CORROSION OF METALS UNDER THERMAL INSULATION

ASTM-STP 880

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The Society is not responsible, as a body,
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Foreword

The symposium on Corrosion of Metals Under Thermal Insulation was presented at San Antonio, TX, 11-13 Oct. 1983. The symposium was sponsored by ASTM Committees C-16 on Thermal Insulation and G-1 on Corrosion and by the National Association of Corrosion Engineers, the Institution of Corrosion Science and Technology, and The Materials Technology Institute of the Chemical Process Industries. Warren I. Pollock, E. I. du Pont de Nemours and Company, and Jack M. Barnhart, Thermal Insulation Manufacturers Association, presided as chairmen of the symposium and are editors of this publication.

Related ASTM Publications

Atmospheric Corrosion of Metals, STP 767 (1982), 04-767000-27

Atmospheric Factors Affecting the Corrosion of Engineering Metals, STP 646 (1978), 04-646000-27

Chloride Corrosion of Steel in Concrete, STP 629 (1977), 04-629000-27

A Note of Appreciation to Reviewers

The quality of the papers that appear in this publication reflects not only the obvious efforts of the authors but also the unheralded, though essential, work of the reviewers. On behalf of ASTM we acknowledge with appreciation their dedication to high professional standards and their sacrifice of time and effort.

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Contents

Introduction

Very serious corrosion problems can occur to plant equipment, tankage, and piping components that are thermally insulated if the insulation becomes wet. Many companies have had to repair or replace major pieces of equipment at considerable expense. At one chemical process plant alone, the cost was reported to be in the millions of dollars.

On carbon steels, the corrosion is usually of a general or pitting type. On austenitic stainless steels, the corrosion is almost always chloride stress corrosion cracking. It is an insidious problem. The insulation usually hides the corroding metal and the problem can go undetected for years until metal failure occurs. This sometimes occurs five or more years after the insulation becomes wet.

Insulation materials received from manufacturers and distributors are dry, or nearly so. Obviously, if they remain dry there is no corrosion problem. So, the solution to the corrosion under wet insulation problem would appear to be fairly obvious: keep the insulation dry or protect the metal.

Unfortunately, application of these solutions is not that simple. Insulation can get wet in storage and field erection. Weather barriers are not always installed correctly or they are not effective in fully preventing water ingress. Weather barriers and protective coatings get damaged and are not maintained and repaired.

To further complicate the problem, it appears that the degree of corrosion when an insulation gets wet is dependent on the type of insulation. Some insulations contain elements that promote corrosion, such as chloride stress corrosion cracking of austenitic stainless steels.

Inspection for the problem is often difficult. Good inspection techniques to determine that the insulation is wet or that the metal surface is corroded or stress cracked have not been widely available.

Many companies have developed the practice of applying a protective coating to steels to keep moisture from contacting the metal. Some do this only for carbon steels, some only for stainless steels, some for both. What coatings to use have varied considerably from one plant site to another.

Wet insulation is significantly less thermally efficient than dry insulation. This alone should be a high driving force for keeping insulation dry, but, interestingly, this has not been the case on many plant sites.

Little has appeared on this overall problem in the literature, and there has not been a major conference in North America before this one. In Nov. 1980, a conference was held in Britain on "Corrosion Under Lagging." The success of that meeting stimulated the organization of a similar type conference in the U.S.

The purpose of this conference was to provide a forum for a thorough review of the problem and the various control and inspection methods being used and under development. Because the problem is broad based, several technical societies were cosponsors: ASTM Committee C-16 on Thermal Insulation and Committee G-1 on Corrosion; the National Association of Corrosion Engineers (NACE); Materials Technology Institute of the Chemical Process Industries (MTI); and Institution of Corrosion Science and Technology, a sponsor of the British conference.

The conference was very successful with some 150 people attending. It provided high recognition to a costly problem where the solutions are many faceted, as indicated by the papers in this publication.

Warren I. Pollock

E. I. du Pont de Nemours & Co., Inc., Engineering Department, Wilmington, DE 19898; symposium cochairman and editor.

Technical Overview

Jack M. Barnhart[1]

The Function of Thermal Insulation

REFERENCE: Barnhart, J. M., **"The Function of Thermal Insulation,"** *Corrosion of Metals Under Thermal Insulation, ASTM STP 880*, W. I. Pollock and J. M. Barnhart, Eds., American Society for Testing and Materials, Philadelphia, 1985, pp. 5-8.

KEY WORDS: corrosion, insulation, energy, chlorides, stress corrosion

Thermal insulations or thermal insulation systems are usually defined as materials or combinations of materials that retard the flow of heat energy by conductive, convective, or radiative modes of transfer or a combination of these. In order to be effective, they must be properly applied.

Primarily, thermal insulation serves one or more of the following functions:

1. Conserve energy by reducing heat loss or gain of piping, ducts, vessels, equipment, and structures.
2. Control surface temperatures of equipment and structures for personnel protection and comfort.
3. Facilitate temperature control of a chemical process, a piece of equipment, or a structure.
4. Prevent vapor condensation at surfaces having a temperature below the dew point of the surrounding atmosphere.
5. Reduce temperature fluctuations within an enclosure when heating or cooling is not needed or available.

Thermal insulations may also serve additional functions:

1. Add structural strength to a wall, ceiling, or floor section.
2. Provide support for a surface finish.
3. Impede water vapor transmission and air infiltration.
4. Prevent or reduce damage to equipment and structures from exposure to fire and freezing conditions.
5. Reduce noise and vibration.

[1] Thermal Insulation Manufacturers Association, 7 Kirby Plaza, Mt. Kisco, NY 10549.

Thermal insulation is used to control heat flow in temperature ranges from near absolute zero through 1650°C (3000°F) and higher. Insulations normally consist of the following basic materials and composites:

(1) inorganic, fibrous or cellular materials such as glass, asbestos, rock or slag wool, calcium silicate, bonded perlite, vermiculite, and ceramic products.
(2) organic fibrous materials, such as cotton, animal hair, wood, pulp, cane, or synthetic fibers, and organic cellular materials, such as cork, foamed rubber, polystyrene, polyurethane, and other polymers.
(3) metallic or metalized organic reflective membranes (which must face air, gas-filled, or evacuated spaces).

The structure of mass-type insulation may be cellular, granular, or fibrous, providing gas-filled voids within the solid material that retard heat flow. Reflective insulation consists of spaced, smooth-surfaced sheets made of metal foil or foil surfaced material that derives its insulating value from a number of reflective surfaces separated by air spaces.

The physical forms of industrial and building insulations are

(1) loose fill and cement,
(2) flexible and semirigid,
(3) rigid,
(4) reflective, and
(5) foamed in place.

Depending on design requirement, the choice of a particular thermal insulation may involve a set of secondary characteristics in addition to the primary property of low-thermal conductivity. Characteristics, such as resiliency or rigidity, acoustical energy absorption, water vapor permeability, air flow resistance, fire hazard and fire resistance, ease of application, applied cost, or other parameters, may influence the choice among materials having almost equal thermal performance values.

Some insulations have sufficient structural strength for use as load-bearing materials. They may be used occasionally to support load-bearing floors, form self-supporting partitions, or stiffen structural panels. For such applications, one or more of the following properties of an insulation may be important: strength in compression, tension, shear, impact, and flexure. These temperature dependent mechanical properties vary with basic composition, density, cell size, fiber diameter and orientation, type and amount of binder (if any), and both temperature and environmental conditioning.

The presence of water as a vapor, liquified or solid in insulation will decrease its insulating value; it may cause deterioration of the insulation and eventual structural damage by rot, corrosion, or the expansion action of freezing water. Whether or not moisture accumulates within the insulation depends on the hygroscopic properties of the insulation, operating temperatures, ambient conditions, and the effectiveness of water vapor retarders in relation to other vapor resistances within the composite structure.

The moisture resistance depends on the basic material of the insulation and the type of physical structure. Most insulations are hygroscopic and will gain or lose moisture in proportion to the relative humidity of the air in contact with the insulation. Fibrous and granular insulations permit transmission of water vapor to the colder side of the structure. A vapor retarder should therefore be used with these materials where moisture transmission is a factor. Other insulations having a closed cellular structure are relatively impervious to water and water vapor. Properties that express the influence of moisture include: absorption (capillarity), adsorption (hygroscopicity), and the water vapor transmission rate.

Other properties of insulating materials that may be important, depending upon the application, include: density; resilience; resistance to settling; permanence; reuse or salvage value; ease of handling; dimensional uniformity and stability; resistance to chemical action and chemical change; ease in fabricating, applying, or finishing; and sizes and thickness obtainable.

In some specific applications, thermal insulation is called on to perform another function, namely, to retard chloride induced stress corrosion.

An inherent characteristic of austenitic stainless steel is its tendency to crack at stress points when exposed to certain corrosive environments. The mechanisms of stress corrosion cracking are complex and incompletely understood, but apparently related to certain metallurgical properties. Chloride ions concentrated at a stress point will catalyze crack propagation. Other halide ions are also suspect.

Chlorides are common to most environments, so great care must be taken to protect austenitic stainless steels. Water, dust and soil, process liquids, chemical fumes, even the air in coastal regions, contain chlorides in measurable, and thus additively significant quantities.

Most thermal insulations will not, in themselves, cause stress corrosion cracking as may be shown by tests. However, when exposed to environments containing both chlorides and moisture, insulation systems may act as collecting media, transmigrating and concentrating chlorides on heated stainless steel surfaces. If, however, moisture is not present, the chloride salts cannot migrate, and stress corrosion cracking will not take place.

Insulations may also be specially formulated to inhibit stress corrosion cracking in the presence of chlorides through modifications in basic composition or incorporation of certain chemical additives. Stress corrosion cracking is a metallurgical shortcoming of austenitic stainless steel. It is unrealistic to expect an insulation to overcome this shortcoming. If the conditions are such that stress corrosion cracking will occur, then, the very best an insulation could hope to do is delay the inevitable. This is demonstrated by the occurrence of stress corrosion cracking under insulations that were mostly sodium silicate, a known "inhibitor." Stress corrosion cracking under insulations is not a simple insulation problem; to quote from William G. Ashbaugh of Union Carbide in a paper presented to the National Association of Corrosion Engineers:

> The inhibition of insulation by the addition of neutralizers or other agents to the insulation is insufficient protection against externally introduced chlorides which are the major source of stress corrosion cracking.

and from later in the paper:

> The author does not claim that insulation materials cannot or will never cause stress corrosion cracking, but plant experience and laboratory screening tests indicate that most insulation materials which remain relatively dry play only a secondary role in stress corrosion cracking. The real problem in chemical plants exists as a result of the combination of corrosive atmosphere and the many types of crevices, joints, and areas where atmospheric chloride contamination and concentration can occur.

The real problem and need of insulation manufacturers is to inform the users of the "real problem" and ways to address it. The insulation cannot and should not be forced to overcome the shortcomings of austenitic stainless steel when used in real world environments.