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FIELD RESULTS AND APPLICATIONS
STRESSED STEEL LINER CASING REPAIR PROCESS

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ABSTRACT

The Stressed Steel Liner Casing Repair Process has been successfully applied to many types of casing damage which could not be readily repaired with other, more common methods.

Since the introduction of the process in Aug., 1962, approximately 100 jobs have been successfully run to repair leaks, to alter the production characteristics or to vary the injection rates into various formations in flooding operations. Another application has been the use of the Stressed Steel Liner to temporarily close off an existing set of perforations for down casing treatments of deeper formations.

The advantages associated with the Stressed Steel Liner Process stem from the fact that the repair is contained almost completely within the casing string. The process being limited to the casing also allows its use for applications where either formation damage or casing salvage value must be considered.

Equipment, procedure and cost of this repair method will be discussed along with applications made to date.

INTRODUCTION

For many years a need has been apparent for means of downhole casing repair to supplement the older established methods of squeeze cementing, setting of casing liners and isolating of leaks by means of straddle packers.

Because of the familiarity of the oil industry with these more common methods of repair, a situation where one of these methods can best be applied is readily recognized. Almost all problems which may be encountered and the chances of obtaining a successful repair are known within narrow limits because of this past experience. This paper proposes to discuss one of the most recent developments in the casing repair field and relay sufficient background concerning this process to allow its addition to the list of casing repair methods.

Process and Materials

The process is known as the Stressed Steel Liner Casing Repair Process. This repair method consists of cold forming a fiberglass and plastic coated steel tube out tightly against the inside diameter of damaged casing. This, in effect, does nothing more than install a second layer of casing over the damaged area of the existing casing string. Fig. 1 shows the Stressed Steel Liner both before and after expansion in the casing string.

The materials used to effect the repair are a stressed steel liner and a thermal setting plastic. The basic material from which the liner is made is a 1/8-in. thick steel tube slightly

References and illustrations at end of paper.

larger in outside diameter than the inside diameter of the casing in which it will be used. The transformation of the round tube into a Stressed Steel Liner is accomplished by drawing the tubing through a die which forms corrugations down its length and reduces its effective outside diameter approximately 1/2 in. This reduction in outside diameter is sufficient to allow the liner to be transported through the casing string to the area in which the repair is to be made. After forming, a sheet of fiberglass cloth is permanently affixed to the outside surfaces of the corrugated tube. The final material component, the thermal setting resin, is applied to the outside of the Stressed Steel Liner at the well site immediately prior to running the tool string. The fiberglass and resin provide the necessary gasket material to effect a seal between the outside surfaces of the Stressed Steel Liner and the inside of the casing.

Tool String and Equipment

The assembled tool string required for the installation or setting of a Stressed Steel Liner is shown in Fig. 2. A circulating valve is usually the uppermost item in the tool string and provides a means to fill the tubing as the tools are being run and a means to drain the tubing after the job has been completed. A drag spring assembly is run below the Circulating Valve and provides the necessary anchor or backup to allow tubing rotation to operate the valve. The drag spring body is replaced by a mechanical collar locator when it is desirable to set the Stressed Steel Liner in relation to a collar in the casing string. This is almost always desirable when using the liner to close perforations.

The next item in the tool string is a Hydraulic Tubing Anchor. The Tubing Anchor is provided to contain the force required to expand the Stressed Steel Liner. This tool prevents the running string or tubing from having to withstand the extra 30,000 to 50,000 lb force required to expand the liner. When looking at the manner in which the setting tool operates, it will be seen that the tubing anchor is required only after one stroke of the setting tool has been completed.

The Stressed Steel Liner Tool completes the tool string and normally will be run immediately below the Hydraulic Tubing Anchor. The purpose of this tool is to provide both a means for carrying the steel liner and a means to set or expand the liner in the casing string. The tool is comprised of two components, the Hydraulic Ram and the Expanding Section. The purpose of the Hydraulic Ram is to develop the force necessary to draw the expander members up through the liner expanding it tightly in the casing string. This part of the tool consists of three pistons which are connected in series so that pressure applied to the tubing string is applied across the combined areas of the three pistons. On the larger tool sizes, this combined area is 24 sq in. This will yield a pull of 24 000 lb for each 1,000 psi pressure applied to the tubing string. Upon the application of the required setting pressure, the pistons of the Hydraulic Ram will be pumped upward. This will draw the expanding or swaging members up through the liner setting it tightly in the casing string. The Hydraulic Ram will make a power stroke of 5-1/2 ft. At the completion of the stroke, a by-pass port is automatically opened that allows communication between the tubing and annulus.

The lower section of the tool consists of a solid pull mandrel which extends through the I.D. of the liner and two expander elements. The pull mandrel connects the pistons of the Hydraulic Ram to the elements which expand the liner in the casing string. The first of these expander members is a solid cone of metal considerably less in outside diameter than the inside diameter of the expanded liner. This member does only the preliminary forming leaving only the crests of the corrugations touching the casing after its passage. The second expanding member is a collet type spring with a free O.D. slightly greater than the I.D. of the expanded liner. This spring is the member which completes the shrink fit of the liner in the casing string. The two expander members are connected to the remainder of the tool string through a left-hand safety joint thread. This thread is provided to allow release of the tool and running string from the expanders if the liner cannot be completely expanded.

Procedure

The sequence of events followed in the installation of the Stressed Steel Liner consist of first locating the depth and extent of the damage. This has been accomplished in past operations by any one of a number of methods. Use of packers and bridge plugs, straddle packers, and electric logs have been the most common methods employed on past jobs. After the leak has been located, a gauge ring and casing scraper are run to clean and gauge the casing prior to the installation of the steel liner. A 3-in. long drift pin is normally used in the gauging operation. On some occasions where casing inside diameter enlargement is suspected, a more elaborate measure of the inside diameter might be necessary. In instances where additional information is required concerning the casing I.D., a caliper survey can be run to determine the unknown information. It has been common practice to run the packer, gauge ring, and casing scraper on the same trip in the well. Following the completion of casing inspection and preparation, the Steel Liner can be prepared for running. The well site preparation of the liner consists of saturating the glass fabric of the liner with the proper resin. The resin select is based on the temperature at the depth the liner is to be set and the length of time required to run the tool. Shown in Fig. 3 is the selection of resin systems that are available for use with this process. Because of the desirability of expanding the liner while the resin coating is still fluid, the liner should be expanded in place before the time corresponding to the temperature at the leak has lapsed. Under normal operating conditions this will allow this method of repair to be employed as deep as 9,000 ft. Sub-normal bottom-hole temperatures or more elaborate work-over rigs will allow use of this process at greater depths.

After reaching the desired depth, the expansion of a 10-ft liner is accomplished by two pressure applications. A pressure of 2,000 psi is normally sufficient to complete the setting operation. The operating time on bottom is usually less than 1/2 hour including surface rigging. Because of the 5-1/2-ft stroke of the setting tool, the numer of strokes or pressure applications required to set the liner will be determined by the length of the liner. A copy of the pressure chart from a 30-ft long liner job run in Canada is shown in Fig. 4. This chart shows a maximum pressure of 2,150 psi and a time of 20 minutes required for the expansion of this liner.

After completion of the setting operation, the tool should be free and the tubing and tools may be removed from the well. When the desired test pressure is 900 psi or less the liner may be tested immediately and the well put back on production. It is advisable to allow the resin gasket material to reach a final cure prior to application of pressures in excess of 900 psi. The curing time required is dependent on the temperature at the leak but is less than 20 hours.

Advantages and Limitations

The advantages and limitations associated with this process all stem from the fact that the repair is contained completely within the casing string. As expected when a repair is effected on the inside of the casing, a subsequent inside diameter reduction results. Attempts have been made to minimize the amount of the reduction while maintaining desirable pressure resisting ability and force requirement for setting. Laboratory tests have indicated a maximum reduction of 0.330 in. can be expected when a Stressed Steel Liner is installed in the casing string. In the majority of instances, this inside diameter reduction will not impose serious limitations on the future operations that may be conducted through the repaired casing; that is, the use of retrievable tools through the liners normally is not eliminated except possibly in the heaviest weight of the particular casing size being considered. An expected limitation associated with this process is its limited ability to withstand external or collapse pressure. When a Stressed Steel Liner is applied across a parted section or large split in the casing string, external pressures of 500 psi for the 7-in. size, 900 psi for the 5-1/2-in. size and 1,500 psi for the 4-1/2-in. liner size may be applied. Laboratory tests have indicated that a considerably greater external pressure should be resisted when the damage is in the form of one hole or several holes in the casing string. Because of the inability to correlate the laboratory tests run using drilled holes with the conditions of holes in the casing string, it is advised that the minimum pressure rating of the liner be considered when evaluating this method for a repair job. In past operations, a squeeze job followed by a Stressed Steel Liner has yielded successful repairs where neither method used alone would have resulted in a successful job.

Another limitation of this repair method is its dependence upon the condition of the casing string in which it will be set. In the setting or expansion of the liner, the lower 5 ft of liner is relied upon to anchor the liner while the remainder is expanded. This 5 ft will provide a resistance to movement of 200,000 lb or more when set in casing of the proper inside diameter. If the inside diameter is larger than expected, the anchor effect provided by the initial 5 ft is reduced. Tests indicate that an insufficient anchor or an incorrect casing weight may prevent the repair process from being successful. For instances where the casing weight is unknown or enlargement of the casing inside diameter is suspected, it is advisable to run a casing caliper prior to the installation of the Stressed Steel Liner.

The repair being contained to the inside of the casing string has advantages and features that are very difficult to attain employing other more common methods of repair. A repair of this type will not prevent the pulling of salvageable casing upon depletion of the well. This makes the process particularly well suited for repair of marginal or stripper wells. Another unique advantage offered by this method of repair is the ability to seal existing perforations and induce no measurable amount of damage to the adjoining formation. This can be a very important feature in zones that may later be opened for water flooding or pressure maintenance programs. Other advantages of the process are derived from its use for hard-to-squeeze leaks such as collar leaks or shallow leaks in uncemented areas of the casing. Another advantage is gained from the fact that old casing strings are not subjected to the high pressures often encountered in squeeze cementing operations. Some of the applications discussed later will best point up the desirability of the use of this process for many problems commonly encountered in repairing leaks and closing perforations.

Applications

Because of the extent of the operation with this process, the results of the first 61 jobs will be drawn upon for the following examples and comparisons. The jobs considered were run in 4-1/2 in., 5-1/2 in., 6-5/8 in. and 7 in. casing sizes. The specific jobs and applications discussed will include liners of 10, 20 and 30-ft lengths. For the reported jobs the success ratio has been approximately 89 per cent.

Among the more interesting or unusual applications that have been found to be well lended to this repair method are uses of the Stressed Steel Liner for covering perforations for a recompletion in the same zone. This application was employed in West Texas where old wells perforated for production only, were converted to injection wells. The injection rates into the individual sands were controlled by setting Stressed Steel Liners over both open formations and selectively re-perforating. This eliminated the need for installing production packers and controlling of the injection into each zone.

Similar jobs provided another operator in Southwest Texas with a means to control the gas-oil ratio of producing wells. On these jobs, Stressed Steel Liners were used to seal off existing perforations so that the zone could be reopened at a lower level. Of the three jobs run in the gas-oil ratio; the third yielded only a minor change in the amount of gas production.

Another application has been the use of the steel liner as a temporary protection for upper zones when treatment and/or workover operations were conducted on lower formations. This has proved to be a simple means to direct a fracture to the proper zone in some instances and prevent contamination from drilling muds in other applications.

Perhaps the most impressive of past applications include those where both time and expense involved in attempts to repair leaks had become excessive using more conventional repair methods. One such example was encountered in Southwest Texas where several previous squeeze jobs had proved unsuccessful in the repair of one - one-half diameter bullet hole at 970 ft. This hole was the result of a stray bullet used to penetrate the tubing in an earlier fishing job. An estimate of $50,000.00 was made as the cost of previous squeeze attempts to repair this leak. By employing a Stressed Steel Liner the job was completed in approximately 24 hours and a cost of approximately $1,400.00. Another application falling in the realm of "difficult to repair" jobs was encountered in a gas storage field in Illinois. This problem was particularly difficult because no pressure in excess of the overburden pressure could be applied on any squeeze attempt. This pressure limitation was imposed because of the possibility of creating a fracture which would allow the use of an excessive amount of cement and incur damage to the storage formation. In these cases, the leaks had been reduced to only very small proportions but were not completely stopped after several squeeze jobs. The Stressed Steel Liner was used to repair three wells in this field with no difficulties.

Another of the more interesting applications for the Stressed Steel Liner Casing Repair Process has been the repair of shallow leaks in steam injection wells in California. Although the evaluation of two jobs run to repair leaks is not yet complete, its performance thus far as a means to repair casing damage in steam injection wells has been very satisfactory.

Past jobs using this process have covered almost the complete range of geographic areas in the United States and Canada. Tools necessary for the installation of liners are also being maintained in Venezuela but no jobs have yet been reported.

The job depths range from a minimum of 40 ft to a maximum of 8,521. The average job depth has been 3,100 ft. Of the jobs mentioned, 3 - 30-ft liners, 18 - 20-ft liners and 40 - 10-ft liners have been run. The costs associated with this type repair has been approximately $1,300.00 plus the cost of four to six hours rig time above that required to make two round trips with the tubing string. The costs associated with this process have compared very favorably with the normal or expected cost of a squeeze job. With only rare exceptions, the length of time required for all operations has been under 30 hours including time required for location of the leak, preparation of the casing and installation of the liner.

CONCLUSION

It is felt that sufficient field experience has now been attained to prove the advisability of the use of the Stressed Steel Liner for both the repair of leaks and certain other more specialized jobs that are often encountered in oil field operations. This process, when its use is tempered by consideration of its limitations, can be a very valuable tool to any operation where casing leaks may present expensive, time consuming problems.

ACKNOWLEDGMENT

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1. Vincent, R. P. and Jennings, E. R.: "Stressed

Steel Liner for Casing Repair", paper presented at the Rocky Mountain Regional Meeting, Society of Petroleum Engineers, AIME, in Billings, Mont., May, 1962.

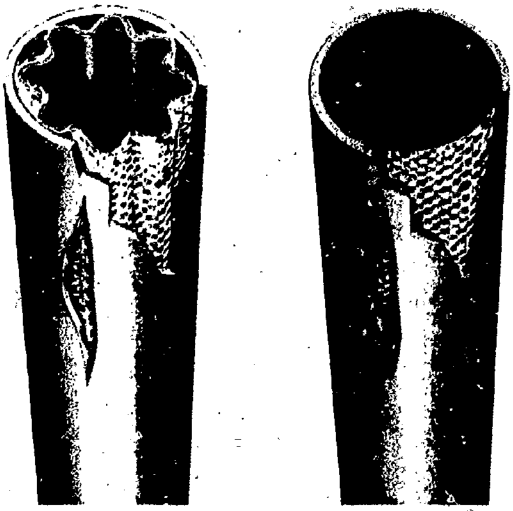

Fig. 1 - Stressed Steel Liner Before and After Expansion in Casing

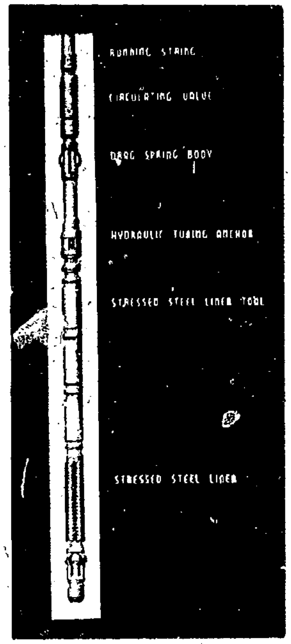

Fig. 2 - Assembled Tool String Required for Installation of Stressed Steel Liner

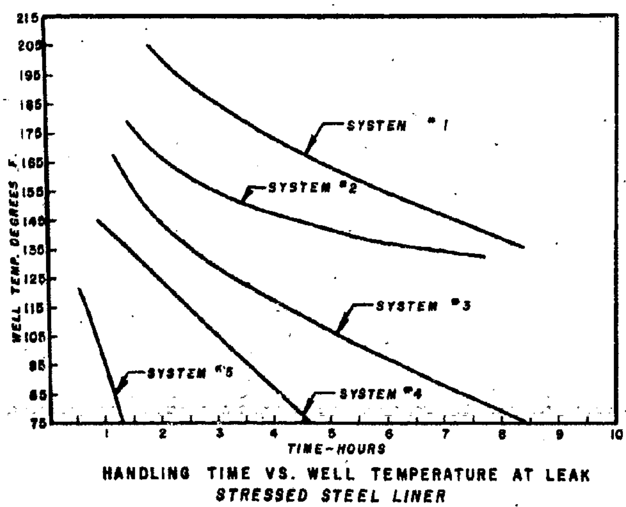

Fig. 3 - Handling Time for Resin System Used for Stressed Steel Liner

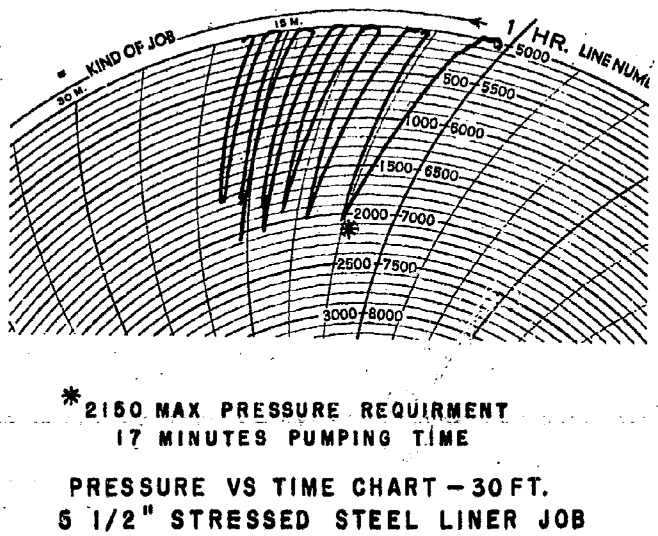

Fig. 4 - Pressure Chart from 30-Ft Stressed Steel Liner Job