CLOCK SPRING®

Application Note
Field Inspection

Introduction

Occasionally, during the course of routine maintenance, a Pipeline Company will daylight an existing Clock Spring® repair. The Company might then like to assess and confirm the condition of the Clock Spring®.

Field Inspection

There is very little testing that can be done, insitu, to test the Clock Spring®. Visual inspection will provide the best indication of performance. The Clock Spring® installation should be inspected to ensure that…

- the coating is continuous and free of defects.
- there are 8 layers of Clock Spring® material. (thickness >0.36 inches (9 mm)).
- the repair is a monolithic structure.
- there is no evidence of movement.
- the resin is hard and the glass fibers fully contained.

The adhesive can be tested to ensure that it has a minimum hardness of 40 durometer on the Shore "A" hardness scale.

Clock Spring® repairs, properly installed, will not fail because of exposure to the environment. The conservative estimate of life is a minimum of 50 years. This is fully documented in a number of technical reports.

Prior Testing

Clock Spring's effectiveness as a permanent repair for high-pressure transmission pipelines is substantiated by an impressive series of tests. These tests were necessary to satisfy both Pipeline Companies and Regulators that the technique is effective. These tests are detailed in GRI Report 98/0032 "Field Validation of Composite Repair of Gas Transmission Pipelines" These tests are further summarized in GRI Report 98/0227 "Summary of Validation of Clock Spring® for Permanent Repair of Pipeline Corrosion Defects".

The Field Verification Testing of over 100 Clock Spring® installations was done to confirm laboratory testing in actual field operating environments. Following is a brief summary of the key elements of the laboratory research pertinent to the field validation effort.

Composite Short-term Strength and Physical Properties

Clock Spring® is manufactured by encapsulating tows of continuous E-glass fibers in an isophthalic polyester resin matrix. The wet fibers are then wound and cured around a cylindrical mandrel to form the characteristic Clock Spring® shape. The resulting composite laminate layers are nominally 0.065-inches thick and have a glass fiber content ranging from 60 to 70 percent by weight (45 to 55 percent by volume). The density of the cured composite laminate ranges from 0.61-to 0.69-lb/cubic inches.

Short-term and long-term tensile tests were carried out using standard ASTM composite tensile specimens cut from 12 inch wide flat plate panels of the Clock Spring® composite system. The tensile strength of these samples, under worst-case conditions of full immersion in water at 140º F, was 52 to 85 ksi. These data are from narrow 0.5-inch wide strips and represent a lower bound to the actual strength of the full 12-inch wide commercial panel.

The Clock Spring® composite material exhibits linear elastic behavior up to the point of failure in tension, typically 1.5 to 2 percent strain. Typical values of the elastic modulus are 5×10^{6} psi in the fiber direction and 1.4×10^{6} psi in the transverse direction. The coefficient of thermal expansion was found to be 6.0×10^{-6} inch/inch/degree F in the fiber direction and 3.2×10^{-5} inch/inch/degree F in the transverse direction.

Long-term Composite Strength in Pipeline Environment

The strength of polymer composites subjected to high stress in severe environments is known to decrease with time. In pipeline repair applications, Clock Spring® is not highly stressed, nor is the environment unusually severe or deleterious. Long-term static load (stress-rupture) tests were performed in the laboratory research program on saturated, 0.5-inch wide samples at elevated 140º F temperatures. These tests were to verify sufficient long-term residual strength and performance of the Clock Spring® material as a permanent repair. These tests represented a worst-case condition for the environment to which the Clock Spring® would be subjected.

Figure 2 summarizes the results of the long-term testing. In these tests the gauged sections of saturated 0.5-inch wide samples were continuously immersed in de-ionized water at nominal pH ranging from 4 to 9.5, representing typical soil moisture conditions, and at temperatures of 120º F and 140º F. No fundamental change in the failure mechanism was observed in the long-term stress-rupture specimens to indicate degradation in properties. The lower bound line to the worst-case failure data indicates that 20 ksi is a conservative long term operating stress for a 50-year life.

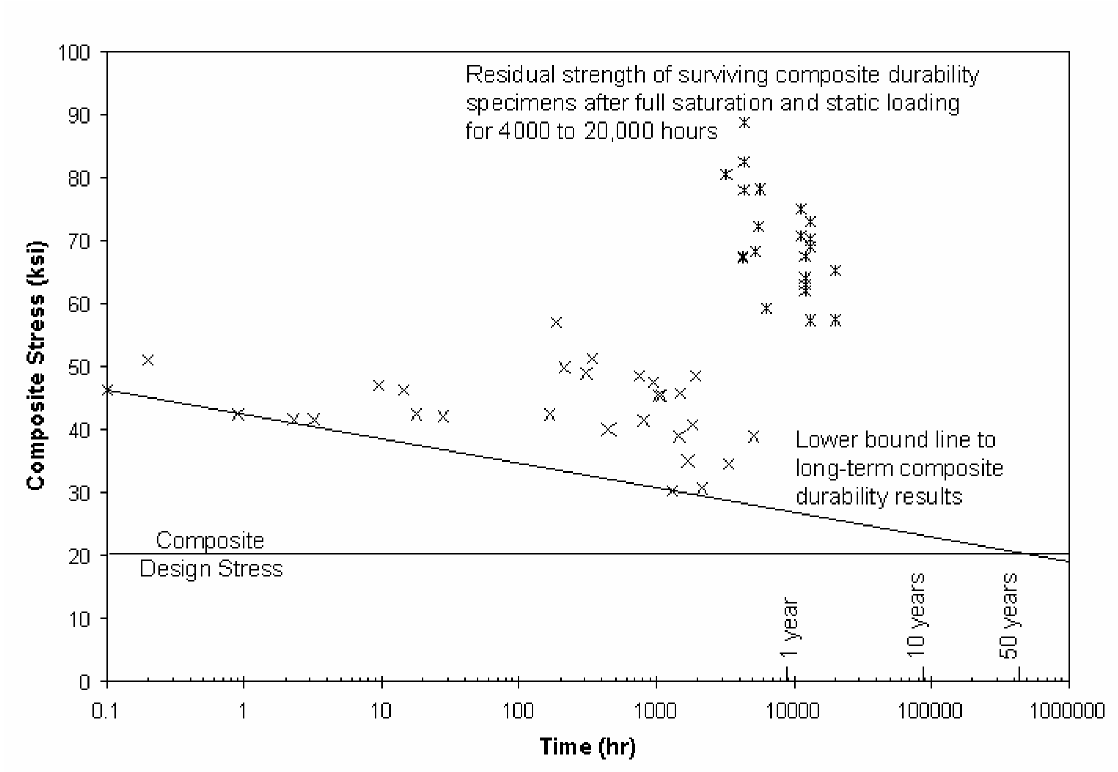

Figure 2. Long-term Durability and Residual Strength of Saturated Clock Spring at 140 F.

Long-term static load tests were maintained for up to 20,000 hours (27 months). During this time, no specimen failed at less than 30 ksi. At the conclusion of the static load testing the un-failed specimens were subjected to conventional tensile testing at 140º F. The residual strength of the un-failed specimens, coupled with the test duration, indicate that no significant damage had been sustained by the samples at stresses of 18 to 35 ksi for test durations up to 20,000 hours.

Long-term Clock Spring® Design Stress

The maximum operating stress for transmission pipelines in the United States ranges from 40 to 72 percent of their specified minimum yield strength (SMYS), depending upon the class location. ASME pipeline design codes require that any defect present in the pipeline due to corrosion or other factors must be able to withstand a hydrostatic test of the pipe to the equivalent of 100 percent of SMYS. Similarly the composite repair model GRIWrap™ uses the 50 year maximum stress of 20 ksi for long term Clock Spring® composite repair. GRIWrap™ requires that the repaired defect also be able to withstand a hydrostatic test of the pipe to the equivalent of 100 percent SMYS hoop stress throughout its design life.

Adhesive Material Investigation

The Clock Spring® composite is bonded to the pipe and to itself with an interlayer adhesive. A typical Clock Spring® installation consists of 8 complete wraps of the pipe to form a monolithic, 0.50-inch thick structure. The adhesive is a proprietary epoxy/methyl methacrylate known as MA440.

An analysis of the stress field in the Clock Spring® adhesive by Stress Engineering Services Inc. shows that the maximum adhesive stress is at the ends of unit and will likely remain below 200 psi. The Clock Spring® adhesive strength was measured in the laboratory to range from 1100 to 1500 psi.

The effects of stress and variability of soil pH were investigated. In these tests the Clock Spring® laminates were submerged in heated water baths at different pH levels and loaded under constant stress for periods of up to 10,000 hours (13 months). While the adhesive strength did diminish in these tests, it remained well above that strength required for the Clock Spring® application.

Field Validation Program

Laboratory analysis showed that Clock Spring® is an effective permanent repair technique for high-pressure transmission pipelines. To fully validate this laboratory data a comprehensive Field Validation Program was established. Over 100 Clock Springs were installed at various locations across the United States in conjunction with this investigation. The locations and installation conditions varied widely, representing the broad range of conditions expected for application of the composite wrap. Soil conditions at the sites ranged from red clay to dry sand. Installation temperatures ranged from 40º F to 95º F. This program focused on three areas:

- Comprehensive monitoring of Clock Spring® on an operating pipeline, including inspection and laboratory testing after 2 to 4 years of exposure, electronic monitoring of strains over 4 years, and testing of adhesive panels buried with the Clock Springs.
- Installation of Clock Springs on 10 operating pipelines and subsequent inspection and laboratory testing after 2 to 4 years of exposure.
- Field inspection, recovery, and laboratory testing of first generation Clock Spring® installations after 3 to 7 years of exposure.

This program yielded the following results:

- Monitoring selected installations with strain gauges showed no loss of reinforcement or system degradation.
- Detailed visual inspection after 2 to 7 years of exposure showed no evidence of degradation or loss of serviceability.

- Laboratory analysis of Clock Springs removed from service after 2 to 7 years of exposure showed the following:

- The buried composites did not diminish in strength.
- The residual strength of test specimens under 15 to 20 ksi constant tensile load showed no measurable loss of strength or degradation.
- The residual strength of Clock Spring® composite after 2 to 4 years of exposure was higher than the initial laboratory worst-case samples.
- There is no deterioration of the resin matrix or glass fibers.
- Physical properties of the composite and adhesive did not change with exposure.
- Chemical evaluation showed no evidence of chemical breakdown.
- Lap shear strength of the adhesive was not affected by long-term exposure to field conditions.

The conclusion drawn from this extensive battery of tests was that Clock Spring® repair technology could be used to permanently repair pipeline defects.

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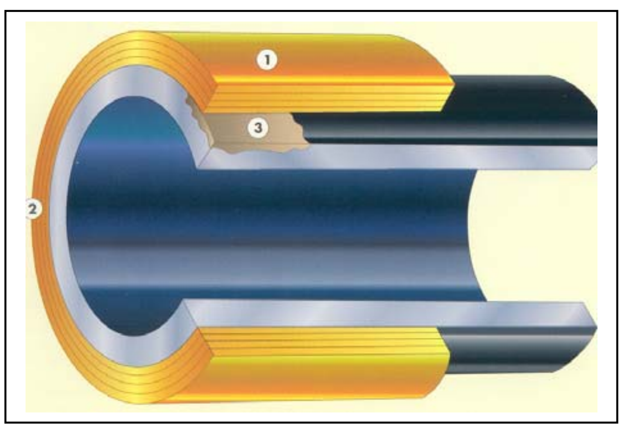

Simply the smartest pipeline repair decision you can make!

Clock Spring Company L.P.● 14107 Interdrive West ● Houston, Texas, 77032
Telephone 281.590.8491 ● 800.471.0060 ● Fax 281.590.9528
Clock Spring ● UK 4A The Causeway, Godmanchester, Huntingdon, Cambs, PE29 2HA
Telephone 011 44 1480 414 703 ●Fax 011 44 1480 414 705
www.clockspring.com