Jan. 26, 1965 H. M. LANG 3,167,122

METHOD AND APPARATUS FOR REPAIRING CASING

Filed May 4, 1962 3 Sheets-Sheet 1

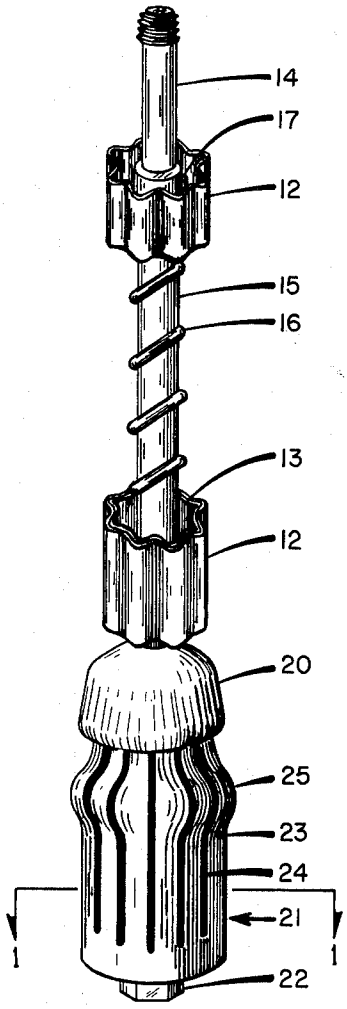

FIG. 1

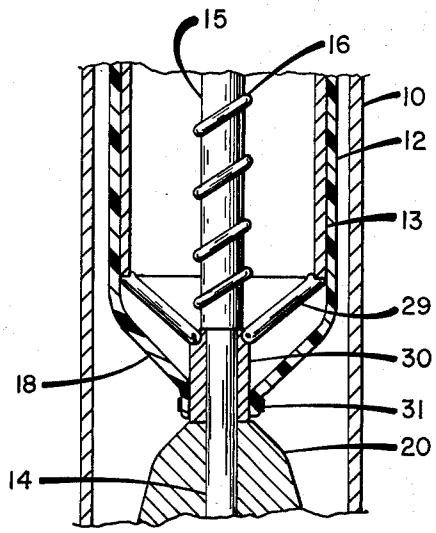

FIG. 4

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METHOD AND APPARATUS FOR REPAIRING CASING

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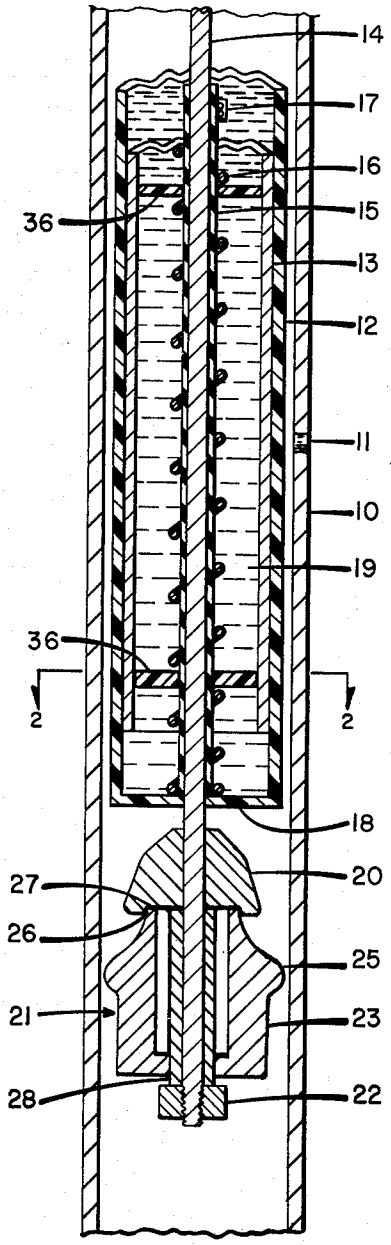

FIG. 2

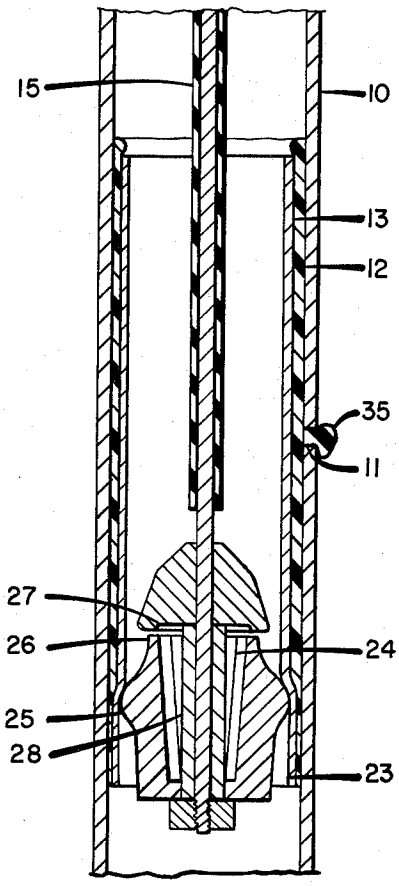

FIG. 3

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METHOD AND APPARATUS FOR REPAIRING CASING

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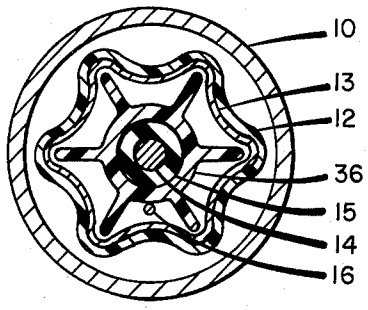

FIG. 7

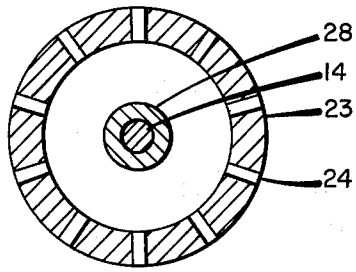

FIG. 5

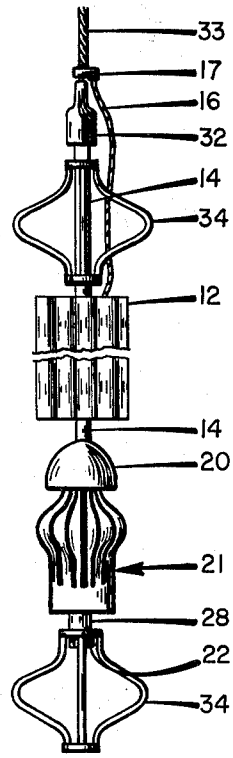

FIG. 6

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3,167,122

METHOD AND APPARATUS FOR REPAIRING CASING

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Filed May 4, 1962, Ser. No. 192,492
13 Claims. (Cl. 166—14)

This invention concerns the installation of a patch or repair liner in a well casing. More specifically, it relates to a method and apparatus for expanding a steel liner in a pipe or other cylindrical hollow body wherein the liner is first partially expanded with an explosive charge to anchor it in the pipe, then further expanded and smoothed with a wire line tool.

Oil and gas wells are ordinarily completed by first cementing casing in the hole. Occasionally, a leak develops at some point in the casing and permits the loss of well fluids to a low pressure, porous zone behind the casing, or permits an unwanted fluid such as water to enter the well. A method of repairing these leaks has been developed recently wherein a steel liner is placed in the well, then expanded against the inside surface of the casing. The liner is corrugated longitudinally to reduce its diameter so that it will pass through the casing easily. A thin coating of an epoxy resin or other cementing material and a glass cloth mat are applied to the outside of the liner before it is run in the well. The corrugated liner is run in the well on a tubing string, then expanded against the casing by drawing an expander device through the liner with the upper end of the liner resting against the lower end of the tubing. The expander device is moved through the liner by a hydraulic pump, operated by fluid supplied through the tubing.

This method of placing the liner sometimes presents two problems which contribute significantly to the expense of the operation. One problem is that the tubing string must be pulled and run in the well twice, once to attach the sleeve and setting tool and once to remove the setting tool. The other problem is that weak sections in the tubing sometimes fail under the force of the hydraulic pressure used to operate the expander.

My invention concerns a method and apparatus for expanding a steel liner in a casing using wire line equipment after the tubing has been removed from the well, thereby reducing the amount of time necessary to place the liner and avoiding the risk of rupturing the tubing with hydraulic pressure. In practicing my invention, the corrugated liner is supported on a rod attached to the wire line or cable with the rod passing through the longitudinal axis of the liner and the expander device attached to the rod below the liner. An explosive charge inside the liner is detonated when the liner is opposite the leak in the casing to expand the liner against the casing with sufficient force to anchor the liner so that the expander can be pulled through to complete the expansion of the liner.

The apparatus used in carrying out my invention is shown in the accompanying drawings.

FIGURE 1 illustrates the components of the apparatus prior to runnning it into the well.

FIGURE 2 is a cross-sectional view of the apparatus before the liner has been anchored in the casing.

FIGURE 3 is a view in cross-section showing the expander as it is pulled through the anchored liner.

FIGURE 4 is a view in cross section showing a method of attaching the assembly for support by the rod and wire line as it is run in the well.

FIGURE 5 is a cross-sectional view at section 1—1 in FIGURE 1.

FIGURE 6 illustrates an assembly of the apparatus of my invention in combination with centralizers.

FIGURE 7 is a cross-sectional view of section 2—2 in FIGURE 2.

Referring to these figures for a descripiton of the apparatus, rod 14 supports the entire assembly. Threads at the upper end of the rod provide a means for attaching a wire line rope socket. The expander consisting of collet head 21 and expanding cone 20 are retained by nut 22 at the base of rod 14. Recess 27 in cone 20 engages arm tips 26 to hold spring arms 23 retracted while the tool is being lowered into the well. Spring arms 23 are separated by slots 24 in collet head 21, as shown in FIGURE 5. Enlarged portions 25 on the spring arms engage the liner as the collet head is pulled through.

The patch assembly is made up of corrugated steel liner 13 surrounded by resin-impregnated fabric coating 12. The coating preferably extends beyond the ends of the liner by a distance at least as great as the radius of the casing to be patched. A spiral of cord explosive 16 extending throughout the length of the coating is provided to expand liner 13 and anchor it within the casing so that expanding cone 20 and collet head 21 can be pulled through. Jacket 15 protects rod 14 from damage by the explosive charge. This jacket may be made of rubber or other resilient material which cushions the shock wave produced by the explosive. Detonator 17 is provided at the upper end of the spiral charge so that it can be triggered either by a clock mechanism or by a go-devil device which is dropped down the casing. It might be desirable in some instances to place the detonator above the rope socket attached to the top of rod 14, as shown in FIGURE 6, for better access to the detonator by the go-devil.

The energy produced by the explosive is utilized most efficiently in expanding the steel liner when the space between the explosive and the liner is filled with a substantially non-compressible fluid such as water or oil. Also, it is desirable that the annular space between the corrugated liner and the casing contain a highly compressible fluid such as a gas. Lower extension 18 is provided between resin coating 12 and rod 14 so that the corrugated liner can be filled with liquid 19 to aid in transmitting the shock wave from the explosive to the liner. A small flow of liquids entering the well at hole 11 will run down the wall of the casing, tending to hold the liner away from the casing during the explosive step. The collet head will expand that part of the liner, displacing the liquids which interfere with explosive expansion.

In preparing to use this apparatus to patch a hole in casing, a steel liner having about six or eight longitudinal corrugations is placed over rod 14. The liner is wrapped with a sheath of a fabric such as glass cloth. The fabric is shaped into the corrugations and preferably extends beyond the ends of steel liner 13 by a distance of at least the radius of the casing to be patched. The bottom end of the fabric sheath is enclosed. This closure may be comparatively flat as at 18 in FIGURE 2, or it may have a somewhat conical shape as shown in FIGURE 4 where the end of the fabric sheath is drawn around rod 14 and collar 30, then closed with clamp 31. The steel liner may be supported entirely by the bottom closure of the glass fiber and hardened resin sheath extending beyond the end of the liner, as shown in FIGURE 2, or a support of the type shown in FIGURE 4 may be employed. In this embodiment of the liner supporting member, collar 30 resting on the top of expanding cone 20 carries arms 29 which pivot outwardly to engage the bottom of steel liner 13. These

arms may be made of a frangible material such as cast iron or a phenol-formaldehyde resin which shatters when the explosive charge is detonated. Another arrangement uses spring-loaded arms which retract against rod **14** and jacket **15** after the liner has been anchored by the explosive. With the fabric sheath in place on the liner, the ends of the sheath extending beyond the steel liner are coated with a material which hardens rapidly to produce a liquid-tight container. An epoxy resin may be used for this purpose. Thereafter rubber jacket **15** wrapped with explosive cord **16** is slipped over rod **14** to a position inside the steel liner as shown in FIGURE 2. Detonator **17** is connected to the explosive cord.

Spring arms **23** on collet head **21** should be retracted to avoid drag against the casing as the assembly is run into the well. This is done by latching arm tips **26** in recess **27** in the bottom surface of expanding cone **20**.

The glass fabric surrounding steel liner **13** between the liquid-sealing ends is coated with a cementing material such as epoxy resin. The resin should contain a catalyst or activator which will delay the hardening of the resin until after the patch has been placed in the casing. When the liner has been coated in this manner, it is filled with liquid **19**.

The top of rod **14** is attached to a wire line, then the assembly is lowered into casing **10** until the liner is opposite hole **11** in the casing. In carrying out my invention, it is desirable that the well be free of liquid at the level where the liner is to be placed. It might be necessary to lower the level of well fluids by bailing or pressuring the well with gas before placing the patch. With the apparatus so positioned in the casing, the cord explosive is detonated to produce a pressure wave which travels through liquid **19** and expands the corrugations in steel liner **13** and resin coating **12** against the casing as shown in FIGURE 3. The liquid-tight sheath extending beyond the ends of the steel liner usually is shattered by the force of the explosion. The small bits of explosion debris fall down the well past the expansion tool. Some of the unset resin on the outside of the steel liner is forced through hole **11** in the casing forming button or plug **35**, as seen in FIGURE 3.

With the steel liner thus anchored in the casing, tension is placed on wire line **33** attached to rod **14** at rope socket **32** to pull the expander mechanism through the liner. Expanding cone **20** first enters the liner, engaging any corrugations which were not flattened by the explosive. Thereafter, enlarged portions **25** on collet head **21** engage the partially expanded liner. As the collet head enters the liner, sleeve **28** resting on nut **22** bears against the bottom of expanding cone **20**, lifting the cone so that arm tips **26** are unlatched. This enables spring arms **23** to exert additional lateral force as shown in FIGURE 3. The expander mechanism is thus drawn through the liner to smooth out all of the corrugations. During this final expansion step, excess resin will be extruded from the outside of the liner. While part of the resin is extruded through hole **11**, most of the excess usually flows out at the upper end of the liner and is spread along the casing by the collet head. After a short while, usually 2–3 hours, the resin filling the glass fiber sheath between the liner and the casing hardens to cement the liner to the casing.

When the explosive charge is of sufficient density to expand the steel liner fairly uniformly, there will be little need for expanding cone **20**. Therefore, it may be omitted and only the collet head used to shape the liner into a cylindrical sleeve. It is preferred, however, to use the expanding cone to reduce the possibility of the tool sticking in the liner at points where there has not been sufficient expansion by the explosive.

The explosive charge is designed to expand the steel liner so that the ridges along the outer surface of the liner engage the casing with sufficient force to prevent movement of the liner as the collet head presses the

troughs outward, giving a cylindrical shape to the liner. Care should be taken to avoid rupturing the casing with an excessive charge of explosive. This danger is not great and a wide latitude of charge sizes is possible so long as the casing is open above and below the charge. The explosive density, i.e., the amount of explosive per foot of liner, varies with the diameter of the casing and the malleability of the steel liner. As an example of an effective charge, a helix of Primacord containing 100 grains of explosive per foot having a ratio of pitch to diameter of approximately 1.0 is suitable for expanding an annealed liner having a wall thickness of ⅛ inch inside a 5½ inch casing. In place of the spiral explosive charge described above, I may use a charge having either multiple helices or longitudinal components. Also, sheets of a high velocity explosive such as PETN, RDX, and the like may be wrapped on rubber jacket **15** instead of the cord-type explosive.

Detonator **17** is preferably a pressure-actuated device which can be triggered with a go-devil. Other devices which can be used include clock-controlled switches and electrical devices operated by a cable extending to the surface. The apparatus used should be designed to leave as little debris in the well as possible.

Various modifications of my invention are possible for best operation in a particular situation. Although I have referred to the liner as an annealed steel liner, it should be understood that other malleable metals can be used. Also, while the explosive charge and liquid container have been described as extending beyond the ends of the liner, it should be understood that a shorter charge and liquid container can be used. When a shorter charge is used, the ends of the liner will not be expanded as far as the central portion of the liner. This will make it necessary for the expanding cone and collet head to do a greater portion of the work in expanding the liner. A small flow of liquids entering the well at hole **11** will run down the wall of the casing, tending to hold the liner away from the casing during the explosive step. The collet head will expand that part of the liner, displacing the liquids which interfere with explosive expansion.

An alternative arrangement for containing the liquid between the explosive charge and the steel liner is that of placing the container or enclosure inside the liner. The walls of the container should be flexible so they will conform to the inner surface of the liner. A bag made of rubber or plastic film might be used. The container should extend beyond the ends of the liner as described earlier to obtain uniform expansion of the liner. It may be necessary to provide support for the fluid container beyond the ends of the liner to hold it away from the casing as the apparatus is lowered into the well. This might be provided by drawing the fabric sheath around the rod as shown in FIGURE 4. In this instance it will not be necessary to coat the ends of the fabric to make them liquid-tight.

Centralizers **36** between jacketed rod **14** and liner **13** can be used to center the explosive charge inside the liner. The centralizers may be placed on the resilient jacket at the time the explosive cord is wound about it. These centralizers can be made of a frangible material which is shattered by the explosive or they may be shock-resistant and reusable. Also, bow-spring centralizers **34**, as shown in FIGURE 6, may be installed above and below the resin-coated steel liner to hold the liner away from the casing as the assembly is lowered into the well.

In describing the preferred embodiment of my invention, it was stated that the steel liner was coated with a cementing material. It should be understood that my invention is not so limited. In view of the stresses produced in the liner, it may be desirable to place the liner without a cement coating. In some instances, an expansible gasket of rubber or other resistant material may be used in place of the cementing material. A rubber gasket

having a waffle-like pattern as shown in U.S. Patent 2,681,706 Pottorf is especially useful for this purpose.

Although this invention has been described with reference to the repair of casing, it should be understood that it can be used to repair tubing. Ordinarily, the tubing string is pulled from the well and defective joints replaced; however, that procedure is sometimes very expensive when a well contains several strings of tubing with packers separating multiple producing zones. My invention is especially applicable to those installations.

I claim:

1. A method of expanding a metal liner in a substantially cylindrical hollow body comprising:
placing a rod having an expander tool near one end along the axis of said liner,
attaching said liner to said rod above said expander tool,
enclosing said liner with a liquid-tight sheath,
placing an elongated explosive charge in said liner,
filling said sheath with a liquid,
attaching a wire line to said rod above said liner,
positioning said rod and liner in said hollow body,
detonating said explosive charge to expand and anchor said liner in said hollow body, then
pulling said expander tool through said liner to complete the expansion thereof.

2. The method of claim 1 wherein the outside surface of said liner is coated with a cementing material before said liner is lowered in said hollow body.

3. The method of claim 1 wherein
said liner is attached to said rod by first covering said liner with a fabric sheath having a length substantially greater than that of said liner,
clamping the lower end of said sheath to said rod above said expander tool,
then coating said sheath between said liner and said rod with a quick-setting resin prior to filling said sheath with said liquid.

4. A method of expanding a metal liner in a substantially vertical cylindrical hollow body at great depth comprising:
attaching an elongated explosive charge to a rod covered with a resilient material,
attaching said liner to said rod so that said liner is released from said rod upon the detonation of said explosive charge,
closing the space between the bottom end of said liner and said rod below said charge to form a liquid container,
attaching an expander tool to said rod below said liner,
filling said container with a liquid, thereafter
attaching a wire line to said rod above said liner and lowering said rod and liner into said hollow body,
detonating said explosive charge to anchor said liner in said hollow body, then pulling said expander tool through said liner to complete the expansion of said liner.

5. The method of claim 4 including the step of coating the outside of said liner with a cementing material before said liner is lowered into said hollow body.

6. The method of claim 4 including the step of placing an expansible gasket on the outside of said liner before said liner is lowered into said hollow body.

7. An apparatus for placing a metal liner in a substantially cylindrical hollow body comprising:
a liner,
a rod passing through the longitudinal axis of said liner,
a resilient sleeve covering said rod,
means to support said liner on said rod,
a liner expanding device at one end of said liner including a collet head carried by said rod,
an elongated explosive charge surrounding said rod and passing through said liner,
an enclosure for said liner adapted to contain a liquid inside said liner,
means to detonate said explosive charge, and
means to connect a wire line to the other end of said rod.

8. An apparatus for lowering a metal liner into a well casing at great depth and thereafter expanding said liner against said casing having in combination:
a rod,
an expanding tool attached to one end of said rod,
a liner supporting member on said rod,
a resilient sleeve covering said rod,
an elongated explosive charge distributed over said resilient sleeve,
an expansible metal liner surrounding said charge and held by said liner supporting member,
means to contain liquid in the space between said liner and said charge,
means to attach a wire line to the other end of said rod, and
means to detonate said explosive.

9. The apparatus of calim 8 wherein said explosive charge extends beyond the ends of said metal liner by a distance approximately equal to the radius of said casing.

10. The apparatus of claim 8 wherein:
said expansible metal liner has multiple longitudinal corrugations, and said elongated explosive charge is adapted to expand said metal liner so that the crests of said corrugations engage said casing with sufficient force to prevent movement when said expanding tool is moved through said liner.

11. The apparatus of claim 8 wherein said means to contain liquid consists of frangible extensions on the ends of said metal liner, the lower extension being fluidly sealed with said rod above said expanding tool.

12. The apparatus of claim 8 including a coat of glass fiber and a cementing material on the outside surface of said metal liner.

13. The apparatus of claim 8 including an expansible gasket on the outside of said liner.

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