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Technical Conference Paper

REMEDIATION OF CASING AND MICROANNULUS CEMENT LEAKS UTILIZING PRESSURE ACTIVATED SEALANT

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Seal-Tite International

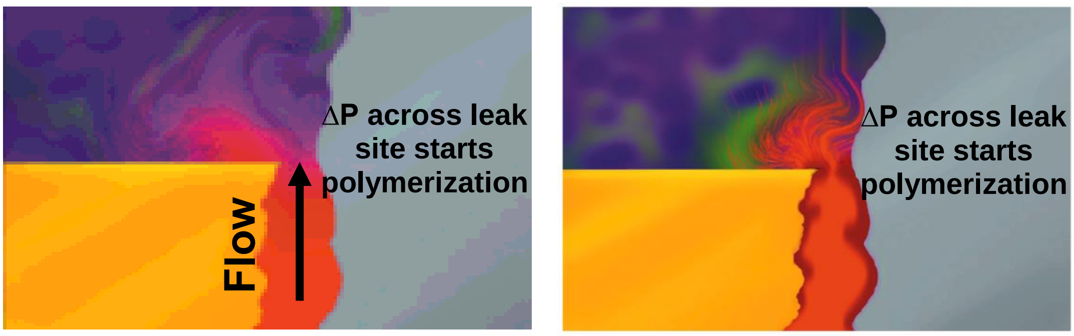
Abstract

The utilization of pressure activated sealants has proven to be a cost-efficient solution to mitigate casing integrity issues, cemented annulus integrity issues, and sustained casing pressure in storage cavern wells. The sealant approach can eliminate the need for rig interventions and mitigate a majority of the risks inherent in such large-scale operations, all while reducing out of service time for the cavern. This paper presents the latest field proven techniques used to restore mechanical integrity of storage cavern wells using pressure activated sealants. Three sealant repair techniques are presented: floating sealant on top of well fluid at the leak site, atomizing sealant into the nitrogen flow stream at the leak site, and foaming sealant with nitrogen on surface before injecting it into the wellbore. Case studies for each technique are included. The subject wells had previously failed a Mechanical Integrity Test (MIT) with nitrogen. Post sealant treatment, the wells passed the MIT and were returned to service. Lessons learned to improve the efficiency and efficacy of the sealants and procedures are noted.

Key Words: Leak, Mechanical Integrity, Sealants, Wellbore Remediation, Microannulus

1. Introduction

This paper presents three application techniques used to apply pressure-activated sealant technology in storage cavern wellbores. The sealant is unique in that it is activated by pressure differential at the leak and polymerizes to a flexible solid. As it flows through the leak site, the sealant plates out on the edges and builds upon itself until the leak is sealed (See Figure 1 below). The resulting seal is a flexible bond similar to a 80 durometer elastomer. Any excess sealant that is not polymerized will remain in a liquid state which can either be left in the system or flushed from the system.



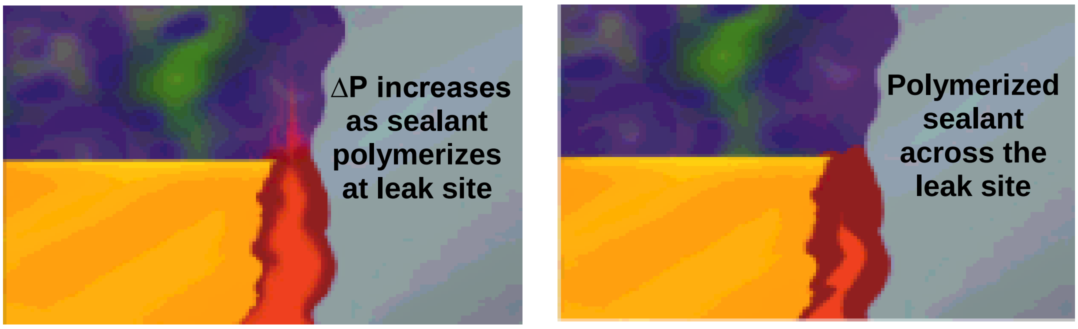


Figure 1. Leak Site Sealant Entry and Polymerization Sequence

A key factor towards the success of pressure-activated sealant repairs is proper and detailed diagnostics via techniques including wireline logging and nitrogen-liquid interface movements. Wireline leak detection logs are useful to monitor noise, temperature, and pressure to identify leak sites. Fiberoptic wireline cable can also be utilized to provide distributed temperature sensing (DTS) and distributed acoustic sensing (DAS), which can provide real-time data throughout the entire wellbore. Nitrogen leakage and the associated nitrogen-liquid interface movement should stop at the leak site. A density log with casing collar locator can identify the depth of the interface at the leak site.

1.1 Literature Review

Realizing the need to develop a sealant formulation and procedure to seal microchannels and cracks that can develop in annulus cement, Rusch and Slezak, 2005 detail laboratory testing performed where a test annulus (See Figure 2 below) was created with fissures and cracks to model microannulus channeling. The permeability of these leak paths was confirmed and then treated with pressure activated sealant. Post-treatment, the integrity of the cement was re-stored to beyond the level of competent cement. This paper also provides three case studies which used pressure-activated sealant to restore wellbore integrity.

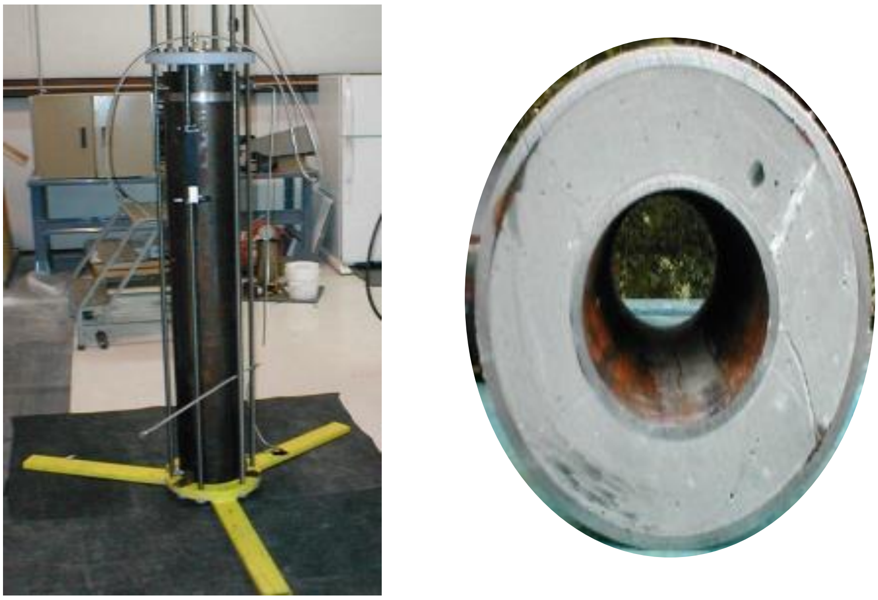


Figure 2. Microannulus Test Fixture and Cross Section from Rusch and Slezak, 2005

Johns et al., describes two applications utilizing sealant pills and their placements to achieve mechanical integrity. Chivvias, Julian, and Cary, 2009 detail logging techniques and sealant repair case studies which were successful. Kumar et al., 2015 outlines a sealant repair on a newly completed well, demonstrating the range of conditions that can be treated by pressure-activated sealant. These published works provide a foundation for understanding repair procedures and potential outcomes for storage cavern well applications.

2. Sealant Repair Techniques

Seal-Tite International engineers a leak remediation plan custom-tailored considering the leak parameters and well configuration, among other factors to restore wellbore integrity. Research and development of new techniques to improve the delivery of pressure-activated sealant is ongoing to provide the safest and most cost-efficient solution possible. As an alternative to a conventional workover, the sealant approach has a smaller footprint, less safety considerations, and a reduction in lost operational time for the well.

2.1 Floating Sealant on Well Fluid

This technique is commonly utilized to cure leaking casing shoe microannulus channels. The sealant used for this technique will have a lighter density than the wellbore fluid so that an interface can be created, allowing the sealant to straddle the leak site (See Figure 3).

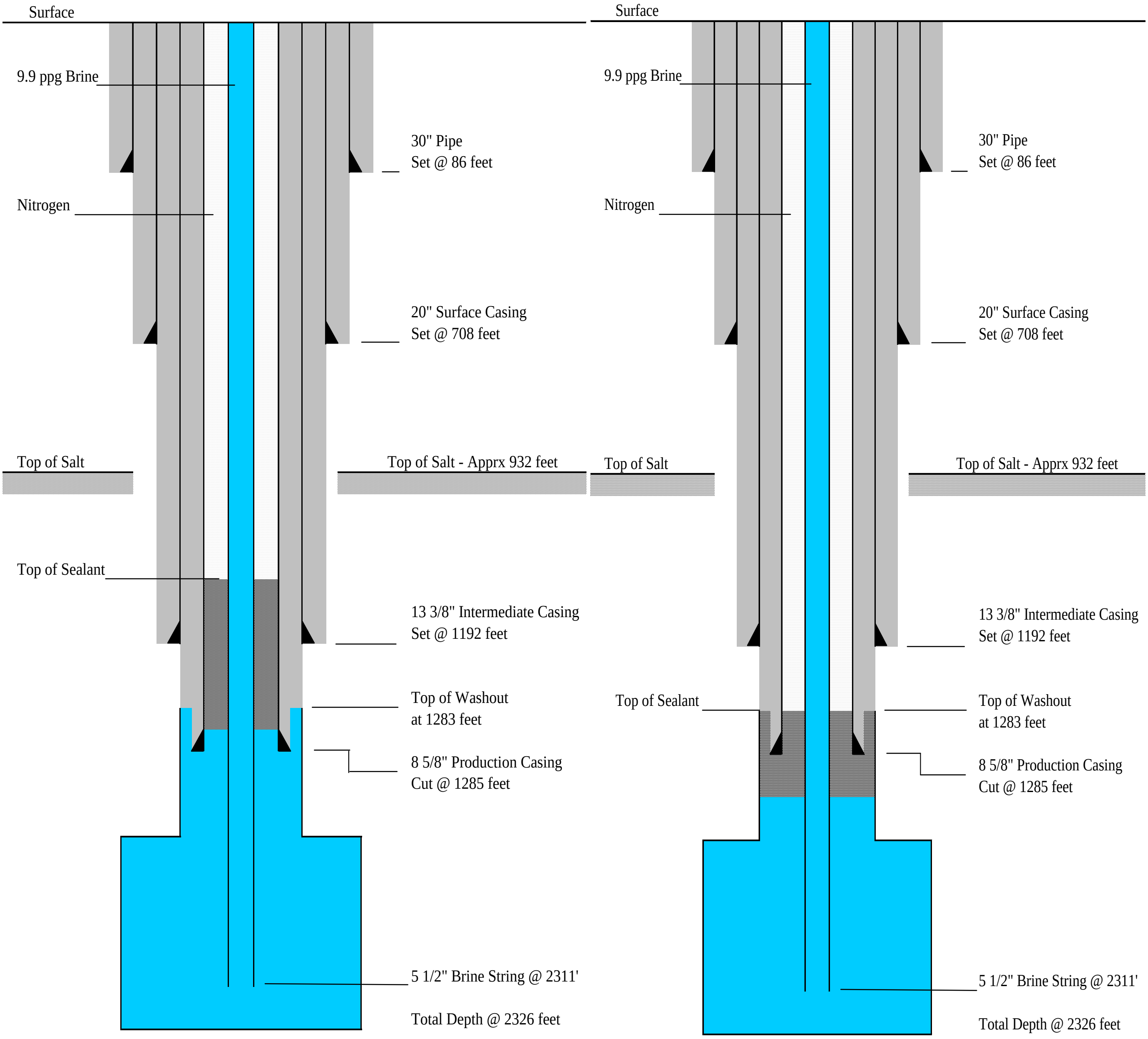


Figure 3. Typical Operational Wellbore Schematic Before and During Floating Sealant Application

Once the sealant pill is across the leak site, differential pressure causes sealant penetration as well as polymerization up to the pre-determined test pressure. At the test pressure, the sealant will be allowed to cure to provide a robust and long-lasting seal.

2.1.1 Case Study

In August 2015, a crude oil storage cavern well was experiencing a leak at the 10 ¾" production casing shoe. The well had a suspended 8 5/8" brine string. The wellbore schematic can be found below in Figure 4. The oil stored in this cavern had a density of 7.06 ppg (0.86 kg/L). The maximum allowable operating pressure was 0.76 psi/ft (0.17 bar/m), resulting in a maximum allowable nitrogen pressure near the 10 ¾" shoe of 1464 psi (100.9 bar). The operator reported a nitrogen leak rate of 90 to 134 bbl/yr.

During a failed nitrogen MIT, the nitrogen/crude interface was seen to rise to the casing shoe and stop. Given these conditions, a solution was formulated to remedy the leaking casing shoe.

The procedure began by bleeding the nitrogen from the production annulus to allow a sample of crude oil to be taken to measure its density. After doing so, a sealant blend was formulated to provide a pill that would be injected to float on top of the crude oil at the leak site. Ultimately, a 2 bbl pill of sealant was determined to provide adequate coverage and volume to seal the shoe leak. The sealant was injected into the production annulus and displaced with nitrogen to spot the pill across the leaking casing shoe. The slug was allowed to straddle the shoe for two weeks prior to the MIT, which proved successful.

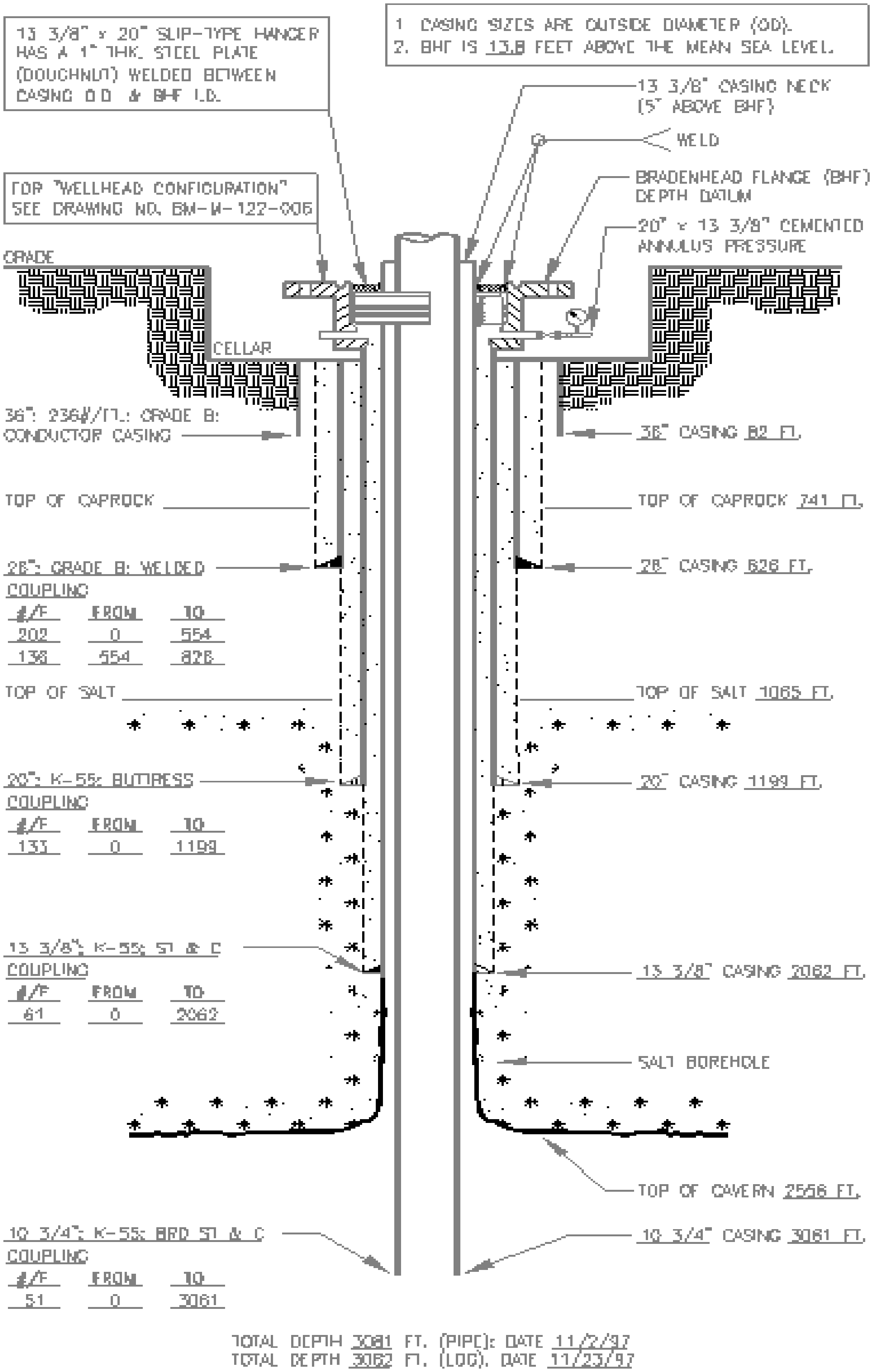


Figure 4. 2.1.1 Crude Oil Cavern Wellbore Schematic

2.2 Misting Sealant into Nitrogen Flow Stream

Atomizing sealant into the gas stream is ideal for small gas leaks where a liquid sealant approach may be unable to penetrate the leak site. In order to create the mist, a specially formulated blend of sealant that has been filtered is pumped through a nozzle with a 0.015" (0.381 mm) to 0.020" (0.508 mm) orifice (See Figure 5). The atomized sealant droplets are then carried with the gas stream through the leak site, where they accumulate and polymerize to seal the leak. This approach can be used for both casing shoe microannulus leaks and casing thread leaks.

Figure 5: Misting Nozzle Atomizing Sealant

This application requires careful monitoring of the pump rate and pump pressure because the misting nozzle is a source of significant differential pressure which can cause the sealant to polymerize. If this were to happen, the nozzle must be pulled out of the hole and changed to provide an optimal mist.

If the leak is a shallow casing leak, a casing injection tool (See Figure 6) can be installed on the wellhead annulus gate valve to insert a misting nozzle into the annulus to spray sealant down the nitrogen filled annulus from surface. It is equipped with a secondary hydraulic pack-off to ensure pressure containment while stinging in and out of the well. The tool is approximately 9 feet (2.74 m) long with a maximum stroke of 6 feet (1.83 m).

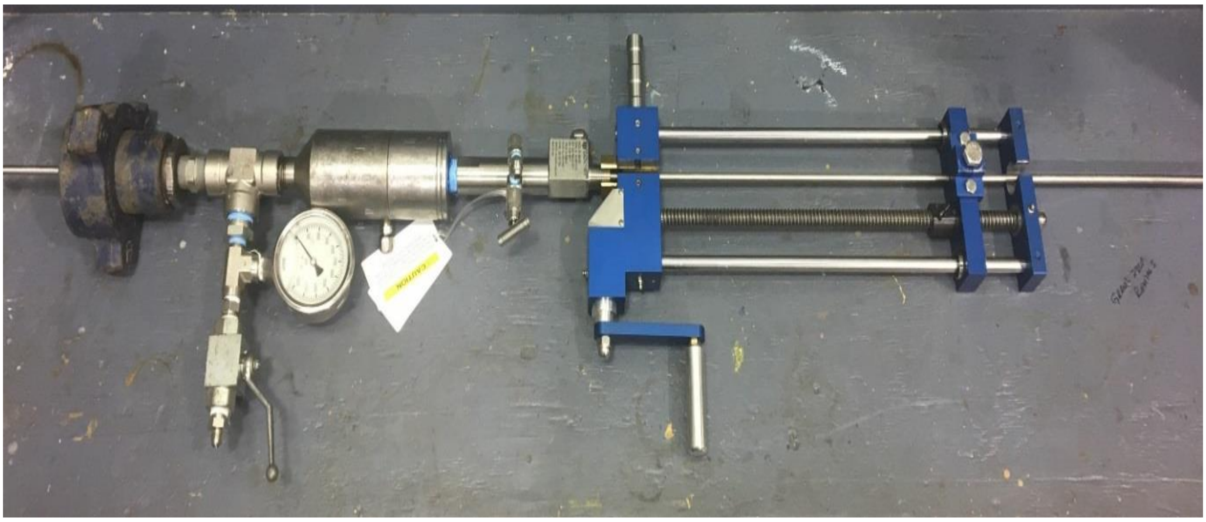


Figure 6. Casing Injection Tool For Shallow Misting Applications

If the leak is deeper, a BHA can be installed onto capillary coil tubing and run to the leak site (See Figure 7 Below). Centralizers are generally installed above the BHA to centralize the nozzle and allow the mist to disperse and cover as much area as possible as well as to prevent damage to the BHA. Additionally, the handle of the ball valve is removed prior to running it into the hole with the coil tubing.

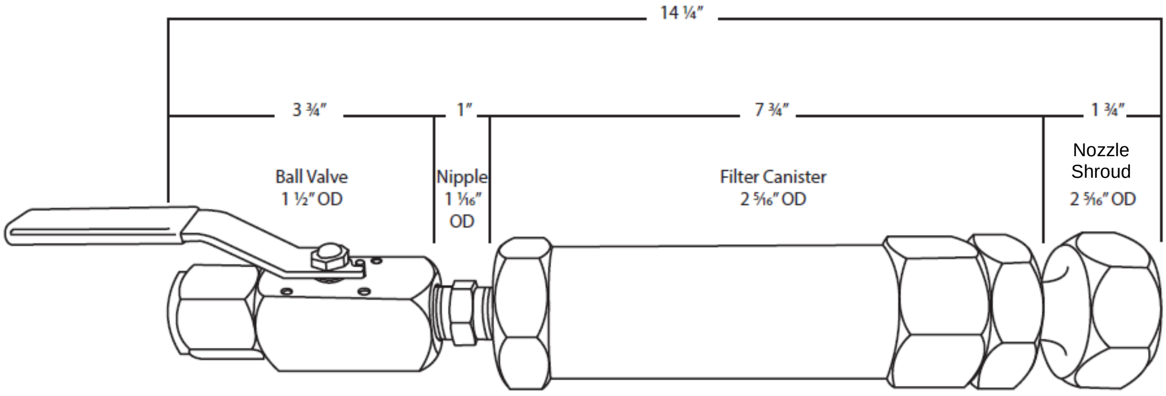


Figure 7: Bottom Hole Assembly for Coil Tubing Misting Applications

2.2.1 Case Study

In October 2010, an Ethane storage cavern well failed a nitrogen MIT on its 10 ¾" production casing. The sporadic leak was calculated to be 0.1 m^3/day (3.53 scf/day) nitrogen or 0.5 lit/day (0.13 gal/day) liquid ethane at 2400 psi operating pressure with vent flow up the cemented 10 ¾" x 16" annulus observed at surface. The Seal-Tite proposed solution to use a nozzle to spray the leak site with sealant while nitrogen was flowing through the leak site was accepted by the operator. A 0.015" (0.381 mm) misting nozzle was selected and sealant was developed for the job. A bottom hole assembly consisting of an inline filter, rupture disk, and misting nozzle was procured and a procedure prepared for the job. During a scheduled tubing replacement workover, attempts to locate the leak site in the 9 5/8" production string were unsuccessful with suspected leak sites identified at 115 ft (35 m) and 295 ft (90 m) from surface. The operator elected to spray the entire casing string with sealant from 689 ft (210 m) to surface using a capillary coiled tubing string.

After a day of testing, a ¼" capillary coiled tubing string and centralizers were selected and mobilized to the well site in Fort Saskatchewan. The sealant misting nozzle was run on the capillary tubing to 689 ft (210 m) and the casing pressured up with nitrogen to 500 psi (34.5 bar) against a deep-set bridge plug. The base line casing pressure loss was 0.25 psi/min (0.017 bar/min) at 500 psi (34.5 bar). The capillary tubing was pulled from 689 ft (210 m) to surface at 32.8 ft/min (10 m/min) while spraying sealant through the nozzle at 400 ml/min. Two passes over the suspected leak sites at 295 ft (90 m) and 115 ft (35 m) were made during the trip. After this low pressure pass the capillary tubing was removed and the well shut in for 36 hours. The casing pressure stabilized at approximately 496 psi (34.2 bar) overnight indicating that the sealant had achieved a low pressure seal.

The casing was then pressured up to 2600 psi (179.3 bar) with nitrogen and a base line casing pressure loss of 0.37 psi/min (0.026 bar/min) at 2600 psi (179.3 bar) recorded. The capillary tubing with nozzle was run to 689 ft (210 m), sealant injection initiated, and the capillary tubing pulled to surface at 32.8 ft/min (10 m/min) while spraying sealant through the nozzle at 400 ml/min. Two passes made were over the suspected leak sites at 295 ft (90 m) and 115 ft (35 m). After this high pressure pass the capillary tubing was removed and the well shut in at 2600 psi (179.3 bar) for three days. After the second day the casing pressure stabilized to below the acceptable MIT test criteria. After the three-day cure period the sealant was circulated from the casing and a nitrogen MIT performed successfully, allowing the wellbore to be returned to service.

2.3 Foaming Sealant with Nitrogen

Foaming sealant is a novel technique currently being developed and tested where sealant and nitrogen are injected through a static mixing tube to commingle and create a low-density sealant foam (See Figure 8). With a weight of 5.5 ppg (0.120 kg/L), the sealant foam is capable of floating on a variety of well fluids. When using this approach, it is critical to accurately locate the fluid level to spot/float the foam across the leak site.

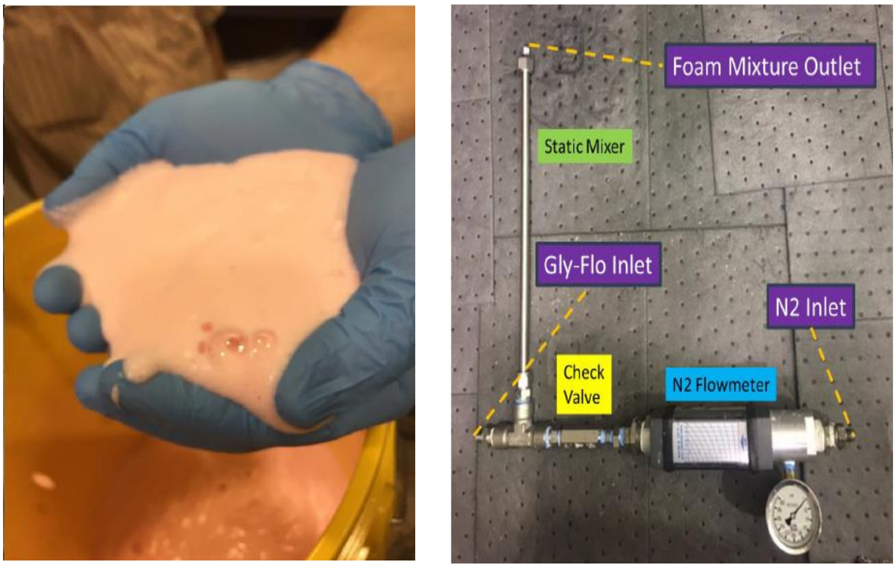


Figure 8. Sealant Foam and Foaming Manifold

3. Conclusions

With a variety of sealant blends and methods for application, pressure-activated sealant is a field-proven technique to seal leaks in storage cavern wellbores. Beyond this, it is a safer and more cost-efficient remediation strategy.

4. Acknowledgements

Being primarily an upstream oil and gas leak remediation service company, we would like to thank the storage cavern operators that have allowed us to expand our horizons to develop sealants and repair procedures for the storage cavern industry.

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