Johns Manville
Industrial Insulation Group

Thermo-12® Gold With XOX Corrosion Inhibitor Inhibits Corrosion

Technical Bulletin

THERMO-12 GOLD WITH XOX Corrosion Inhibitor INHIBITS CORROSION UNDER INSULATION (CUI)

Since the inception of the Industrial Insulation Group in 2002, Thermo-12 Gold Calcium Silicate high-temperature pipe and block insulation has incorporated XOX, a unique process and formulation, that actually inhibits corrosion under insulation (CUI) on steel surfaces. The testing reported in this bulletin, which was done by an independent lab, shows that the XOX feature inhibits corrosion significantly relative to other calcium silicate and to other high temperature insulation products. Since product performance characteristics can vary greatly from
"out-of-the-box" to "in-service" conditions, the following evaluations were designed and incorporated to consider both.

ASTM CUI TEST METHODS

Today there are two "Insulation Industry" accepted test methods for determining corrosion of carbon steel under thermal insulation. As many thermal insulation materials are manufactured differently or have different physical properties, no single test can be used to predict or measure the amount of CUI that will occur when an insulated pipe is exposed to environmental conditions that can allow corrosion to occur. There are too many variables and too many different combinations of exposure to evaluate easily.

The first ASTM document containing a CUI test method was C665 "Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing". Although this method was developed for "visual comparison" of CUI from mineral fiber insulation materials used in light construction ceilings, walls and floors, it continues to be specified for virtually all types of thermal insulation materials. Considering the toxicity of the required chemicals, the special handling required of these chemicals and the extended length of time to perform the test, it is difficult to contract with a certified laboratory to perform this test method.

The most recent CUI test method published by ASTM in 2005 is C1617 "Standard Practice for Quantitative Accelerated Laboratory Evaluation of Extraction Solutions Containing Ions Leached from Thermal Insulation on Aqueous Corrosion of Metals". This method not only visually compares CUI, but by weighing the test coupons and comparing them before and after testing it is now possible to physically measure and calculate the potential corrosion rates of mild steel under different insulation materials due to exposure to liquids with different concentration of ions. This method provides quantitative values rather than a visual comparison as defined by the C665 test methods.

A third test method, ASTM C692 "Standard Test Method for Evaluating the Influence of Thermal Insulation on External Stress Corrosion Cracking Tendency of Austenitic Stainless Steel" was published in 1971. Although this test method defines pass/fail based on a visual determination of the cracking of austenitic stainless steel coupons, by substituting carbon steel for the stainless steel test coupons used in the test method, one can visually compare the relative corrosion under insulation.

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THERMO-12 GOLD WITH COX Corrosion Inhibitor INHIBITS CORROSION UNDER INSULATION (CUI)

ASTM C665 - STANDARD SPECIFICATION FOR MINERAL-FIBER BLANKET THERMAL INSULATION FOR LIGHT FRAME CONSTRUCTION AND MANUFACTURED HOUSING
SUMMARY OF TEST METHOD:

This method is used to determine the relative corrosion potential of mineral fiber insulation on specific metals under elevated temperature and high humidity condition. The method requires the following steps:

- Sandwich five each of specially cleaned steel, copper, or aluminum test plates between pieces of insulation.
- Hold the insulation uniformly against each side of the test plate with wire screens and rubber bands.
- Sandwich an equal number of potassium hydroxide and de-ionized (DI) water cleaned metal test plates between samples of acetone washed sterile cotton in an identical manner.
- Vertically suspend the samples in a humidity test chamber at 95 % RH and 120°F for time periods determined by the type of metal being tested. Steel is tested for 96 h copper and aluminum is tested for 720 h.
- After the test period, compare the test plates exposed to the insulation to the control plates exposed to sterile cotton for severity of corrosion.

Preparing a 15 % potassium hydroxide (KOH) for 15 min immersion

INDUSTRY ISSUES WITH ASTM C665:

- Chemicals required to perform this test are toxic and require special handling and storage.
- Finding a laboratory that is capable and willing to run this very time consuming test can be very difficult.
- Cotton is processed differently today than cotton processed when this test method was developed making it virtually impossible to cause corrosion caused by the cotton which makes the visual comparison difficult to determine the insulation's CUI potential.

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ASTM C1617 ACCELERATED CORROSION TEST METHOD

Due to the inherent problems associated with the C665 corrosion test, in 2005 ASTM developed and issued the new ASTM C1617 Standard Practice for Quantitative Accelerated Laboratory Evaluation of Extraction Solutions Containing Ions Leached from Thermal Insulation on Aqueous Corrosion of Metals." This test method can be used to measure the corrosion rate of steel when exposed to liquid extracted from an insulation material and them deposited directly on a coupon. This extraction contains chlorides and other chemicals leached from the insulation material.

ASTM C1617 CORROSION OF METALS APPARATUS

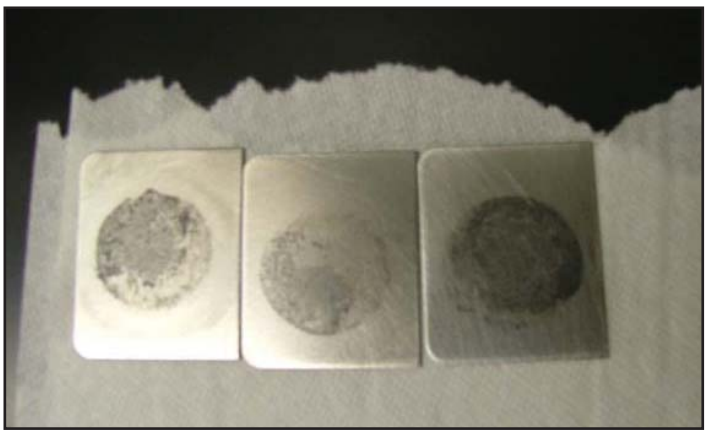
Test Apparatus

ASTM C1617 TEST IN PROGRESS

Boiling off the Extractions

This procedure is a quantitative accelerated laboratory evaluation of the influence of extraction solutions (ASTM C871). However, some products cannot be tested by this method because the solids in the extract plug the filters. The initial solution for CUI comparison is DI water. The insulation extraction solutions used in the test can be altered by the addition of corrosive ions. The test method allows for other standard solutions to be used as reference solutions and controls, in order to provide a means of calibration and comparison. This procedure can be used to evaluate almost all types of thermal insulation and fireproofing materials. The cleaning procedure of the test coupons is important to determine the accurate weight lost due to corrosion. Physical weighing of the test coupons, before and after, to three decimal places provides an accurate CUI determination.

ASTM C1617 Test Coupons After Cleaning



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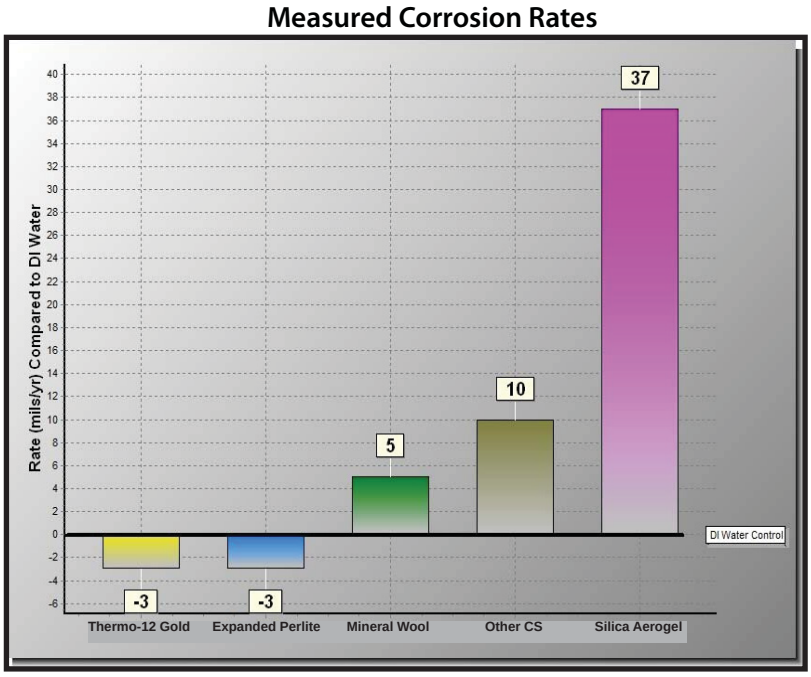

FIGURE 1
Corrosion rate(Mils/Year) of Carbon Steel compared to the corrosion caused by DI water

Corrosion rate less than zero indicates the rate of the tested materials with XOX were less than the rate caused by DI water

This method allows the laboratory to compare accelerated corrosion rates, between different insulation materials and between different corrosive agents. By using DI water as the control solution, the test can show a comparison of the ability of the tested insulations to inhibit corrosion. Figure 1 shows the mills/year difference caused by liquids leached from insulation compared to the corrosion rate caused by DI water that was used as a control. If the corrosion rate in mills/year falls below zero, then the insulation inhibited corrosion. Notice that the corrosion rate for Thermo-12 Gold is below zero indicating that Thermo-12 Gold inhibited the corrosion rate by the DI water control. The corrosion rate for the other materials, other than the expanded perlite, are well above zero indicating they did not inhibit CUI.

ASTM C1617 TEST RESULTS:

- C1617 Accelerated Corrosion Rate Results Thermo-12 Gold with XOX measured corrosion rate was less than the corrosion caused by DI Water.
- Thermo-12 Gold with XOX inhibits CUI.
- Expanded perlite corrosion rate was less than the corrosion caused by the DI water control so expanded perlite inhibits CUI.
- The corrosion rates for other manufactured calcium silicates, mineral wool and two samples of flexible silica aerogel materials were much higher than the corrosion rate caused by DI Water.
- These insulation materials DO NOT inhibit corrosion of carbon steel.

Calcium Silicate Insulations
Calcium silicate insulations in general have been regarded as having a poor performance when used over austenitic stainless steel or carbon steel. The objective of this report is to set the record straight about the corrosion inhibiting performance of Thermo-12 Gold with XOX

Industrial Insulation Group's Thermo-12® Gold with
Industrial Insulation Group has incorporated a unique formulation and process that inhibits corrosion on the surface of steel pipe and equipment.

- The XOX feature is unique to all Industrial Insulation Group's Thermo–12 Gold Calcium Silicate materials.
- XOX was not a feature of historical brands of calcium silicates.
- XOX functions for the life of the insulation product, unaffected when the process is cycled from ambient temperature to 1200°F (650°C).

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PROVING XOX Corrosion Inhibitor WORKS

The ASTM C692 "Standard Test Method for Evaluating the Influence of Thermal Insulations on External Stress Corrosion Cracking Tendency of Austenitic Stainless Steel" was chosen because of its long history and ease of evaluating surface corrosion. The objective was to evaluate the potential of CUI from Thermo-12 Gold with XOX and other high-temperature insulation materials and to determine if the corrosion inhibitor has any effect on CUI.

The test procedure used ASTM C692 test method but substituted Carbon Steel for Stainless Steel "U" shaped coupons. Test condition of the insulation samples was as received, "out-of-the-box" and after "heat treatment". Prior to testing, samples were submerged in the test solution as required by ASTM C1511. The insulation samples sit on top of the coupon and DI water was dripped on top of the insulation as required in the C692 test method. The following insulation materials were tested.

- Thermo-12 Gold with XOX Pipe Insulation
- Expanded Perlite Pipe Insulation
- Mineral Wool Pipe Insulation
- Needled "E" Glass Pipe Insulation
- Flexible Silica Aerogel Blanket

Although the C692 test method was designed to evaluate Stress Corrosion Cracking of Austenitic Stainless Steel, it was modified to use carbon steel coupons to make a quick, direct comparison of corrosion under insulation of various products. For this test program, the steel coupons were made from 16 gage, carbon steel which were cut to 7 x 2 inches, sanded and cleaned to eliminate any oxides or surface contaminates, then bent into a "U" shape. A piece of block or pipe insulation material was cut to fit the coupon, submerged under DI water for 15 minutes, removed, wiped dry and placed on top of the steel coupon. The steel coupon is placed on a 1½ inch, 205°F to 212°F hot pipe facing down. Figure 2 shows the blocks of insulation resting on top of the steel "U" shaped carbon steel coupon. Liquid is dripped on top of the insulation at a constant rate for the entire test time period.

DI water and a solution containing 300 ppm chloride were used as corrosive agents. The 300 ppm chloride solution was used to simulate the accelerated effects of the industrial environment. Tests were done on "as received" insulation and on insulation that was exposed to heat to simulate in service conditions. The corrosive agents were introduced by dripping them on top of the insulation material and allow the liquid to wick through insulation materials. If the insulation did not wick, the material was sliced into 2 pieces and the liquid was dripped on top of the two pieces.

Figure 2 – Sample of insulation resting on top of steel "U" bend coupons. This is the procedure specified in the ASTM C692 test method.

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ASTM C692 CUI TEST METHOD RESULTS WITH DI WATER

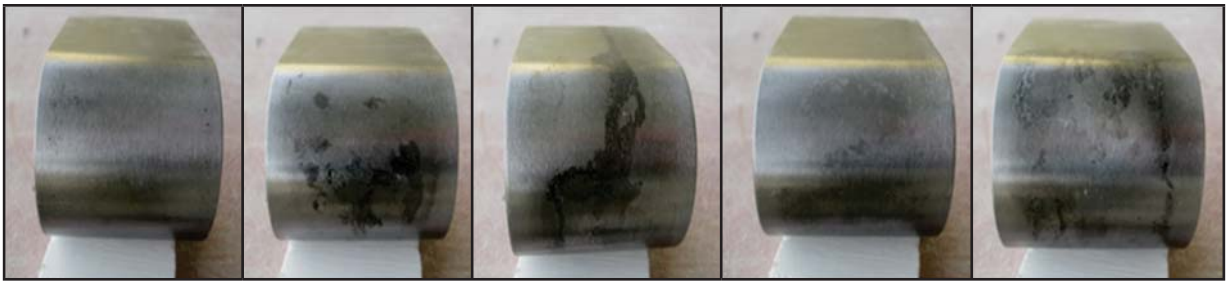
"OUT-OF-THE-BOX, 28 DAY TEST"

THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

"24 HOUR HEAT SOAK 450°F, 6 DAY TEST"

THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

"24 HOUR HEAT SOAK 800°F, 6 DAY TEST"



THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

Two additional tests were added to the DI water evaluation. These tests required heat soaking the insulation samples prior to the DI test solution to check the ability of the insulation to provide protection after externally induced heat. Second and third test samples were conditioned by heat soaking for 24 hours at 450°F or 800°F accordingly, as were the fifth and sixth samples.

SALT CONTENT OF RAIN:

At the 2006 Fall Meeting of the American Geophysical Union, professors Lawrence, Gedzelman & Padilla of the USM Gulf Coast Research Laboratory, presented their paper "Salt Content and Oxygen Isotope Ratios of Rain as Indices." Findings of their tests show that "for most storms chloride concentrations (3.5 to 11 ppm) fell in the same range as those of average coastal rainfall. For two storms, George '98 and Katrina '05, the chloride concentrations were 25 and 50 ppm respectively."

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ASTM C692 CUI TEST METHOD
RESULTS WITH 300 PPM CL WATER

"OUT-OF-THE-BOX, 28 DAY TEST"

THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

"24 HOUR HEAT SOAK 450°F, 6 DAY TEST"

THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

"24 HOUR HEAT SOAK 800°F, 6 DAY TEST"

THERMO-12 GOLD | NEEDLED "E" GLASS | FLEXIBLE SILICA AEROGEL BLANKET | EXPANDED PERLITE | MINERAL WOOL

TEST WITH ACCUMULATED RAIN SALT CONTENT:

To represent the accumulated effects of the salt content in rain water, an additional test was added to the evaluation by using salt water as a test solution to check the ability of the insulation to provide some protection from externally induced chloride.

The corrosive solution was 300 ppm chloride or approximately 1% of the salt content of seawater or the accumulation of 5 to 10 exposures to rain. This test was terminated after 6 days due to the amount of corrosion.

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CUI EVALUATION – RESULTS

Thermo-12 Gold with XOX inhibitor properties does not change as the temperature increases. "Out-of-the-Box" Thermo-12 Gold inhibits CUI caused by DI and salt water and continues to inhibit CUI after the insulation has been exposed to heat. Mineral Wool, Needled "E" Glass and Flexible Silica Aerogel Blanket allowed more CUI with DI Water, salt water (chloride solution) and with increasing temperature.

There was a significant increase in surface corrosion at all test conditions for Mineral Wool, Needled "E" Glass and Flexible Silica Aerogel Blanket as compared with Thermo-12 with XOX.

ASTM C692 Test results confirmed the CUI performance by insulation materials per the ASTM C1617 "Standard Practice for Quantitative Accelerated Laboratory Evaluation of Extraction Solutions containing Ions Leached from Thermal Insulation on Aqueous Corrosion of Metals"

EVALUATION ANALYSIS RESULTS:

- XOX is a long-term inhibitor that is only present in IIG Thermo-12 Gold. Thermo-12 Gold with XOX will inhibit corrosion of both stainless steel and carbon steel.
- XOX ability to inhibit CUI is not affected by heating.
- XOX is activated when the insulation is exposed to water and it remains in the insulation after it dries out.

CONCLUSION: Thermo-12 Gold with XOX delivers consistent performance throughout the life of the system:

- Thermal Performance
- Proven Durability
- Added CUI protection
- Added fire protection

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