Use of Lynes Inflatable Packers in Solution Mining

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ABSTRACT

The broad application developed for Lynes packers derives primarily from the unique inflatable sealing element. Original development, and one of the most successful applications, was for effective packer sealing in open hole. Use of the packers has since expanded to include sealing in casing and tubing.

There are four principal types of Lynes inflatable packers, each having special advantages. They include: 1) production-injection packer (PIP); 2) straddle packer; external casing (ECP) packer; and 4) impression packer.

Each type of packer has found successful application in solution mining. The PIP and Straddle packers are widely used to pack-off in open hole for hydraulic fracturing, particularly where desirable to isolate and protect the cemented casing shoe area from possible damage resulting from high frac pressures. Further, with the straddle packer, application of hydraulic fracture pressure could be restricted to a short vertical interval to provide greater assurance for fracture initiation at the desired zone, and also protect weak zones above and below the frac zone from damage.

Both packers have had extensive use in post-frac operations; the most common being washing-in to lower injection pressure. Where desired frac-connection is not achieved, these packers are used to isolate and test different salt beds to determine flow and pressure relationships for interpretation of vertical fracturing, or frac-connection with other beds. The straddle packer is ideal for such testing because it can be set and reset down-hole, precluding the necessity for tripping the pipe each time.

Common ECP use is repair of wells where casing has been sheared by roof collapse. In such wells, a liner run with an ECP at the top insures a tight seal with the casing and prevents injected fresh water from dissolving upper salt adjacent to the well.

Impression packers have soft rubber elements which when inflated against bore of the hole provide three-dimensional impressions of fractures, bedding planes, and other formation features. In cased wells they're used to determine condition of casing.

All the inflatable packers have attained wide acceptance through successful application in solution mining and it is expected that new applications will continue to be made.

HISTORY OF LYNES

In 1939 John Lynes commenced operations as the Lynes Packer Company; in 1942 several patents covering an unusual concept in 'balloon' packers were issued to Mr. Lynes; and in 1949 George Conover was hired as an engineer and it was he who developed the first successful inflatable element. The first acidizing job using the straddle packer arrangement was done in December, 1950, and Lynes established their first service station in Midland, Texas, in 1951. Six years later, spring of 1957, DiKor became a licensee of Lynes for the Northeastern United States and that relationship continues today.

INFLATABLE SEALING ELEMENT

Description

The heart of the Lynes Packer System—the 'Inflatable Sealing Element' is shown in Figure 1. The sealing unit consists of a heavy resilient synthetic rubber outer cover over the entire length of the element, which is backed by a strong flexible braided metal sheath to provide the strength necessary to withstand high pressures and to retain the innertube which in turn confines the inflation fluid. A mandrel extends through the entire sealing element forming the inner wall of the inflation chamber.

Inflation fluid enters the space between the mandrel

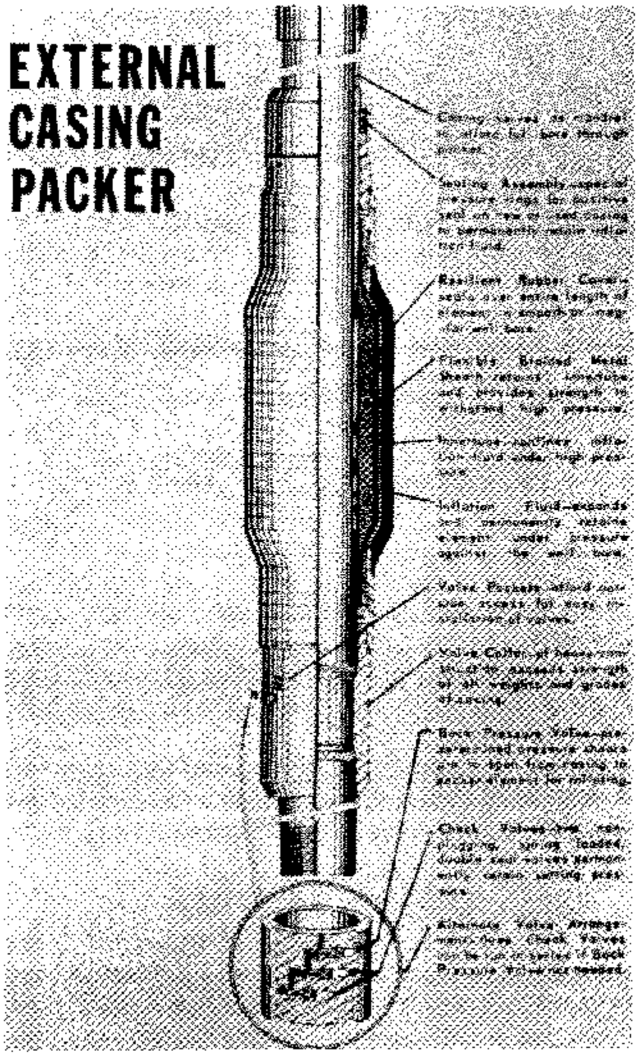

Figure 1. Lynes Inflatable Sealing Element External Casing Packer.

and the innertube causing the outer cover, braid, and innertube to expand and seal against the well bore or casing. The element must conform to irregular holes within its expansion limits.

External pressure against the end area of the inflated element transmits to the smaller end area inside so that the pressure of the fluid inside the element *always* exceeds the external pressure. As the external pressure increases, the element is anchored more tightly against the well bore or casing.

Unique features of the inflatable sealing element

The inflatable sealing element offers several unique features heretofore unavailable in 'packers.'

1. *Positive Setting.*—Pressure gauge and weight indicator at surface tell positively when the inflatable element is 'set' in the well bore.

2. *Greater Expansion.*—More 'running in' clearance permits use of the inflatable element in a wide range of sizes, under liners, and below casing restrictions.

3. *Positive Sealing.*—Hole fluid cannot leak past the inflatable element even with high differential pressures. External squeeze pressure is transmitted through the rubber and flexible braid to the fluid center thus increasing the sealing pressure.

4. *Effective Sealing Over Entire Length.*—When the element is inflated, the fluid center is under high pressure and *all* the sealing surface is in contact with the well bore. The 'sealing surface' is from 12" to 16" less in length than the overall element to allow room to 'tie' the expanding components to the mandrel (or stationary) parts and to provide space for the 'upset' to occur.

5. *Seals in Irregular Holes.*—The innertube, expandable metal sheath, and outer cover form a flexible body which readily conforms to irregular open hole or casing.

6. *Release Without Pulling.*—The inflatable element unsets by simply equalizing the high pressure within the element with that pressure existing in the annulus and/or tubing.

7. *Anchors Against Sliding.*—Although the large contact area between element and well bore provides for adequate friction against sliding in most instances, elements are available that have bands of metallic particles imbedded in the outer cover to provide even higher anchoring friction.

While the Inflatable Sealing Element cannot yet seal off vertical fractures, applications to help overcome this problem have 1) used 'dual-seal' or double length elements, 2) straddled the vertical fractured zone, and 3) set and reset the element until a zone without vertical fractures is located.

USE OF INFLATABLE SEALING ELEMENTS IN TOOLS APPLICABLE TO SOLUTION MINING

During the early 1960's, DiKor, in pursuit of its various services throughout the Northeastern United States, realized that companies involved in brine production had downhole conditions and problems that were quite often more severe and difficult than those experienced in oil and gas wells; and that the Lynes Inflatable Packers offered a possible solution to many of these problems.

The three tools most widely used in the Solution Mining Industry (all using the basic Inflatable Sealing Element) are: the External Casing Packer or ECP; the Production-Injection-Packer or PIP; and the Treating & Testing Straddle Packer. Most of these tools have been developed through Lynes' program of constant innovation in the use of their basic packer concept.

External casing packer

This packer device shown in Figure 1, was originally designed to improve the effectiveness of primary casing cement jobs by (1) zone separation, (2) establishing a positive seal between casing and well bore and (3) centering the casing in the well bore.

The 36" long sealing element is mounted on casing having the same dimensions and specifications as that to be used in the casing string—with that portion of the casing within the sealing element serving as a mandrel for the packer. At the top of the inflatable element a sealing assembly creates a permanent seal between casing and innertube so as to retain the inflation fluids. At the bottom of the element a valve collar in which is located either a shear plug or a back pressure valve for initiating packer inflation, and two nonplugging, spring loaded, double seal, one-way check valves for sealing inflation fluid inside the element. Any reasonable clear fluid is pumped into the casing string at a pressure of approximately 1500 psi and the pressure held for about 5 minutes. The ECP outside diameter is normally 2" larger than the casing outside diameter and the overall length of the packer assembly (with sufficient casing on either end of the element to accommodate slips and elevators) is approximately 11 feet. To give an example of the pressure differentials these ECP's can withstand following is a typical case: 4-1/2" O.D. casing with ECP packer run inside 8-5/8" O.D. casing (8" I.D.±) will take a pressure differential across the element of 4,000 psi. There are available two basic ECP models; the BT (or Braid Type) for normal and higher pressure differentials and the RT (or Rib Type) for low differentials. All examples will refer to the BT type.

Liner hanger. Figure 2 shows an application of the ECP used many times. The 'morning glory' type brine cavity has resulted in roof collapse and shearing of casing near the top of the salt section. Problem: to increase brine saturation by keeping fresh water entry as low as possible in the gallery; and, at a minimum of time and expense. Solution: run a liner with an ECP near the upper end and set packer up in the undamaged casing (or down in the damaged portion, if necessary—the packer will conform to any irregularities); drill out the 8 to 10" of cement in the plug now on bottom of liner (this plug is necessary to allow liner to be pressured up in order to inflate and set ECP), and commence injection just a few feet above the rubble pile. Because of the longevity and hole conditions normally experienced in such operations, it is recommended that a liner hanger be used in conjunction with the ECP. On relatively short liners and/or jobs of limited duration (12 months or so) the liner hanger is not necessary.

Sleeve liner. Figure 3 illustrates another problem—localized casing damage that plays havoc with (or eliminates) use of a well because of dissolution behind casing, loss of brine, and contamination of other formations. One simple solution is to select a liner of proper diameter of sufficient length to cover the hole, collar leak, split, or other damage, and attach an ECP packer at each end of

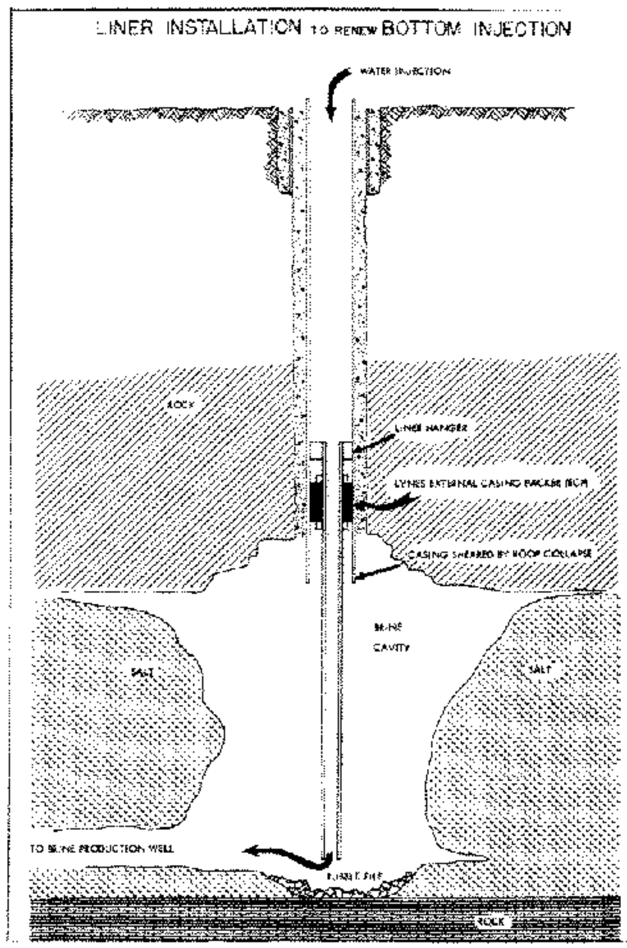

Figure 2. ECP as Liner Hanger.

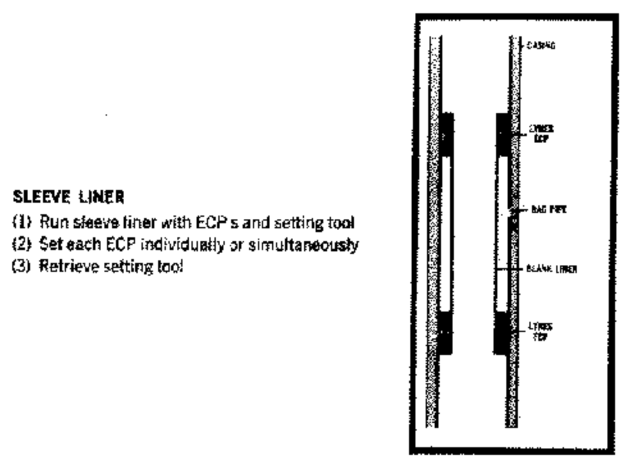

Figure 3. ECP used to pack-off sleeve liner.

the liner; run liner to proper depth, set the ECP's; drill out the cement baffle serving as bottom plug in the liner; and put the well on stream. The ECP's are normally 2" larger in outside diameter than the casing they are run on. In cases such as this one, where pressure differentials are small or non-existent, the packer O.D. can be turned down to 1-5/8" over casing O.D.; and in certain instances (depending on a specific casing being used as liner) the packer O.D. can be as little as 1-1/8" over the casing O.D. Naturally, reducing the ECP outside diameter reduces the maximum pressure differential it can sustain.

Other possible use of the ECP. Other uses of the ECP in Solution Mining operations might include (2) protection of sensitive zones below the casing (i.e., set an ECP on bottom of casing and cement through D.V. tool just above the ECP); or (b) zone separation; that is, where it would be desirable to set casing through the salt section and selectively cement the non-salt zones.

Production-Injection-Packer (PIP)

The Production-injection-packer is normally referred to as a PIP and is shown in Figure 4. Where a single-set packer is needed for either temporary or permanent use in cased or open hole this tool is ideal.

Normally, the packer is run on either 2" or 2-1/2" tubing with a shear plug on the bottom of the tool. Two joints of tubing are filled with clear fluid, followed with a slug of heavy grease or a few gallons of heavy oil, (to prevent tubing dirt, scale, or solids in the injection fluid from entering the valve assembly on the element). Tubing is run at a moderate speed and without rotation to setting depth where the tubing is filled with fluid and pressured up to recommended inflation pressure (normally from 1200 to 2000 psi). Pressure is held on tubing string for about 5 minutes; a strain of 5000 ± lbs. is taken on tubing to check for a tight set. Tubing is then pressured up to shear the pin in bottom plug (normally 500 psi over setting pressure) and plug is left in bottom of hole and packer is in 'open below' position for pumping, swabbing, etc. The plug, if a problem, can be drilled up, dissolved with acid, or caught and retrieved in a perforated nipple run below the packer.

At the completion of the below packer work, the packer is released by picking up weight of the tubing and rotating to the right, approximately six turns; pick up tubing 6" to allow pressures above and below packer to equalize; pick up another 6" to release the high pressure fluid within the Inflatable Element; wait for a few minutes to allow time for the element to completely deflate, and come out of the hole.

To accommodate the various hole conditions encountered, packer elements are available in 42", 66", and 132" lengths with, or without, grit impregnated covers. Should it be desirable to pump through the tubing string before setting the PIP, a ball-and-seat type bottom shear plug is available, as is shown in Figure 4.

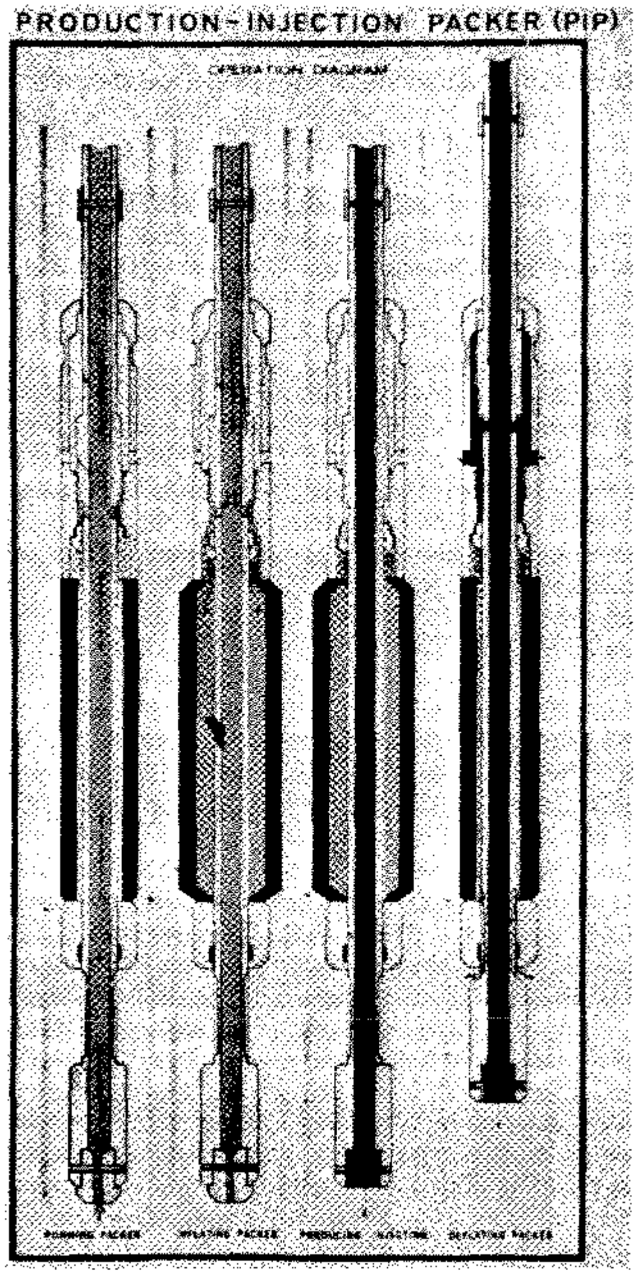

Figure 4. Operation diagram of Lynes Production-Injection-Packer (PIP).

Although the ratio of packer O.D. to maximum hole size in which it can operate approaches 1 to 1.8, the use of PIP elements in this range is normally not recommended because the greater expansion inflatable element is forced to make, the less pressure differential the element can withstand. Assume a typical use as follows: A well has 8-3/4" hole below 7" casing; packer is to be set in open hole for hydraulic fracturing in the bottom salt section; a

5-5/8" OD X 2" mandrel PIP will withstand 3500 psi differential pressure. (Should lower differential pressures be expected and higher volume be desired a 5-3/8" OD X 2-1/2" bore element will handle a 2000 psi differential). Should this 5-3/8" X 2-1/2" packer be set in 6-1/4" hole (or where the casing had been set on top of the salt section and subsequently drilled to T.D. after the casing had been set) the differential capabilities increase to 5,000 psi, as compared to the 2,000 pound differential in 8-3/4" hole.

Frac connecting brine wells. A most typical use of the PIP packer in a brine well is shown in Figure 5. Here the primary objective is to frac connect the two brine wells. A competent and fairly thick rock section is chosen as a packer seat. The packer is set in the 6-1/4" hole below the 7" casing; the bottom plug is pumped out and the packer is ready to sustain a break-down hydraulic fracturing pressure of up to 5,000 psi (without loading the annulus). It should be noted that the pressure differential referred to is that which exists at the packer. If that pressure is expected to approach the limits of the packer element, the differential pressure across the packer can be significantly reduced by loading the annulus. Further decrease in differential pressure across the packer can be effected by pressuring-up the fluid column in the annulus. After fracture connection, high pressure pumping is continued and maintained until such time as the injection pressure and volume relationship desired can be obtained with plant pumping equipment. Packer is then released, brought out of hole, and the well is put on production.

Other PIP uses. Should conditions exist which are not so ideal as those discussed (i.e. packer seat across thin and/or weak rock with majority of seat in the salt) substantially increased pumping time nevertheless can be obtained, before the packer seat washes out, by use of a 'dual seal' element. This is two 66" sealing elements run in tandem. Again the versatility of the inflatable element tools is demonstrated.

The treating and testing tool using the straddle packer arrangement

This tool, shown in Figure 6, is extremely versatile and with it virtually *any* type of open or cased hole packer need may be accomplished. Spacing between the packer is infinitely variable (within 2-1/2' increments); the tools can be activated to 'open below' both packers, 'open between' the elements, or 'open above' both packers; the tool can be set and reset many times without coming out of the

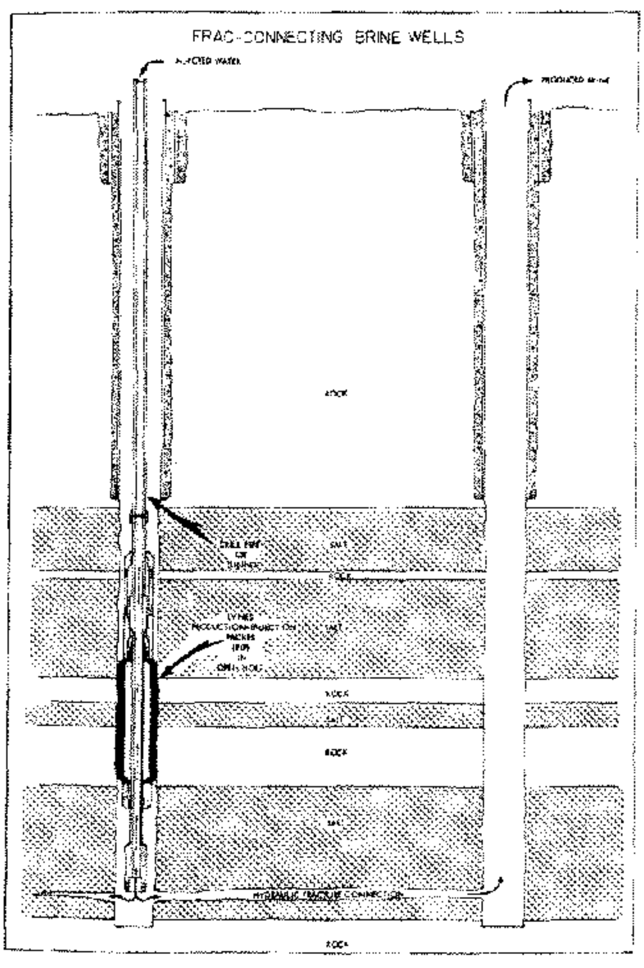

Figure 5. Use of Lynes PIP packer to frac-connect brine wells.

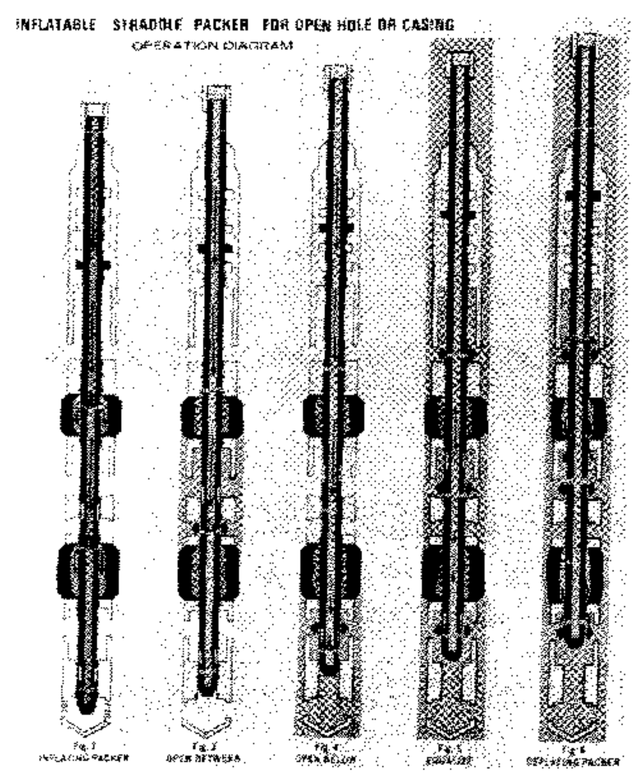

Figure 6. Operation diagram of Lynes Straddle Packer.

hole. The multifold advantages of the inflatable sealing element are clearly evident with this tool.

The tool consists of a hydraulic positioning assembly above the packer elements which provides a positive method of moving and locking the mandrel parts in five different 'in-line' positions. The mandrel is essentially a long hydraulic valve created by a series of "O" rings, slotted mandrel, and block-out sleeves. The five different positions allow the packer elements to be inflated, each screen (or section of perforated spacing) to be opened separately to the well bore, and the tool to be unset by deflating the elements. All tool positioning is accomplished by right hand rotation of the tubing and with weight set, or pulled, on the hydraulic positioning assembly. No tubing weight, drag springs, or anchor is needed to set the tool. Surface pressure gives positive indication that the elements are expanded against the well bore and that the tubing string is free of leaks before treating or testing begins. It is not necessary that 'shut-in' pressure be bled off the casing while activating or moving the tool. Working through a good casing head, all tool functions can be carried out under 'shut-in' pressure.

On the most commonly used Straddle packer (the 5" OD size), although the mandrel I.D. is reduced to 1-5/8", flow rates in the neighborhood of 500 to 600 GPM are not uncommon (this reduced diameter is only about nine feet long through the locking device—plus whatever mandrel is needed for the spacing required).

Straddle packer use—frac connection in brine wells. A typical application of the Lynes Straddle Packer in solution mining, establishing a hydraulic fracture between brine wells, is illustrated in Figure 7.

The objective here was to establish a hydraulic fracture connection in the lowest salt section. In an area where inter-connection had been difficult to achieve, straddle packers were run in both wells to provide maximum flexibility in fracture operations and maximum knowledge of location of the frac connection, if achieved. As illustrated,

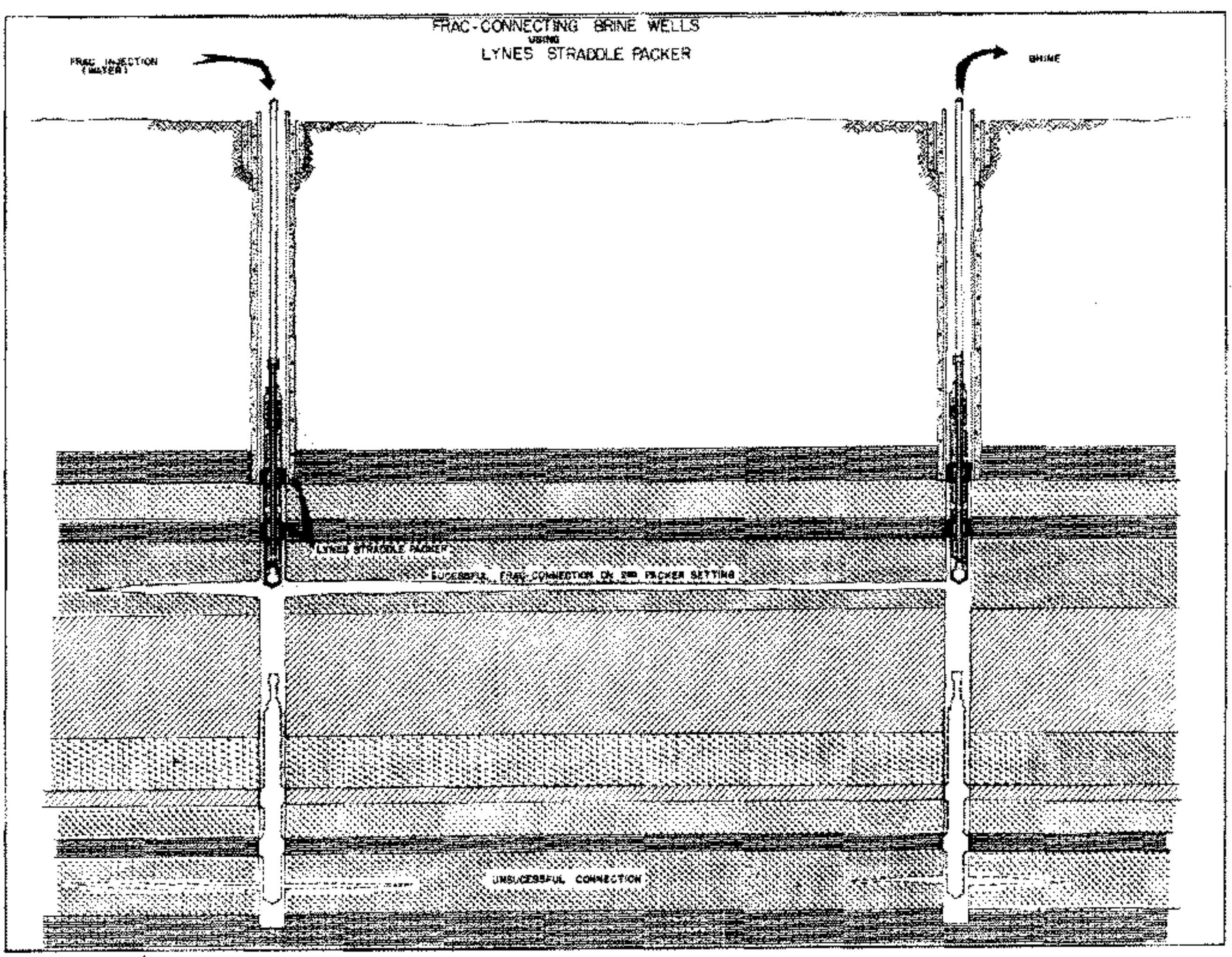

Figure 7. Use of Lynes Straddle Packer in frac-connecting brine wells.

a connection was not obtained in the lowest salt zone even though frac attempts were made from each well. Note while the tool could have been opened 'between' the two packers and an attempt made to establish fracture communication through the relatively thin salt section, it was decided instead to attempt a fracture connection in the thicker 'second' salt. Therefore, both packers were set above the zone of interest (with the upper packer set across the casing shoe), a hydraulic fracture was established, and high pressure pumping continued until a 'low-pressure' connection was established. (The lower packer seat washed out after almost three hours of pumping but, because the upper packer had been set across the casing shoe continued pumping was possible until desired results were achieved.

An alternative procedure could have been followed using the straddle packers in the situation shown. Assume that the majority of the injection fluid is known to enter the various salt sections below the rather massive anhydrite section, and that flow from the producing well is also from the lower portion of the hole. But exactly which zones are being dissolved? Are the connections 'straight-line' or does the bulk of the injection fluid enter one zone and exit from all three? The straddle packer is ideal for this type of testing. For instance, set both inflatable elements as shown in the lower part of the slide. On the injection well 'open below' both packers and pump test to determine what percentage of total injection volume is entering the lower zone; then 'open between' the packer elements and test in a similar manner. It is also possible to 'open above' both packers and test the upper portion of the entire section if desired.

In the producing well a straddle packer can be set across the same zones and, with either the bottom zone or middle zone selectively opened to the tubing, the exact quantity of brine production from that particular zone can be determined. Should the salt section immediately below the anhydrite require a separate test, the packers can quickly be released, moved, and reset in such a manner to open 'between' and take an exact measurement of the fluid being produced from that zone. The procedure is simple, safe, and accurate, and the positive knowledge thus gained greatly enhances the production engineer's information for maximizing total salt recovery from existing brine fields.

ANOTHER LYNES TOOL

Impression packer

The Lynes Impression Packer consists of 'memory retention' rubber applied directly to the sealing elements (as a part of the outer cover) or to a rubber sleeve that in turn fits over the element. It is used for making sidewall impressions that are three dimensional, cover 360° of the well bore, and up to 10 feet of uninterrupted length on a single setting.

Examples are shown in Figure 8 of impressions of a casing collar, casing perforations, open hole vertical frac-

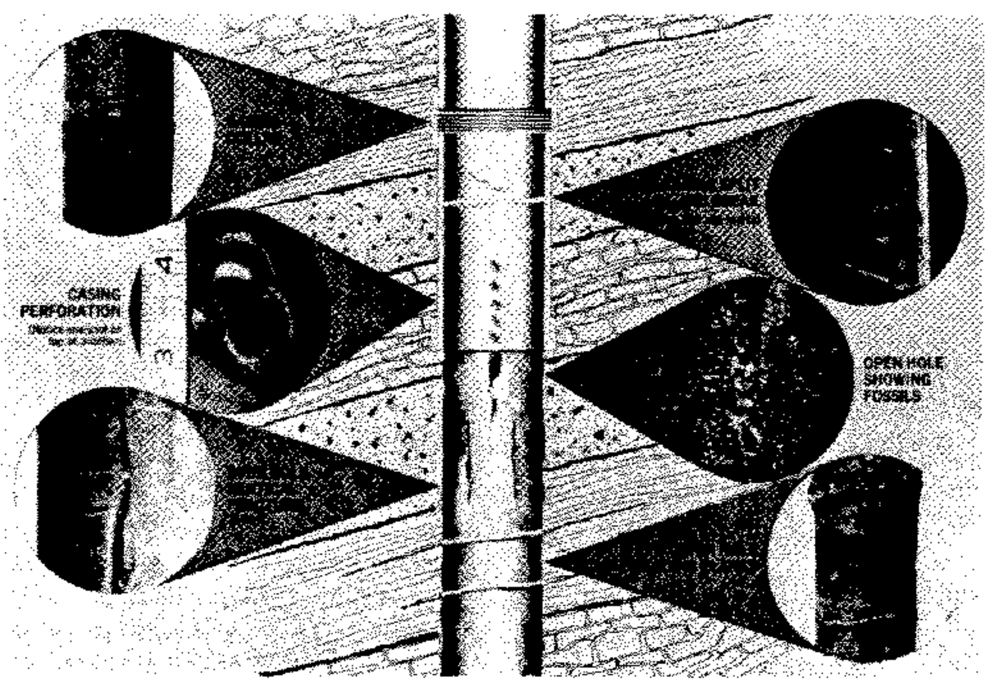

Figure 8. Applications of Lynes Impression Packer.

tures, a casing split and break, open hole showing fossils, and bedding planes in open hole. The impression packer is normally run on tubing, the sealing element inflated for a few minutes, then released and brought out of the hole. The large clearance afforded by the inflatable element allows the impressed rubber to be retrieved without marring the impression. Conventional directional tools may be run in connection with the impression packer to determine fracture orientation. Possible applications are: inspection of casing damage, examination of perforations or slots, or determination of horizontal or vertical fracture orientation.

The details presented on the four Lynes packers and the discussion of their versatile and varied applications to the solution mining industry are just part of the story. As new problems continue to arise, and engineering innovations in packer design continue to be made, brine field superintendents will continue to recognize new applications for the Lynes inflatable packers to help resolve their problems.