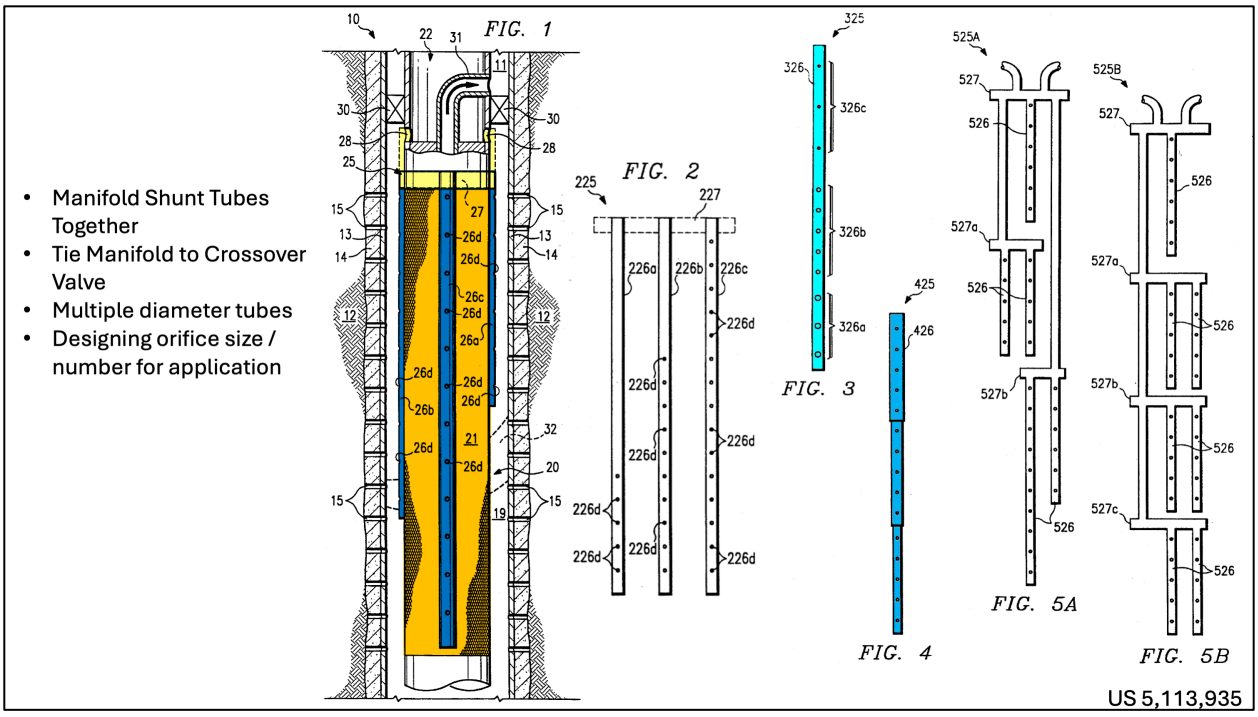
174. The most common pressure ratings found for tubes used in the oil and gas industry is either 3,000 psi or 7,000 psi.

12. Wall Thickness

175. Jones2 disclosed different configurations for conduits, including one where the diameter changed with depth (Figure 4) as shown below in **blue**:



EX1008 at Figs. 1-5 (Figs. 1, 3, and 4 annotated).

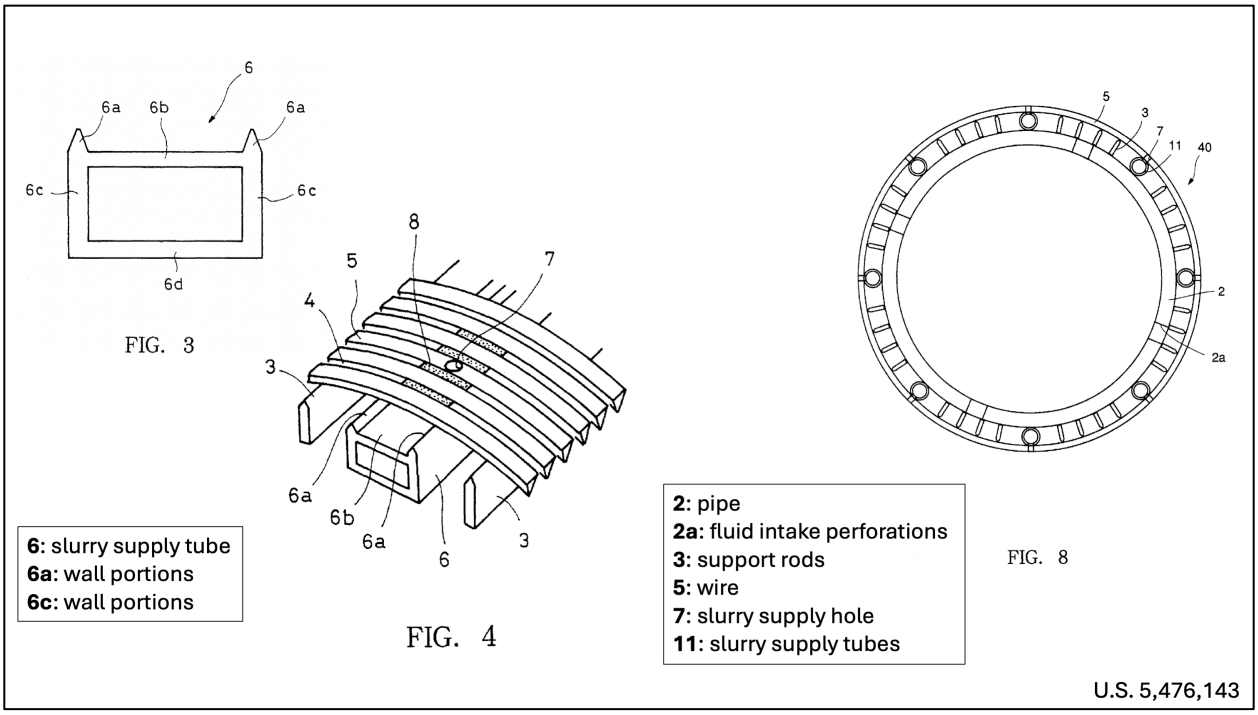
176. In addition to Jones2, the co-inventors of the ’143 Patent were working on similar techniques to install tubes insides screens. The ’143 Patent figures shown below, also disclosed rectangular slurry flow paths which were inside the wire structure. EX1023 at Fig. 4. The slurry supply tube wall thickness was being used

to contain slurry fluid as well as designed as a support structure to resist collapse of the screen. Specifically, the '143 Patent taught:

> In the embodiment, since the **two wall portions** 6a, 6c and the wire support portions 6a, 6a integrally perform a function of a support rod against the wire 5, the number of support rods can be saved by forming this slurry supply tube 6. Further, **since the two wall portions 6c, 6c of** the slurry supply tube 6 are connected to each other by the top plate 6b and the bottom plate 6d (see FIG. 3), these top plate 6b and bottom plate 6d function as reinforcing members in performing the function of the support rod whereby the supporting strength to support the wire 5 against the outer pressure is increased.

EX1023 at 5:15-25 (emphases added).

177. Therefore, in some instances the wall thickness was used not only to contain pressure but also as a structural support.



EX1023 at Figs. 3, 4, and 8 (annotated).

178. U.S. Patent No. 9,797,226 ("Yeh" or "'226 Patent") entitled *Crossover Joint for Connecting Eccentric Flow Paths to Concentric Flow Paths*, was co-invented by Yeh, Barry, Hecker, Moffett, Entchev, and Hyde and assigned to ExxonMobil Upstream Research Company. Yeh described considerations that come into play when designing shunt tube systems including the wall thickness of the tube:

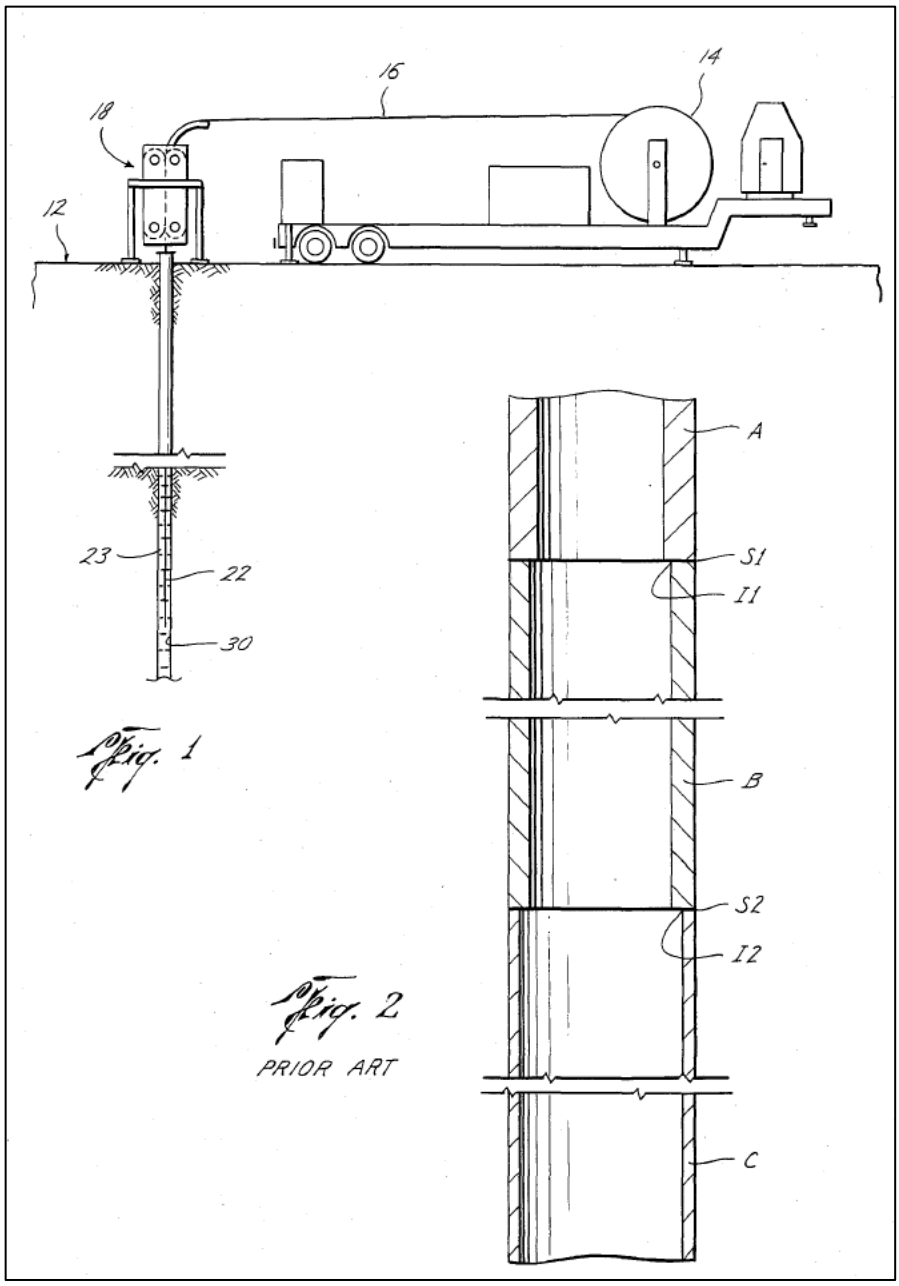
> When using a crossover joint, other design options may be considered. For example, when the secondary flow paths serve as alternate flow channels for gravel packing, a high differential pressure can occur between the secondary flow paths and the primary flow path. Additionally, a high differential pressure may occur between the secondary flow paths and the annulus between the

> crossover joint and the surrounding wellbore, that is, the wellbore annulus. For example, ***a 6,500 psi*** differential pressure is expected near the heel of [sic] when gravel packing a 5,000-foot horizontal completion interval. In order to maintain the mechanical integrity (that is, to stay within the ***burst, bending, and collapse ratings) of the secondary flow paths, a certain surrounding wall thickness is required.*** This, in turn, limits the inside diameter of the crossover joint.

EX1005 at 28:9-24 (emphases added).

179. It is common in the oil and gas industry to vary wall thickness to tailor the pressure rating to the required depth. U.S. Patent No. 4,629,218 ("'218 Patent"), filed in January 1985 and entitled *Oilfield Coil Tubing* disclosed an example in coil tubing where multiple wall thicknesses are used in a single continuous string. EX1030 at 1.

180. The '218 Patent taught that a "tubing string with dissimilar wall thicknesses is formed by welding individual tubing sections formed from tubing strips in ascending order with the thickest wall tubing section at the top, and the thinnest wall tubing section at the bottom." *Id.* at 2:33-38. An example of varying the wall thickness was illustrated in Figure 2, which I provide below:

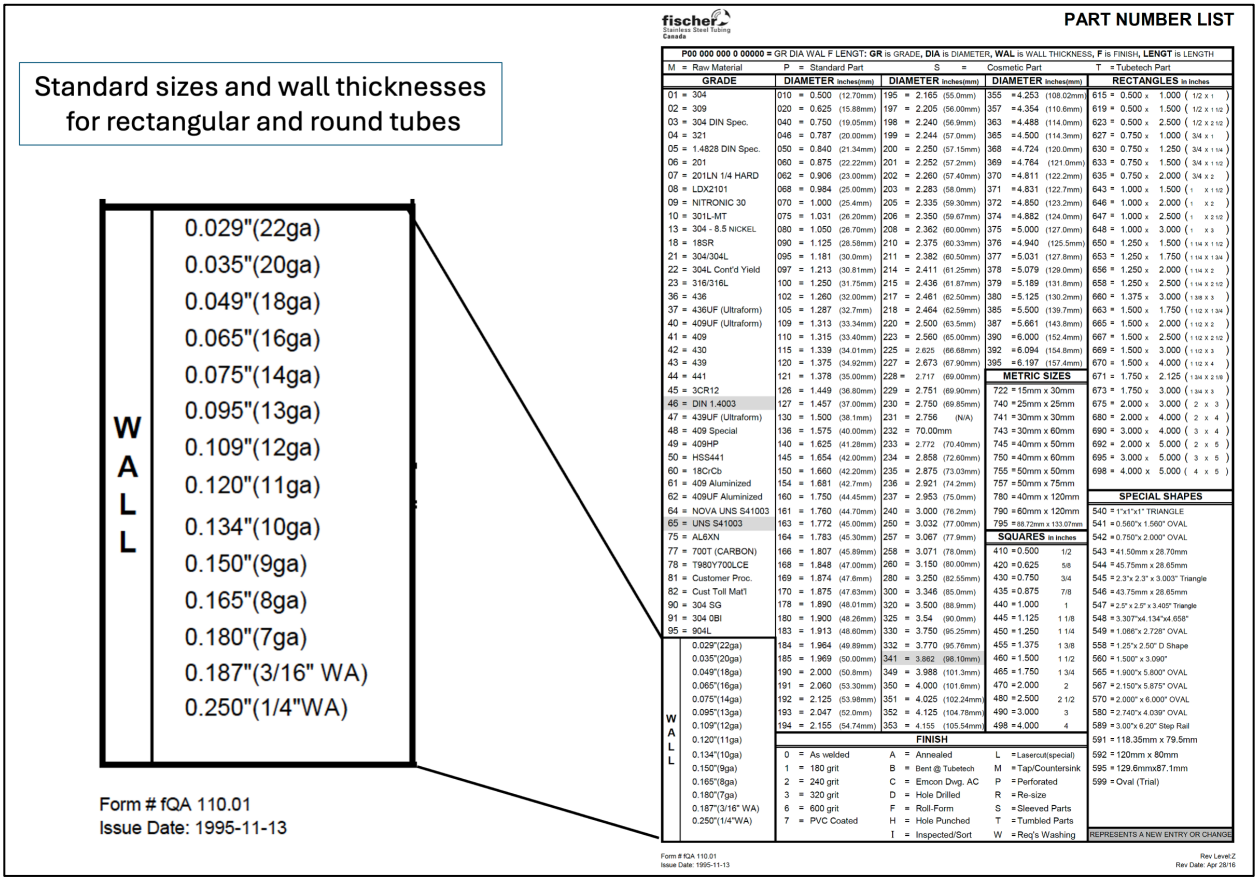


Id. at Figs. 1 and 2.

181. Most of the base tubulars for shunt tubes whether round or rectangular are off the shelf items. New tubes have been developed for the higher-pressure requirements but are of the same basic design as was first used or proposed in the

early 1990s. Most tubes were made by taking metal plates, bending the plate into the desired shape, and welding the seam to create a tube.

182. Shown below is an annotated table of standard sizes and wall thicknesses for round and rectangular tubes made of stainless steel that the Fischer Group, a supplier of stainless steel tubing, provided its customers before the '007 Patent's claimed priority date. *See* EX1031 ¶4.



EX1032 at 1 (cropped and annotated). As I noted above, shunt tubes started out using a 1/16" (0.0625") wall thickness. EX1041 at 3:54-58. However, due to longer

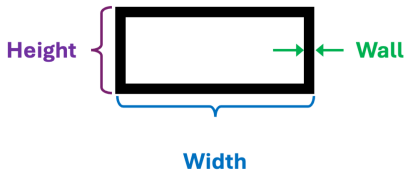
shunt tube lengths and the resulting higher pressures, shunt tube wall thickness increased over time.

183. The table shows numerous sizes and wall thicknesses available "off the shelf" for purchase. One of the most common wall thicknesses for the 1.5" × 0.75" rectangular tube was 0.095". Some suppliers specified this tubing as a 0.086" wall thickness because ASTM A554 allowed for a ± 10 % variation in wall thickness, which would permit a 0.095" tubing wall to be as thin as 0.086". *See* EX1018 at Table 5 (listing "Wall Thickness Tolerance" as "± 10 % of specified wall thickness"). A common wall thickness for the 1.0" × 0.50" packing tube was 0.075". Even though this was a thinner wall, because packing tubes had a smaller length and width dimension, the pressure rating likely would have been comparable.

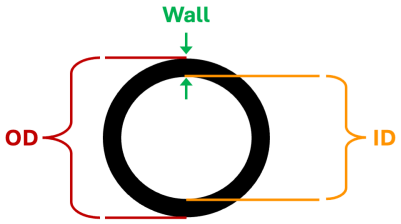
184. Below, I provide calculations I performed using data from the Fischer Part Number List, EX1032, I included above to show how the size and wall thickness could be combined to create a system of upstream higher-pressure tubes and downstream lower-pressure tubes that both would have the same cross-sectional area. In the case of a rectangular tube, a similar capacity of 7.1 cubic inches per foot length could be achieved by using a 1.5" and 1.25" tube. In the case of a round tube, a 0.787" and 0.75" tube could be used to create the same 3.4 cubic inches per foot of tube length. In both cases, the smaller tube would have less steel, and therefore

would cost less because cost was priced primarily by weight of material. This exercise demonstrates that given readily available tubing materials, a POSITA could readily substitute tubing of different sizes to save cost or to adjust to any other constraints imposed by a particular job.

Shunt Tube Capacity: different size tube – same capacity



	Rectangular Tubing						
	OD width (in)	ID width (in)	OD height (in)	ID height (in)	Wall (in)	Wallx2 (in)	Cubic Inches/Foot (in³/foot)
10 Gauge	1.5	1.232	0.75	0.482	0.134	0.268	7.1
13 Gauge	1.25	1.06	0.75	0.56	0.095	0.19	7.1



	Round Tubing					
	OD (in)	ID (in)	Wall (in)	Wallx2 (in)	Burst Pressure* (psi)	Cubic Inches/Foot (in³/foot)
13 Gauge	0.787 (20mm)	0.6	0.095	0.19	14,745	3.4
14 Gauge	0.75 (19mm)	0.6	0.075	0.15	12,030	3.4

* Calculated from API TR5C3 at 24, Equation 14

Data Source - Fischer catalog, API TR5C3

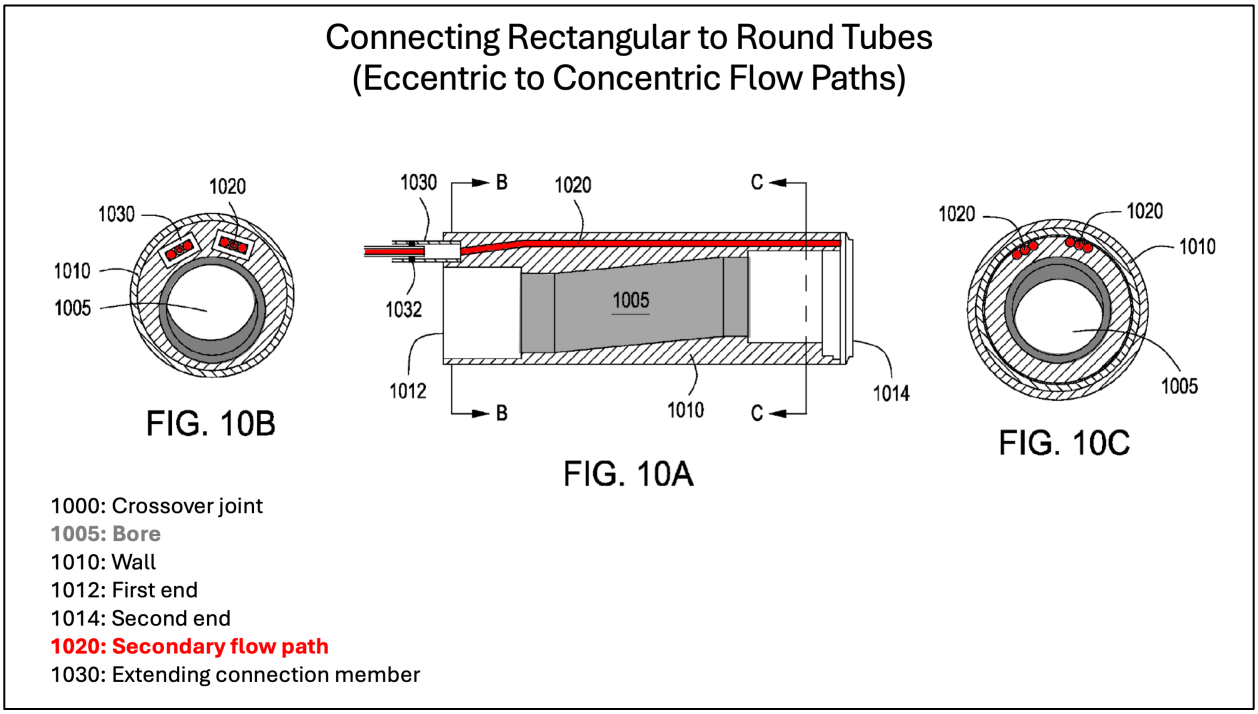
See EX1032; EX1017 at 24 (Equation 14).

13. Mating High Pressure Tubes to Low Pressure Tubes

185. Yeh taught a coupling, to join high pressure tubes to low pressure tubes to reduce costs: "The new crossover tool allows the operator to use the less-expensive eccentric screens on the toe or lower-pressure side of the interval during gravel-packing operations, and to use the concentric screens on the heel or higher-

pressure side of the interval during the gravel-packing operations. This reduces the overall cost of completion while still achieving the gravel packing goal." EX1005 at 30:20-26.

186. Yeh's crossover tool 1000 is shown in Figure 10 and was described as connecting a first wellbore tool to a second wellbore tool. *See* EX1005 at 26:41-44, Fig. 10. Annotated Figure 10A below showed the crossover joint 1000 with a primary flow path 1005 (**dark gray**) through the crossover joint body from a first end 1012 to a second end 1014. *Id.* at 25:44-51.



EX1005 at Figs. 10A-C (annotated).

187. The secondary flow path 1020 (**red**) ran through the body 1010 from the first end 1012 to the second end 1014. EX1005 at 25:52-55. An extending

connection member 1030 could be used to connect the secondary flow path 1020 to the alternate flow channel of an eccentric sand screen. *Id*. at 25:62-65. Yeh also disclosed that "the concentric wellbore tool may connect to the second end 1014 of the crossover joint 1000 either directly through a threaded connection, or indirectly ***through the use of a coupling*** and a torque sleeve or a load sleeve." *Id.* at 26:28-32 (emphasis added). The secondary flow path 1020 preferably included a plurality of shunt tubes or a shunt annulus for transporting a gravel slurry. *Id.* at 26:44-46.

188. Annotated Figure 10B illustrated crossover joint 1000 at line B–B of Figure 10A. EX1005 at 25:56-59. Annotated Figure 10C illustrated crossover joint 1000 at line C–C of Figure 10A. EX1005 at 25:66-26:3. The first end 1012 was configured to fluidly connect with an eccentric wellbore tool such as the sand control device 800A illustrated in Figure 8A. *Id.* at 26:7-12. The second end 1014 was configured to fluidly connect with a concentric wellbore tool such as the packer 900C shown in Figure 9C. *Id.* at 26:16-21. Specifically, the second end 1014 could connect to a concentric wellbore tool "either directly through a threaded connection, or indirectly through the use of a coupling and a torque sleeve or a load sleeve." *Id.* at 26:28-32. But Yeh also disclosed that "the eccentric wellbore tool or the concentric wellbore tool may be a sand screen, a packer, or a blank pipe." *Id.* at 26:35-37.

H. Orifice Design

189. There are many factors that go into shunt tube orifice designs including but not limited to:

a. Size (typically from 1/8" to 3/8" in diameter)

b. Size of Gravel to prevent bridging.

c. Gravel Concentration (concentration increases with leak-off)

d. Viscosity and friction properties of carrier fluids (water vs gel)

e. Location –

   i. On tube or Manifold (coupling)

   ii. On tube - distance between manifold and first orifice

   iii. On tube – distance along tube

   iv. Open Ended or Closed Ended Tubes

f. First orifice distance from manifold – high leak-off

g. Number over a given distance – typically pack 6 to 8 feet

h. Metallurgy to prevent erosion – e.g., tungsten carbide inserts

i. Turbulent and non-turbulent flow

j. Angle of orifice

k. With or without control valves / rupture discs

l. Amount of leak-off to different formations (high perm, low perm, in same wellbore)

m. Wellbore temperature at orifice location

190. In addition to the above design considerations, the ultimate design is also a function of where the tube is in the string. For example, a packing tube near the heel of the well will be a different design than a packing tube at the toe of the well. As I explained before, the gravel pack slurry will be at a higher concentration at the toe than the heel. *See supra* §VIII.G.6. The available pressure will also be higher at the heel than the toe. And, as Yeh2 disclosed in its Figure 15, the following changes occur as you move from heel to toe: (1) gravel slurry concentration increases (**orange line**), (2) pressure decreases (**blue line**), and (3) slurry flow rate decreases (**red dashed line**), wherein the flow rate was lower at the toe (2.6 BPM) than the flow rate at the heel (5.0 BPM):

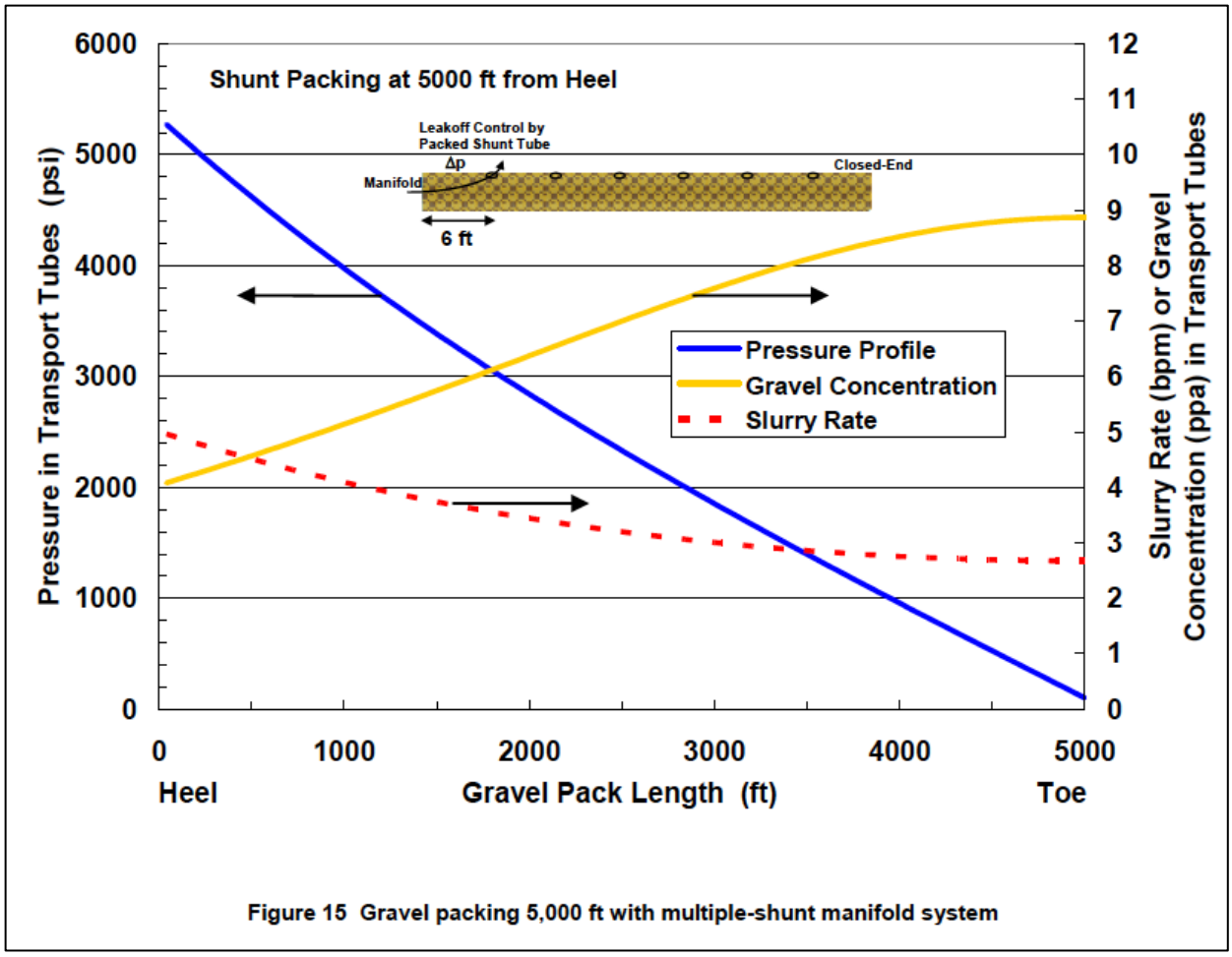


Figure 15 Gravel packing 5,000 ft with multiple-shunt manifold system

EX1006 at Fig. 15.

191. The slurry concentration can vary from the inlet to the outlet. The first orifice can even have a lower slurry concentration than the inlet slurry. This is shown in Figure 5 of SPE 38640 ("'640 Paper"), entitled *Gravel Packing Horizontal Wellbores with Leak-Off Using Shunts*, which published in 1997 and was co-authored by Jones, Tibbles, Myers, Bryant, Hardin, and Hurst who were affiliated with Lloyd Jones & Associates, Schlumberger, Mobil Equatorial Guinea, Mobil E&P, U.S. Filter/Johnson Screen or STIMLAB. EX1033 at 1.

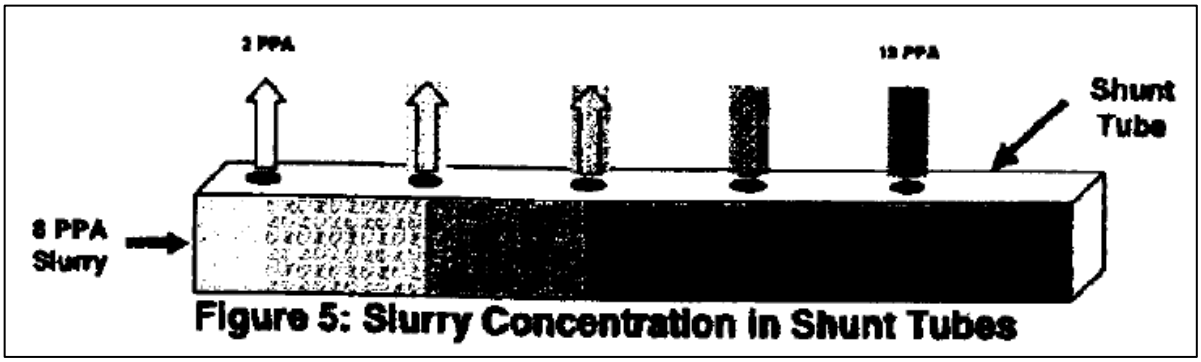


Figure 5: Slurry Concentration in Shunt Tubes

EX1033 at 3, Fig. 5.

1. Orifice – Effect of Fluid Viscosity

192. SPE 27359 ("'359 Paper") was published in 1995 and was entitled *Completion and Production Results From Alternate-Path Gravel-Packed Wells*, co-authored by Bryant and Jones who were affiliated with Mobil E&P or L.G. Jones & Associates. EX1034 at 146. The '359 Paper disclosed further design parameters.

> Optimum uses of alternate-path gravel packing ultimately require a thorough knowledge of the various flow mechanisms provided by the shunts, **Sand transport is dominated by one of the following mechanisms:** (1**) viscous fluid flow**, as in packing with a carrier fluid like xanthan (XC) gel, where the sand does not settle and is carried to and deposited at locations where fluid exits from the casing/screen annulus; (2) **velocity and gravity**, as in packing with water, where sand is transported downward by gravity and laterally by turbulent fluid flow; or (3) some combination of these two mechanisms.

EX1034 at 146 (emphases added, citations omitted).

193. The ’359 Paper further described shunt design considerations. “Most shunts are designed with very small holes so that slurry will exit from 10 to 40 holes simultaneously. Whenever a pack forms in the annulus over one or more shunt holes, the small size of the holes restricts leakoff to such a negligible amount that the slurry is diverted to uncovered shunt holes farther downstream.” EX1034 at 146.

194. When discussing fluid rheology (*i.e.*, the study of flow behavior), the ’359 Paper explained that in “addition to the different mechanisms, the rheology plays a large part in the performance of the shunt tube. As Fig. 2 shows, the pressure drop through a single tube at 0.75 bbl/min for low-viscosity carrier fluid is greater than that of hydroxyethylcellulose (HEC) or clarified xanthan gum (XANVIS™). ***The greater the rate through the tube, the greater the pressure-loss differences between low-viscosity and gelled carrier fluids.***” EX1034 at 147 (emphasis added).

2. Orifice – Distance Between Manifold and Orifice

195. The packed length between the manifold and the first orifice is a consideration for a sustained self-diversion of slurry through shunt tubes in extreme length.

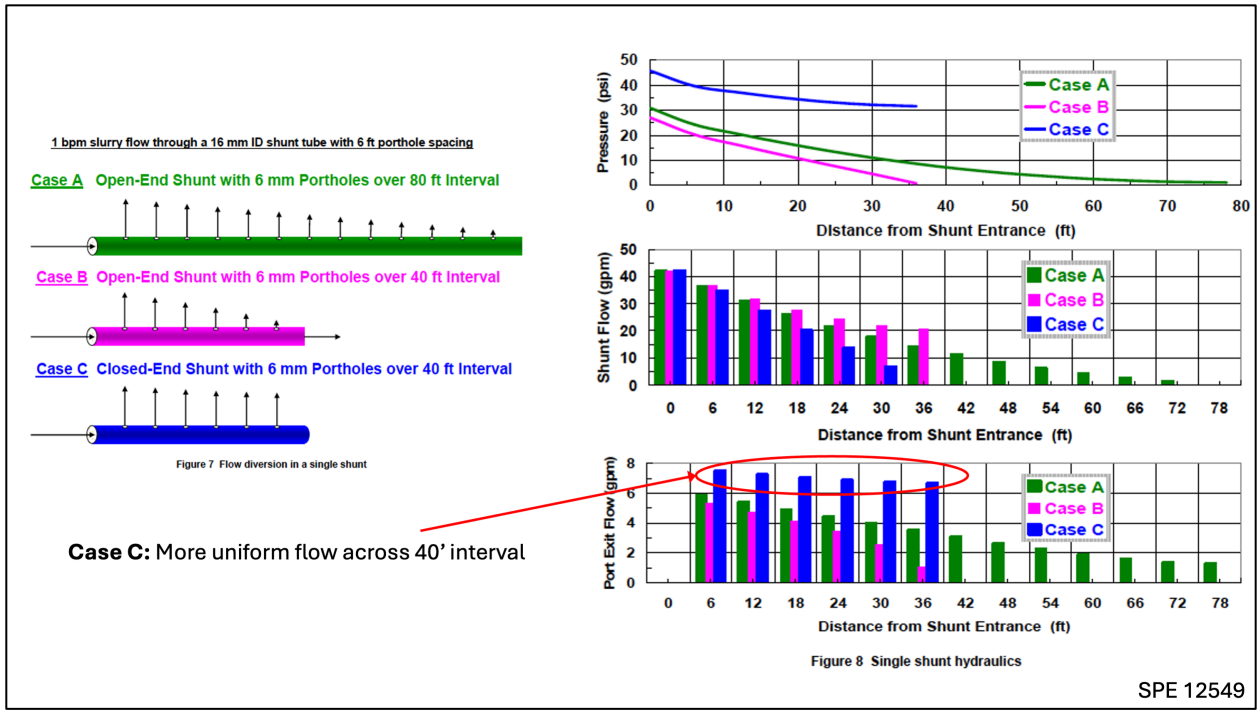
196. When discussing the process of fluid movement inside a packing tube, Yeh2 described why it would be disadvantageous to have a large porthole (orifice) too near the inlet of the packing tube because that could result in very high fluid loss.

"As the slurry enters the shunt tube, the high axial momentum of gravel resists the change of direction to comply with the pressure gradient at the porthole exit. Testing verified that the gravel concentration exiting the leading portholes proved to be less than the inlet slurry concentration. The concentration increased rapidly, however, further down the shunt tube at the subsequent portholes." EX1006 at 2.

197. Yeh2 further explained since the fluid loss in the first porthole could be high, the distance between the first porthole and the manifold needed to be increased but within the design of the overall porthole spacing. In the example provided, the spacing had to be within the 6' spacing. "In order to reduce the leakoff rate, the distance between the manifold and the first porthole needs to be increased. However, this distance must be within the acceptable range of porthole spacing for shunt packing, e.g. 6 ft in the example of Figure 9." EX1006 at 5.

198. Yeh2 also disclosed in Figures 7 and 8 how shunt tube length and having an open or closed end impacted gravel slurry flow characteristics when porthole spacing was held constant at 6'. Figure 8 illustrated that a 40' closed-ended shunt (*i.e.*, Case C) produced a more uniform packing arrangement: "The characteristics of Case C promotes uniform shunt packing across the 40 ft interval, minimizing the amount of slurry passing by any packed porthole and avoiding the

potential plugging mechanism described in Figure 4b." EX1006 at 4. I provide Figures 7 and 8 below for reference:



EX1006 at Figs. 7 and 8 (annotated).

199. Yeh2 also explained why using too large a porthole caused plugging: "Although larger portholes could prevent plugging by a concentrated slurry, a different shunt plugging mechanism was observed after the annulus was packed as shown in Figure 4b. The large portholes allow excessive fluid leakoff through the surrounding annular pack (resulting in ever increasing slurry concentrations) and deposit gravel inward from the inner porthole face." EX1006 at 2. I reproduce Figures 4 and 5 below for reference:

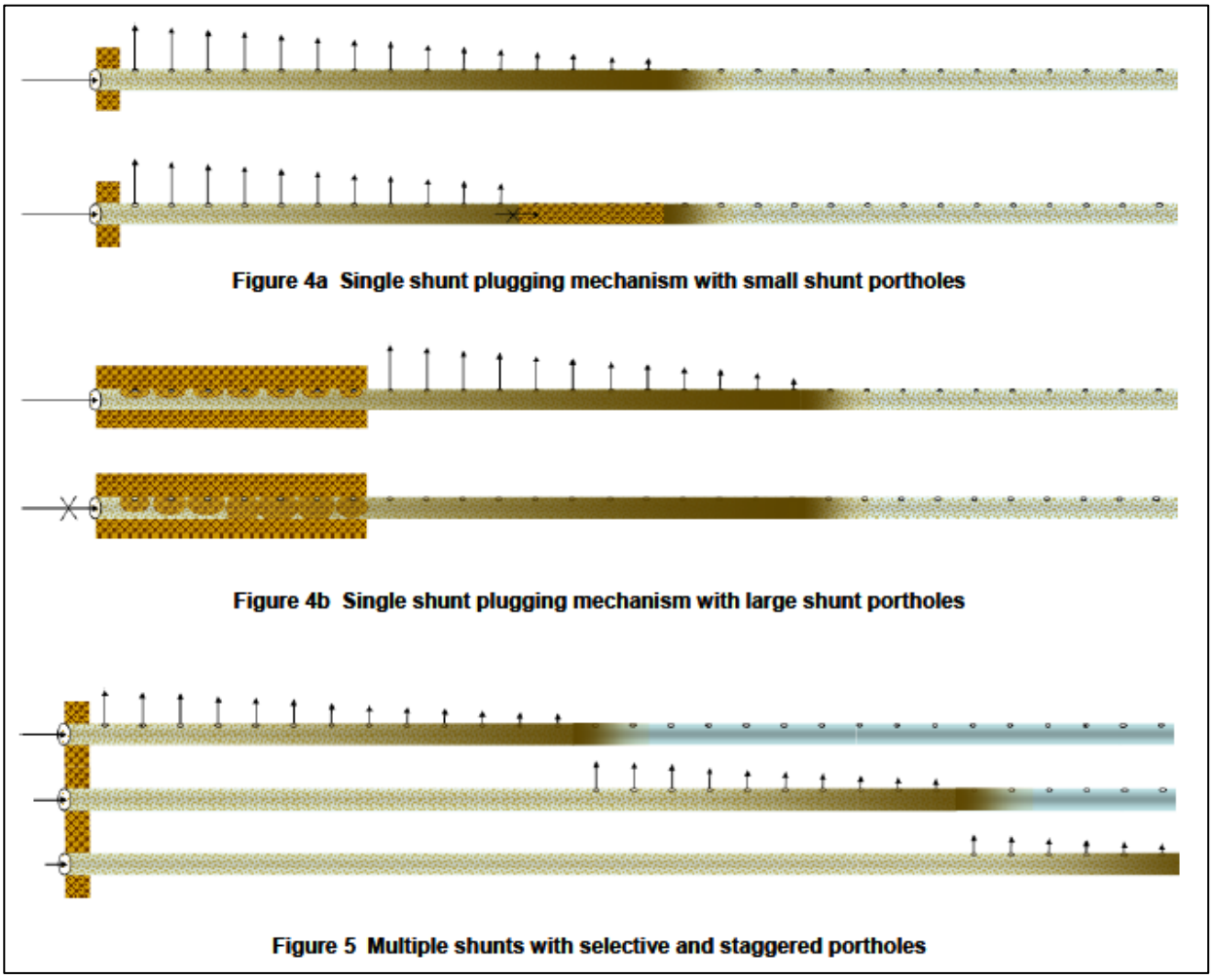


Figure 4a Single shunt plugging mechanism with small shunt portholes

Figure 4b Single shunt plugging mechanism with large shunt portholes

Figure 5 Multiple shunts with selective and staggered portholes

EX1006 at Figs. 4a-b, 5.

200. When discussing port holes sizes for larger concentrations of sand that had been dehydrated (especially in horizontal wellbores), Yeh2 recommended larger port holes: "Larger portholes, ratio 10 or greater, were found to facilitate the discharge of concentrated slurry and prevent plugging in a horizontal ported shunt tube." EX1006 at 2.

201. U.S. Patent No. 6,588,506 ("'506 Patent"), which was filed in 2001, entitled *Method and Apparatus for Gravel Packing a Well*, invented by Jones and assigned to ExxonMobil Corporation**,** disclosed the importance of not spacing the first orifice too close to the shunt entrance: "Preferably, each shunt tube will be perforated only along a portion of its length towards its outer end, leaving a substantial inlet portion of each shunt tube (i.e. a length of at least about 2 feet up to about one-half of the length of the shunt tube) blank (i.e. having no exit openings) for a purpose to be discussed below." EX1035 at 5:36-41.

202. The '506 Patent further taught that leaving the section blank encouraged turbulent flow: "By leaving the inlet portion of each shunt tube blank, the slurry encounters a certain resistance as it flows within this blank portion thereby creating turbulent flow which aids in keeping the proppants (e.g. sand) in suspension until the slurry reaches the exit openings at the outer or exit end of the tube." EX1035 at 6:1-6.

203. Finally, the '506 Patent also recognized that "since there are no openings in the blank portion of each shunt tube, there can be no loss of fluid from the slurry so the probability of premature sand-out in the shunt tube is virtually eliminated." EX1035 at 6:6-10.

3. Tungsten Carbide Inserts

204. Hurst explained the importance of installing nozzles with tungsten carbide inserts to prevent erosion:

> The third improvement was the replacement of holes with nozzles with tungsten carbide inserts. This modification was a result of earlier experiments conducted with the original shunt tube design. In these experiments, shunt tubes with 30-ft length containing 22 holes of 1/8-in diameter were used with the end of the shunt tube blocked, forcing all the slurry through the holes. An 80-lb/1,000-gal HEC solution with 2.0-ppa 40/60-U.S. mesh gravel was injected at 2.0 bbls/min. The key observations can be summarized as follows:
>
> 1. Holes closer to the inlet section of the shunt erode very quickly, as most of the flow occurs through these holes, and
>
> 2. As those holes elongate (increased flow area) with further erosion, all of the slurry flow occurs through the first several holes,
>
> 3. After 5 mins (10-bbls) of slurry injection, the first hole had already elongated to 0.4-in, growing to 0.6 and 0.8-in after 10 and 20 minutes, respectively.

EX1013 at 2.

205. Shown below is Figure 1 from Hurst illustrating shunt tube nozzles without tungsten carbide inserts on the left and nozzles with the inserts on the right after erosion tests indicating the importance of inserts to minimize erosion.



EX1013 at Fig. 1.

206. For the reasons Hurst provided, it was very important that the nozzle ID did not erode. It was possible to install a thicker walled carbide seat where greater erosion was anticipated. For example, one could maintain ¼" ID but increase the outside diameter with a thicker wall.

4. Gravel Particle Size vs. Orifice Size

207. The '359 Paper explained that "laboratory studies have shown that premature plugging can occur inside the shunts if the exit ports are too large and allow too much leakoff or if too much packing takes place through a short section of a shunt." EX1034 at 1-2.

208. Hurst investigated the maximum size gravel an orifice could take without plugging. Hurst reported that the mean gravel ratio is less than approximately 5: "The first improvement involved the optimization of the hole

diameter on the shunt tubes. A series of yard tests were conducted with various hole diameters (3/32-in to ¼-in) using gravels from 40/60 to 12/20 U.S. mesh. These tests indicated that bridging could occur when the hole diameter to mean gravel diameter ratio is less than approximately 5, preventing exit of the slurry out of the shunt tubes." EX1013 at 1.

209. Hurst also referred to the nozzle table below the maximum size gravel that could be used for 1/4" and 3/8" nozzles: "Note that gravel sizes up to and including 16/30 U.S. mesh can be used with 1/4-in nozzles, while 3/8-in would be required for 12/18 U.S. Mesh, with nozzle length of 5/8-in in both cases." EX1013 at 2.

Gravel U.S. Mesh	¼ -in Nozzles		3/8-in Nozzles	
	Nozzle-to-Mean Gravel Diameter Ratio	Nozzle-to-Largest Gravel Diameter Ratio	Nozzle-to-Mean Gravel Diameter Ratio	Nozzle-to-Largest Gravel Diameter Ratio
40/60	**19.0**	**15.1**	**28.4**	**22.7**
20/40	**10.1**	**7.6**	**15.1**	**11.3**
16/30	**7.3**	**5.5**	**10.9**	**8.3**
12/18	4.9	3.9	**7.3**	**5.9**
8/12	3.1	2.6	4.7	3.8

Table 1 - Nozzle Diameter versus Gravel Mesh Size.

EX1013 at Table 1.

210. Yeh2 also noted on orifice size in relation to gravel size. He found shunt plugging in horizontal applications "was observed when the ratio of porthole diameter to gravel diameter was 7 or less" and larger "portholes [with a] ratio of 10 or greater" were found to be more effective when the slurry concentration was higher. EX1006 at 2.

I. Yeh

1. A Sand Control System for Open-Hole Completions

211. Yeh described a sand control system that included a shunt tube assembly for gravel packing open-hole completions and a method for installing said sand control system. EX1005 at 1:17-20, 4:25-30, 9:5-9:21, 30:13-16. Yeh's system considered previous industry knowledge indicated by Yeh referencing numerous patents and printed publications included in this Oil and Gas Background, some of which were incorporated by reference. *See, e.g., id.* at 3:13-15 ('487 Patent, EX1012), 3:19-20 (Jones, EX1007), 3:20 (Jones2, EX1008), 3:20 ('476 Patent, EX1010), 3:21-22 ('460 Paper, EX1027), 3:27-31 (Hurst, EX1013), 3:38-41 (Hecker, EX1015), 26:34 ('184 Patent, EX1024).

212. Yeh's sand control system included wellbore tools, or completion devices, *see id.* at 19:31-32, such as packers and sand screens for installation in an open-hole completion. *Id.* at 4:25-30; *see, e.g., id.* at 11:53-60, Fig. 2. Yeh used packers to isolate certain areas (*i.e.*, an interval) within an open-hole completion. *Id.* at 10:51-11:2, 11:26-35, Figs. 1 and 2. Yeh's system used sand screens to prevent formation sand from entering and eroding the production equipment. *Id.* at 1:25-36, 11:4-8, 15-25, Figs. 1 and 2.

213. Below I provide Yeh's Figures 1 and 2, which illustrated a wellbore with multiple packers and sand screens installed in series within an open-hole

portion 120 wherein Figure 2 showed an expanded view of open-hole portion 120. Above the open-hole portion of the wellbore was a casing 104, 106, 108 (**dark purple**), which created an annular space 204 (light purple) between the casing and the production tubing. *Id.* at 10:18-19.

214. An example of Yeh's system included a series of sand control devices 200 installed in production intervals 112, 114, and 116 of wellbore 100. *Id.* at 11:9-11, 11:53-56. Packers 212, 214, and 216 (**green**) could be used to isolate production intervals 112, 114, and 116 from each other. *Id.* at 11:66-12:2, 12:62-65, 13:13-15. The sand screens had a base pipe 205 (**dark gray**) with an external filter medium 207 (**orange**). *Id.* at 4:44-46, 9:11, 11:17. The sand screens also included at least one shunt tube that ran outward of the base pipe. *Id.* at 4:46-47. A POSITA would understand that a series of wellbore tools installed in an open-hole completion would be considered together as a completion assembly.

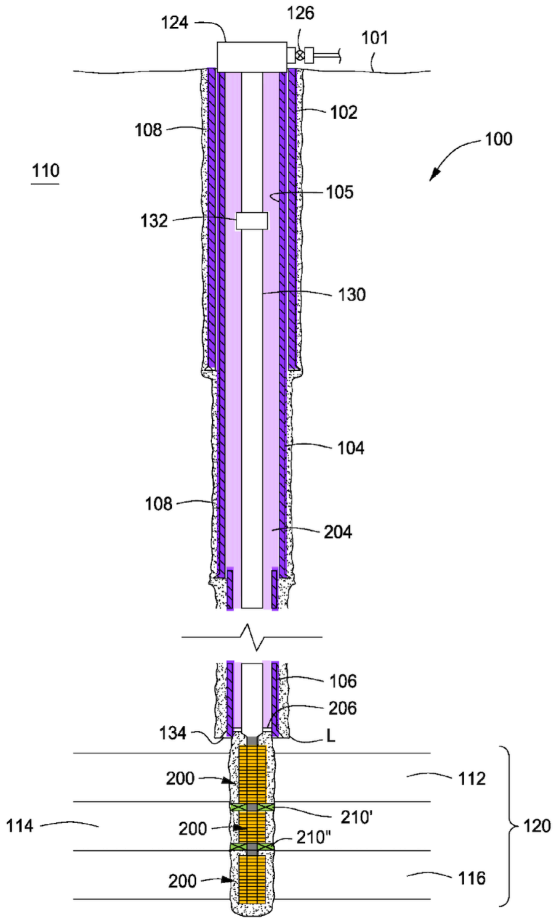


FIG. 1

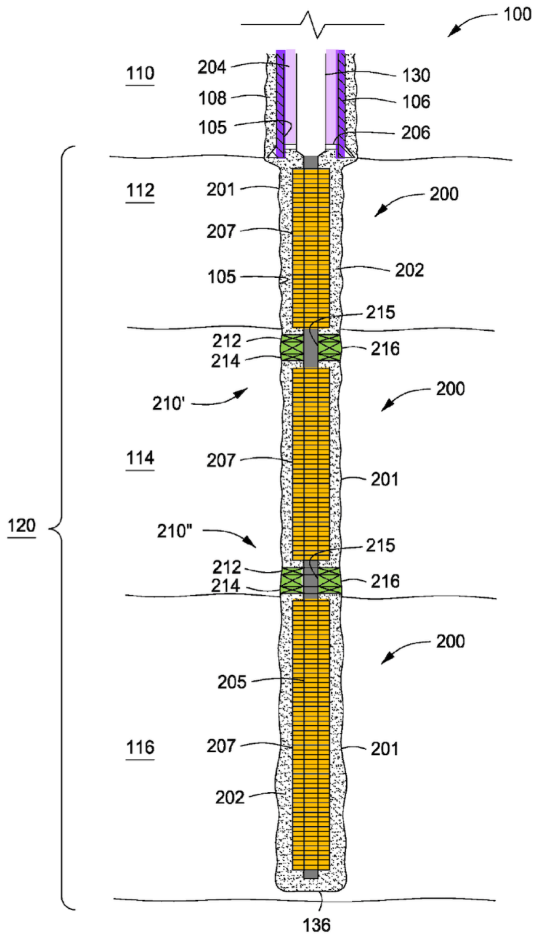


FIG. 2

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

215. A POSITA understood that when describing the components of a system of wellbore tools installed in a well, all positional references are with respect to the surface. However, Yeh explained that "[w]hen the descriptive terms 'up and down' or 'upper' and 'lower' or similar terms are used in reference to a drawing or in the claims, they are intended to indicate relative location on the drawing page or with respect to claim terms, and not necessarily orientation in the ground, as the

present inventions have utility no matter how the wellbore is orientated." EX1005 at 9:35-41. For example, Yeh's open-hole portion 120 included an "upper interval," (interval 112) and a "lower interval," (interval 116), wherein each interval had an upstream proximal end (closer to top in Figure 2) and a downstream distal end (closer to the bottom of Figure 2). Relatedly, a POSITA would have also understood that gravel slurry was pumped from the surface down into the production zone. *Id.* at 2:47-48; EX1012 at 5:4-5 ('487 Patent, incorporated by reference in Yeh at 3:13, explaining a gravel slurry is pumped down a work string); EX1005 at 1:54-57 ("As part of the completion process, a wellhead is installed at the surface. The wellhead controls the flow of production fluids to the surface, or the injection of fluids into the wellbore.").

216. A POSITA also understood that open-hole production zones were selected for installation of sand screens and a gravel pack. This is because the gravel pack served to prevent particles from the formation from being carried by the fluids into the wellbore production equipment and to maintain wellbore integrity. EX1005 at 2:51-52. Specifically, once the gravel pack was installed, the production fluids within the open-hole portion 120 of the formation traveled through the gravel pack, through the sand screens, where any sand in the production fluids was kept out by

the gravel pack and the filter medium 207, then into the perforated base pipe 205 and up to the surface 101. *Id.* at 2:34-41, 2:55-60, 9:5-10, 9:48-50, 11:12-14.

217. Yeh's sand control system utilized Alternate Path® Technology to allow gravel slurry to bypass premature sand bridges formed in the annulus during the gravel packing process. *See id.* at 3:8-62 (describing Alternate Path® sand screen technology); 9:10-21 (defining "alternate flow channels" as a means for providing fluid communication, for example, through an obstruction in the annulus, to continue gravel packing downstream of that obstruction).

2. Yeh's Sand Screen Assembly Design

218. Yeh's Figures 4A and 4B illustrated an example of a sand control system that included a packer in between two sand screens, which I provide annotated below. EX1005 at 15:53-58, 16:1-4. Each end of the packer base pipe 302 was connected to a sand screen base pipe 205 (**dark gray**). *Id.* at 15:23-32, 15:55-58. Each sand screen included an outer mesh 220 (**orange**) outwardly disposed about the perforated base pipe 205. *Id.* at 16:4-12. Figure 4A showed that the sand screen shunt tubes 218 (**blue**) were connected (**yellow**) to the packer shunt tubes 318. *Id.* at 15:58-60, Fig. 4A. The sand screen had a shunt tube assembly that included transport tubes 218 and packing tubes 218 (light blue). *Id.* 15:60-64, 24:26-28, Fig. 4A. The transport tubes 218 did not have nozzles, but the packing tubes 218 included nozzles 209 that provided a pathway for gravel slurry to enter the annular

space. *Id.* Figure 4B, which provided a cross-sectional view of Figure 4A at line 4B—4B, showed that Figure 4A's sand screen had a concentric design with shunt tubes 218 (**dark blue**) distributed outwardly around the entire screen. *Id.* at 7:16-19; *see supra* ¶ 133.

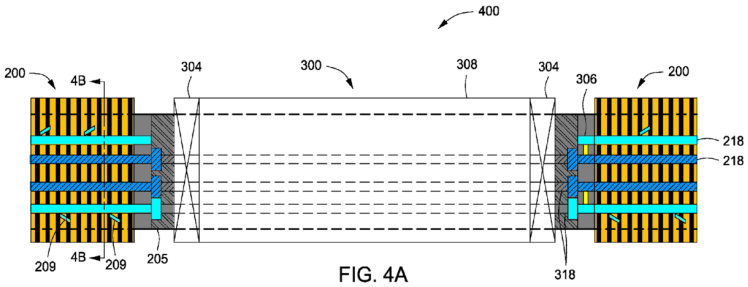


FIG. 4A

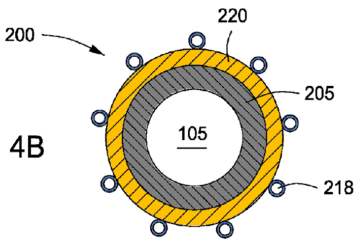


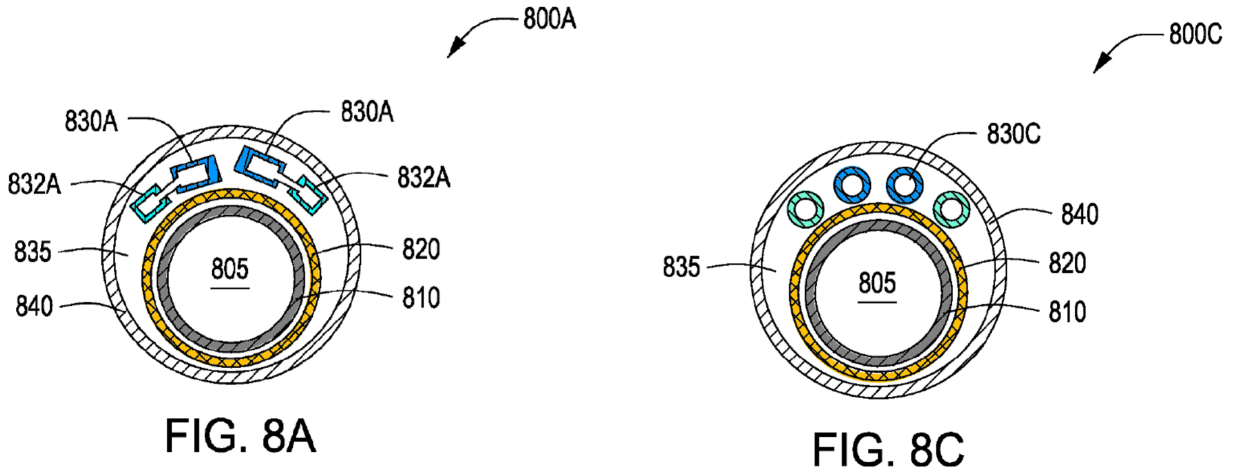
FIG. 4B

EX1005 at Figs. 4A and 4B (annotated).

219. Yeh also disclosed screens having an eccentric arrangement. Figure 8A illustrated an eccentric sand control device 800A, which had a base pipe 810 (**dark gray**) providing a primary flow path 805, a filter medium 820 (**orange**), transport tubes 830A (**blue**), and packing tubes 832A (**light blue**). EX1005 at 24:1-8, 24:22-29, 24:53-54.

220. Figure 8C illustrated another eccentric sand control device 800C but with round shunt tubes. Yeh taught that it was "known to use rectangular shunt tubes that are eccentrically attached to the outside of a sand screen." *Id.* at 3:23-24. However, Yeh also explained that sand screen shunt tubes could have "a round profile, a square profile, or a rectangular profile," and that eccentric screens used

both "packing tubes and transport tubes." *Id.* at 4:58-60, 16:30-37, 24:10-12 ("The alternate flow channels in the illustrative sand screens 800A, 800C are rectangular or round shunt tubes …."). It follows then that the shunt tubes 830C would include packing (light blue) and transport tubes (**blue**) in Yeh's eccentric round tube example. Below I provide an annotated version of Figures 8A and 8C for reference:



Id. at Figs. 8A and 8C (annotated).

221. As I explained earlier in Section VIII.G.13 covering shunt tube design, Yeh also disclosed a crossover tool specifically designed with a primary flow path 1005 (**dark gray**) and secondary flow path 1020 (**red**) to fluidly connect the primary and secondary flow paths of two wellbore tools wherein one wellbore tool had a concentric configuration and the other wellbore tool had an eccentric configuration. *Id.* at 25:44-55, 26:7-12, 26:16-21. Yeh's crossover tool in Figures 10A-C is shown annotated below:

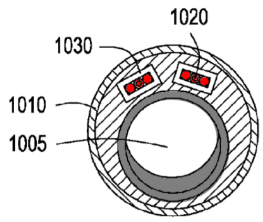


FIG. 10B

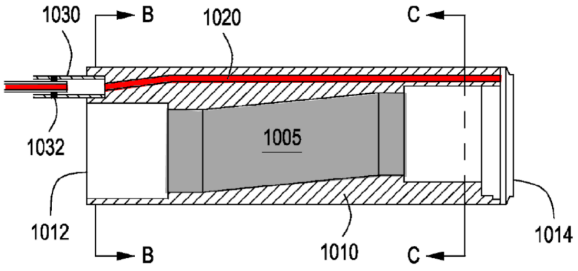


FIG. 10A

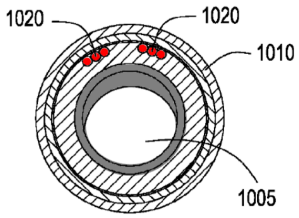


FIG. 10C

Id. at Figs. 10A-C (annotated).

222. Yeh's crossover tool was specifically designed to permit transitioning from concentric screens (high pressure) to eccentric screens (low pressure): "concentric screen→crossover tool→eccentric screen." EX1005 at 30:13-14. Yeh understood that the shunt tube differential pressure was highest at the heel (upstream) and decreased toward the toe due to friction pressure drop. *Id.* at 28:11-24 ("For example, a 6,500 psi differential pressure is expected near the heel of [sic] when gravel packing a 5,000-foot horizontal completion interval."). As Yeh explained, "[t]he new crossover tool allows the operator to use the less-expensive eccentric screens on the toe or lower-pressure side of the interval during gravel-packing operations, and to use the concentric screens on the heel or higher-pressure side of the interval during gravel-packing operations." *Id.* at 30:20-25.

223. When referring to shunt tube assemblies installed in either the concentric or eccentric screens, a POSITA would understand that these shunt tube assemblies could be identified as "high pressure" or "low pressure" wherein "high"

or "low" pressure was understood to be relative to the shunt tube assembly of the other sand screen assembly. EX1005 at 30:15-26 (describing use of concentric screens "on the heel or higher-pressure side of the interval" and eccentric screens "on the toe or lower-pressure side of the interval").

3. Yeh's Method of Installation

224. Yeh also disclosed a method for installing wellbore tools into a subsurface formation. EX1005 at 30:13-17. Yeh taught in Figure 12 "steps for a method 1200 for completing a wellbore in a subsurface formation, in one embodiment. The method 1200 is applicable for the installation of wellbore tools having flow paths that do not align." *Id.* at 28:31-33, Fig. 12.

225. Yeh's method taught to select a first wellbore tool, a second wellbore tool, and a crossover joint that each had a primary and at least one secondary flow path. *Id.* at 28:35-54. An exemplary wellbore tool sequence could be a "concentric screen → crossover tool → eccentric screen." *Id.* at 30:13-14.

226. Yeh next taught to fluidly connect the first end of the crossover joint to the first wellbore tool and to fluidly connect the second end of the crossover joint to the second wellbore tool such that the primary flow paths of the first and second wellbore tools were in fluid communication and the at least one secondary flow paths of the first and second wellbore tools were also in fluid communication. *Id.* at 28:51-60.

227. After the series of wellbore tools were fluidly coupled, then they were installed into a wellbore at a selected subsurface location. *Id.* at 28:61-64. Gravel slurry was then pumped or injected into the wellbore, which would then be injected into the secondary flow paths. *Id.* at 28:66-29:3.

J. Knowledge of a POSITA

228. Given Exxon-Mobil's extensive background in this space, a POSITA considering a problem in the gravel-packing area had a wealth of research to consider in June 2018. As I discussed at length above, every aspect of shunt tubes in sand screens had been studied and documented extensively in publicly available literature, such that a POSITA would have been familiar with all the design parameters surrounding shunt tubes in sand screens. In addition to all the publications discussed, a POSITA also had background engineering knowledge both from engineering education and from the extensive resources available to a practitioner in this field. For example, practitioners in the oil and gas industry relied upon industry standards providing guidance on engineering concepts and data, such as the American Petroleum Institute ("API") and ASTM International.

229. API published Technical Report 5C3 in December 2008 with an Addendum in October 2015. EX1017 (API TR 5C3). This technical report provided guidance on various calculations for casing, tubing, and line pipe. EX1017 at 1. The report consolidates basic engineering knowledge to permit POSITAs to perform

engineering calculations necessary to design tools and select tubing for use in various applications. As the report explains, "Design equations, on the other hand, are a reference point for users to characterize tubular performance and begin their own well design or research of pipe input properties." *Id.*

230. The report describes calculations for tubing including tubing burst pressure. The yield pressure can be calculated using the "Barlow Equation," which I have simplified a bit to P = 2fkt/D where **P** is yield or burst pressure; **f** is the minimum yield of the tubing material, which is a property of the metal out of which the tubing is made; **k** is 0.875 (assuming a 12.5% design tolerance for tubing wall thickness); **t** is tubing wall thickness; and **D** is tubing outside diameter. EX1017 at 19. Although API 5C3 describes more complicated formulas that can provide better accuracy in certain situations, the basic relationship of yield pressure to tubing strength, tubing wall thickness, and outside diameter as described in the Barlow Equation does not change. Notably, the Barlow Equation is for round tubing only and does not apply to rectangular cross section tubing. A POSITA understood from this equation that for a given material (with given **f**), yield pressure is directly proportional to tubing wall thickness and inversely proportional to outside diameter. When considering design changes for tubing, there were only a few available options to consider.

231. Additionally, a POSITA would have ready access to ASTM published standards, such as A554-16, which was published in March 2016, EX1018 at 1, and provided tensile strengths for various stainless steels, *id.*, Table S2.1, 7; *supra* ¶¶166-169; EX1018. Similar ASTM standards existed for other materials, such as ASTM A500/A500M-13, which described similar properties for carbon steel. EX1029 at 1.

232. Consider the example below wherein two round tubes with the same 1.05" OD but dissimilar wall thicknesses and metallurgies need to meet a 7,000 psi yield pressure requirement. Using Barlow's Equation and the yield strength values from ASTM A554 and A500, a POSITA would understand that a +7,000 psi yield pressure rating could be achieved using either a (1) stainless steel 316L tube with a 0.065" wall or a (2) carbon steel H40 tube with a 0.113" wall. Adjusting the tube specifications by increasing the OD to 1.315", 1.33" wall and 40,000 psi yield strength material would also result in a tube with a 7,000 psi yield pressure. I provide these data below:

Example	Wall Thickness (in)	Outer Diameter (in)	Yield (psi)	Burst (psi)
1	0.065	1.05	70,000	7,583
2	0.113	1.05	40,000	7,533
3	0.133	1.315	40,000	7,080

233. Note that a POSITA would understand that yield strength determines the pressure the tubing could withstand while enduring a specified deformation.

E.g., EX1018 ¶S2.3 ("The yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length under load shall be determined."); EX1029 ¶15.3 (similar). Thus, yield strength is a determination of the point at which the pipe will yield or deform by a certain percentage.

234. A POSITA would understand that the tensile strength determines the pressure the tubing could withstand without rupturing. EX1017 at 21 ("While the yield equations of Clause 6 are intended to describe ***the onset of permanent plastic deformation and not loss of pressure integrity***, ***the rupture equations are intended to describe the ultimate pressure capacity of the pipe at a pressure which fails the pipe body with loss of internal pressure integrity***. The equations for ductile rupture depend on the minimum physical wall thickness, the pipe outer diameter, the maximum depth of imperfections which have a reasonable probability of passing through the inspection process undetected, the fracture toughness of the material, the work hardening of the material and the ***ultimate tensile strength of the pipe***." (emphases added)). The yield strength is lower than the burst strength such that a pipe will yield before it will rupture.

235. The ductile rupture equation is Equation (14) in API 5C3: $P_{iR}= 2k_{dr}f(k_{wall}t – k_aa_N)/[D – (k_{wall}t - k_aa_N)]$. EX1017 at 24. While more complicated

than the Barlow Equation, Equation (14) generally shows the same basic correlation in that the rupture or burst pressure is roughly directly proportional to the minimum tensile strength (f) and the tubing wall thickness (t) and inversely proportional to the outside diameter (D). Thus, a POSITA would understand that when considering burst pressure of tubing, the same basic design criteria are in play to manipulate burst pressure for a given design scenario as those at issue for yield pressure.

K. Summary

236. In summary, Alternate Path Gravel Packing Technology was first introduced in the early 1990s primarily for vertical wellbores but has evolved into longer and longer distances where today over 5,000' in a horizontal wellbore is possible. This has been primarily done through planning, but ultimately confirmed through laboratory testing. Much has been learned about tube design, manifolds, and number of and placement of orifices along the tube, as well as number of tubes required. For example, shunt tube wall thickness has grown from the original 1/16" thick thin-walled tube to address the increased pressure requirements for longer shunt tube runs, and ultimately concentric screens with round tubes were introduced to address the increased pressure requirements as well as other concerns. In my opinion, nothing shown in the '007 Patent is a new concept or inventive given this large body of prior art that would be known to a POSITA.

237. Below, I provide a timeline showing the evolution of the Alternate Path Technology from the original patent in 1989 by Jones (EX1007) to the high-pressure gravel pack assemblies made available before the time of the '007 Patent's filing:

Initial Patent	Staggered Design	Eccentric 2x2	Concentric Round Tube	Eccentric 2x2 High Pressure
1989	Mid to Late 1990's	Late 1990's	Mid-2000's	~2014
Pack length: <100'	Pack length: <400'	Pack length: <3,200' Max Pressure: ~3,000 psi	Pack length: ~5,000' Max Pressure: ~10,000 psi	Pack length: ~5,000' Max Pressure: >5,000 psi

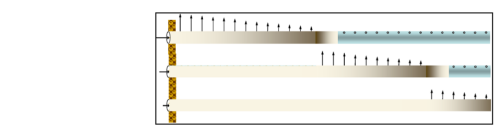


Fig. 2—Staggered shunt tube design.

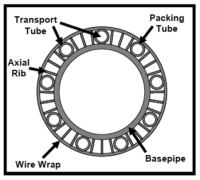
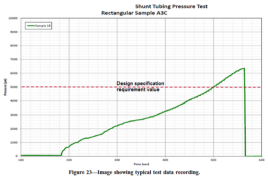


Fig. 5—Cross-Section of ISAPT



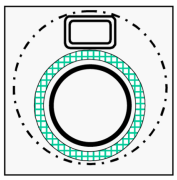


Fig. 1—Single shunt tube design.

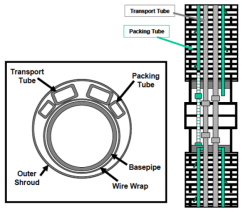
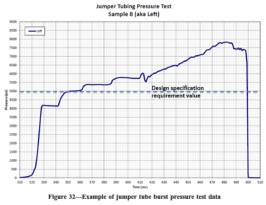


Fig. 3—Eccentric 2x2 design.



See EX1015 at Figs. 1-3, 5; EX1016 at Figs. 23, 32.

IX. ANALOGOUS ART

238. All of the cited references I discussed above are relevant to the subject matter of the '007 Patent because they are (1) from the same field of endeavor as the claimed invention and/or (2) reasonably pertinent to the problem faced by the inventors for all the reasons I provided above in discussing those references.

239. A POSITA in June 2018 would have been aware of these references and would have readily looked to them to understand the state of the art for gravel packing with sand screens that incorporate shunt tubes for gravel slurry distribution.

X. OVERVIEW OF HALLIBURTON'S '007 PATENT

A. The '007 Patent

240. The '007 Patent challenged here, entitled "Multiple Shunt Pressure Assembly for Gravel Packing" purports to describe and claim an improvement on shunt tube assemblies for gravel packing. EX1001 at 1, 2:4-13. The (incorrect) premise of the patent is that existing equipment included "multiple sand screen assemblies with shunt tube assemblies all of the same pressure rating" selected based on "the highest operating pressure expected to be required across the entire length of the gravel packing interval." *Id.* at 9:3-7, 9:20-24. These higher pressures required "heavier and/or bulkier tubing and components" and correspondingly "heavier" production assemblies. *Id.* at 9:15-25.

241. Figure 2 showed a cross-section of two sand screen assemblies 202 and 204 forming a joint 236 (**purple**). EX1001 at 2:23-24, 5:6-9, 5:65-66. Both assemblies have their own base pipes 206a (**dark gray**) and 206b (**light gray**). *Id.* at 5:63-65. The base pipes 206 have a series of perforations 208 allowing for "fluid communication of production fluid between an interior through bore 228 and an exterior 230 of the screen assembly." *Id.* at 5:19-20, 5:38-40.

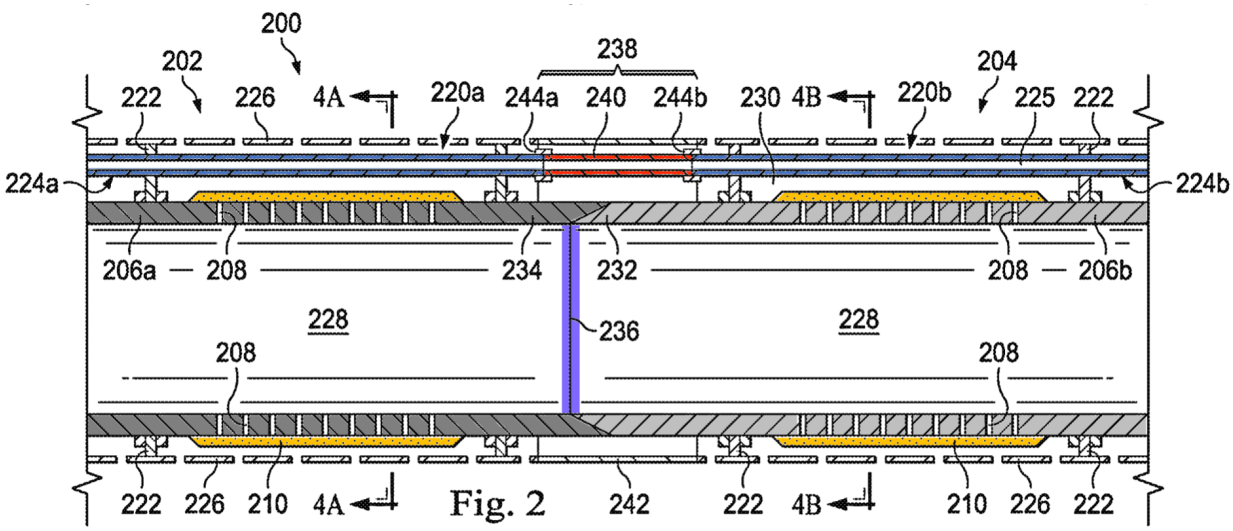


Fig. 2

EX1001 at Fig. 2 (annotated).

242. The sand screen (filter media 210 shown in **orange**) surrounds a section of the base pipes 206. EX1001 at 5:17-19. It allows formation fluid to flow into the through bore 228, while preventing the entry of sand or other particulates. *Id.* at 5:50-56. Each sand screen also includes an exterior shunt tube assembly 224 (**dark blue**) running generally parallel to the base pipes 206. *Id.* at 5:20-26. The two shunt tubes 224a/224b can be fluidly coupled via jumper tube 240 (**red**). *Id.* at 6:19-22.

243. Annotated Figure 3, shown below, provides a "partial side view of an embodiment of a shunt tube assembly deployed on a base pipe of a lower completion assembly," with the filter media 210 and outer shroud 224 shown in Figure 2 removed for better view of the shunt tube assemblies. EX1001 at 2:25-27, 6:37-40.

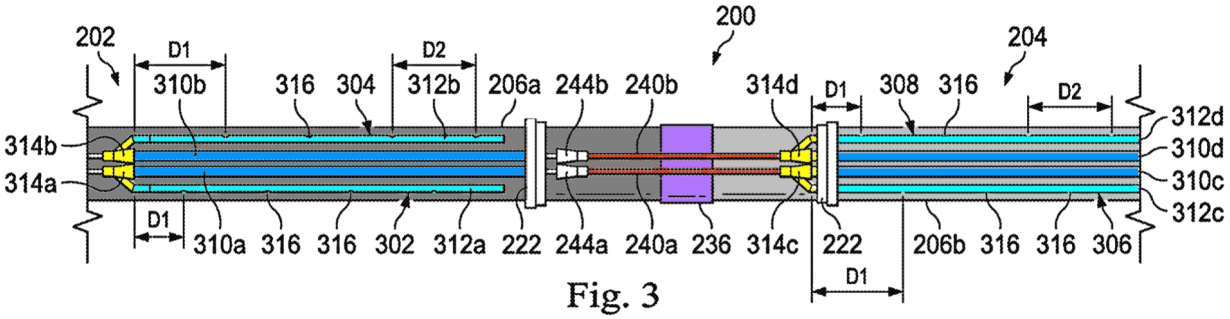


Fig. 3

EX1001 at Fig. 3 (annotated).

244. The shunt tube assembly can be made up of a transport tube and a packing tube. EX1001 at 5:24-26. The first sand screen assembly 202 includes two shunt tube assemblies 302 and 304. *Id.* at 6:44-45. Shunt tube assembly 302, for example, includes a transport tube 310a (**blue**) and packing tube 312a (light blue), which are fluidly coupled via junction block 314a (yellow). *See id.* at 6:52-56. The same transport and packing tube arrangement is shown for shunt tube assemblies 304, 306, and 308. *Id.* at 6:45-56. Each packing tube 312 includes at least one nozzle 316. *Id.* at 7:4.

245. Figure 4A, shown below, provides "a cross-sectional view of an embodiment of a shunt tube assembly along line A'—A' of FIG. 2." EX1001 at 2:28-29. The shunt tubes 224 are "eccentrically aligned with respect to the base pipe 206…. [However,] other alignments of the one or more shunt tubes about the base pipe 206 may also be possible." *Id.* at 7:42-48. In Figure 4A, the transport tubes 410 (**blue**) and packing tubes 412 (light blue) are arranged eccentrically outside the

base pipe 206a (**dark gray**) and sand screen or filter media 210 (**orange**). *Id.* at 5:61-64, 7:42-47, 7:50-51. An outer shroud 226 can be disposed about base pipe 206 and the shunt tubes 224. *Id.* at 5:30-31.

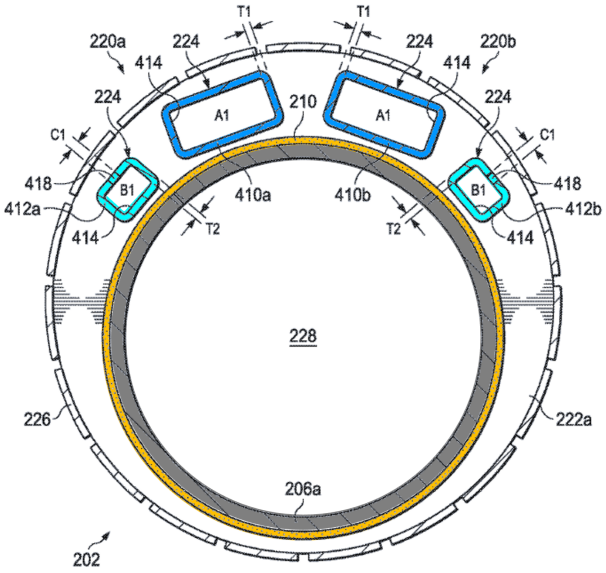


Fig. 4A

EX1001 at Fig. 4A (annotated).

B. Prosecution History of the '007 Patent

246. The '007 Patent claims priority to U.S. Provisional Application No. 62/688,813, which was filed on June 22, 2018. EX1001 at 1. I have been asked to assume for purposes of my analysis that all claims of the '007 Patent are entitled to priority to that filing date.

247. On July 6, 2021, the Examiner, Jennifer Gay, issued an office action rejecting claims 1-23 under 35 U.S.C. § 112(a) as lacking enablement. EX1002 at 261-263. The Examiner objected that the claims seemed to reflect the "pressure of

the gravel slurry decreasing as the slurry flows from the upstream portion to the downstream portion." *Id.* at 264. However, the Examiner stated, "It is a well-known and established principle that fluids in a wellbore increase in pressure as the depth of the well increases …." *Id.* The Examiner further rejected claims 5, 7-10, 12, 13, and 15 under 35 U.S.C. § 112(b) for a list of informalities including indefinite terminology ("substantially") as well as various open-ended pressure ranges (e.g., "a pressure rating over 5000 psi" in claim 7) and claims 7-10's recitation of "a shunt tube assembly" without making it clear whether these were the same shunt tube assemblies already recited in claim 1. *Id.* at 266-269. Finally, the Examiner rejected 1, 5-15, and 18-23 under 35 U.S.C. § 103 as obvious over Sessa (US Patent Publication No. 2019/01452321) in view of Langlais (U.S. Patent Publication No. 2021/0123327). *Id.* at 270-284.

248. On October 6, 2021, Halliburton filed its Response to Non-Final Office Action dated July 6, 2021. EX1002 at 563-574. Halliburton amended the claims to address the Examiner's Section 112 rejections as well as adding a source of pressurized working fluid to the independent claims to make clear the order of the tools in the downhole completion assemblies. In its remarks, Halliburton provided an explanation of a POSITA's understanding of hydraulics in downhole well environments including an explanation of why friction pressure drop would cause

the pressure in shunt tubes to drop down the length of a horizontal well. *Id.* at 570-572. Halliburton also addressed the Section 112 rejections. *Id.* at 572-573.

249. Then, Halliburton asserted that the claims were patentable over the prior art of record. Halliburton stated,

> The Office Action asserts that it would have been obvious to have modified the tubes of Sessa to accommodate the "varying operating pressures along the length of the assembly as suggested by Lang. Applicant respectively submits however, that "traditionally, when a lower production assembly is installed along the length of a production zone, the lower production assembly is generally comprised of multiple sand screen assemblies with shunt tube assemblies all of the *same pressure rating*." Thus, Applicant respectfully submits that it would not have been obvious to change the characteristics of the shunt tube assemblies along the length of a production zone at a location downstream of a source of pressurized fluid as recited in the independent claims 1, 11, 14 and 21 (for example, ***placing the higher pressure rated components at an upstream location and lower pressure rated components at a downstream location***).

Id. at 573 (citing EX1002 at 18, lines 20-23) (second emphasis added, internal citations omitted). But as I discussed above, that is precisely what Yeh disclosed.

250. On October 7, 2021, the Examiner issued an interview summary detailing Halliburton's discussion of the Section 112 and Section 103 obviousness

rejections. EX1002 at 578. The Examiner indicated that limiting the claims to a horizontal wellbore would overcome the Section 112 and 103 rejections. *Id.*

251. On October 21, 2021, the Examiner issued a second Office Action allowing claims 1-7, 9-15, and 17-24 but rejecting claim 8 under 35 U.S.C. § 112 because it claimed a pressure rating of less than 4000 psi. *Id.* at 583-593.

252. On December 8, 2021, Halliburton submitted its response, amending claim 8 to eliminate the pressure rating of less than 4000 psi. *Id.* at 608-615.

253. The Examiner subsequently allowed the pending claims on January 21, 2022. *Id.* at 620-624.

XI. SUMMARY OF GROUNDS

254. The table below summarizes the Grounds upon which I believe the claims 1-12 and 14-23 of the ’007 Patent are invalid.

Ground	Challenged Claim(s)	Ground
1	1-12	Yeh optionally in view of Yeh2
2	14-20	Yeh in view of Yeh2 and optionally Jones2
3	21-22	Yeh in view of Jones
4	23	Yeh in view of Jones and Yeh2

255. For purposes of my analysis, I have been asked to assume that the following references are prior art. I explain the bases for that understanding below.

- I understand that Yeh is prior art under 35 U.S.C. § 102(a)(1) and (2) (AIA) because it was effectively filed in December 2010, was actually filed November 17, 2011, and issued on October 24, 2017 before the earliest June 22, 2018 priority date claimed in Halliburton's '007 Patent. EX1005; EX1001.
- I understand that Yeh2 is prior art under 35 U.S.C. § 102(a)(1) (AIA) because it published in 2008 (EX1019, ¶10) before June 22, 2018. EX1006; EX1001.
- I understand that the '476 Patent is prior art under 35 U.S.C. § 102(a)(1) and (2) (AIA) because it was effectively filed in November 2006, was actually filed on November 9, 2007, was published on June 5, 2008, and issued on February 16, 2010 before June 22, 2018. EX1010; EX1001.
- I understand that Hurst is prior art under 35 U.S.C. § 102(a)(1) (AIA) because it published in February 2004 (EX1019, ¶8) before June 22, 2018. EX1013; EX1001.
- I understand that Lagrone is prior art under 35 U.S.C. § 102(a)(1) (AIA) because it published in July 1963 (EX1019, ¶17) before June 22, 2018. EX1014; EX1001.
- I understand that Hecker is prior art under 35 U.S.C. § 102(a)(1) (AIA) because it published in September 2010 (EX1019, ¶9) before June 22, 2018. EX1015; EX1001.

- I understand that Jones2 is prior art under 35 U.S.C. § 102(a)(1) and (2) (AIA) because it was effectively filed in May 1991 and issued on May 19, 1992 before June 22, 2018. EX1008; EX1001.
- I understand that the '487 Patent is prior art under 35 U.S.C. § 102(a)(1) and (2) (AIA) because it was effectively filed in September 1995 and issued December 31, 1996 before June 22, 2018. EX1012; EX1001.
- I understand that Jones is prior art under 35 U.S.C. § 102(a)(1) and (2) (AIA) because it was effectively filed in August 1989 and issued August 7, 1990 before June 22, 2018. EX1007; EX1001.
- I understand that Bonner is prior art under 35 U.S.C. § 102(a)(1) (AIA) because it published in May 2014 (EX1019 ¶¶13-14) before June 22, 2018. EX1016; EX1001.

XII. GROUND 1

A. Claim 1

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

256. It is my opinion that claim 1 would have been obvious over Yeh optionally in view of Yeh2 because Yeh and the combination disclose or suggest each of the limitations in claim 1. A POSITA looking to implement Yeh's teachings regarding APT would have readily looked to Yeh2 because Yeh2 also describes the

APT system. EX1005 at 3:8-62 ("The problem of sand bridging has been addressed through the use of Alternate Path® Technology, or 'APT.'"); EX1006 at 1 ("Alternate Path® technology (APT) is a field-proven gravel packing technique for multi-zone, long interval, or horizontal wells."). Both also describe a similar 5,000-feet long horizontal completion with APT. *E.g.*, EX1005 at 30:13-20 ("[K]nown concentric screens are capable of gravel packing 5,000 feet, compared to 3,000 feet with the commercial eccentric screens."); EX1006 at 5 ("The leakoff effect is further explained by an example of gravel packing a 5,000 ft horizontal well with the multiple-shunt manifold system."). The difference is that Yeh describes using a combination of concentric and eccentric screens in this example. EX1005 at 30:20-25. Nevertheless, a POSITA would understand that Yeh2 provided additional details regarding this example that one of skill could use in implementing the system and would have expected success because they describe essentially the same application of the same system.

257. I understand that claim preambles may or may not constitute an actual limitation of the claims. I have been asked to assume that the preambles of the claims in the '007 Patent are limitations of the claims. Assuming that the preamble is a limitation, it is my opinion that Yeh discloses the preamble.

258. Yeh explained that its invention related "to the completion of wellbores using sand screens and gravel packs. The application also relates to a downhole tool that may be used to connect eccentric flow paths to concentric flow paths for the installation of a gravel pack." EX1005 at 1:27-30. Yeh's downhole tool connecting eccentric flow paths to concentric flow paths constitutes a completion assembly. Yeh refers to the assembly as "a downhole tool," which a POSITA would understand refers to its use downhole in a wellbore. Additionally, Yeh's reference to the completion of wellbores using sand screens and gravel packs also refers to deploying sand screens and gravel packs as part of a completion, which means they are to be deployed downhole in a wellbore.

259. A POSITA would understand that Yeh's "completion of wellbores using sand screens and gravel packs" is analogous to the '007 Patent's disclosure of its invention that "relates to screen assemblies of lower production systems used in wellbore gravel packing." EX1001 at 1:17-20. This is because the '007 Patent's lower completion assembly (like in Figure 1) comprises packers and sand screens, *id.* at 4:40-47, that are used in the gravel packing process, *id.* at 5:50-60 (explaining "filter media" includes tools, such as sand screens, that "are commonly used in gravel pack well completions").

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;"

260. It is my opinion that Yeh disclosed a first sand screen assembly with all the characteristics required by claim 1[a].

261. First, Yeh disclosed a first sand screen assembly comprising a base pipe having perforations therein.

262. Yeh taught that a possible sequence of serially connected wellbore tools can be a "concentric screen → crossover tool → eccentric screen." EX1005 at 30:13-14. Yeh's example is specifically in the context of a long horizontal completion: "The use of concentric screens may be beneficial when gravel packing long intervals. … It may be difficult to acquire more complex concentric sand screens in quantities needed for extended horizontal completions." *Id.* at 30:15-29.

263. In Yeh's example, the crossover tool functions to fluidly connect the primary flow path of the concentric screen with the primary flow path of the eccentric screen and the secondary flow path of the concentric screen with the secondary flow path of the eccentric screen. EX1005 at 25:41-44 (cross over tool

fluidly connects two wellbore tools), 25:46-48 (crossover tool has a primary flow path), 25:52-53 and 25:62-65 (crossover tool has at least one secondary flow path), 28:48-60 (crossover joint connects primary and secondary flow paths of two wellbore tools).

264. Thus, according to Yeh's example of a wellbore tool sequence, the "concentric screen" is the first sand screen assembly required by claim 1. The "first" sand screen assembly refers to the sand screen assembly closer to the heel of the horizontal interval: [heel] "concentric screen → crossover tool → eccentric screen" [toe]. EX1005 at 30:13-14; *see also id.* at 30:20-25 ("The new crossover tool allows the operator to use the less-expensive eccentric screens on the toe or lower-pressure side of the interval during gravel-packing operations, and to use ***the concentric screens on the heel*** or higher-pressure side of the interval during the gravel-packing operations." (emphasis added)).

265. Yeh disclosed a concentric screen in its Figures 4A and 4B, which illustrate a zonal apparatus 400 with a packer 300 with a concentric screen 200 attached to each end. EX1005 at 15:53-58, 16:1-4, 16:18-19 ("The configuration of the shunt tubes 218 is preferably concentric."). Figure 4B also shows that the shunt tubes are provided in a concentric configuration. I provide annotated Figures 4A and 4B below:

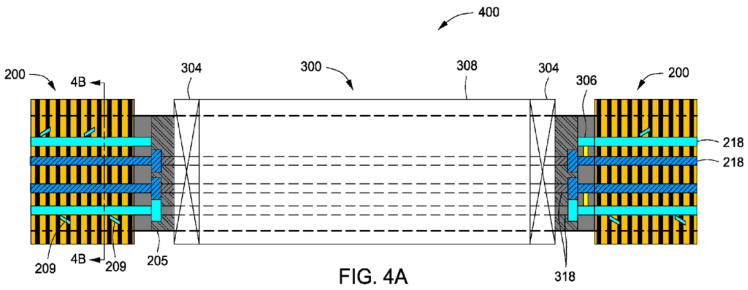


FIG. 4A

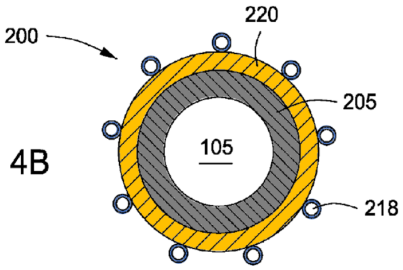


FIG. 4B

EX1005 at Figs. 4A and 4B (annotated).

266. Figure 4A illustrates a cross-sectional side view of packer assembly 300 with sand screens 200 with an outer mesh 220 (**orange**) disposed about a perforated base pipe 205 (**dark gray**) and placed on opposing ends of the packer assembly. EX1005 at 15:53-58, 16:1-12. A POSITA would understand that outer mesh 220 is a screen. *Id.* at 16:10-12 ("The outer mesh 220 preferably comprises a wire mesh or wires helically wrapped around the base pipe 205, and serves as a screen."). Yeh discloses that the screen only covers a portion of the base pipe. EX1005 at Fig. 2 (showing partial coverage of the sand screens over the base pipes), Fig. 4A (same). Even if it had not shown this, a POSITA would understand that the screen only needs to cover the perforations or slots in the base pipe or enough space to permit fluid to pass through it to get to the perforations or slots and does not need to cover the entire pipe, such that a POSITA would be motivated to only include as much screen as necessary due to cost and weight concerns.

267. Figure 4B shows a cross-sectional view of the zonal apparatus 400 cut through line 4B–4B of Figure 4A. EX1005 at 16:1-4.

268. The base pipe 205 in Figure 4 corresponds with the "elongated tubular body" base pipe 205 of Figures 1 and 2, which receives production fluids through its perforations from the surrounding formation. EX1005 at 11:9-11, 16:5-6. As can be seen in Figures 1 and 2, the sand screens themselves are essentially joints of tubing each with first and second ends of the base pipe 205 as shown for example in interval 116 in Figure 2. *Id.* at 11:11-14 ("The base pipe 205 typically is made up of a plurality of pipe joints. The base pipe 205 (or each pipe joint making up the base pipe 205) typically has small perforations or slots to permit the inflow of production fluids."), Fig. 2.

269. It is also my opinion that Yeh discloses the claimed shunt tube assembly wherein the shunt tube assembly is disposed outwardly of a sand screen assembly. Shunt tubes 218 in Yeh's Figures 4A and 4B are positioned outwardly of the outer mesh 220 of the sand screen assembly. EX1005 at 16:38-39. Further, Yeh discloses that shunt tubes include both packing and transport tubes. For example, Yeh discloses that "[t]he selective shunt tubes 218 on the sand control devices 200 include ports or nozzles or orifices 209, such shunt tubes called packing tubes, to allow flow of gravel slurry between a wellbore annulus and the packing tubes." *Id.*

at 15:60-64. Packing tubes (light blue) are shown in Figure 4A, and Figure 4A shows that the nozzles are spaced apart. A POSITA would understand that the ports, nozzles, and orifices of the packing tubes have an internal cross-sectional area of the opening. Similarly, all shunt tubes (both packing and transport) have a passageway defined inside for flow with a cross-sectional area defined by the shape of the tube, such as rectangular or round. *Id.* at 4:47-48 ("The shunt tube serves as an alternate flow channel."), 4:53-56 (same). Figure 4B, for example, shows the round passageways in both the shunt tubes and the base pipe with a defined cross-sectional area.

270. The shunt tubes without nozzles or orifices are referred to as transport tubes (**blue** in Figure 4A above). *E.g.*, EX1005 at 16:21-25 (referring to the '476 Patent's disclosure of packing tubes 208a and transport tubes 208b in Figure 2B of the '476 Patent, which I reproduce below), 24:26-28 ("The use of transport tubes and packing tubes as alternate flow channels for gravel slurry in general is known in the art."); EX1010 at 7:35-39 ("The packing tubes 208a may have one or more valves or nozzles 212 that provide a flow path for the gravel pack slurry, which includes a carrier fluid and gravel, to the annulus formed between the sand screen 204 and the walls of the wellbore.").

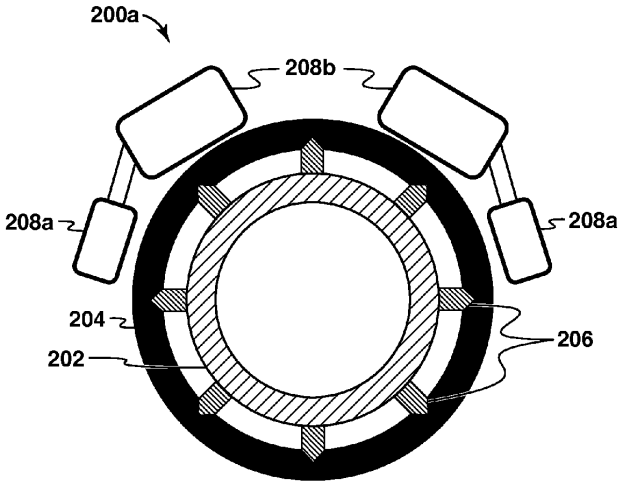


FIG. 2B
Prior Art

EX1010 at Fig. 2B.

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;"

271. In my opinion, Yeh disclosed or suggested this limitation.

272. It is my opinion that, according to Yeh's example of its wellbore tool sequence arrangement that I described in claim 1[a], the "eccentric screen" would be the second sand screen assembly. *See* EX1005 at 30:13-14 ("concentric screen → crossover tool → eccentric screen").

273. I provide below Yeh's exemplary sand screen shunt tube assembly in an eccentric configuration illustrated in annotated Figure 8A below, which is also configured similarly to the '007 Patent's sand screen shunt tube assembly in Figure 4A (right, below). *Compare* EX1005 at Fig. 8A *with* EX1001 at Fig. 4A. Both are the conventional 2×2 eccentric sand screens I described extensively in my discussion of the prior art.

274. As shown in Figure 8A, Yeh's eccentric screen comprised "a base pipe 810 that defines a bore 805 therein." EX1005 at 24:4-6. As I explained in claim 1[a], the base pipes are joints of pipe that a POSITA would understand have a first end and a second end. *E.g.*, *id.* at 3:60-62 ("[I]t [is] desirable to connect to joints of sand screen, wherein one joint has a concentric primary flow path, and another has an eccentric primary flow path."), 11:11-14 ("The base pipe 205 typically is made up of a plurality of pipe joints. The base pipe 205 (or each pipe joint making up the base pipe 205) typically has small perforations or slots to permit the inflow of production fluids."), Fig. 2. Base pipe 810 has slotted openings. EX1005, 2:37-39, 2:57-61, 24:4-8. Figure 8A shows the filter medium (screen) 820 "around the base pipe 810." EX1005 at 24:7-8. Yeh discloses that the screen only covers a portion of the base pipe. *Id.* at Fig. 2 (showing partial coverage of the sand screens over the base pipes), Fig. 4A (same). Even if it had not shown this, a POSITA would

understand that the screen only needs to cover the or enough space to permit fluid to pass through it to get to the perforations or slots and does not need to cover the entire pipe, such that a POSITA would be motivated to only include as much screen as necessary due to cost and weight concerns. Figure 8A also shows the shunt tubes disposed outwardly of the sand screen 820 in annular area 835. *Id.* at 24:22-26.

275. Additionally, the shunt tubes of Figure 8A's sand screen 800A included transport tubes 830A (**blue**) and packing tubes 832A (light blue) wherein the shunt tubes provide a secondary flow path for gravel slurry, a concept that was generally "known in the art." EX1005 at 24:26-28. As I explained in claim 1[a], Yeh disclosed that "packing tubes" had "ports or nozzles or orifices" that were spaced apart and had a cross-sectional flow area. *Id.* at 15:60-64, Figs. 4A, 8A. Shunt tubes were also understood to have a passageway with a cross-sectional flow area, which was shown in Yeh's Figure 8A. *Id.* at 4:47-48, 4:53-56.

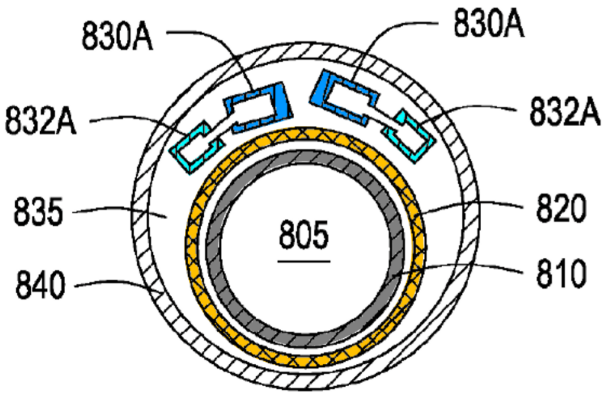


FIG. 8A

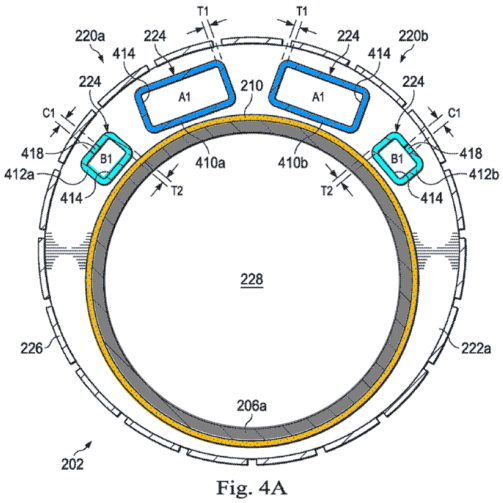


Fig. 4A

EX1005 at Fig. 8A (annotated); EX1001 at Fig. 4A (annotated).

276. Yeh disclosed that "[t]he alternate flow channels in the illustrative sand screens 800A, 800C are rectangular or round shunt tubes …." EX1005 at 24:10-12; *see also id.* at 4:57-60 ("In the sand screen, the elongated base pipe is preferably eccentric to the sand screen. Each of the at least one shunt tube then may have a round profile, a square profile, or a rectangular profile."). Yeh's Figure 8C provided an example of an eccentric screen with round shunt tubes, which I provide below. Yeh taught that eccentric screens included "packing tubes and transport tubes." *Id.* at 16:30-37. A POSITA would understand from this disclosure that in Yeh's eccentric sand screen example that round shunt tubes 830C would include packing (light blue) and transport tubes (**blue**).

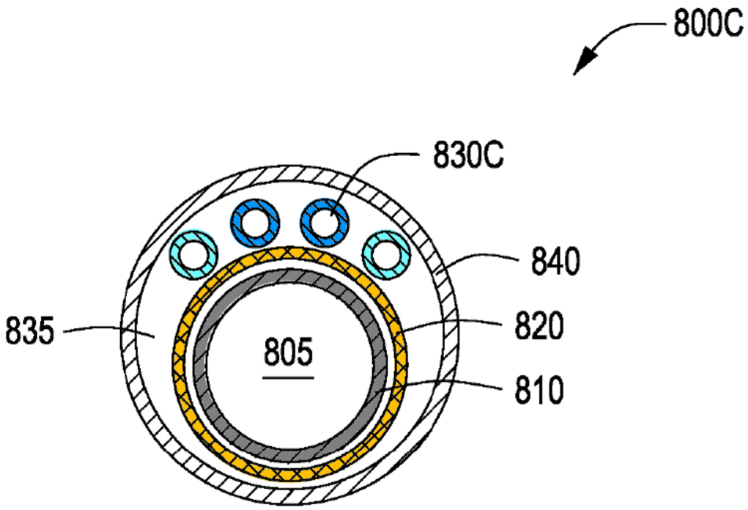


FIG. 8C

EX1005 at Fig. 8C (annotated).

277. Even without Yeh's express disclosure, a POSITA would have found it obvious to use transport and packing tubes in an eccentric screen because their use had a demonstrated efficacy and likelihood of success in the art as I explained above in Section VIII.G.4. Yeh referenced this well-known history when explaining that the "use of transport tubes and packing tubes as alternate flow channels for gravel slurry in general is known in the art." EX1005 at 24:26-28. A POSITA would have readily understood the well-known efficacy of using packing tubes to distribute gravel slurry in a production zone while using transport tubes to bypass the zone once gravel packing completed in that zone as taught by Yeh. Additionally, a POSITA understood that packing tubes cause leak-off while transport tubes do not, as I explained in Section VIII.E, which would also motivate a POSITA to use this design. Indeed, Patent Owner Halliburton itself recognized this demonstrated efficacy. EX1016 at 2 (describing importance of using "industry-proven designs" including "the branching of flow to secondary tubes (packing tubes) from the primary flow tubes (transport tubes)").

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;"

278. In my opinion Yeh optionally in view of Yeh2 disclosed this limitation.

279. Yeh incorporated the '487 Patent by reference when addressing the problem of sand bridging by using shunt tube alternate path technology. EX1005 at

3:12-18. The '487 Patent specifically taught pumping a gravel slurry into fluidly coupled sand screen shunt tubes. EX1012 at 5:4-13 ("For example, a gravel slurry is pumped down workstring 31, out ports 32 in 'cross-over' 33, and into the top of well annulus 35 below packer 36. The gravel fills the annulus 35a above packing means 26 either directly and/or through the perforations in shunt tubes 18a, 18b even if a 'sand bridge' occurs before the operation is complete."). Yeh also taught that its method 1200 included "injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool." EX1005 at 28:66-29:2. In the case of Yeh's sand screen example, *id.* at 30:13-14, the injected fluid would be a gravel slurry. A POSITA understood that the only way the fluid would flow down the wellbore against natural formation pressure is if it were pressurized as I explain below. A POSITA understood that gravel slurry pressure comes from a pump. EX1012 at 1:30-33 ("Particulate material, collectively referred to as gravel, is then pumped in a liquid slurry down a workstring and into the well annulus surrounding the screen."). The pump was located at the surface and delivered its pressurized gravel slurry through a wellhead to the downhole equipment. *See id.*; EX1005 at 1:54-57 ("As part of the completion process, a wellhead is installed at the surface. The

wellhead controls the flow of production fluids to the surface, or ***the injection of fluids into the wellbore***." (emphasis added)).

280. Even had Yeh not disclosed this feature, POSITAs knew that any working fluid, such as gravel slurry, must be pressurized to be used for injection or circulation downhole. Wellbores generally contain oil and/or gas under pressure. In fact, the oil and/or gas typically contain so much pressure in the formation that they will naturally flow to the surface if given the chance to do so. Keeping them from doing so during well completion, for example, typically requires exerting continuous pressure on the wellbore to overcome this natural formation pressure. Pushing a fluid down the wellbore against this natural formation pressure requires some source of pressure. A POSITA understood this was true for any working fluid in a wellbore. POSITAs also understood that pressure is applied to liquids (including slurries) using a pump.

281. The '007 Patent specifically identifies gravel packing slurry as a type of "working fluid." EX1001 at 4:11-14 ("Working fluid source 52 may supply any fluid utilized in wellbore operations, including without limitation, ***gravel packing slurry***, acidizing fluid, liquid water, steam or some other type of fluid." (emphasis added)).

282. My opinion that a POSITA already understood these aspects of gravel packing is confirmed by Yeh2's express disclosure that "[g]ravel packing for sand control involves ***pumping slurry*** (gravel + carrier fluid) into a wellbore annulus." EX1006 at 2 (emphasis added). This disclosure is illustrated in Yeh2's Figure 1. Specifically, Figure 1 showed the flow path of gravel slurry (light green arrows) being pumped through shunt tubes thereby bypassing a blockage in an annulus, such as a sand bridge (**dark orange**), and distributed through portholes and out into the annular space (light orange) to complete the gravel pack. *Id.* at 2. I provide Figure 1 below:

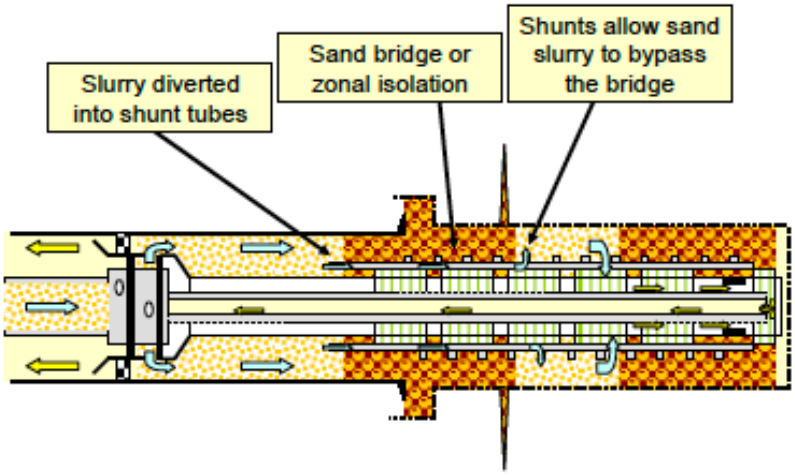


Figure 1 Alternate Path gravel packing with shunt tubes

Id. at Fig. 1.

283. As I explained in claim 1[preamble], a POSITA would have understood that Yeh2 described the same system as Yeh. *See* EX1005 at 3:8-62 (describing Alternate Path® sand screen technology); EX1006 at 1 (same). A POSITA would

have known that Yeh's system worked in the same way as described in Yeh2 and would have expected Yeh2's description to already apply to Yeh's concentric sand screens and thus would have expected success in applying Yeh2's teachings to Yeh. Alternatively, for the same reasons, a POSITA would have been motivated to combine Yeh2's gravel slurry pump with Yeh to supply the source of gravel slurry a POSITA understood was necessary for the reasons I explained above. A POSITA would have expected success based on Yeh2's teachings.

284. Yeh also explained that the "Alternate Path® fluid bypass technology employs shunt tubes (or shunts) that allow the gravel slurry to bypass selected areas along a wellbore," showing that the shunt tubes are fluidly coupled to the source of pressurized working fluid at the upstream end. EX1005 at 3:9-12; *see also id.*, 4:47-53 ("The shunt tube serves as an alternate flow channel."); EX1012 ('487 Patent) at 1:58-61 (Shunt tubes "receive gravel slurry as it enters the wellbore annulus."). Yeh also expressly disclosed this when it described "injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool." EX1005 at 28:66-29:2. Yeh disclosed that the fluid (gravel slurry in the sand screen example) flows through the shunt tubes of the first wellbore tool, crossover joint, and second wellbore tool, confirming that it is fluidly coupled to an upstream end of the transport tube of the

first sand screen assembly (first wellbore tool or concentric sand screen) as required by claim 1[c].

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 that 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"

285. In my opinion, Yeh disclosed this limitation.

286. As I discussed earlier in claim 1[a], Yeh described the following exemplary wellbore tool sequence: "concentric screen → crossover tool → eccentric screen." *See* EX1005 at 30:13-14. It is my opinion that Yeh's "concentric screen" would be the "first sand screen assembly" and Yeh's "eccentric screen" would be the "second sand screen assembly," as required by claim 1. Yeh's wellbore tool sequence arranged the concentric screen and eccentric screen end to end relative to each other with a crossover tool in between the two screens to form a fluid connection between them.

287. Specifically, Yeh's crossover tool included a primary and secondary flow path to fluidly connect the base pipes (*i.e.*, the primary flow path) of each screen and the transport tubes (*i.e.*, the secondary flow path) of each screen. The flow paths of Yeh's crossover tool were illustrated in Figure 10A, which I provide below with

the primary flow path 1005 (**dark gray**) and secondary flow path 1020 (**red**) annotated:

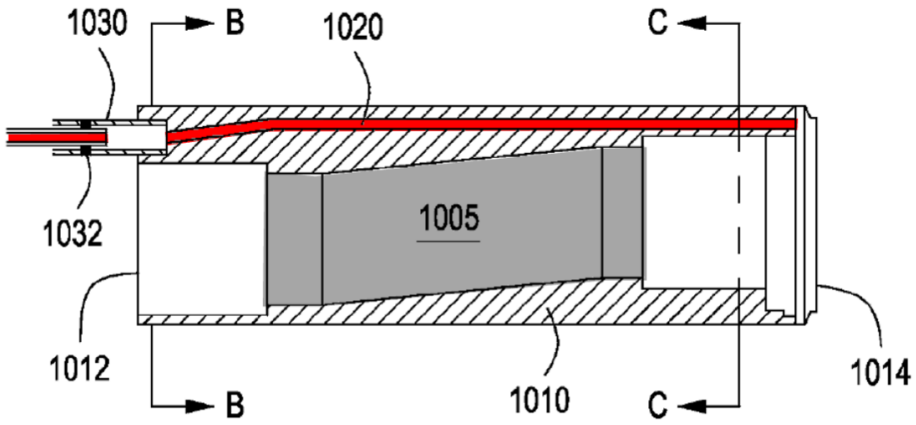


FIG. 10A

EX1005, Fig. 10A (annotated).

288. The pressurized gravel slurry that originated upstream from the pump would then travel through the concentric screen, the crossover tool, and then the eccentric screen (from right to left in Figure 10A above). By fluidly connecting the primary and secondary flow paths of the concentric and eccentric sand screen in this tool sequence, the pressurized gravel slurry described in claim 1[c] that fluidly coupled to the upstream end of the transport tube of the first sand screen assembly (concentric screen) would flow first through the secondary flow paths of the concentric screen, then through primary and secondary flow paths 1005 and 1020 within the crossover tool, and then into the primary and secondary flow path of the

eccentric screen. EX1005 at 30:13-14 (disclosing wellbore tool series arrangement), 25:41-44 (crossover tool fluidly connects two wellbore tools), 26:35-41 (each wellbore tool fluidly connected by a crossover tool must have a primary and secondary flow path), 28:66-29:3 (describing flow through secondary paths of these tools), 30:51-67 (similar).

289. Additionally, as I explained above in claim 1[c], Yeh expressly disclosed the flow sequence of fluid passing through the transport tube of the concentric screen into the crossover tool and then into the transport tube of the eccentric screen when it described "injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool." EX1005 at 28:66-29:2. Yeh disclosed that the fluid (gravel slurry in the sand screen example) flows through the shunt tubes of the first wellbore tool, secondary flow path 1020 of the crossover joint, and shunt tubes of the second wellbore tool, confirming that 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 as required by claim 1[d].

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 thickness."

290. In my opinion Yeh suggested this limitation.

291. Yeh disclosed that concentric screen shunt tubes should be installed in the higher-pressure heel side because they have a higher pressure tolerance, or containment (*i.e.*, burst pressure) capacity, compared to shunt tubes in eccentric screens. EX1005 at 28:10-24. Yeh also expressly taught that "to maintain the mechanical integrity (that is, to stay within the burst, bending, and collapse ratings) of the secondary flow paths, a certain surrounding wall thickness is required." *Id.* at 28:20-24. As I discussed in the background regarding API TR 5C3, a POSITA understood that containing internal pressure within tubing required a certain wall thickness, wall thickness being one of three parameters (wall thickness, tubing material, and tubing outside diameter) that could be adjusted to meet pressure containment requirements. *See supra* Section VIII.J.

292. Yeh's proposed wellbore tool sequence: "concentric screen → crossover tool → eccentric screen," *see* EX1005 at 30:13-14, considered these different pressure tolerance demands at the heel versus the toe of the horizontal interval wherein the high-pressure concentric screen would be installed upstream towards the heel and the lower-pressure eccentric screen positioned downstream in

the toe region of the horizontal wellbore, *see id.* at 30:15-20. This understanding was expressed by Yeh in its explanation that "[c]oncentric sand screens can be more robust for gravel packing long intervals. For example, known concentric screens are capable of gravel packing 5,000 feet, compared to 3,000 feet with the commercial eccentric screens." EX1005 at 30:16-20. This means that in a 5,000-feet horizontal interval, the concentric screen shunt tube assembly, which includes transport tubes, would have to contain a higher differential pressure near the heel, such as 6,500 psi, compared to the eccentric screen shunt tubes installed near the lower pressure side of the toe. *See id.* at 28:17-24.

293. A POSITA taking into consideration these pressure tolerance considerations together with Yeh's express disclosure that a "certain surrounding wall thickness is required" to "maintain the mechanical integrity (that is, to stay within the burst, bending, and collapse ratings) of the secondary flow paths," would have understood that lower pressure toward the toe could readily lead to cost savings in tool design as taught by Yeh. *See* EX1005 at 28:20-23.

294. A POSITA, motivated by reducing material costs where possible, would know that there were only three shunt tube design parameters to decrease burst pressure in tubing according to Equation (14) in API TR 5C3: (1) weaker material selection (lower tensile strength material, which decreases **f**), (2) decrease tubing

wall thickness (decrease **t**), or (3) increase the outside diameter (increase **D**). EX1017 at 24; *see also supra* Section VIII.J.

295. A POSITA would be motivated to use a weaker material or decrease wall thickness because these would lead to lower cost (less expensive material and/or less material needed) versus increasing outside diameter, which would require a greater tool size. Thus, a POSITA would be led to use thicker-walled transport tubes in the concentric screens installed near the heel compared to the transport tubes in the eccentric screens installed downstream closer to the toe, to maximize cost savings as Yeh expressly discloses by using less material in the eccentric screen shunt tubes. *See* EX1005 at 30:25-26. Where the eccentric shunt tubes were round as disclosed by Yeh, *id.* at 24:10-14 ("rectangular or round shunt tubes"), a POSITA would understand that the tubing wall thickness in the eccentric screens would be less than the tubing wall thickness in the concentric screens due to the lower pressure requirement and the well understood direct proportionality between tubing wall thickness and burst pressure as explained in API TR 5C3. *See supra* Section VIII.J.

296. A POSITA would have also recognized and Yeh disclosed that reducing the wall thickness would increase the cross-sectional area available for flow thus reducing friction pressure drop. EX1005 at 28:20-24 ("In order to maintain the mechanical integrity (that is, to stay within the burst, bending, and collapse ratings)

of the secondary flow paths, a certain surrounding wall thickness is required. This, in turn, limits the inside diameter of the crossover joint."); *see also id.* at 24:54-60 ("In one embodiment, an eccentric screen arrangement offers lower friction in the secondary flow paths when compared to shunt tubes in a concentric screen. It is believed that the use of eccentric screens at the toe of a horizontal completion will reduce the overall friction or extend the maximum gravel packing length of the completion."). A POSITA understood that reducing friction pressure drop reduced the overall pressure requirements for all shunt tubes in the installation because friction pressure drop through the shunt tubes determined the pressure requirements for the shunt tubes. *E.g.*, EX1006 at 4 ("The friction loss in transport tubes and manifold limits the overall distance of shunt diversion."); *see also supra* Section VIII.G.6. Thus, a POSITA had additional motivation to reduce the wall thickness of the transport tubes in the eccentric screens in Yeh's design. Confirming that a POSITA understood the effect of these parameters on shunt tube design in gravel packing, Hurst (EX1013), which is specifically referenced in Yeh, EX1005 at 3:27-31, explained that "[f]or a given fluid composition and gravel concentration, ***friction and thus the pressure applied to each zone can be controlled through the shunt tube dimensions (diameter and length)*** as well as the nozzle diameter and frequency." EX1013 at 3-4 (emphasis added).

297. Taking all these considerations together, it is my opinion that it would have been obvious to a POSITA reading Yeh to use a second sand screen assembly (eccentric screen) with a transport tube with a second wall thickness that is less than the first wall thickness of the transport tubes of the first sand screen assembly (concentric screen).

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 assembly."

298. It is my opinion that claim 2 would have been obvious over Yeh optionally in view of Yeh2 because claim 2 adds nothing more than routine optimization.

299. For all the reasons I explained in claim 1[e], a POSITA understood the gravel slurry pressure drops as it flows through shunt tubes from heel to toe in Yeh's example 5,000-feet horizontal well using concentric and eccentric screens. This drop in pressure along the horizontal would also influence the design of slurry injection nozzle cross-sectional flow area. Specifically, a POSITA recognized that there was less pressure available near the toe to force the gravel slurry out of the packing tubes and into the annulus. To account for this pressure drop, a POSITA would be motivated to increase the cross-sectional flow area of the nozzles to permit

more gravel slurry flow into the annulus using less pressure for the reasons I explain below.

300. A POSITA would have also understood the need to account for leak-off, which would also impact accomplishing a complete gravel pack, as I explained above in the background discussion. *See* Section VIII.E. Specifically, as the gravel packing process continued down a horizontal interval, the gravel slurry would experience leak-off and become dehydrated. As a result, the gravel slurry would become more concentrated, or viscous, as it traveled down the horizontal toward the toe, resulting in greater friction pressure drop through the tubing and any nozzles. Thus, a POSITA would be motivated to design a downstream sand screen assembly to effectuate a complete gravel pack near the toe of the interval that accounted for leak-off and the lower available injection pressure.

301. Representing what a POSITA would have known, Yeh2 graphically illustrated the relationship between leak-off and the pressure drop across the horizontal interval in its Figure 15, which I provide below for reference. *See* EX1006 at 5. Specifically, Yeh2 illustrated the known transport tube pressure drop (**blue line**) in transport tubes (left y-axis) as the gravel slurry was pumped down the horizontal interval starting at the heel and flowing toward the toe (x-axis). EX1006 at Fig. 15. As the gravel slurry progressed down the horizontal toward the toe, there

is a corresponding increase in the gravel slurry concentration (**orange line**; right y-axis). *Id.*

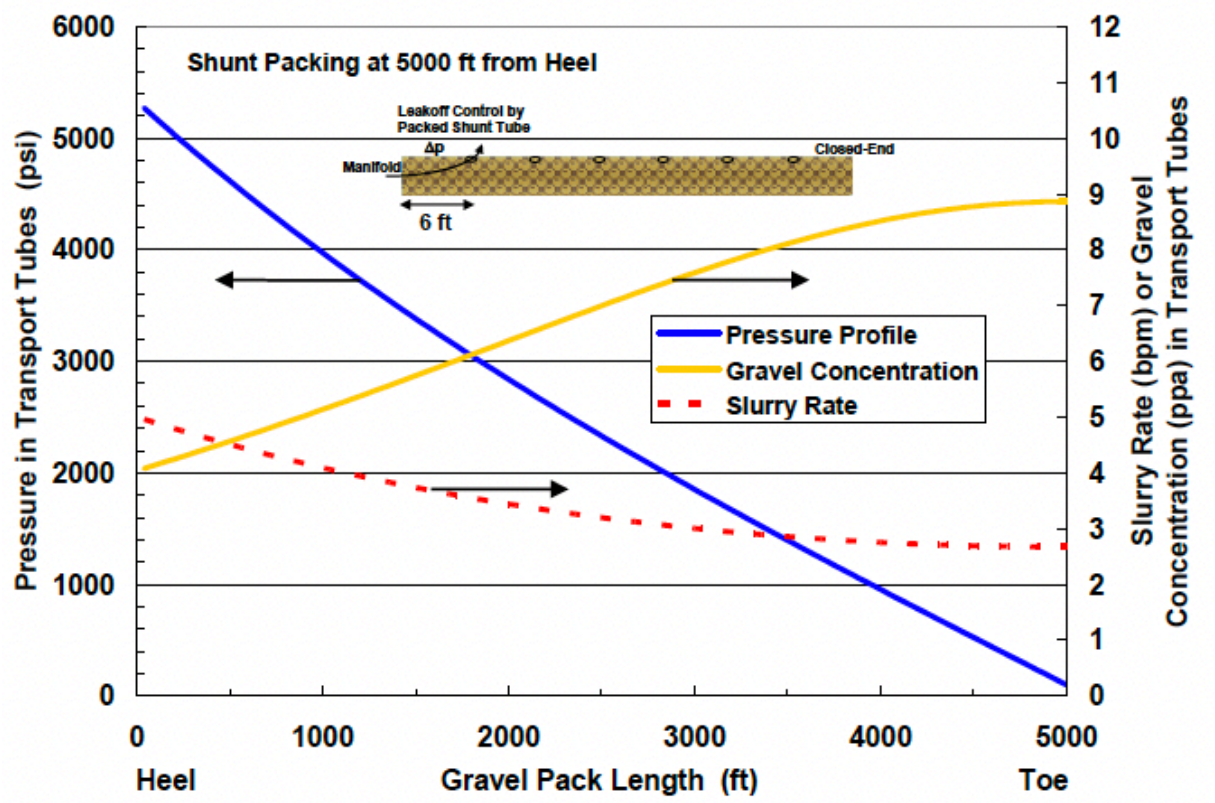


Figure 15 Gravel packing 5,000 ft with multiple-shunt manifold system

EX1006 at Fig. 15.

302. Yeh2 provided additional examples illustrating some of the extensive field testing done to optimize nozzle size and number to control the extent of gravel slurry leak-off and the pressure drop down the horizontal interval. In Figure 6a, Yeh2 illustrated the drop in the gravel slurry flow rate down a 3,000-ft horizontal

interval when nozzle size and spacing held constant, with the flow rate illustrated by arrow size. EX1006 at 3, Fig. 6a. Below, I provide Figure 6a:

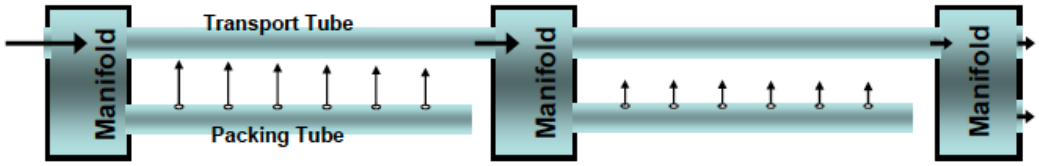


Figure 6a Shunt manifold system

EX1006 at Fig. 6a. Similarly, Yeh2's Figure 7 also demonstrated the same known flow rate drop as gravel slurry was pumped down the shunt tubes toward the toe of a horizontal interval:

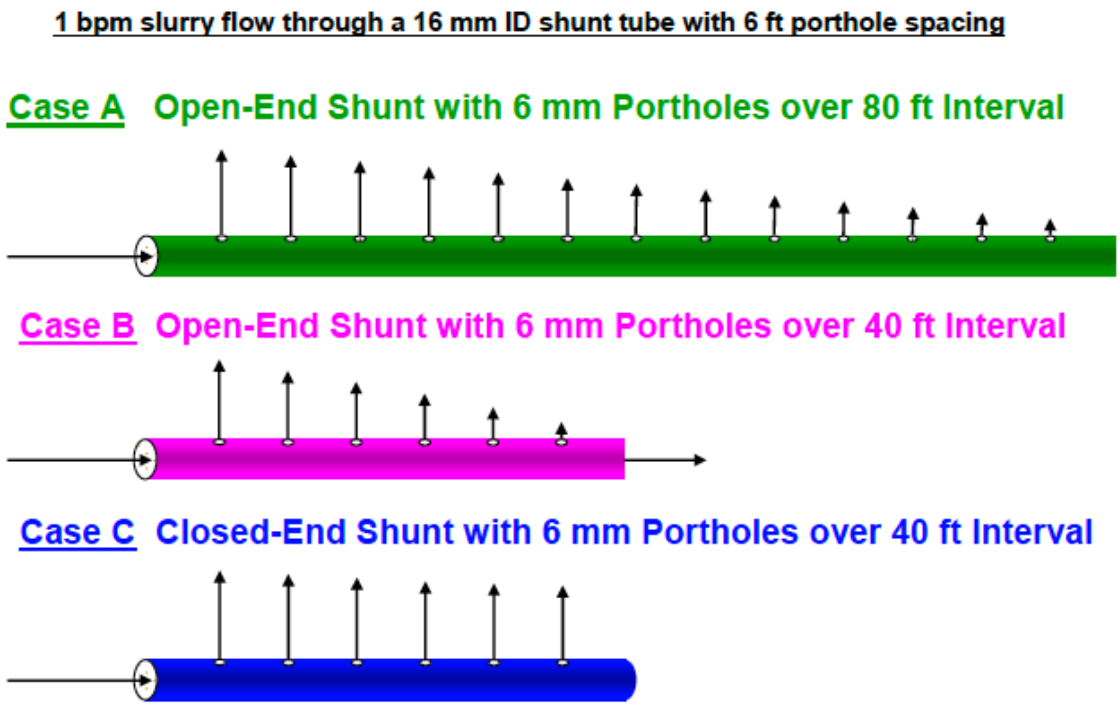


Figure 7 Flow diversion in a single shunt

EX1006 at 4 (discussing Figure 7), Fig. 7.

303. Yeh2's examples illustrate a basic fluid dynamics concept a POSITA would have learned during their undergraduate engineering degree. Specifically, flow through a hole in a pipe is roughly directly proportional to the drop in pressure across that hole. This concept is shown in Figure 3 of SPE 530 ("Lagrone") (EX1014). Lagrone, entitled *A New Development in Completion Methods—The Limited Entry Technique*, was published in 1963 co-authored by Lagrone and Rasmussen from Shell Oil Co.

304. Lagrone's Figure 3 illustrated that for a given hole size and fluid, flow rate (y-axis) was roughly directly proportional to friction pressure loss across perforations, or holes, (x-axis). Lagrone's Figure 3 is provided below:

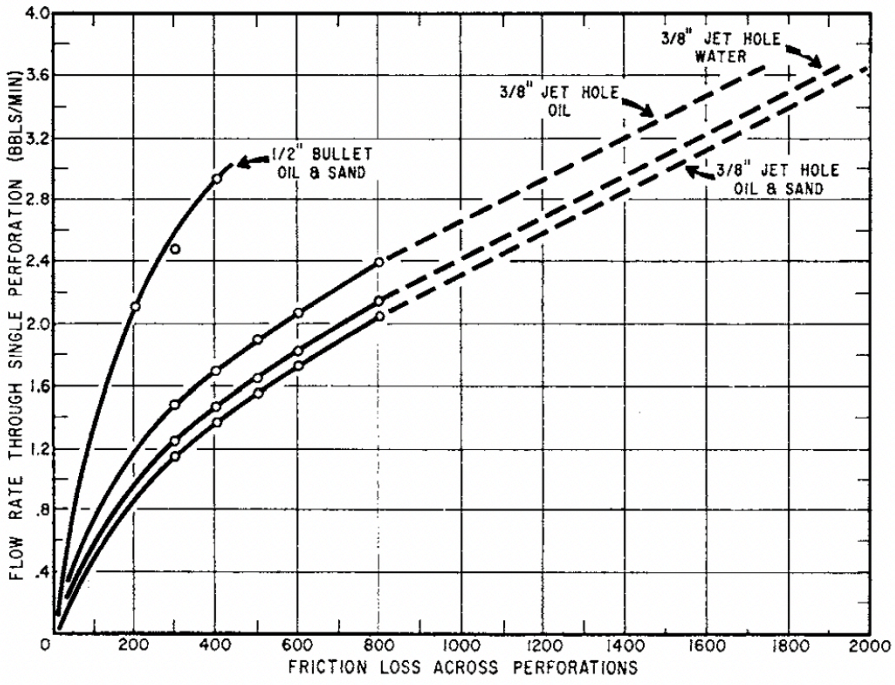


Fig. 3—Flow rate vs friction loss, laboratory measured (courtesy of The Halliburton Co.).

EX1014 at 696 (discussing Figure 3), Fig. 3. Jones2 illustrates this concept when it states with reference to its Figure 3, "[T]he 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 4:59-65.

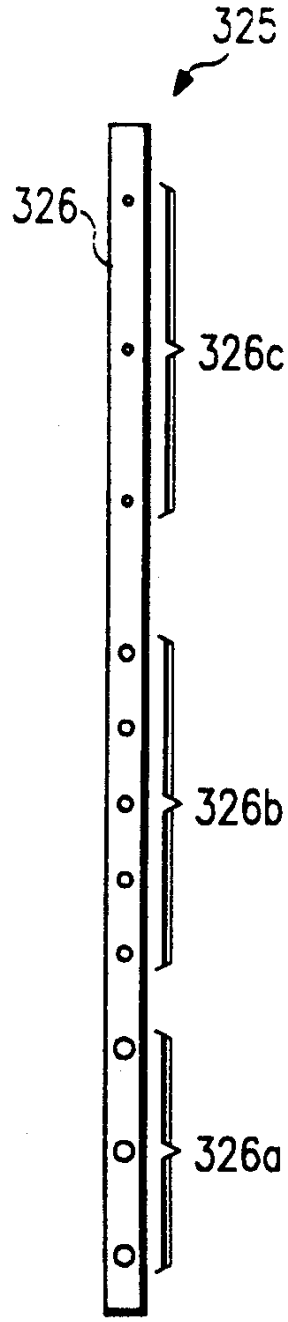


FIG. 3

Id. at Fig. 3.

305. A POSITA, taking into consideration these concepts and known field testing results, would have been motivated to design packing tubes with larger diameter nozzles near the toe of the horizontal interval compared to the nozzle size near the heel. A larger nozzle size, or increased cross-sectional flow area, would help offset the decrease in gravel slurry flow through the nozzles near the toe where pressure loss had reduced the available driving force and increased viscosity further reduced the flow. Doing so would increase the likelihood of a complete gravel pack near the toe.

306. Hurst's disclosure again confirmed that this would be a POSITA's understanding. Hurst explained that "[f]or a given fluid composition and gravel concentration, ***friction and thus the pressure applied to each zone can be controlled through*** the shunt tube dimensions (diameter and length) as well as ***the nozzle diameter and frequency***." EX1013 at 3-4 (emphases added).

307. A POSITA looking to gravel pack across a long horizontal well would understand, as taught by Yeh and optionally Yeh2, that the cross-sectional flow area of nozzles on packing tubes near the toe of the horizontal (*i.e.*, packing tubes in the second sand screen assembly) should be larger compared to the cross-sectional area of nozzles on packing tubes near the heel (*i.e.*, packing tubes in the first sand screen assembly).

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 wherein 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."

308. In my opinion, claim 3 would have been obvious over Yeh in view of Yeh2 because it adds nothing more than routine optimization.

309. Based on my review of the '007 Patent, the "junction block," which is items 314a-d shown in yellow in annotated Figure 3 that I provide below, is a manifold for gravel slurry flow between a packing tube and transport tube:

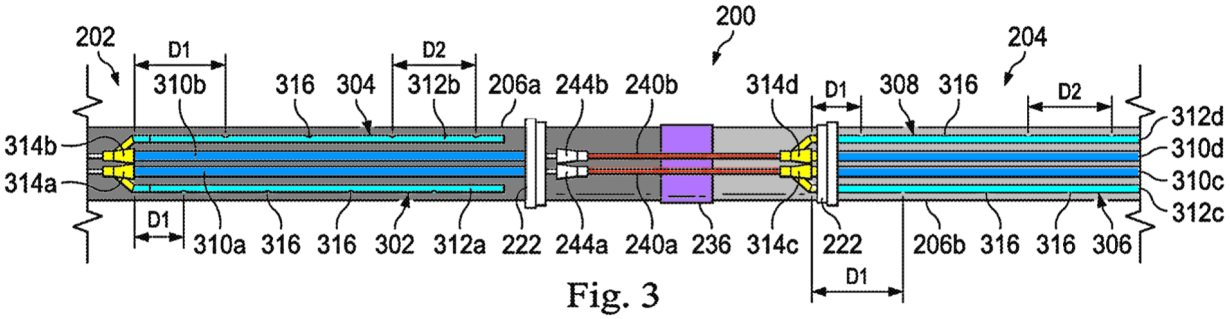
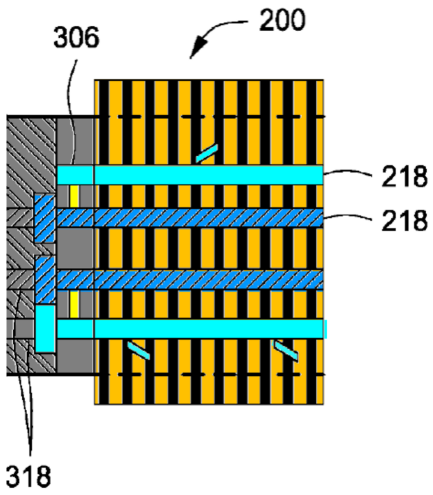


Fig. 3

EX1001 at Fig. 3 (annotated), 6:47-51.

310. Once the industry moved to using separate packing and transport tubes, some type of fluid communication between them at the entrance to a sand screen

became necessary. EX1006 at 3 ("The [manifold] concept was to differentiate shunt slurry transport from shunt packing as shown in Figure 6a."). Yeh itself showed the junction block connecting transport and packing tubes in Figure 4A in yellow below.



EX1005, Fig. 4A (annotated and cropped). Yeh2 explained that a manifold is needed at the entry point of each shunt tube assembly wherein the "shunt manifold incorporates a non-ported shunt tube to transport the slurry and a non-continuous, ported packing tube on each joint used to discharge the slurry." EX1006 at 3. An example of the manifold is illustrated in Yeh2's Figure 6a, which I reproduced below:

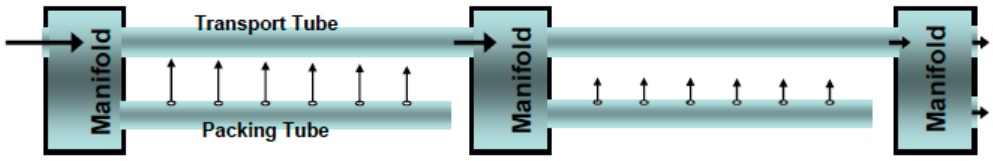


Figure 6a Shunt manifold system

EX1006 at Fig. 6a.

311. Based on Yeh2's disclosure, a POSITA would have understood that the manifold is a junction block from which the transport tube and packing tube extend. A POSITA would have been motivated to use the manifold as recommended by Yeh2 to distribute flow to both transport and packing tubes to gravel pack a long interval as taught by Yeh and would have expected to be successful given Yeh2's teachings. In fact, the system would not function without some interconnection between packing and transport tubes at the entrance to each sand screen.

312. Also, as I explained in detail above in Section VIII.H.2, Yeh2 also explained the limitations and considerations involved in optimizing the nozzle spacing on a packing tube to achieve complete gravel packs of long, horizontal intervals, such as the 5,000-feet horizontal interval described in Yeh's example.

313. First, as I discussed above in Section VIII.E, a POSITA was aware of gravel slurry leak-off. Specifically, that in long, horizontal wells: "some fluid (gel) leaks off and is lost through the packing tubes into the annulus and screen" in previously packed zones. EX1006 at 5. Yeh2's Figure 6b, shown below, illustrates

this concept in that as gravel slurry flows past the blocked packing tube in the first sand screen, some carrier fluid leaks off through the gravel pack in that tube while the remainder of the slurry carries on through the transport tube to the next sand screen.

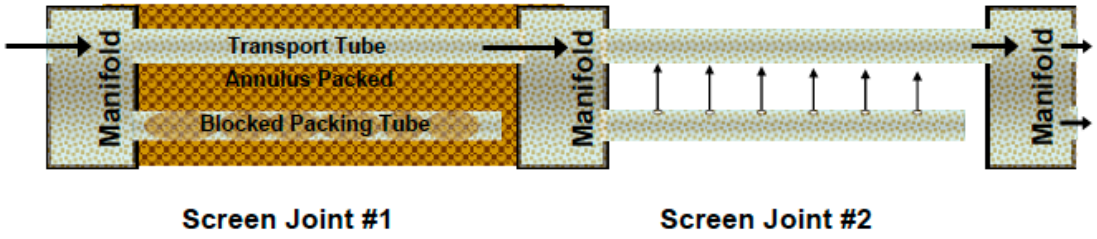


Figure 6b Shunt manifold system bypassing shunt plugging

EX1006 at Fig. 6b.

314. Yeh2 taught that one way to reduce the leak-off rate was to increase the distance of the first nozzle, or porthole, from the manifold in the packing tube. EX1006 at 5, Fig. 14. Yeh2 explained that the high pressure in extreme length horizontal intervals was associated with significant leak-off. *Id.* at 5. Yeh2 illustrated this phenomenon in Figure 14 (below), which showed that the magnitude of the leak-off rate was a function of the pressure conditions and the distance of the first packing tube nozzle from the manifold. *Id.* at Fig. 14. Figure 14 provided leak-off rate data for two packing tube designs wherein the distance of the first nozzle of

the packing tubes from the manifold was either six feet (**solid purple line**) or one foot (**dashed blue line**).

315. Data from Yeh2's Figure 14 demonstrated that to overcome excessive leak-off resulting from this higher pressure near the heel, the distance of the first packing tube nozzle from the manifold had to be increased. EX1006 at 5. For example, at 1,000 psi of pressure, the leak-off rate in the packing tube with a six-foot spaced nozzle was less than 0.01 bpm, whereas the leak-off rate was about four-fold higher (*i.e.*, 0.04 bpm) at the same pressure in the packing tube with a one-foot spaced nozzle. *See id.* at Fig. 14. The six-foot spaced nozzle packing tube did not reach a 0.04 bpm leak-off rate until the pressure was much higher at about 5,000 psi. *Id.* Although these rates may seem low in absolute terms, this leak-off occurs in each sand screen used in a long horizontal wellbore, such that the leak-off rate gets multiplied by, for example, 125 sand screens in a 5,000-feet long horizontal wellbore (5,000-feet horizontal at 40 feet per sand screen).

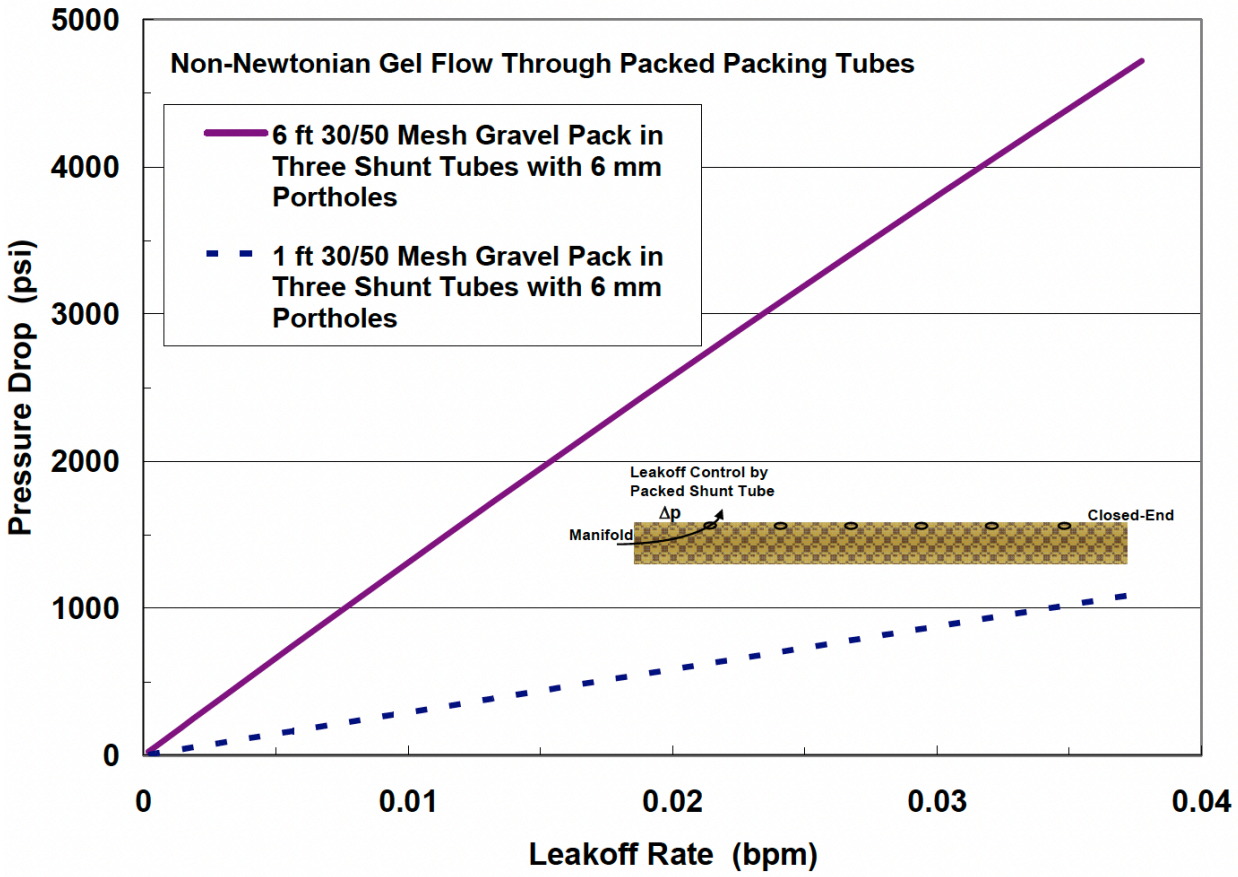
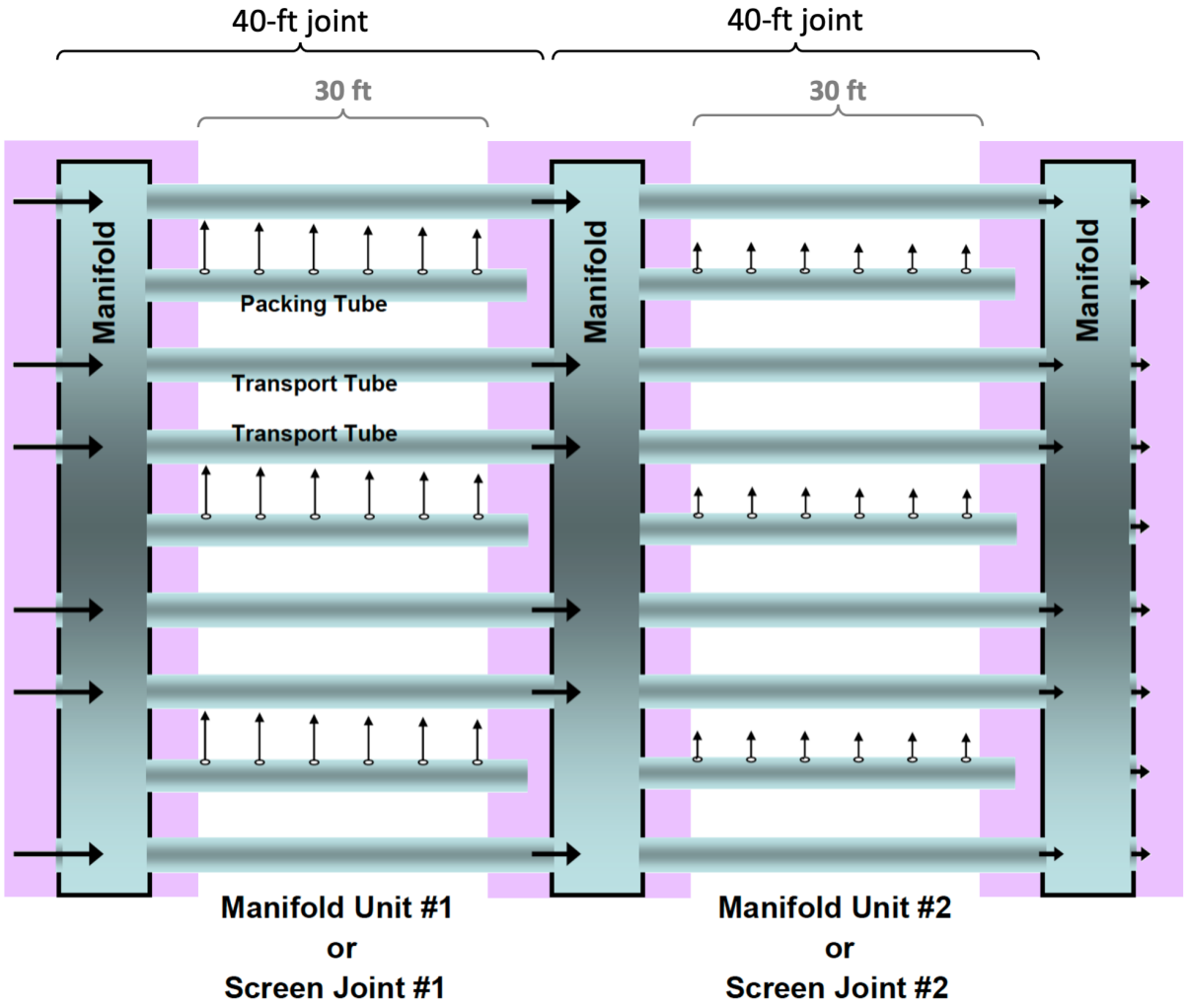


Figure 14 Leakoff through packed shunt tube

EX1006 at Fig. 14.

316. Second, a POSITA would have also considered that nozzle spacing could not be more than the distance that a single nozzle could gravel pack, which is 8-10 feet. EX1006 at 4. Yeh2 disclosed in Figure 9 the nozzle spacing of its multiple-shunt tube manifold system, which was designed to obtain a complete gravel pack in long horizontal intervals. Yeh2 disclosed that each joint of this system was a 40-feet joint with 6-feet nozzle spacing. *Id.* ("The 6 ft porthole spacing in Figure 9 utilizes six portholes to pack one screen joint (40 ft) interval."). A POSITA

would understand that while this system could provide a full gravel pack in a region immediately surrounding each nozzle, the area around the manifold upstream from the first nozzle or downstream from the last nozzle of the packing tube would be less likely to be fully gravel packed. The result would be that about a 30-foot region (**gray**) would likely obtain a complete gravel pack, and a 10-foot region, which I indicated in **purple** in annotated Figure 9 below, would possibly not be completely gravel packed. This likelihood of incomplete gravel packing increased toward the toe where injection pressure was lower as I explained above in claim 1[e].



EX1006 at Fig. 9 (annotated).

317. A POSITA would have also appreciated that as the gravel slurry pressure dropped as it was pumped down to gravel pack the long horizontal interval toward the toe, the pressure available to cause leak-off also dropped. EX1006 at Fig. 15. These two factors would have motivated a POSITA to shorten the distance between the manifold and the first nozzle in the second sand screen assembly packing tubes, which would be located closer to the toe.

318. Specifically, in the second sand screen assembly, a POSITA would shorten the distance between the manifold and the first nozzle of the packing tube such that the spacing between nozzles is less than 10 feet, which would increase the likelihood of achieving a full gravel pack in the annulus around the manifold in sand screens in the low-pressure area near the toe.

319. For example, at 4,000 psi differential pressure and a six-foot distance from the manifold to the first nozzle, the leak-off rate would be about 0.3 bpm. *See* EX1006 at Fig. 14. At about 4,000 feet away from the heel, that differential pressure drops to about 900 psi, and the leak-off rate for a 900 psi differential pressure with a one-foot distance between the manifold and first nozzle would also be about 0.03 bpm, indicating that spacing could be dropped substantially without increasing the leak-off rate. *See id.* at Fig. 15.

320. A POSITA, considering these teachings in Yeh2, would have expected that by decreasing the distance between the manifold, or junction block, and the first nozzle in the packing tube of the second sand screen assembly compared to the distance between the manifold and the first nozzle in the packing tube of the first sand screen assembly, the likelihood of a successful gravel pack would increase.

321. Together, a POSITA would have understood based on the teachings in Yeh and Yeh2 that one way to achieve a complete gravel pack in a long horizontal

interval would be to adjust the distance of the first packing tube nozzle from the manifold such that this distance was greater in the first sand screen assembly (Yeh's concentric screen) installed near the heel to counter the high pressure-induced leak-off than in the second sand screen assembly (Yeh's eccentric screen). At the same time, a POSITA would also understand that decreasing the nozzle distance from the manifold in the packing tubes of the second sand screen assembly (Yeh's eccentric screen) as compared to the first sand screen assembly (Yeh's concentric screen) would facilitate a complete gravel pack where there was less available pressure to gravel pack using a more viscous gravel slurry. I also note that decreasing the distance from manifold to first nozzle would decrease the distance between the manifold and all nozzles on that packing tube assuming a 6-feet spacing is maintained as taught by Yeh2.

322. A POSITA would have expected success with using a smaller manifold to first nozzle spacing in the eccentric screens due to the detailed teachings provided in Yeh and Yeh2 as discussed above.

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."

323. It is my opinion that claim 4 would have been obvious over Yeh optionally in view of Yeh2 because it adds nothing more than routine optimization.

324. All my reasoning that I provided in claim 2 would apply equally here and would have made it obvious to a POSITA to use more nozzles in the packing tubes in the second sand screen assembly (*i.e.*, Yeh's eccentric screen) than the packing tubes of the first sand screen assembly (*i.e.*, Yeh's concentric screen).

325. A POSITA would have understood that there was less pressure available near the toe of the horizontal for gravel packing. Consequently, a POSITA would have been motivated to add more nozzles to packing tubes in sand screen assemblies installed near the toe for two reasons: (1) to decrease the annular space that any particular nozzle would have to pack and (2) to increase the cross-sectional area available for gravel slurry to enter the annulus. *See* EX1006 at Fig. 15; *see also id.* at 5. ("Figure 15 shows the predicted pressure, rate, and gravel concentration profile in the shunt tubes over the 5,000 ft interval."). Hurst's disclosure confirmed that a POSITA would have known that gravel slurry flow could be manipulated by adjusting the number of nozzles on a packing tube. Specifically, Hurst explained that "[f]or a given fluid composition and gravel concentration, ***friction and thus the pressure applied to each zone can be controlled through*** the shunt tube dimensions (diameter and length) as well as ***the nozzle diameter and frequency***." EX1013 (Hurst) at 3-4 (emphases added). As I explained in claim 2, with decreased gravel slurry pressure near the toe, a POSITA would have been motivated to utilize either

or both of the two known options for controlling slurry injection—"the nozzle diameter and frequency." *Id.*

326. A POSITA would therefore know to vary packing tube nozzle frequency to distribute gravel slurry flow and would have expected to successfully gravel pack a long horizontal interval by increasing the nozzle frequency in packing tubes of sand screen assemblies installed near the toe of the horizontal (Yeh's eccentric screens).

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."

327. It is my opinion that claim 5 would have been obvious over Yeh optionally in view of Yeh2 because it adds nothing more than routine optimization.

328. All my reasoning that I provided in claim 1[e] would apply equally here and a POSITA would have known that in the example I provided for claim 1[e], the transport tube in the second sand screen assembly would have had a smaller wall thickness than the transport tube of the first sand screen assembly. If the outside diameter is held constant, reducing the wall thickness can result in a larger inside diameter. *See* EX1005 at 28:20-24. However, a POSITA would have also understood that with a lower pressure rating, the outside diameter of the transport tubes could be reduced while keeping the inside diameter constant by taking advantage of the lesser wall thickness required. *See supra* Sections VIII.G.12

(discussing wall thickness), VIII.J (discussing factors considered in sizing tubes for a given pressure rating). Decreasing the wall thickness by reducing the transport tube outside diameter would reduce overall cost because tubing is sold by the weight of the metal used to construct the shunt tubes.

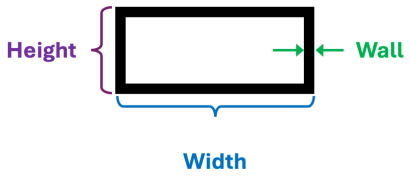
329. For example, consider two transport tubes that were being manufactured using the same metal. Both tubes had the same cross-sectional flow area and therefore the same internal diameter. However, one tube had a thinner wall than the other while maintaining the same cross-sectional flow area (*i.e.*, inside diameter). This could be achieved by reducing only the outer diameter thereby using less metal. These cost savings would motivate a POSITA to reduce the outside diameter in shunt tubes intended for installation in the lower pressure side of a horizontal.

330. A POSITA would understand that when a lower pressure rating is needed, such as in Yeh's example at the toe of a long horizontal wellbore, there are only a finite (three) set of parameters that can be adjusted to take advantage of the lower cost opportunity. Those three are tubing material, tubing thickness, and tubing outside diameter. *See supra* Section VIII.J. It would have been obvious to choose any of these three options or a combination to save cost. Reducing tubing outside diameter and tubing thickness to achieve a tubing with the same inside diameter

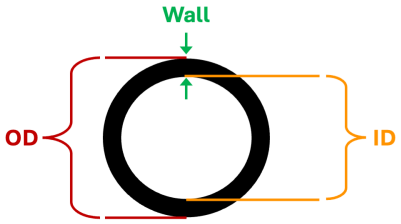
gives up an alternative benefit in the form of larger cross-sectional area available for flow and thus reduced frictional pressure drop in exchange for lower cost in tubing metal even compared to lowering tubing thickness while holding tubing outside diameter the same. A POSITA understood all these tradeoffs and would have been motivated to use a smaller diameter tubing with smaller wall thickness to save tubing cost.

331. I provided an example of precisely this type of calculation above in Section VIII.G.12. There, I provided the following example calculation:

Shunt Tube Capacity: different size tube – same capacity



	Rectangular Tubing						
	OD width (in)	ID width (in)	OD height (in)	ID height (in)	Wall (in)	Wallx2 (in)	Cubic Inches/Foot (in³/foot)
10 Gauge	1.5	1.232	0.75	0.482	0.134	0.268	7.1
13 Gauge	1.25	1.06	0.75	0.56	0.095	0.19	7.1



	Round Tubing					
	OD (in)	ID (in)	Wall (in)	Wallx2 (in)	Burst Pressure* (psi)	Cubic Inches/Foot (in³/foot)
13 Gauge	0.787 (20mm)	0.6	0.095	0.19	14,745	3.4
14 Gauge	0.75 (19mm)	0.6	0.075	0.15	12,030	3.4

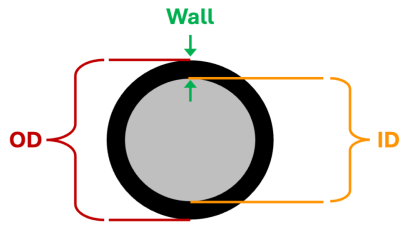
* Calculated from API TR5C3 at 24, Equation 14

Data Source - Fischer catalog, API TR5C3

See EX1032, EX1017 at 24 (Equation 14). As shown in the above figure for round tubing, for example, a 0.787" outside diameter tube with 0.095" wall thickness provides the same cross-sectional flow area (cubic inches/foot) as does the smaller

3/4" outside diameter tube with a 0.0748" wall thickness. And note that in this example, the cross-sectional area of metal in the 0.787" tube is 0.8 in^2 versus 0.6 in^2 in the 3/4" tube, showing a reduction in metal usage of 25% for the reduced outside diameter. Reducing the outside diameter of the tube from 0.787" to 0.748" with the corresponding reduction in wall thickness reduces the burst pressure in 316 stainless steel from 14,745 psi to 12,030 psi, which would be well within the design parameters for the pressures involved in Yeh's example 5,000-feet horizontal wellbore example. I provide a table below showing these calculations:

Round Shunt Tube: burst pressure calculations



Round Tubing Dimensions					Values for Burst Pressure Calculation								
					Formula from API TR5C3 at 24, Equation 14								
	OD (in)	ID (in)	Wall (in)	Cross - Sectional Area	n (316SS)*	k_{DR}	f_{umn}**	k_{wall}	t	k_a	a_N	D	P_{IR}
13 Gauge	0.787 (20mm)	0.6	0.095	0.826	0.145	0.985	70,000	0.9	0.095	2	0.00475	0.787	14,785
14 Gauge	0.75 (19mm)	0.6	0.075	0.634	0.145	0.985	70,000	0.9	0.075	2	0.00375	0.748	12,030

*From API TR5C3 at 99, Figure B1
**From ASTM A554 at 7, Table S2.1

Data Source - Fischer catalog, API TR5C3, ASTM A554

See EX1032; EX1017 at 24 (Equation 14); EX1018 at 7 (Table S2.1).

332. I obtained very similar burst pressure values using the simplified Barlow Equation. I provide my results in the table below:

Round Shunt Tube: burst pressure calculations
Using the historical method (Barlow Equation)

Round Tubing Dimensions					Values for Burst Pressure Calculation				
	OD	ID	Wall	Cross - Sectional Area	*Barlow Equation (API TR5C3 at 19, Equation 10)*				
	(in)	(in)	(in)		F_{ymn}*	k_{wall}	t	D	P_{iR}
13 Gauge	0.787 (20mm)	0.6	0.095	0.826	70,000	0.9	0.095	0.787	14,787
14 Gauge	0.75 (19mm)	0.6	0.075	0.634	70,000	0.9	0.075	0.748	12,250

*From ASTM A554 at 7, Table S2.1

Data Source - Fischer catalog, API TR5C3, ASTM A554

See EX1032; EX1017 at 19 (Equation 10); EX1018 at 7 (Table S2.1).

333. As I mentioned above, a POSITA would understand that one could increase the inside diameter of the tubing in response to the reduction in pressure rating, which would also lessen the friction pressure drop in these tubes and thus the overall pressure requirements of the shunt tube system. However, a POSITA also understood as I explained above in Section VIII.H, that slurry flow rate decreases due to carrier fluid leak-off down the horizontal wellbore, resulting in a reduced flow rate of slurry as the slurry progresses toward the toe. EX1006 at Fig. 15 (showing slurry flow dropping from 5 BPM at the heel to 2.6 BPM at the toe). A POSITA would be motivated by the cost savings of making this outside diameter and thickness modification with the understanding that less cross-sectional flow area is

required to pump the gravel slurry located closer to the toe because of the drop in frictional forces. EX1006 at 5 ("Approximately 3 bpm (vs. 5 bpm at the heel) eventually gets down to the toe to fill the void."); *see also id.* at Fig. 15; EX1013, 3-4 ("[F]riction … can be controlled through the shunt tube dimensions (diameter and length) ….").

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 comprising 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."

334. In my opinion, claim 6 would have been obvious over Yeh in view of Yeh2.

335. For all the same reasons that I discussed in claim 3, Yeh and Yeh2 disclosed the "junction block" of claim 6 and its use in Yeh's wellbore apparatus.

336. As I explained for claim 3, the '007 Patent's "junction block" is just a manifold for distributing gravel slurry between packing tubes and transport tubes. The '007 Patent's "jumper tube" is part of the secondary flow path that establishes fluid communication between the first shunt tube assembly and the second shunt tube assembly. EX1001 at 6:47-51, 7:20-25. I provide an annotated Figure 3 below

wherein I highlighted the junction block 314a-d in yellow and the jumper tube 240 in **red**:

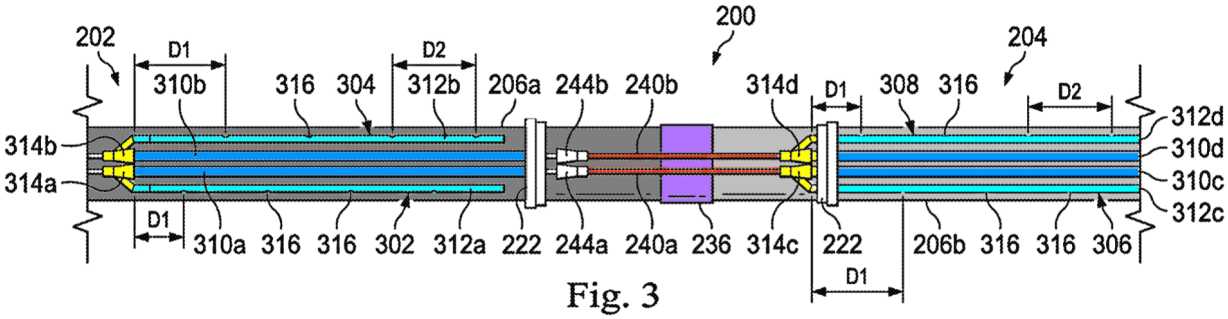


Fig. 3

EX1001 at Fig. 3 (annotated).

337. Claim 6 depends from claim 1. Claim 1 refers to a "first end and a second ends [sic]" of a base pipe but does not identify whether the first end or the second end of the base pipe is the upstream or downstream end. *See* EX1001 at 18:19-21, 18:30-32, 18:43-45. Because the claim does not require the first or second ends of the base pipes to be any particular end, I will designate the first ends as upstream ends and the second ends as downstream ends. Yeh's exemplary wellbore tool sequence: "concentric screen → crossover tool → eccentric screen," EX1005 (Yeh) at 30:13-14, disclosed connecting the downstream, or second end, of the first sand screen assembly base pipe to the upstream, or first end, of the second sand screen assembly base pipe forming a joint therebetween. In this case, the joint is literally called a crossover ***joint*** by Yeh. EX1005 at 30:13.

338. Yeh also disclosed a jumper tube. The secondary flow path 1020 of Yeh's crossover joint 1000 is a jumper tube. I annotated the flow path 1020 as **red** in annotated Figures 10A-C that I provide below:

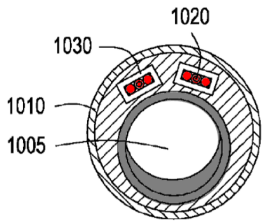


FIG. 10B

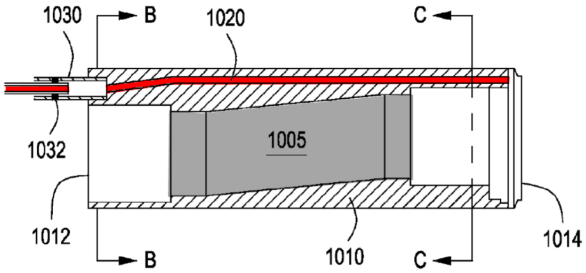


FIG. 10A

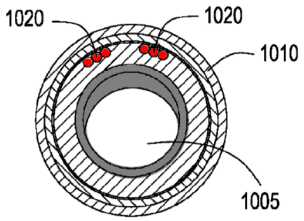


FIG. 10C

EX1005 at Figs. 10A-C (annotated).

339. Yeh disclosed that flow path 1020 connected the secondary flow path of the first wellbore tool to the secondary flow path of the second wellbore tool and that the "secondary flow path 1020 comprises a plurality of shunt tubes or a shunt annulus for carrying a gravel slurry." EX1005 at 26:44-46; *see id.* at 25:56-26:21, 26:41-65. Yeh also expressly disclosed that the connection is a fluid connection when it described "injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool." *Id.* at 28:66-29:2. Yeh disclosed that the fluid (gravel slurry in the sand screen example) flows through the shunt tubes of the first wellbore tool, crossover joint, and second wellbore tool, confirming that the other end of the

jumper tube (downstream end) is in fluid communication with the junction block (manifold) of the second sand screen assembly (eccentric screen).

340. Yeh also explained that the "concentric wellbore tool [first sand screen assembly] may connect to the second end 1014 of the crossover joint 1000 either directly through a threaded connection, or indirectly through the use of a ***coupling*** and a torque sleeve or a load sleeve." *Id.* at 26:28-32 (emphasis added). Thus, Yeh disclosed the coupling interconnecting one end of a jumper tube (secondary flow path 1020) to the transport tube of the first sand screen assembly (concentric screen).

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 no more than 5000 psi."

341. It is my opinion that claim 7 would have been obvious over Yeh in view of Yeh2 because it adds nothing more than routine optimization.

342. First, Yeh disclosed that at the heel of the horizontal interval the shunt tubes of the first sand screen assembly (the concentric screen) could have an operating pressure of 6,500 psi, which would require shunt tubes installed in this part of the horizonal to be able to withstand that internal pressure thereby requiring those shunt tubes to have a 6,500 psi burst pressure rating. EX1005 at 28:10-24. An operating pressure of 6,500 psi is within the "5000 psi and 10000 psi" required in claim 7.

343. Second, Yeh2 provided data in Figure 15 for a 5,000-feet horizontal wellbore, which is the same as Yeh's example I relied on for claim 1. The data provided in Yeh2's Figure 15 confirmed Yeh's disclosure that higher pressure-rated shunt tubes were required toward the heel of a horizontal interval. EX1006 at Fig. 15; *see also id.* at 5. The data in Figure 15 demonstrated that the shunt tube operating pressure (**blue line**) at the heel (left side of x-axis) was about 5,300 psi, which would require shunt tubes installed in that section to also have an internal pressure tolerance or burst pressure rating of at least 5,300 psi. EX1006 at 5 ("Transporting 5 bpm slurry at the heel through the shunt tubes to the toe void requires 5,300 psi. Burst strength of shunt tubes must therefore be capable of accommodating this high hydraulic pressure."). I provide Figure 15 below:

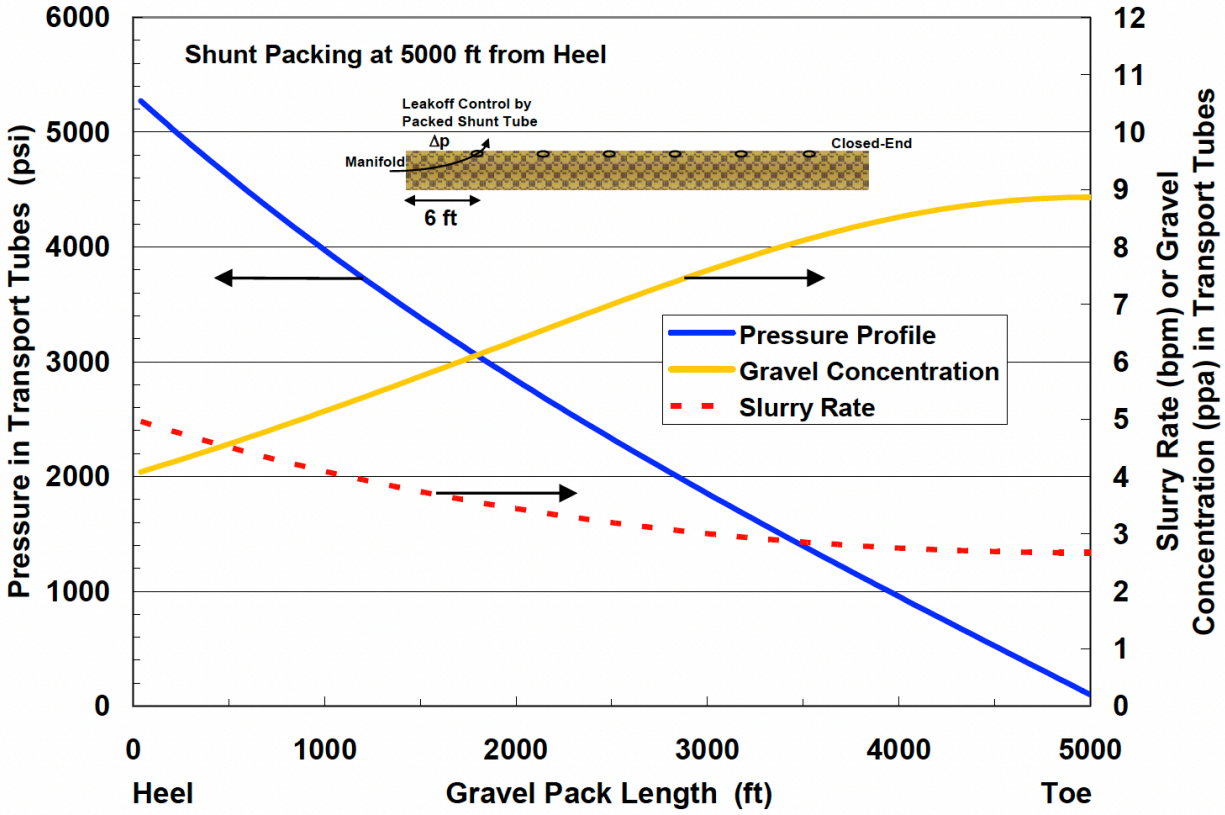


Figure 15 Gravel packing 5,000 ft with multiple-shunt manifold system

EX1006 at Fig. 15.

344. Therefore, Yeh2 expressly taught that a burst pressure of 5,300 psi, which is a pressure rating between "5000 psi and 10000 psi" as recited in claim 7.

345. Third, Yeh explained that commercial concentric screens could gravel pack a 5,000-feet horizontal interval and could be installed in the higher-pressure side towards the heel of the well. EX1005 at 30:15-26. However, the eccentric screens would be capable of gravel packing a 3,000-feet horizontal well and could be installed in the lower-pressure side towards the toe of the well. *Id.* Yeh's

disclosure would inform a POSITA that eccentric screens installed in the lower-pressure side of the well had lower pressure ratings compared to the concentric screens installed upstream and yet could still complete a gravel pack while maintaining structural integrity. EX1005 at 30:44-45 ("The concentric round shunt tubes allow for higher fluid injection pressures.").

346. A POSITA would also use Yeh2's data in its Figure 15 to determine the pressure requirements for these eccentric screens because Yeh did not provide this data in as much detail as Yeh2. Referring to the transport tube pressure profile values 2,500 feet down the horizonal, the shunt tubes would be operating at about 2,400 psi. This would therefore require those shunt tubes to have a pressure rating of at least 2,400 psi, which is "no more than 5000 psi" as required by claim 7.

347. A POSITA would have expected to successfully obtain a complete gravel pack using these pressure ratings taken from Yeh's Figure 15 because these data were generated from a 5,000-feet horizontal well, which is the same example Yeh discloses for its exemplary completion assembly. EX1005 at 30:13-26 ("For example, known concentric screens are capable of gravel packing 5,000 feet, compared to 3,000 feet with the commercial eccentric screens. The new crossover tool allows the operator to use the less-expensive eccentric screens on the toe or lower-pressure side of the interval during gravel-packing operations, and to use the

concentric screens on the heel or higher-pressure side of the interval during the gravel-packing operations.").

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."

348. It is my opinion that claim 8 would have been obvious over Yeh in view of Yeh2.

349. Specifically, as I discussed in claim 7, Yeh's concentric screen (*i.e.*, the first sand screen assembly) was disclosed to have a pressure rating that falls between "5000 and 10000 psi." Yeh2 confirmed that disclosure in the same example 5,000-feet horizontal wellbore.

350. It is also my opinion that Yeh in view of Yeh2 disclosed or suggested the remainder of claim 8 for the same reasons I provided in claim 1.

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 more than the select threshold."

351. It is my opinion that claim 9 would have been obvious over Yeh in view of Yeh2 for the same reasons that I discussed for claim 7.

352. For example, at the select threshold of 5,000 psi, Yeh in view of Yeh2 disclosed and/or suggested claim 9 for the reasons I provided for claim 7. Additionally, Yeh in view of Yeh2 discloses or suggests claim 9 for any select

threshold between the pressure rating of the shunt tube assembly of the eccentric screen and that of the shunt tube assembly of the concentric screen. Yeh discloses that the pressure rating of the shunt tubes of the eccentric screen is lower than that of the shunt tubes of the concentric screen confirming that claim 9 is satisfied. EX1005 at 30:16-20 ("Concentric sand screens can be more robust for gravel packing long intervals. For example, known concentric screens are capable of gravel packing 5,000 feet, compared to 3,000 feet with the commercial eccentric screens."), 30:44-45 ("The concentric round shunt tubes allow for higher fluid injection pressures.").

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 pressure."

353. It is my opinion that claim 10 would have been obvious over Yeh in view of Yeh2 for the same reasons that I provided for claim 7.

354. A POSITA would understand that the "burst pressure" would be considered a type of "pressure rating" for the shunt tube assembly, particularly the ability of that shunt tube assembly to hold internal pressure without rupturing. That is the same pressure rating I used from Yeh and Yeh2 regarding claim 7. Yeh also used this terminology. Yeh referred to a 6,500 psi differential pressure in reference to its concentric sand screens installed near the heel of the horizontal, which is a

reference to the concentric screen shunt tube assemblies' internal pressure tolerance—meaning, its burst pressure rating. *See* EX1005 at 28:17-24 ("For example, a 6,500 psi differential pressure is expected near the heel of [sic] when gravel packing a 5,000-foot horizontal completion interval. In order to maintain the mechanical integrity (that is, to stay within the ***burst***, bending, and collapse ratings) of the secondary flow paths, a certain surrounding wall thickness is required." (emphasis added)). Yeh2's disclosure confirms my understanding. EX1006 at 5 ("Transporting 5 bpm slurry at the heel through the shunt tubes to the toe void requires 5,300 psi. ***Burst strength*** of shunt tubes must therefore be capable of accommodating this high hydraulic pressure." (emphasis added)).

K. Claim 11

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

355. In my opinion, claim 11 would have been obvious over Yeh in view of Yeh2. Yeh in view of Yeh2 disclosed or suggested each of the limitations in claim 11. For the reasons I explained in claim 1[preamble], a POSITA would have looked to Yeh2 for data on Yeh's APT system.

356. It is also my opinion, that to the extent limiting, Yeh disclosed the preamble for the same reasons I provide for claim 1[preamble].

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

357. It is my opinion that Yeh disclosed this limitation for the same reasons that I provided for claim 1[c].

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

358. It is my opinion that Yeh disclosed this limitation for the same reasons that I provided for claim 1[d].

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"

359. It is my opinion that Yeh in view of Yeh2 disclosed or suggested this limitation for the same reasons I provided for claims 1[e], 7, and 10.

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."

360. It is my opinion that Yeh in view of Yeh2 disclosed or suggested this limitation.

361. For the same reasons that I provided for claims 1[c] and 1[d], it is my opinion that Yeh in view of Yeh2 disclosed a source of pressurized working fluid (that is, a pump at the surface) that was in fluid communication with an upstream end of the shunt tube assembly of a first sand screen assembly (*i.e.,* Yeh's concentric

screen) with a first burst pressure. Further, as I explained for claim 1[d], Yeh disclosed installing downstream from the first sand screen assembly a second sand screen assembly (*i.e.,* Yeh's eccentric screen) with a shunt tube assembly that had a second burst pressure that was less than the burst pressure of the first shunt tube assembly. The final arrangement of the disclosed wellbore tool sequence was a first sand screen assembly with its shunt assembly installed between the source of the pressurized working fluid (the pump) and the shunt tube assembly of the second sand screen assembly, all of which were fluidly coupled according to the explanations I provided for claims 1[c]-[d].

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 disposed to operate at pressures of no more than 5000 psi.

362. It is my opinion that claim 12 would have been obvious over Yeh in view of Yeh2 for the same reasons that I provided for claim 7.

363. A POSITA would understand the limitation "disposed to operate" to refer to an operating pressure, not a pressure rating. An operating pressure is the pressure at which a shunt tube system is expected to operate. This is different than a pressure rating, which instead refers to the maximum pressure that a tubing system is understood to be able to withstand. But as I explained regarding claim 7, a

POSITA understood that the expected operating pressure sets a minimum pressure rating for the tubing system.

364. The disclosed operating pressures of the shunt tube assemblies of Yeh's concentric and eccentric screens in the example I provided in claim 7 fall within the operating pressure ranges recited in claim 12. Similarly, the operating pressures Yeh2 disclosed also fall within the ranges recited in claim 12 for the reasons I explained for claim 7.

XIII. GROUND 2

A. Claim 14

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

365. It is my opinion that claim 14 would have been obvious over Yeh in view of Yeh2 and optionally Jones2.

366. As I explained in claim 1[preamble], it is also my opinion that a POSITA would have understood that Yeh2 described the same system as Yeh. *See* EX1005 at 3:8-62 (describing Alternate Path® sand screen technology); EX1006 at 1 (same). A POSITA would have known that Yeh's system worked in the same way as described in Yeh2 and would have expected Yeh2's description to already apply to Yeh's concentric sand screens and thus would have expected success in applying Yeh2's teachings to Yeh. For the same reasons, a POSITA would have understood

that Yeh2's teachings applied to Yeh and would have been motivated to combine them with a reasonable likelihood of success.

367. Assuming that the preamble is limiting as I have been asked to assume, Yeh disclosed a method of installing a completion assembly in a wellbore. Yeh taught in its Figure 12 "steps for a method 1200 for completing a wellbore in a subsurface formation, in one embodiment. The method 1200 is applicable for the installation of wellbore tools having flow paths that do not align." EX1005 at 28:31-34, Fig. 12. Yeh's "wellbore tools" constitute a completion assembly. Additionally, one example of this method is the completion assembly: "concentric screen → crossover tool → eccentric screen." EX1005 at 30:13-14.

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;"

368. It is my opinion that Yeh disclosed or suggested this limitation.

369. First, as I explained in claim 1[c], the '487 Patent and Yeh taught to pump a pressurized gravel slurry, which is considered a working fluid, *see, e.g.,* EX1001, 4:11-14, into fluidly coupled sand screen shunt tubes and out of those shunt tubes into the annulus, EX1012 at 5:4-13. The pump was located at the surface as I explained in claim 1[c]. Thus, all references to the source of pressurized working fluid would be in reference to the pump at the surface, which is upstream of all producing zones. *See supra* Section VIII.I.1.

370. Second, Yeh's method 1200 provided a way for installing a completion assembly into a wellbore in a subsurface formation. One example to which Yeh's method applied was the following: "Another tool sequence for use with a crossover joint is: concentric screen → crossover tool → eccentric screen." EX1005 at 30:13-14. As I explained in claim 1[a], the crossover tool (joint) connects the primary (base pipe) and secondary (shunt tubes) flow paths of the completion assembly. EX1005 at 25:41-65, 28:48-60.

371. Once these wellbore tools have been connected together with the crossover tool, Yeh then taught running this fluidly-connected completion assembly into "a selected subsurface location within the wellbore." EX1005 at 28:61-64. The next step was to inject fluid through the secondary flow paths of the first wellbore tool, which subsequently flowed down the secondary flow paths of the crossover joint and then through the secondary flow paths of the second wellbore tool. *Id.* at 28:66-29:3 ("The method 1200 then includes further injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool. This is provided at Box 1280.").

372. Yeh disclosed that this example completion assembly (concentric and eccentric screens) is used for gravel packing ***long*** intervals. EX1005 at 30:13-20

("Concentric sand screens can be more robust for gravel packing long intervals. For example, known concentric screens are capable of gravel packing 5,000 feet, compared to 3,000 feet with the commercial eccentric screens.").

373. A POSITA knew that sand screens are installed and gravel packing is performed in producing zones. *See supra* Section VIII.B. Yeh confirmed this understanding of a POSITA: "To control the invasion of sand and other particles, sand control devices may be employed. Sand control devices are usually installed downhole ***across formations*** to retain solid materials larger than a certain diameter while ***allowing fluids to be produced***." EX1005 at 2:33-37 (emphases added); *see also id.* at 2:37-41 (describing sand control devices as including a slotted base pipe "wrapped with a filtration medium such as a screen or wire mesh"). Yeh also disclosed:

> In an open-hole gravel pack completion, the gravel is positioned between a sand screen that surrounds a perforated base pipe and a surrounding wall of the wellbore. During production, formation fluids flow from the subterranean formation, through the gravel, through the screen, and into the inner base pipe. The base pipe thus serves as a part of the production string.

EX1005 at 2:55-61. The purpose of gravel packing and sand screens is to exclude sand from production fluids such that they need to be installed in a producing zone to serve their purpose.

374. The ’487 Patent also disclosed, “Casing 11 has perforations 13 adjacent at least two productive zones 14a, 14b of the subterranean, productive formation(s) which forms interval 12. Well screen 15 is positioned within wellbore 10 and extends through interval 12.” EX1012 at 4:2-6. Thus, the ’487 Patent disclosed installing sand screens extending across a producing interval or zone. Figure 1 of the ’487 Patent reproduced below also illustrated a production interval 12, which would be understood to be an elongated production zone. EX1012 at 3:66-4:6. From the ’487 Patent’s disclosure, which was incorporated by reference in Yeh, EX1005 at 3:12-18, as well as Yeh’s separate disclosure, a POSITA knew that sand screens were installed in production intervals to filter out sand from production fluids entering the base pipe from the surrounding formation thereby preventing sand that would otherwise erode the wellbore equipment. Thus, a POSITA understood that Yeh’s example involved a “long” (elongated) production zone.

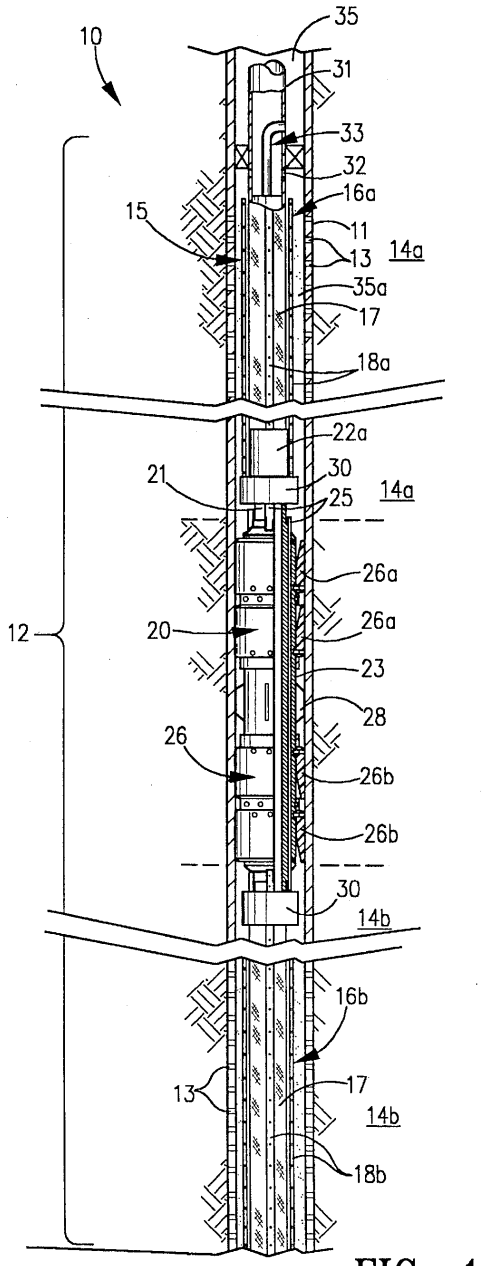


FIG. 1

EX1012 at Fig. 1.

375. As I explained above, Yeh disclosed that this elongated production zone is "a selected subsurface location within the wellbore." EX1005 at 28:61-65. A

POSITA understood where the producing zone(s) were in a well before a completion was installed. That is how a POSITA knew where to install the completion assembly. When Yeh says that the location of the completion assembly was "selected," a POSITA understood that the producing zone(s) had been previously identified and were selected as the location to install the completion assembly. A producing zone could not be "selected" without having been previously identified.

376. Third, Yeh disclosed installing sand screens throughout a production zone in a wellbore to prevent sand from the surrounding formation entering the wellbore tools. Specifically, Yeh taught that sand in production fluid could "erode production components in the flow path" and that "[w]hen formation sand is expected to be encountered, one or more lower production assemblies [typically sand screens] may be installed in the production zone between the formation and the production tubing." EX1001 at 1:25-36.

377. Yeh's figures 1 and 2 illustrated an example of such a sand screen installation in an open-hole portion of a wellbore. Yeh's Figure 2 provided an expanded cross-sectional view of the open-hole portion of the cross-sectional view of a wellbore illustrated in Figure 1. EX1005 at 6:62-65.

378. Yeh's Figure 2, which I show annotated on the right, taught that the open-hole portion 120 of wellbore 100 included three subsurface intervals 112, 114, and 116, wherein each interval could contain valuable production fluids. EX1005 at 10:28-45. That is, intervals 112, 114, and 116 could be considered together as one production zone or individually as separate production zones. Sand control devices 200 were installed in each interval 112, 114, and 116. EX1005 at 11:59-60. The sand control devices 200 included a base pipe 205 (**dark gray**) and a filter medium or sand screen 207 (**orange**) wrapped around the base pipe 205. EX1005 at 11:9-25. Thus, the sand control devices 200 are sand screen assemblies. As shown in Figure 2, Yeh taught disposing sand screen assemblies throughout a producing zone from "upper interval 112" to "lower interval 116." Figure 2 shows that each of intervals 112, 114, 116, and the collective set of all three has an upstream proximal end (top in Figure 2) and a downstream distal end (bottom in Figure 2) with respect to a source of pressurized working fluid, which as I explained above is at the surface, which would be above

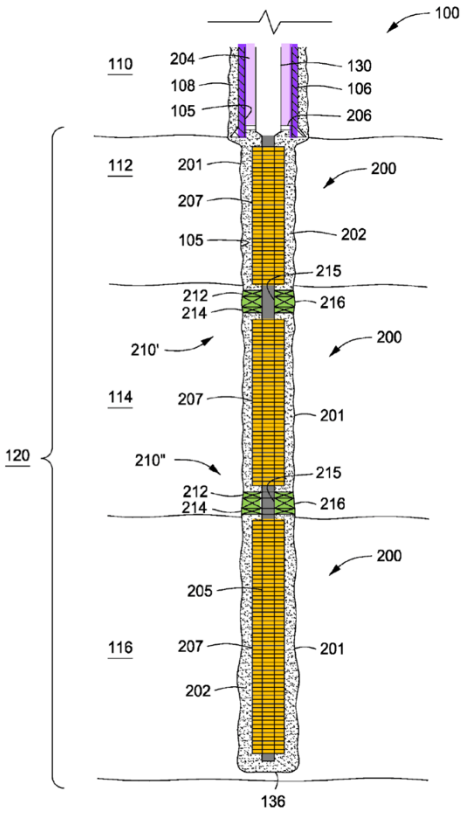


FIG. 2

the top of Figure 2. The source of pressurized gravel slurry (pump) would be at the surface for every producing zone in a wellbore.

379. A POSITA would understand that the elongated production zone would have a section that was closer to the pump relative to another section of the elongated production zone. The section closest to the pump would be installed in the upstream proximal end, which would be located near the heel of the Yeh's horizontal wellbore example. The section farther away from the pump would be installed in the downstream distal end, which would be located near the toe of Yeh's horizontal wellbore example. EX1005 at 30:15-32 ("[T]he crossover joint allows ***a horizontal completion*** to continue without delay by combining concentric screens with the more readily available eccentric screens." (emphasis added)). Yeh described installing a sequence of wellbore tools according to this positioning wherein Yeh's crossover tool was used to fluidly connect concentric screens which were installed in the heel with eccentric screens which were installed in the toe.

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;"

380. It is my opinion that Yeh disclosed or suggested this limitation as I explained in claim 1[e].

381. I did not find a definition for "high pressure" in the '007 Patent or in claim 14. However, based on the '007 Patent's disclosure I understand "high pressure" to mean that the proximal end shunt tube assembly had a higher-pressure rating compared to the distal end shunt tube assembly. *See, e.g.*, EX1001 at 11:9-13, 11:35-40. Yeh disclosed this limitation under this definition.

382. Yeh disclosed designing a sand screen assembly that was pressure rated according to the location it was to be installed in a horizontal wellbore, which a POSITA understood was an elongated production zone for the reasons I provided in claim 14[a]. Yeh disclosed that the proximal end of the horizontal, or the heel, was the "higher-pressure side of the interval during the gravel-packing operations." EX1005 at 30:24-25. Yeh taught to install concentric screens at the heel, which was the higher-pressure side, of the interval because it was understood that concentric screen shunt tubes were "more robust for gravel packing long intervals," as long as 5,000 feet; while eccentric screens were to be placed on the toe, or lower-pressure side. *Id.* at 30:15-26. Consistent with its teaching, Yeh proposed using the following completion assembly: "concentric screen→crossover tool→eccentric screen." *Id.* at 30:13-14.

383. A POSITA reading Yeh's teaching regarding the expected pressures in the horizontal wellbore example and the need to select tubing to withstand those

pressures understood the need to determine the shunt tube system operating pressure throughout the horizontal wellbore to confirm that the tools being selected could withstand that pressure. EX1005 at 28:10-24 ("In order to maintain the mechanical integrity (that is, to stay within the burst, bending, and collapse ratings) of the secondary flow paths, a certain surrounding wall thickness is required."); *see also* EX1006 at 5 ("Transporting 5 bpm slurry at the heel through the shunt tubes to the toe void requires 5,300 psi. Burst strength of shunt tubes must therefore be capable of accommodating this high hydraulic pressure.").

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;"

384. It is my opinion that Yeh disclosed or suggested this limitation for the same reasons I provided for claim 1[e]. A POSITA would have known to determine the shunt tube system operating pressure associated with the entire production zone including the distal end and select an appropriate shunt tube system based on the determined pressure for the reasons I provided in claim 14[b].

385. While I did not find a definition for "low pressure" in the '007 Patent, this term only has meaning when considering it in relation to the "high pressure shunt tube system" in claim 14[b]. Specifically, the claim requires that a shunt tube assembly installed downstream in the distal end of a production zone near the toe

would have a pressure rating that is lower compared to the pressure rating of a shunt tube assembly of a sand screen assembly installed upstream in the proximal end towards the heel.

386. A POSITA reading Yeh would understand that the pressure containment requirements of a shunt tube assembly decreased toward the toe of the horizontal. A POSITA would understand that this is due to friction pressure drop as the gravel slurry proceeds through the shunt tubes toward the toe where the pressure will be zero—*i.e.*, the shunt tube internal pressure will be equal to the annular pressure outside the shunt tubes. Yeh expressly disclosed that the toe (the downstream distal end) is the "lower-pressure side of the interval during gravel packing operations." EX1005 at 30:22-23; *see also id.* at 24:54-60, 28:10-20.

387. A POSITA also understood that the pressure drop that occurred along the length of the production zone was a near-linear relationship, which was illustrated in the pressure profile (**blue line**) of Yeh2's figure 15. EX1006 (Yeh2) at Fig. 15; *see also id.* at 5. I provide Figure 15 below, which shows the pressure in transport tubes at the heel to be about 5,300 psi and decreased to nearly zero after traveling down 5,000 feet along the horizontal to the toe:

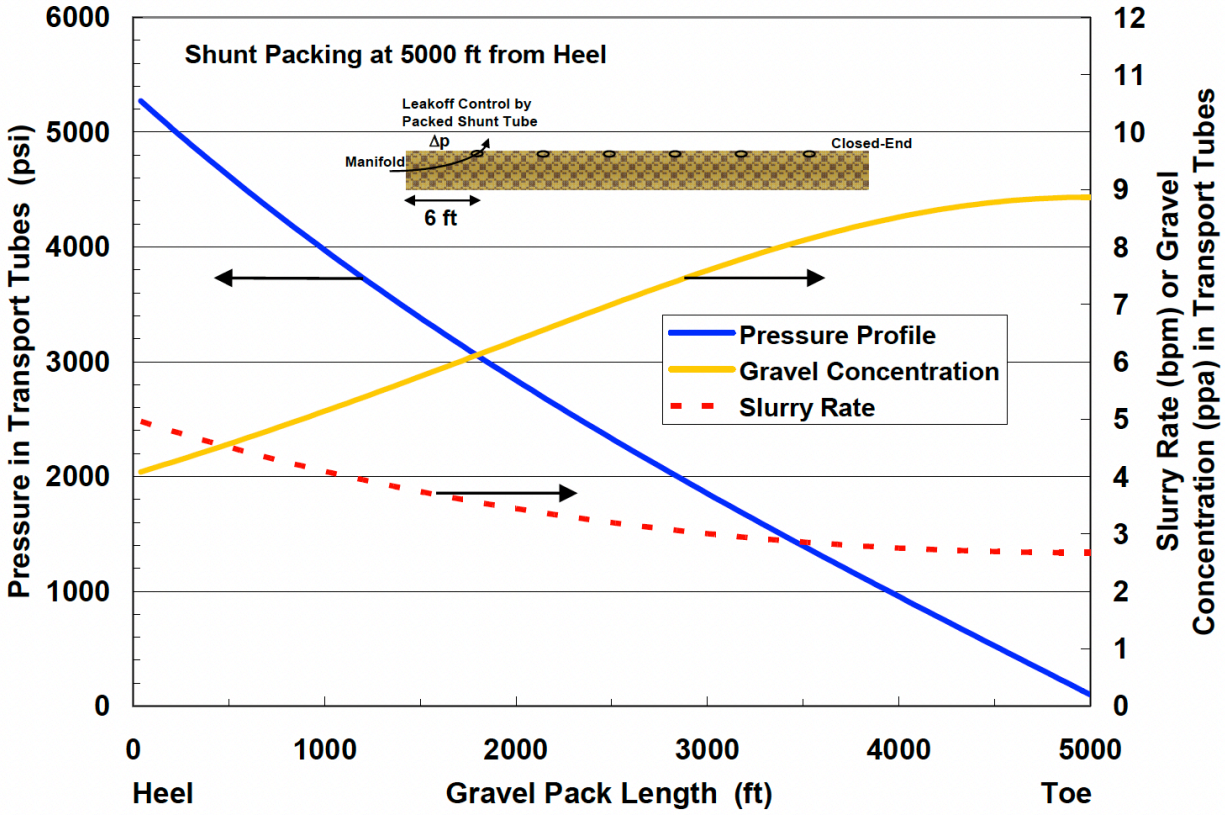


Figure 15 Gravel packing 5,000 ft with multiple-shunt manifold system

EX1006 at Fig. 15.

388. As I explained in claim 1[e], Yeh taught to use eccentric screens at the toe or lower-pressure side of the horizontal production zone because eccentric screen shunt tubes had a lower pressure rating. EX1005 at 30:15-26. When determining at what point along a horizontal to install eccentric screens, a POSITA would understand to place the eccentric screens starting at a point along the horizontal where the pressure dropped below the pressure tolerance limits of Yeh's recommended commercial eccentric screens. According to Yeh, this transition point

would be about 3,000 feet down the horizontal from the heel. *See* EX1005 at 30:16-20. Data from Yeh2's Figure 15 confirmed this understanding. According to Figure 15, the pressure in the shunt tube assembly is about 2,800 psi at 2,000 feet from the heel (or 3,000 feet from the toe). EX1006 at Fig. 15. Hecker, which was expressly referenced by Yeh, EX1005 at 3:34-44, confirmed that a POSITA would have this understanding: "Maximum [current eccentric screen] shunt system working pressure of 3,000 psi which limits the packable length to ~3,200 ft pumping at 5 barrels per minute (bpm)," EX1015 (Hecker) at 1. A POSITA would have understood that Yeh's recommended transition to eccentric screens could thus occur anywhere between 3,000 feet from the toe and the toe of the horizontal wellbore.

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

389. It is my opinion that Yeh disclosed or suggested this limitation.

390. Yeh's method 1200 provided for "a first wellbore tool. This is shown at Box 1210," EX1005 at 28:35-36, wherein the first wellbore tool could be a sand screen, *id.* at 29:10-11. In Yeh's example cited in claim 14[a], the first sand screen assembly would be an eccentric sand screen installed adjacent the distal downstream end of an elongated horizontal production zone. *Id.* at 30:13-29.

391. Yeh's method included installation instructions for the first wellbore tool by: "running the … first … wellbore tool[] into a wellbore. This is seen at Box

1260. The crossover joint is run to a ***selected subsurface location within the wellbore***." *Id.* at 28:61-63 (emphasis added). As I explained in claim 14[a], a POSITA would have understood to install sand screens across a production zone to prevent sand entry into the wellbore throughout the production zone because sand would erode the wellbore equipment. This understanding would include installing a sand screen assembly in a wellbore adjacent to the distal downstream end of the elongated production zone for the reasons I provided for claim 14[a].

392. As I discussed in claim 14[c], Yeh also expressly taught to install eccentric screens, which would be the first sand screen assembly according to claim 14's pressure requirements, at the toe or distal end of an elongated production zone. As I have already explained, Yeh provided the following exemplary wellbore tool sequence: "concentric screen → crossover tool → eccentric screen." EX1005 at 30:13-14.

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 screen 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,"

393. It is my opinion that Yeh disclosed this limitation for the same reasons I explained in claims 14[a] and 14[b].

394. Yeh's method 1200 also provided for "a second wellbore tool. This is indicated at Box 1220," EX1005 at 28:40-41, wherein the second wellbore tool could be a sand screen, *id.* at 28:43-44. Yeh's method also explained installing or "running the crossover joint and connected first and second wellbore tools into a wellbore. This is seen at Box 1260." *Id.* at 28:61-63.

395. Yeh expressly taught to install concentric screens, which would be the second sand screen assembly according to claim 14's pressure requirements, at the proximal or heel end of an elongated production zone. EX1005 at 30:20-25. The concentric screens have the high pressure shunt tube system as I explained in claim 14[b]. I also already discussed that Yeh provided the following exemplary wellbore tool sequence: "concentric screen → crossover tool → eccentric screen." *Id.* at 30:13-14. Thus, Yeh disclosed attaching the downstream end of a second sand screen assembly (concentric screen) to the upstream end of a first sand screen assembly (eccentric screen). EX1005 at 28:66-29:3; *see also id.* at 28:48-60. The eccentric screens have the low pressure shunt tube system as I explained in claim 14[c].

396. As I explained in claim 14[a], a POSITA understood that sand screens and gravel packing have to be installed throughout the production zone to avoid sand production. Thus, a POSITA would understand that Yeh's sand screens would have

to be installed throughout the horizontal wellbore in the example I discuss above. *See* EX1005 at 30:27-29 ("It may be difficult to acquire more complex concentric sand screens in quantities needed for extended horizontal completions.").

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

397. In my opinion, Yeh in view of Yeh2 and optionally Jones2 expressly or inherently disclosed this limitation.

398. For example, Yeh disclosed this limitation in the following passage:

> The method 1200 further includes running the crossover joint and connected first and second wellbore tools into a wellbore. This is seen at Box 1260. The crossover joint is run to a selected subsurface location within the wellbore. ***Fluid is then injected into the wellbore.*** This is shown at Box 1270.
>
> ***The method 1200 then includes further injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool***, the crossover joint, and the secondary flow paths for the second wellbore tool. This is provided at Box 1280.

EX1005 at 28:61-29:3 (emphases added).

399. A POSITA would understand that to inject fluid through the secondary flow paths, like Yeh's concentric screens that had high-pressure shunt tube systems, the source of pressurized working fluid (*i.e.,* the pump I discussed in limitation 14[a]) necessarily must be coupled to the most upstream shunt tube assembly (*i.e.*,

Yeh's concentric screen with its high-pressure shunt system) because shunt tube assemblies were connected in series beginning at the heel of the wellbore and continued this connection with the remaining downstream sand screen assemblies as expressly disclosed by Yeh and as I explained in claim 14[e].

400. Therefore, it is my opinion that the required coupling of this limitation would be inherent in Yeh. Indeed, without this coupling, it would not be possible to complete a gravel pack because the series of shunt tube assemblies would not receive gravel slurry rendering them useless.

401. Even if the series of shunt tube assemblies were not "coupled" when installed at the surface, Yeh taught they would become coupled when a sand bridge formed in the annulus. EX1005 at 3:8-12 ("The problem of sand bridging has been addressed through the use of Alternate Path® Technology, or 'APT.' The Alternate Path® fluid bypass technology employs shunt tubes (or shunts) that allow the gravel slurry to bypass selected areas along a wellbore."), 4:47-53 ("The shunt tube serves as an alternate flow channel. In this respect, the shunt tube is configured to allow gravel slurry to at least partially bypass the first wellbore tool when any premature sand bridge occurs in the surrounding annular region between the sand screen and the wellbore during a gravel-packing operation in the wellbore."), 9:10-15 ("The term 'alternate flow channels' means any collection of manifolds and/or shunt tubes

that provide fluid communication through or around a packer to allow a gravel slurry to by-pass the packer elements or any premature sand bridge in the annular region, and to continue gravel packing further downstream."). Yeh2's Figure 1, which I provide below, illustrated this phenomenon. Specifically, if gravel slurry (light green arrows) being pumped down the annulus (light orange) encountered a sand bridge or zonal isolation (**dark orange**), it was diverted into shunt tube systems to bypass that blockage, then out into the annulus downstream of that blockage to continue gravel packing.

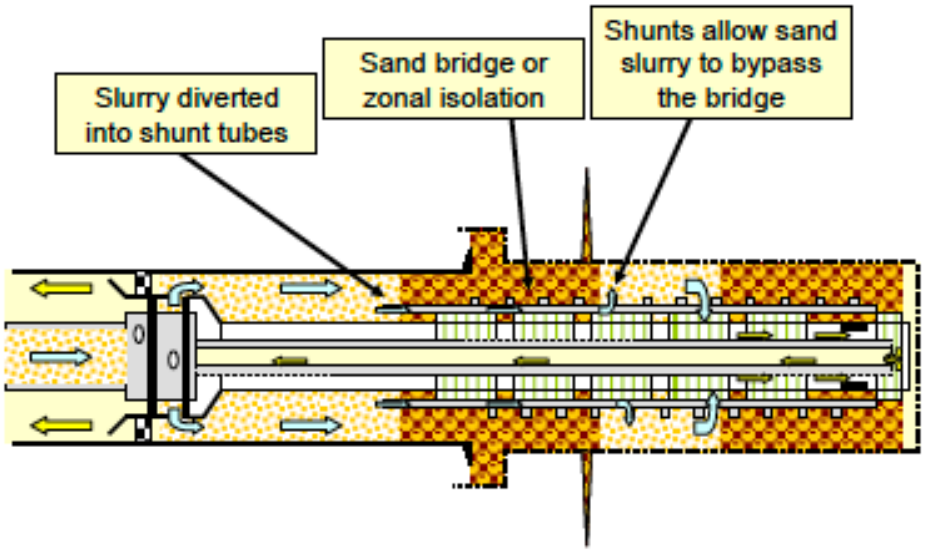


Figure 1 Alternate Path gravel packing with shunt tubes

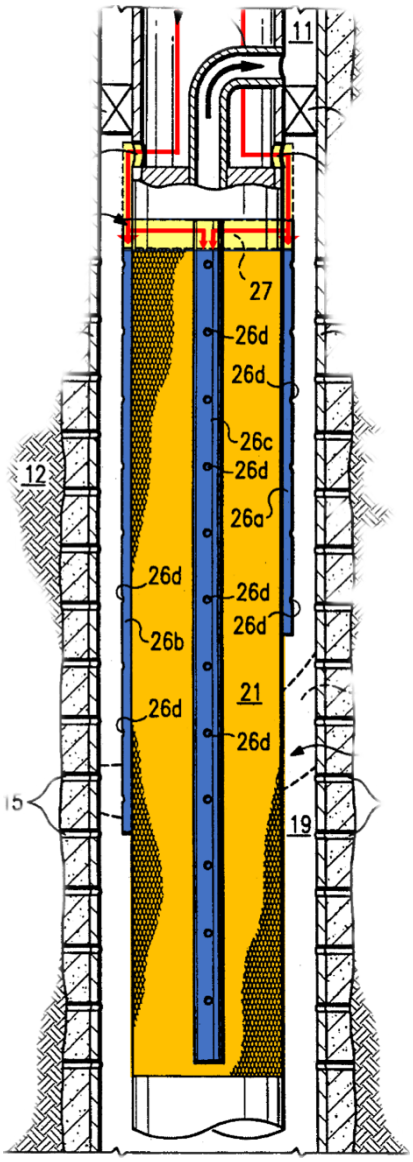
EX1006 at Fig. 1. Because Yeh2 was describing the same Alternate Path® system, a POSITA would understand that Yeh2's description applied to Yeh's sand screen technology.

402. To the extent that this limitation was not disclosed or inherent in Yeh, it would have been obvious because a POSITA would have known that the source of pressurized working fluid (pump) had to be coupled to the upstream end of the high-pressure shunt tube system to deliver gravel slurry to that system and to the subsequent shunt tube systems connected in series downstream of that high-pressure system. Again, this concept was shown in Yeh2's Figure 1. Yeh2 explained the process of injecting gravel slurry into a production zone: "Shunt tubes remain inactive until the annulus is blocked during the gravel pack operation. [Alternate Path Technology] diverts flow through the shunt tubes and by-passes any blockage, such as a premature sand bridge, to continue gravel packing. As shown in Figure 1 [above], shunt tubes divert slurry through distributed portholes to fill annular voids until a complete pack is placed." EX1006 at 2.

403. Therefore, it is my opinion that Yeh2 disclosed coupling a source of pressurized working fluid to the shunt tube system associated with the most upstream sand screen assembly, which was the high-pressure shunt tube system of Yeh's concentric screen. This is the same method disclosed in Yeh. *See* EX1005 at 28:61-29:3.

404. It is also my opinion that Yeh in view Yeh2 and Jones2 disclosed "coupling." Jones2, entitled *Gravel Packing of Wells*, was co-invented by Lloyd

Jones and Charles Yeh of what is now ExxonMobil. EX1008 at 1. A POSITA considering a downhole gravel packing system using shunt tubes would have readily looked to Jones2 because Jones2 is in the same field of gravel packing using shunt tubes as Yeh and Yeh2 and included Charles Yeh as a co-inventor. Indeed, Yeh expressly referenced Jones2 as an "[a]dditional reference[] which discusses fluid bypass technology." EX1005 at 3:18-20.



405. As seen in my annotated Figure 1 (right), Jones2 provided an "[a]pparatus for gravel packing a wellbore interval having shunt means (i.e. conduits) [(**dark blue**)] on the external surface of a sand screen [(**orange**)] which can selectively deliver a gravel slurry [(**red arrows**)] to different levels of the interval during operation." EX1008 at Abstract. Jones2 taught that in "some embodiments of the present invention, the conduits [shunt tubes] are open to receive slurry as it flows into the interval while in others ***the conduits are manifolded together and are connected to the outlet ports in the cross-over so that the slurry flows directly into the conduits*** for distribution in the interval."

EX1008 at 2:48-54 (emphasis added). Jones2 also disclosed a manifold 27, which I show in yellow. EX1008 at Fig. 1 (annotated), 4:4-9 (describing manifold 27). Jones2 taught that "by selectively delivering the gravel ***directly to the various levels in the annulus***, it is believed that a better distribution of gravel will be accomplished and a better overall gravel pack efficiency will be obtained in certain applications such as those where long intervals are being completed." *Id.* at 4:34-39 (emphasis added).

406. A POSITA reading Jones2 would be motivated to directly connect the gravel slurry to the shunt tube manifolds of Yeh and Yeh2 for a "better distribution of gravel" and a "better overall gravel pack efficiency" as explained by Jones2. This direct connection constitutes coupling.

407. A POSITA would have expected success with Jones2's modification because Jones2 taught that it produced better gravel packing results with better efficiency in long intervals, EX1008 at 4:34-39, such as Yeh and Yeh2's 5,000-feet long horizontal interval.

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 sand screen assembly upstream of the first sand screen assemblies."

408. It is my opinion that Claim 15 would have been obvious over Yeh in view of Yeh2 and optionally Jones2 for the same reasons discussed in claim 14.

409. Yeh expressly disclosed installing a plurality of interconnected concentric sand screens and eccentric sand screens across a long interval, such as the extended horizontal interval example I discussed in claim 14:

> It may be difficult to acquire more complex concentric sand screens in ***quantities needed for extended horizontal completions***. Therefore, the crossover joint allows a horizontal completion to continue without delay by ***combining concentric screens with the more readily available eccentric screens***. Thus, the use of crossover joints provides flexibility in maintaining and managing the inventory of sand screens.

EX1005 at 30:27-33 (emphases added).

410. As I explained in claim 14, the second sand screen assemblies (concentric screens) would be connected to an uppermost first sand screen assembly (eccentric screens) according to Yeh's exemplary wellbore tool sequence: "concentric screen→crossover tool→eccentric screen." EX1005 at 30:13-14.

411. As I explained above in claim 1[a], a POSITA understood that sand screens are joints and that any extended length production zone greater than the length of a joint (e.g., 30-40 feet) required a plurality of sand screens. Yeh and Yeh2 confirm this understanding. Yeh explained that "quantities [of sand screens were] needed for extended horizontal completions." EX1005 at 30:27-33. Yeh's reference to "combining concentric screens with the more readily available eccentric screens,"

id. at 30:30-32, taught a POSITA that a plurality of each of these types of screens would be required to complete a long interval. Yeh2 described, "Shunt packing over one screen joint length (~30-40') has been well studied and proven in laboratory testing." EX1006 at 3; *see also id.* at 4 ("one [sand] screen joint (40 ft)"). Yeh2 also disclosed a series of multiple sand screen joints in its Figure 6a-b reproduced below.

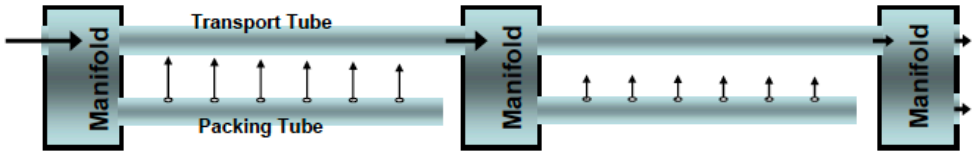


Figure 6a Shunt manifold system

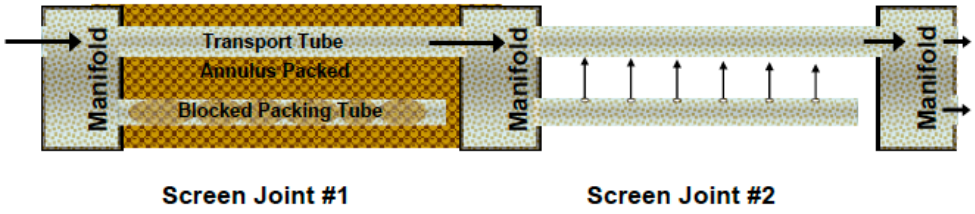


Figure 6b Shunt manifold system bypassing shunt plugging

EX1006 at Fig. 6b. Yeh also illustrated in its Figure 2 installing a plurality of sand screens that were interconnected to cover a production zone, which included three sand control devices 200 arranged in series along intervals 112, 114, and 116. EX1005 at Fig. 2.

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."

412. It is my opinion that Claim 16 would have been obvious over Yeh in view of Yeh2 and optionally Jones2 for the reasons discussed in claim 14[f].

413. As I described in claim 1[e], Yeh disclosed that 6,500 psi is required at the heel to gravel pack a 5,000-feet interval, teaching a POSITA that the shunt tube system of the concentric screens at the heel would be exposed to a 6,500 psi, which was also the operating pressure of the high-pressure shunt tube system taught by Yeh. EX1005 at 28:11-23.

414. A POSITA would have understood that the "pressurized working fluid" of limitation 14[a] is also a "working fluid" as required by claim 16, and gravel slurry satisfies both. *See* EX1001 at 4:11-14.

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."

415. It is my opinion that claim 17 would have been obvious over Yeh in view of Yeh2 and optionally Jones2. Although claim 17 does not specify which "shunt tube system" it references, claim 17 would have been obvious if it references any of the "shunt tube systems" identified in claim 14.

416. Yeh's method 1200 disclosed injecting the working fluid "into the wellbore. This is shown at Box 1270. The method 1200 then includes further injecting the fluid from the wellbore and through the secondary flow paths of the first wellbore tool, the crossover joint, and the secondary flow paths for the second wellbore tool. This is provided at Box 1280." EX1005 at 28:61-29:3. A POSITA understood "wellbore" to refer to the annulus in proximity to the shunt tube systems identified in claim 14. *See* EX1005 at 6:3-8. This understanding is also confirmed by Yeh2.

417. As I described in claim 14[f], Yeh2's Figure 1 illustrated gravel slurry flow through the annulus adjacent the shunt tube systems to gravel pack the annulus. Gravel slurry (**light green arrows**) was pumped down the annulus (**light orange**). If a sand bridge or other obstruction (**dark orange**) formed in the annulus, the gravel slurry was diverted into the shunt tube systems to bypass that blockage, then through and out of the packing tubes, and into the annulus downstream of that blockage to continue gravel packing the annulus. Below I provide Yeh2's Figure 1 for reference:

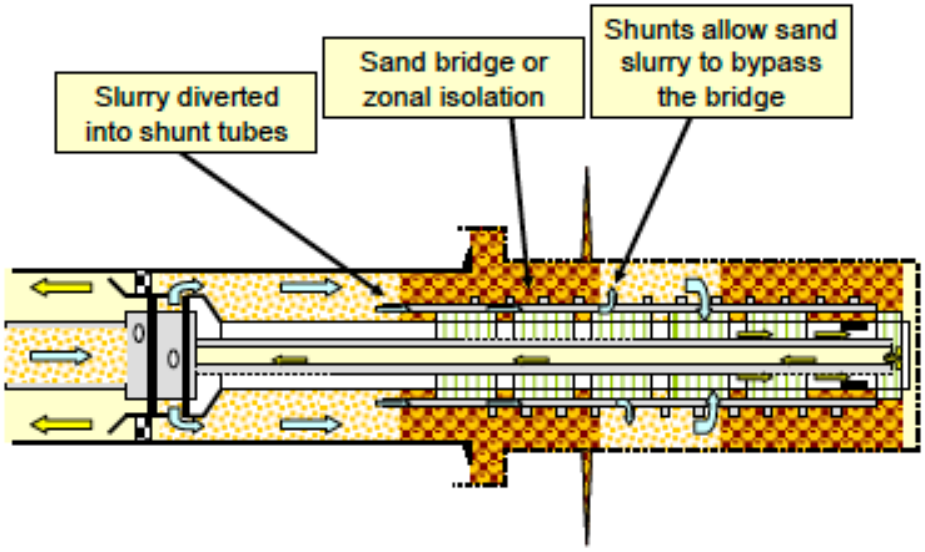


Figure 1 Alternate Path gravel packing with shunt tubes

EX1006 at Fig. 1. Thus, Yeh2 taught injecting the working fluid (gravel slurry) into the annulus at the entrance to the shunt tubes as well as through the ports of the shunt tubes downstream.

418. A POSITA understood that Yeh's system worked the same way as the system described in Yeh2 because both references described the same shunt tube system. Yeh described using Alternate Path® Technology as a method for gravel slurry to bypass sand bridges using shunt tubes. *See* EX1005 at 3:8-62. So did Yeh2. *See, e.g.*, EX1006 at 2 (describing Alternate Path® Technology as providing "alternate flow paths around a sand bridge by diverting the slurry (gravel + carrier fluid) through shunt tubes.").

419. Alternatively, in the scenario in which the system of Yeh and Yeh2 were modified in view of Jones2 to directly connect the gravel slurry to the shunt tube

entrance as I described in claim 14[f], the gravel slurry would then be injected into the annulus via the packing tube nozzles or ports to gravel pack the annulus. EX1008 at 2:48-54 ("[T]he conduits are manifolded together and are connected to the outlet ports in the cross-over so that the slurry flows directly into the conduits for ***distribution in the interval***." (emphasis added)), 4:34-39 ("[B]y selectively delivering the gravel directly to the various levels in the annulus, it is believed that a better distribution of gravel will be accomplished and a better overall gravel pack efficiency will be obtained in certain applications such as those where long intervals are being completed."). As explained by Jones2, in this alternative, all the gravel slurry would be distributed through the nozzles throughout the wellbore annulus and thus adjacent to all the shunt tubes.

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."

420. It is my opinion that claim 18 would have been obvious over Yeh in view of Yeh2 and optionally Jones2 because it adds nothing more than routine optimization.

421. As I explained for claims 1[e] and 14[c], Yeh described the pressure conditions under which shunt tube systems would be expected to operate. Similarly, a POSITA would appreciate that Yeh2 described the same 5,000-feet horizontal

gravel pack example using the same shunt tube system to gravel pack the horizontal interval, with the exception that Yeh2's system used concentric screens throughout. *See* EX1006 at 5, Fig. 15.

422. As I also explained in claim 14[c], Yeh2 also provided the specific pressure profile for the shunt tube systems according to the position of each along the 5,000-feet horizontal interval. *See* EX1006 at 5, Fig. 15. Specifically, according to Yeh2, the operational pressure of the shunt tube at the heel was about 5,300 psi and dropped to almost 0 psi 5,000 feet down the horizontal at the toe. *Id.* at Fig. 15. Because Yeh disclosed that eccentric screens could be used to gravel pack a horizontal up to 3,000 feet in length, EX1005 at 30:17-20, the shunt tube systems in the eccentric screens would have been exposed to about 2,800 psi at 2,000 feet from the heel (or 3,000 feet from the toe) to 0 psi at the toe. This entire pressure range falls within "no more than 5000 [psi]" such that the eccentric screen low pressure shunt tube systems were disposed to operate at no more than 5000 psi.

423. A POSITA would also understand that because the high pressure shunt tube systems included in concentric screens operated at pressures ranging from 5,300 to about 2,800 psi (according to Yeh2) or between 6,500 psi (Yeh) to about 2,800 psi (Yeh2), these high pressure shunt tube systems were disposed to operate "at pressures of 5,000 psi" as required by claim 18.

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."

424. It is my opinion that claim 19 would have been obvious over Yeh in view of Yeh2 and optionally Jones2 for the same reasons discussed in claims 9 and 18.

425. A POSITA understood that if 2,800 psi was the chosen threshold as I described in claim 18, the high-pressure shunt tube system of Yeh's concentric screens would operate at pressures above 2,800 psi and the low-pressure shunt tube system of Yeh's eccentric screens would operate at pressures of 2,800 psi or lower. However, for the same reasons I provided in claim 18, the threshold could be anywhere between 2,800 psi and 6,499 psi according to the disclosures in Yeh2 and Yeh, respectively.

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 wellbore."

426. In my opinion, claim 20 would have been obvious over Yeh in view of Yeh2 and optionally Jones2 for the same reasons discussed in claim 14.

427. Specifically, Yeh described using both concentric and eccentric screens in a horizontal wellbore. EX1005 at 30:15-32. Yeh also explained that its wellbore

completion disclosures applied to both vertical and horizontal intervals. *Id.* at 9:33-41.

XIV. GROUND 3

A. Claim 21

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

428. In my opinion, claim 21 would have been obvious over Yeh in view of Jones (EX1007).

429. Assuming that the preamble is limiting as I have been asked to assume, it is also my opinion that Yeh disclosed the preamble for the same reasons discussed for claim 1[preamble].

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

430. It is my opinion that Yeh disclosed this limitation for the same reasons that I discussed in claims 1[c] and 11[a].

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 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; and"

431. It is my opinion that Yeh disclosed this limitation for the same reasons that I discussed in claim 1[a].

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;"

432. It is my opinion that Yeh disclosed this limitation for the same reasons that I discussed in claim 1[b].

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

433. It is my opinion that Yeh disclosed this limitation for the same reasons that I discussed in claim 1[d].

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."

434. It is my opinion that Yeh in view of Jones disclosed or suggested this limitation for the reasons discussed in limitation 1[e] as well as Jones' additional teaching on shunt tube materials. As I explained earlier in Section VIII.D.1, Jones described gravel packing using sand screens with shunt tubes and identified Lloyd Jones of Mobil as the sole inventor. EX1007 at 1. A POSITA considering gravel packing with shunt tubes would have looked to Jones, which is addressed to the same technology area and the same problems as Yeh. A POSITA would have been motivated to consider Jones' teachings because Yeh specifically referred to Jones regarding its fluid bypass technology teachings. EX1005 at 3:18-20.

435. As I explained in claim 1[e], Yeh disclosed that one could use lower-pressure rated shunt tubes in the second sand screen assembly (eccentric screens) toward the toe and higher-pressure rated shunt tubes in the first sand screen assembly (concentric screens) toward the heel. EX1005 at 28:17-23. Based on this disclosure, a POSITA would have understood that Equation (14) governed for round tubes when considering shunt tube burst pressure. EX1017 at 24 (Equation (14) for rupture (burst) pressure); *see also supra* Section VIII.J.

436. A POSITA, motivated by reducing material costs where possible as suggested by Yeh, would know that there were only three shunt tube design variables according to Equation (14) that could be used to decrease shunt tube burst pressure: (1) use a lower tensile strength material (decrease **f**), (2) decrease tubing wall thickness (decrease **t**), or (3) increase the outside diameter (increase **D**). EX1017 at 24; *see also supra* Section VIII.J. Because there were only a finite number of options for reducing burst pressure, it would have been obvious to try any of these three. Increasing the outside diameter (**D**) is likely not possible given the sizing constraints of sand screens. *E.g.*, EX1028 ('533 Patent) at 2:1-7 ("In order to keep the effective diameter of a tool as small as possible, external shunt tubes are typically formed from 'flat' rectangular tubing even though it is well. [sic] recognized that it is easier and substantially less expensive to manufacture a round tube and that a round tube

has a substantially greater and a more uniform burst strength than does a comparable rectangular tube."); *see also* Section VIII.G.1.b). That leaves only two options using a less costly lower tensile strength material or decreasing wall thickness, either or both of which a POSITA would readily employ to save cost.

437. Jones disclosed a sand screen with an alternate flow path and taught that while shunt tubes "may be made of any pressure-resistant material, [they are] preferably to be made of stainless steel," EX1007 at 4:11-13. A POSITA would have been motivated to follow Jones' teaching regarding shunt tube materials because Jones was focused on the same gravel packing with shunt tubes problems as Yeh and because Yeh specifically referenced Jones' teachings on this issue. EX1005 at 3:18-20; *see also supra* Section VIII.G.10. A POSITA would have expected success because Yeh specifically referred to Jones' teachings on gravel packing with shunt tubes and based on a POSITA's understanding of the factors controlling burst pressure as laid out in API TR 5C3.

438. Jones' disclosure confirms that a POSITA would have understood that shunt tubes could have been manufactured with any type of pressure-resistant material and particularly of stainless steel. Given this understanding and a POSITA's understanding that lower pressure could save cost toward the toe in a long horizontal well, a POSITA would have been motivated to select a less strong material using

material options available from manufacturers as well as published tensile strength numbers in, for example, the ASTM standards, which were readily available to POSITAs in June 2018. EX1018 at Table S2.1 (listing tensile and yield strengths of various stainless steels); EX1029 at Table 2 (listing tensile and yield strengths of various carbon steels). Together, it would have been obvious to a POSITA to use different steels to achieve a different pressure rating between Yeh's concentric and eccentric screens.

439. Therefore, it is my opinion that it would have been obvious to a POSITA reading Yeh in view of Jones to select a transport tube of the first sand screen assembly of a first material and to select a transport tube of the second sand screen assembly of a second material, the first material having a greater tensile strength than the second material.

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 greater than the second wall thickness."

440. It is my opinion that claim 22 would have been obvious over Yeh in view of Jones.

441. For the same reasons I discussed in claims 1[e] and 21[e], Yeh suggested the wall thickness limitations for claim 22. And as I discussed in limitation 21[e], it would have been routine optimization for a POSITA to modify

Yeh's shunt tube system by adjusting the wall thickness, tensile strength, or both as disclosed in Yeh and Jones and based on a POSITA's knowledge of how to adjust burst pressure based on Equation (14) in API TR 5C3. It would have been obvious to a POSITA what were the tradeoffs between different materials, different wall thicknesses, and the costs related to those material choices.

442. A POSITA would have had the knowledge and skill to perform such routine optimizations when designing shunt tube systems and would have expected success based on the detailed teachings in the art including a firm understanding of how to design such tubing in API TR 5C3.

XV. GROUND 4

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 pressure rating."

443. It is my opinion that claim 23 would have been obvious over Yeh in view of Jones and Yeh2. Yeh in view of Yeh2 disclosed or suggested the added limitations of claim 23 for the same reasons discussed in claim 7 and with respect to limitations 1[e] and 21[d]. A POSITA would have readily applied Yeh2's teachings to Yeh and Jones because a POSITA would have understood that Yeh and Yeh2 describe the same Alternate Path® Technology as I explained in claim 1[preamble]. *See* EX1005 at 3:8-62 (describing Alternate Path® sand screen technology); EX1006

at 1 (same). A POSITA would have known that Yeh's system worked in the same way as described in Yeh2 and would have expected Yeh2's description to already apply to Yeh's concentric sand screens and thus would have expected success in applying Yeh2's teachings to Yeh.

XVI. SECONDARY CONSIDERATIONS OF NON-OBVIOUSNESS

444. Relevant to each of the Grounds I have provided above, I am not aware of any evidence of secondary considerations of non-obviousness for which there is any nexus to any claim of the '007 Patent. Should I become aware of such evidence, I may offer opinions on it at that time.

XVII. CONCLUSION

445. Based on the foregoing, it is my opinion that claims 1-12 and 14-23 of the '007 Patent are rendered obvious as discussed above.

446. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be called upon to testify in deposition or before the Patent Trial and Appeal Board. If called upon to testify, I would testify truthfully and competently to all matters stated in this Declaration.

447. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner raises and to take into account new information as it becomes available to me.

448. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true and that such statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: 5/30/2024

Michael R. Chambers, Sr.

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APPENDIX

TABLE 1				
	Patent No.	**Filed**	**Authors**	**Taught**
1	4,945,991	8/23/1989	Jones	Original concept
2	5,082,052	1/31/1991	Jones, Yeh, Chow	Shunt control values
3	5,113,935	5/1/1991	Jones, Yeh	Tie shunt to crossover, perf sizing, manifolds
4	5,161,613	8/16/1991	Jones	Treating multiple different stratta
5	5,161,618	8/16/1991	Jones, Strubhar, Donion	Fracturing using shunts or alternate path
6	5,165,476	6/11/1991	Jones	Temporary screen sealer (wax) in place of wash pipe
7	5,417,284	6/6/1994	Jones	Horizontal packing
8	5,419,394	11/22/1993	Jones	Fracturing exit tubes
9	5,435,391	8/5/1994	Jones	Fracturing
10	5,515,915	4/10/1995	Jones, Yates	Internal shunt tubes, collar flow connector
11	5,560,427	7/4/1995	Jones	Slurry splitter to replace cross-over tool
12	5,588,487	9/12/1995	Bryant	Blank shunt through cup packer
13	6,059,032	12/10/1997	Jones	Ball sealers to seal shunt perfs
14	6,220,345	8/19/1999	Jones, Tibbles, Hurst	Alternate flow path w/o tubes
15	6,227,303	4/13/1999	Jones	Alternate flow path w/o tubes but compartments
16	6,464,007	8/22/2000	Jones	Shunt valves
17	6,588,506	5/25/2001	Jones	Overlapping shunts (down/up fed)
18	6,644,406	7/31/2000	Jones	Fracturing dedicated intervals
19	7,108,060	7/31/2000	Jones	Fracturing dedicated intervals
20	7,661,476	11/9/2007	Yeh, et al.	Load sleeve w/ separate transport and packing tubes

TABLE 1				
	Patent No.	**Filed**	**Authors**	**Taught**
21	7,938,184	11/9/2007	Yeh, et al.	Load sleeve w/ shunt connection
22	7,971,642	2/12/2010	Yeh, et al.	High pressure connection
23	8,356,664	4/20/2012	Yeh, et al.	Load sleeve with manifold coupling
24	8,839,861	3/12/2010	Yeh, et al.	Sleeve coating (friction/erosion)
25	9,133,705	11/2/2011	Boza et al.	Downhole communications module
26	9,638,012	9/18/2013	Yeh et al.	Gravel Pack Packer
27	9,670,756	4/8/2014	Yeh	Sand reserve between shroud & screen
28	9,797,226	11/17/2011	Yeh, et al.	Connecting high press concentric to low press eccentric tubes
29	9,816,361	8/11/2014	Yeh, et al.	Inflow ring controls flow in conduit
30	10,107,093	7/7/2016	Yeh, et al.	Inflow control to isolate production intervals

TABLE 2				
	No.	**Year**	**Authors**	**Title**
1	SPE 22796	1991	Jones, Yeh, et al.	Alternate Path Gravel Packing
2	SPE 27359	1995	Bryant, Jones	Completion and Production Results from Alternate-Path Gravel-Packed Wells
3	SPE 38640	1997	Jones, Tibbles, et al.	Gravel Packing Horizontal Wellbores with Leak-Off Using Shunts
4	SPE 39433	1998	Myers, et al.	Case History in Achieving High Rate Producers in Sub Sea Gravel Packed Completions
5	SPE 58743	2000	Chambers, et al.	Successful Application of Oil-Based Drilling Fluids in Subsea Horizontal, Gravel-Packed Wells in West Africa
6	SPE 90758	2004	Hecker	Reducing Well Cost by Gravel Packing in Nonaqueous Fluid
7	SPE 110460	2007	Barry, et al.	Openhole Gravel Packing With Zonal Isolation
8	SPE 135102	2010	Hecker, Barry, Yeh, et al.	Extending Openhole Gravel Packing Capability: Initial Field Installation of Internal Shunt Alternate Pathway Technology
9	SPE 146361	2011	Hecker, Barry, Yeh, et al.	First Installation of Alternate Path Openhole Packer Providing True Zonal Isolation in Openhole Gravel Packs
10	SPE 151171	2012	Yeh et al.	True Zonal Isolation in Openhole Alternate Path Gravel Pack Completions
11	SPE 174958	2015	Barry, Hecker, et al.	Extending Openhole Gravel Packing Capability - Initial Applications of Alternate Path Openhole Shunt Packers to Provide Upfront Zonal Isolation
12	IPTC 12549	2008	Yeh, Barry, Hecker, et al.	Unlocking the Limits of Extreme Length in Alternate Path Gravel Packing

13	IPTC 14623	2011	Yeh, Barry, Hecker, et al.	Unlocking the Limits of Sand Screen Reliability with an Innovative and Self-Adapting Technology
14	IPTC 14644	2011	Barry, Hecker, et al.	Advancements in Openhole Completion Technology - Establishing and Sustaining Differentiating Sand Control Completion Performance