Insulation, the Forgotten Technology for Energy Conservation

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ABSTRACT

Mechanical insulation is a proven technology that can provide an unrivaled return on investment. Yet, despite the overwhelming evidence insulation is often overlooked and undervalued as a primary means for energy conservation in the new construction and maintenance segments of the building – commercial and industrial industries. Why? This paper explores the answer to that question and provides evidence as to the power of insulation for energy conservation, reducing greenhouse gas emissions and other operational cost reduction initiatives.

Introduction

Insulation is the "Rodney Dangerfield" of the construction industry – it gets very little respect and is taken for granted. When designed, applied and maintained properly, insulation is a powerful energy conservation technology — one that provides long lasting benefits. However, insulation is often overlooked or relegated to the bottom of the list and ignored. One reason may be that insulation systems have no moving parts, no bells and whistles, no computer chips, or fancy gauges — and, it certainly is not sexy. The principles of insulation are simple and not necessarily revolutionary – another reason why it is often overlooked. However, the bottom line is that insulation can often provide an annual return on investment of greater than 100%. With energy efficiency a major priority, it's time to begin thinking differently about this under-valued and under-appreciated technology and its contribution to energy conservation.

The knowledge base of mechanical insulation systems at the engineering, architectural, and facility owner level has, in most cases, decreased over the last fifteen or twenty years. The root cause can be summarized as a by-product of the corporate world's drive for profits today, right sizing, multi-tasking, etc. Regardless, the fact remains that insulation is not a field that is attracting specialization in the engineering, architectural or maintenance arenas. This reduced knowledge base has led to the improper or under- utilization of mechanical insulation in many applications.

The scope of this paper focuses upon "Mechanical Insulation Systems" — insulation systems that are utilized for piping, equipment, vessels, ducts, boilers and other similar mechanical equipment/piping applications.

While the most widely recognized benefits of mechanical insulation are energy conservation and process control, there are a number of additional benefits such as condensation control, reduced greenhouse gases, personnel protection, an improved workplace environment and a contribution to sustainable development. This paper will examine all the benefits – or what is referred to as the "Power of Insulation."

Energy Conservation

Energy is often one of the most costly components of operating a manufacturing facility and its processes. A reduction in energy consumption reduces cost. Without exception, this is a continual objective of most companies. It may not be at the top of the list, but certainly within the top ten of corporate initiatives, along with safety, quality, shareholder value, and the environment. While insulation can be one of the easiest, fastest and least costly "technologies" to reduce energy cost, it is often the last option considered.

Energy Conservation Seldom a Design Criteria

It is interesting to review the process for determining the design criteria for insulation on new construction or expansion projects verses the maintenance process and how priorities are established. In new construction, the primary driver in determining the insulation system is the process, which is the way it should be. Very seldom is the insulation system or thicknesses examined from an energy conservation perspective. Once a plant is operating and the energy consumed is a reality, as opposed to a theory, it seems that compliancy or acceptance of the results outweighs examining actual results in comparison to original expectations.

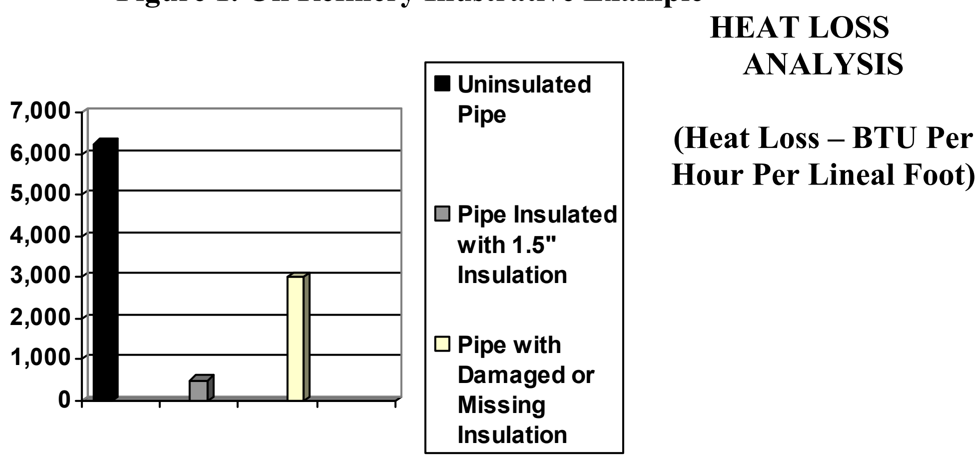
Return on Investment (ROI)

The return on investment with an insulation initiative usually exceeds expectations. Many times the return is less than a year. It can provide a faster return than many of the fancier and more visible energy efficiency investments. In today's competitive and shareholder-driven bottom line world, insulation can make a difference. But, it is not normally a Board Room discussion. Maybe it should be? Was your insulation system designed for 1977 or 2007? – You may be missing a significant investment – return on investment opportunity.

Damaged or Missing Insulation Can Significantly Lower ROI

It has been estimated by some insulation industry participants that between 20 – 30% of all installed mechanical insulation is either damaged or missing. An article in the National Insulation Association Insulation Outlook, entitled "*How Many Barrels of Oil Can Insulation Save,"* contained a heat loss analysis of a "typical" insulated piping system in an oil refinery comparing the heat loss from uninsulated piping to that of both insulated piping and piping with 21% of the pipe insulation damaged or missing (see Figure 1). With 21% of the pipe insulation missing or damaged, only 52% of the potential heat loss savings, BTUs per hour, were being obtained. This is big number – even if you discount it by 50%. The question that must be asked is why does this condition exist when it can be corrected and provide a significant return on the capital employed or maintenance dollars expended?

Figure 1. Oil Refinery Illustrative Example



This "typical" oil refinery example equated to 400,000 lineal feet of piping with missing or damaged insulation, which, in turn, equated to 5,800 barrels of oil being lost per day — or at $60.00 barrel, $348,000 lost per day. These are huge numbers in any industry!

Program Identifies Opportunities for Improving Energy Efficiency

Other examples of energy inefficiency can be found within the Department of Energy (DOE) – Industrial Technologies, "Save Energy Now" (SEN) Program. The program is part of a national campaign by the DOE to help manufacturing facilities reduce energy and operating costs and operate more efficiently and profitably. Independent specialists who have been trained in the utilization of sophisticated software assessment tools and have passed a rigorous qualifying exam, visit a plant and work with personnel to identify immediate and long-term opportunities for improving energy efficiency and bottom-line results. Mechanical insulation is one of the many opportunities that are examined.

Of the SEN assessment studies published to date, 51% have identified replacing, repairing and upgrading the mechanical insulation as an opportunity of which 81.5% have estimated a return on investment in less than a year. Annual dollar savings in some studies were approaching $1,000,000 and many exhibited returns in less than 4 months.

Assessments Use 3E Plus® Software

The "Save Energy Now" program assessment specialists use the 3E Plus® software program to analyze mechanical insulation. 3E Plus® is specifically designed to help the user understand and quantify the effects and benefits of insulation vs. bare surfaces. The "3E" part of the 3E Plus® name is an acronym for Energy, Environment and Economics, the three major features of the program that was developed by the North American Insulation Manufacturers Association (NAIMA). Table 1 provides an overview of the program features, and Table 2 provides two examples of information obtained by using the program.

3E Plus® allows the user to determine energy gains or losses for a variety of surfaces, at a number of insulation thicknesses, plus understand the cost of energy loss or gain. This is accomplished by the application of the ASTM 680 Standard, *"Standard Practice for Estimate of* *the Heat Gain or Loss and the Surface Temperature of Insulated Flat, Cylindrical and Spherical Systems by the Use of Computer Programs."*

3E Plus® provides the user with a large existing database of insulation materials, costs, etc. which can be easily customized for specific insulation material, jacketing, fuels, etc. This is a valuable tool since the existing insulation materials within the 3E Plus® database utilize the ASTM values (thermal conductivity (k) and emittance) that correspond to all products within that generic group. Some insulation manufacturers offer products with better performance characteristics that the ASTM values. Using the manufacturer provided performance values gives a more accurate analysis if those materials are actually used.

The Following Are Features of the 3e Plus® Insulation Thickness Computer Program

- Determines economic thickness of insulation based on return on investment for chosen fuel cost, installed cost, tax rates, maintenance, etc.
- Calculates the amount of insulation needed for personnel protection for various design conditions.
- Calculates the thickness of insulation needed for condensation control.
- Calculates greenhouse gas emissions and reductions.
- Determines surface temperatures and heat loss/gain calculations of individual insulation thickness up to 10 inches.
- Calculates bare vs. insulated heat loss efficiency percentages for horizontal and vertical piping, ducts and flat surfaces.
- Performs calculations for various flat surfaces, selected pipe sizes and all standard iron pipe sizes from ½" to 48".
- Calculates heat loss/gain and outside insulation surface temperature for any insulation material provided the thermal conductivity, associated mean temperature, and temperature limit are entered by the user.
- Solves for outside-insulated surfaces temperatures for all types of insulation applications at different process temperatures and configurations.

The Following Examples Provide Information Obtained with the Use of the 3E Plus® Insulation Thickness Computer Program

Note: These examples are not actual illustrations of the 3E Plus® Program screens. Actual screens provide more detailed information.

<u>Example #1-Condensation Control:</u>

Conditions for calculation:

- **4" NPS Stainless Steel Horizontal Pipe**
- **40 F Process and 85 F Avg. Ambient Temperatures**
- **0 mph Average Wind Speed**
- **Relative Humidity – 85%**
- **Dew Point – 80 F**
- **Fuel Source – Electric @ $.10 /kwh**
- **Project Location – Anywhere USA**
- **Insulation – Polyiso System with PVC Jacket**

Table 1

Variable Insulation Thickness	Surface Temperature (F)	Heat Gain (BTU/ft/yr	Cost ($/ft/yr)	Savings ($/ft/yr)	CO2 Emission Reduction (lbs./ft/yr)	NOX Emission Reduction (lbs./ft/yr)	CE Emission Reduction (lbs./ft/yr)
Bare	40.1	504,000	$4.92		71.54	.160	19.50
1 inch	80.7	85,610	$0.84	$4.08	12.14	.027	3.10
1 ½ inch	82.1 (*)	64,610	$0.63	$4.29	9.16	.020	2.50
2 inch	82.8	53,170	$0.52	$4.40	7.54	.017	2.06

(*) 1 ½" minimum is required for Condensation Control

Example 2-Heat Loss – Energy Conservation & Emission Reduction:

Conditions for Calculation:

- **8 " NPS Steel Pipe**
- **350 F Process and 75 F Avg. Ambient Temperatures**
- **8 mph Average Wind Speed**
- **Fuel Source – Natural Gas @ $10/Mcf**
- **Project Location – Florida**
- **Insulation System – Mineral Wool System with Aluminum Jacket**

Table 2

Variable Insulation Thickness	Heat Loss (BTU/ft/yr)	Estimated Insulation Cost ($/LF)	Annual Cost ($/LF)	Payback Months	CO2 Emission Reduction (lbs./ft/yr)	Surface Temperature (F)
Bare	23,180,000				3,376	
1 ½ inch	1,200,000	$17.87	$18.56	1.2	174.7	101
2 inch	954,900	$21.00	$16.27	1.4	139.1	92
3 inch	679,100	$29.35	$14.76	1.6	98.2	83

The 3E Plus® Software Program is being made available to attendees of today's meeting or you can download the program free of charge at www.pipeinsulation.org.

An Investment with Few Rivals

Energy conservation with the use of properly designed, installed and maintained mechanical insulation, whether it is a hot or cold application, is simply an opportunity that should not be overlooked. Said another way, it is an investment that may have few rivals from a return perspective.

Economic Considerations

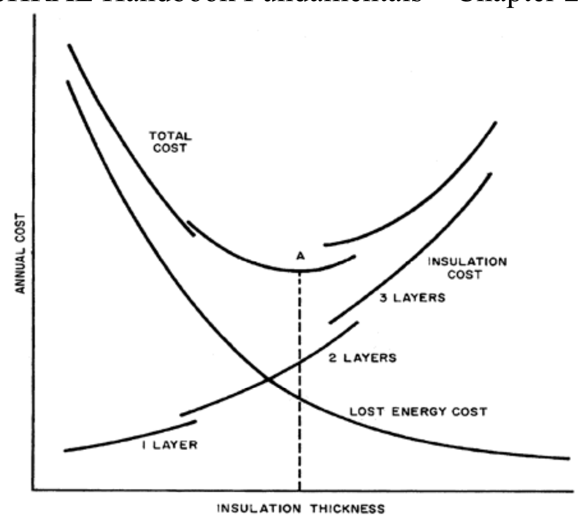
The concept of economic thickness of insulation considers the initial installed cost of the insulation system plus the ongoing value of energy savings over the expected service lifetime. The economic thickness is defined as the thickness that minimizes the total life-cycle cost (see Figure 2). The installed costs of the insulation systems increase with thickness and multilayer applications. Figure 2 also shows the present value of the "lost energy" cost over the expected life of the project, which decreases as the insulation thickness is increased. The total cost curve, which is the sum of the installed insulation cost and the present value of the lost energy cost curves, show a minimum value at Point A. This point on the total cost curve corresponds to the economic insulation thickness, which, in this example is in the double layer range.

Initially, as insulation is applied, the total life-cycle cost decreases rapidly because the value of incremental energy savings is greater than the incremental cost of insulation. Additional insulation reduces total cost up to a thickness where the change in total cost is equal to zero. At this point, no further reduction can be obtained; beyond it, incremental insulation costs exceed the additional energy savings derived by adding another increment of insulation.

An economic thickness analysis should consider the time value of money, which can be based on a desired rate of return for the insulation investment. Energy cost are volatile, and a fuel cost inflation factor should be taken into account that allows for the possibility that fuel costs may increase more quickly and higher than general inflation. Insulation system maintenance costs should also be included, along with any identifiable cost savings associated with the ability to specify lower capacity equipment or to extend the life of equipment.

Figure 2 provides a graphic overview of the cost of energy in comparison to the cost of insulation and total cost.

Figure 2: Determination of Economic Thickness of Insulation
(2005 ASHRAE Handbook Fundamentals – Chapter 26)



Process Control

Process control is one area where mechanical insulation is normally "engineered" into the process. Whether a process contains fluid, air or gas the design is to leave Point A at one temperature, or pressure, and arrive at Point B at another temperature, or be stored at a given temperature. Loss or gain in temperature or fluctuating temperatures can cause significant problems in manufacturing quality and productivity.

Insulation is a major component of the equipment and manufacturing design process. However, in many cases the system designer does not have sufficient knowledge of the various insulation systems that are available, or lacks an understanding of the mechanics of what is required to determine the correct insulation system, or material properties for the specific application. In many instances, the insulation system, or thermal value utilized, is determined by what may, or may not, have worked in the past or what is referred to in the industry as, "dusting off the old specification." In reality, many insulation systems are installed but rarely designed or engineered for the specific application.

Maintaining Insulation Systems Essential to Process Control, Energy Conservation, Etc.

One of the problems that exists in many industries is that the insulation system that has been designed, selected and installed is not being maintained in a timely and proper manner. Therefore, it would seem likely the process temperatures, pressures etc. are not being maintained as designed, or it is taking more energy in some form to maintain them, and potentially throughput or other cost has been negatively affected.

Process control, quality and product throughput, is a major consideration in all industries. Thus, properly designing, installing and maintaining the mechanical insulation system should be an integral part of both the initial design and operational /maintenance management plan. A good rule is always to "inspect what you expect."

Condensation Control

Moisture is an enemy! If the insulation system is not properly designed to maintain the surface temperature above the dew point, condensation will develop. Condensation is a real world problem that, if not corrected, can certainly lead to other real problems such as a work hazard due to moisture on the floor, and the development of mold.

Mold Prevention

Mold is a problem into today's work environment. Insulation cannot stop mold from developing but it certainly can help eliminate moisture due to condensation, which must be present for mold to develop. The insulation system must be designed to maintain the surface temperature above the dew point Prevention is normally less costly than the cure. If the insulation system is neither designed to prevent condensation under realistic adverse conditions, nor installed correctly, and/or is not maintained in a proper and timely manner, condensation can occur. There is nothing to be gained and everything to lose in not addressing the problem in an aggressive manner. Prevention, as well as timely and effective correction of the problem, will be less costly in the long run. The 3E Plus® Program Insulation Thickness Computer Program is an excellent tool for calculating the proper insulation thicknesses to prevent condensation.

Corrosion Under Insulation (Cui)

CUI is a not new and in many circles the problem is well understood. Yet, it is costing industry many millions of dollars annually. It is generally accepted that carbon steel operating in the temperature range of 25°F to 300°F is at the greatest risk. Corrosion tends to occur at those points of water entry into the insulation when the temperature is below 300°F and the piping/equipment is idle. Corrosion – stress cracking of stainless steel under insulation is primarily manifested by a combination of water and external sources of chlorides.

Carbon or Stainless Steel does not corrode because it is covered with insulation, but because moisture is present and insulation can provide an annular space or crevice for the retention of water with full access to air and other corrosive media. Insulation material may wick or absorb moisture and may increase or accelerate the corrosion rate. CUI under the right conditions is possible under all types on insulation.

If insulation does not directly cause corrosion, could maintaining the integrity of the insulation system minimize CUI and or be less expensive over time? To answer that question a life cycle cost analysis would need to be employed. Without question, removal of an insulation system and subsequent replacement of the piping/equipment and installing a new insulation system is an expensive process. Would an aggressive maintenance program combined with regular inspections be less costly over time? - An interesting question for another time.

How Moisture Penetrates an Insulation System

The primary moisture sources are rainwater, water from a wash down, roof or other equipment, piping leaks and even condensation within the insulation system, especially on dual operating systems. The most likely area of intrusion is at the insulation system penetration points – gauges, attachments etc. If the integrity or exterior of the insulation system is not installed correctly and moisture sources are present, moisture will more than likely penetrate the insulation system. The rate of moisture migration and/or wicking within the insulation system will vary depending upon the insulation system, the temperature of the operating system, and other conditions that are present.

Moisture intrusion can negatively affect all aspects of the insulation system such as thermal values, which can have a direct impact on process control, energy cost, condensation control, safety, the potential of mold development etc. Not to mention the potential of corrosion under the insulation (CUI).

Reduction of Greenhouse Gas Emissions

The reduction of energy consumption derived from the use of mechanical insulation can reduce the number of pounds of greenhouse gas emissions currently being released into the atmosphere. This benefit is not being considered in many applications. Why not? Many people do not relate the reduction of energy consumption to the reduction of greenhouse gas emissions. How do you calculate this benefit into the return on investment or decision making process? The answer will vary, depending upon the facility, carbon credits if applicable, regulatory requirements etc. However, the public relations benefit cannot be ignored, plus it is the right thing to do.

Again, the 3E Plus® Program is an excellent tool for determining the impact that insulation can have on the reduction of greenhouse gas emissions. Using the same algorithms as those used for determining energy loss or gain, 3E Plus® allows the user to determine the impact that any repair or upgrade to an insulation system can have on the reduction of emissions if fossil fuels are used for the energy source. 3E Plus® calculates CO_2, NO_X and Carbon Equivalents (CE).

Personnel Protection

The role of mechanical insulation in providing a safe work environment is very seldom ever considered. Protecting workers from coming in contact with hot or cold surfaces as well as protecting them from excessive equipment or other workplace noise should be a focus of any safety program. Yet, insulation is very seldom, if ever, on the agenda for safety meetings.

The current practice or standard is that a surface temperature above 140°F should be insulated for personnel protection. Would you want to put your hand on, or work next to a 140°F pipe or piece of equipment? The same question would apply to an area that is iced over. Considering safety first and economics second, is the current practice practical and effective? The 3E Plus® Program can provide surface temperature information with the use of various insulation thicknesses and systems.

Improved Workplace Environment

Insulation is a major component in improving facility occupant comfort and thus increasing productivity. Many studies have been conducted that confirm time and again that occupant productivity increases when indoor air quality and temperature, sound management etc. are managed within an acceptable range on a consistent basis. Again, insulation is called upon for its thermal and noise absorption properties but very seldom are the results taken into consideration when determining the return on investment.

Sustainable Design Contribution

Mechanical insulation's role in sustainable design is normally included within discussions related to heat and air conditioning or other equipment. In some cases, the size of the equipment required has been reduced due to the use of increased insulation values. Capital investment is reduced and the return increased – this is a winning combination.

Many are pursuing sustainable design certification for their building, plant etc. Certification is a very effective means to measure success. However, is thinking green and employing that philosophy as important, if not more important, than certification? Thinking, promoting and selling green can be an advantage within an organization, with its customers and certainly within the community.

Summary

In order to take full advantage of the "Power of Insulation", it is essential to begin thinking differently about insulation and the value it can provide. While mechanical insulation is neither sexy, nor an exciting topic of discussion, it is a resource that, when all the benefits are considered, should prompt the question "Why haven't we paid more attention to this before?"

There are educational programs, software tools, such as the 3E Plus® program, and resources available to help explore the many benefits of mechanical insulation. An increased knowledge of mechanical insulation can provide, in many cases, an unrivalled return on investment opportunity in the new construction and the maintenance arenas. All of this while helping to reduce our dependency on foreign energy sources, helping our environment and our economy. Not a bad formula.

References

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. – 2005 ASHRAE Handbook, Fundamentals I-P Edition, Chapter 26, Insulation for Mechanical Systems

ASTM – Standard Practice for Estimate of the Heat Gain or Loss and the Surface Temperature of Insulated Flat, Cylindrical and Spherical Systems by the Use of Computer Programs, Standard 680

North American Insulation Manufacturers Association - 3E Plus Insulation Thickness Computer Program, Pub. C12128/05 and Software Program

National Insulation Association – Insulation Outlook, November 2006, CUI: An In Depth Analysis

National Insulation Association – Insulation Outlook, May 2005, How Many Barrels of Oil Can Insulation Save?

National Insulation Association – The Power of Insulation and Insulation and The Forgotten or Lost Technology presentations

The U.S. Department of Energy - Industrial Technologies Program, Save Energy Now, Partner Results