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Use of Pressure Activated Sealants to Cure Sources of Casing Pressure

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Abstract

Pressure leaks in a wellhead or in downhole tubulars or equipment can lead to inoperable subsurface safety valves, casing pressure, environmental pollution, loss of production and, in extreme cases, blowouts. As such, it is essential to the safe and environmentally sound operation of a well that the sources of the pressure leaks be identified and cured. Use of a new and unique pressure activated sealant technology allows utilization of a method of repairing wellhead and downhole leaks in-situ without employing any mechanical downhole operations. Only at the point of differential pressure, through the leak site, will the sealant reaction occur and create a bond across the leak. Use of the pressure activated sealant technology obviates the need to employ expensive and risky rig or wireline operations to cure downhole leaks.

Introduction

Despite the best efforts of equipment manufacturers, service companies and operators, a certain percentage of seals, connections, fittings and other components of wellheads, downhole tubulars or other equipment weaken or fail over time. When any of these components fail, a leak develops and the pressure integrity of the downhole barrier systems is compromised.

Studies conducted by the Petroleum Engineering Department of Louisiana State University (the "LSU/MMS Study") document the existence of over 11,000 sources of casing pressure in over 8,000 wells in the Gulf of Mexico [1].

Pressure leaks in a wellhead or in downhole tubulars or equipment can lead to inoperable subsurface safety valves, casing pressure, environmental pollution, loss of production and, in extreme cases, blowouts. Potential causes of blowouts due to casing pressure are well known and documented in the LSU/MMS Study. As such, it is essential to safe and environmentally sound operation of a well that the sources of the pressure leaks be cured.

With the current environment of low oil prices, limited personnel and reduced maintenance budgets, the operating companies must embrace new low-risk, cost-effective technologies to cure pressure leaks that result in dangerous casing pressure.

This paper describes a new and unique hydraulic sealant technology that is specifically designed to seal leaks in severe environment hydraulic systems. What distinguishes this new sealant technology from other downhole sealant technologies is that the sealants are pressure activated. The sealants will remain fluid in any hydraulic system until the sealant is released through a leak site.

The capabilities of the sealant technology will be presented in this paper through lab tests and case studies involving leaks in chemical injection lines, subsurface safety valves, casing, tubing and wellheads.

Use of the term- "Hydraulic System". As used in this paper, the term- "hydraulic system" refers to any containment system used to regulate, carry or direct liquids or gases. Specifically, in this paper, "hydraulic system" includes those components of a well that contain or exclude pressure or are used to operate downhole equipment. Hydraulic systems include wellheads, casing, tubing, subsurface safety valves, chemical injection lines and other downhole components.

Prior Technology

Use of previously available technology to cure downhole leaks and sources of casing pressure involved either risky and expensive equipment replacement or ineffective and risky non-selective sealant mechanisms.

Equipment Replacement. The most common means of curing sources of pressure leaks has been use of risky and expensive rig operations to cure the leak. A major component of the total cost of curing leaks in wellheads and downhole tubulars and equipment is the cost of mobilizing expensive equipment and numerous personnel to the well location. In many instances, the well must be shut-in until the leak is cured.

A separate–but intangible–cost of such wellhead and downhole operations is the risks associated with such operations including personnel injury risks, environmental risks, wellbore damage risk and the risk that the operator may not be able to re-establish production from the well.

What is needed is a method of repairing wellhead and downhole leaks in-situ without the need of mobilizing expensive and risky rig or wireline operations.

Non-selective Sealant Mechanisms. The difficulty to date with attempting to cure the leak in-situ without utilizing rig or wireline operations has been to find a sealant mechanism that seals the leak without clogging or damaging critical components in the wellbore or hydraulic system.

Current sealant technology involves either clogging the leak with particulates or the use of a catalyzed sealant.

Particulate Sealants. The problems with plugging the leak with particulates are that (1) the particulates may clog or plug more than the leak site and (2) there is no bonding of the particles across the leak site to maintain the seal against further leakage, pressure reversals or surges.

Catalyzed Sealants. Catalyzed sealants use various reaction activation methods including time, temperature or the mixing of a catalyst into the basic sealant components.

The problem with each of these catalyzed sealant technologies is that the sealant reaction is not sufficiently selective to be able to seal the leak site without sealing, clogging or plugging other areas in the hydraulic system. There is the potential of sealing, not just the leak, but also other components of the wellbore. Often, the hydraulic system becomes inoperable due to the complete blockage of the hydraulic system by the hardened non-selective sealant.

What is needed is a sealant that cures wellhead and downhole leaks in-situ without clogging or damaging critical components in the wellbore or hydraulic system.

New Technology

Pressure Activated Sealants

A new and unique sealant technology has been developed that is specifically designed to seal leaks in severe environment hydraulic systems. What distinguishes this new sealant technology from other downhole sealant technologies is that these sealants are pressure-activated. The sealant will remain fluid in any hydraulic system until the sealant is released through a leak site. Only at that point of differential pressure, through the leak site, will the sealant reaction occur and bridge across the leak.

The sealant is analogous to blood coagulating at a cut. Blood only heals the location of the cut. The pressure-activated sealant only "heals" the point of differential pressure, that is, the leak site. The remainder of the sealant continues in the fluid phase. It will not clog or plug the hydraulic system or well components. The sealant can be left in the system or flushed out without plugging the system or having any detrimental effect on any components.

Pressure Activation Mechanism. The pressure-activated sealant formula consists of a super-saturated mixture of short-chain polymers, monomers and other components. At a point of high differential pressure through the leak site, the release of pressure causes a chemical reaction between the monomers, short-chain polymers and other components of the formula. As the reaction proceeds, the catalyzed sealant plates out on the edges of the leak site and, simultaneously, links with itself across the leak site to seal the leak. This process if illustrated in Figures 1 through4.

Flexible Seal. The resulting seal is a flexible product that fills in holes, scars or cuts in the leak site. Again, we use the blood analogy. The sealant creates a "scab" across the cut or leak. Initially, the seal is very fragile. Over the course of two weeks, the seal gains strength but remains flexible.

Broad Temperature/Pressure Range. Because each sealant formula is custom-blended to the particular conditions of the leaking hydraulic system-whether it is tubing, casing, wellhead or SCSSV-the pressure activated sealing mechanism is effective regardless of the temperature (to 350°F), pressure (to 17,000 psi) or delay in reaching the leak site. The uncatalyzed sealant remains fluid regardless of the temperature, pressure or the time that the sealant remains in the system.

Laboratory Testing

Filter Test. To verify the ability of the sealant formula to be carried through the hydraulic system without clogging or plugging components and still create a seal at the point of differential pressure, the sealant formula was pumped through a 25-micron filter at various pressure drops.

*Low Pressure Flow***.** Due to the fact that the components of the basic sealant either are in solution or are microscopic, the sealant can be flowed through a 25-micron filter at low-pressure drop without clogging the filter. At low pressure drop, the pressure activation mechanism of the sealant does not occur. The sealant will flow through the filter without clogging the filter.

*High Pressure Flow***.** If the flow of sealant through the filter is increased, resulting in an increase in the pressure drop through the filter, the pressure activation mechanism occurs. The components of the sealant formula link together to bridge across the pore space of the filter. The filter is sealed by the sealant mechanism within five minutes. Flow through the filter is blocked.

Leak Test. In a more "real world" lab test of the sealant technology, a test was performed to determine if the pressure-activated sealant could seal a leak in a damaged control line fitting. Using a metal saw, both the ferrule and threaded nut of a connection fitting were cut to a depth of six millimeters (6 mm). The pressure-activated sealant was pumped through the damaged fitting. By regulating the pressure drop through the damaged fitting, a seal was established across the damaged connection. A pressure of 10,000 psi was attained and maintained across the sealed leak of the damaged fitting.

Chemical Injection Line Leak Test. The best illustration of the capabilities of the sealant was in sealing a leak from a chemical injection line fitting into an annulus without plugging the actual chemical injection port.

On a test bench, a chemical injection fitting was damaged to simulate a leak into the annulus. A simulated wellbore was built and heated to 150°F. A custom-blended formula of the pressure-activated sealant was prepared and injected through a hot tap and into the chemical injection line. The sealant was pumped into the chemical injection line at a pressure of 2000 psi while releasing pressure through the annulus but maintaining 2000 psi on the tubing. As such, the differential pressure of 2000 psi was established through the leak site while there was little or no differential pressure through the injection port. After the leak into the annulus was sealed, the injection port was opened and remainder of the sealant was displaced at low-pressure drop through the injection port and into the tubing.

By selectively creating high differential pressure through a leak site while maintaining low differential pressure through essential flow paths, it is possible for the pressure-activated sealant to catalyze in and cure isolated leaks without affect the critical flow paths.

Applications

The pressure activated sealant technology has successfully performed leak-sealant operations in a number of different applications, including the following:

1. Subsurface safety valves;
2. Wellhead tubing and casing hanger seals;
3. Casing and tubing pinholes and connections;
4. Umbilical lines; and
5. Subsea well control systems.

The benefit of using a pressure-activated sealant process is that, using only a single skilled technician and a small self-contained equipment dolly, the custom-blended sealant is injected through the system until the leak is corrected. The excess, uncatalyzed sealant can be flushed out or maintained in the system without harm to the system. The well may return to production without the expense and risk of using a rig or any mechanical downhole operation.

Case Histories

The product has been used successfully in the Gulf of Mexico, Alaska, the North Sea, Malaysia, Africa and the Middle East. The following representative case histories outline the capabilities of the sealant, the procedures used and the results of operations.

SCSSV Leaks. While the chemical injection line leak lab test best illustrates the unique capabilities of using pressure activated sealants, it is not illustrative of the most common use of pressure activated sealants. Leaks in subsurface safety valves are experienced in every producing region in which SCSSVs are used as a safeguard against blowout.

In the North Sea, the operator was experiencing a severe leak of 1,000 ml/min in the SCSSV control line, causing the well to shut-in. Using data on temperature, pressure and leak rate, a custom-blended sealant formula was prepared. A technician ran troubleshooting diagnostics at the well location. Diagnostics indicated leaks, in both directions, between the V-packing of the wireline retrievable SCSSV and polished bore nipple. The operating company was unable to retrieve the valve due to ongoing operations on an adjacent well, which prevented access to the well with wireline equipment.

Using a custom-designed injection system, the technician pumped sealant into the hydraulic control line of the safety valve until the pressure-activated sealant–after only 10 minutes of pumping– had repaired the leak. The normal valve-operating pressure of 6,000 psi was maintained. After four hours, the technician performed function tests that verified full capability of the valve, and the well was returned to production.

Leaks in SCSSVs have been cured in systems operated at up to 16,000 psi and 310°F.

Casing leaks. In Alaska, artificial-lift gas was leaking from an inner annulus through a connection leak to the outer annulus. The operator was unable to bleed outer annulus pressure below 800 psi. A custom-blended sealant formula was atomized into the artificial-lift gas and injected into the inner annulus, while bleeding outer annulus to atmosphere. By this procedure, sealant entrained in the artificial-lift gas was carried to the leak site. After sealing the leak, the outer annulus pressure dropped to 14 psi. The sealant allowed a successful casing integrity test to 3,000 psi, and the well was put back on production.

Tubing leaks. In the Gulf of Mexico, gas was leaking from the tubing through connection leaks to the annulus. The leaks were in joints between the surface and the safety valve. A temporary plug was set above the safety valve and a custom-blended sealant formula was atomized into nitrogen and injected into the tubing. As with the casing leak, sealant in the nitrogen was carried through the leak site. After sealing the leak, the well was put back on production and the annulus pressure stabilized within normal limits.

Wellhead leaks. In wellheads, leaks can occur in casing and tubing hangers, pack-offs and other wellhead components.

Pack-off Leaks. In Alaska, an operator was experiencing pack-off leaks in wellheads. High viscosity greases had failed to seal the leaks and the operator did not want to use cements or epoxies that would "set up" throughout the wellhead. The pressure activated sealant was injected through one test port of the wellhead while releasing pressure through the second test port. Once sealant had filled the void area, the void area was "pressured up" to 80% of the rated wellhead pressure. By this procedure, the sealant was extruded through the pack-off leak sites. The pressure on the void area was then cycled between 0 psi and 80% of the rated wellhead pressure to create a two-way seal through the leak sites.

Hanger Leaks. A similar success occurred in tubing and casing hangers by installing a back-pressure valve into the tubing hanger, dumping the sealant into the wellhead and pressuring the sealant from the interior of the wellhead and out through the leaking hangers. Using a pump connected to the crown valve, the wellhead was pressured to 5,000 psi and held there until the leak was sealed. The technician cycled pressure between zero and 5,000 psi to force additional sealant into the hanger seals, until the bleed-off rate subsided to zero at 5,000 psi differential pressure. After the seal was verified, the backpressure valve was removed, excess sealant was flushed out and the well was put back online.

Factors Affecting Success Rates

The likelihood of the sealant operation being successful is highly dependent on (1) obtaining accurate well data, (2) properly interpreting the well data and nature of the leak, (3) preparing the proper sealant formula for the well conditions and (4) properly regulating the sealant injection rate and pressure.

Data Accuracy. The pressure-activated sealant has to be custom-blended to the conditions of the well including temperature, pressure, leak rate, system fluids, type of hydraulic system and other pertinent data. Inaccurate data on the conditions of the well results in the preparation of an improper formula and a higher likelihood of the operation not being successful.

Leak Geometry. Both laboratory and field testing of the sealant technology indicates that the success of the sealant operation is highly dependent on the geometry of the leak. Narrow leaks, regardless of the length or number are easy to cure. Circular leaks are difficult to cure.

Connection Leaks. In connection leaks, there is a large metal to leak size ratio. The sealant is able to easily bridge across the leak and seal the leak. The sealant catalyzes in the leak site and is very hard to dislodge while the connection is "made-up." At the same time, our sealant is flexible and will tear when the connection is "broken-out." We have had good success in connection leaks.

Circular Leaks. In a circular leak, even if there is an initial seal of the leak, there is a high likelihood that the seal will fail. Because of the large exposed open area of a circular leak, high pressure will "blow-out" the flexible seal. Therefore, there is a low likelihood of successfully sealing circular leaks.

Landing Nipple Leaks. When used to seal leaks between a wireline retrievable safety valve and a scarred landing nipple, the seal can be created to seal the leak, but you can still pull the valve. When you pull the valve, the thin, pliable sealant film between the valve and the nipple is torn. The catalyzed sealant still fills the scars in the nipple and seals. When you re-seat the valve, only a small amount of sealant needs to be pumped to reestablish the seal. There is a high likelihood of success in all types of safety valves.

Injection Pressure Regulation. To properly activate the sealant mechanism in the leak site, it is necessary to carefully regulate the injection rate and pressure during the period that the sealant is flowing through the leak site. By regulating injection rate and pressure, the technician is able to build the seal in the leak path without clogging other components or "blowing out" the seal during the time that it is forming in the leak site. Once the seal is established, it is necessary to allow the seal to "heal" and strengthen prior to exposing the seal to the full system pressure.

Sealant Operation Success Rates

When accurate data is available and the leak is within the capabilities of the pressure-activated sealant, there is a very high (90%) likelihood that the leak can be cured. If the leak is not within the capabilities of the pressure-activated sealant technology, then the old technologies outlined above will have to be employed to repair the leak.

Additional Applications

This pressure-activated sealant technology must be viewed, not as a solution for particular pressure and leak problems, but as a new and unique sealant concept. The list of potential applications described above is not exclusive. If a pressure differential can be established through a leak site, regardless of the nature or location of the leak, it is possible that a seal can be established at that leak site.

The possibilities are limited only by the ability to create a pressure drop and the capability of the sealant to bridge across the leak site. Further studies of the capabilities of the pressure-activated sealants and potential applications are necessary.

Conclusion

Leaks in wellhead and wellbore equipment are sources of dangerous casing pressure problems that need to be addressed. It is essential to safe and environmentally sound operation of a well that the sources of the pressure leaks be cured. The use of pressure-activated sealant is a safe, low-risk, economical alternative to use of rigs or wireline operations to repair or replacement of the leaking wellhead, wellbore or hydraulic systems.

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References

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