UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WEATHERFORD U.S., L.P.,
Petitioner,

v.

HALLIBURTON ENERGY SERVICS, INC.,
Patent Owner.

Case No. IPR2024-00990
U.S. Patent No. 11,333,007

DECLARATION OF MICHAEL R. CHAMBERS, SR. IN SUPPORT OF WEATHERFORD U.S., L.P.'S PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 11,333,007

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XII. GROUND 1 135

A. Claim 1 135

1. Claim 1[preamble]: "A completion assembly for deployment in a wellbore, the completion assembly comprising:" 135

2. Claim 1[a]: "a first sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;" 138

3. Claim 1[b]: "a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;".....143

4. Claim 1[c]: "a source of pressurized working fluid fluidly coupled to an upstream end of the transport tube of the first sand screen assembly;".....147

5. Claim 1[d]: "wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another such tat the transport tube of the second sand screen assembly is fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the first sand screen assembly; and".....152

6. Claim 1[e]: "wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen assembly has a second wall thickness, the first wall thickness being greater than the second wall thicknss." 155

B. Claim 2: "The completion assembly of claim 1, wherein a cross-sectional flow area of the packing tube nozzle opening in the first sand screen assembly is less than a cross-sectional flow area of the packing tube nozzle opening in the second sand screen asembly."....159

C. Claim 3: "The completion assembly of claim 1, wherein the first sand screen assembly further comprises a junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block; and whrein the second sand screen assembly further comprises a

junction block from which the transport tube and the packing tube extend, the plurality of nozzles being spaced apart from the junction block, wherein the distance between the first sand screen assembly junction block and the packing tube nozzles is greater in the first sand screen assembly than the distance between the second sand screen assembly junction block and the packing tube nozzles in the second sand screen assembly." 167

D. Claim 4: "The completion assembly of claim 1, wherein the number of packing tube nozzles in the first sand screen assembly is less than the number of packing tube nozzles in the second sand screen assembly."....176

E. Claim 5: "The completion assembly of claim 1, wherein the cross-sectional flow areas of the passageway in the first and second transport tubes is the same." 178

F. Claim 6: "The completion assembly of claim 1, wherein the second end of the first sand screen assembly base pipe is connected to the first end of the second sand screen assembly base pipe forming a joint therebetween, the completion assembly further compising a coupling interconnecting one end of a jumper tube to the transport tube of the first sand screen assembly, the other end of the jumper tube in fluid communication with the junction block of the second sand screen assembly whereby the jumper tube straddles the joint between the first and second sand screen assemblies."....183

G. Claim 7: "The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a pressure rating between 5000 psi and 10000 psi, and the shunt tube assembly of the second sand screen assembly has a pressure rating of o more than 5000 psi." 186

H. Claim 8: "The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a pressure rating of between 5000 and 10000 psi."....190

I. Claim 9: "The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a

pressure rating of over a select threshold and the shunt tube assembly of the second sand screen assembly has a pressure rating of no moe than the select threshold." 190

J. Claim 10: "The completion assembly of claim 1, wherein the shunt tube assembly of the first sand screen assembly has a first burst pressure and the shunt tube assembly of the second sand screen assembly has a burst pressure less than the first burst presure." 191

K. Claim 11 192

1. Claim 11[preamble]: "A completion assembly for deployment in a wellbore, the completion assembly comprising:" 192

2. Claim 11[a]: "a source of pressurized working fluid;" 193

3. Claim 11[b]: "a first sand screen assembly attached to a second sand screen assembly," 193

4. Claim 11[c]: "wherein the first sand screen assembly comprises a shunt tube assembly with a first burst pressure and the second sand screen assembly comprises a shunt tube assembly with a burst pressure less than the first burst pressure, and" 193

5. Claim 11[d]: "wherein the shunt tube assembly with the first burst pressure is fluidly coupled between the source of pressurized working fluid and the shunt tube assembly with the burst pressure less than the first burst pressure." 193

L. Claim 12: "The completion assembly of claim 11, wherein the shunt tube assembly of the first sand screen assembly is disposed to operate at pressures between 5000 psi and 10000 psi and the shunt tube assembly of the second sand screen assembly is dispose to operate at pressures of no more than 5000 psi. 194

XIII. GROUND 2 195

A. Claim 14 195

1. Claim 14[preamble]: "A method of installing a completion assembly in a wellbore, the method comprising:".....195

2. Claim 14[a]: "identifying an elongated production zone having an upstream proximal end and a downstream distal end with respect to a source of pressurized working fluid;" 196

3. Claim 14[b]: "determining a shunt tube system operating pressure associated with the proximal end of the production zone and selecting a high pressure shunt tube system based on the proximal end determined pressure;".....203

4. Claim 14[c]: "determining a shunt tube system operating pressure associated with the distal end of the production zone and selecting a low pressure shunt tube system based on the distal end determined pressure;".....205

5. Claim 14[d]: "installing a first sand screen assembly in a wellbore adjacent the distal downstream end of the elongated production zone;".....208

6. Claim 14[e]: "attaching a second sand screen assembly to the first sand screen assembly at the proximal upstream end of the elongated production zone, wherein the first sand screen assembly has the low pressure shunt tube system and the second sand scree assembly has the high pressure shunt tube system, such that a downstream end of the high pressure shunt tube system is coupled to an upstream end of the low pressure shunt tube system; and," 209

7. Claim 14[f]: "coupling the source of pressurized working fluid to an upstream end of the high pressure shunt tube system." 211

B. Claim 15: "The method of claim 14, further comprising: installing a plurality of interconnected first sand screen assemblies in a wellbore adjacent the production zone; and attaching a plurality of second sand screen assemblies to an

uppermost first sandscreen assembly upstream of the first sand screen assemblies." 216

C. Claim 16: "The method of claim 14, further comprising introducing a working fluid into the shunt systems, wherein the working fluid is pressurized in accordance with the operating pressure of the high pressure shunt tube system." 219

D. Claim 17: "The method of claim 16, further comprising injecting the working fluid into the annulus adjacent the shunt tube system so as to form a gravel pack in the annulus." 219

E. Claim 18: "The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures of 5000 psi and the low pressure shunt tube system is disposed to operate at pressures of no more than 5000." 222

F. Claim 19: "The method of claim 14, wherein the high pressure shunt tube system is disposed to operate at pressures above a select threshold and the low pressure shunt tube system is disposed to operate at pressures of no more than the select threshold." 224

G. Claim 20: "The method of claim 14, wherein installing the first sand screen assembly and attaching the second sand screen assembly include disposing the first sand screen assembly and the second sand screen assembly in a horizontal portion of the wellbor." 224

XIV. GROUND 3 225

A. Claim 21 225

1. Claim 21[preamble]: "A completion assembly for deployment in a wellbore, the completion assembly comprising:" 225

2. Claim 21[a]: "a source of pressurized working fluid;" 225

3. Claim 21[b]: "a first sand screen assembly comprising a base pipe having perforations therein and extending

between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of te sand screen, the shunt tube assembly having a transport tube and a packing tube, where each of the tubes has a passageway defined therein, the packing tube further including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area; and" 226

4. Claim 21[c]: "a second sand screen assembly comprising a base pipe having perforations therein and extending between a first end and a second ends, a sand screen disposed around a portion of the base pipe, and a shunt tube assembly disposed outwardly of the sand screen, the shunt tube assembly having a transport tube and a packing tube, the packing tube including a plurality of nozzles spaced apart from each other, wherein each of the tubes and each nozzle has a cross-sectional flow area;" 226

5. Claim 21[d]: wherein the first and second sand screen assemblies are arranged end to end relative to one another so that the base pipes are in fluid communication with one another and the transport tubes are in fluid communication with one another and the source of pressurized working fluid, the transport tube of the second sand screen assembly fluidly coupled to the source of pressurized working fluid downstream of the transport tube of the first sand screen assembly; and 227

6. Claim 21[e]: "wherein the transport tube of the first sand screen assembly is formed of a first material and the transport tube of the second sand screen assembly is formed of a second material, the first material having a greater tensile strength than the second material." 227

B. Claim 22: "The completion assembly of claim 21, wherein the transport tube of the first sand screen assembly has a first wall thickness and the transport tube of the second sand screen

assembly has a second wall thickness, the first wall thickness being reater than the second wall thickness.” 230

XV. GROUND 4.....231

A. Claim 23: “The completion assembly of claim 21, wherein the first sand screen assembly has a shunt tube assembly with a first pressure rating and the second sand screen assembly has a shunt tube assembly with a second pressure rating less than the first ressure rating.” 231

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XVII. CONCLUSION.....232

I, Michael R. Chambers, Sr., hereby declare as follows:

I. INTRODUCTION

1. I have prepared this Declaration in connection with Weatherford U.S., L.P.'s Petition for *Inter Partes* Review of U.S. Patent No. 11,333,007 (the "'007" Patent).

2. In the course of preparing this Declaration, I reviewed the '007 Patent, its prosecution file history, as well as the documents listed in Section IV and/or discussed in this Declaration.

3. I have been retained by Weatherford U.S., L.P. ("Weatherford" or "Petitioner") as an expert in the field of gravel packing oil and gas completions. I am being compensated at my normal consulting rate for my time. My compensation is not dependent on and in no way affects the substance of my statements in this Declaration. I have no financial interest in Weatherford, the '007 Patent, or the owner of the '007 Patent.

II. BACKGROUND AND QUALIFICATIONS

4. I received a B.S. in Petroleum Engineering from Texas A & M University in 1979.

5. I have over 40 years of experience in the drilling, completion, and production of all types of vertical, horizontal, conventional, and unconventional wells. I have worked worldwide on wells both onshore and offshore. I have been

associated with many industry firsts on some of the deepest, hottest, and most prolific wells in the world.

6. My extensive career in the field of oil and gas well technologies since receiving my degree can be subdivided into five stages: (1) Roughly 10 years working for a division of the Mobil Oil Corporation ("Mobil") in West Texas and New Mexico in various engineering, supervision, and field assignments relating to drilling, completing, testing, and producing wells; (2) Roughly 10 years working for Mobil in their technical service and research facility on industry firsts and challenging drilling, completing, testing, and producing wells worldwide; (3) Roughly 7 years working for Anadarko Petroleum Corporation where I was responsible for many of the company's completing and producing operations and personnel; (4) Roughly 8 years working for EXCO Resources, Inc. as Vice President Operations responsible for drilling, completing, and producing wells for the company in the United States; and (5) Roughly 8+ years consulting on various oil, gas, and geothermal related projects.

7. During my tenure at Mobil, I was personally responsible for implementing many of their designs on some of the first and most difficult horizontal, and multi-lateral wells in the world.

8. I had worked for Mobil in West Texas for 10 years when in 1990, I transferred to the Dallas technical center. That is when I began working alongside gravel packers / sand control experts Lloyd G. Jones, Charles Yeh, David Bryant, Michael Hecker, Chris Chow, Darrel Hebert, William Donlon, Eve Sprunt, Larry Myers, and many others. All of the preceding authors are seen on patents and papers (from 1989 to 2015) about gravel packing and specifically with technologies involving shunt tubes.

9. Mobil's Midway Road facility where I worked from 1990 to 2000 had numerous laboratories and a machine shop. One of the laboratories was dedicated to gravel packing where Mobil personnel analyzed:

a. Fluid systems (friction, rheology, etc.);
b. Gravel loading as well as gravel density;
c. Shunt tube designs, rectangular tubing, round tubing, and connectors;
d. Interaction between components and gravel pack fluids (like leak-off);
e. The interaction between drilling fluids and gravel pack fluids and formations;
f. Shunt tube orifice (or nozzle) angle;

g. Shunt tube orifice erosion;

h. Shunt tube orifice size;

i. Distance between shunt tube orifices; and

j. Number of shunt tube orifices.

10. Many of the above designs had to be replicated for different hole sizes, screen sizes, and pump rates. Tests were also conducted at service companies' sites, especially as lengths exceeded Mobil's facility.

11. Tommy Yates was our technician who ran most of the tests. Lloyd Jones, Charles Yeh, and the staff conducted some specific experiments for me for wells I was planning to complete open hole in Austria, Nigeria, and Equatorial Guinea, specifically on the interaction of the drilling fluid and completion fluids.

12. Mobil was very proud of the Alternate Path® sand screen shunt tube technology, and trademarked and licensed the associated products and technology to numerous service companies.

13. In 1994, I prepared a paper at The Mobil International Horizontal Well Conference detailing prepacked screens I ran for sand control in the Ubit 64I (first horizontal well offshore West Africa). In 2000, I prepared SPE 58743 (EX1019, Ex. N) detailing gravel packing horizontal wells in West Africa using shunt tubes in the SPE Formation Damage Symposium in Lafayette, Louisiana. The focus of gravel

packing was to prevent formation collapse and the movement of formation sand to the sand screen and permit use of a normal screen (unlike the expensive prepacked screens I had run in Nigeria), which wouldn't be plugged by the few fines that move through the gravel pack.

14. Between 1989 and 2017, the group I had worked with were awarded at least 30 patents and presented 14 papers on Alternate Path® Technology. A listing is provided in the Appendix.

15. I have been heavily involved with the Society of Petroleum Engineers (SPE), where I have organized and run meetings on the latest developments and theories relating to Horizontal Completions, Horizontal Stimulations, and Multi-Lateral Well Construction, and Completion methods. I was a distinguished lecturer for the SPE and a reprint chairman. I have presented papers, run forums and workshops, and conducted training sessions for SPE as well as the American Association of Petroleum Geologists (AAPG).

16. I am past president of the Completion Engineering Association (CEA) which was heavily involved with funding research and promoting new and innovative completion techniques and methods.

17. I was a founding member of TAML (Technology for the Advancement of Multi-Laterals), which is a group of industry experts classifying, promoting, and understanding multi-lateral (or horizontal) wells.

18. I was Mobil's Completion Representative in MoBPTeCh—a consortium of 4 major oil production companies (Mobil, BP, Texaco, and Chevron) in partnership with the Texas A&M Petroleum Engineering Department to research and test new emerging technologies in drilling and completion (*e.g.*, technologies like Multi-Lateral Junctions, expandables, and downhole laser welding). Working with this group I received Texaco's Chairman's award for assistance in their first difficult Level 4 Multi-lateral well.

19. From the various executive positions that I have held in both large and small corporations, I have gained a thorough appreciation of the economics of well drilling and completions.

20. I am an author or co-author of numerous publications and presentations relating to oil and gas production and in particular well completions methods. A sample of my publications and presentations are listed in my curriculum vitae. EX1004.

21. I am familiar with the procedures involved in patenting inventions, and I am a named inventor on the following U.S. patents:

a. Patent No. 5,406,983, entitled *Corrosion-Resistant Composite Couplings and Tubular Connections*, co-invented by Chambers and Sukup and assigned to Mobil Oil Corporation.

b. Patent No. 5,443,119, entitled *Method for Controlling Sand Production from a Hydrocarbon Producing Reservoir,* co-invented by Chambers and Sprunt and assigned to Mobil Oil Corporation.

c. Patent No. 5,462,118, entitled *Method for Enhanced Cleanup of Horizontal Wells*, co-invented by Jennings and Chambers and assigned to Mobil Oil Corporation.

d. Patent No. 5,960,873, entitled *Producing Fluids from Subterranean Formations Through Lateral Wells*, co-invented by Alexander, Chambers, and Pickett and assigned to Mobil Oil Corporation.

e. Provisional Application, entitled *Controlling Tensile-Splitting and Hydro-Shearing Parameters during Completion of Enhanced Geothermal System Wells*, co-invented by Chambers, Lines, Pate, El Rabaa, and Pearson.

22. Further details regarding my qualifications, including my employment and academic history, are set forth in my curriculum vitae. EX1004.

III. COMPENSATION

23. I am being compensated at a rate of $295 USD per hour for my time working on this case and am being reimbursed for reasonable expenses incurred in providing my services in this case. My compensation is not dependent upon my testimony or the outcome of the case.

IV. MATERIALS CONSIDERED

24. I have reviewed the ’007 Patent (EX1001) and its file history (EX1002). Additionally, and in addition to any other documents cited or referenced herein, I have reviewed the following materials in preparing this Declaration, which are listed below:

U.S. Patents
2,905,245
4,945,991
7,661,476
5,588,487
8,839,861
5,113,935
5,476,143
7,938,184
5,890,533
9,797,226
4,629,218
6,588,506

Printed Publications
Chambers et al., *Successful Application of Oil-Based Drilling Fluids in Subsea Horizontal, Gravel-Packed Wells in West Africa*, Society of Petroleum Engineers, SPE 58743 (Feb. 2000)
Tibbles et al., *Design and Execution of a 3000-ft Horizontal Gravel-Packed Completion (A Kazakhstan Case History*), Society of Petroleum Engineers, SPE 64410 (Oct. 2000)
Saebi, *The Evolution of Completion Designs Using Alternate Path (Shunt-Tubes) Technology*, Society of Petroleum Engineers, SPE 155129 (March 2012)
Jones et al*., Alternate Path Gravel Packing*, Society of Petroleum Engineers, SPE 22796 (Oct. 1991)
Hurst et al., *Alternate Path Completions: A Critical Review and Lessons Learned From Case Histories With Recommended Practices for Deepwater Applications*, Society of Petroleum Engineers, SPE 86532 (Feb. 2004)
Bonner et al., *Design and Validation of an Improved Shunt Tube System*, Society of Petroleum Engineers, SPE 169440 (May 2014)
Hecker et al., *Extending Openhole Gravel Packing Capability: Initial Field Installation of Internal Shunt Alternate Path Technology*, Society of Petroleum Engineers, SPE 135102 (Sept. 2010)
Barry et al., *Openhole Gravel Packing With Zonal Isolation*, Society of Petroleum Engineers, SPE 110460 (Nov. 2007).
Myers et al., *Case History in Achieving High Rate Producers in Sub Sea Gravel Packed Completions*, Society of Petroleum Engineers, SPE 39433 (Feb. 1998)
Bryant and Jones, *Completion and Production Results From Alternate-Path Gravel-Packed Wells*, Society of Petroleum Engineers, SPE 27359 (Feb. 1994)
Yeh et al., *Unlocking the Limits of Extreme Length in Alternate Path Gravel Packing*, International Petroleum Technology Conference, IPTC 12549 (Dec. 2008)
Jones et al., *Gravel Packing Horizontal Wellbores with Leak-Off Using Shunts*, Society of Petroleum Engineers, SPE 38640 (Oct. 1997)
Lagrone and Rasmussen, *A New Development in Completion Methods —The Limited Entry Technique*, Journal of Petroleum Technology, SPE 530 (July 1963)
ASTM A554-16: Standard Specification for Welded Stainless Steel Mechanical Tubing (2016)
ASTM A500/A500M-13: Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Round and Shapes (2013)

Printed Publications
API Technical Report 5C3, published in December 2008 with an Addendum in October 2015
Fischer Group Part Number List (Rev. date 2016)
Halliburton Cementing Tables (1979)
Introduction to Otis Multi-Position Gravel Pack System, Otis Engineering Corporation, Technical Manual 2004/88
Johnson Oil and Gas Well Screens Catalog (1991)
ExxonMobil Awards Alternate Path Technology License to Weatherford, ExxonMobil Press Release (Aug. 27, 2013)

V. RELEVANT LAW

25. I am not an attorney. For the purposes of this Declaration, I have been informed about certain aspects of the law that are relevant to my opinions. My understanding of the law is summarized below.

26. I have been informed and understand that determining whether a patent claim is valid requires a two-step analysis. First, the claim must be construed. Second, the properly construed claim must be compared to the prior art.

27. I have been informed and understand that in the context of an *Inter Partes* review, claims are construed from the perspective of a person of ordinary skill in the art at the time of the purported invention (which is approximated based on the earliest priority date of the patent). I understand that absent disclaimer or express definition, claim terms are given their plain and ordinary meaning to a person of

ordinary skill in the art in view of the specification and file history and knowledge of a person of skill in the art.

28. I have been informed and understand that a patent claim is invalid if it is anticipated by the prior art (*i.e.*, lacks novelty). I understand that anticipation requires the disclosure in a single prior art reference of every limitation of the claim, expressly or inherently, with the limitations arranged as specified in the claim.

29. I have been informed and understand that, although not expressly disclosed, subject matter may be inherently disclosed in a prior art reference where that subject matter is necessarily present in the expressly disclosed subject matter and would be understood to be so by those of ordinary skill in the art. I understand that the fact that a certain result or characteristic may occur or be present in the prior art is not sufficient to establish the inherency of that result or characteristic.

30. I have been informed and understand that a patent claim is obvious and therefore invalid if the claimed subject matter, as a whole, would have been obvious to a person of ordinary skill in the art as of the priority date of the patent based on one or more prior art references and/or the knowledge of one of ordinary skill in the art. I understand that an obviousness analysis must consider (1) the scope and content of the prior art, (2) the differences between the claims and the prior art, (3) the level of ordinary skill in the pertinent art, and (4) secondary considerations, if any, of non-

obviousness (such as unexpected results, industry praise, commercial success, long-felt but unmet need, failure of others, copying by others, and skepticism of experts).

31. I understand that a prior art reference may be combined with other references to disclose each element of the invention under 35 U.S.C. § 103. I understand that a reference may also be combined with the knowledge of a person of ordinary skill in the art, and that this knowledge may be used to combine multiple references. I further understand that a person of ordinary skill in the art is presumed to know the relevant prior art. I understand that the obviousness analysis may take into account the inferences and creative steps that a person of ordinary skill in the art would employ.

32. In determining whether a prior art reference could have been combined with other prior art or other information known to a person having ordinary skill in the art, I understand that the following principles may be considered:

a. A combination of familiar elements according to known methods is likely to be obvious if it yields predictable results;

b. The substitution of one known element for another is likely to be obvious if it yields predictable results;

c. The use of a known technique to improve similar items or methods in the same way is likely to be obvious if it yields predictable results;

d. The application of a known technique to a prior art reference that is ready for improvement can be obvious if it yields predictable results;

e. Any need or problem known in the field and addressed by the reference can provide a reason for combining the elements in the manner claimed; and

f. The proper analysis of obviousness requires a determination of whether a person of ordinary skill in the art would have a "reasonable expectation of success" – not "absolute predictability" of success – in achieving the claimed invention by combining prior art references.

33. I am informed that whether a prior art reference invalidates a patent claim as obvious is determined from the perspective of a person of ordinary skill in the art. While there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior

art as a whole, or individually, as filtered through the knowledge of one skilled in the art. In addition, the inferences and creative steps a person of ordinary skill in the art would employ are also relevant to the determination of obviousness.

34. When a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field or in another. If a person of ordinary skill in the art can implement a predictable variation and would see the benefit of doing so, that variation is likely to be obvious. In many fields, there may be little discussion of obvious combinations, and in these fields market demand – not scientific literature – may drive design trends. When there is a design need or market pressure and there are a finite number of predictable solutions, a person of ordinary skill in the art has good reason to pursue those known options.

35. It is my understanding that there is no rigid rule that a reference or combination of references must contain a "teaching, suggestion, or motivation" to combine references. But, I understand that the "teaching, suggestion, or motivation" test can be a useful guide in establishing a rationale for combining elements of the prior art. This test poses the question as to whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention, and it seeks to counter impermissible hindsight analysis.

VI. LEVEL OF ORDINARY SKILL IN THE ART

36. Based on my review of the '007 Patent and my background and experience in the field of horizontal well completions, it is my opinion that one of ordinary skill in the art ("POSITA") as of the claimed priority date (June 22, 2018) would be someone with a bachelor of science degree in mechanical or petroleum engineering or a similar technical discipline, with at least five years of experience in oil or gas well drilling, completion, and/or subsurface production operations or in technical support of such operations including at least some experience in unconsolidated formations utilizing sand control methods and means. Also, in my opinion, additional education in a relevant technical discipline can compensate for less experience in the relevant field and *vice versa*. My opinion would not change if the '007 Patent were not entitled to the June 22, 2018 date but instead were only entitled to the March 28, 2019 PCT filing date.

37. I have been informed and understand that claim construction is viewed from the perspective of a person of ordinary skill in the art in question at the time of the invention. I have been asked to assume that the filing date of June 2018 is the proper priority date for the '007 Patent and thus the relevant date for determining a person of ordinary skill in the art. Throughout this declaration, when I refer to one of ordinary skill, I'm referring to one of ordinary skill in the art as of June 2018

unless otherwise specified. But my opinions would not change if the ’007 Patent priority date were instead the March 28, 2019 PCT filing date.

38. Based on my education and experience, I am familiar with the level of knowledge that one of ordinary skill would have possessed during the relevant period of time.

39. In reaching this opinion as to the qualifications of the hypothetical person of ordinary skill in the art, I have considered the types of problems encountered in the art, the prior art solutions to those problems, the rapidity with which innovations are made, the sophistication of the technology, and the educational level of active workers in the field.

40. By the claimed priority date of the ’007 Patent, I was a person who had more than ordinary skill in the art.

VII. CLAIM CONSTRUCTION ANALYSIS

41. In my opinion, the claims are unpatentable in view of the grounds discussed below based on the plain and ordinary meaning of the claim terms in view of the ’007 Patent’s specification and file history. I have been informed and understand that the plain and ordinary meaning of a claim term is the meaning according to a person of ordinary skill in the art who reads the claim term in the context of the particular claim as well as the entire patent, including the specification.

42. With this in mind, I have interpreted the claims according to their plain and ordinary meaning as I believe they would be understood by a person of ordinary skill in the art in June 2018, which would not change if the relevant date were March 2019. Should Halliburton propose any constructions for any terms in the '007 Patent, I may be asked to respond to those constructions at that time.

VIII. OIL AND GAS DRILLING BACKROUND

A. Well Drilling and Completion

43. Drilling a well generally includes drilling a hole to construct a wellbore in a geological formation with oil or gas reserves. The wellbore starts out vertical and can continue vertically or transition to horizontal. Below I provide an annotated illustration of a horizontal wellbore. The vertical to horizontal transition point in the wellbore is referred to as the "heel" and the end of the wellbore is called the "toe."

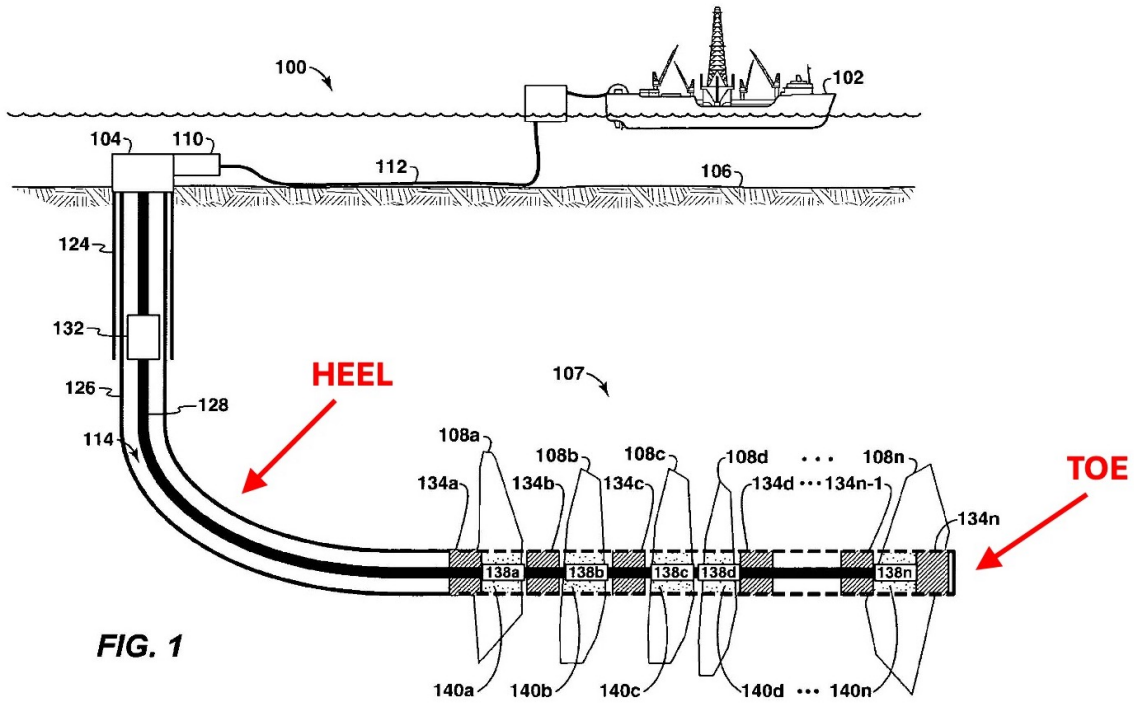


FIG. 1

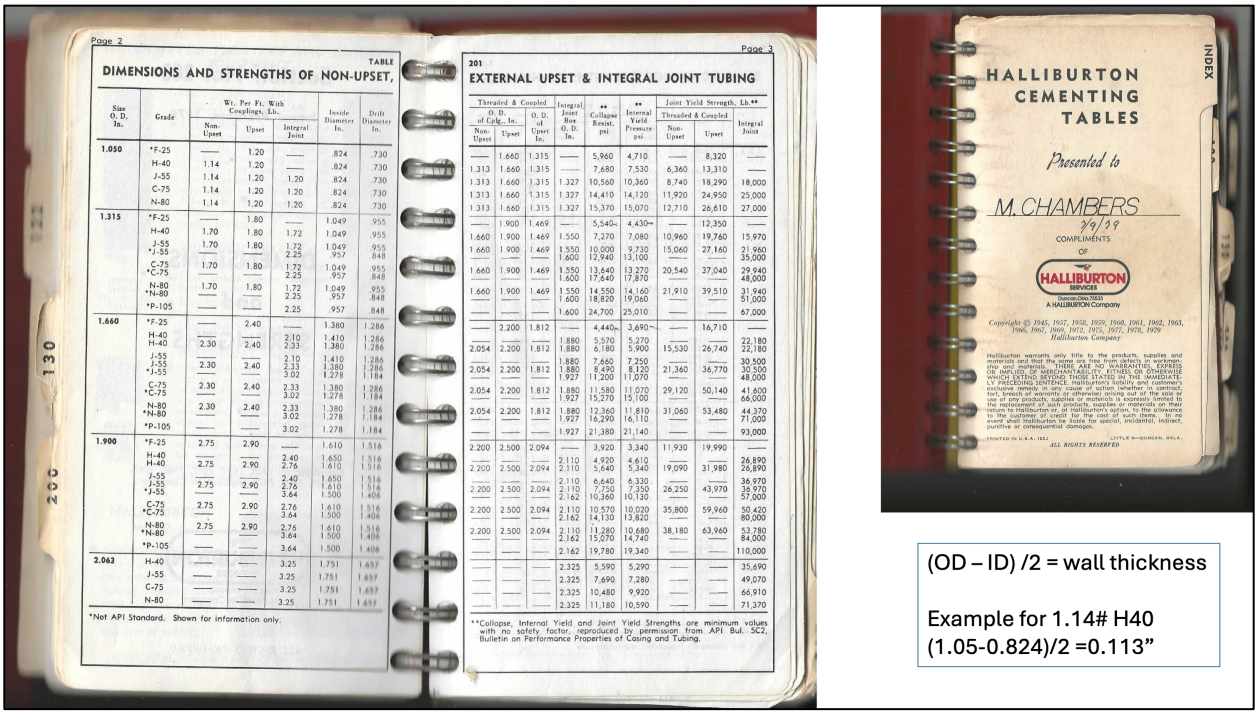
EX1010 at Fig. 1 (annotated).

44. After the hole is drilled, the hole is typically lined with a steel casing. Specifically, at selected intervals determined by geologic considerations, tubular pipes referred collectively to as "casing" (a separate length of tubular or pipe is referred to as a "joint" and is conventionally 40 feet in length) are joined together typically using threads and will be run from the well's total depth ("TD") drilled to the surface. When several joints of casing are connected, it is often called a "string" of casing. When a string of casing does not extend all the way back to surface, but instead is suspended from inside the bottom of a prior casing string, it is called a

"liner" or "liner string." The casing size, thickness, thread, and metallurgical properties are determined by each well condition.

45. The process of drilling and casing off geologic formations is repeated in a telescoping manner until the final depth objective of the well is met. A typical well will start with the conductor casing string (to prevent undermining the rig), followed by the surface string (to protect ground water), followed by the intermediate casing string (to case off undesirable zones), and will finish with the flow casing string (to accommodate the production fluids). Thus, the typical process of constructing a well includes one or more "strings" of casing secured together at their ends by threaded connections. This process results in drilled intervals, whereby each new string of casing must be lowered through the previously installed casing. Therefore, the casing of the lower interval must necessarily be a smaller diameter than the casing of the upper interval, which creates the well-known nested arrangement of casing diameters decreasing in downward direction. In the reservoir the completion may consist of setting and cementing casing (which is perforated) or leaving it as "open hole" with no casing. If the reservoir containing the oil and/or gas is composed of a loosely cemented sandstone, then the gravel pack designs described below would be used to prevent hole collapse and sand migration which could plug or erode downhole and surface equipment.

46. A POSITA involved with drilling and completing would understand the metallurgical properties and strength of tubulars. Shown below is a handbook I used extensively in my career. It is opened to a section on dimensions and strengths of casing. An 1.050" outer diameter ("OD") tubing with an inside diameter ("ID") of 0.824" would have a wall thickness of 0.113" according to the following formula: (OD – ID)/2. The amount and type of heat treatment would then determine the grade and thus strength and pressure ratings in burst and collapse.

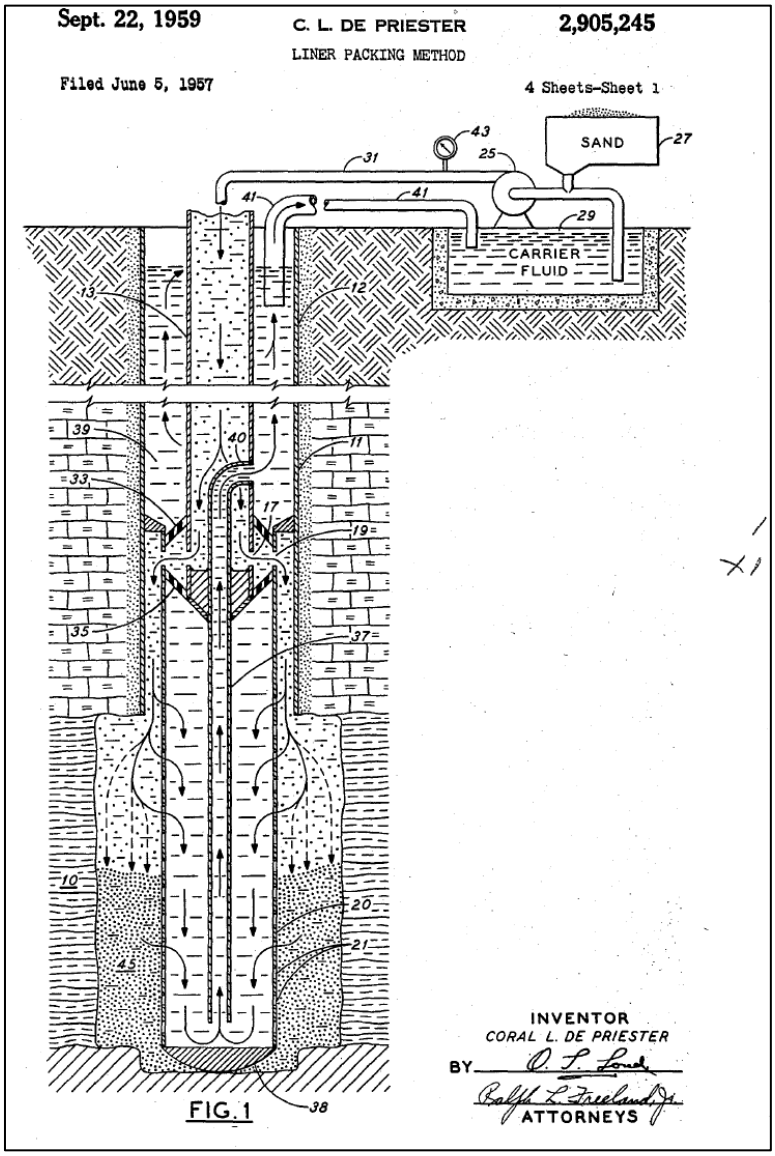


EX1036 at 3.

47. I received the Halliburton Cementing Tables from a Halliburton sales representative on or about July 9, 1979 very shortly after starting my career at Mobil.

B. Gravel Packing Overview

48. Gravel packing wellbores to prevent formation movement/plugging/damage to completion equipment began pre-1950. The basic process is shown in U.S. Patent 2,905,245 (EX1039), filed in 1957 and entitled *Liner Packing Method*, whereby a carrier fluid transported sand (gravel) down the annulus of the well between the open hole formation (or perforated casing) and a screen or slotted pipe filling the annulus with packed gravel and preventing formation particles from entering the production well stream. EX1039 at 1:15-32. The gravel pack is porous, and oil and gas were still able to enter in the perforated base pipe. As shown below, a crossover tool 40 diverted gravel slurry fluid from the tubing to the completion zone annulus 45 while simultaneously diverting carrier fluid from inside the screens (with gravel removed by the screen) to the tubing annulus 39 for return to the surface. *Id.* at 5:54-58. A packer (not numbered) was used to anchor the liner and isolate the annulus. *See id.* at 5:62-67. Swab cups 33 and 35 were used to isolate the injection string. *Id.* at 5:36-41.



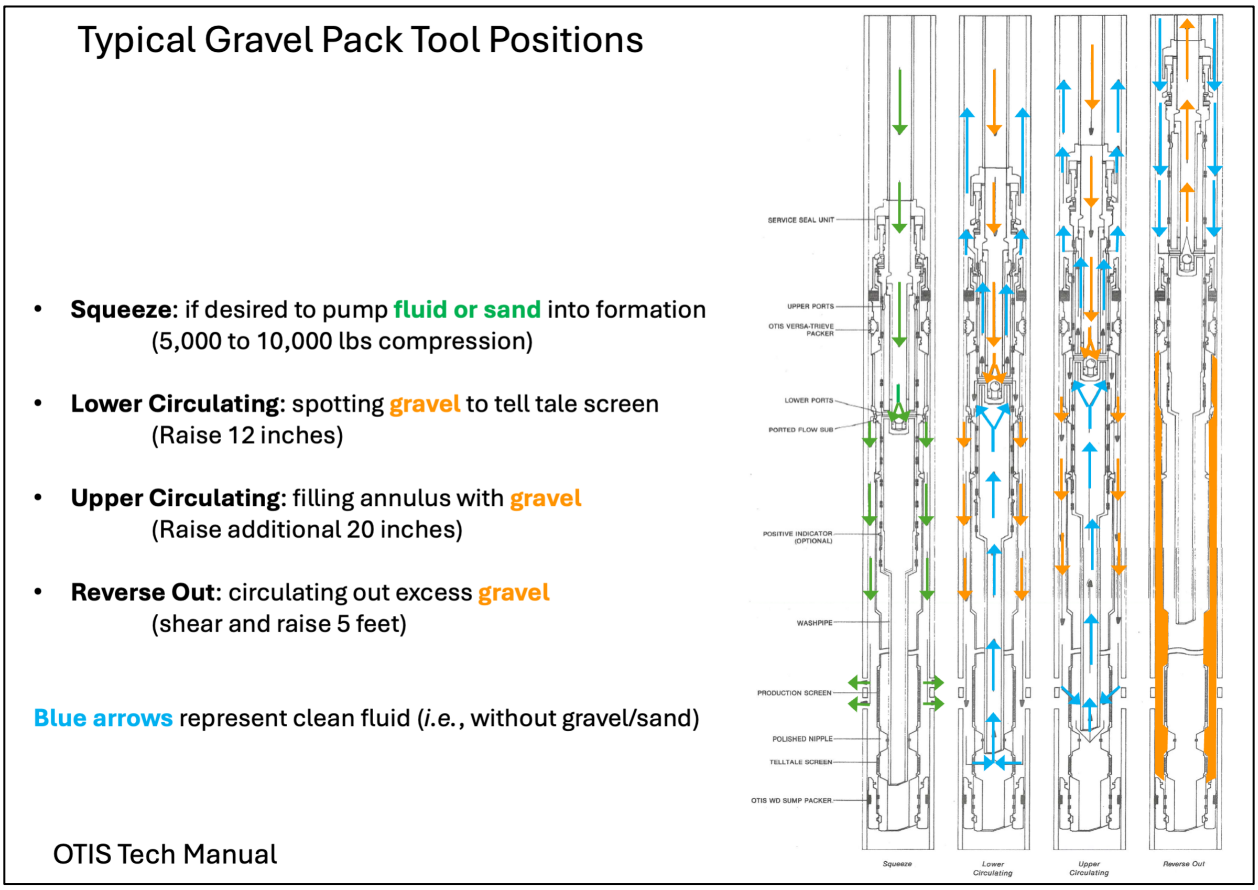
EX1039 at Fig. 1.

49. Sand screens are installed and gravel packing is performed in producing zones where oil and/or gas are present in the formation but may carry sand with them into production tubing. EX1039 at 1:41-44 ("One of the most perplexing problems in producing oil and gas from a sand formation that is loosely consolidated is how to prevent sand from running into the well bore under normal fluid flow

conditions."), 3:12-21 ("With the pack sand selected and mixed in accordance with the foregoing, it is then positioned ***between a liner set in the well opposite the formation whose sand flow is to be controlled***. The pack sand is desirably hydraulically rammed under pressure in the annular space between the walls of the well bore and the liner. The liner may be pre-slotted with a series of openings proportioned in size and in proper relation to the size distribution of the sand pack, such that the pack sand will not flow through the liner openings." (emphasis added)).

50. With some improvements to fluids, screens, gravel, and running tools this was the same basic system in use in the late 1990's and even today on non-alternate path gravel-packed wells. Numerous companies have researched and published literature in the area of gravel packing, including at least: Mobil, ExxonMobil, Chevron, Texaco, Halliburton, Schlumberger, Weatherford, University of China, BJ Services, MI-Drilling Fluids, BP, Amerada Hess, and CNR International.

51. Shown below is a typical gravel pack assembly. You will note this particular assembly was designed for four different positions:



See EX1037 at 5-6 (annotated).

52. I received the Otis Sand Control Customer Manual sometime between 1990 and 2000 from a Halliburton-Otis salesperson in Dallas, Texas while working for Mobil.

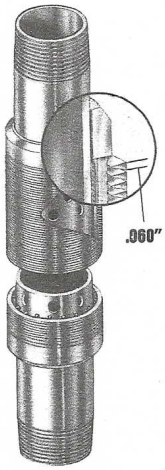
C. Wire Wrapped Screen Technology

1. Conventional

53. By 1991, wire wrapped screen technology (as shown below) was well evolved and numerous tubular and mesh sizes were available as well as PREPACK

versions that incorporated resin coated sand in addition to the screen. The following figures on screens were reproduced from a Johnson Oil and Gas Well Screens Catalog published in 1991.

SUPER-WELD™ Screens



Superior screen performance provides total sand control.

Key design features make SUPER-WELD™ screens a better choice than other pipe-base screens for excellent sand control.

Their jackets are fabricated with very narrow-faced screen wire that has been welded to a large number of vertical support rods. This creates more welds per square inch to resist installation stress which may cause slot deformation in lower-quality screens. Boss rings provide double-welds for maximum strength and protection of the screen jacket. And a precise hole pattern in the pipe base, produced by computer-controlled multi-spindle perforating machines, maintains structural integrity and ensures flow performance.

This superior construction means SUPER-WELD screens have closer slot tolerances, more open area, and a rounder shape. Potential wash-outs—due to necked wires, over-sized slots and pin-holes often found in other screens—are eliminated. The net result is more reliable sand control.

SUPER-WELD™ and SUPER-WELD HT™ Screen specifications

	PIPE BASE								SCREEN JACKET							
Size (in.)	Pipe OD in.	Wt. lbs./ft.	Pipe ID in.	Thread ends	Coupling OD in.	No. of holes per ft. of pipe	Diam. of each hole in.	Total area of holes Sq. in./ft.	Screen jacket OD in.	Square inches of open area per ft. of screen for gauge opening listed .008 in.	.010 in.	.012 in.	.020 in.	Blank Length * inches	Approx. shipping weight lbs./ft.	No. of Rods
¾	1.050	1.48	0.742	14NPT	1.313	72	¼	3.53	1.55	6.8	8.2	9.6	14.4	6	2.7	10
¾S	1.050	1.48	0.742	14NPT	1.313	72	¼	3.53	1.37	7.5	9.1	10.5	15.4	6	2.9	10
1	1.315	2.18	0.957	NU 10RD	1.660	60	5/16	4.60	1.82	8.0	9.7	11.3	16.9	6	3.6	12
1S	1.315	2.18	0.957	NU 10RD	1.660	60	5/16	4.60	1.63	8.9	10.8	12.5	18.3	6	3.8	12
1¼	1.660	2.30	1.380	NU 10RD	2.054	72	5/16	5.52	2.16	9.4	11.5	13.4	20.1	6	4.5	14
1½	1.900	2.75	1.610	NU 10RD	2.200	84	5/16	6.44	2.40	10.5	12.7	14.9	22.3	6	5.2	16
2 1/16	2.063	3.25	1.751	1.9EU 10RD	2.500	84	5/16	6.44	2.56	11.2	13.6	15.9	23.9	6	6.0	18
2⅜	2.375	4.60	1.995	NU 10RD	2.875	96	⅜	10.60	2.88	12.6	15.3	17.8	26.8	6	7.6	22
2⅞	2.875	6.40	2.441	NU 10RD	3.500	108	⅜	11.93	3.38	14.8	17.9	20.9	31.5	6	10.0	26
3½	3.500	9.20	2.992	NU 10RD	4.250	108	½	21.21	4.00	17.5	21.2	24.8	37.3	6	12.9	30
4	4.000	9.50	3.548	NU 8RD	4.750	120	½	23.56	4.50	19.7	23.9	27.9	41.9	6	13.9	36
4½	4.500	11.60	4.000	LTC CSG	5.000	144	½	28.27	5.00	21.8	26.5	31.0	46.5	6	14.3	40
5	5.000	15.00	4.408	LTC CSG	5.563	156	½	30.63	5.51	24.1	29.2	34.1	51.3	9	18.2	44
5½	5.500	15.50	4.950	LTC CSG	6.050	168	½	32.99	6.01	26.3	31.9	37.2	55.9	9	19.8	48
6⅝	6.625	24.00	5.921	LTC CSG	7.390	180	½	35.34	7.14	31.2	37.9	44.2	66.5	9	31.3	58
7	7.000	23.00	6.366	LTC CSG	7.656	192	½	37.70	7.52	32.9	39.9	46.6	70.0	9	30.5	62
7⅝	7.625	26.40	6.969	LTC CSG	8.500	204	½	40.06	8.15	35.6	43.3	50.5	75.9	9	34.8	72
9⅝	9.625	36.00	8.921	LTC CSG	10.625	264	½	51.84	10.17	44.4	54.0	63.0	94.7	9	46.1	82

*Length of blank pipe from top of screen to first thread.

- SUPER-WELD screens are available in a variety of materials to work in different sub-surface environments.
- 304 stainless steel screen jackets and perforated pipe in J/K 55 and L/N 80 material are stocked for fast response to urgent requirements.

8

EX1038 at 8.

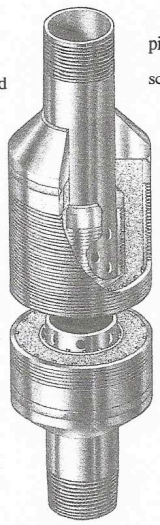
2. Prepacked

54. Screens were also available in a pre-pack stand-alone design or in combination with conventional gravel packing as shown below. The addition of the resin coated sand provides an additional barrier to the wire wrapped screen. Many times, this was the only tool installed in a wellbore to prevent sand migration, as I show below:

PRE-PACK™ Screens

Extra protection in hard-to-pack wells.

PRE-PACK™ screens provide an added level of safety against voids that can occur in highly deviated completions. They are also effective in completions of questionable or partially-depleted zones, and multi-zone wells with two zones that are too close together to allow for a sufficient gravel pack in the lower zone.



Each PRE-PACK screen consists of a drilled pipe base inside two concentric stainless steel screen jackets that have been packed with resieved silica sand. The outer screen is longer to guard against any possible settling.

Specify PRE-PACK screens when conventional gravel packing methods are difficult or impractical, and when restrictions on casing size and planned use of wireline tools are not key well completion parameters.

PRE-PACK™ Screen specifications

Pre-Pack Size (in.)	Outer Screen O.D. (in.)	Annulus (inches)	Base Pipe				Thread Ends	Est. Shipping Wt. (lb./ft.)
			Size (in.)	PPF (lb./ft.)	I.D. (in.)	Holes/ft. No. (Diam.)		
1½ x 4	4.00	.660	1½	2.75	1.610	84 (5/16 ϕ)	1.900 NU 10RD	13.5
2⅜ x 4	4.00	.420	2⅜	4.6	1.995	96 (⅜ ϕ)	2⅜ NU 10RD	16.0
2⅞ x 4½	4.50	.310	2⅞	6.4	2.441	108 (⅜ ϕ)	2⅞ NU 10RD	18.0
2⅞ x 5	5.00	.670	2⅞	6.4	2.441	108 (⅜ ϕ)	2⅞ NU 10RD	20.4
3½ x 5½	5.51	.620	3½	9.2	2.992	108 (½ ϕ)	3½ NU 10RD	24.3
3½ x 6	6.01	.870	3½	9.2	2.992	108 (½ ϕ)	3½ NU 10RD	28.4

- Screens are 304 stainless steel or 316L stainless steel on J/K 55 or L/N 80 drilled pipe. Other sizes and materials are available upon request.
- Standard overall lengths are 6, 10, 20 and 30 ft. Corresponding screen lengths are 4, 8, 18 and 28 ft.
- Available with resin coated or loose sand.

EX1038 at 6.

3. Shrouded Screens

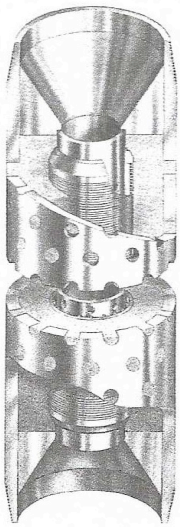
55. If the pre-pack screens were to be run in an open hole, an ULTRA-PACK Screen version was available to prevent damage to the external screen by employing an outer shroud:

ULTRA-PACK™ Screens

The choice for open-hole completions and workovers.

Install Ultra-Pack™ screens in open-hole completions for effective sand control, without the expense and time involved in placing a gravel pack. Its baked-resin sand construction has a large open area to permit maximum fluid flow with a minimum pressure drop.

You can also run ULTRA-PACK on coil tubing or wireline to dramatically reduce costs of sand control in workovers. ULTRA-PACK is often used in difficult cased-hole completions when you need extra protection against damage to the screen surface.



- Resieved sand, sized to industry standards, withstands bottom-hole fluids, acids, and temperatures to 650°F.
- Computer-controlled hole pattern and heavy-duty construction maintains assembly strength. Suitable for installation to 15,000 feet.
- Cone fittings at each end facilitate entry and exit of wireline and other running tools.
- Flush connections eliminate gravel bridging at section joints.

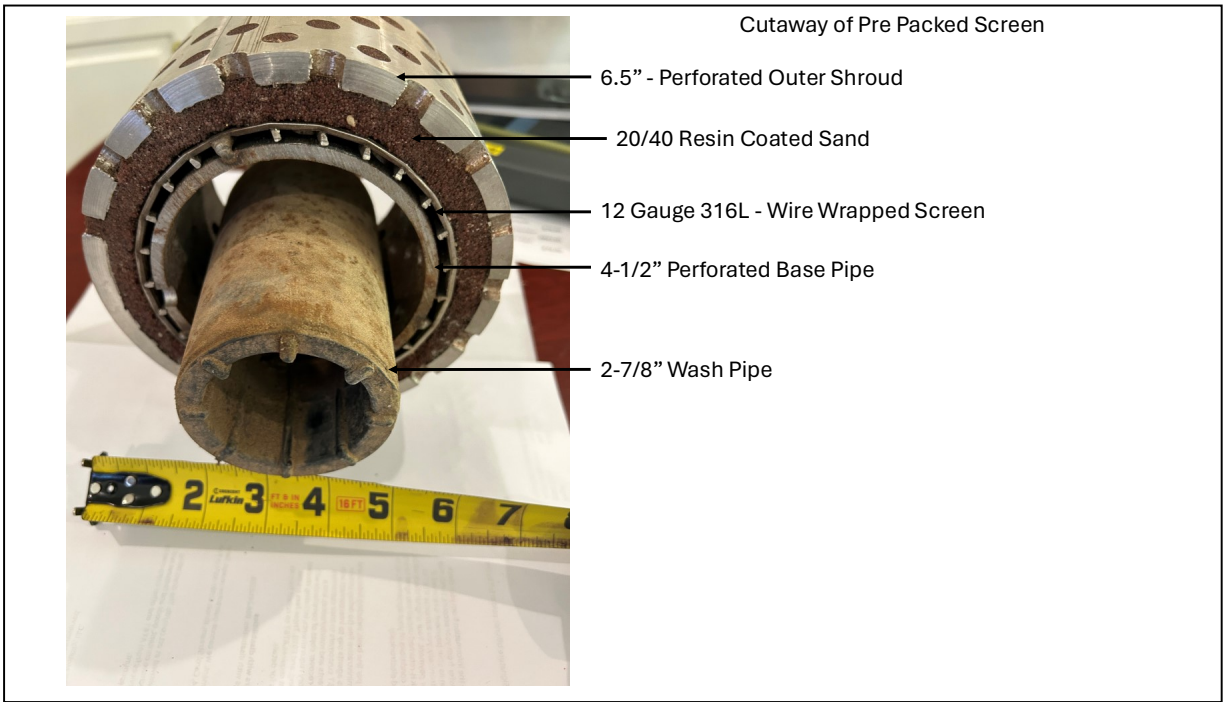
ULTRA-PACK™ Screen specifications

Ultra-Pack Size (inches)	O.D. (inches)	I.D. (inches)	Outer Casing Grade	Outer Casing lbs./ft.	Connection	Approx. Wt. (lb./ft.)	Annulus (inches)	Holes per ft. No. (Diam.)	Casing Inlet Area (in.²/ft.)
1¼ x .70	1.660	0.700	J-55	2.3	FJ	3.4	.215	72 (5/16)	5.52
2 1/16 x .70	2.063	0.700	J-55	3.25	FJ	5.1	.400	84 (5/16)	5.68
2⅞ x 1S	2.875	1.380	J-55	6.4	FJ	11.9	.310	108 (⅜)	11.93
3½ x 1¼	3.500	1.380	J-55	9.2	FJ	15.9	.406	108 (½)	21.21
4 x 2 1/16	4.000	1.751	K-55	9.5	FJ	18.6	.484	120 (½)	23.56
4½ x 2⅜	4.500	1.995	K-55	9.5	FJ	23.4	.596	144 (½)	28.27
5 x 2⅞	5.000	2.441	K-55	15.0	FJ	29.5	.504	156 (½)	30.63
5½ x 3½	5.500	2.992	J-55	15.5	FJ	34.2	.465	168 (½)	32.99

- Internal screen is 304 stainless steel or 316L stainless steel, drilled pipe is J/K 55 or L/N 80 material.
- Standard lengths are 5, 10, 15 and 20 ft., except 1¼ and 2 1/16 sizes are 10 ft. maximum.
- Other sizes, thread forms and materials are available upon request.

EX1038 at 7.

56. Shown below is a cutaway example of a PrePacker Screen I ran in the first 1,500' open hole horizontal well offshore in Nigeria in mid-1993.



57. In the early 1990s most, if not all, gravel packing was done in relatively short (less than 500') vertical or inclined wells. The horizontal craze had not yet begun.

58. There were numerous electric logging tools available at the time to help evaluate how effectively gravel was placed in the annulus between the screen and formation (or casing perforations). A complete pack (*i.e.*, no void spaces free of gravel) was important to prevent sand from bypassing the gravel pack through the void spaces. Void spaces were effectively like a hole in a filter.

59. To improve productivity, it was not uncommon to underream (meaning to enlarge the wellbore diameter) the zone to be gravel packed. Thus, with the increased area, it made it even more difficult to get a gravel pack without a void.

60. Voids were fairly common, and in many cases resulted in the formation sand (also known as fines) eroding holes in the screen, which would ultimately have to be replaced. Sand plugging the screen and restricting rates was also a major problem. Where sand could reach the screen, for example, it may form a tightly packed layer around the outside of the screen effectively restricting the flow of oil and/or gas into the screen to be produced.

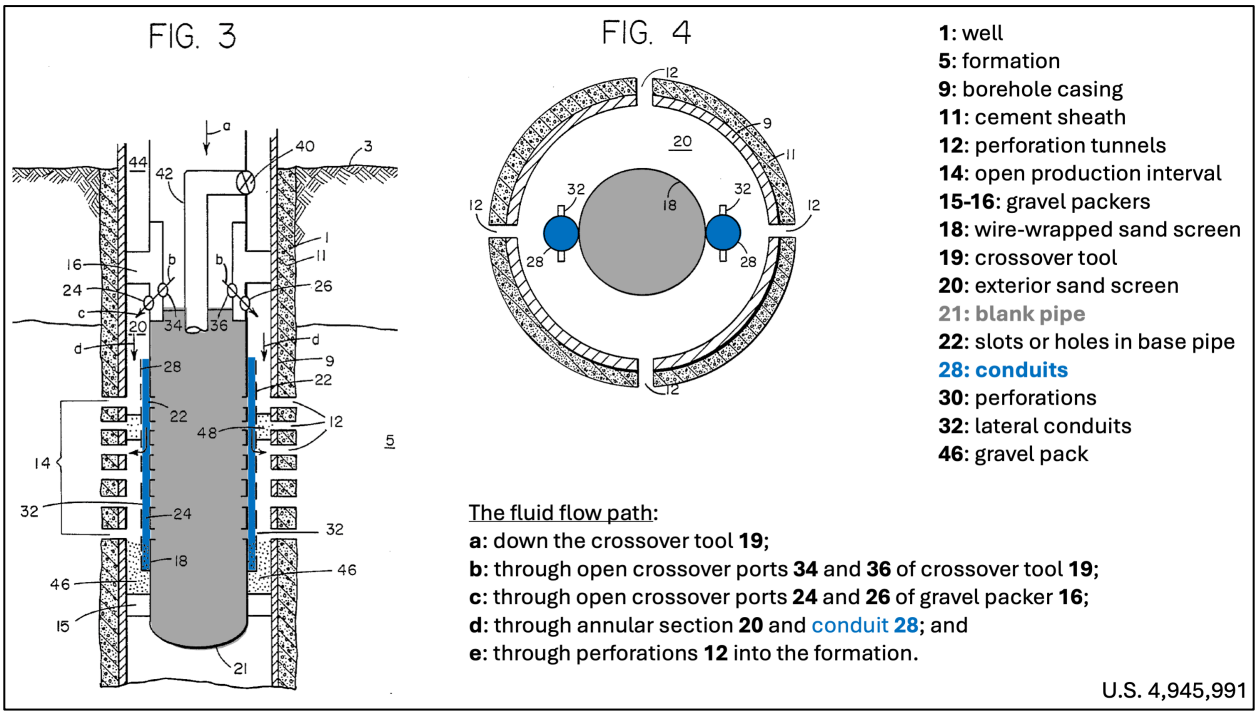
D. Introduction of Shunt Tubes

1. The First Patent

61. U.S. Patent 4,945,991 ("Jones," EX1007), filed in 1989 and entitled *Method for Gravel Packing Wells*, invented by Lloyd G. Jones and assigned to Mobil Oil Corporation, is widely regarded as the introduction of a solution to a problem which had plagued gravel packing since inception. Jones disclosed a method to bypass bridge(s) or voids in the annulus during the gravel-packing pumping operation and fill those voids with sand. EX1007 at 2:57-63. In this patent, Jones' solution was to add specially perforated shunt tubes to the outside of screens such that if a bridge occurred while pumping fluids down the annulus between a screen

and the wellbore or casing wall, then fluids would continue to flow down the tubes and out the perforations to fill the void.

62. Shown below are annotated Figures 3 and 4 from Jones along with the flow paths of the process:



EX1007 at Figs. 3 and 4 (annotated), 4:60-68 (describing the fluid flow path).

63. Figure 3 (above) illustrated sand screen 18 located in a borehole with a wire wrap or ribbon (not shown) on a blank pipe 21 (**dark gray**) with perforations 22 and a diagrammatic fluid flow pattern showing a sand bridge formation. *Id.* at 2:44-46, 3:16-26. Figure 4 (above) provided a cross-sectional view along line 4–4 of Figure 1 (which was also a cross-section of the well completion shown in Figure 3). *Id.* at 2:47-49.

64. Conduits 28 (**dark blue**) were outwardly disposed about the sand screen 18. *Id.* at 3:56-58. The conduits 28 could be open at both ends or open at the top and sealed at their lower ends and provided a secondary gravel slurry flow path wherein the gravel slurry could flow through and out the perforations or openings 30 into the annulus 20 downstream of the annular blockage. *Id.* at 3:60-68.

65. Jones understood the relationship between the size of the shunts and the annulus they had to fill. He noted, "(f) sizing the cross-sectional area of said conduit and said annulus so that if gravel forms a bridge in a portion of said annulus thereby blocking the flow of fluid slurry through the said annulus, fluid slurry containing gravel will continue to flow through the conduit and into the annulus around the gravel bridge." *Id.* at 2:16-21.

66. Jones also disclosed:

a. **One or more conduits**, EX1007 at 3:56;

b. **Sufficient size conduits** to permit the flow of sand or gravel, *id.* at 3:59-60;

c. **Extends (through conduits)** the distance of the annular space to packed, *id.* at 3:60-61;

d. Conduit can be **open at top and sealed at lower or open at both ends**, *id.* at 3:62-64;

e. Conduit 28 is provided with a **plurality of openings or perforations**, *id.* at 3:64-65;

f. **Perforations** are at **preselected intervals** along the conduit, *id.* at 3:65;

g. **These perforations** are in **sufficient number and size** to permit the flow of fluid containing gravel pack material from conduit 28 to annular section 20, *id.* at 3:66-4:2;

h. Conduit can comprise **pipe (either circular, square, rectangular, or curved**, etc.), *id.* at 4:7-9;

i. Although the conduit 28 may be made of **any pressure-resistant material**, it is preferably made of stainless steel, *id.* at 4:11-13;

j. Instead of pumping down the annulus the gravel may be pumped down the tubular and up the annulus, *id.* at 5:30-34; and

k. The gravel may be pumped **only through the conduit**, *id.* at 5:38-39.

2. Gravel Packing Terminology

67. Although Jones used the term openings or perforations, these holes in the conduit have been referred to by others in the field as orifices, ports, port holes, holes, nozzles, etc. to describe the same item. I typically prefer the term orifices but may use other terms, such as the term an author is using.

68. Jones used the term lateral conduits or lateral extensions when referring to a conduit extending from an opening in the conduit. Others likely refer to this as a nozzle.

69. Jones used the term conduits, but many others used the term tubes, shunts, shunt tubes, flow paths, etc. to describe the same item.

70. Jones used the term creating separate pathways for sand laden slurry, but Mobil and ExxonMobil later trademarked the phrase "Alternate Path Technology" to describe the same method. *E.g.*, EX1005 at 3:8-22 ("The problem of sand bridging has been addressed through the use of Alternate Path® Technology, or 'APT.'"). Some use the term APT referring to Alternate Path Technology. *Id.*

71. When describing the gravel packing fluid, others use the term NAFPac for Non-aqueous Fluid Gravel Packing referring to the gravel packing technique that enables an operator to run the gravel-pack screens in non-aqueous fluid ("NAF"), gravel pack the well, and then subsequently displace the casing to completion brine, all in a single trip. Running the screens in NAF increases the probability of successful screen installation and a complete gravel pack.

3. Basic Gravel Packing

72. Shown in the following two figures is the basic gravel pack technology method using separate or alternate path technology Lloyd disclosed in 1989. The figures are taken from U.S. Patent No. 7,661,476 ("'476 Patent," EX1010), which

was filed in 2007 and issued in 2010 and is entitled *Gravel Packing Methods*, co-invented by Yeh, Haeberle, Barry, Hecker, and Long and assigned to ExxonMobil Upstream Research Company. EX1010 at 1. The '476 Patent described an apparatus and method "that provides alternate flow paths for a variety of well tools, including, but not limited to sand control devices, sand screens, and packers to gravel pack different intervals within a well, and a system and method for efficiently coupling the well tools." *Id.* at 3:23-28.

73. In a simplified sense, the gravel packing process involved:

a. Running screens in a cased or open hole with tubes attached below a packer, EX1010 at 19:22-30 (Fig. 11A). The screens are "installed downhole across [producing] formations to retain solid material, [and] allow formation fluids to be produced without the solid materials above a certain size," *id.* at 2:10-13;

b. A crossover tool was used to inject fluid containing gravel down the drill pipe, past the packer and into the annulus, *id.* at 19:38-45 (Fig. 11B);

c. As the gravel packing fluid deposited sand and had its gravel filtered out, the fluid was returned to surface, *id.* at 19:50-20:3, 20:27-41 (Figs. 11C, 11C', 11F);

d. When gravel no longer traveled down the screen/formation annulus due to a blockage, it was diverted through the shunt system to bypass bridges and fill voids, *id.* at 20:42-64 (Fig. 11G);

e. After completion of pumping, the inner wash pipe string was removed. *Id.* at 20:65-21:21 (Figs. 11H-11J).

Gravel Pack Method Using Alternate Path Technology

1 of 2

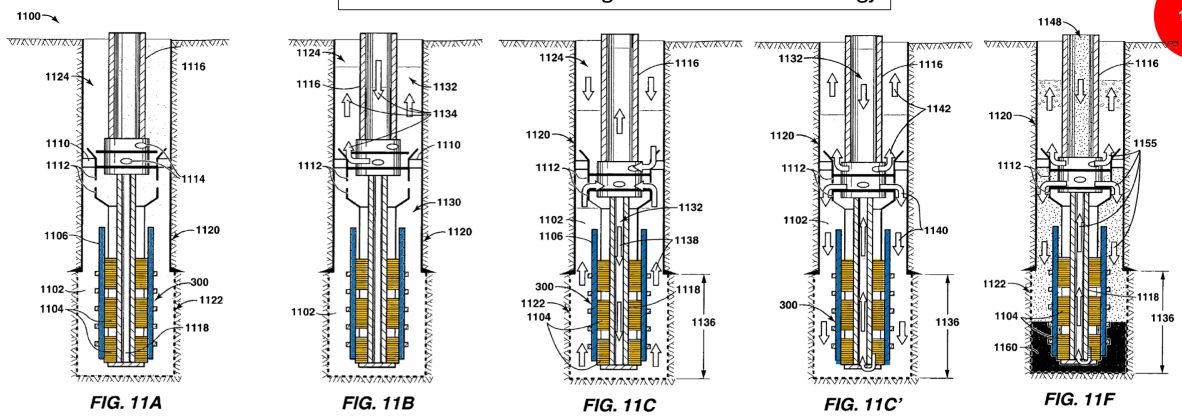


FIG. 11A FIG. 11B FIG. 11C FIG. 11C' FIG. 11F

1100: system
1104: screen
1106: shunt tubes
1110: packer
1112: crossover tool
1114: fluid ports
1116: drill pipe
1118: wash pipe

Step B:
- Packer set
- Crossover tool shifted to reverse position

Step C:
- Crossover tool shifted to circulate GP position (bottom fill)

Step C cont.:
- Crossover tool shifted to reverse position to circulate spacer fluid

Step C cont.:
- Pumping GP fluid

U.S. 7,661,476

Gravel Pack Method Using Alternate Path Technology

2 of 2

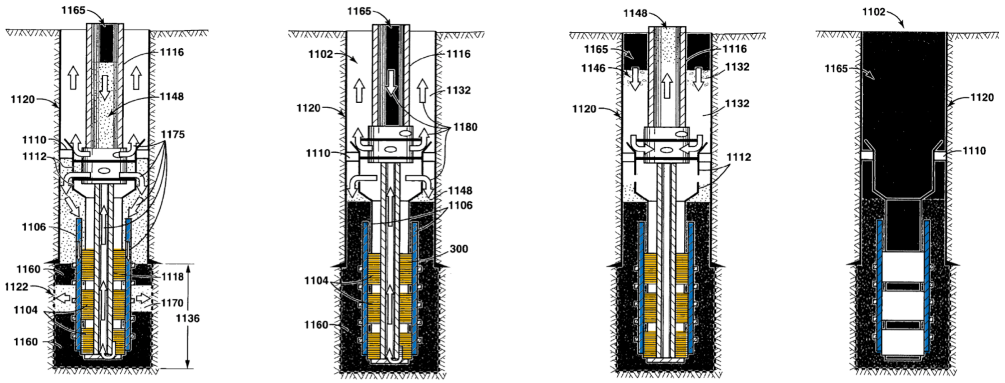


FIG. 11G FIG. 11H FIG. 11I FIG. 11J

Step D:
- Gravel pack fluid is diverted into shunts filling voids in annulus 1136

Step E:
- Wellbore fully packed

Step E cont:
- After screen out, crossover tool shifted to reverse position

Step E cont.:
- Crossover 1112 and wash pipe 1118 and drill pipe 1116 removed

U.S. 7,661,476

EX1010 at Figs. 11A-C', 11F-J (annotated).

74. The above process includes the use of "wash pipe" to channel the fluid from the inside of the screen to the entrance of the wash pipe at the bottom of the assembly. Using wash pipe was the most common method, but some operators were able to achieve the same results without using wash pipe.

75. The process described above also demonstrated packing from the top down, but many operators used the same basic process to pack from the bottom up.

E. Fluid Leak-Off Paths

76. As gravel (sized sand) is deposited, the carrier fluid slurry dehydrates as the pack is compressed. In other words, the gravel is separated from the carrier fluid.

77. The fluid therefore needs an escape path (or circulation path) to permit the continuous introduction of new gravel slurry into the wellbore. Shown below is

a figure demonstrating the potential leak-off paths for the gravel pack slurry.

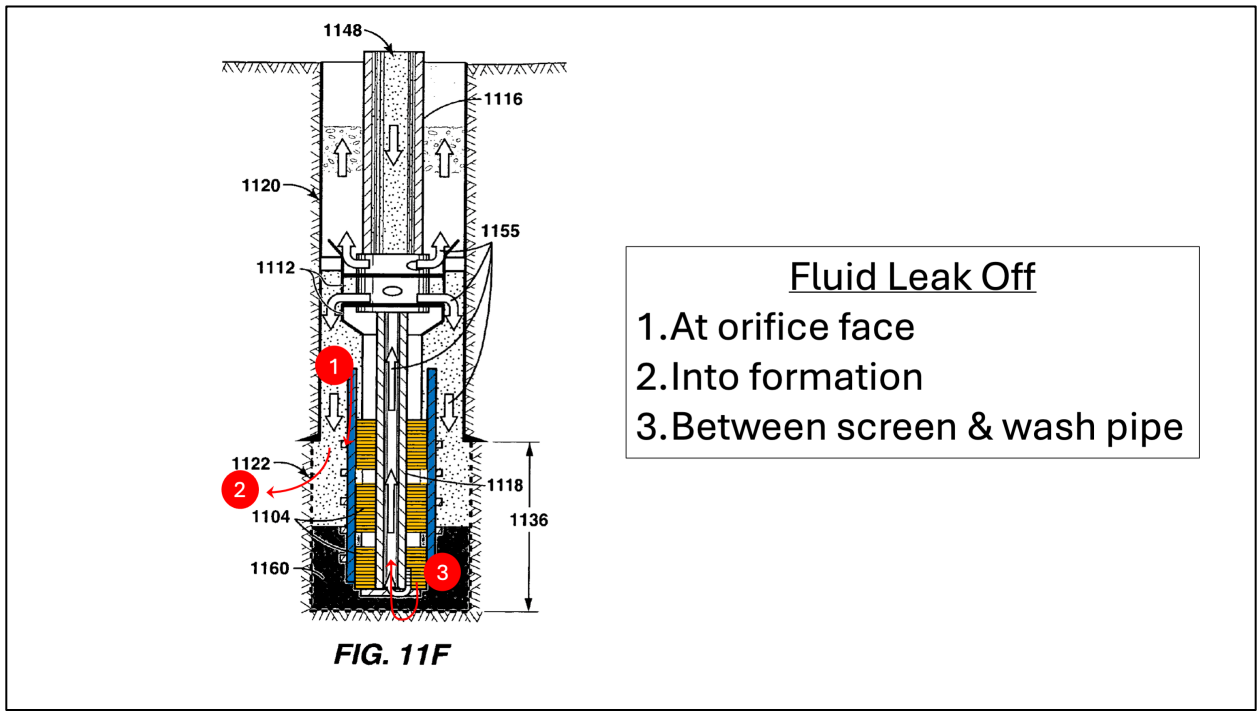


FIG. 11F

EX1010 at Fig. 11F (annotated).

78. Initially the fluid will start to dehydrate at the shunt tube orifice interface. If it totally dehydrates, it will form a bridge inside the shunt tube. As will be discussed later, this is a common phenomenon and is controlled by the type of fluid, volume of the tube, proppant type, proppant loading, and the size / design / position of the orifice. Even after the annulus has been packed, fluid will continue to leak off through the orifices.

79. The second place it will leak off is the formation. The amount of fluid leaking off will be a function of the formation permeability, through the drilling fluid filter cake, and also the fluid properties and pressures at which it is being pumped.

If the pressure is too high, it could fracture the formation, and sand would be lost into the formation. In some applications, fracturing (known as frac packing) would be the desired outcome.

80. The third place will either be passing through the screen (if no wash pipe was used) or between the screen and wash pipe annulus eventually flowing into the base of the wash pipe and back to the surface.

81. In 2000, the prior art reference SPE 64410, entitled *Design and Execution of a 3000-ft Horizontal Gravel-Packed Completion (A Kazakhstan Case History),* co-authored by Tibbles, Blessen, Qian, Steven, Pardo, Hurst, Kubota, and Mysko, who were affiliated with Schlumberger, Texaco, and M-I Drilling Fluids, disclosed a new shunt design using transport tubes and packing tubes for a 3,000' application. EX1026 at 1. One of the big benefits was to reduce the leak-off or fluid loss. This new design will be discussed in more detail later. Relevant here is that the reference taught reducing the amount of slurry dehydration that occurs in the process. As will be discussed later in more detail, this is one of the most important design considerations for this method of gravel packing: "The new screen design consisted of two large transport tubes that branched off on each joint of screen to feed the packing tubes (Figure 4). This design reduced the number of shunt connections *required between screen joints by 50%. In addition, it significantly*

reduced the potential for fluid loss (slurry dehydration).” EX1026 at 3 (emphasis added).

F. Open Hole Isolation Packers and Shunt Tubes

82. There has long been a need to separate gravel packed zones. Before the Alternate Path Technology, this was typically accomplished by gravel packing zones separately.

83. U.S. Patent No. 5,588,487 (“’487 Patent”), filed in 1995 and entitled *Tool for Blocking Axial Flow in Gravel-Packed Well Annulus*, invented by Bryant and assigned to Mobil Oil Corporation, proposed using blank shunts which passed through the packer(s). EX1012 at 1. Packers are tools that are run into a wellbore at an initial diameter and then expand once installed in the wellbore tool to seal off one section of the wellbore annulus from another.

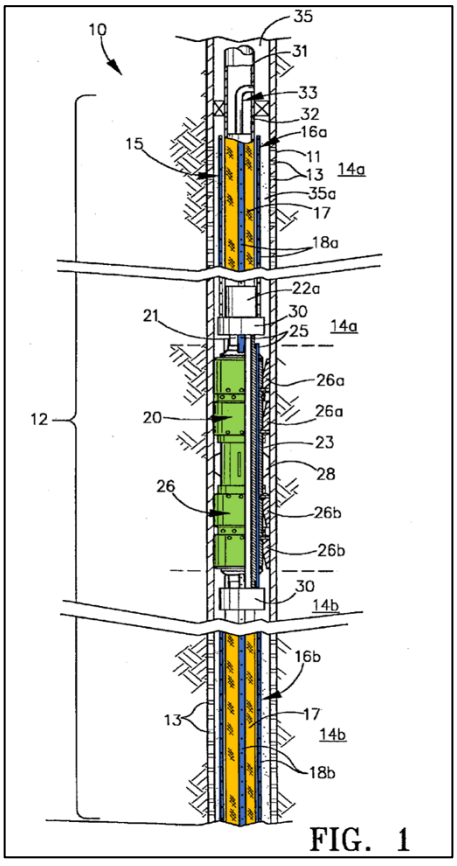


FIG. 1

84. The ’487 Patent disclosed a “well screen for gravel-packing a wellbore interval comprising at least two joints connected by a well tool. Each joint is comprised of a length of screen section which has at least one, axially-extending shunt conduit thereon for carrying gravel slurry to different levels within the interval. The well

tool has at least one by-pass tube therein which is adapted to align with and fluidly-connect the shunt conduits on respective joints whereby gravel can flow from one of the shunt conduit [sic], through the by-pass tube, and into and out of the other shunt conduit." *Id.* at Abstract; *see also id.* at Fig. 1 (annotated, above).

85. The '487 Patent disclosed pumping a gravel slurry down a wellbore into shunt tubes 18 (**dark blue**), which were positioned outward of sand screen 17 (**orange**) and through perforations in the shunt tube to fill the wellbore annulus. *Id.* at 4:11-19, 4:27-29, 5:5-10, Fig. 1.

86. The sand screen in productive zone 14a was separated from the productive zone 14b by a well tool 20, which included a packing means 26 (**green**) that was made up of two cup packers. *Id.* at 4:2-4, 4:55-60. The shunt tubes from each sand screen were fluidly connected using by-pass tube 25 (**dark blue**). *Id.* at 4:60-65.

87. In later years many other operators ran tubes through the packers to isolate zones using cup packers and swellable packers. For example, SPE 155129 ("'129 Paper") published in 2012 and entitled *The Evolution of Completion Designs Using Alternate Path (Shunt-Tubes) Technology* authored by Saebi, who was affiliated with Schlumberger, disclosed utilizing MZ (cup type) packers together with ExxonMobil's Alternate Path Technology to isolate zones in an interval while

still allowing for a full gravel pack. EX1022 at 1-2. Figure 2, which I provide below, illustrated the MZ packer:

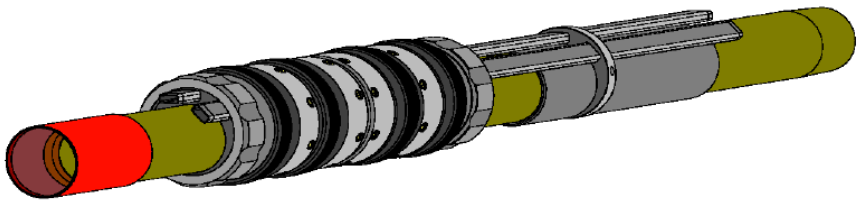


Fig. 2—MZ (cup type) packer allows flexibility in gravel packing separate zones simultaneously.

Id. at Fig. 2 (annotated).

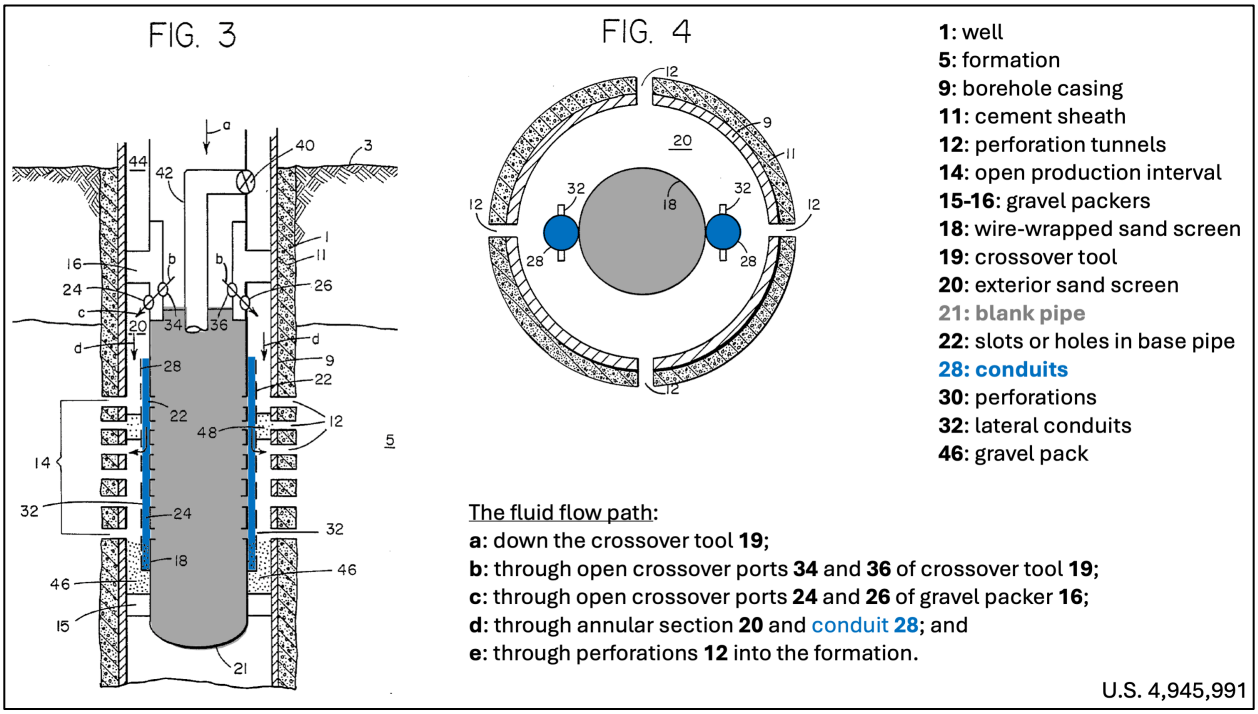
88. U.S. Patent No 8,839,861 ("'861 Patent," EX1040), filed in 2010 and entitled *Systems and Methods for Providing Zonal Isolation in Wells* co-invented by Yeh, Barry, Hecker, and Haeberle and assigned to ExxonMobil Upstream Research, disclosed multiple isolation assemblies and multiple tubes could be used: "As can be understood, the length of the gravel-based zonal isolation system is limited only [by] the practicalities of the materials costs and the characteristics of the well and formation. In some implementations where a long gravel-based zonal isolation system is desired, it may be preferred to utilize multiple tubular assemblies in series rather than a single, long tubular assembly." EX1040 at 13:32-39.

G. Shunt Tube Designs

1. Initial Designs

89. Filed in 1989, the Jones '991 Patent appears to be the origin of shunt tubes for gravel packing. Jones disclosed that the conduits could be used to back up

conventional annular gravel packs, or they could be stand alone and be the only means of gravel placement. "In still another embodiment, all of the gravel or sand slurry may be pumped ***only through the conduit 28***. By proper design of the perforations 22, the entire annular space 20 can be packed by using the perforations to divert gravel pack slurry along the entire interval to be packed. In this case, the annular space 20 could be essentially closed off except to flow from conduit 28." EX1007 at 5:38-44 (emphasis added). An annotated example of Jones' shunt system is reproduced below:



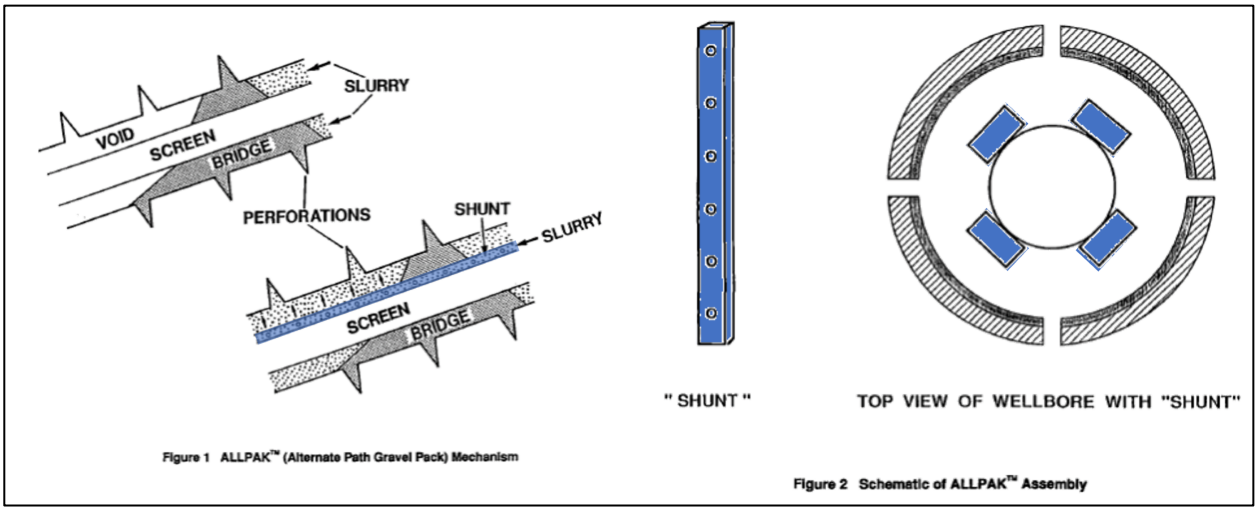
EX1007 at Figs. 3 and 4 (annotated); *see supra* §VIII.D.1.

90. Although it was possible to gravel pack wells without shunts, most operators chose to use shunt tubes in the backup role to reduce the pumping time and potential erosion to the shunt tubes until they were required.

a) The Origin of Alternate Path® Technology

91. In 1991, the Mobil research group including Jones, Yeh, Yates, Bryant, Doolittle, and Healy discussed in SPE 22796 ("'796 Paper"), entitled *Alternate Path Gravel Packing*, developing a "new and superior gravel packing method called ALLPAK™ for alternate path gravel packing" to address the issue of sand bridging. EX1009 at 1; EX1005 (Yeh), 3:8-22.

92. This publication was first to present this new method to fill voids in gravel packs and trademarked it ALLPAK™. The authors used this nomenclature to explain that adding tubes or shunts created an "Alternate Path" for fluids to flow once bridges had been formed. This Alternate Path Technology ("APT") included injecting gravel slurry through small tubes attached to the sand screen. EX1009 at 1. I annotated the shunt tubes in **dark blue** in Figure 2 below, which had small perforations every few feet allowing for the gravel slurry to flow into the annulus. *Id.* at 1. Figure 1, also annotated below, illustrated how the alternate path shown in **dark blue** allowed for gravel slurry to bypass a sand bridge:



Id. at Figs. 1 and 2 (annotated).

93. The '796 Paper taught that the flow paths could either be inside or outside the screen: "These could either be inside or outside the screen, although the mechanical assembly is much simpler if the alternate paths are placed in the annulus. The alternate paths consist of small separate tubes or pipes attached to the screen and perforated with small holes every few feet." *Id.* at 1.

94. The '796 Paper described the factors involved in designing a shunt system: "For every sand size, hole angle, and slurry density relative to completion fluid density, gel rheology, and shunt design, there is a minimum shunt fluid slurry velocity, and hence pumping rate, required to pack a given length of interval." *Id.* at 2.

95. The '796 Paper also taught that slurry could either be routed directly into the shunts, or they could act as a standby system: "Slurry can either be injected

directly into the tubes, or the tubes can be left open at the top of the annulus to act only as shunts." *Id.* at 1. And that "[u]ltimately, injecting the slurry directly into the tubes may prove to be the preferred arrangement because this would provide a more orderly, controllable, and predictable process." *Id.* at 1-2.

96. The authors understood that there were a large number of variables when designing the alternate path system, including the size, and number of shunts and orifices, leak-off zones, etc. Due to so many variables, a one size fits all numerical simulation design was nearly impossible, so they concentrated on a system that would work by using laboratory simulations. The '796 Paper taught that "*[f]or every sand size, hole angle, and slurry density relative to completion fluid density, gel rheology, and shunt design, there is a minimum shunt fluid slurry velocity, and hence pumping rate, required to pack a given length of interval." Id.* at 2 (emphasis added).

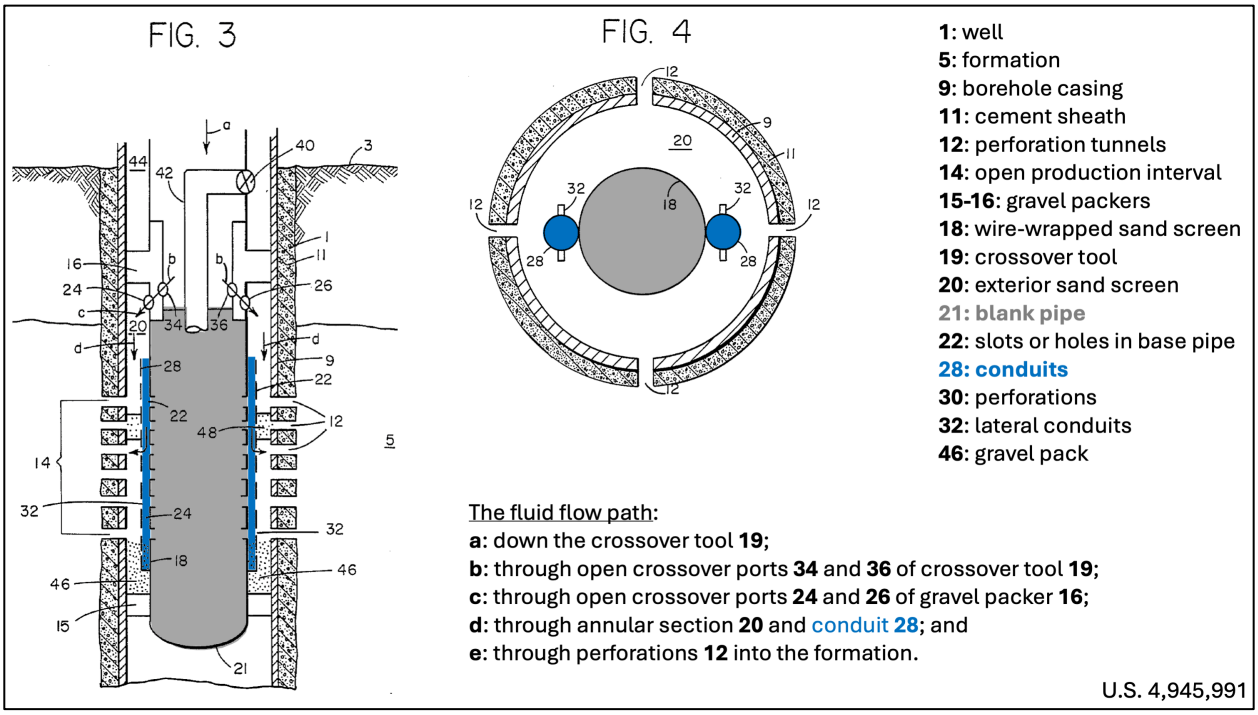
97. When discussing shunt design, the authors noted that rectangular shunts were simply chosen for mechanical advantage: "The rectangular tubes were chosen strictly for mechanical design advantages. Smaller shunt holes, 36# XC/WOO gal. clarified gel, and 40/60 sand were chosen primarily as a result of the long shunt tube tests." *Id.* at 2.

98. The ’796 Paper further discussed problems designing systems due to differences in geology. “One difficulty in developing detailed design information is that determining the mix between annular flow and shunt flow is beyond current engineering theoretical prediction capabilities, especially since the mix is dependent on geology.” *Id.* at 2.

99. One important design recommendation found in early laboratory testing was not using a large number of large holes because sizing orifices, nozzles, or ports was critical. “From the first set of experiments, it was found that numerous relatively large shunt holes produce a disorderly packing mechanism. We believe that such a mechanism would fail when packing long intervals.” *Id.* at 2.

b) Shunt Tube Geometry

100. Jones disclosed round conduits (shunt tubes) 28 on the outside of the screen:



EX1007 at Figs. 3 and 4 (annotated).

101. However, it appears the first installations were of a rectangular eccentric design to take advantage of achieving a large flow area. For example, this rectangular eccentric arrangement was shown in SPE 86532 ("Hurst"), published in 2004 entitled, *Alternate Path Completions: A Critical Review and Lessons Learned from Case Histories with Recommended Practices for Deepwater Applications*, and co-authored by Hurst, Cooper, Norman, Dickerson, Claiborne, Parlar, and Tocalino, who were affiliated either with Schlumberger, Amerada HESS, or ChevronTexaco. EX1013 at 1.

102. Hurst's Figure 5, which I provide below, illustrated how using an eccentric design allowed for placement of the largest tubes, wherein the outer

diameter was reduced from 5.04" (concentric) to 4.86" (eccentric). *Id.* at Fig. 5. Hurst further explained that the "key advantage of the eccentric design is the increased base-pipe size, allowing, for example, 5.5-in base pipe in an 8.5-in open hole." *Id.* at 3.

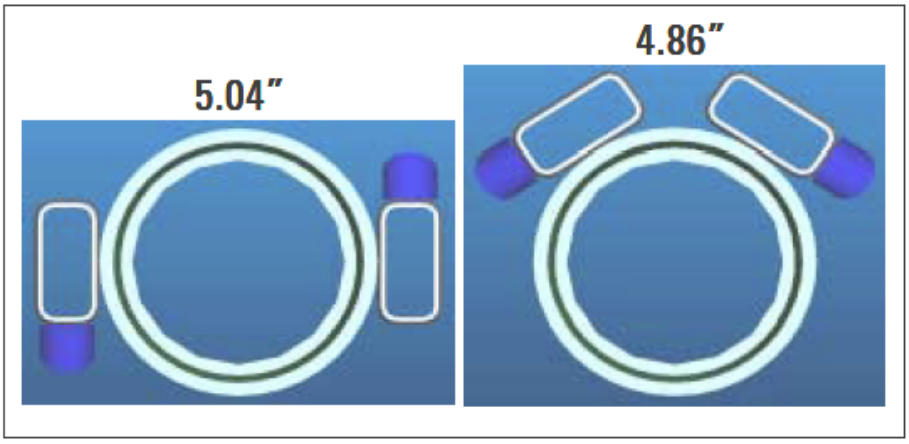


Figure 5 – Example of outer diameter reduction with eccentric design (right) versus concentric design (left).

Id. at Fig. 5.

103. It is important to note that even though rectangular tubes can provide a larger cross-sectional area for flow within a confined eccentric annular space, it does not necessarily translate to lower friction pressure or pressure loss. Patent Owner Halliburton disclosed that it understood this concept in 2014 in SPE 169440 ("Bonner"), entitled *Design and Validation of an Improved Shunt Tube System*, co-authored by Bonner, Hailey, and Veit. EX1016 at 1. Specifically, Bonner explained that when deciding on what shape of jumper tube to implement, it compared the

friction pressure in round tubes versus rectangular tubes and, based on that testing, chose to use smaller round tubes as jumpers because the friction or pressure loss was essentially identical:

> In certain parts of the design (i.e., for the jumper tubes across connections), it was determined that round tubes instead of the common industry design of rectangular tubes would be better. This choice led to a decrease in the amount of flow area in certain parts of the new design. For these parts, analyses were made to verify that although the flow areas were less, the friction pressure loss for these parts were essentially identical to those for the rectangular tube designs, owing to the nature of friction pressure loss in round tubes versus rectangular tubes.

Id. at 2.

104. As shown in Bonner's Figure 42 below, a round tube with a smaller diameter mated to a larger rectangular tube was able to fit in the same confined space with the same pressure loss:

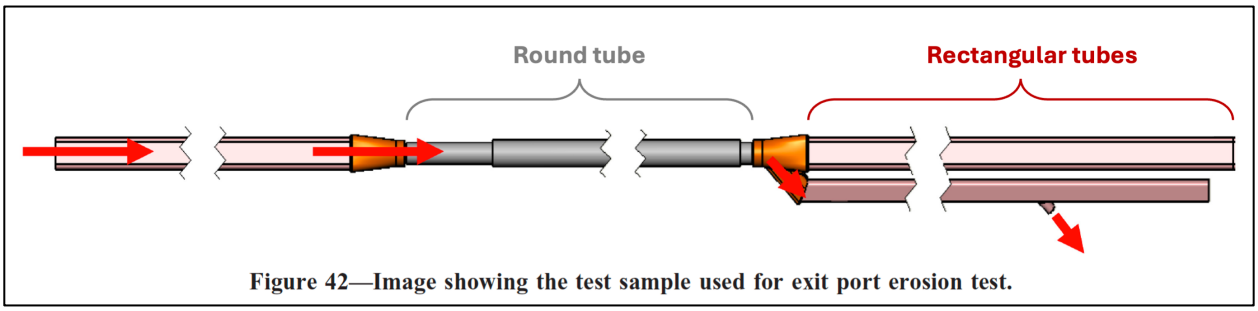


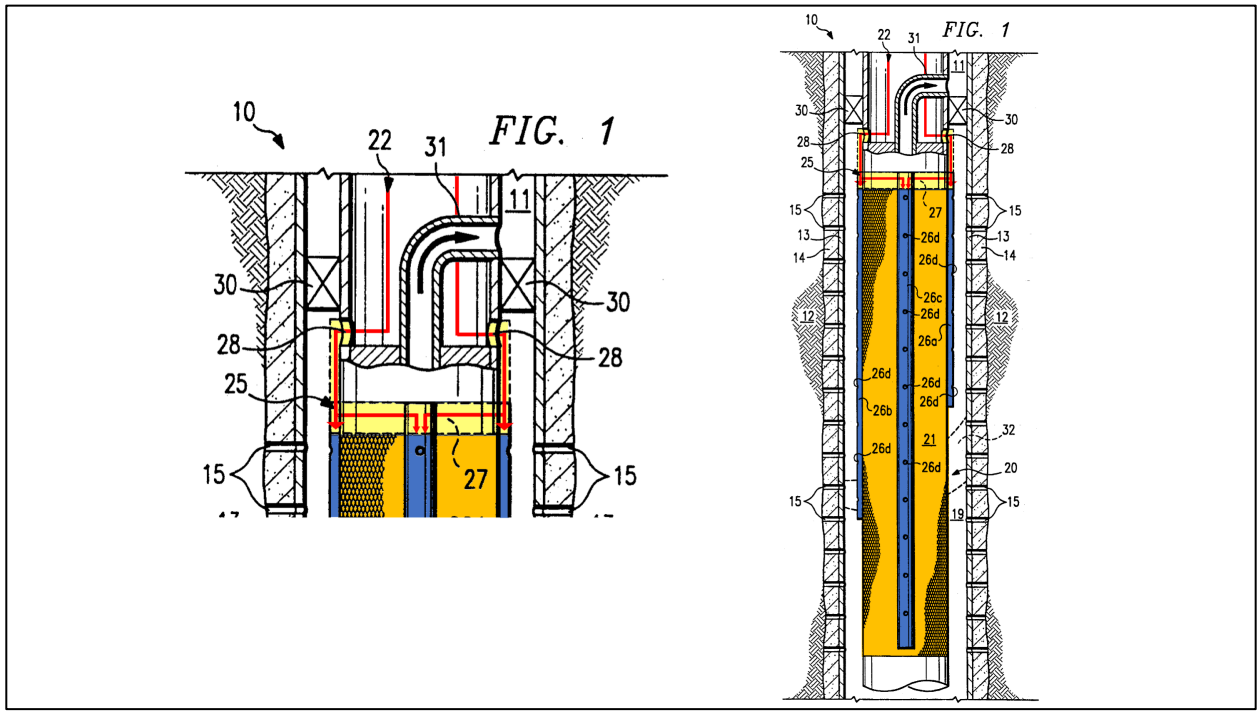
Figure 42—Image showing the test sample used for exit port erosion test.

Id. at Fig. 42 (annotated).

c) Shunt Tube Manifolds and Orifices

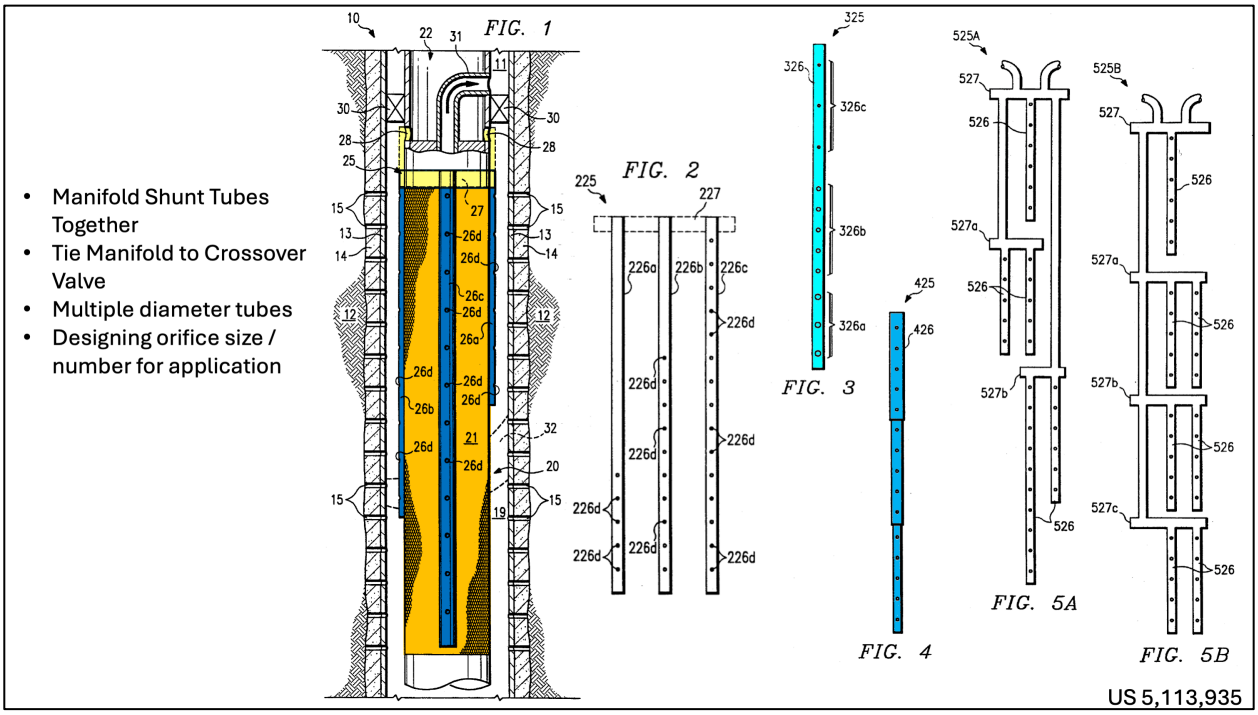
105. U.S. Patent No. 5,113,935 ("Jones2" or "'935 Patent"), filed in 1991 and entitled *Gravel Packing of Wells*, co-invented by Jones and Yeh and assigned to Mobil Oil Corporation, disclosed a gravel packing apparatus that was capable of bypassing sand bridges and providing a complete gravel pack. EX1008 at 2:20-24. This wellbore tool could be used in cased or open-hole completions and in vertical or horizontal wellbores. *Id.* at 3:31-35.

106. Annotated Figure 1 below illustrated a gravel packing apparatus of the invention. Figure 1 illustrated conduits 26a-c (**dark blue**) or shunt tubes disposed outwardly of sand screen 21 (**orange**) and in the closed configuration wherein the conduits were coupled together using manifold 27 (**yellow**), which in turn was directly connected to outlet ports 28 (**yellow**) in the crossover sub 22. *Id.* at 3:58-61, 4:1-9. In this configuration, the gravel slurry (**red arrows**) is pumped directly through outlet ports 28 into manifold 27 into the conduits 26a-c and out into the annulus 19 via perforations or openings 26d. *Id.* at 4:10-13, 4:31-34. Jones2 also disclosed that if the conduits 26a-c were open at their upper ends then the pumped gravel slurry would flow through the work string into the annulus 19, into the upper ends of the conduits 26a-c, and out through perforations 26d. *Id.* at 2:48-51, 4:13-30.



Id. at Fig. 1 (annotated and cropped).

107. Jones2 also disclosed methods to manifold shunt tubes together and also used orifice size and placement to distribute flow along a shunt tube. In annotated Figure 4 below, Jones2 showed tube 425 (**blue**), which is a stair stepped design with a larger cross section at the top and a smaller cross section below:



Id. at Figs. 1-5 (Figs. 1, 3, and 4 annotated).

108. Jones2 also understood the relationship between the size of perforations or orifices. In reference to Figure 3, Jones2 taught:

> FIG. 3 illustrates a shunt means 325 [light blue] in accordance with the present invention which is comprised of at least one conduit 326 which has perforations spaced over substantially its entire length wherein the sizes (diameter) of the perforations vary from one end to the other. That is, conduit 326 has perforations 326a at one end which are relatively large (e.g. 1/8 inch diameter), intermediate perforations 326b which are smaller (e.g. 3/32 inch diameter), and still smaller perforations 326c (e.g. 1/16 inch diameter) at the other end. ***During a gravel pack operation, the gravel slurry will take the path of least resistance through the conduits and will tend to flow through the***

> ***bigger perforations first until they become blocked and then will flow through the next larger perforations which remain open and so forth***.

EX1008 at 4:50-65 (emphasis added).

109. IPTC 12549 ("Yeh2") was published in 2008 and entitled *Unlocking the Limits of Extreme Length in Alternate Path Gravel Packing* and was co-authored by Yeh, Clingman, Dale, Moffett, Harrison, Barry, Hecker, and Haeberle who were affiliated with ExxonMobil Upstream Research Company and ExxonMobil Development Company. EX1006 at 1. Yeh2 described the history of APT beginning in the 1990s and explained how it was used. *Id.* at 2. Yeh2's Figure 1 illustrated how "shunt tubes divert slurry [light green arrows] through distributed portholes to fill annular voids until a complete pack is placed." *Id.* at 2.

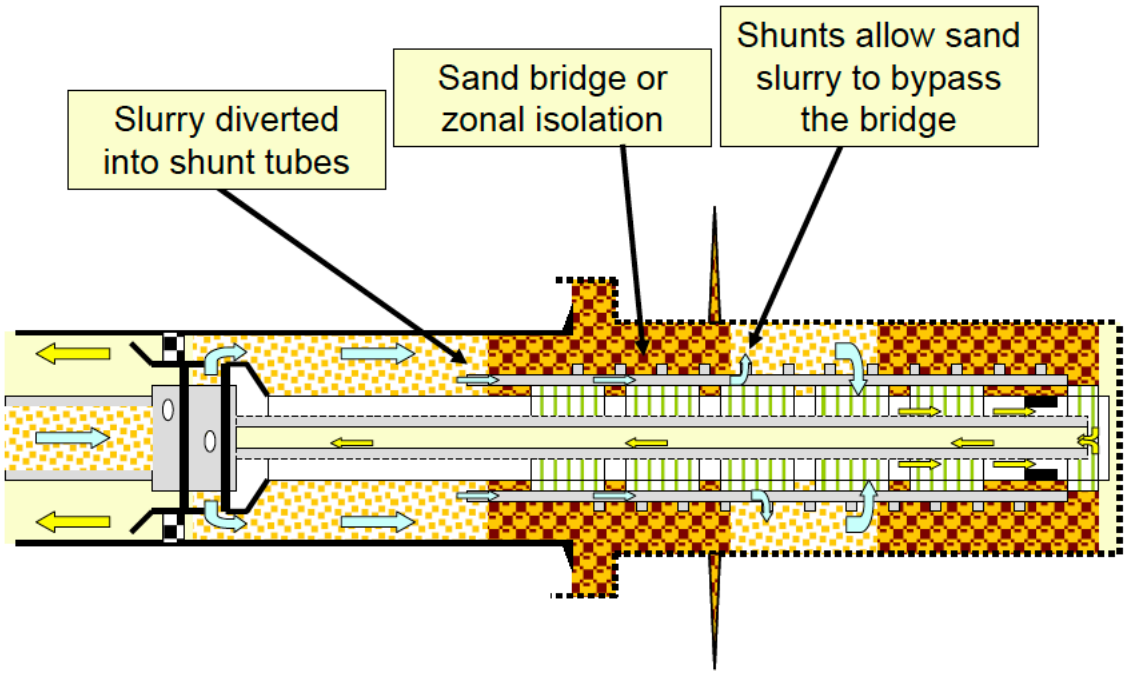


Figure 1 Alternate Path gravel packing with shunt tubes

Id. at Fig. 1.

110. One of the issues Yeh2 discussed was the tendency of shunt tubes to plug in extended intervals. *Id.* at 2-3. Yeh2 suggested that the use of manifolds at the entrance of each shunt tube assembly and the use of separate transport and packing tubes ("a continuous non-ported shunt tube to transport the slurry and a non-continuous, ported packing tube on each joint used to discharge the slurry") would help solve this problem. *Id.* at 3. Yeh2 explained that this shunt tube assembly design was "field-proven" and successful in "hundreds of wells." *Id.* Yeh2 also taught that testing results demonstrated that a 6-feet nozzle spacing on packing tubes

was recommended because a single nozzle could pack up to 8-10 feet of annulus. *Id.* at 4. An example of this design was shown in Figure 6a, shown below:

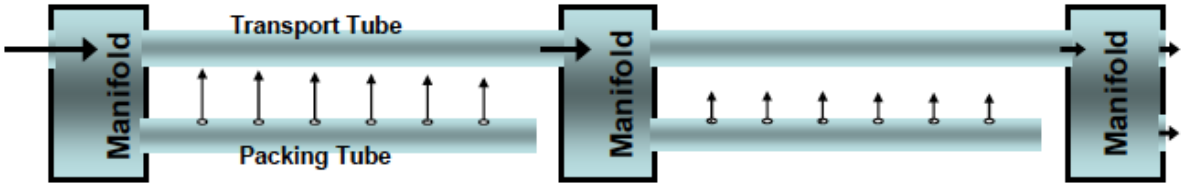


Figure 6a Shunt manifold system

Id. at Fig. 6a.

d) Modern 2×2 Eccentric Design

111. Shown below is a typical shunt system, as disclosed in Figure 9 of the '129 Paper (EX1022), which was published in 2012. I labeled the main components according to the color scheme in Figure 9 for reference:

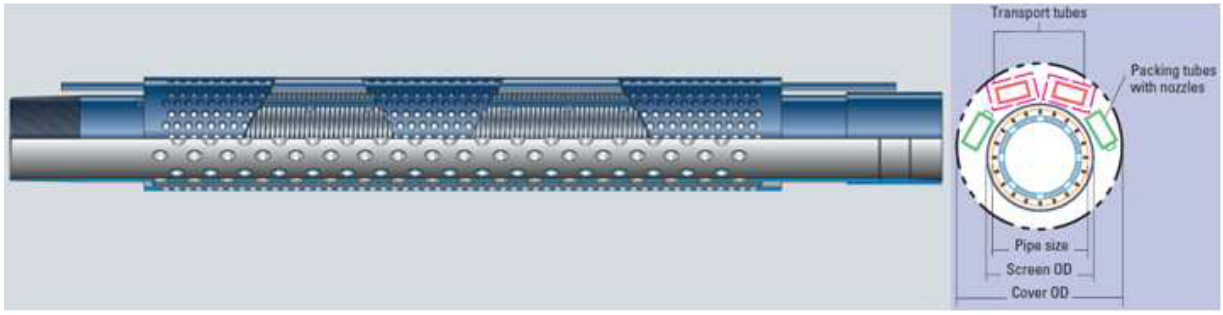
a. **Base Pipe** – may be perforated or slotted;

b. **Screen** – typically wire wrapped, numerous gauge sizes;

c. **Outer Cover** – Optional to prevent damage to screen, or create a backup gravel pack area;

d. **Transport Tubes** (discussed *infra*); and

e. **Packing Tubes** (discussed *infra*).

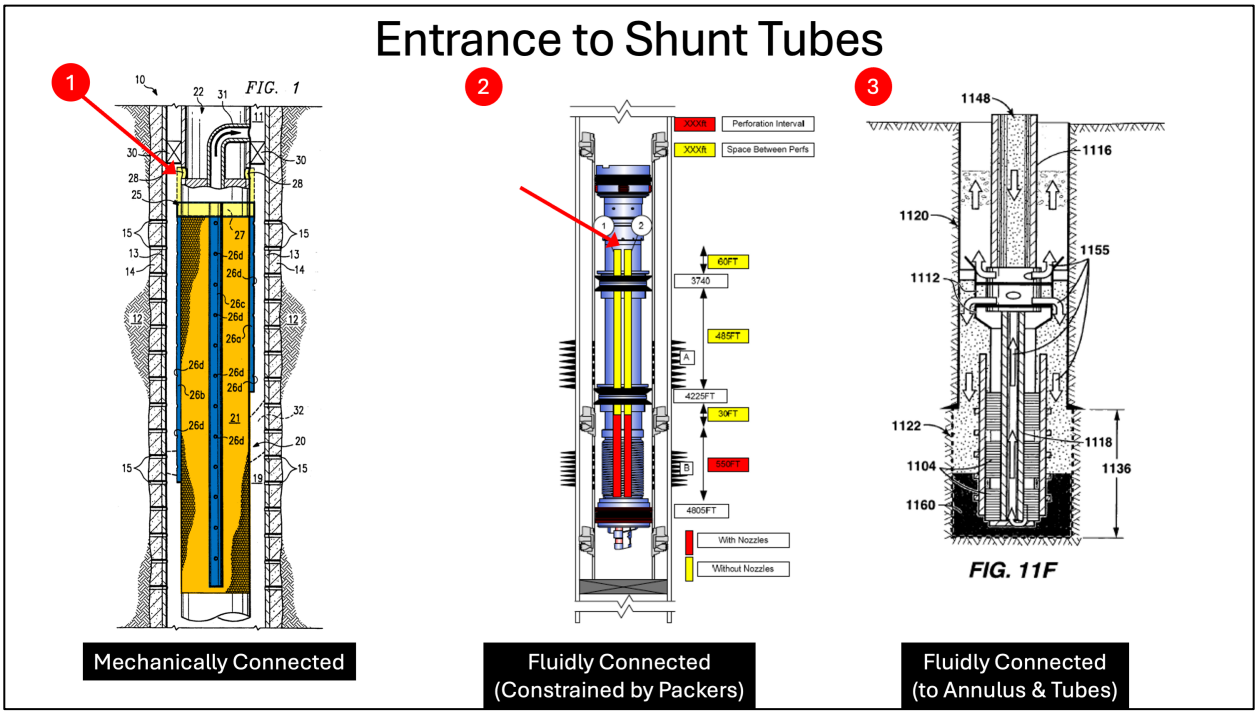


EX1022 at Fig. 9. The figure above shows the conventional 2×2 eccentric shunt tube design that has become commonplace in the industry.

2. Shunt Tube Fluid Entrance

112. Shunt tubes can be fluidly connected to the crossover tool at either the heel or toe of the well. In most cases they are fluidly connected at the heel and inside the casing to provide additional pressure support above a formation breakdown pressure if required.

113. Shunt tubes may be (1) directly fluidly connected to the crossover tool (EX1008 at Fig. 1) (2) encased in a confined part of the wellbore where they are fluidly connected to the crossover tool (EX1022) or in the most common method (3) fluidly connected to the crossover tool via the sand screen annulus (EX1010 at Fig. 11F). The figure below shows the three different methods with a red arrow indicating the connection point, if any:



EX1008 at Fig. 1; EX1022 at Fig. 7; EX1010 at Fig. 11F (all annotated).

114. In example one, the crossover tool is fluidly connected via being directly piped to the shunt tube entrances.

115. In the confined annulus of example two, the only path fluid can travel is from the crossover tool into the shunt tube.

116. Example three shows slurry has the option to travel down the annulus or down the shunt tubes and will flow down the one with the least pressure resistance, which may change as fluid movement and pressures dictate. For example, should a sand bridge form downstream of the shunt tube entrance, example three effectively becomes example two with the sand bridge substituting for the packer in example two.

3. Gravel Concentration vs. Depth

117. As lateral lengths grew it became common to adapt tube design with blank sections to combat the issue of fluid leak-off at the tube orifice interface as I describe below in §VIII.H.2.

118. This is shown in the figure below from SPE 135102 ("Hecker") (EX1015), where orifice placement design modifications were made to extend packing lengths.

119. Hecker was published in 2010 and entitled *Extending Openhole Gravel Packing Capability: Initial Field Installation of Internal Shunt Alternate Path Technology*; it was co-authored by Hecker, Barry, Sweeney, Arnold, and Yeh, who were affiliated with ExxonMobil Upstream Research Company and ExxonMobil Development Company. EX1015 at 1.