82 couples to charging coil 78 to provide a fixed output voltage for a varying input voltage. If charge winding 78 is wound to supply 12 VAC at 300 rpm, it could supply 144 VAC at 3600 rpm. Applying 144 volts could quickly destroy a solenoid designed to operate at 12 volts. Accordingly, voltage regulator 82 may comprise a switching power supply circuit 84 that regulates a rectified DC power output from magneto 76 and provides a fixed voltage to fuel cut solenoid 74. Switching circuits are very efficient, dissipate very little power, and can be made small and inexpensive. Switching power supply circuit 84 allows for low rpm, recoil starter electrical power generation with charge coil 78 voltage control over engine speed range.

[0056] In the embodiment shown in FIGS. 4A and 4B, fuel cut solenoid 74 is operated by an electro-mechanical switch 86. Electro-mechanical switch 86 connects one fuel source to carburetor 62 and is connected to magneto 76 for a power source. Electro-mechanical switch 86 may comprise an electrical switch 88 that provides electrical connection between fuel cut solenoid 74 and magneto 76. Electro-mechanical switch 86 may also comprise mechanical fuel lockout switch 38, and electrical switch 88 can be mechanically actuated and controlled by mechanical fuel lockout switch 38. Fuel cut solenoid 74 connects to open and close a fuel path to pull-start engine 60 in response to reception of electrical power from electro-mechanical switch 86.

[0057] Fuel cut solenoid 74 can operate as a normally open valve that closes when powered by alternator or magneto 76. The normally open valve is activated to close and prevent gasoline flow to engine 60 for LPG mode, and deactivated to open and allow gasoline flow to engine 60 for gasoline mode. As such, actuation of mechanical fuel lockout switch 38 to first position 38(a) opens electrical switch 88 to interrupt power and open fuel cut solenoid 74 as represented in FIG. 4A, and actuation of mechanical fuel lockout switch 38 to second position 38(b) closes electrical switch 88 to power and close fuel cut solenoid 74 as represented in FIG. 4B. Alternatively, fuel cut solenoid 74

can operate as a normally closed valve where actuation of mechanical fuel lockout switch 38 to first position 38(a) closes electrical switch 88 to power and open fuel cut solenoid 74, and actuation of mechanical fuel lockout switch 38 to second position 38(b) opens electrical switch 88 to interrupt power and close fuel cut solenoid 74.

[0058] In an alternative embodiment of the invention, a microcontroller 89 operates fuel cut solenoid 74 so that fuel cut solenoid 74 opens to operate engine 60 on gasoline and is closed when the engine operates on LPG. While engine 60 is running, charging coil 78 provides power available to microcontroller 89 for operation of fuel cut solenoid 74. Fuel cut solenoid 74 may operate in a normally open mode to allow gasoline flow to engine 60 without power from microcontroller 89, and microcontroller 89 may operate fuel cut solenoid 74 to operate as an after-fire solenoid when shutting down engine 60 from gasoline operation. That is, microcontroller 89 powers fuel cut solenoid 74 to a closed position preventing fuel being drawn into engine 60 and muffler during engine shutdown from operation on gasoline. When engine 60 runs on LPG, microcontroller 89 switches on power to close fuel cut solenoid 74 to prevent engine 60 from drawing in gasoline from the float bowl of carburetor 62 and first fuel line 66. Microcontroller 89 may also operate fuel cut solenoid 74 configured to be normally closed. Implementation of microcontroller 89 is further described with respect to FIG. 14.

[0059] 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.

[0060] 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.

[0061] Liquid fuel cut-off 72 couples to carburetor 62 to regulate liquid fuel flow through the carburetor as described with respect to FIG. 4A. Liquid fuel cut-off 72 may comprise a fuel cut solenoid 74 powered by magneto 76. Engine 60 has recoil starter 80 that cranks the engine and drives magneto 76 to power fuel cut solenoid 74 when starting the engine. Voltage regulator 82 reduces the voltage delivered to fuel cut solenoid 74 at higher engine operating speeds. Fuel cut solenoid 74 is activated by electro-mechanical switch 86 providing electrical connection to magneto 76 via electrical switch 88. Electrical switch 88 can be manually actuated and controlled by mechanical fuel lockout switch 38. FIG. 4B shows electrical switch 88 closed to power a normally open configured fuel cut solenoid 74 to a closed position for LPG mode when mechanical fuel lockout switch 38 is in second position 38(b).

[0062] FIG. 4A and FIG. 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. In another embodiment of the invention, a manual fuel petcock is coupled along second fuel line 70 to provide an independent shut-off from second fuel source 30 to the engine.

[0063] Referring to FIG. 5, a dual fuel carburetor having a manual fuel shutoff system is shown, in accordance with a mechanical embodiment of the invention. Carburetor 62 attaches to an intake 90 of the engine to mix air and fuel and connect to a liquid fuel source and a gaseous fuel source. Carburetor 62 has a mixing passage or throat 92 having an inlet 94 for air and an outlet 96 for an air-fuel mixture. A venturi 98 is located in throat 92 with a choke valve 100 located upstream from the venturi and a throttle valve 102 located downstream from the venturi. Carburetor 62 has a float bowl 104 that provides fuel through a fuel passage into a narrow portion of venturi 98. Float bowl 104 has a liquid fuel inlet 106 to receive liquid fuel from first fuel source 28. Throat 92 has a gaseous fuel inlet 108 to receive gaseous fuel from second fuel source 30. Dual fuel carburetor 62 mixes air with fuel from first fuel source 28 and second fuel source 30 and provides the respective air-fuel mixtures for operation of the dual fuel generator.

[0064] Liquid fuel cut-off 72 couples to carburetor 62 to control liquid fuel flow downstream of float bowl 104 in the carburetor. Liquid fuel cut-off 72 can close off float bowl 104 to stop liquid fuel flow to the engine and prevent an overly rich air-fuel ratio during gaseous fuel operation. As such, liquid fuel cut-off 72 prevents engine flooding when starting on gaseous fuel. Liquid fuel cut-off 72 also traps fuel in float bowl 104 to eliminate delay in filling the bowl when starting the engine on liquid fuel, and can stop liquid fuel flow to the engine immediately after ignition shutdown. As such, liquid fuel cut-off 72 reduces emissions and prevents afterfire by stopping the engine from continuing to draw in fuel from float bowl 104 during shutdown.

[0065] In the embodiment of FIG. 5, liquid fuel cut-off 72 comprises a manually operated fuel shutoff 110 coupled to carburetor 62 to control liquid fuel flow downstream of float bowl 104. Manual fuel shutoff 110 can be cable actuated for use on engines without battery power, for instance engines with recoil starters. Manual fuel

shutoff 110 actuates between a first position to allow gasoline flow to the engine, as shown in FIG. 7A, and a second position to prevent gasoline flow to the engine, as shown in FIG. 8. Referring back to FIG. 5, manual fuel shutoff 110 may comprise a shaft 112 extending into carburetor 62 that actuates between the first position and second position. A manually operated control system 114 couples to shaft 112 external to carburetor 62 to control manual fuel shutoff 110.

[0066] A bracket 116 couples to the outer surface of carburetor 62 to support manual control system 114. Bracket 116 mounts to a boss 118 extending outwards from float bowl 104. Boss 118 has a flat vertical surface with a pair of tapped holes for mounting bracket 116 to float bowl 104. Screws 120, 122 extend through respective holes in bracket 116 and into the tapped holes to mount the bracket to carburetor 62. Manual fuel shutoff 110 extends out of carburetor 62 and through an opening 124 in bracket 116. Bracket 116 has a first stopping tab 126 and a second stopping tab 128 extending away from float bowl 104 to hold manual fuel shutoff 110 in a respective open or closed position. A fuel drain screw 130 extends into an opening in carburetor 62 adjacent bracket 116.

[0067] Bracket 116 has a lower arm 132 extending downward and to the air inlet side of carburetor 62. Lower arm 132 has a bottom portion 134 bent outward from carburetor 62 to couple to a control system spring 136. Bottom portion 134 has a hole 138 for control system spring 136 adjacent a positioning groove 140 for the spring. Control system spring 136 is held in position by groove 140 as it hooks through hole 138. Bracket 116 also has an upper arm 142 extending first outward from carburetor 62 and then vertically and to the outlet side of the carburetor. Upper arm 142 has a cable clamp 144 for holding a Bowden cable 146. Cable clamp 144 has a flat midsection and two curved ends contacting bracket 116 to hold the midsection slightly apart from the bracket. Cable clamp 144 is coupled to bracket 116 by a bolt 148 extending through a hole in the midsection and through upper arm 142 of the bracket.

[0068] A lever 150 couples to shaft 112 to actuate manual fuel shutoff 110. A cap 152 holds lever 150 on shaft 112. Alternatively, lever 150 may be coupled to the shaft

112 by welding or staking. Lever 150 has a first lever arm 154 to contact and hold lever 150 against first and second stopping tabs 126, 128 of the bracket. Lever 150 has a second lever arm 156 to actuate shaft 112. First lever arm 154 is in plane with an opening in the lever for shaft 112 and second lever arm 156 extends first outward from carburetor 62 and then parallel to first lever arm 154. Second lever arm 156 extends outward from carburetor 62 to provide clearance between bracket 116 and the second lever arm for control system spring 136 and screw 122. Second lever arm 156 has two holes 158, 160 for coupling control system spring 136 and Bowden cable 146 to lever 150.

[0069] Manual fuel shutoff 110 operates as a valve within carburetor 62 to selectively interrupt liquid fuel flow to the engine. Control system spring 136 preferably pulls on lever 150 to hold manual fuel shutoff 110 in an open valve position, and Bowden cable 146 pulls lever 150 against control system spring 136 to rotate manual fuel shutoff 110 to a closed valve position. As such, control system spring 136 holds manual fuel shutoff 110 open for gasoline mode until Bowden cable 146 is pulled to close the valve for LPG mode. Alternatively, control system spring 136 can hold manual fuel shutoff 110 in a closed valve position until Bowden cable 146 is pulled to open the valve. Therefore, actuation of the Bowden cable 146 acts as a switch to assist in changeover between the dual fuels. Manual fuel shutoff 110 may rotate 90 degrees between the open and closed positions with stopping tabs 126, 128 positioned about bracket 116 accordingly. Lever 150 can be positioned on shaft 112 so that second lever arm 156 is pulled upward by a generally vertical Bowden cable 146. Second lever arm 156 may actuate between a position 45 degrees below horizontal for an open valve and a position 45 degrees above horizontal for a closed valve. When holding the valve open, control system spring 136 may be oriented at a right angle to second lever arm 156 for increased leverage.

[0070] Referring to FIG. 6, a cross-sectional view of the carburetor taken generally about line 6-6 of FIG. 5 is shown, in accordance with an embodiment of the invention. Carburetor 62 includes a throat 92 to mix gaseous fuel with air and liquid fuel with air. Throat 92 includes a gaseous fuel inlet port 162 in communication with gaseous fuel

inlet 108 coupled to a second fuel line 70. Carburetor 62 also includes float bowl 104 and a fuel passage 164 to provide a liquid fuel path from float bowl 104 through a main nozzle 166 into venturi 98. Float bowl 104 has a liquid fuel inlet port 168 and a float valve 170 to regulate liquid fuel flow through liquid fuel inlet port 168. Liquid fuel inlet port 168 is in communication with the liquid fuel inlet 106 coupled to first fuel line 66.

[0071] Manual fuel shutoff 110 couples to carburetor 62 to regulate liquid fuel flow downstream of float bowl 104. Manual fuel shutoff 110 attaches to carburetor 62 to close fuel passage 164 upon selection of engine operation to gaseous fuel. Manual fuel shutoff 110 may have a first end 172 positioned in carburetor 62 adjacent an inlet port 174 to fuel passage 164, and the first end 172 actuates to close fuel passage 164. That is, first end 172 actuates between a first position to permit fuel flow into fuel passage 164, as shown in FIG. 7A, and a second position to prevent fuel flow into fuel passage 164, as shown in FIG. 8.

[0072] Referring back to FIG. 6, manual fuel shutoff 110 has a second end 176 positioned external to carburetor 62 that is manually actuated to operate manual fuel shutoff 110. Manual fuel shutoff 110 may have a rotating shaft 112 that extends through an opening 178 in carburetor 62. A blocking member or valve tip 180 couples to shaft 112 in carburetor 62 to create a valve-shaft assembly 179. Valve tip 180 rotates parallel to inlet 174 of fuel passage 164 between a blocking position and non-blocking position to selectively block fuel flow into fuel passage 164. Lever 150 couples to shaft 112 external to carburetor 62 and actuates to rotate shaft 112 and valve tip 180.

[0073] Shaft 112 may be horizontal or substantially horizontal to allow valve tip 180 to be positioned directly in float bowl 104 adjacent inlet port 174 of fuel passage 164. That is, manual fuel shutoff 110 may be coupled to carburetor 62 such that second end 176 is horizontal from first end 172. Inlet 174 of fuel passage 164 can face horizontal or substantially horizontal to accommodate valve tip 180 in float bowl 104. As such, fuel passage 164 may have a horizontal component that receives fuel from float bowl 104 leading to a vertical component to provide fuel to venturi 98. The interior surface

of the float bowl 104 may also have a recess or cavity 182 to provide room for valve member 180 in the bowl.

[0074] Opening 178 in carburetor 62 has a plug 184 to hold shaft 112 and prevent fuel flow out of the carburetor. Shaft 112 extends through a hole 186 in plug 184 and hole 186 is positioned to align valve tip 180 with fuel passage 164. Plug 184 has a larger outer diameter 188 toward the external side of carburetor 62 and a smaller outer diameter 190 toward the internal side. Larger outer diameter 188 and smaller outer diameter 190 mate with corresponding diameters of opening 178. Plug 184 has a counterbore 192 to hole 186 on the external side of the plug. A compression spring 194 is positioned around shaft 112 in float bowl 104 to push valve tip 180 against plug 184. Compression spring 194 holds valve tip 180 against inlet 174 of fuel passage 164 in order to seal the fuel passage.

[0075] A primary o-ring 196 and a secondary o-ring 198 are positioned around shaft 112 to provide a respective first and second fuel seal between the shaft and plug 184 and to seal first end 172 of manual fuel shutoff 110 in carburetor 62. Primary o-ring 196 may be positioned in an o-ring groove 200 in shaft 112 and secondary o-ring 198 may be positioned in counterbore 192 of plug 184. A bracket 116 or other support member mounts over counterbore 192 and around shaft 112 to hold secondary o-ring 198 in counterbore 192. Bracket 116 has an opening 124 large enough for shaft 112 but small enough to hold secondary o-ring 198 in counterbore 192. Manual fuel shutoff 110 actuates in a rotative motion free from linear motion in part to ensure fuel will not leak through primary o-ring 196 or secondary o-ring 198. Compared to a sliding valve, a rotating valve, such as manual fuel shutoff 110, reduces the likelihood that fuel will leak from carburetor 62.

[0076] Liquid fuel cut-off 72 may regulate fuel flow through multiple fuel passages in carburetor 62 that provide fuel from float bowl 104 to the engine. For instance, carburetor 62 may have a main fuel circuit 202 and an idle fuel circuit 204. Main fuel circuit 202 provides fuel through main nozzle 166 into a narrow portion of venturi 98. Idle fuel circuit 204 provides fuel to throat 92 downstream from the throttle valve.

Liquid fuel cut-off 72 may regulate fuel flow through some or all of the fuel circuits that provide fuel from float bowl 104 to the engine. FIG. 6 shows an embodiment where idle fuel circuit 204 branches off from main fuel circuit 202 and liquid fuel cut-off 72 actuates to block fuel flow into both main fuel circuit 202 and idle fuel circuit 204. In other embodiments, liquid fuel cut-off 72 closes main fuel circuit 202 while small amounts of liquid fuel pass through idle fuel circuit 204. Fuel passing through idle fuel circuit 204 may not negatively affect engine performance during LPG operation but will eventually drain the gasoline tank.

[0077] Referring to FIG. 7A, a partial sectional view of a float bowl shows a manual fuel shutoff system in an open position for gasoline mode, in accordance with an embodiment of the invention. The partial sectional view is taken through a portion of float bowl 104 along fuel passage 164 while showing another portion of float bowl 104 in front of fuel passage 164 and coupled to manual fuel shutoff 110. Inlet 174 to fuel passage 164 is in a boss 206 extending outward from a central region of float bowl 104. Boss 206 has an oval top with sides that extend to the floor of float bowl 104. Inlet 174 to fuel passage 164 extends through boss 206 and has a substantially flat perimeter edge 208 around inlet port 174 on the surface of the boss. Manual fuel shutoff 110 presses against substantially flat perimeter edge 208 surrounding fuel passage 164 to block fuel flow into fuel passage 164.

[0078] Manual fuel shutoff 110 may have a rotating shaft 112 extending through an aperture 178 in float bowl 104. Shaft 112 has a first end 210 coupled to valve tip 180 and located in float bowl 104 that is held against inlet port 174 to fuel passage 164. Shaft 112 rotates valve tip 180 against inlet port 174 between a first position 180(a) allowing fuel flow through the inlet port 174, as shown in FIG. 7A, and a second position 180(b) blocking fuel flow through the inlet port 174, as shown in FIG. 8. That is, valve tip 180 uncovers the inlet 174 of fuel passage 164 to permit fuel flow into the inlet 174 when rotated to first position 180(a), FIG. 7A, and covers inlet 174 of fuel passage 164 to prevent fuel flow into inlet 174 when rotated to second position 180(b), FIG. 8.

[0079] Referring back to FIG. 7A, the manual fuel shutoff system further includes bracket 116 to support shaft 112 in float bowl 104 and provide mounting locations for manually operated control system 114. Bracket 116 also has a pair of stopping tabs 126, 128 to hold the manual fuel shutoff 110 in an open or closed position. Shaft 112 extends through bracket 116 and lever 150 couples to a second end 212 of shaft 112 located outside of float bowl 104. Control system spring 136 couples lever 150 to bracket 116 to hold lever 150 against stopping tab 126 and hold manual fuel shutoff 110 in the open position for gasoline mode. Bowden cable 146 couples to lever 150 to pull against control system spring 136 and rotate manual fuel shutoff 110 to the closed position for LPG mode. As such, second end 176 of manual fuel shutoff 110 is positioned external to float bowl 104 and coupled to manually operated control system 114 to operate manual fuel shutoff 110.

[0080] Referring to FIG. 7B, a detailed partial sectional view of the float bowl of FIG. 7A taken along line 7B-7B shows a manual fuel shutoff in an open position for gasoline mode, in accordance with an embodiment of the invention. Float bowl 104 includes boss 206 through which fuel passage 164 extends and having a substantially flat perimeter edge 208 surrounding inlet 174 to fuel passage 164. Substantially flat perimeter edge 208 preferably has a flat finished surface for improved sealing against valve tip 180. Valve tip 180 maintains planar contact with substantially flat perimeter edge 208 while rotating between an open position permitting fuel flow into inlet 174 and a closed position blocking fuel flow into inlet 174. As such, valve tip 180 rotates parallel to inlet 174 of fuel passage 164 between the open or first position 180(a) and closed or second position 180(b), FIG. 8.

[0081] Referring again to FIG. 7B, valve tip 180 may comprise an oval or stadium 214 having a flat surface 216 that contacts perimeter edge 208 around inlet 174 of fuel passage 164. Valve tip 180 may have a recessed portion or cutout 218 in the flat surface 216 to provide a flow passage through the valve tip. Fuel flows through the cutout 218 into the inlet 174 of fuel passage 164 when cutout 218 is aligned with inlet 174. That is, cutout 218 in valve tip 180 aligns with inlet port 174 when valve tip 180 is rotated to the open position such that fuel can pass from float bowl 104 through cutout 218 into fuel

passage 164. Cutout 218 in valve tip 180 is strategically positioned in a narrow portion of stadium 214 so a long portion of stadium 214 can be rotated to cover and block inlet 174. Valve tip 180 may comprise one of many shapes including a stadium, an oval, a disk, a rectangle, an irregular shape, among others.

[0082] Referring to FIG. 8, a partial sectional view of a float bowl shows a manual fuel shutoff system in a closed position for LPG mode, in accordance with an embodiment of the invention. Valve tip 180 pushes against inlet 174 to fuel passage 164 to seal the inlet when in second position 180(b). Valve tip 180 may have a stadium shape 214 with a cutout 218 in the narrow portion of the stadium to provide a flow passage. Valve tip 180 blocks fuel flow into fuel passage 164 when the cutout 218 in valve tip 180 is rotated away from inlet 174 of fuel passage 164. Cutout 218 may face downward when in the closed position and horizontal when in the open position. Lever 150 couples to shaft 112 outside of float bowl 104 and is actuated by Bowden cable 146 to operate manual fuel shutoff 110.

[0083] Bowden cable 146 may be coupled to mechanical fuel lockout switch 38, FIG. 1, to automatically open and close manual fuel shutoff 110 upon selection of a corresponding fuel source. Mechanical fuel lockout switch 38 may have a lever arm inside of the generator housing for actuating Bowden cable 146, FIG. 8. Alternatively, Bowden cable 146 may have a push-pull knob located on an external surface of the generator housing to independently actuate manual fuel shutoff 110. In either case, manual fuel shutoff 110 can attach to the carburetor to close fuel passage 164 downstream from float bowl 104 upon actuation of the mechanical fuel lockout switch 38, FIG. 1, from liquid fuel to gaseous fuel.

[0084] Referring to FIG. 9, a perspective view of a shaft for the manual fuel shutoff system of FIGS. 5-8 is shown, in accordance with an embodiment of the invention. Shaft 112 has two “D” shaped ends each located at a respective first end 210 and second end 212 of the shaft. Shaft 112 also has a first diameter 220 and a larger second diameter 222 each extending radially from shaft 112 outward beyond the two “D” shaped ends. First diameter 220 and second diameter 222 are separated by o-ring

groove 200 with first diameter 220 toward first end 210 of shaft 112 and second diameter 222 toward second end 212 of shaft 112. First diameter 220 also has a groove 224 for a retaining ring. Lever 150, FIG. 8, has a “D” shaped opening to fit on the second end 212 of shaft 112 and held against the second diameter 222.

[0085] Referring to FIG. 10, a side view of a valve member for the manual fuel shutoff system of FIG. 5-8 is shown, in accordance with an embodiment of the invention. Valve tip 180 has a flat surface 216 to seal and rotate against a mating surface in the carburetor. Valve tip 180 is preferably made from polyoxymethylene (POM) or other thermoplastic material to provide a surface suitable for sealing. Valve tip 180 may be shaped as a stadium 214 with a short direction 226 and a long direction 228 extending from a center of rotation 230. The long direction 228 rotates over inlet 174, FIG. 8, to selectively block fuel passage 164. As such, valve tip 180 may rotate less than 360 degrees between the open and closed positions, and valve tip 180 rotates substantially 90 degrees between the positions in an exemplary embodiment of the invention.

[0086] Referring back to FIG. 10, cutout 218 may be located along a straight side of stadium 214 to create a flow passage through valve tip 180. Cutout 218 may have a depth less than the thickness of stadium 214 or may extend through the thickness of the stadium. Cutout 218 may be a half circle with tangent side components extending perpendicular to a straight edge of stadium 214, through a side of valve tip 180. Cutout 218 may extend into valve tip 180 short of the center of stadium 214 and positioned slightly offset along the length of the stadium from the stadium center.

[0087] Valve tip 180 may have a “D” shaped opening 232 to press onto shaft 112 of FIG. 9, defining center of rotation 230, FIG. 10. Center of rotation 230 may be equal distance from straight edges of stadium 214 and positioned between cutout 218 and a rounded end of the stadium that is the closest rounded end to the cutout. Cutout 218 is askew from center of rotation 230 along the length of stadium 214 in part to cover more distance when rotated away from inlet port 174, FIG. 8. In addition, valve tip 180 is

positioned off center on shaft 112 to increase the length of long direction 228 from center of rotation 230 that is rotated to cover inlet port 174.

[0088] Referring to FIG. 11, a perspective view of the carburetor of FIG. 5 with the manual fuel shutoff system exploded from a float bowl of the carburetor is shown, in accordance with an embodiment of the invention. Carburetor 62 has a throat 92, a float bowl 104, and a fuel passage 164 from float bowl 104 to an outlet port 234 in throat 92. Manual fuel shutoff 110 includes shaft 112 having first end 210 to be positioned in float bowl 104 and a second end 212 to be positioned external to float bowl 104. A primary o-ring 196 installs on shaft 112 and positioned in an o-ring groove 200 in shaft 112. A retaining ring 236 installs on shaft 112 in a groove 224 toward first end 210 from o-ring groove 200. Compression spring 194 installs on shaft 112 followed by valve tip 180 pressed onto first end 210 of shaft 112 creating a valve-shaft assembly 179. Orientation of valve tip 180 is controlled by a “D” shaped hole 232 in valve tip 180 mating with a “D” shaped end of shaft 112.

[0089] Plug 184 installs on shaft 112 pushing compression spring 194 against valve tip 180. Primary o-ring 196 seals between shaft 112 and plug 184. Valve-shaft assembly 179 inserts through opening 178 in float bowl 104 and plug 184 presses into the opening. Plug 184 anchors in opening 178 so that compression spring 194 holds valve tip 180 against fuel passage 164. Secondary o-ring 198 installs around shaft 112 to seal between the shaft and plug 184. Secondary o-ring 198 may be positioned in a counterbore 192 in plug 184. Bracket 116 couples to float bowl 104 and holds secondary o-ring 198 positioned in counterbore 192. Bracket 116 may be 2.0 mm thick and stamped from Q235 grade steel. A pair of screws 120, 122 each having a spring lock washer 238, 240 extend through a respective hole 242, 244 in bracket 116 to mount bracket 116 to carburetor 62. Screws 120, 122 may be M5 screws. A spacer 246 installs on shaft 112 and against bracket 116.

[0090] Lever 150 couples to shaft 112 and held apart from bracket 116 by spacer 246. Shaft 112 has a “D” shape at second end 212 that is inserted into a corresponding “D” shaped opening 248 in lever 150. The orientation of lever 150 is controlled by “D”

shape hole 248 in lever 150 mating with a “D” shape end of shaft 112. Lever 150 may be 1.5 mm thick and stamped from Q235 grade steel. Cap 152 presses onto shaft 112 to hold lever 150 on shaft 112. Control system spring 136 attaches to lever 150 and bracket 116 to hold manual fuel shutoff 110 open. Cable clamp 144 couples to bracket 116 by bolt 148. Cable clamp 144 has a tab 250 at one or both ends that fits into a corresponding slot or recess 252 in bracket 116. Cable clamp 144 also has a midsection with a notch 254 to pinch and hold Bowden cable 146 to bracket 116. Bowden cable 146 is held by cable clamp 144 and attaches to lever 150 to actuate manual fuel shutoff 110 to the closed position. Fuel drain screw 130 and drain screw spring 256 insert into carburetor 62. In one embodiment, drain screw spring 256 is the same type of spring used for compression spring 194.

[0091] Referring to FIG. 12, and with continued reference back to FIG. 11, a method of fabricating a manual fuel shutoff system for a carburetor is shown, in accordance with an embodiment of the invention. Process 300 begins by providing carburetor 62 at STEP 302. Process 300 continues with making a valve-shaft assembly 179 at STEP 304, with valve tip 180 pressed onto shaft 112. Also in STEP 304, a compression spring 194 is stalled on shaft 112 and primary o-ring 196 is installed around shaft 112. Process 300 continues by installing plug 184 on valve-shaft assembly 179 at STEP 306. Next, valve-shaft assembly 179 is inserted through opening 178 in float bowl 104 and plug 184 is pressed into the opening at STEP 308. Process 300 continues at STEP 310 by installing secondary o-ring 198 in a groove on plug 184. Next, bracket 116 is coupled to float bowl 104 of carburetor 62 in STEP 312. Process 300 continues at STEP 314 by installing lever 150 on shaft 112. Next, cap 152 is pressed onto shaft 112 to hold lever 150 to shaft 112 in STEP 316. In STEP 318, control system spring 136 is installed on lever 150 and bracket 116. Also, in STEP 318, Bowden cable 146 is attached to lever 150 to actuate shaft 112.

[0092] Referring to FIG. 13, a magnetic fuel shutoff system for a carburetor is shown, in accordance with an embodiment of the invention. Magnetic fuel shutoff system 320 couples to the carburetor to provide a magnetically actuated liquid fuel cut-off for the internal combustion engine. Magnetic fuel shutoff system 320 controls liquid

fuel flow through a fuel passage leading from the float bowl to the throat in the carburetor. Magnetic fuel shutoff system 320 can be manually actuated between an open position to allow gasoline flow to the engine for gasoline operation and a closed position to prevent gasoline flow to the engine for LPG operation.

[0093] Magnetic fuel shutoff system 320 includes a housing at least partially enclosing the liquid fuel cut-off. That is, magnetic fuel shutoff system 320 has a first section 322 housing magnetic fuel shutoff 324 and a second section 326 housing a manually actuated magnet 328 to operate the magnetic fuel shutoff. First section 322 has a forward wall 330 and a back wall 332 with the forward wall facing internal to the carburetor. Forward wall 330 has a flange 334 around an outer perimeter for coupling to the carburetor. Forward wall 330 also has an opening 336 through which a plunger 342 of the magnetic fuel shutoff 324 extends into the carburetor. A lip 338 extends forward from forward wall 330 around opening 336 and an o-ring 340 is installed around lip 338. Flange 334 may be mounted to a plug in an opening of the carburetor with magnetic fuel shutoff 324 entering the carburetor through a hole in the plug.

[0094] First section 322 provides a sealing member enclosing plunger 342 of magnetic fuel shutoff 324 to the carburetor and holding fuel in the carburetor. The plunger 342 extends through opening 336 in forward wall 330 with a pointed end that is selectively inserted into a fuel supply path in the carburetor to block fuel flow downstream from the float bowl. Magnetic fuel shutoff 324 has a back plate 344 coupled to plunger 342 in first section 322. Plunger 342 extends perpendicular from a forward face of back plate 344. A spring 346 pushes a back face of back plate 344 against back wall 332 to push plunger 342 through opening 336 in forward wall 330 to block the fuel supply path in the carburetor. Accordingly, the first section 322 holds the spring 346 against the plunger 342. Magnetic fuel shutoff 324 is guided through its actuation by back plate 344 sliding through first section 322 and plunger 342 through opening 336 in forward wall 330.

[0095] Second section 326 couples to first section 322 and is located behind back wall 332. Second section 326 encloses an actuating magnet 328 to selectively pull

magnetic fuel shutoff 324 against spring 346. Second section 326 preferably guides actuating magnet 328 along a path perpendicular to that of magnetic fuel shutoff 324. As such, the magnetic force to pull magnetic fuel shutoff 324 to an open valve position is the strongest when actuating magnet 328 is aligned with the path of magnetic fuel shutoff 324. Actuating magnet 328 pulls magnetic fuel shutoff 324 against spring 346 when actuating magnet 328 approaches magnetic fuel shutoff 324 and releases magnetic fuel shutoff 324 while traveling away from magnetic fuel shutoff 324. Actuating magnet 328 may comprise a rare-earth or other permanent magnet.

[0096] In an exemplary embodiment of the invention, magnetic fuel shutoff 324 actuates horizontally between an open position to permit fuel flow into a fuel passage in the carburetor and a closed positioned to prevent fuel flow into the fuel passage. Actuating magnet 328 preferably follows a vertical path and a spring 348 couples to a top of second section 326 pushing downward on actuating magnet 328. Bowden cable 146 couples to the top of second section 326 and to actuating magnet 328 to pull the magnet vertically against spring 348 and operate magnetic fuel shutoff system 320.

[0097] Referring now to FIG. 14, a wiring diagram of a microcontroller 89 receiving input signals and operating engine components is shown, according to an embodiment of the invention. Microcontroller 89 closes fuel cut solenoid 74 when the engine operates on LPG and opens the fuel cut solenoid to operate the engine on gasoline. For LPG mode, microcontroller 89 switches on power to fuel cut solenoid 74 to close the solenoid preventing the engine from drawing in gasoline from the float bowl of the carburetor. During shutdown from gasoline operation, microcontroller 89 can also power fuel cut solenoid 74 to a closed position preventing additional gasoline being drawn into the engine. While microcontroller 89 can operate fuel cut solenoid 74 operating in a normally open configuration, microcontroller 89 can also operate a fuel cut solenoid operating in a normally closed configuration.

[0098] Microcontroller 89 may include a module 350 to connect fuel cut solenoid 74, charging coil 78, switches and a ground terminal. Module 350 has a first connection 352(a) to couple fuel cut solenoid 74 and a second connection 352(b) to couple charging

coil 78 to power the fuel cut solenoid. Fuel cut solenoid 74 may be coupled to a fuel switch 354 and a combination switch 356 that are also connected to module 350 via a third connection 352(c). Fuel switch 354 changes operation of the engine between LPG and gasoline, and combination switch 356 can operate to kill the engine. A ground terminal 358 connects to module 350 via a fourth connection 352(d) in order to ground fuel cut solenoid 74 via fuel switch 354 or combination switch 356.

[0099] In LPG mode, fuel switch 354 connects a first contact 360(a) to a second contact 360(b), instead of third contact 360(c), to complete an electrical circuit for fuel cut solenoid 74 by connecting the fuel cut solenoid to ground terminal 358. A fuel cut solenoid 74 operating in a normally open configuration is therefore powered and closed to prevent gasoline flow from the fuel bowl of the carburetor to the engine. Fuel switch 354 also connects a fourth contact 360(d) to a fifth contact 360(e), instead of sixth contact 360(f), to prevent combination switch 356 from grounding magneto 76 thereby maintaining power to spark plug 362.

[0100] In gasoline mode, fuel switch 354 connects first contact 360(a) to third contact 360(c) to interrupt an electrical circuit for fuel cut solenoid 74 by disconnecting the fuel cut solenoid from ground terminal 358. A fuel cut solenoid 74 operating in a normally open configuration is therefore unpowered and opened to allow gasoline flow from the fuel bowl of the carburetor to the engine. Fuel switch 354 also connects fourth contact 360(d) to sixth contact 360(f) to allow combination switch 356 to ground magneto 76 upon shutdown thereby interrupting power to spark plug 362.

[0101] Combination switch 356 can actuate fuel cut solenoid 74 upon engine shutdown from gasoline operation to prevent after-fire. That is, combination switch 356 connects a first point 364(a) to a second point 364(b) to kill the engine by connecting magneto 76 to ground terminal 358. At the same time, combination switch 356 connects a third point 364(c) to a fourth point 364(d) completing an electrical circuit for fuel cut solenoid 74 by connecting the solenoid to ground terminal 358. Fuel cut solenoid 74 is then powered and closed to prevent continued gasoline flow to the engine after combination switch 356 stops power supply to spark plug 362.

[0102] In one embodiment of the invention, combination switch 356 can operate as a kill switch only for gasoline operation. That is, combination switch 356 can be decoupled from magneto 76 by fuel switch 354 so that combination switch 356 cannot be actuated to shut down the engine during LPG operation. In another embodiment of the invention, combination switch 356 can operate as a kill switch for both gasoline operation and LPG operation. During LPG operation, combination switch 356 may actuate fuel switch 354 with actuation of combination switch 356 to ground magneto 76 and kill the engine. That is, combination switch 356 connects first point 364(a) to second point 364(b) and also actuates fuel switch 354 to connect fourth contact 360(d) to sixth contact 360(f) so that magneto 76 is coupled to ground terminal 358 killing the engine. At the same time, combination switch 356 connects third point 364(c) to fourth point 364(d) so that fuel cut solenoid 74 maintains connection to ground terminal 358 to remain closed even though fuel switch 354 interrupts connection between first contact 360(a) and second contact 360(b).

[0103] Microcontroller 89 may also include a Voltage Frequency and Low Oil Shutdown (VFO) module 366. VFO module 366 can measure parameters of an alternator driven by an engine in a generator. VFO module 366 monitors alternator voltage and frequency by receiving an input signal 368 from the alternator. Input signal 368 is 120 VAC and 60 Hz from the alternator as a monitoring point for VFO module 366. VFO module 366 allows the engine to run if alternator parameters are within preset limits and shuts down the engine if the parameters are outside the limits. VFO module 366 can also monitor oil volume within the engine by receiving an input signal from an oil level switch 370 shown in the wiring diagram engine block 372. VFO module 366 may allow the engine to operate only if the oil volume is greater than a preset lower limit and can shutdown the engine by initiating connection between the ignition coil or magneto 76 and ground terminal 358.

[0104] Beneficially, embodiments of the invention provide for a fuel lockout switch to ensure that two fuels are not simultaneously delivered to a dual fuel internal combustion engine and to efficiently convert operation of the engine between the fuel sources. Embodiments of the invention also provide for a dual fuel generator with a

remotely mounted gaseous fuel regulator system. Embodiments of the invention also provide for a batteryless dual fuel internal combustion engine having a liquid fuel cut-off coupled to a carburetor to selectively interrupt liquid fuel.

[0105] Therefore, according to one embodiment of the invention, a dual fuel engine includes an engine operable on a gaseous fuel and a liquid fuel and a switch to change operation of the engine between gaseous fuel and liquid fuel. The dual fuel engine also includes a carburetor attached to an intake of the engine to mix air and fuel and connect to a gaseous fuel source and a liquid fuel source. A liquid fuel cut-off attaches to the carburetor to interrupt liquid fuel upon actuation of the switch from liquid fuel to gaseous fuel.

[0106] According to another embodiment of the invention, a batteryless dual fuel generator includes a housing containing a pull start engine coupled to drive an alternator, the engine operable on a gaseous fuel and a liquid fuel. A carburetor attaches to an intake of the engine and includes a throat to mix fuel with air, a float bowl, and a fuel passage to provide liquid fuel from the float bowl to the throat. The generator also includes a fuel shutoff attached to the carburetor to close the fuel passage upon selection of engine operation to gaseous fuel.

[0107] According to yet another embodiment of the invention, a carburetor having a fuel shutoff includes a carburetor with a float bowl, a throat, and a fuel passage to provide fuel from the float bowl to the throat. The carburetor further includes a fuel shutoff coupled to the carburetor having a first end in the carburetor that actuates to close the fuel passage and a second end external to the carburetor to actuate the first end, and the fuel shutoff can actuate free from linear motion.

[0108] According to yet another embodiment of the invention, a method of assembling a dual fuel engine includes providing an engine operable on a gaseous fuel and a liquid fuel. The method also includes attaching a carburetor to an intake of the engine, the carburetor includes a throat to mix gaseous fuel with air and liquid fuel with air, a float bowl, and a fuel passage to provide liquid fuel from the float bowl to the throat. The method also includes coupling a switch to the engine to change operation of

the engine between gaseous fuel and liquid fuel and attaching a liquid fuel cut-off to the carburetor to close the fuel passage upon actuation of the switch from liquid fuel to gaseous fuel.

[0109] 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.

ABSTRACT

A dual fuel engine includes an engine operable on a gaseous fuel and a liquid fuel and a switch to change operation of the engine between gaseous fuel and liquid fuel. The dual fuel engine also includes a carburetor attached to an intake of the engine to mix air and fuel and connect to a gaseous fuel source and a liquid fuel source. A liquid fuel cut-off attaches to the carburetor to interrupt liquid fuel upon actuation of the switch from liquid fuel to gaseous fuel.

CLAIMS

What is claimed is:

1. A dual fuel generator comprising:
 - an engine operable on a gaseous fuel and a liquid fuel;
 - an electrical power generator driven by the engine and comprising a charging coil;
 - a switch to change operation of the engine between gaseous fuel and liquid fuel;
 - a carburetor attached to an intake of the engine to mix air and fuel and connect to a gaseous fuel source and a liquid fuel source;
 - a liquid fuel cut-off solenoid to interrupt liquid fuel flow to the engine upon actuation of the switch from liquid fuel to gaseous fuel; and
 - a voltage regulator coupled to the charging coil to receive power therefrom and that operates to provide a regulated voltage to the liquid fuel cut-off solenoid.
2. The dual fuel generator of claim 1 further comprising:
 - a liquid fuel valve along a liquid fuel line coupling the liquid fuel source to the carburetor; and
 - a gaseous fuel valve along a gaseous fuel line coupling the gaseous fuel source to the carburetor.
3. The dual fuel generator of claim 2, wherein each of the liquid fuel valve and the gaseous fuel valve comprises a mechanical valve.
4. The dual fuel generator of claim 2, wherein the liquid fuel cut-off solenoid is attached to the carburetor.
5. The dual fuel generator of claim 1, wherein the gaseous fuel is LPG and the liquid fuel is gasoline.

6. The dual fuel generator of claim 1, wherein the switch is an electro-mechanical switch connecting one fuel source to the carburetor and connected to the electrical power generator, and wherein the liquid fuel cut-off solenoid is connected to open and close a fuel path to the engine in response to reception of electrical power from the switch.

7. The dual fuel generator of claim 6, wherein the switch selectively powers the solenoid valve by controlling electrical connection between the solenoid valve and the electrical power generator.

8. The dual fuel generator of claim 1, wherein the liquid fuel cut-off solenoid is normally open to provide liquid fuel to the engine when the liquid fuel cut-off solenoid is unpowered.

9. The dual fuel generator of claim 8, wherein the dual fuel generator is a batteryless dual fuel generator and the engine is a pull-start engine, the batteryless dual fuel generator further comprising a pull-starter that drives the electrical power generator to power and close the liquid fuel cut-off solenoid while starting the engine on gaseous fuel.

10. The dual fuel generator of claim 1, wherein the electrical power generator comprises a magneto or an alternator.

11. A dual fuel generator comprising:
an engine operable on a gaseous fuel and a liquid fuel;
a carburetor attached to an intake of the engine to mix air and fuel and connect to a gaseous fuel source and a liquid fuel source; and
a manually actuated fuel shutoff coupled to the carburetor, the manually actuated fuel shutoff comprising:
a first end in the carburetor that actuates to selectively allow or block a flow of fuel through the carburetor; and

and a second end external to the carburetor to actuate the first end.

12. The dual fuel generator of claim 11, wherein the engine is a pull start, batteryless engine.

13. The dual fuel generator of claim 11, wherein the gaseous fuel is LPG and the liquid fuel is gasoline.

14. The dual fuel generator of claim 11 wherein the manually actuated fuel shutoff comprises a rotating mechanical valve.

15. The dual fuel generator of claim 14 wherein the carburetor comprises:
a float bowl;
a throat; and
a fuel passage to provide fuel from the float bowl to the throat;
wherein the manually actuated fuel shutoff comprises a shaft extending into the carburetor through an aperture in the float bowl, the shaft being coupled to a valve tip in the float bowl that rotates to open and close the fuel passage.

16. The dual fuel generator of claim 15 wherein the valve tip rotates parallel to an inlet of the fuel passage between a first position permitting fuel flow into the inlet and a second position blocking fuel flow into the inlet.

17. The dual fuel generator of claim 15, wherein the fuel passage has an inlet with a substantially flat perimeter edge and the valve tip maintains planar contact with the perimeter edge while rotating to open and close the fuel passage.

18. The dual fuel generator of claim 17 further comprising:
a plug in the aperture around the shaft; and

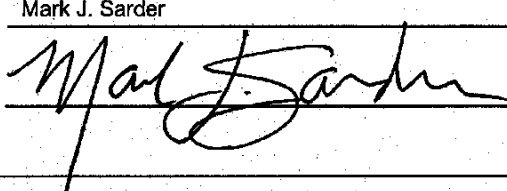
a compression spring around the shaft in the float bowl pushing against the plug to hold the valve tip against the perimeter edge of the inlet.

19. The dual fuel generator of claim 15 further comprising:
 - a lever coupled to the shaft outside of the carburetor;
 - a spring coupled to the lever to hold the fuel shutoff opening the fuel passage; and
 - a cable coupled to the lever to move the lever against the spring and rotate the fuel shutoff to close the fuel passage.

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

Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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 identify 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:	Kendall J. Collie
Date (Optional):	10/27/15
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.	

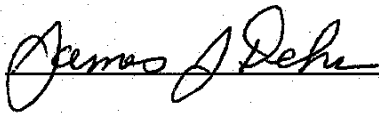
DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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:	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.	

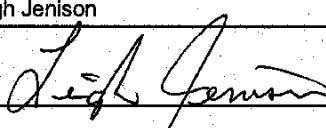
**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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: <u>Aleko D. Sotiriades</u> Date (Optional): <u>10/23/2015</u> Signature: <u><i>Aleko D. Sotiriades</i></u>	
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.	

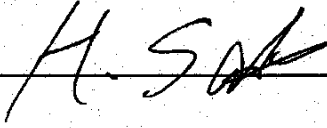
**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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LEGAL NAME OF INVENTOR Inventor: <u>James J. Dehn</u> Date (Optional): <u>10/23/2015</u> 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	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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LEGAL NAME OF INVENTOR	
Inventor: Leigh Jenison	Date (Optional): 10-23-2015
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.	

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

Title of Invention	BATTERYLESS DUAL FUEL ENGINE WITH LIQUID FUEL CUT-OFF
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LEGAL NAME OF INVENTOR	
Inventor: Hiroaki Sato	Date (Optional): 10/23/15
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.	

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.

Application Number

Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)



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

OR



I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) 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 patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:



The address associated with the above-mentioned Customer Number

OR



The address associated with Customer Number:

OR



Firm or
Individual Name

Address

City

State

Zip

Country

Telephone

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.

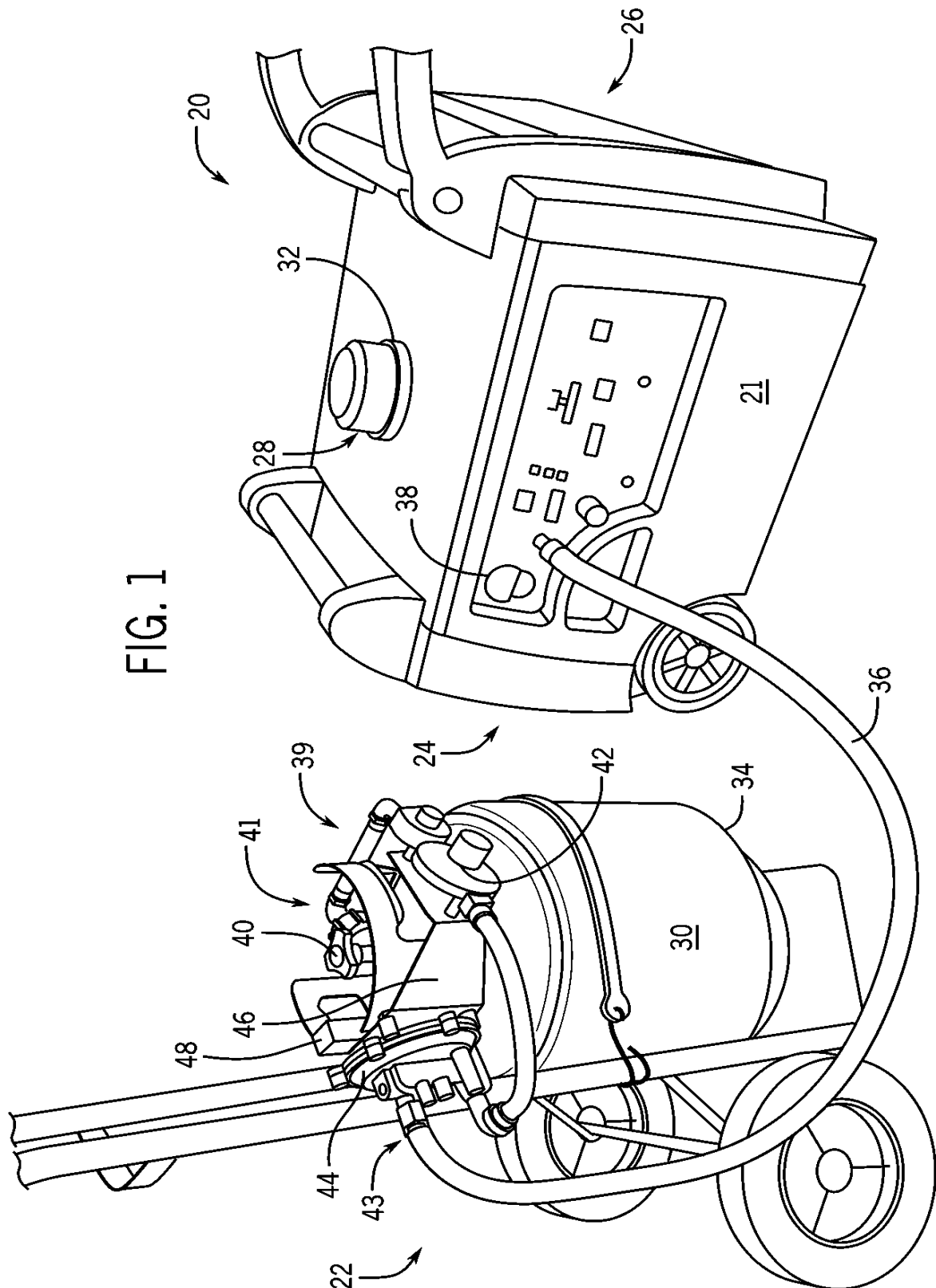


Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

FIG. 1



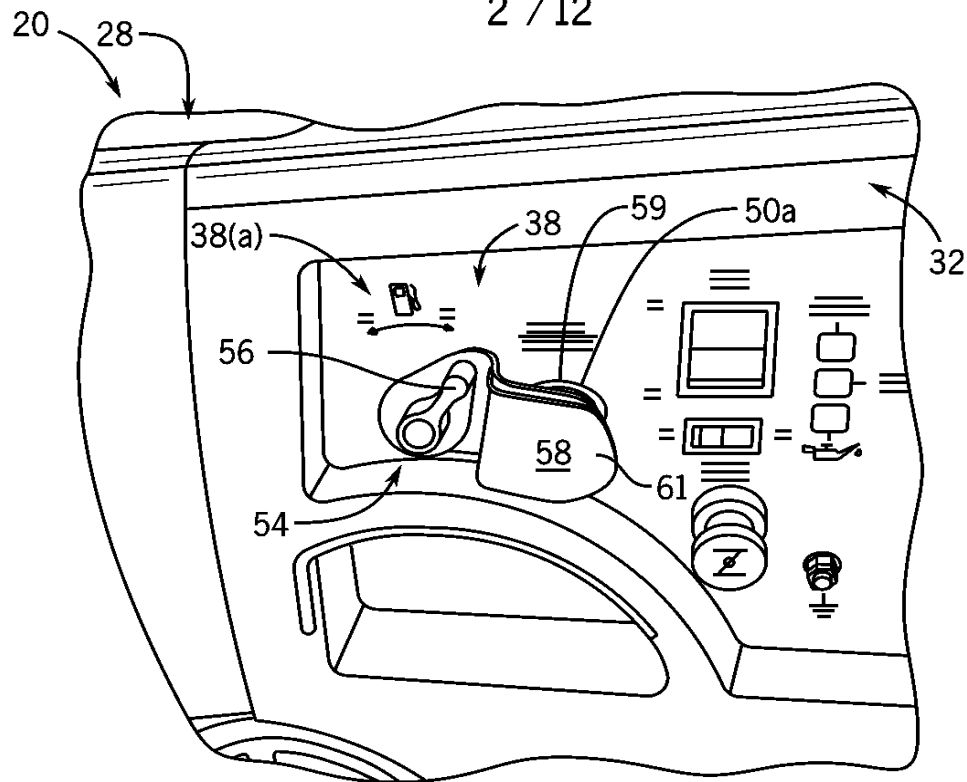


FIG. 2

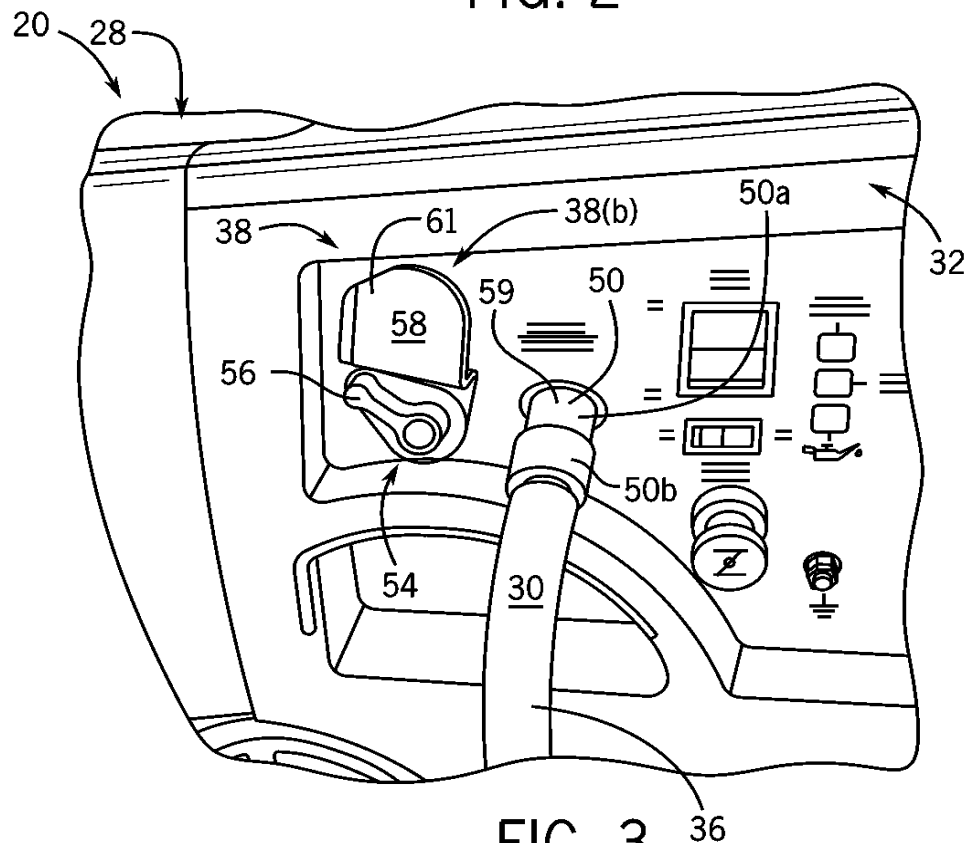


FIG. 3 36

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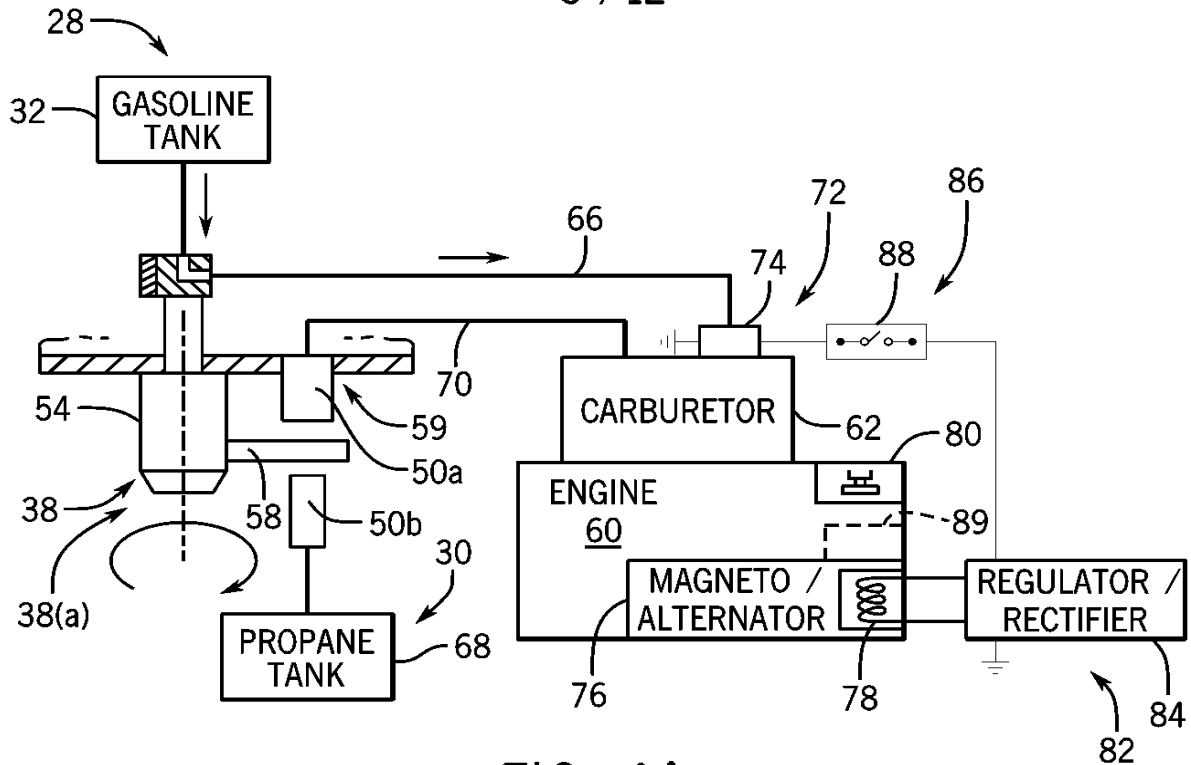


FIG. 4A

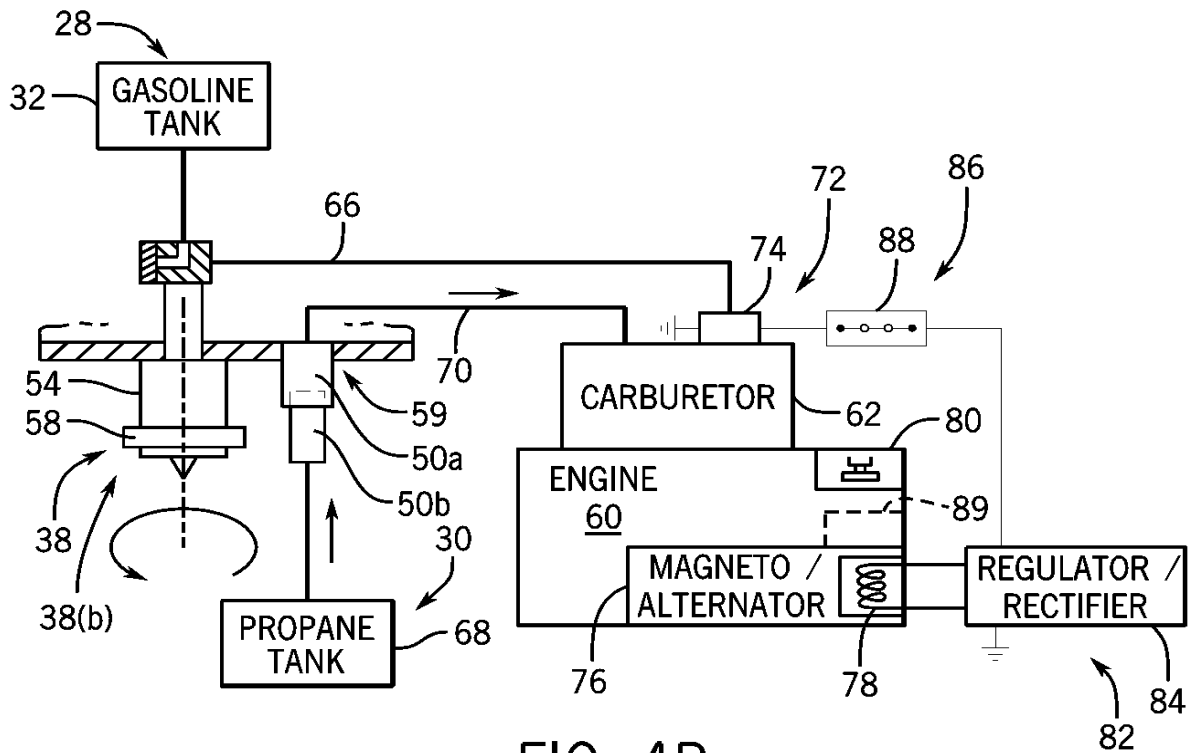
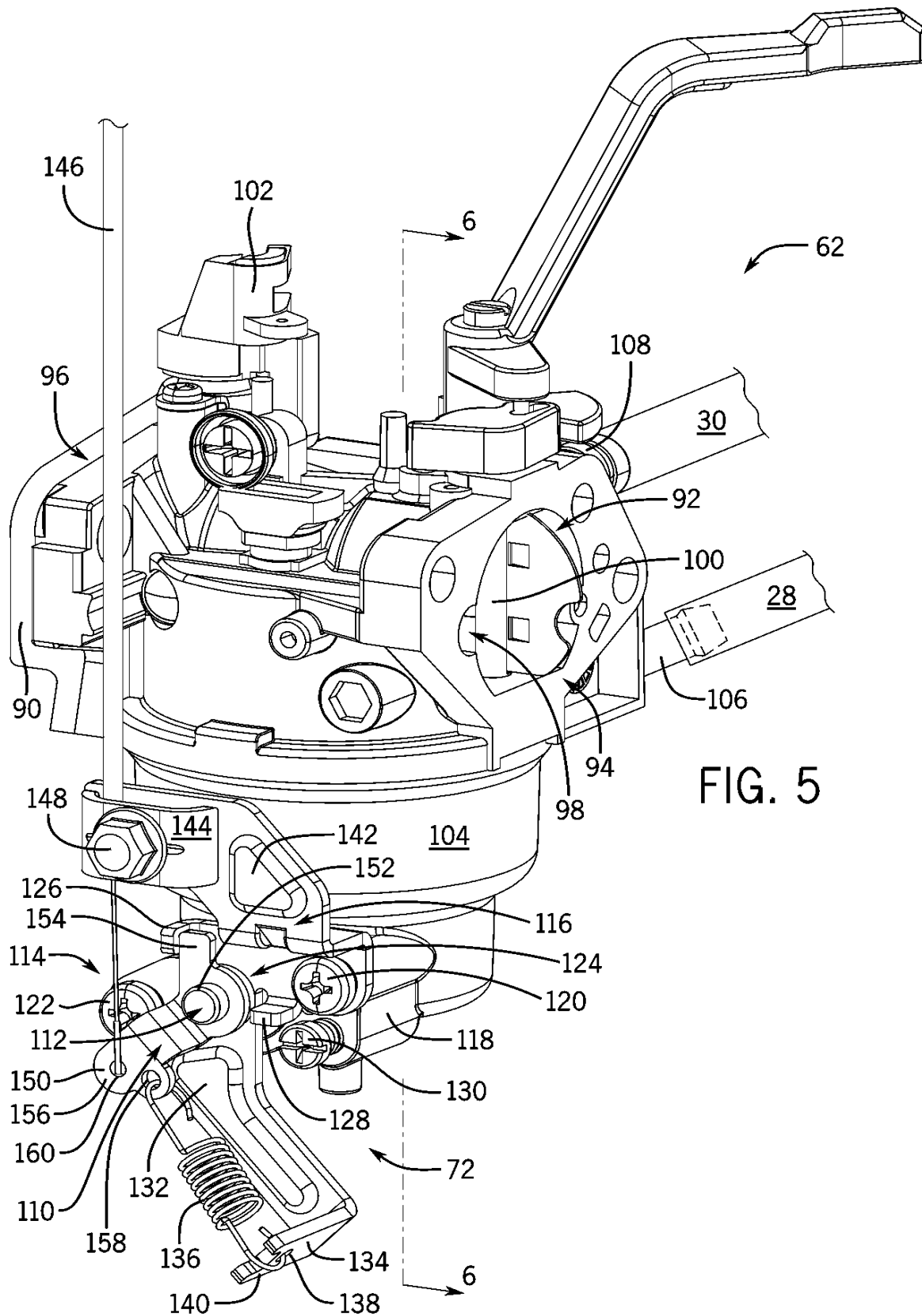
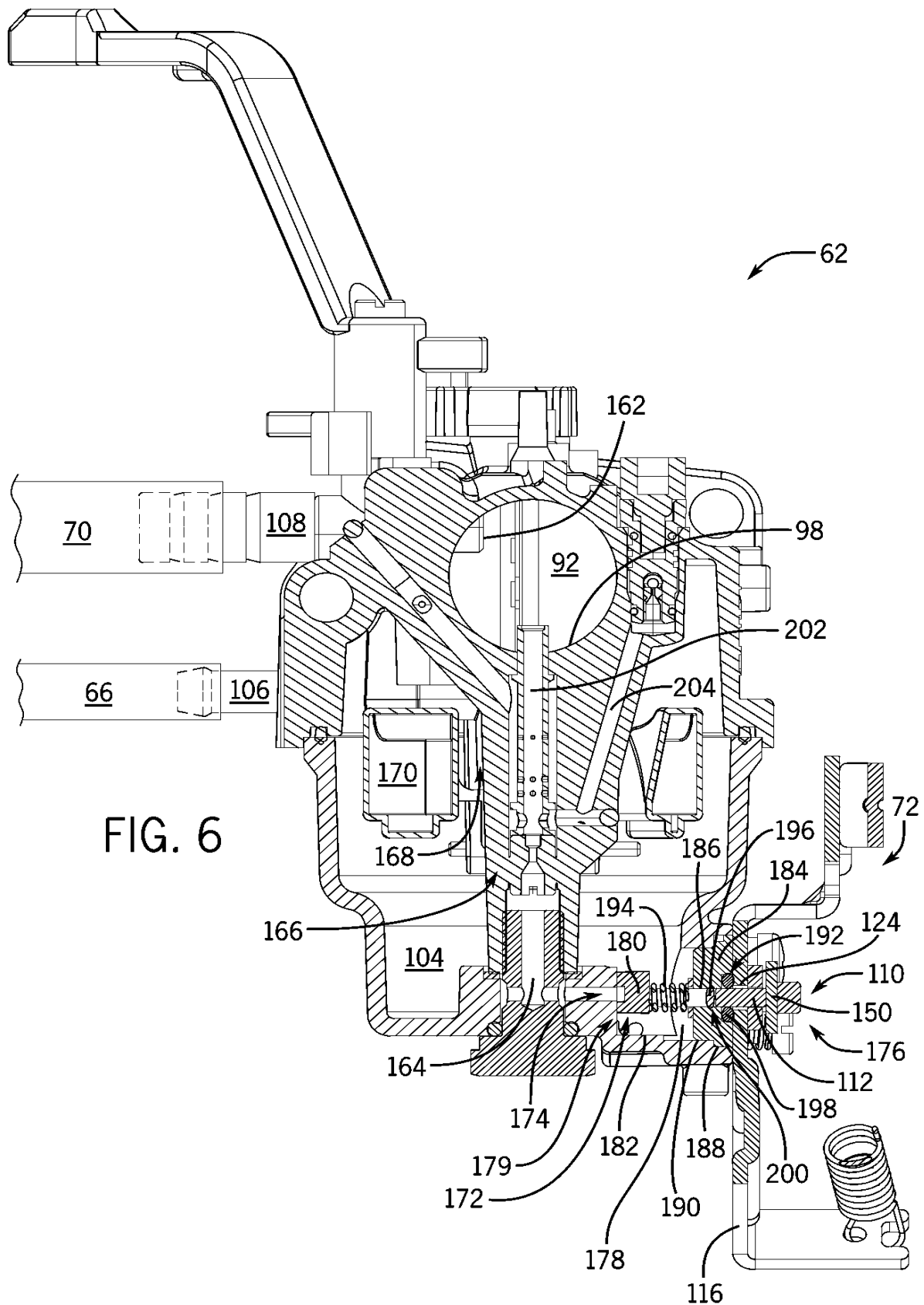
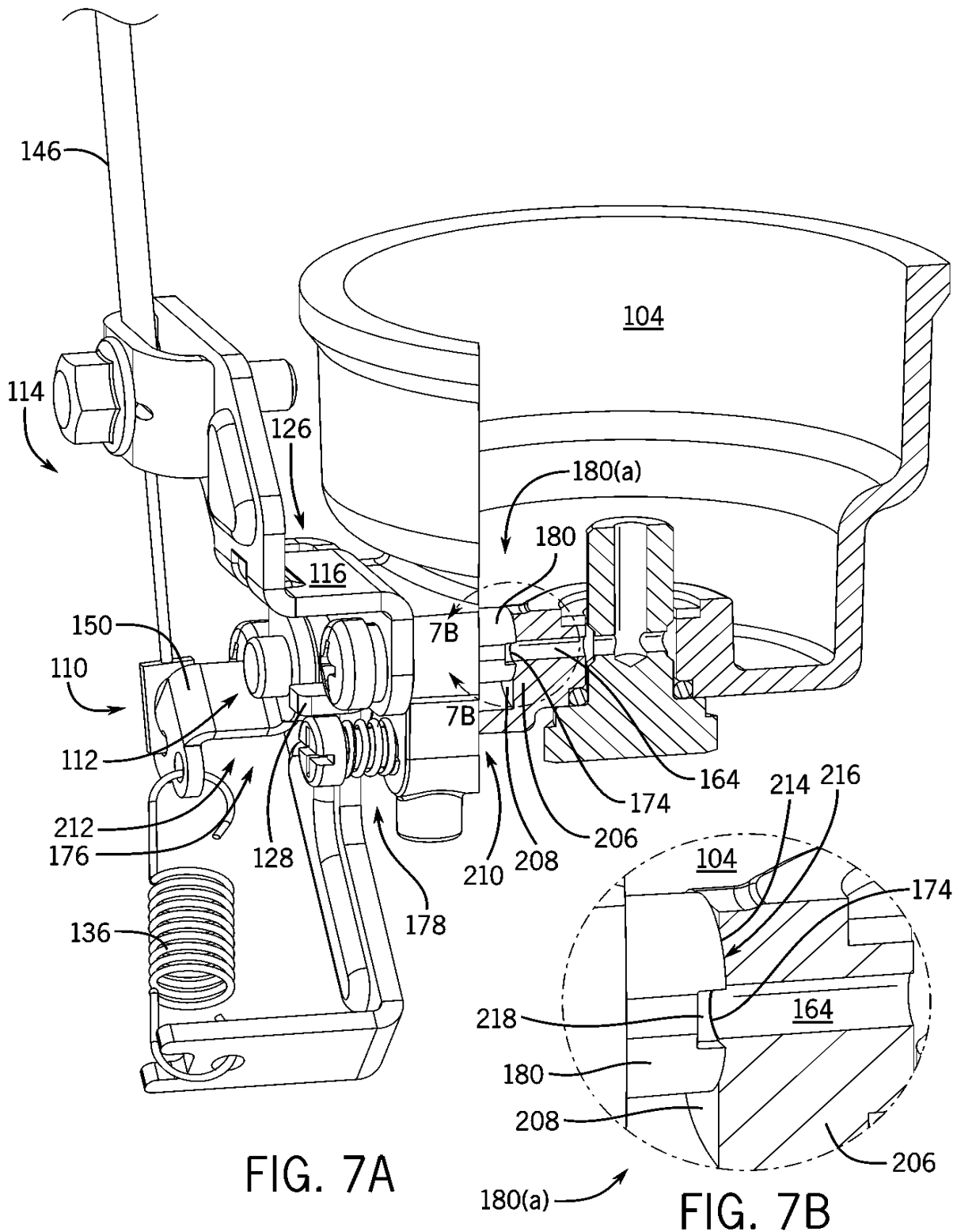


FIG. 4B



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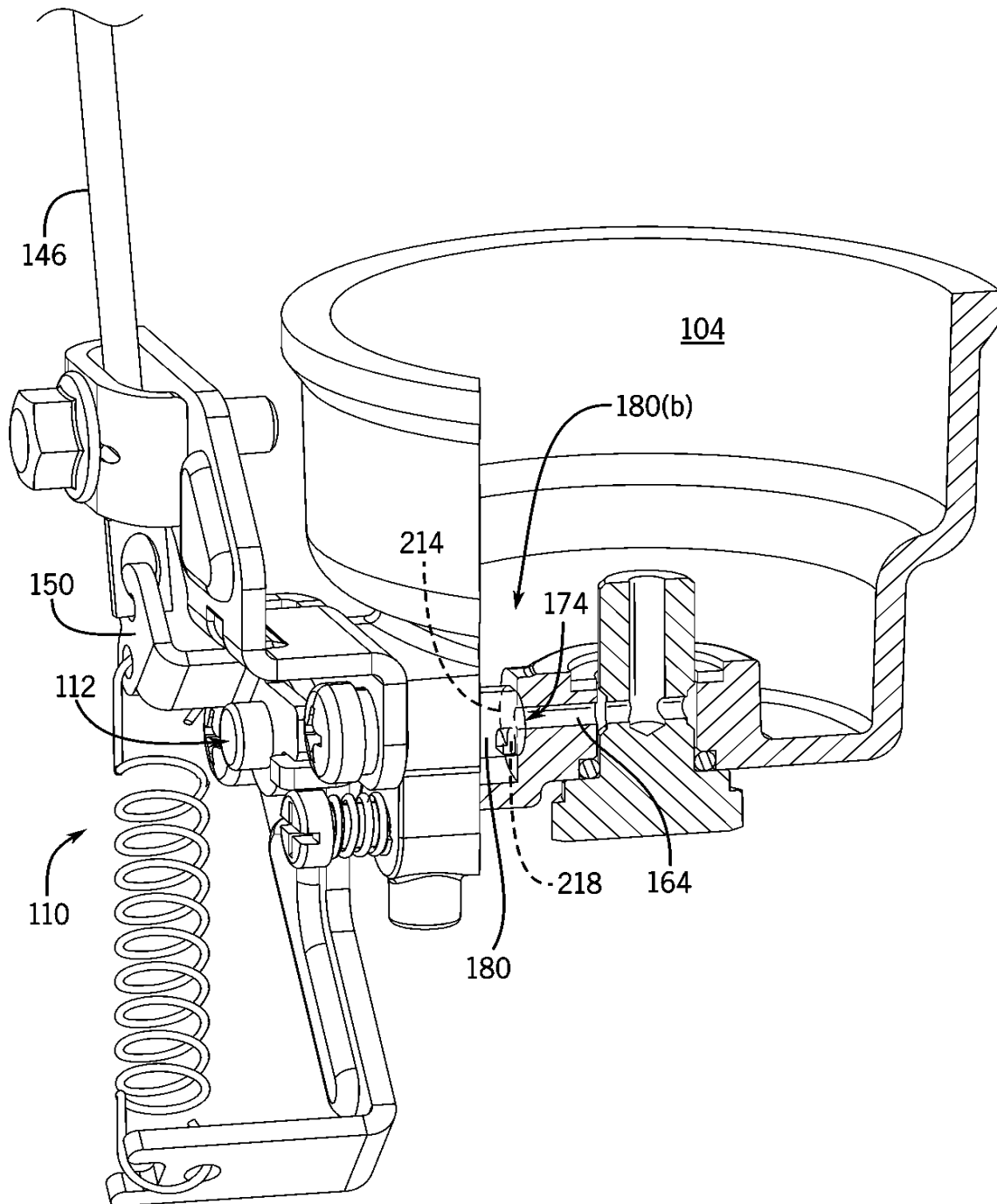
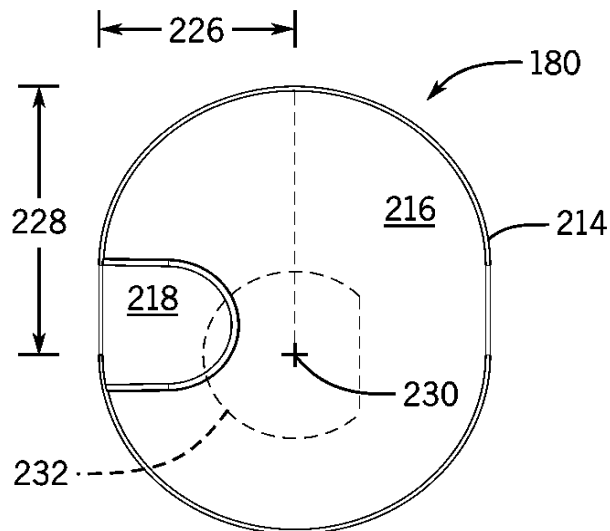
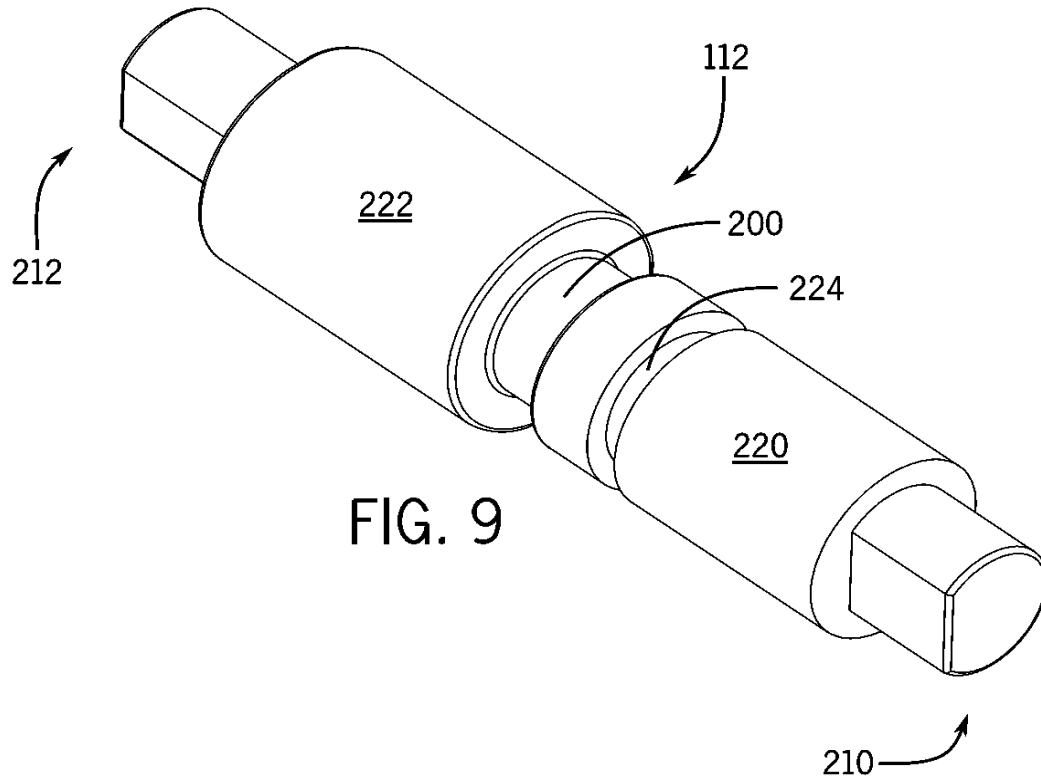


FIG. 8

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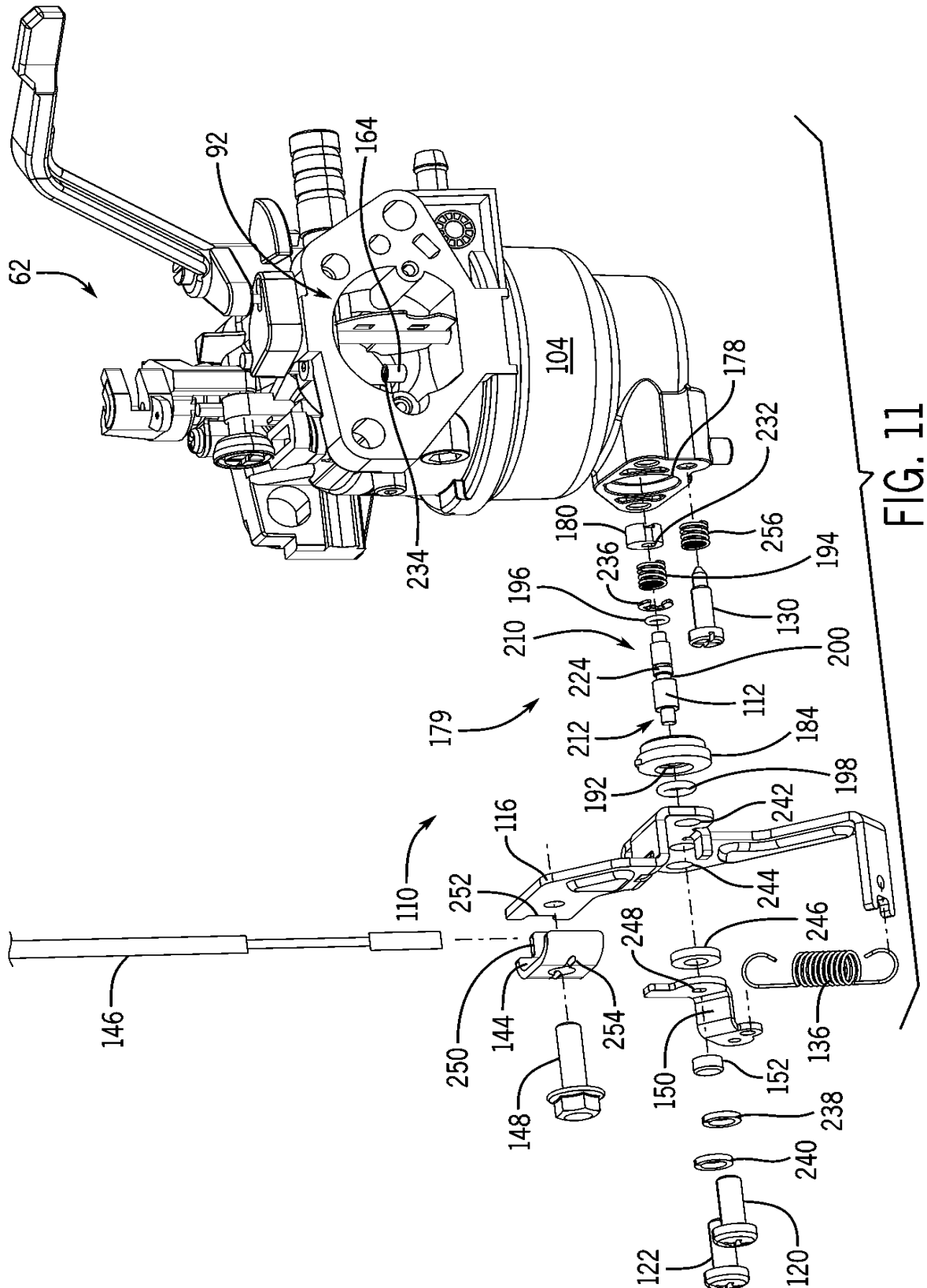


FIG. 11

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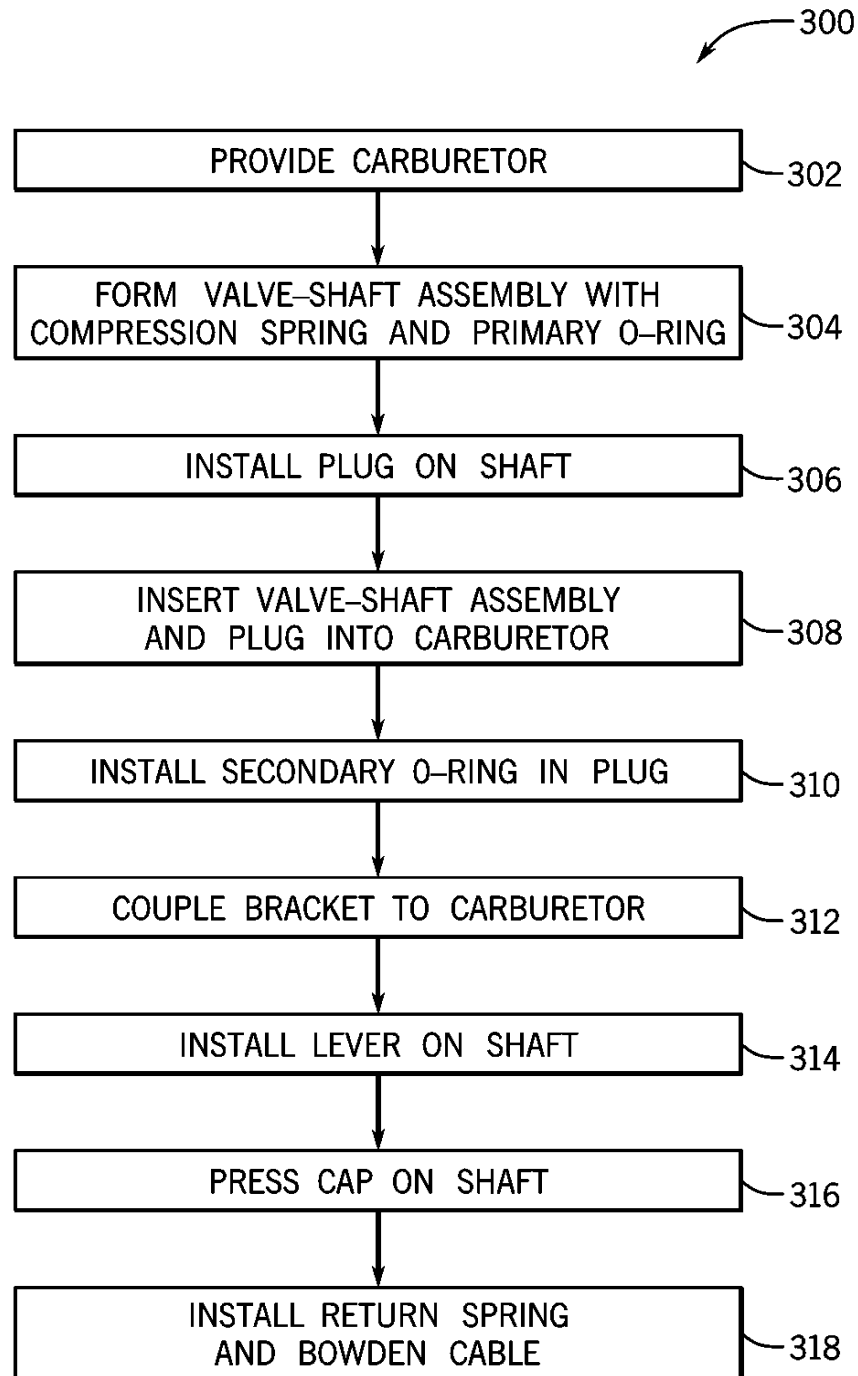


FIG. 12

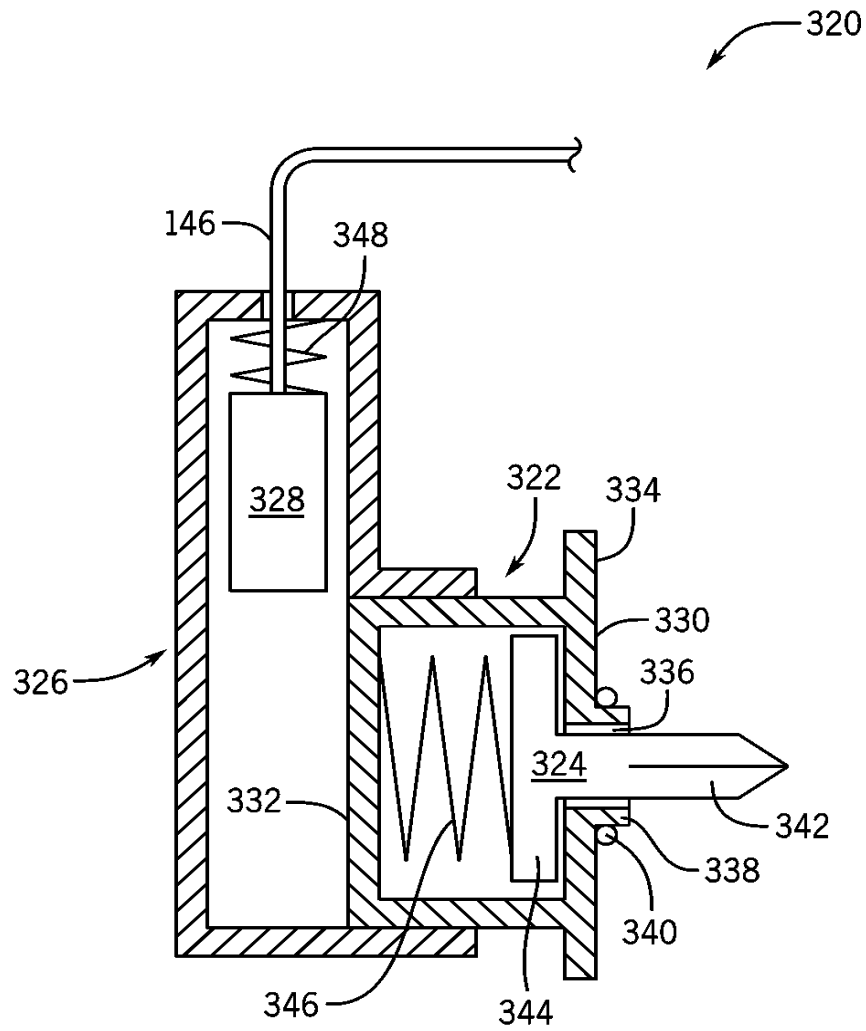


FIG. 13

FIG. 14

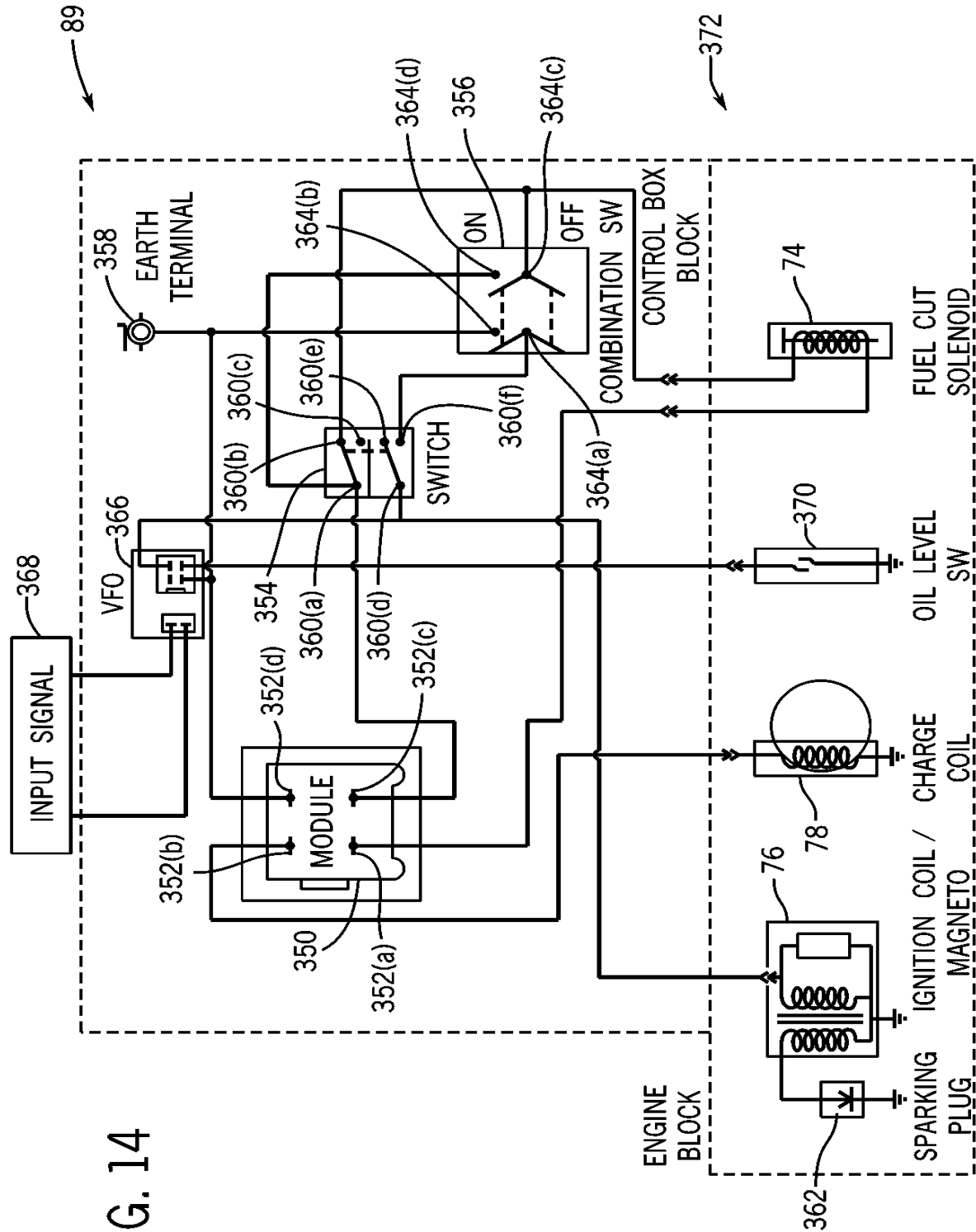


EXHIBIT 1003

MAHDI SHAHBAKHTI, Ph.D., P.Eng.

5-281 DICE Building, Mech. Eng. Dept.
University of Alberta, Edmonton, AB T6G 1H9
Tel: (780) 492-8409

E-mail: mahdi@ualberta.ca
URL: <https://sites.ualberta.ca/~mahdi/>
Linkedin: [mahdi-shahbakhti-a5457816/](https://www.linkedin.com/in/mahdi-shahbakhti-a5457816/)

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.

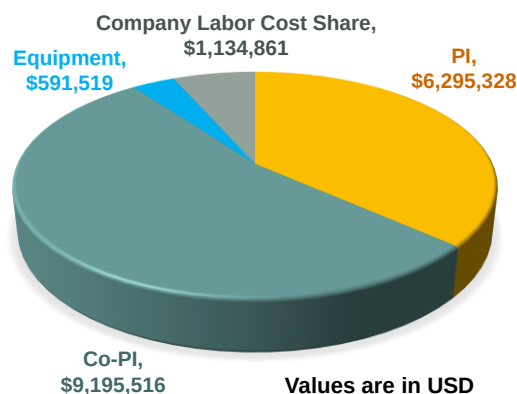
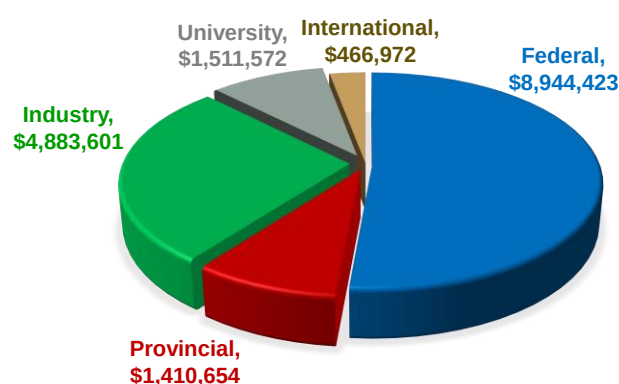
Teaching

- SAE Ralph R. Teeter 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.
- 55- E. Ansari*, M. Shahbakhti, J. Naber, " Optimization of Performance and Operational Cost for a Dual Mode

- Diesel-Natural Gas RCCI and Diesel Combustion Engine ", *Applied Energy*, Vol. 231, Pages 549-561, 2018.
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- 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. Shahpour, 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

⑫ 公開特許公報(A)

昭61-283734

⑤Int.Cl.⁴

識別記号

庁内整理番号

⑬公開 昭和61年(1986)12月13日

F 02 D 19/06
F 02 M 13/086718-3G
7713-3G

審査請求 未請求 発明の数 1 (全5頁)

⑭発明の名称 ガソリン・LPG併用エンジン

⑰特 願 昭60-124725

⑱出 願 昭60(1985)6月7日

⑲発明者 仲 伏 敏 明 広島県安芸郡府中町新地3番1号 マツダ株式会社内
⑲発明者 山 下 繁 樹 広島県安芸郡府中町新地3番1号 マツダ株式会社内
⑲出願人 マツダ株式会社 広島県安芸郡府中町新地3番1号
⑲代理人 弁理士 前 田 弘

明 細 書

1. 発明の名称

ガソリン・LPG併用エンジン

2. 特許請求の範囲

(1) フロート室を備えエンジンの吸気通路に配設された気化器と、該気化器と直列に吸気通路に配設されたLPGミキサーと、上記気化器にガソリンを供給するガソリン供給手段と、上記LPGミキサーにLPGを供給するLPG供給手段と、上記ガソリン供給手段およびLPG供給手段を選択的に作動させる切換手段とを備え、かつ該制御弁は上記切換手段によるLPG供給手段の作動の選択時にガソリンの吸出しを阻止するよう作動するように構成されていることを特徴とするガソリン・LPG併用エンジン。

3. 発明の詳細な説明

(産業上の利用分野)

本発明は、燃料としてガソリンまたはLPGを選択的に使用するようにしたガソリン・LPG併用エンジンに関する。

(従来の技術)

従来、ガソリン・LPG併用エンジンとして、エンジンにガソリンまたはLPGを選択的に供給し得るようにして、エンジンの出力を要するときにはガソリンを供給してエンジンをガソリンエンジンとして運転する一方、経済性を要するときにはLPGを供給してエンジンをLPGエンジンとして運転するようにしたものは知られている(例えば特開昭57-102547号公報参照)。

(発明が解決しようとする問題点)

ところで、上記従来のガソリン・LPG併用エンジンにおいて、フロート室を備えた気化器によってガソリンを供給するようにした場合、ガソリンエンジン運転とLPGエンジン運転との切換は、フロート室へのガソリンの供給とエンジンへのLPGの供給とを選択的に行うことによりなされる。

しかし、この場合、ガソリンエンジン運転の状態からLPGエンジン運転に切替えるべくフロート室へのガソリンの供給を中断しても、フロート室にはまだ所定量のガソリンが残留しているので、この残留ガソリンが吸気通路へ吸出されてLPGと混合する結果、混合気の空燃比がオーバーリッチになる。しかも、この残留ガソリンの吸出しによってフロート室のガソリンのレベルが低下するので、逆にLPGエンジン運転状態からガソリンエンジン運転に切替えるべくフロート室へのガソリンの供給を開始しても、ガソリンのレベルが所定値に回復するまでの間、フロート室から吸気通路へのガソリンの吸出しが遅れる結果、混合気の空燃比がオーバーリーンになる。

本発明はかかる点に鑑みてなされたものであり、その目的とするところは、上述のようにフロート室付気化器を備えたガソリン・LPG併用エンジンにおいて、LPGエンジン運転時にフロート室から吸気通路へのガソリンの吸出しを阻止することにより、LPGエンジン運転への切替時の混合

気のオーバーリッチ化およびガソリンエンジン運転への切替時のオーバーリーン化を生じることなくエンジン運転中におけるガソリンエンジン運転とLPGエンジン運転との切替えを可能とすることにある。

(問題点を解決するための手段)

上記目的を達成するため、本発明の解決手段は、フロート室を備えエンジンの吸気通路に配設された気化器と、該気化器と直列に吸気通路に配設されたLPGミキサーと、上記気化器にガソリンを供給するガソリン供給手段と、上記LPGミキサーにLPGを供給するLPG供給手段と、上記ガソリン供給手段およびLPG供給手段を選択的に作動させる切替手段とを備えることを前提とする。さらに、上記フロート室から吸気通路へのガソリンの吸出しを許容又は阻止する制御弁を備えかつ該制御弁は上記切替手段によるLPG供給手段の作動の選択時にガソリンの吸出しを阻止するように作動するように構成したものである。

(作用)

上記の構成により、本発明においては、エンジン運転時、切替手段によりLPG供給手段の作動が選択されたLPGエンジン運転切替時には、制御弁によってフロート室から吸気通路へのガソリンの吸出しが阻止されるので、フロート室に残留するガソリンが吸気通路に吸出されることがなくなって、混合気のオーバーリッチ化が防止される一方、ガソリンエンジン運転への切替時には上記所定レベルの残留ガソリンが速かに吸気通路に吸出されて、混合気のオーバーリーン化が防止されることになる。

(実施例)

以下、本発明の実施例を図面に基づいて説明する。

第1図は本発明の第1実施例を示す。同図においてEは既存の気化器仕様のエンジン、Iは該エンジンEに接続された吸気通路であって、該吸気通路Iには2パレルタイプの気化器1が配設されている。該気化器1の1次側吸気通路I₁および2次側吸気通路I₂にはそれぞれベンチュリ部2

a, 2bが形成されているとともに該ベンチュリ部2a, 2b下流側にはスロットル弁3a, 3bが配設されている。また、1次側吸気通路I₁のベンチュリ部2a上流側にはエンジン冷機時に該1次側吸気通路I₁を絞るチョーク弁4が配設されている。さらに、5はガソリンを貯溜するフロート室であって、該フロート室5は小径の燃料流出通路6を介して上記気化器1のベンチュリ部2a, 2bに連通されており、エンジンEの運転時にフロート室5のガソリンを該ベンチュリ部2a, 2bに吸出して霧化供給するようにしている。

そして、上記吸気通路Iの気化器1上部には、LPGを気化して吸気通路Iに供給するLPGミキサー7が載置されている。

上記フロート室5はガソリン供給通路8により、ポンプ9およびフィルター10を介してガソリンタンク11に連通されており、以上により該ガソリンタンク11内のガソリンをフロート室5を介して上記気化器1に供給するようにしたガソリン供給手段12が構成されている。また、上記LPG

Gミキサー7はLPG供給通路13により、LPGを気化するペーパライザー14およびフィルター15を介してLPG供給手段としてのLPGポンベ16に連通されている。

また、上記フロート室5とポンプ9との間のガソリン供給通路8には後述のカット信号を受けて該ガソリン供給通路8を閉じるガソリンカットバルブ17が介設されている。一方、上記ペーパライザー14とフィルター15との間のLPG供給通路13にはカット信号(後述)を受けて該LPG供給通路13を閉じるLPGカットバルブ18が介設されている。上記両カットバルブ17, 18は2極の燃料切換スイッチ19のガソリン側接点19aおよびLPG側接点19bにそれぞれ接続されており、該燃料切換スイッチ19の共通接点19cはイグニッションスイッチ20を介してバッテリー21に接続されていて、イグニッションスイッチ20のON作動時、エンジンEをガソリンエンジンとして運転するときには燃料切換スイッチ19をガソリン側接点19aに切換えてカ

ット信号をLPGカットバルブ18に入力することにより、LPGミキサー7へのLPGの供給を阻止すると共にガソリン供給手段12を作動させてガソリンを気化器1に供給する一方、エンジンEをLPGエンジンとして運転するときには燃料切換スイッチ19をLPG側接点19bに切換えて、ガソリンカットバルブ17にカット信号を入力することにより、気化器1へのガソリン供給を阻止すると共にLPG供給手段(LPGポンベ)16を作動させてLPGをLPGミキサー10に供給するように切換える切換手段22が構成されている。

そして、上記燃料流出通路6には該燃料流出通路6を開閉する制御弁23が介設されている。該制御弁23は、上記燃料切換スイッチ19のガソリン接点19aに接続されていて、燃料切換スイッチ19のガソリン接点19a側切換時つまりガソリン供給手段12の作動の選択時にはカット信号を受けてON作動して燃料流出通路6を開くことにより、フロート室5からベンチュリ部2a,

2bへのガソリンの吸出しを許容する一方、燃料切換スイッチ19のLPG接点19b側切換時つまりLPGポンベ16の作動の選択時にはカット信号の非受信によりOFF作動して燃料流出通路6を閉じることにより、フロート室5からベンチュリ部2a, 2bへのガソリンの吸出しを阻止するように構成されている。

尚、24はLPGミキサー7上部に載置されたエアクリーナである。

したがって、上記実施例においては、エンジン運転中、LPGエンジン運転への切換時には制御弁23のOFF作動により燃料供給通路6が閉じられてフロート室5に残留するガソリンがベンチュリ部2a, 2bに吸出されないで、ガソリン吸出しに起因する混合気のオーバーリッチ化を防止できるとともに、フロート室5のガソリンのレベルを所定値に維持することができる。また、エンジン運転中、ガソリンエンジン運転への切換時には、燃料切換スイッチ19のガソリン側接点19aからのカット信号により制御弁23がON作動

して、燃料供給通路6が開かれ、このことによりフロート室5に所定値にレベルで残留するガソリンがベンチュリ部2a, 2bに速やかに吸出されるので、混合気のオーバーリーン化を防止できる。よって、LPGエンジン運転への切換時の混合気のオーバーリッチ化およびガソリンエンジン運転への切換時のオーバーリーン化を防止して良好な燃焼状態を確保しながら、エンジン運転中にガソリンエンジン運転とLPGエンジン運転とを適宜切換えることができる。

また、既存の気化器仕様のエンジンEにおける吸気通路Iの気化器1上部にLPGミキサー7を載置することだけであるので、ガソリン・LPG併用エンジンを新規に設計するよりも簡易に提供することができるとともにそのコストを低減することができる。

さらに、第2図は本発明の第2実施例を示し、上流側が1次側吸気通路I₁の上流側に開口し下流側が燃料流出通路6に連通するエアブリード通路25に、カット信号を受けて該エアブリード通

路25を開く制御弁23'を介設するとともに、該制御弁23'を燃料切換スイッチ19のガソリン接点19aに接続して、燃料切換スイッチ19のガソリン接点19a側切換時にはカット信号の出力により制御弁23'をON作動させてエアブリード通路25を開くことにより燃料流出通路6にエアを供給してフロート室5からベンチュリ部2a, 2bへのガソリンの吸出しを許容する一方、燃料切換スイッチ19のLPG接点19b側切換時にはカット信号の出力の停止により制御弁23'をOFF作動させてエアブリード通路25を閉じることにより燃料流出通路6へのエアの供給を阻止してフロート室5からベンチュリ部2a, 2bへのガソリンの吸出しを阻止するように構成したものであり、上記第1実施例と同様の作用、効果を奏する。

(発明の効果)

以上説明したように、本発明のガソリン・LPG併用エンジンによれば、LPGエンジンとしての運転時において気化器のフロート室から吸気通

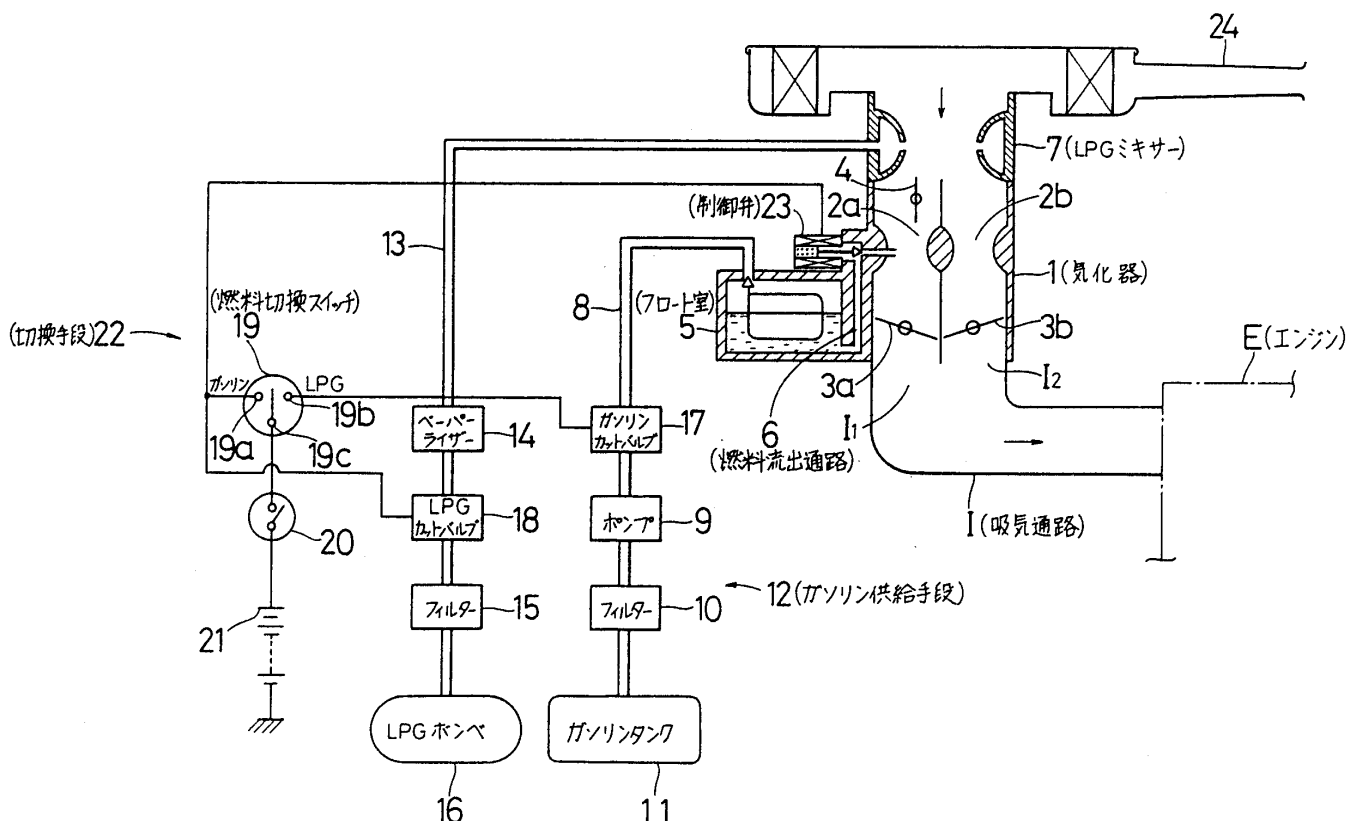
路へのガソリンの吸出しを阻止するようにしたので、エンジン運転状態からLPGエンジン運転への切換時におけるフロート室に残留するガソリンの吸気通路への吸出しに起因する混合気のオーバーリッチ化を防止できるとともに、ガソリンエンジン運転への切換時には上記所定量の残留ガソリンの吸気通路への吸出しにより混合気のオーバーリッチ化を防止することができ、よって良好な燃焼状態を確保しながら、エンジン運転状態時にガソリンエンジン運転とLPGエンジン運転とを適宜切換えることができるものである。

4. 図面の簡単な説明

第1図および第2図は本発明の実施例を示し、第1図は第1実施例を示す全体概略構成図、第2図は第2実施例を示す第1図相当図である。

E…エンジン、I…吸気通路、1…気化器、5…フロート室、6…燃料流出通路、7…LPGミキサー、12…ガソリン供給手段、16…LPGポンプ、19…燃料切換スイッチ、22…切換手段、23, 23'…制御弁。

第1図



第 2 図

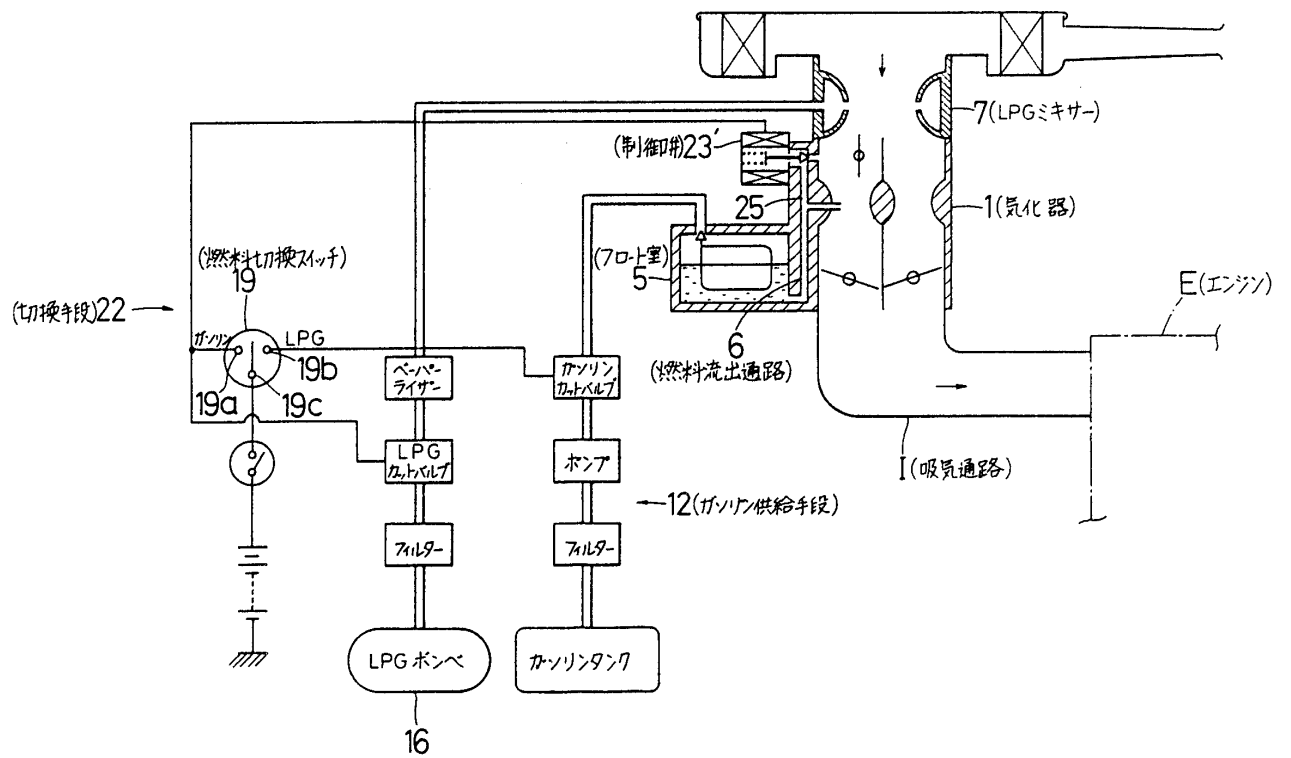


EXHIBIT 1005

(19) Japan Patent Office (JP)

(11) Patent Application Laid-Open No.

(12) Patent Application Publication (A)

S61-283734

(51) Int. Cl.⁴

ID Number

JPO File Number

(43) Publication Date: December 13,
1986 (Showa 61)

F 02 D 19/06

6718-3G

F 02 M 13/08

7713-3G

Request for Examination: Not requested yet Number of Inventions: 1 (5 pages in total)

(54) Title of the Invention: GASOLINE-LPG COMBINED ENGINE

(21) Japanese Patent Application No. S60-124725

(22) Filing date: June 7, 1985 (Showa 60)

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DESCRIPTION
1. TITLE OF THE INVENTION
GASOLINE-LPG COMBINED ENGINE

5 3. DETAILED DESCRIPTION OF THE INVENTION

(Industrially Applicable Field)

[0001] The present invention relates to a gasoline-LPG combined engine
10 configured to selectively use gasoline or LPG as a fuel.

(Known Technology)

[0002] There have been known that a gasoline-LPG combined engine which is
15 configured to be able to selectively supply gasoline or LPG to an engine so
that the engine is operated as a gasoline engine by supplying gasoline when
an output of the engine is required, whereas the engine is operated as an LPG
engine by supplying LPG when economy is required (see, for example,
Japanese Patent Application Laid-Open No. S57-102547).

20

(Problems to be Solved by the Invention)

[0003] Meanwhile, in the case when gasoline is supplied by a carburetor
including a float chamber in the above-mentioned known gasoline-LPG
25 combined engine, the operation of the gasoline engine and the operation of
the LPG engine are switched by selectively supplying gasoline to the float
chamber and supplying LPG to the engine.

[0004] However, in this case, even if the supply of gasoline to the float chamber
30 is interrupted in order to switch from the gasoline engine operation state to the
LPG engine operation, a predetermined amount of gasoline still remains in the
float chamber, so that this residual gasoline is sucked into an intake passage

and mixed with LPG, and as a result, the air-fuel mixture has an over-rich air-fuel ratio. Furthermore, since the level of the gasoline in the float chamber decreases due to this suction of the residual gasoline, even if the supply of gasoline to the float chamber is started in order to reversely switch the LPG engine operating state to the gasoline engine operation state, the suction of the gasoline from the float chamber to the intake passage is delayed until the level of the gasoline recovers to a predetermined value, and as a result, the air-fuel ratio of the air-fuel mixture becomes over-lean.

[0005] The present invention has been made in view of such points, and an object of the present invention is, in a gasoline-LPG combined engine comprising a carburetor equipped with a float chamber, to enable switching between a gasoline engine operation and an LPG engine operation during the operation of the engine without causing becoming over-rich of an air-fuel mixture when switching to the LPG engine operation and becoming over-lean when switching to the gasoline engine operation by blocking suction of gasoline from the float chamber to an intake passage during operation of the LPG engine.

(Means for Solving Problems)

[0006] In order to achieve the above-mentioned object, the solution means of the present invention is based on the premise that it includes a carburetor comprising a float chamber and being disposed in an intake passage of the engine; an LPG mixer disposed in series with the carburetor in the intake passage; a gasoline supplying means configured to supply gasoline to the carburetor; an LPG supplying means configured to supply LPG to the LPG mixer; and

[0007] a switching means configured to selectively operate the gasoline supplying means and the LPG supplying means. Furthermore, the solution means includes a control valve configured to allow or block suctioning of

gasoline from the float chamber to the intake passage, wherein the control valve is configured to operate to block the suctioning of gasoline when the operation of the LPG supplying means is selected by the switching means.

5 (Action)

[0008] According to the above-mentioned configuration, in the present invention, during the operation of the engine, at the time of switching the LPG engine operation in which the operation of the LPG supplying means is
10 selected by the switching means, the control valve blocks the suction of gasoline from the float chamber to the intake passage, so that the gasoline remaining in the float chamber is not sucked out to the intake passage, which blocks the air-fuel mixture from being over-rich. On the other hand, at the time of switching to the gasoline engine operation, the residual gasoline at the
15 above-mentioned predetermined level is rapidly sucked out to the intake passage, which blocks the air-fuel mixture from being over-lean.

(Examples)

20 [0009] Examples of the present invention will be described below based on the drawings.

[0010] FIG. 1 shows First Example of the present invention. In this drawing, E denotes an engine with a specification of an existing carburetor, I denotes an
25 intake passage connected to the engine E, and a two-barrel type carburetor 1 is disposed in the intake passage I. Venturi portions 2a and 2b are formed in a primary side intake passage I₁ and a secondary side intake passage I₂ of the carburetor 1, respectively, and throttle valves 3a and 3b are disposed downstream of the Venturi portions 2a and 2b. Furthermore, a choke valve 4
30 for choking the primary side intake passage I₁ when the engine is cold is disposed on the upstream side of the Venturi portion 2a of the primary side intake passage I₁. Furthermore, 5 denotes a float chamber in which gasoline

is stored, and the float chamber 5 is communicated with the Venturi portions 2a and 2b of the carburetor 1 via a fuel outflow passage 6 having a small diameter, so that the gasoline in the float chamber 5 is sucked into the Venturi portions 2a and 2b and atomized and supplied during the operation of the engine E.

[0011] Furthermore, an LPG mixer 7 for vaporizing LPG and supplying the vaporized LPG to the intake passage I is mounted on the upper portion of the carburetor 1 in the intake passage I.

10

[0012] The float chamber 5 is communicated with a gasoline tank 11 by a gasoline supplying passage 8 via a pump 9 and a filter 10, thereby constituting a gasoline supplying means 12 configured to supply the gasoline in the gasoline tank 11 to the carburetor 1 via the float chamber 5. Furthermore, the LPG mixer 7 is communicated with an LPG bomb 16 as an LPG supplying means by an LPG supplying passage 13 via a vaporizer 14 for vaporizing LPG and a filter 15.

[0013] Furthermore, a gasoline cut valve 17 configured to close the gasoline supplying passage 8 in response to a cut signal (described later) is provided in the gasoline supplying passage 8 so as to intervene between the float chamber 5 and the pump 9. On the other hand, an LPG cut valve 18 configured to close the LPG supplying passage 13 in response to a cut signal (described later) is provided in the LPG supplying passage 13 so as to intervene between the vaporizer 14 and the filter 15. Both of the cut valves 17 and 18 are connected to a gasoline-side contact point 19a and an LPG side contact point 19b of a two-pole fuel switching switch 19, respectively, and a switching means 22 in which a common contact point 19a of the fuel switching switch 19 is connected to a battery 21 via an ignition switch 20. When the ignition switch 20 is turned ON, when the engine E is operated as a gasoline engine, the fuel switching switch 19 is switched to the gasoline-side contact point 19a and a cut signal is input to the LPG cut valve 18 to block the supply of LPG to the

LPG mixer 7 and operate the gasoline supplying means 12 to supply gasoline to the carburetor 1, whereas when the engine E is operated as an LPG engine, the fuel switching switch 19 is switched to the LPG side contact point 19b and a cut signal is input to the gasoline cut valve 17, whereby the gasoline supply
5 to the carburetor 1 is blocked, and an LPG supplying means (LPG bomb) 16 is operated to switch so as to supply LPG to the LPG mixer 10, is provided.

[0014] Furthermore, a control valve 23 configured to open and close the fuel outflow passage 6 is disposed so as to intervene in the fuel outflow passage
10 6. the control valve 23 is connected to the gasoline contact point 19a of the fuel switching switch 19, and is configured so that when the fuel switching switch 19 is switched to the gasoline contact point 19a side, that is, when the operation of the gasoline supplying means 12 is selected, the control valve 23 is turned ON upon receiving a cut signal to open the fuel outflow passage 6,
15 thereby allowing the gasoline to be sucked from the float chamber 5 to the Venturi portions 2a and 2b, whereas when the fuel switching switch 19 is switched to the LPG contact point 19b side, that is, when the operation of the LPG bomb 16 is selected, the control valve 23 is turned OFF by not receiving a cut signal to close the fuel outflow passage 6, thereby blocking the suction
20 of the gasoline from the float chamber 5 to the Venturi portions 2a and 2b.

[0015] Incidentally, 24 refers to an air cleaner mounted on the upper portion of the LPG mixer 7.

25 [0016] Therefore, in the above-described Example, during the operation of the engine, when the operation is switched to the LPG engine operation, the control valve 23 is turned OFF to close the fuel supplying passage 6 so that the gasoline remaining in the float chamber 5 is not sucked into the Venturi portions 2a and 2b. Therefore, becoming over-rich of the air-fuel mixture due
30 to the suction of the gasoline can be prevented, and the level of the gasoline in the float chamber 5 can be maintained at a predetermined value. Furthermore, during the engine operation, when the operation is switched to

the gasoline engine operation, the control valve 23 is turned ON by a cut signal from the gasoline-side contact point 19a of the fuel switching switch 19 to open the fuel supplying passage 6, whereby the gasoline remaining in the float chamber 5 at a predetermined level is quickly sucked into the Venturi portions 5 2a and 2b, thereby preventing the air-fuel mixture from becoming over-lean. Therefore, it is possible to appropriately switch between the gasoline engine operation and the LPG engine operation during the engine operation while securing a good combustion state by preventing the air-fuel mixture from becoming over-rich when switching to the LPG engine operation and from 10 becoming over-lean when switching to the gasoline engine operation.

[0017] Furthermore, since it is only necessary to mount the LPG mixer 7 on the upper portion of the carburetor 1 in the intake passage I in the engine E having an existing carburetor specification, it is possible to provide a gasoline- 15 LPG combined engine more easily than that in the case of newly designing it, and the cost therefor can be reduced.

[0018] Furthermore, FIG. 2 shows Second Example of the present invention, in which a control valve 23' configured to open an air bleed passage 25, of 20 which the upstream side is open to the upstream side of a primary side intake passage I₁ and the downstream side is communicating with a fuel outflow passage 6, is disposed so as to intervene in the air bleed passage 25, and the control valve 23' is connected to a gasoline contact point 19a of a fuel switching switch 19 so that when the fuel switching switch 19 is switched to the gasoline 25 contact point 19a side, the control valve 23' is turned ON by outputting a cut signal to open the air bleed passage 25 to supply air to a fuel outflow passage 6 to allow gasoline to be sucked from a float chamber 5 to Venturi portions 2a and 2b, whereas when the fuel switching switch 19 is switched to the LPG contact point 19b side, the control valve 23' is turned OFF to close the air bleed 30 passage 25 by stopping the output of the cut signal to block the supply of the air to the fuel outflow passage 6 to block the gasoline from being sucked out of the float chamber 5 to the Venturi portions 2a and 2b. Second Example

exerts similar action and effect to those exerted by the above-mentioned First Example.

(Effects of the Invention)

5

[0019] As described above, according to the gasoline-LPG combined engine of the present invention, since the engine is configured so that the suction of gasoline from the float chamber of the carburetor to the intake passage is blocked during the operation as an LPG engine, the air-fuel mixture due to the suction of the gasoline remaining in the float chamber to the intake passage during the switching from the engine operation state to the LPG engine operation state can be prevented from being over-rich, whereas during switching to the gasoline engine operation state, the air-fuel mixture can be prevented from being over-lean by suction of the residual gasoline to the intake passage at the above-mentioned predetermined amount. Therefore, gasoline engine operation and LPG engine operation can be appropriately switched during the operation of the engine while keeping a fine combustion state.

4. BRIEF DESCRIPTION OF THE DRAWINGS

20

[0020] FIGs. 1 and 2 show Examples of the present invention, wherein FIG. 1 is an overall schematic diagram showing First Example, and FIG. 2 is a diagram corresponding to FIG. 1 showing Second Example.

25 [0021] E ... Engine, I ... Intake passage, 1 ... Carburetor, 5 ... Float chamber, 6 ... Fuel outflow passage, 7 ... LPG mixer, 12 ... Gasoline supplying means, 16 ... LPG bomb, 19 ... Fuel switching switch, 22 ... Switching means, 23, 23' ... Control valve.

2. Claims

1. A gasoline-LPG combined engine, comprising:
 - a carburetor comprising a float chamber and being disposed in an
 - 5 intake passage of the engine;
 - an LPG mixer disposed in series with the carburetor in the intake passage;
 - a gasoline supplying means configured to supply gasoline to the carburetor;
 - 10 an LPG supplying means configured to supply LPG to the LPG mixer;
 - and
 - a switching means configured to selectively operate the gasoline supplying means and the LPG supplying means; and
 - further comprising a control valve configured to allow or block suctioning
 - 15 of gasoline from the float chamber to the intake passage,
 - wherein the control valve is configured to operate to block the suctioning of the gasoline when the operation of the LPG supplying means is selected by the switching means.

FIG. 1

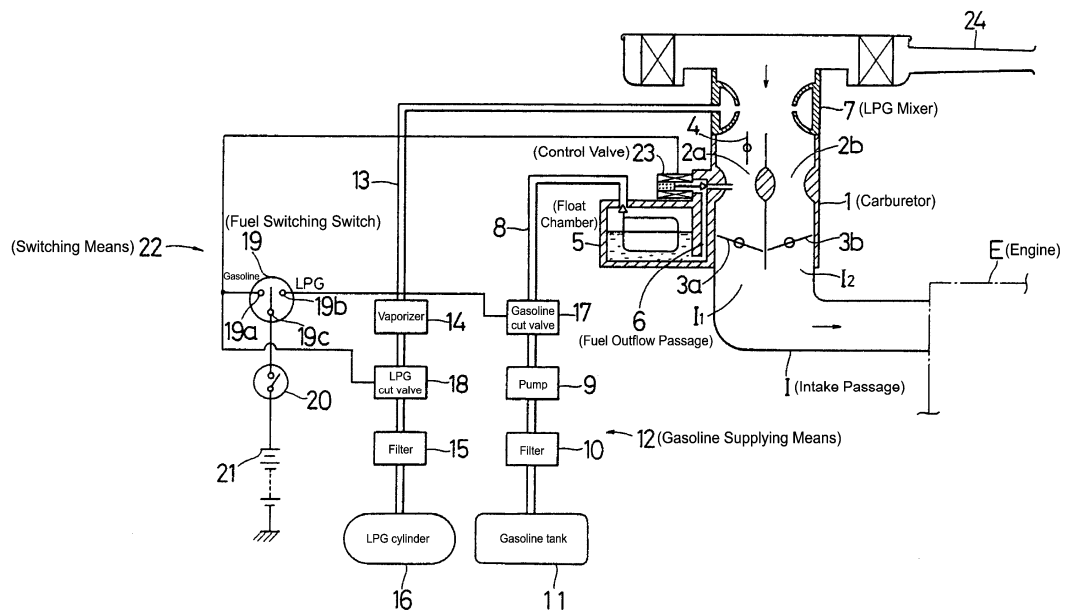
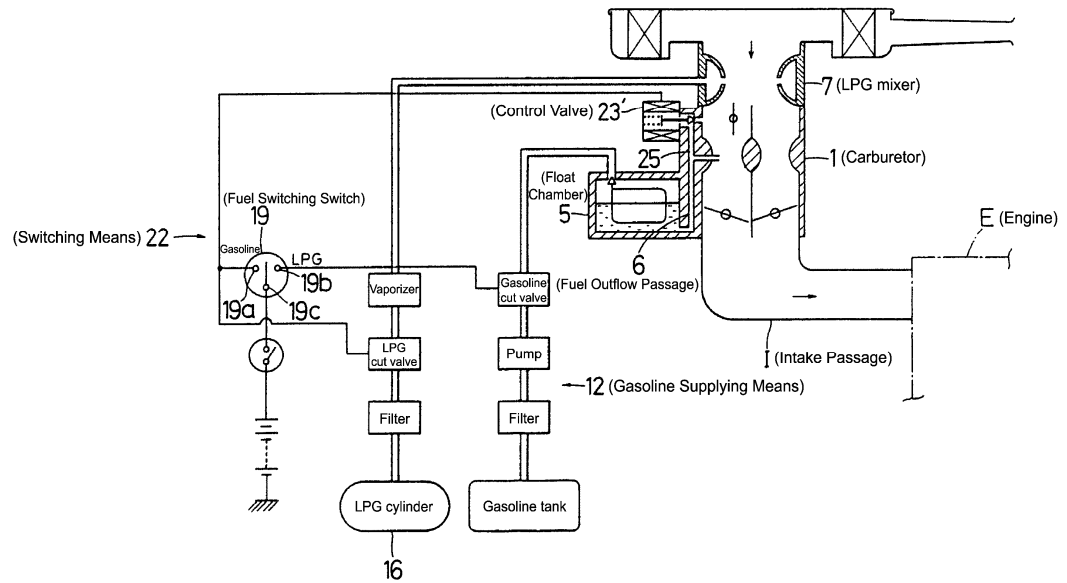


FIG. 2



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Date: October 16, 2024

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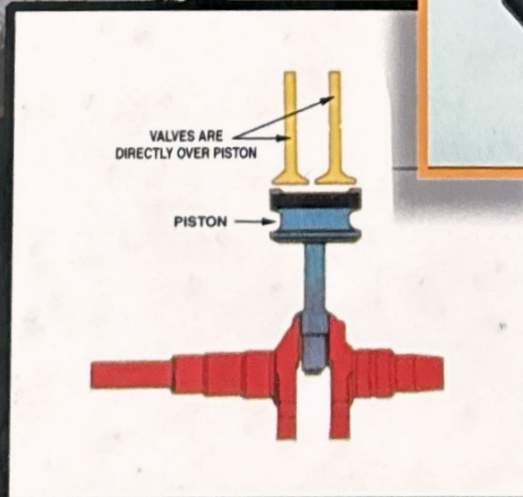
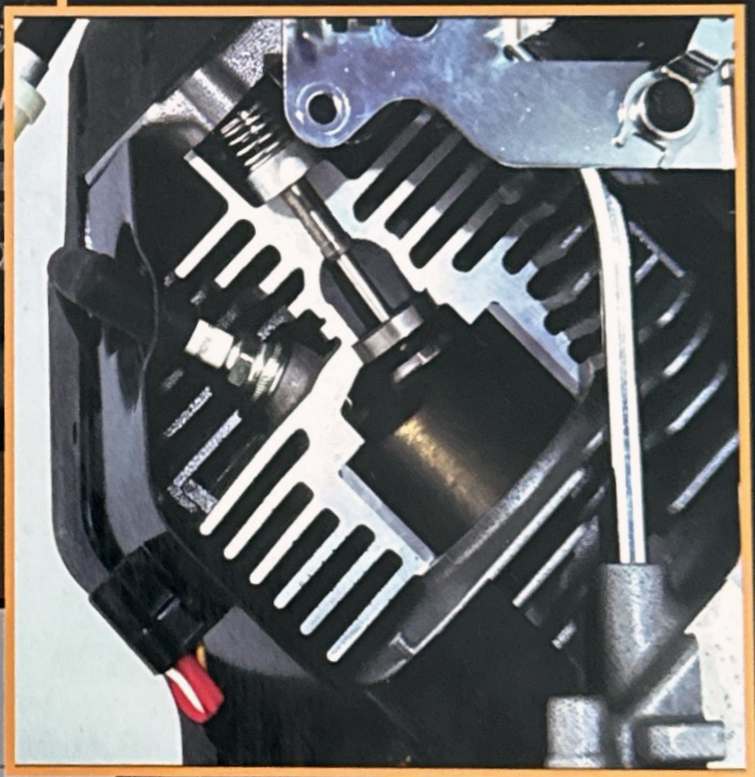
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EXHIBIT 1006

Small Engine Technology

SECOND EDITION



William A. Schuster

Petitioner MVE Investments, LLC, et al.
Exhibit 1003, Page 568

SMALL ENGINE TECHNOLOGY, SECOND EDITION

William A. Schuster

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For more information, contact:

Delmar Publishers
3 Circle, Box 15015
Albany, New York 12212-5015

International Thomson Publishing Europe
Berkshire House
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London, WC1V 7AA
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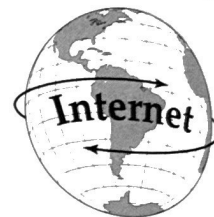
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2 3 4 5 6 7 8 9 10 XXX 03 02 01 00 99 98

Library of Congress Cataloging-in-Publication Data

Schuster, William A.
Small Engine technology / William A. Schuster.—2nd. ed.
p. cm.
Includes bibliographical references and index.
ISBN 0-8273-7778-9 (soft)
ISBN 0-8273-7699-5 (hard)
1. Small gasoline engines. I. Title.
TJ790.S38 1998

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CHAPTER 4

Carburetors

INTRODUCTION

The carburetor measures the correct quantity of fuel to be supplied to the engine, breaking it down into small droplets called atomization and mixing the fuel with air. The carburetor must correctly proportion the amounts of fuel and air, regardless of the speed and load at which the engine is operating. Due to the differences in weight between fuel and air and the changing pressures to which they are subjected, the problem of maintaining correct mixture proportions is very difficult. For this reason, good carburetors have complicated construction.

The carburetor breaks the fuel into various sizes of drops suspended in an air stream so that the droplets vaporize easily before they reach the combustion chamber. The completeness of the vaporization depends on the following factors:

1. Volatility of the fuel. The more volatile fuels vaporize more rapidly.
2. Temperature of the air. Higher temperatures increase the rate of vaporization.
3. Degree of atomization. A greater degree of fuel atomization presents the maximum amount of surface, and the fuel is more readily vaporized.

In the time allowed for mixing the vapors of fuel with air, it is not possible to obtain a thorough mixing so that all the fuel particles will react with all of the oxygen particles. In order to consume all of the fuel or oxygen, there must be an excess of one or the other. Maximum power will occur when all the oxygen is consumed, which necessitates extra fuel particles. Maximum power fuel will be a rich mixture. The most economical mixture will have all the fuel particles consumed by supplying a lean fuel mixture with excessive air.

A carburetor must be able to provide different air-fuel ratios between 11:1 and 16:1 to provide the maximum power and greatest economy.

CARBURETOR CONSTRUCTION

A carburetor is a metering device for mixing fuel and air, as shown in Figure 4-1. The correct mixture in the combustion chamber is essential for the engine to run properly. Two conditions must be met for proper carburetion. The fuel must be introduced to the incoming air stream and it must be vaporized.

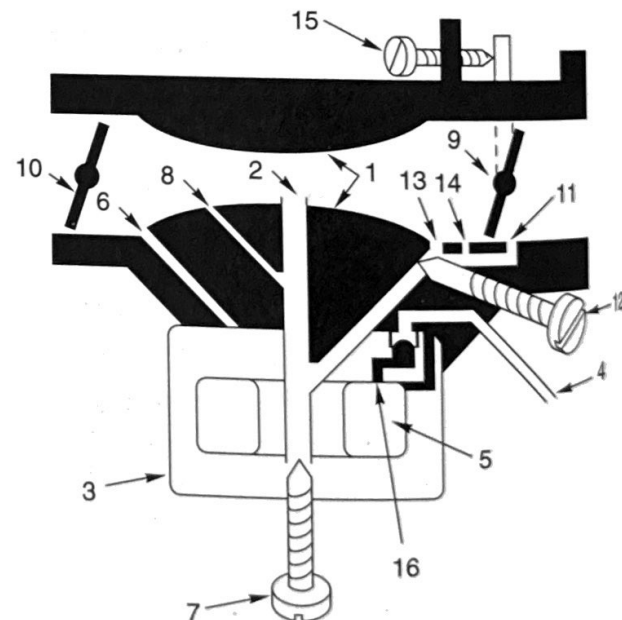


Fig. 4-1 Carburetor construction.
(Courtesy of William A. Schuster)

VENTURI

The venturi, marked with #1 in Figure 4-1, is the narrowed part of the carburetor tube where a suction is created and the velocity of the incoming air is increased (see Figure 4-2). If you open the choke and throttle plate of the carburetor and look through the channel or air horn, you will notice that the venturi is the constricted section, as shown in Figure 4-3.

MAIN DISCHARGE TUBE

The main discharge tube, marked with #2 in Figure 4-1, is the part through which the fuel travels from the fuel container to the air stream in the venturi during high-speed operation.

The main discharge tube of the carburetor is a tube, one end of which is connected to the venturi and the other in the fuel container found below. While air is flowing through the venturi, the effect will be the

Effects of venturi
1. Air speed increased.
2. Vacuum created.

Fig. 4-2 Effects of venturi. (Courtesy of William A. Schuster)

same as putting a straw in one's mouth and sucking on it. If one end of the straw is placed into a liquid, the fluid will be drawn up the straw. The fuel container can be the float bowl, part of the fuel tank, or the entire fuel tank. The fuel is actually pushed through the main jet tube by the difference in pressure between the atmosphere and the venturi throat, as shown in Figure 4-4. Normal atmospheric pressure pushes on the fuel in the reservoir and moves the fuel to the low pressure area in the venturi.

The greater the volume of air passing through the venturi, the higher the vacuum and the larger the amount of fuel that will be sprayed into the air stream at the main discharge tube.

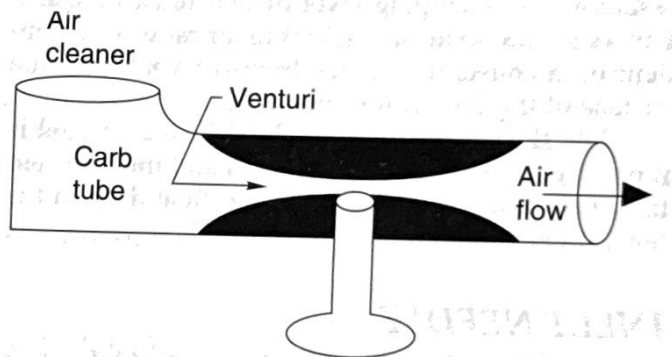


Fig. 4-3 Venturi is the constricted section in the air horn. (Courtesy of William A. Schuster)

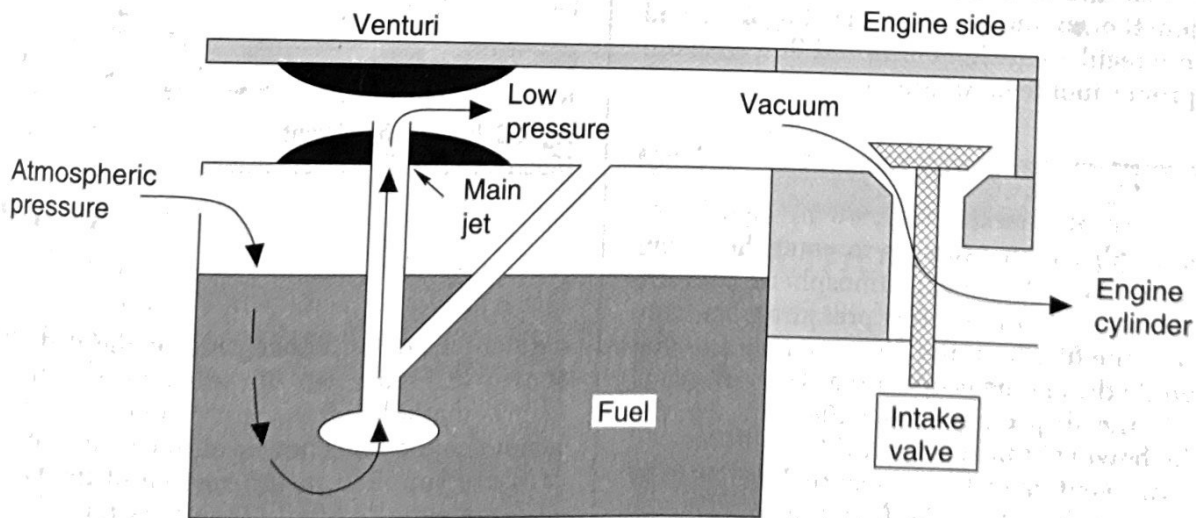


Fig. 4-4 Fuel is pushed through the main jet tube. (Courtesy of William A. Schuster)

FUEL CONTAINER

The fuel container, marked with #3 in Figure 4-1, holds the fuel for use by the different metering circuits in the carburetor.

FUEL SUPPLY INLET

The fuel supply inlet, marked with #4 in Figure 4-1, is where fuel enters the fuel container from the engine's fuel tank.

FLOAT

The float, marked with #5 in Figure 4-1, is used to control the level of fuel in the fuel container. An essentially unchanging level of fuel must be maintained. Proper metering of fuel-to-air ratios is dependent on a constant distance from the venturi to the surface of the fuel in the container.

When the engine speed or load increases, fuel is rapidly pulled out of the fuel bowl and into the venturi. This makes the fuel level and float drop in the bowl. Fuel enters the bowl and the float rises.

INLET NEEDLE

The inlet needle, marked #16 in Figure 4-1, opens as the float level drops and fuel is allowed to enter the bowl area. As the fuel level rises, the float pushes the inlet needle back and shuts off the incoming fuel. When the engine is operating, the float and inlet needle regulate the incoming fuel flow to maintain the proper fuel level in the fuel container.

BOWL VENT

The bowl vent, marked with #6 in Figure 4-1, allows atmospheric air pressure to enter the carburetor system. The difference in atmospheric pressure (relatively high) and the venturi pressure (relatively low) pushes the fuel from the fuel container into the venturi while the engine is operating. The vent tends to maintain the air pressure above the surface of the fuel in the bowl at atmospheric levels.

The bowl vent may be an external or internal type. An external vent can be found on the outside of the carburetor body, as shown in Figure 4-5. An internal vent is commonly found in the carburetor

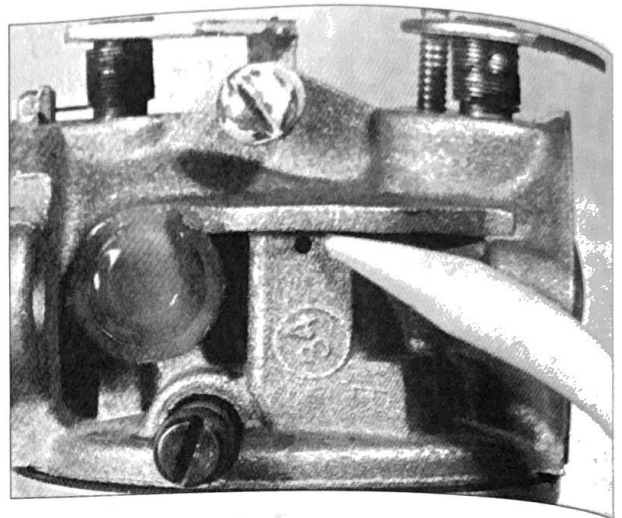


Fig. 4-5 External bowl vent.
(Courtesy of William A. Schuster)

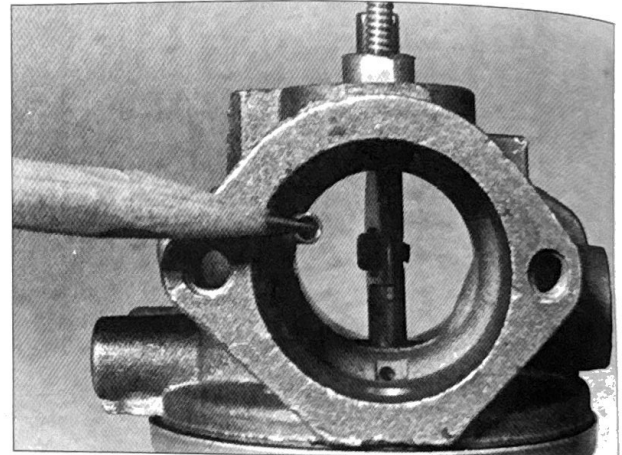


Fig. 4-6 Internal bowl vent.
(Courtesy of William A. Schuster)

air horn near the choke side of the carburetor, as shown in Figure 4-6. An advantage of an internal vent is that a larger venturi can be used in order to maximize the horsepower of the engine because the pressure supplied to the surface of the fuel in the fuel container is higher than the atmospheric pressure since air moving through the carburetor is forced into the vent opening.

HIGH-SPEED MIXTURE ADJUSTMENT NEEDLE

The high-speed mixture adjustment needle, marked with #7 in Figure 4-1, is used to control the amount of fuel entering the air stream at high speed. It can be turned in to decrease the amount of fuel, which makes the air-fuel mixture lean (in fuel), or turned out for a rich (in fuel) air-fuel mixture.

HIGH-SPEED AIR BLEED

The high-speed air bleed, marked with #8 in Figure 4-1, allows air to break up the fuel before entering the air stream in the venturi. When the air enters the carburetor, it forms a slight pressure near the venturi as the molecules are backed up while waiting to enter the venturi. This backup of air molecules increases the pressure slightly on the choke side of the venturi. With the high-speed air bleed located in this high-pressure area, some of the air moves through this channel to mix with the fuel in the main discharge tube.

THROTTLE PLATE

The throttle plate, marked with #9 in Figure 4-1, controls the air flow through the venturi, thereby controlling the fuel flow to the engine. When the throttle plate is closed, all the air flow to the engine would cease; therefore, the throttle plate must be held open slightly by the idle speed screw, marked with #15 in Figure 4-1. When the throttle plate is opened fully, the air flow into the engine is limited by the size of the venturi.

CHOKE PLATE

The choke plate, marked with #10 in Figure 4-1, partially blocks off air flow, creating low pressure throughout the carburetor to provide a rich in-fuel mixture for cold starting. The fuel is drawn into the limited air flow from the main discharge tube and the idle passages.

IDLE PASSAGE

The idle passage, marked with #11 in Figure 4-1, connects the carburetor's bowl to the engine side of

the throttle plate. Fuel is forced through this passage when the throttle plate moves to the idle position.

LOW-SPEED MIXTURE ADJUSTMENT SCREW

The low-speed mixture adjustment screw, marked with #12 in Figure 4-1, is used to meter the precise amount of fuel for engine operation at idle.

IDLE AIR BLEED

The idle air bleed, marked with #13 in Figure 4-1, allows air to atomize the fuel before entering the air stream while the engine is idling. This premixing of the fuel and air increases the efficiency of engine combustion. When the throttle plate is in the idle position, the transitional fuel passage, marked with #14 in Figure 4-1, also allows air to bubble into the idle passages.

TRANSITIONAL FUEL PASSAGES

The transitional fuel passage, marked with #14 in Figure 4-1, provides a temporary fuel supply to the engine during the transition from idle to high-speed operation. As the throttle plate begins to open, both the transitional fuel passages and the idle passage provide the air-fuel mixture.

CARBURETOR FUNCTIONS

EVAPORATION OF GASOLINE

Liquid gasoline will not support rapid combustion without being changed to a mist or broken down or atomized into tiny drops. When liquid gasoline is introduced to the venturi, it is gasified by its collision with the rapidly moving air mass. The atomized fuel then flows to the intake manifold where the pressure is low, and any remaining liquid gasoline evaporates further. Vaporization is finally completed with the heat generated by the compression of the air-fuel mixture in the cylinder.

FUEL CONTROL

The size of the venturi is matched with the power of the engine. If the engine is operated constantly in a full-load condition, a relatively large venturi can be used for maximum efficiency and power, but since most engines are designed to run from no-load to full-load (idle to high speed), the air-to-gasoline ratio must be changed for different operating conditions. Heavy loads and fast acceleration necessitate a richer mixture. The venturi is narrowed enough to allow good suction at midrange speeds, and an idle circuit is added so that the engine will still draw fuel at low speeds. Either a fuel adjustment screw regulates the amount of fuel going up the main nozzle or a nonadjustable metering jet is used.

The venturi size directly affects the volumetric efficiency of the engine, which determines the horsepower rating of the engine.

EFFICIENT COMBUSTION

If the engine is warm, the air-fuel mixture enters the combustion chamber in a vaporized state. In an engine that has not yet reached operating temperature, some of the gasoline condenses before it goes into the cylinder. The ratio of air-fuel for proper combustion is dependent upon engine and intake air temperatures as well as many other factors.

During combustion the air-fuel mixture burns very rapidly. Combustion is not an uncontrolled explosion, but rather a regulated burn with a rapid release of heat energy, causing the air molecules in the cylinder to expand and force the piston downward.

STARTING THE ENGINE

When the air-fuel mixture is drawn into the cylinder on the intake stroke of the piston and the engine is cold, the gasoline vapors tend to condense into large drops on their way to the cylinder. Because all the gasoline supplied to the cylinders does not vaporize, it becomes necessary to supply a rich mixture in order to have enough vapor for combustion to occur. This is accomplished by a choke, enrichment system, or primer.

Choke system

When the choke is tilted in the carburetor to restrict the amount of air entering the air horn, greater suction is created and a larger amount of fuel is drawn into the combustion chamber from the idle passages and the main discharge tube, as shown in Figure 4-7.

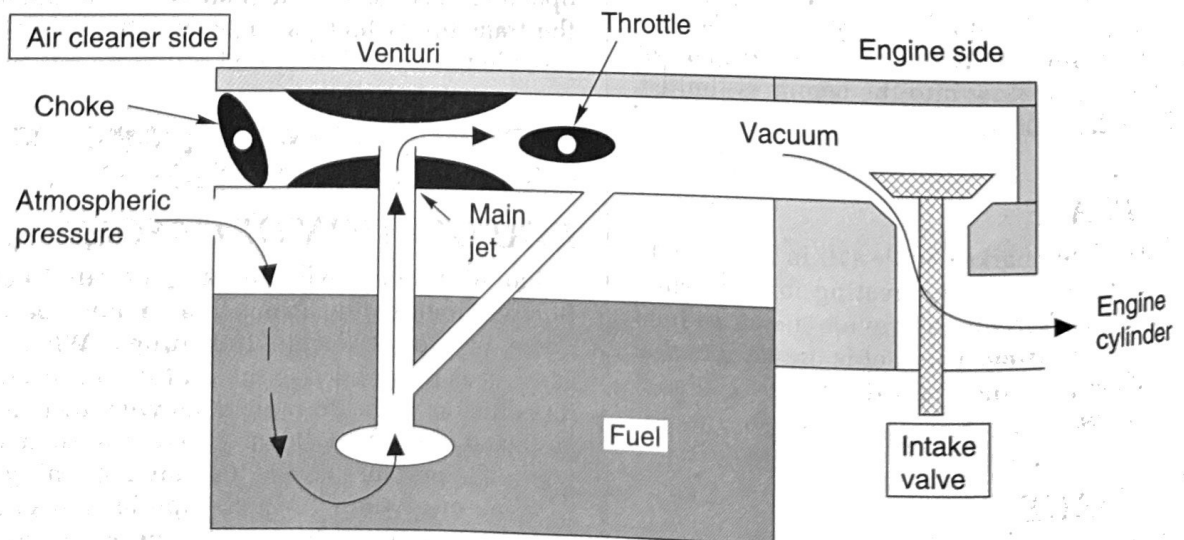


Fig. 4-7 Choke system. (Courtesy of William A. Schuster)

Enrichment system

An enrichment system is an air-fuel metering circuit separate from other carburetor circuits. Fuel for the circuit is drawn from the float bowl through an enrichment jet. The enrichment jet is activated by the user through a special lever. When the plunger is down, the enrichment circuit is blocked and does not operate. When the plunger is raised, a rich air-fuel mixture is discharged from the enrichment port, which is located directly behind the venturi.

Primer system

The primer system provides a rich mixture by increasing the pressure in the top of the fuel bowl to force extra fuel into the venturi. Another way is by pushing down on the float to force a higher than normal float bowl level and create a rich condition.

In a diaphragm carburetor, the diaphragm may be lifted mechanically or pneumatically, as shown in Figure 4-8.

HIGH-SPEED OPERATION

The high-speed circuit is provided by the main discharge tube, marked with #2 in Figure 4-1, which is centered in the venturi. When the throttle plate is opened sufficiently, the air passing through creates a

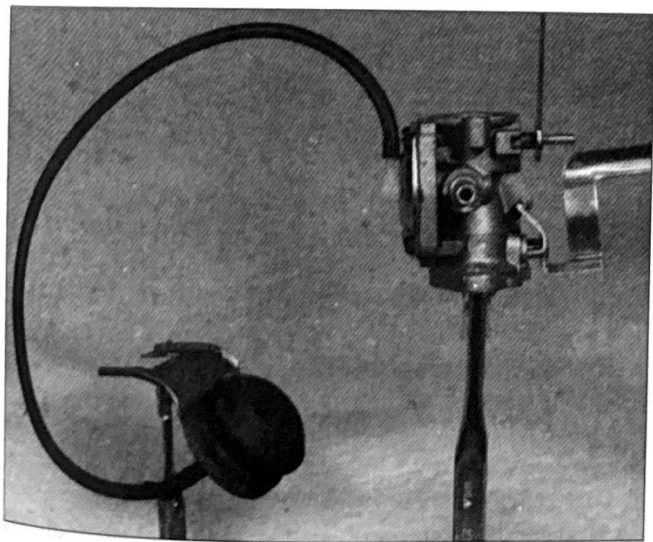


Fig. 4-8 Pneumatic primer system.
(Courtesy of William A. Schuster)

pressure difference in the venturi, which causes a discharge of fuel from the nozzle, as shown in Figure 4-4. Throughout the intermediate and high-speed ranges, this discharge increases with the volume of air passing through it so that a uniform air-fuel mixture ratio is maintained.

An adjusting needle or preset main jet controls the amount of fuel that enters the air stream. Maximum power is obtained with a mixture of from 12 to 14 parts of air to 1 part fuel. An excessively lean or rich fuel mixture will not burn properly and will not produce maximum power. If an engine is operating on too lean a mixture for maximum power and carburetor adjustments are made to increase the amount of fuel in the mixture, the horsepower output will also increase.

At partially open throttle plate position, it is possible to obtain maximum power at a leaner fuel mixture wherein the best air fuel ratio is 16:1.

IDLE SPEED OPERATION

When the throttle plate is closed or slightly open, only a small amount of air can pass through the air horn and flow around the throttle plate, as shown in Figure 4-9. The air speed is so low, and there is such a small amount of air passing through, that hardly any vacuum develops in the venturi; thus, the main discharge tube in the venturi will not feed any fuel. For this reason, the carburetor must have an idle circuit.

When the throttle plate is in the idle position, the amount of air and fuel is greatly reduced as compared with wide-open throttle plate conditions. The mixture tends to burn more slowly and a richer fuel mixture is necessary.

Idling speed of the engine is controlled by the air flow past the throttle plate, and the volume of the air flow is controlled by the setting of the idle speed adjusting screw.

INTERMEDIATE SPEED OPERATION

When the throttle plate is placed at a position that is less than the high-speed position but greater than the idle position, not only does the vacuum formed in the main venturi draw fuel into the air stream, but

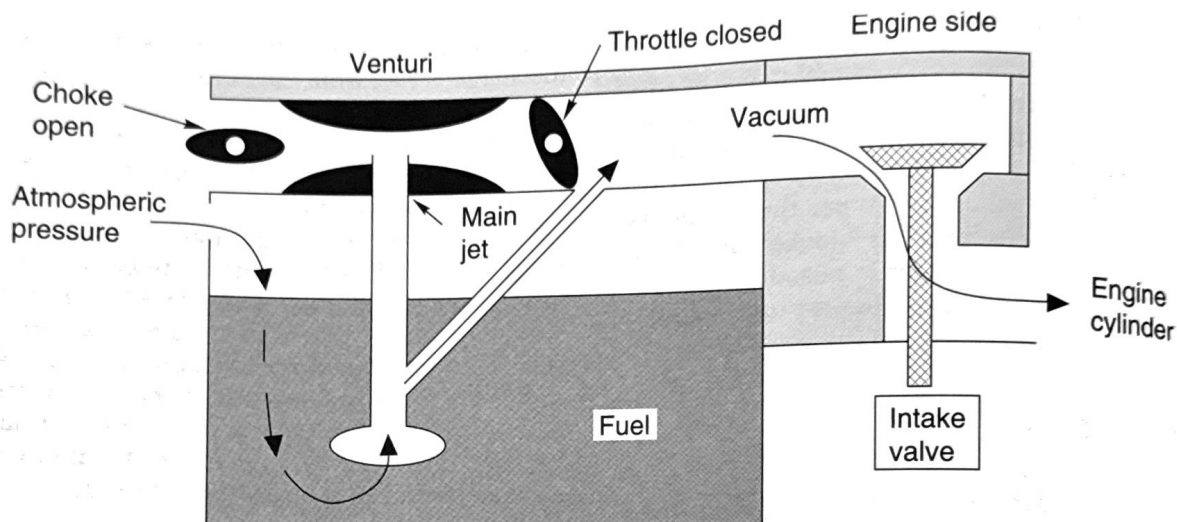


Fig. 4-9 Idle speed operation. (Courtesy of William A. Schuster)

the idle circuit also delivers fuel at the secondary low-pressure area around the idle fuel inlets. Both the high-speed and the low-speed mixture adjustments affect the air-fuel ratio.

MAINTENANCE AND TROUBLESHOOTING

Many engine performance problems are mistaken for carburetor malfunctions.

PRELIMINARY CHECKLIST

Good carburetor adjustments require reasonable integrity of all other engine systems.

Fuel tank

The interior of the tank must be free of corrosion or other contaminants that may settle in the bottom and block the flow of fuel.

Fuel lines

The fuel line must not be bent so that the flow of fuel is obstructed in any way. Some fuel lines may disintegrate and collapse, causing the flow to the carburetor to stop.

Clean fuel

Check the fuel to determine if it is stale or dirty. White scale in the carburetor is evidence of water in the fuel. Once this type of oxidation has developed, there is no stopping it. The carburetor must be replaced.

Filter

The filter must be clean and installed in the correct direction. Arrows are stamped on the filter's cover showing the direction of the flow. The filter should be changed often.

Ignition

The symptoms of poor-running carburetor adjustment may stem from a faulty ignition. A faulty ignition will cause an intermittent symptom of carburetor misadjustment. The proper spark plug must be used, with the gap adjusted to the manufacturer's specifications.

Compression

Without proper compression, the engine will be difficult to adjust. Ensure that the compression is adequate.

Exhaust

A restricted exhaust port will cause a loss of power and difficulty in adjusting the carburetor. Make sure that the exhaust port is clear of any carbon obstructions.

Manifold gasket

The manifold gasket must be in good condition and not leak. An air leak will cause the engine to operate in a lean condition. An intake manifold leak can be detected by putting oil in the area while the engine is idling and then listening for a change in engine speed. The oil will temporarily block the leaking gasket, and the mixture and engine sound will be affected.

Vapor lock

Vapor lock is a term used to describe the action of liquid fuel transforming into a gaseous "vapor" state, typically caused by heat. During this transformation, air bubbles are formed. Always use clean, fresh fuel that has been blended for the appropriate season.

Air bubbles from a vapor lock condition can become trapped at a high point in the fuel line or at a fuel filter, stopping the flow of fuel. Vapor lock may occur when the equipment is being operated or when restarting a warm engine.

Vapor lock during operation can be caused from insufficient cooling air. The exhaust gases may be trapped by the equipment design and recirculated to the cooling system. The warm cooling air may be misdirected near or at fuel lines, carburetor, and fuel supply.

Vapor lock occurs when a hot engine is shut down. Since the engine is hottest at about 1 minute after it has been turned off, it is best to cool the engine by letting it run at a speed just above idle for about 30 seconds before stopping it.

AIR CLEANER

Observe how the unit has been maintained. Check to see if the air cleaner is plugged or missing. The poly-foam element may have been oiled incorrectly. A dirty element can cause cylinder bore wear that will affect performance. Dirt may be brought into the

engine with air that is sucked around a worn choke or throttle plate shaft, and the engine may be difficult to adjust properly. Tecumseh furnishes dust seals on chrome-plated shafts on their current carburetors to prevent this type of wear.

INITIAL SETTINGS

Make certain the governor linkage is connected correctly and adjust the mechanical governor. Make the initial settings on the carburetor and let the engine warm up for 3 to 5 minutes.

PROPER ADJUSTMENT

The home technician may have fine-tuned his or her machine, and the repair job may be as simple as correcting the work by adjusting the carburetor. Find the lean and rich points of the main adjustment screws and put the setting at halfway between the two points. It is best to find the lean point first, then the rich point, to make a proper adjustment.

Bring the engine to idle and adjust the idle screw in the same manner as the main mixture adjustment. Although the idle mixture screw may be adjusting either air or fuel flow, the procedure will apply to both systems.

Take the engine back to high speed and reset the main mixture adjustment. Return the engine to idle again and reset the idle mixture adjustment. It is important to make the adjustment between the main and idle at least twice in order to ensure proper operation.

AIR LEAKS

Air leaks at the carburetor gaskets can cause a hunting condition. Anytime a gasket is disturbed, a new one should be used in its place. Make sure the float is adjusted properly.

FUEL SYSTEM FAILURES

Although the fuel system is very simple, pinpointing the difficulty can be frustrating. Fuel system problems can be separated into five categories:

1. Incorrect fuel
2. Bad fuel

3. Too little fuel
4. Too much fuel
5. No fuel supplied to the engine

Incorrect fuel

Some possible ways incorrect fuel may make its way into the system are:

- Fuel with an excessive amount of alcohol
- Diesel fuel put into the tank by mistake
- Fuel blended for one season, but used in another

Bad fuel

Some possible ways bad fuel may make its way into the system are:

- Fuel deteriorated
- Fuel with sand, dirt, grass, etc. in it
- Fuel left out in the rain without a cap

Too little fuel

The following may prevent the engine from receiving enough fuel:

- A partially plugged fuel filter
- A restricted fuel tank vent
- A pinched fuel line
- A collapsed fuel line that has separated internally
- A fuel pump with damaged, worn, or dirty parts
- An engine with a poor crankcase vacuum caused by leaking gaskets, loose oil-fill caps, loose oil filters, leaking piston rings, or bad seals
- A sticking or misadjusted carburetor inlet needle
- Damaged, dirty, or misadjusted carburetor mixture jets
- The wrong mixture jets in the carburetor
- The wrong carburetor
- An incorrect or missing air filter
- An excess amount of air being forced through the carburetor by the air intake system
- An incorrectly oiled air filter precleaner

- A loose air cleaner housing
- A worn throttle plate shaft or carburetor body
- Loose, warped, or damaged connections in intake manifold, which allows air to be drawn

Too much fuel

Check for these problems which can result in much fuel being supplied to the engine:

- Misadjusted or leaking carburetor fuel inlet needle
- Misadjusted or damaged carburetor fuel mixture jets
- Leaking internal welch plugs
- Leaking, missing, or incorrectly installed gaskets
- The wrong mixture jets installed in the carburetor
- A fuel pump that has a high output pressure
- The wrong carburetor

No fuel supplied to the engine

Look for the following possible problems:

- A plugged fuel cap vent
- A plugged fuel filter
- An incorrectly positioned or missing fuel pickup hose
- A pinched-off fuel line
- An internally collapsed fuel line
- A disconnected fuel line
- A failed fuel pump
- A sticking or plugged carburetor inlet needle
- Misadjusted or plugged carburetor fuel mixture jets

MISCELLANEOUS PROBLEMS

If the engine dies in-between idle and high speed, the idle circuit must be cleaned with the wick plugs removed.

If the carburetor floods, it is generally because the inlet seat is leaking. The new inlet seat must be installed in the carburetor body in proper direction.

A plugged atmospheric vent hole will cause a lean setting in the carburetor. The external vents must be kept free of debris.

BRIGGS & STRATTON CARBURETORS

INTRODUCTION

The basic purpose of a carburetor is to produce a mixture of fuel and air in the correct proportions so that the engine will operate properly at different speeds and loads. Briggs & Stratton manufactures three different basic types, designated as Vacu-Jet, Pulsa-Jet, and Flo-Jet. Because environmental safety demands stricter emission and performance controls, many manufacturers realize that it is more cost-effective to contract another company (that specializes in carburetors) to design and build them. Briggs & Stratton has entered into a business relationship with Walbro carburetors, and together they are producing a Flo-Jet type of carburetor with both of their names on it.

Prior to removing any carburetors for repair, note and record the position of governor springs, governor link, remote control, or other attachments in order to facilitate reassembly.

VACU-JET CARBURETOR

Vacu-Jet construction

The Vacu-Jet is a simple carburetor that is used in many small displacement Briggs & Stratton engines and functions adequately. The manufacturing cost of this carburetor has helped the corporation stay competitive. It is adjusted differently than are other carburetors because of its unique features, as described below.

Vacu-Jet identification

The easiest way to identify the Vacu-Jet design is to check the engine's model number, as shown in Figure 4-10. Another method is by recognizing its appearance. This is sometimes difficult to do because of changes in outward features from time to

Carburetor identification

Typical model number

9 2 5 0 2

Cubic inch displacement

Type of starter

Basic design series

Bearings, reduction gears and auxiliary drives

- 0—Horizontal diaphragm
- 1—Horizontal vacu-jet
- 2—Horizontal pulsa-jet
- 3—Horizontal flo-jet
- 4—Horizontal flo-jet
- 5—Vertical vacu-jet
- 9—Vertical pulsa-jet

#5 on model number vertical crankshaft vacu-jet carburetor

Fig. 4-10 Briggs & Stratton Vacu-Jet identification. (Courtesy of William A. Schuster)

EXHIBIT 1007



US005301644A

United States Patent [19]

Olmr

[11] **Patent Number:** **5,301,644**[45] **Date of Patent:** **Apr. 12, 1994****[54] FUEL SHUT-OFF MECHANISM FOR
INTERNAL COMBUSTION ENGINES**[75] Inventor: **Jaroslav J. Olmr, Sheboygan, Wis.**[73] Assignee: **Kohler Co., Kohler, Wash.**[21] Appl. No.: **78,526**[22] Filed: **Jun. 16, 1993**[51] Int. Cl.⁵ **F02B 77/00**[52] U.S. Cl. **123/198 DB; 123/DIG. 11**[58] Field of Search **123/DIG. 11, 198 DB****[56] References Cited****U.S. PATENT DOCUMENTS**

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4,996,644 2/1991 Fukuchi et al. 364/431.05*Primary Examiner*—Noah P. Kamen*Attorney, Agent, or Firm*—Quarles & Brady**[57] ABSTRACT**

An engine has a carburetor that includes a bowl for fuel, a venturi in which the fuel is mixed with air, and a tube for carrying fuel from the bowl to the venturi. A solenoid valve is connected to the tube to control the flow of fuel to the venturi. An engine ignition system includes a coil assembly in which electricity is generated by a permanent magnet driven by the engine passing near the coil assembly. A transformer includes a primary winding connected to the coil assembly, and a secondary winding. A storage capacitor and a diode are coupled in series across the secondary winding and a switch couples the solenoid valve to said storage capacitor. When an operator desires to stop the engine, the switch is closed which applies electricity from the capacitor to the solenoid valve to reduce an amount of fuel flowing through the tube.

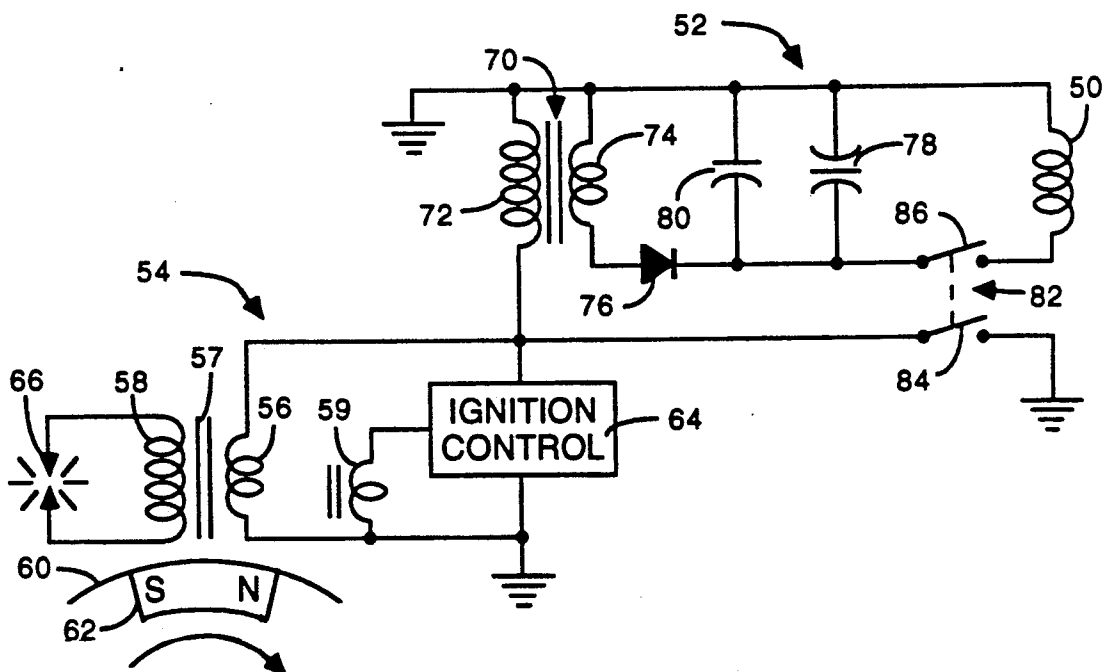
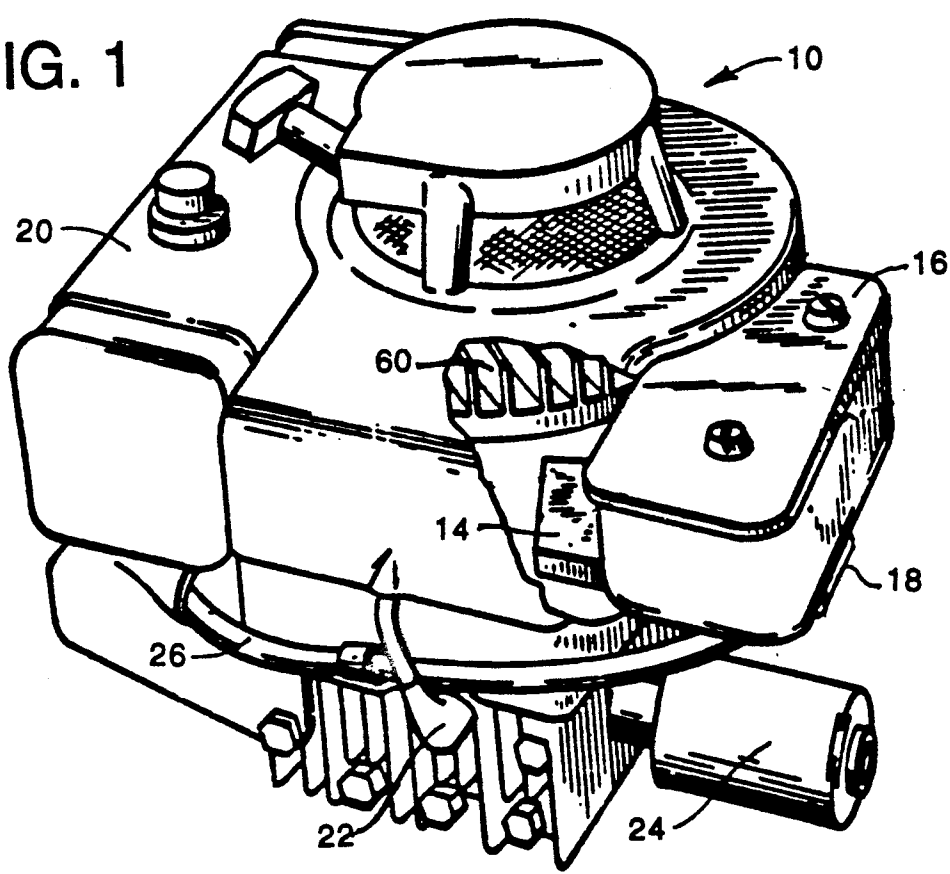
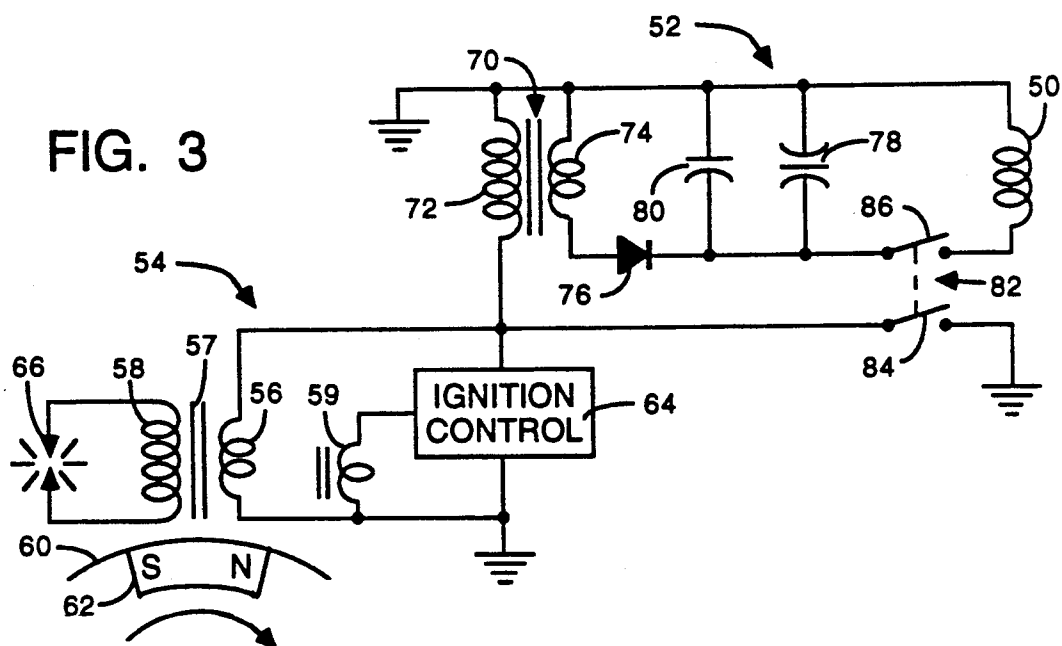
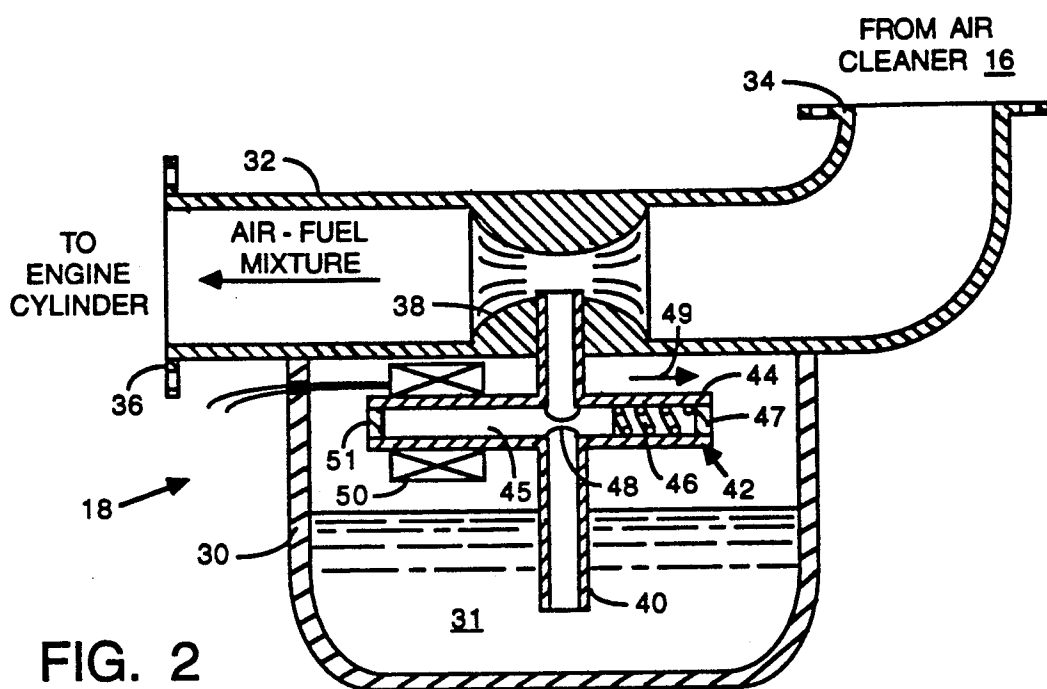
8 Claims, 2 Drawing Sheets

FIG. 1





FUEL SHUT-OFF MECHANISM FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

The present invention relates to internal combustion engines and more particularly to mechanisms for stopping the flow of fuel when such engines are to stop.

Small internal combustion engines, such as those used to power lawn and garden equipment, have carburetors that receive fuel from a tank. The fuel is mixed that air in the carburetor and the mixture is supplied to the engine cylinder where it is ignited. During the exhaust stroke of the engine the combustion gases are forced from the cylinder through and through a muffler. The muffler becomes very hot due to the combustion gases.

When an operator desires to stop the engine a switch is closed that shorts the electrical ignition system to ground. This action prevents the spark plug from continuing to fire. However, the engine does not stop revolving immediately, but continues to revolve for several cycles. During this continued movement, the fuel mixture is drawn from the carburetor into the cylinder. Because the spark plug is not being fired, the unburnt fuel mixture is forced from the cylinder into the muffler. The muffler still is very hot causing ignition of the unburnt fuel mixture. This phenomenon is commonly called a backfire. Aside from producing a very loud noise, repeated backfires can destroy the muffler.

SUMMARY OF THE INVENTION

A general object of the present invention is to provide a mechanism for cutting off the supply of fuel to an internal combustion engine when the engine is being stopped. Such a mechanism prevents unburnt fuel from being expelled from the engine into the exhaust system.

This object is accomplished by placing a solenoid operated valve in the fuel line between the fuel supply and the engine cylinder. Preferably this valve is located in the bowl of the carburetor to decrease the flow of fuel to the venturi where the fuel mixes with air. The valve is normally in the open position due to a spring. When electricity is applied to the electromagnet coil of the solenoid, the valve moves into a closed position at which the fuel supply is shut-off entirely or significantly reduced so that a combustible air-fuel mixture is not formed in the venturi.

During normally operation of the engine, electric current from the ignition system flows through a primary winding of a transformer and a current is induced in a secondary winding. A capacitor is connected to the secondary winding and is charged by the current from that winding.

When an operator desires to shut off the engine the kill switch is closed. While this switch may short the ignition system to prevent the spark plug from firing, the kill switch also applies the voltage across the capacitor to the electromagnet coil of the solenoid. This action produces a magnetic field which closes the valve reducing the flow of gas through the carburetor and to the engine cylinder. This system has the advantage of reducing the air-fuel mixture from the carburetor to a noncombustible level. Thus as the stopping engine continues to rotate and the air-fuel mixture is expelled by the cylinder into a hot exhaust system, the mixture does not burn. As a consequence a back-fire does not occur in the stopping engine.

Another object is to provide such a fuel shut-off mechanism that does not require a battery for power.

A further object of the present invention is to provide a fuel cut-off mechanism that will fail in a position which will not disable operation of the engine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of an single cylinder gasoline engine that incorporates a novel fuel shut-off mechanism;

FIG. 2 is a cross sectional view of the carburetor in the engine; and

FIG. 3 is a schematic diagram of the electric circuit for controlling the solenoid valve in the carburetor.

DESCRIPTION OF THE PRESENT INVENTION

FIG. 1 illustrates a single cylinder gasoline engine 10, such as the type commonly found on lawn mowers. Combustion air enters an inlet tube 14 and flows through an air cleaner 16 into the air inlet of a side-draft carburetor 18. Although the present invention is being described in the context of a side-draft carburetor, the novel concept can be applied to down-draft and up-draft carburetors, as well. The carburetor 18 receives gasoline from a tank 20 and mixes the fuel with the air flowing from the air cleaner 16. The air-fuel mixture passes from the carburetor 18 to the engine cylinder located behind spark plug 22. Combustion gases from the cylinder pass through a muffler 24.

With additional reference to FIG. 2, the carburetor 18 has a bowl 30 into which gasoline 31 flows from a hose 26 connected to the fuel tank 20. Across the upper end of the bowl 30 is a tube 32 having an inlet 34 attached to the air cleaner 16 and outlet 36 coupled to the engine cylinder. The carburetor tube 32 includes a conventional venturi 38 in which the inner diameter of the tube 32 is reduced significantly. A gasoline feed tube 40 extends vertically from the venturi 38 downward into the gasoline 31 within bowl 30. This fuel tube 40 has a solenoid valve 42 located above the level of the gasoline 31 in the bowl 30 and so that fuel residue will not build up on the valve.

The solenoid valve 42 includes a cross tube 44 in which a spool valve plunger 45 is located. The spool valve plunger 45 fabricated from a cylindrical rod of ferromagnetic material and has a smaller diameter portion 48. A compression spring 46 at one end 47 of the cross tube 44 biases the spool valve plunger 45 into a position at which the smaller diameter portion 48 is aligned with the gas feed tube 40, when the solenoid valve 42 is deenergized. Because portion 48 is smaller in diameter than the internal diameter of the cross tube 44, a passage exists at the intersection of tubes 40 and 44 enabling gasoline within the bowl 30 to be drawn upward through the gas feed tube 40 and into the venturi 38 due to the Bernoulli effect.

An electromagnet coil 50 is located around the other end 51 of the cross tube 44 that is remote from the spring 46. When energized, this electromagnet coil 50 produces a magnetic field which pushes the spool valve plunger 45 in the direction of arrow 49 compressing the spring 46. The spool valve plunger 45 slides a sufficient distance that the smaller diameter portion 48 lies outside of the gas feed tube 40. Instead, a full diameter section of the spool valve plunger 45 now is located within the gas feed tube 40 preventing any significant quantity of gas from being drawn through the feed tube into the venturi 38.

FIG. 3 illustrates the control circuit 52 for energizing the solenoid valve 42. Circuit 52 receives power from the ignition system 54 for the engine 10. The ignition system 54 may be a capacitor discharge type similar to that described in U.S. Pat. No. Re. 31,837, which description is incorporated herein by reference. This type of ignition system has a primary coil 56 and a secondary coil 58 mounted on a ferromagnetic core 57 which is adjacent to a flywheel 60 of the engine 10. Also mounted on the core 57 is a charging coil 59. The primary coil 56 and the charging coil 59 are connected to an ignition control circuit 64.

A permanent magnet 62 is attached to the flywheel 60 so as to move past the three coils 56, 58 and 59 as the flywheel rotates. As the permanent magnet approaches the coils, an electric current is induced in the charging coil 59 which charges a capacitor within the ignition control circuit 64. As the permanent magnet continues to move past the coil assembly, a voltage is induced across the primary coil 56 and triggers a switch within the ignition control circuit 64 which dumps the charge stored in the capacitor across the primary coil 56. This action produces a current pulse through the primary coil 56 inducing a high voltage across the secondary coil 58 and producing a spark in spark plug 66.

Part of the current, which in a conventional ignition system would flow through the primary coil 56, flows through a primary winding 72 of a transformer 70 in the solenoid valve control circuit 52. This current induces a current in a secondary winding 74 of the transformer 70 and produces approximately five volts across the secondary winding 72. The secondary current is rectified by diode 76 to charge a 0.47 Farad storage capacitor 78 connected in series with the diode between the terminals of the secondary winding 74 of transformer 70. A smaller 0.33 microfarad filter capacitor 80 is connected in parallel with the larger capacitor 78.

With reference to FIGS. 2 and 3, when the engine 10 is started, the spring 46 within the solenoid valve assembly 42 pushes the spool valve plunger 45 into a position in which gas can flow past the smaller diameter portion 48 into the venturi air stream through the carburetor 18. Electricity is not required to hold the valve in this position during engine starting and normal running. This is a key feature since many small gasoline engines do not utilize a battery or other source of power for starting. Thus upon commencement of engine operation, a source of electricity is not required as solenoid valve is in the normally open position. In addition, should the valve control circuit fail, the spool valve plunger 45 will fail in the normally open position allowing continued operation of the engine. Furthermore, the spool valve plunger 45 does not require a seat, against which the valve can stick in the closed position when the engine stands idle for a prolonged period.

Once the engine 10 reaches a normal running speed, pulses from the ignition system 54 applied to the transformer 70 gradually charge capacitor 78. The transformer must not load down the primary winding 56 of the ignition control circuit 54 to a degree that the spark plug 66 does not fire. This is accomplished by designing the valve control circuit 52 so that, depending upon the speed of the engine, it takes two to seven minutes before the charge on the storage capacitor 78 reaches three volts. The length of this charging period is acceptable as the solenoid valve 42 is energized only while the engine 10 is stopping, which typically does not occur for many more minutes after the engine has started. A three volt

charge on the capacitor can energize the solenoid coil 50 for approximately twenty seconds which is longer than the typical stopping interval of the engine 10. Continued operation of the engine eventually fully charges the storage capacitor 78 to about five volts. At that level the solenoid valve 42 will remain energized for a longer period of time. As will be apparent, the charge on storage capacitor 78 optimally should be sufficient to energize the solenoid valve 42 from when engine shut-off commences until the engine stops rotating.

When it is desired to shut off the engine 10, the operator closes a kill switch 82. Switch 82 is a double-pole, single-throw type having a first set of contacts 84 which connect the ignition circuit output to ground as is conventionally done to stop small gasoline engines. A second set of contacts 86 of the kill switch 82 connect the electromagnet coil 50 of the solenoid valve 42 across the storage capacitor 78. This action causes current to flow from the storage capacitor 78 through the coil 50 producing a magnetic field which pushes the spool valve plunger 45 against spring 46 a sufficient distance so that the spool valve plunger blocks gas from flowing through the feed tube 40 in the venturi 38. This action either cuts off the flow of gas to the venturi or significantly leans the air-fuel mixture. For example, an air-fuel mixture of 150 to 1 or greater is sufficient to prevent backfiring while the engine is stopping.

Immediately after the closure of the kill switch 82, the engine 10 continues to turn due to inertia. Thus, the cylinder continues drawing air through the carburetor 18 and expelling the air through the muffler 24. Since the air-fuel mixture drawn from the carburetor 18 into the cylinder and forced out into the muffler is extremely lean because of the closure of the solenoid valve 42, that mixture will not burn upon contact with the hot muffler 24. Thus, the action of the solenoid valve 42 prevents a backfire from occurring.

The charge on the storage capacitor 78 is sufficient to maintain the solenoid valve 42 energized in the closed state for a sufficient period of time so that the engine will come to rest before the valve reopens. By the time that the charge on capacitor 78 drops to a point where the solenoid coil 50 is no longer energized and the spring 48 returns the spool valve plunger 45 into the open position illustrated in FIG. 2, the engine will have stopped rotating and will no longer draw an air-fuel mixture from the carburetor. Thus, the quiescent state of the solenoid valve will be in the open position enabling the engine to be restarted without the application of any electricity to the solenoid valve.

The present system offers several advantages over other types of fuel shut-off mechanisms. First of all, the spool valve plunger 45 does not have a seat against which a valve surface rests wherein it can become stuck during a long period of non-use. In addition, the valve is biased by the spring 46 into a normally open position, thereby not requiring electricity to open the valve which would not be generated significantly during engine cranking. Thus should a failure of the shut-off system occur, it is most likely that the valve 42 will fail in the open position. As a consequence, failure of the valve will not render the engine inoperable.

The invention being claimed is:

1. In an internal combustion engine having an ignition system for igniting fuel in a cylinder, the improvement comprising:

a valve through which the fuel flows between a fuel source and the cylinder;

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an electromagnetic coil which when energized closes said valve; an electricity generating mechanism driven by the engine;

a capacitor coupled to said electricity generating mechanism to store electricity while the engine is running; and

a kill switch that is closed to shut off the engine and when closed coupling said capacitor to said electromagnetic coil which thereby activates said valve to block fuel from flowing to the engine.

2. The fuel control system as recited in claim 1 wherein said kill switch has a first set of contacts which when closed provide a conductive path between said capacitor and said electromagnetic coil, and a second set of contacts mechanically coupled to the first set of contacts and electrically connected to prevent the ignition system from igniting fuel in the cylinder when the second set of contacts is closed.

3. In an internal combustion engine having an ignition system for igniting fuel in a cylinder, a fuel control system comprising:

a transformer having a primary winding connected to an ignition coil of the ignition system, and having a secondary winding;

a storage capacitor coupled to the secondary winding of said transformer;

a normally open solenoid valve connected in a fuel path through which the fuel flows to the cylinder;

a switch coupling said solenoid valve to said storage capacitor, said switch being closed when the engine is to stop thereby causing said solenoid valve to reduce an amount of fuel flowing to the cylinder.

4. The fuel control system as recited in claim 3 further comprising a diode coupling the secondary winding of said transformer to said storage capacitor.

5. The fuel control system as recited in claim 3 further comprising a filter capacitor connected in parallel with said storage capacitor.

6. The fuel control system as recited in claim 3 wherein said solenoid valve comprises:

a feed tube through which fuel can flow;

a cross tube communicating transversely with said feed tube;

6

a spool valve plunger of ferromagnetic material slideably located within said valve tube, and having a first position in which fuel can flow through said feed tube and a second position in which less fuel can flow through said feed tube than when the spool valve plunger is in the first position;

a spring which biases said spool valve plunger into the first position; and

an coil which when energized by an electric current produces an electromagnetic field that drives said spool valve plunger into the second position.

7. In an internal combustion engine, the apparatus comprising:

a magnet attached to a member driven by the engine; a coil assembly for generating electricity as the magnet passes near to said coil assembly;

a carburetor having a bowl for fuel, a venturi and a tube for carrying fuel from the bowl to the venturi, and further having a normally open solenoid valve connected to the tube to control a flow of fuel through the tube;

a transformer having a primary winding connected to the coil assembly, and having a secondary winding; a diode;

a storage capacitor coupled in series with said diode across the secondary winding of said transformer; and

a switch coupling the solenoid valve to said storage capacitor, said switch being closed to apply electricity to said solenoid valve which causes said solenoid valve to reduce an amount of fuel flowing through the tube.

8. The fuel control system as recited in claim 7 wherein the solenoid valve comprises:

a spool valve plunger of ferromagnetic material slideably located transverse to the tube, and having a first position in which fuel can flow through the tube and a second position in which less fuel can flow through the tube than when the spool valve plunger is in the first position;

a spring which biases the spool valve plunger into the first position; and

an coil which when energized by an electric current produces an electromagnetic field that drives the spool valve plunger into the second position.

* * * * *

EXHIBIT 1008

Oct. 24, 1933.

G. L. HOLZAPFEL

1,931,698

FUEL SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed March 30, 1931

Fig. 1

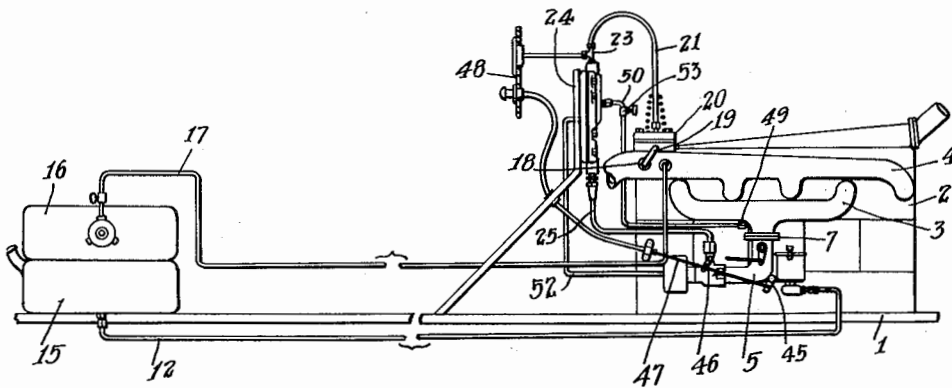
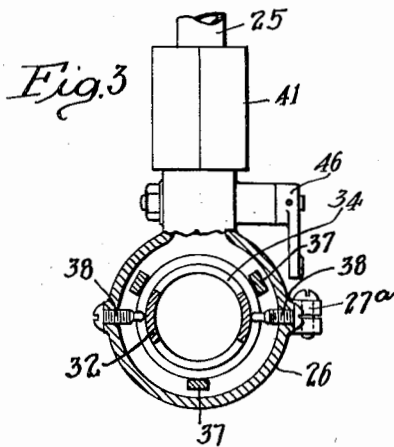
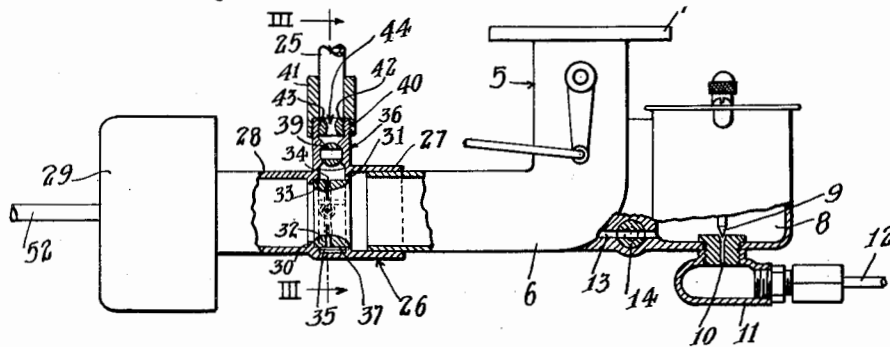


Fig. 2



Inventor.

George L. Holzappel

By

Lyon & Lyon

Attorneys

UNITED STATES PATENT OFFICE

1,931,698

FUEL SYSTEM FOR INTERNAL COMBUSTION
ENGINESGeorge 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 75 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 therein 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 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 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
85 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
90 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 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
95 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
100 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
110 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
115 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 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.

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EXHIBIT 1009

WSM

**WORKSHOP MANUAL
GASOLINE, LPG,
NATURAL GAS ENGINE**

**WG972-E2, DF972-E2,
DG972-E2**

Kubota

TO THE READER

This Workshop Manual tells the servicing personnel about the mechanism, servicing and maintenance of the WG972-E2, DF972-E2 and DG972-E2. It contains 4 parts: "**Information**", "**General**", "**Mechanism**" and "**Servicing**".

■ Information

This section contains information below.

- Safety First
- Specification
- Performance Curve
- Important Items of Exhaust Emission Regulation
- Dimension
- Wiring Diagram

■ General

This section contains information below.

- Engine Identification
- General Precautions
- Maintenance Check List
- Check and Maintenance
- Special Tools

■ Mechanism

This section contains information on the structure and the function of the unit. Before you continue with the subsequent sections, make sure that you read this section.

Refer to the latest version of Workshop Manual (Code No. 9Y021-01870 / 9Y021-18200) for the diesel engine / tractor mechanism that this workshop manual does not include.

■ Servicing

This section contains information below.

- Troubleshooting
- Servicing Specifications
- Tightening Torques
- Checking, Disassembling and Servicing

All illustrations, photographs and specifications contained in this manual are of the newest information available at the time of publication.

KUBOTA reserves the right to change all information at any time without notice.

Since this manual includes many models, information or illustrations and photographs can show more than one model.

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February, 2009

I INFORMATION

INFORMATION

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1. SAFETY FIRST

SAFETY FIRST

- This symbol, the industry's "Safety Alert Symbol", is used throughout this manual and on labels on the machine itself to warn of the possibility of personal injury. Read these instructions carefully.
- It is essential that you read the instructions and safety regulations before you attempt to repair or use this unit.

DANGER

- Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

WARNING

- Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION

- Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

■ IMPORTANT

- Indicates that equipment or property damage could result if instructions are not followed.

■ NOTE

- Gives helpful information.

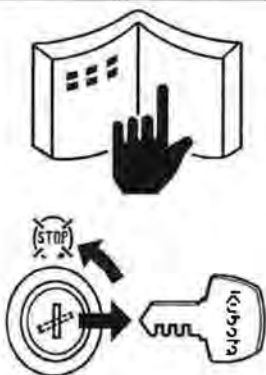
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BEFORE YOU START SERVICE

- Read all instructions and safety instructions in this manual and on your engine safety decals.
- Clean the work area and engine.
- Park the machine on a stable and level ground.
- Let the temperature of the engine decrease before you start a job.
- Stop the engine, then remove the key.
- Disconnect the battery negative cable.
- Hang a "DO NOT OPERATE" tag in the operator station.

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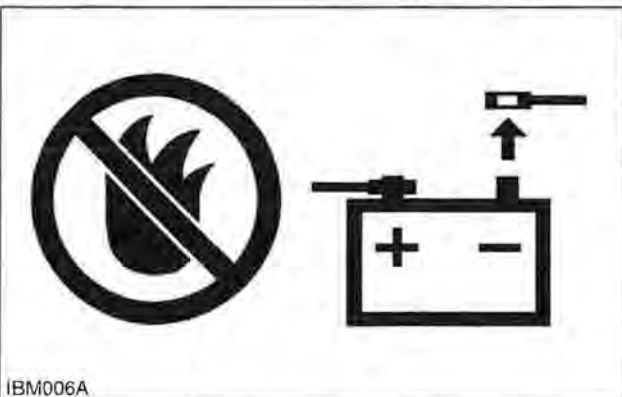
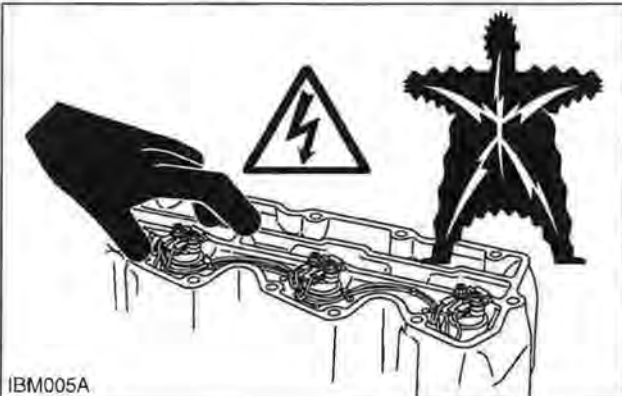
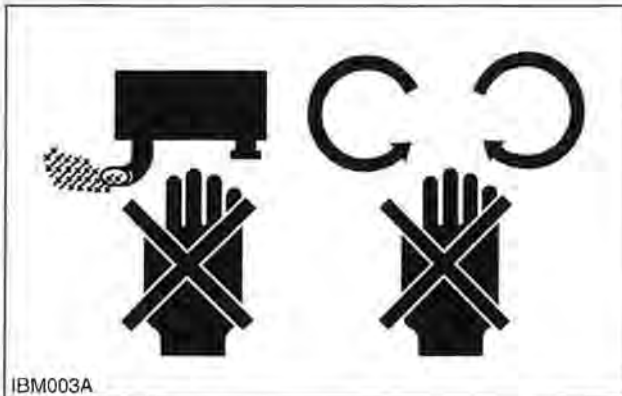
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START SAFELY

- Do not do the procedures below when you start the engine.
 - short across starter terminals
 - bypass the safety start switch
- Do not make unauthorized modifications to the engine. This can cause damage and decrease the engine life.

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OPERATE SAFELY

- Do not use the machine after you consume alcohol or medication or when you are tired.
- Put on applicable clothing and safety equipment.
- Use applicable tools only. Do not use alternative tools or parts.
- When 2 or more persons do servicing, make sure that you do it safely.
- Do not touch the hot parts or parts that turn when the engine operates.
- Do not remove the radiator cap when the engine operates, or immediately after it stops. If not, hot water can spout out from the radiator. Only remove the radiator cap when it is at a sufficiently low temperature to touch with bare hands. Slowly loosen the cap to release the pressure before you remove it fully.
- Released fluid (fuel or hydraulic oil) under pressure can cause damage to the skin and cause serious injury. Release the pressure before you disconnect hydraulic or fuel lines. Tighten all connections before you apply the pressure.
- Do not open a fuel system under high pressure. The fluid under high pressure that stays in fuel lines can cause serious injury. Do not disconnect or repair the fuel lines, sensors, or any other components between the fuel pump and injectors on engines with a common rail fuel system under high pressure.
- Put on an applicable ear protective device (earmuffs or earplugs) to prevent injury against loud noises.
- Be careful about electric shock. The engine generates a high voltage of more than DC100 V in the ECU and is applied to the injector.

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PREVENT A FIRE

- Fuel is very flammable and explosive under some conditions. Do not smoke or let flames or sparks in your work area.
- To prevent sparks from an accidental short circuit, always disconnect the battery negative cable first and connect it last.
- The battery gas can cause an explosion. Keep the sparks and open flame away from the top of battery, especially when you charge the battery.
- Make sure that you do not spill fuel on the engine.

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**KEEP A GOOD AIRFLOW IN THE WORK AREA**

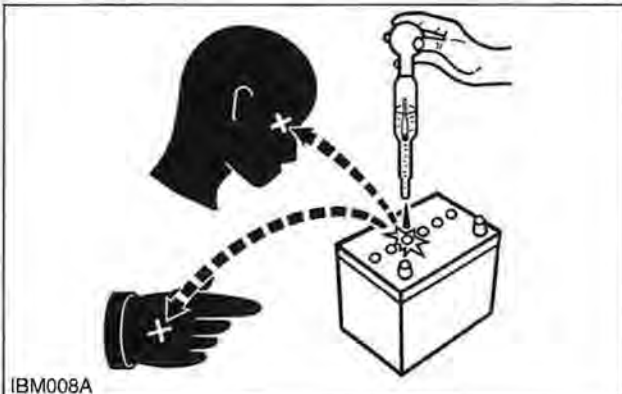
- If the engine is in operation, make sure that the area has good airflow. Do not operate the engine in a closed area. The exhaust gas contains poisonous carbon monoxide.

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**DISCARD FLUIDS CORRECTLY**

- Do not discard fluids on the ground, down the drain, into a stream, pond, or lake. Obey related environmental protection regulations when you discard oil, fuel, coolant, electrolyte and other dangerous waste.

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**PREVENT ACID BURNS**

- Keep electrolyte away from your eyes, hands and clothing. Sulfuric acid in battery electrolyte is poisonous and it can burn your skin and clothing and cause blindness. If you spill electrolyte on yourself, clean yourself with water, and get medical aid immediately.

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**PREPARE FOR EMERGENCIES**

- Keep a first aid kit and fire extinguisher ready at all times.
- Keep the emergency contact telephone numbers near your telephone at all times.

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