Pipe Freezing as an Isolation Technique

Introduction to Pipe Freezing as an Isolation Technique

Pipe freezing is a method of isolating or closing the inside diameter of a pipe for maintenance or repair. To accomplish this, a heat exchanger, such as a fluid-tight metal jacket, is attached to the area of the pipe to be isolated. The jacket is precooled with N\textsuperscript{2} gas then filled with liquid nitrogen to freeze the water-based fluid along the inside surface of the pipe near the jacket. As this cooling process continues inside the pipe, more fluid is frozen and more ice is produced along the axial plane of the pipe. Further cooling produces a highly stable ice plug that can be sustained with careful monitoring of the temperatures and pressures present at the heat exchanger by trained personnel. For liquid nitrogen at low pressure, the system used by Wild Well incorporates common tank trucks or portable 50-gallon bottles, eliminating the need for special pumps. A calibrated temperature monitor is used to measure temperatures of the pipe and jacket.

This pipe freezing technique has been safely and successfully used by Wild Well over many years for many types of repairs. Wellhead repairs, casing valve replacement, and tree repairs are common reasons for below-the-wellhead multistring freezes. The freezing of multiple strings of pipe is not outside of normal operations, but instead a preferred method of isolation for valve replacement when valve failure occurs. Single-string tubing freezes allow a break in the connection above the freeze and provide the opportunity to add a valve without performing a fluid kill operation. Negative and positive pressure testing of the freeze plug’s integrity provides a confirmation of isolation.

To assure that the pipe freezing procedures developed by Wild Well are held to the highest safety standards, independent tests and research of the effects of subjecting tubing and casing to liquid nitrogen temperatures have been conducted.

Cryogenic Testing of API Pipe Grades

Stork Materials Technology performed mechanical testing and a metallurgical examination to determine the effect of exposure to subzero and cryogenic temperatures on several grades of API pipe provided to their facility. Wild Well employed a system of applying liquid nitrogen to assist in certain oilfield activities, using a section of API 5CT pipe, grade N80, in conjunction with a cryogenic chamber for the application of liquid nitrogen, commonly at -60°F, during training and testing procedures. More than 100 applications of the liquid nitrogen have been used on one specific pipe during such procedures. This pipe was provided to Stork, along with one pipe section of API 5CT pipe, grades L80 and P110, and one section of API 5D pipe, grade S135, for pull testing.

Testing involved tensile and Charpy impact on prepared samples from each of the four provided grades of API pipe. One tensile sample from each pipe was tested at ambient conditions to establish a baseline of property values, and another tensile sample from the same pipe was then tested at a temperature ranging from -30 to -100°F throughout the course of the tensile test while yet another tensile sample was tested at a constant temperature near -230°F. Subsequently, a Charpy set from each pipe was tested at the prescribed impact test temperature in the API 5CT and 5D specifications and another set at an impact temperature of -60°F. All test temperatures were monitored with thermocouples attached directly to the samples during the tensile tests performed at temperatures other than ambient.
The Charpy tests were monitored with a thermocouple placed directly in the test bath. In addition, two sections of the N80 test pipe were submitted to Lambda Research for metallurgical assessment of retained austenite. One sample was taken directly from the area that received the cryogenic application during Wild Well’s testing and training procedures. The second sample was taken from a section of pipe located well away from this cryogenic area. Using X-ray diffraction, this examination showed certain effects the frequent cryogenic exposure may have had on the microstructure of the material.

The overall results of the testing showed the tensile strength values of the subzero samples were typically slightly higher than the ambient tensile strength values. The elongation values varied but remained within 5% of the elongation values when comparing subzero to ambient. The Charpy impact values were lower for the subzero impacts in comparison to ambient and +32°F impacts as is expected of any material. The tensile test values from the area of the N80 pipe that had been subjected to the numerous and frequent cryogenic testing at the Wild Well facility also showed a slightly higher tensile strength, but all tensile, yield, and elongation values showed that the cryogenic exposures were not causing a deleterious effect on any of the materials tested.

Additional tests of carbon steel samples exposed to different cryogenic temperatures were performed at the Texas A&M University Microscopy and Imaging Center using a Scanning Electron Microscope (SEM). Images produced by SEM of the surfaces of these samples at fracture initiation zones showed strikingly similar morphological characteristics. During the observation of these samples by SEM, an Energy Dispersive Spectrometry detector was used, producing strikingly similar plots of elements present in each sample. A summary of this research was published in Microscopy and Microanalysis (2010) Vol. 16, Supplement 2, pp. 1260-1261.

Common Uses and Case History
The most frequent use for pipe freezing occurs when a previous operation (wireline, cementing, fracturing) has resulted in a situation wherein isolation from the wellbore cannot be completed because of valve failure. Wellhead and casing valves become inoperable for a variety of reasons and frequently need to be replaced. Performing a fluid kill operation is sometimes not feasible because of either logistics or cost. When tools, inoperable valves, or another type of obstruction is located in the master valves, Wild Well specialists propose a freezing operation below the wellhead to isolate all the valves above the Braden head.

After excavation and jobsite preparation, verification of freezable fluid placement is performed before the freeze process begins. Cement-filled conductors can either be frozen through or removed for the freeze process and reinstalled after the pipe has thawed. This multistring isolation approach gives clients a safe opportunity to reinstall the valves necessary to continue the drilling or production operation.

Safety Concerns
Although use of nitrogen and carbon dioxide have become routine in today’s oilfield applications, their potentially fatal characteristics must be controlled and monitored according to requirements set forth in numerous documented safety standards. When using nitrogen or carbon dioxide as a refrigerant below grade, it will settle in a cellar or excavation. Wild Well will only perform below-confined-space pipe freezes under the supervision of a Safety Specialist trained for confined spaces. Wild Well policy forbids ANY entry into the confined space during a freeze and before qualified safety personnel determine all nitrogen is removed from the confined space after the freeze. An attendant from Wild Well will be present at the excavation until their supervision is no longer needed.

As part of the standard package onsite, the entire process, along with all accompanying equipment, can be operated by remote control outside of the excavation. Adequate shoring, scaffolding, air evacuators, oxygen monitors, and safety personnel are a critical part of job planning that will be reviewed before job execution.

All testing and technical results of the research performed are available upon request. ©Wild Well Control 2010