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ABSTRACT:

Corrosion Under Insulation (CUI) is a very serious problem impacting the oil and gas, petrochemical, power and heavy industries. Due to the high costs associated with CUI, many industries have begun abandoning conventional jacket insulation. Recent advancements in trade association standards have helped engineers select, apply and inspect different types of insulative coatings in lieu of conventional jacket insulation. New insulative coating standards by NACE(1) are helping to minimize corrosion costs while simultaneously improving insulation efficiency with a side benefit of personnel protection. However not all insulative coatings are made to address the same challenges. By differentiating between process and solar heat, engineers can correctly specify insulative coatings which are fit for purpose. This distinction can also help determine the correct application thickness, method and cost. The choice of thickness and type of insulative coating is critical for the end users to receive the perceived benefits they wish to achieve. In the quest for insulation optimization, a variety of insulative coatings are now a proven alternative to conventional jacket insulation.

Key words: CUI corrosion under insulation, insulation, personnel protection, insulative coatings, process heat, solar radiant heat

INTRODUCTION:

Conventional insulation systems such as calcium silicate, perlite, fiberglass, mineral wool, polystyrene, etc suffer from CUI challenges. Since there are many types of insulative coatings, there is no one standard definition for an insulative coating. Not all insulative coatings provide corrosion under insulation and personnel protection. The specific asset to be protected pre-determines the type of insulative coating which will be specified. A typical oil and gas or industrial facility will contain a mixture of processes which are using insulation to mitigate heat loss (heaters, steam pipes, furnaces) or trying to block solar heat gain (tanks, coolers, buildings). The direction of the heat source plays a vital role in selecting an insulative coating which is fit for purpose. For example, tanks storing light hydrocarbons such as LNG tanks are prone to evaporation/boil off resulting from solar heat gain. Whereas, tanks storing hot cargo need to reduce heat lost to the atmosphere. Therefore, the first step in identifying which type of insulative coating to specify is to actually identify the heat source itself, process or solar. Or in other words, keeping Solar radiation heat (mainly visual and infrared) from loading onto and absorbing into a surface to maintain a cooler interior. On process heated units, insulative coatings are designed specifically to minimize heat loss from the exterior surface. The old practice of slowing heat flowing off the exterior surface is only losing heat and nothing more. The more that the heat is allowed to release from the surface, the less insulation effect/benefit you can have. Thus, insulative coatings offer a more efficient method of minimizing heat loss by retaining more heat inside the unit.

(1) NACE – National Association of Corrosion Engineers

FORMULATIONS:

According to Polaris Market Research, the worldwide thermal insulation coating market is anticipated to reach around $13,189 million by 2026. [1] In 2017, the acrylic segment dominated the global market in revenue, with Asia Pacific accounting for the majority share of the global thermal insulation coating market.[1] While acrylic formulations dominate sales, other options are also available for specialized applications and climatic conditions. Where the acrylic formulations have temperature limitations, third generation polysiloxanes can be applied on both elevated and refrigerated temperatures of -60 to 400 °C (-76 to 752 °F)[2]. As the market for insulative coatings expands, additional formulations targeting specific industries will become readily available to all. Therefore, specifying the proper formulation for the specific asset is the second vital step in selecting an insulative coating which is fit for purpose.

IDENTIFYING ASSETS FOR INSULATIVE COATING APPLICATIONS:

Assets requiring hot (or cold) insulation system are normally defined by the system designer. Once the asset is identified, the system designer specifies the target service parameters, and with the insulation system specialist reviews and defines the specific candidate hot/cold insulation systems. Testing and selection optimization of the candidate systems follows. Review of service performance of existing hot/cold insulation systems, life-cycle cost, as well as review of published performance data, and risk assessment are an integral part of the candidate system selection process. With assistance of Corrosion Engineering Specialist, methods and means of prevention of CUI are reviewed and incorporated into the asset service management system. NACE SP 21431 – 2020 [3] "Test Methods to Evaluate Thermal Properties and Performance of Insulative Coatings" states, Insulative coatings are often used to provide thermal insulation and personnel protection against burns to skin and to improve process stability during rapid changes in climatic conditions. Since they are liquid coatings, they can easily be applied to irregular shaped objects used in hot services. In combination with an anticorrosive primer, these coatings also provide corrosion protection to minimize corrosion under insulation (CUI).[3] In addition to oil and gas, thermal insulation coatings are used in various end-use industries such as manufacturing, automotive, construction, aerospace, and defense among others.[1]

For existing assets suffering from repeated shutdowns, sometimes the best prevention of CUI is no insulation at all. As such, any insulation that is not required for heat/cold conservation, personnel burn protection, condensation prevention, or acoustic control should be permanently removed.[4,5] Rigorous front-end engineering and proper insulation specifications can greatly reduce CUI risk and life cycle cost.[4,5] Justification of insulation should be done both during design and after a facility is operating to ensure insulation coverage is optimized. After a facility is in operation, it is important to verify assumptions made during design, determine if any insulation can be removed permanently, and verify insulation was installed per specification.[4,5] An inspection and maintenance plan for insulation will increase short-term cost, but can greatly reduce long-term CUI risk as well as HSE incidents, production and repair costs associated with potential loss of primary containment (LOPC).[4,5] Optimizing insulation requires a balance of conventional insulation, different types of insulative coatings and sometimes no insulation at all.

INSULATIVE COATINGS:

Insulation used to limit the heat lost to or gained from the environment is a very common type of heat/cold conservation. Certain ASTM[(2)] tests related to conduction and reflectivity now allow for more detailed testing of various types of insulative coatings. Test Methods to Evaluate Thermal Properties and Performance of Insulative Coatings NACE SP21431-2020[3] attempts to build on

[(2)] ASTM – American Society for Testing and Materials industry consensus for testing used to evaluate the performance of different types of insulative coatings. For the purposes of this paper, we will differentiate between process heat applications which generally requires a thicker film application above 1mm (39.37 mils) DFT, compared to solar radiation applications which generally requires a thin film application of coating up to 1mm (39.37 mils) DFT. Specifying the correct type of insulative coating is critical to selecting an insulative coating which is fit for purpose.

THICK FILM – INSULATIVE COATING FOR PROCESS HEAT LOSS MITIGATION:

NACE SP 21431-2020[3] lists ASTM C177[6] which measures Thermal Conduction. NAIMA[(3)] (North American Insulation Manufacturers Association) has used ASTM C177[6] to establish an R-Value by sandwiching conventional insulation materials between a hot plate at 23.89 °C (75 °F) and a cold plate at -3.89 °C (25 °F) and registering how much time it takes to raise the cold side by 1 degree F. In essence, the R-value is a time-based formula. It calculates how long it takes for the heat to transfer from point A to point B through the insulation material. However, for insulative coatings, ASTM C177 only measures thermal conduction in a steady state equation. Therefore, comparisons between conventional insulation and insulative coatings are not appropriate due to the fact that insulation coatings are typically not thicker than 25.4mm (1 inch). The traditional form of ASTM C177 is the preferred method for measuring Thermal Conduction for insulative coatings, since insulative coatings do not have an R-Value.

THIN FILM – INSULATIVE COATING FOR SOLAR RADIANT BARRIER:

NACE SP 21431-2020[3] lists ASTM E408[7] and ASTM E903[8] which calculates a coatings emissivity and reflectivity. Reflectivity and emissivity deal with radiation which is completely different from conduction related to other forms of heat transfer. Where conduction is measuring “how fast” heat moves, testing related to emissivity and reflectivity is measuring “how much” heat is absorbed and then transferred through a material. It is important to note that ASTM E408[7] and E903[8] are known as a single light beam bounce. The building industry through the CRRC[(4)] (Cool Roof Rating Council) and Energy Star[(5)] uses a different version of these tests, considered more representative when testing emissivity and reflectivity on structures such as roofing. These tests are ASTM C1371[9] for emissivity and ASTM C1549[10] for reflectivity. Depending on the asset to be protected, some organizations will prefer to specify testing from CRRC. Note that reflectivity testing is measuring short wave visual light and does not consider all nanowaves of heat including infrared radiation. When reviewing these tests, additional ASTM, laboratory, and field testing is needed to fully understand the ability of a coating to repel “actual heat” from the surface facing the sun, not just the light bounce.

ENVIORNMENTAL FACTORS:

Climate is another important factor when specifying insulative coatings. An oil and gas facility in Siberia differ from Saudi Arabia in evaluating the requirements for insulative coatings. A colder climate will use thicker film, process heat related insulative coatings as opposed to solar radiation barrier coatings. Cold climates facilities are less concerned with solar radiation heat as opposed to heat loss mitigation. Conversely, the hot climate conditions will generally utilize more thin film solar radiation barrier coatings and while they may use thick film insulative coatings they will generally require less thickness as compared to the colder climates. Environmental factors also impact curing rates. Acrylic water based coatings generally cure

(3) NAIMA- North American Insulation Manufactures Association
(4) CRRC – Cool Roof Rating Council
(5) Energy Star

faster with higher temperatures and lower humidity. Digital moisture meters can be used to test the moisture level before top coating acrylic based insulative coatings.

ADDITIONAL OPTIONS FOR APPLICATION:

There are scenarios where conventional insulation jacket and a solar radiant barrier can be used together to create a longer lasting, higher performing insulation system. The exterior of existing jacket insulation on cold pipes for example can be top coated with a thin film solar radiant barrier to reduce the "initial heat load" and heat transfer into the cooler side. Another option is to replace the conventional jacket insulation with a thick film insulation coating and then topcoat the thick film with a thin film that blocks out most of the initial heat load and therefore reduces the amount of heat available for transfer to the conduction resistant coating. The thin film reduces solar heat load, while the thick film slows heat transfer. Recent experiments have also been conducted on thick film insulative coatings for below grade piping, which can reduce cathodic shielding, when paired with a fusion bonded epoxy primer and water resistant topcoat.

CORROSION UNDER INSULATION & PERSONNEL PROTECTION:

When corrosion under insulation and/or personnel protection is the primary concern, a thick film insulative coating is recommended. Thin film insulative coatings simply do not have the same type of body and temperature resistance as compared to the thick film insulation coatings which are generally designed for CUI and personnel protection. ASTM B117[11] can be used to test for corrosion resistance of insulative coatings which have not yet been placed into service. Once in service at elevated temperatures, the corrosion mechanisms may be different and not suitable for atmospheric coatings. NACE TM21423[12] is specifically written for personnel protection based on ASTM C1055[13] which allows for a 5 second touch rule up to 59 °C (138 °F) which is the start of a 1st degree burn.

CONCLUSION:

Selecting the proper insulative coating depends on the specific asset to be protected. External factors such as the climate play a crucial role in selecting an insulative coating including the appropriate dry film thickness. Thin film insulative coatings tested for reflectivity and emissivity generally do not have the same level of corrosion protection as thick film insulative coatings, but can block solar heat gain, an important characteristic for tanks storing light hydrocarbons which are prone to evaporation / boil off. Thick film insulative coatings provide insulation, CUI protection and personnel protection in a single system. In some applications, the combination of both thick film and thin film coatings offers unparalleled performance.

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