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National Insulation Association FOUNDATION For Education, Training and Industry Advancement

Insulation Energy Appraisal Program

Study Guide for Recertification Exam

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Sponsoring Organization
The National Insulation Association

NIA is a not-for-profit trade association representing the contractors, distributors, laminators, fabricators and manufacturers that provide thermal insulation, insulation accessories, and components to the commercial, industrial, and institutional markets throughout the nation.

Since 1953, members of NIA have utilized the most advanced insulation technologies to significantly improve the performance of industrial processes, to increase the interior comfort of buildings, to help control energy waste, to help protect workers in hazardous work environments, and to help their customers save billions of dollars in energy costs while reducing greenhouse gases.

The insulation products and services provided by NIA members constitute some of the most cost-effective, energy-saving technologies available. In addition, insulation can help reduce emissions from fossil fuel burning systems (CO_2, CO, and NO_X), which contribute to climate change.

NIA is the voice of the insulation industry and is dedicated to keeping the commercial and industrial industry up to date on the latest industry trends and technologies. NIA's Foundation for Education, Training, and Industry Advancement has fully supported and contributed to this effort.

Developer of 3E Plus Computer Program

North American Insulation Manufacturers Association

The 3E Plus® computer program used in the Insulation Energy Appraisal program was developed by the North American Insulation Manufacturers Association (NAIMA). NAIMA is the association for North American manufacturers of fiber glass, rock wool, and slag wool insulation products. Its role is to promote energy efficiency and environmental preservation through the use of fiber glass, rock wool, and slag wool insulation, and to encourage the safe production and use of these materials.

The Power of Insulation

- Insulation is substantially underutilized by U.S. commercial and industrial facilities despite its enormous cost and energy savings potential.
- A properly selected, specified, installed, and maintained thermal insulation system is an excellent investment with high returns.
- When compared to other conservation measures, the payback is very quick—often less than 6 months—and the savings are tremendous.
- Thermal insulation is the most cost-effective technology available today that allows energy managers to conserve energy, save money, and preserve the environment.

What Is an Insulation Energy Appraisal?

- A tool that quantifies the amount of energy and actual dollars a facility is losing with the current in-place insulation system and demonstrates how a more efficient system could:
    - Save energy;
    - Improve process control and efficiency;
    - Reduce fuel bills; and
    - Contribute to a cleaner environment through reduced emissions.
- It evaluates the thermal performance of insulated versus uninsulated processes in a facility.
- It puts actual dollar costs to Btu losses and calculates greenhouse gas emissions.
- Scope usually includes insulated lines, uninsulated lines, and equipment only. Items such as small, congested lines of piping—sometimes described as spaghetti lines—are not usually included.
- An Insulation Energy Appraisal is not intended to be a total system analysis.

The Appraisal Process

The Insulation Energy Appraisal is a 5-step process and may take a day or longer, depending on the size of the facility and the scope of the appraisal.

1. **Meet with and interview the facility manager or energy manager.**
    - Determine the scope of the appraisal, the scope of the facility's energy usage, energy distribution systems, and the cost to operate.
    - Review the facility layout, facility drawings (if available), and determine the major sources of energy serving the facility.

2. **Conduct a walk-through of facility and gather data.**
    - Measure and document all applicable pipes, ducts, and equipment, including both **insulated** and **uninsulated** sections.

3. **Use 3E Plus software to calculate data.**
    - After the on-site visit, use the 3E Plus computer software program to calculate data.

4. **Prepare the Insulation Energy Appraisal Final Report.**

The Final Report will document:

- The fuel cost savings with the current insulation systems and the potential savings with an insulation upgrade.
- The environmental impact in terms of reduced combustion product gases (CO_2, NO_x, and other greenhouse gases) resulting from increased energy savings and reduced fuel consumption.
- The amount of energy (Btu) loss or gain from uninsulated surfaces in the facility.
- The amount of energy Btu loss or gain from insulated surfaces in the facility.
- The amount of Btu or energy loss or gain from a pipe or vessel if the pipe or vessel is insulated to the most thermally efficient, yet cost effective, thickness determined by the 3E Plus computer program.

5. Present the Final Report.

- Explain all financial savings information as well as energy and environmental data.
- Identify recommendations based on analysis findings and discuss the potential return on investment possible with an insulation upgrade.
- If requested, the appraiser may agree to provide a professional estimate regarding any insulation recommendations.

Energy

Energy is usually defined as the ability to do work. Understanding the flow of energy is important when it comes to insulation energy appraisals.

- **Thermal Energy** (or heat) is a form of energy that is transferred due to temperature differences. Thermal energy refers to the internal energy present in a system by virtue of its temperature. Heat always attempts to flow from hot to cold.
- **Ambient temperature** is the average temperature of the medium (usually air) surrounding the object of interest. For a pipe located in a conditioned space, the ambient temperature is the temperature of the space (usually around 75°F). For a pipe located outdoors, the ambient temperature is the outdoor air temperature. For an underwater tank located on the seabed, the ambient temperature would be the seawater temperature.
- **Operating temperature** and **process temperature** are used interchangeably to describe the temperature of the fluid inside the pipe, vessel, or space of interest.
- **Conversion efficiency** for a conversion process is defined as the ratio of the **Output** (the energy sought) to the **Input** (the energy that costs). The conversion efficiency of a heat pump is usually expressed as the **coefficient of performance** (**COP**). The COP is calculated as the ratio of the heat out (the energy sought) to the **Power** in (the energy that costs).

The Fraction of Lost Heat

In some situations, the heat loss from piping and equipment may be useful for some other purpose (like space heating in winter). A common example is a unit heater in a warehouse. The heat lost from the uninsulated valves and fittings is not “lost.” It goes toward heating the space in the winter.

To account for this complication, we use an adjustment factor called the **“Fraction of Lost Heat”** to account for these situations.

Modes of Heat Transfer

There are 3 modes of heat transfer: conduction, convection, and radiation. Depending on the situation, 1 or more of the 3 modes of heat transfer can come into play.

- **Conduction—**Conduction is the transfer of thermal energy due to temperature differences within a body or between bodies in direct contact.

- **Convection—**Convection is heat transfer by the combined action of conduction and the bulk motion of a fluid. Convection is an important mode of heat transfer between a solid surface and a fluid (a liquid or a gas) that are at differing temperatures.

- **Radiation—**Radiation is the transfer of thermal energy from a hotter object to a colder one due to electromagnetic waves.

Apparent Thermal Conductivity

Thermal conductivity is a material property that describes how well a material conducts heat. Insulation works by suppressing 1 or more of the 3 modes of heat transfer. In the insulation industry, we describe how well they do this by a material property called the "Apparent Thermal Conductivity." The modifier "apparent" is added to the term to indicate the possible presence of "non-conductive" modes of heat transfer (i.e., radiation and/or convection) through the insulation.

The apparent thermal conductivity, also called the **k-factor,** is a measure of the insulation material's ability to conduct heat. Insulations typically have k-factors less than 0.5 Btu-in/ (h ft^2 F) at room temperature; the lower the k-factor, the better the insulator. Apparent thermal conductivity is usually temperature dependent. As the temperature of the material increases, so does the k-factor. The inverse is also true; as temperature decreases, the k-factor also decreases (or improves).

Units for Apparent Thermal Conductivity

Thermal conductivity values are given in various sets of units. The most common are:

1) Btu· in/(h·ft^2· °F)
2) Btu/(h· ft· °F)
3) W/(m°C)

The insulation industry in the United States normally uses the first set of units since insulation thicknesses are commonly given in inches. Physics and Engineering texts, on the other hand, will often use the second set, as it is more dimensionally consistent. The third set is the SI unit for thermal conductivity. Other sets of units are in use throughout the world, so data users need to exercise care to keep the units straight.

Why Insulate

- **Energy conservation**: minimizing unwanted heat loss/gain from systems.

- **Process control**: minimizing temperature change in processes where close control is needed

- **Personnel protection**: controlling surface temperatures to avoid contact burns (hot or cold). Typically, the goal is to keep the exposed surface temperature below 140°F to avoid burns.

- **Condensation control**: minimizing condensation and the potential for mold growth by keeping surface temperature above the dew point of surrounding air.

- **Freeze protection**: minimizing energy required for heat tracing systems and/or extending the time to freezing in the event of system failure.

- **Fire safety**: protecting critical building elements and slowing the spread of fire in buildings.

- **Noise control**: reducing/controlling noise in mechanical systems.

Gathering Information

- Study and verify line drawings.
- Read Process and Instrument drawings (P & IDs).
- Look at "as-built" drawings, if available.
- Confirm that blue prints are current.
- Review facility insulation specifications.
- Note equipment with special insulation requirements. These likely will give the original type(s) and locations of insulation.
- Discuss the measurement system used by the plant, IP (for inch pounds,) or SI (for system international [metric]).

Sample Agenda for a Kick-Off Meeting

- Introductions
- Background on the Insulation Energy Appraisal Process
- Overview of the energy systems
- Review/discussion of energy sources and fuel costs
- Review/discussion of conversion efficiencies
- Discussion of appraisal objectives and scope
- Summarize action items/next steps
- Schedule facility walk-through

Things You Must Know to Complete an Appraisal
A number of questions MUST be answered in an appraisal in order for you to be able to calculate savings using the 3E Plus computer program. These "mandatory" questions appear with a check mark (√) beside them.

The 3E Plus Questionnaire
It is important to receive answers to questions on the list marked with a √ and those with an * in order to run the 3E Plus program and to arrive at an accurate final report. Answers to other questions are also needed, but defaults may be used to complete the spreadsheet.

√ 1. What pipe sizes are most commonly used? Standard or metric?

√ 2. What is the base metal of the pipe, or equipment? Schedule 40? Stainless steel? Copper?
√ 3. What is the geometry of the surface? Horizontal or vertical?
√ 4. What type of insulation are you currently using, if any?
√ 5. What is the external jacketing material? Is the covering a shiny or dull finish?
√ 6. What is the average ambient temperature in the area of the piping or equipment?
√ 7. What is the process temperature in the pipe or equipment?
√ 8. What is the average wind velocity at the pipe for inside and outside applications?
√ 9. Does the energy user require a maximum insulated surface temperature? If yes, what temperature?
√ 10. What is the design relative humidity value for the area of the piping on equipment (for cold systems)?
* 11. What type of energy do you use: gas oil, etc.?
12. Are you controlling a process to a certain temperature?
* 13. List annual number of hours of operation per system and ask whether the plant has scheduled down time.
* 14. What are the different thicknesses of the insulation?
15. What are the energy sources: boiler or process equipment?
* 16. How efficient is each energy source? For example, your boiler?
17. What is the cost of the energy?
18. How did you determine the thickness of insulation you currently have on your piping and equipment?
19. Do you have Process and Instrument Drawings (P & IDs) we can review?
20. Do you have insulation specifications we can review?
21. Is your insulation system designed to a maximum heat loss/gain (Btu/SF)?
22. Do your specifications apply to currently installed insulation systems?

Objectives of the Walk-Through

- Assess the condition of the existing insulation system.
- Identify items where repair or upgrade of the insulation system is likely to generate savings.
- Document the details needed to analyze each item identified.

Facility Walk-Through

- Look at one complete energy supply system at a time, beginning with the hottest system.
- Concentrate on all supply and return piping within the facility. The appraisal agreement should include the main energy-consuming systems. Typically, the main energy consuming system is the steam piping and equipment. When evaluating a steam system, include the condensate return if it is being recaptured.
- Evaluate the chilled water loops used for process cooling. Only appraise the piping out to the tracing headers and back to the heat exchanger. Include the heat exchanger vessel and the main supply and return of energy used to cool the water at the exchanger. This same process of identification will be used on all other types of thermal fluid or liquid/gas cooling or heating system.

- If process control or safety is a part of the appraisal scope, follow the same overall system approach used for identifying the main energy consuming systems.
- In refrigeration and cryogenic applications, the actual process piping can be used to cool buildings, tanks, vessels, and equipment. This should be evaluated, as should energy sources used to cool process lines containing product.

Inventory Systems Separately

Make an inventory of each piping system in linear feet according to process temperature, pipe size, insulation size, thickness, outer jacket, lagging, annual hours of operation, average ambient air temperature, and wind speed (if exposed to the elements). (Consider wind speeds indoors when piping is near exhaust fans and intake vents.) Verify the annual hours of operation for each. These hours may match the plant's annual shutdown period, but should be verified.

Insulation Inspection

- The approach used will vary depending somewhat on personal preference, but one approach is to inspect one complete section at a time.
  - A first pass would include visual inspection aided by infrared thermography (if the energy system is in operation).
  - A second pass would be to document identified items, including measured dimensions.

Your job responsibilities involve assessing the condition of the insulation system and to recommend repairs and/or upgrades that will reduce energy consumption. These may include:

- Uninsulated areas (areas that were never before insulated).
  - This is critical since heat loss from these surfaces can be 20 times higher than for properly insulated surfaces.
- Missing insulation (where insulation was removed and not replaced).
- Damaged insulation (damaged such that it is not functioning as intended).
  - Often the areas of insulation or jacketing systems are damaged from abuse, expansion, and contraction due to cycling temperatures and freeze/thaw cycles, vibrations, and corrosion.
- Under-insulated areas (areas where thicker insulation would be beneficial).
  - These are the most difficult to identify; visually, these areas will appear to be in good shape. Thermography may be helpful, but more often than not the assessor will need to use calculations to determine which areas justify upgrading to higher thicknesses.

Infrared Thermography

- Involves using a camera that sees infrared radiation emitted, or given off, by all objects and creates an image of that heat signature. These are thermal patterns that cannot be seen with the naked eye. That information is then used to diagnose a variety of issues across a number of different applications.
- The energy that a thermal imager detects is from the infrared portion of the electromagnetic spectrum. This is heat energy that is transferred by electro-magnetic waves or particles of energy. It

has a wave form, can travel through a vacuum, and moves at the speed of light.
Thermal imaging works by detecting the heat energy being radiated by objects and requires absolutely no light.

- An infrared image is a picture of heat (not light). False-color overlays are utilized (in the form of color palettes that all infrared cameras have) to help show us, or bring out, areas of thermal contrast within the image.
- A good thermographer will know how to analyze an image and understand the consequences of what they see (and are possibly not seeing).
- Metallic surfaces are problematic for thermographers because highly reflective (low emittance) surfaces can reflect heat from the surroundings.
- When purchasing an infrared camera, be aware of the difference between detector resolution and display resolution. Purchase the camera with the highest detector resolution/image quality your budget allows.
- Also look for infrared cameras that have built-in digital cameras and laser pointers. Digital photos that correspond to your IR images will help document a problem and communicate its location to decision makers.

Determining Average Temperatures

- Both process and ambient temperatures will be needed to estimate the heat loss/gain for the insulation items. While some process temperatures may be controlled to a nearly constant temperature, ambient temperatures will vary depending on the location of the item. What we need is the average temperature over the period of interest.
- Single-point-in-time measurements have some limited value.
  Non-contact thermometers may be useful for measuring the temperature of bare surfaces (which may be used as an estimate of the process temperature, allowing for some temperature drop through the pipe/vessel wall).
- For steam systems, pressure gages may be used to estimate saturated steam temperatures by using steam tables. Saturated steam tables yield the process temperature if the steam pressure is known.
  For instrumented systems, historical data may be available.
  For outdoor piping and equipment, National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center summaries from a nearby weather station may be used to estimate average ambient temperatures and wind speeds over the period of interest.
- Indoor temperatures must be estimated from “local knowledge.” For indoor wind speeds, use ½–1 mph to approximate still air.

Measure Pipe Lengths

- The lengths of insulated and uninsulated piping may be approximated to the nearest foot.
- For horizontal runs, use a tape measurer and/or measuring wheel (a 3 ft. circumference wheel is suggested).
- Pace off the runs if you know your personal length of stride.
- “Measure through” flanges, valves, elbows, and other fittings. Count the number of items and adjust for equivalent length later.

Measuring Pipe Sizes and Insulation Thickness

- o If bare, pipe diameters can be measured directly, but care should be taken if the pipe is hot. Nominal sizes can then be determined by reference to pipe size tables.
- o Pipe calipers, pi-tapes, or standard measuring tapes may be used.
- o Valves and flanges are often marked with pipe size.
- o Alternatively, plant drawings may call out nominal pipe sizes.

Insulation thickness may be determined in a number of ways:

- o In some cases, it may be possible to use a pin probe with a ruler or tape measurer.
- o Measure the insulation outside diameter (OD), subtract the OD of the pipe, and divide by 2 to estimate the thickness.

Accounting for Fittings

For piping runs containing fittings (flanges, valves, elbows, tees, etc.):

- o Measure the overall length of the run (the "measure-through" length).
- o For each fitting within the run, add an appropriate "equivalent length" to the measure-through length.
- o The equivalent lengths for each fitting are calculated so that the overall equivalent length will have the same bare surface area as the actual run.

Measure Equipment, Ducts, and Vessels

- o Equipment, Ducts, and Vessels are analyzed on a surface area basis.
- o Measure the dimensions, then calculate surface areas.

Reminder for Walk-Through

- Review the mandatory 3E Plus questions to ensure that you have gathered data to answer all of the questions for each system (particularly for the mandatory questions).
- Verify the annual hours of operation for each system.
- Keep careful notes during the measurement process.
- Use a tape measure in tight areas and on short runs.
- Use a large diameter measuring wheel for long runs.
- Use an infrared thermometer if available.
- In all cases the process temperature should be evaluated against the engineering data.
- Map each supply system and return system separately and enter the data on the spreadsheet.

Using 3E Plus Computer Program

The task of determining how much insulation is necessary to save money, use less energy, reduce plant emissions, and improve process efficiency has been greatly simplified by the 3E Plus software program. Because insulation calculations for manufacturing processes were so complex, insulation as a viable solution for increasing the efficiency of industrial processes was often overlooked.

3E Plus provides calculations for many fuel types and 5 different surface applications. Thermal conductivity values are built in to the program for several different ASTM referenced insulation materials, but the user also has the option of supplying conductivity values for any other material.

3E Plus Calculates:
- Heat gain or heat loss (actual dollar loss);
- Surface temperature requirements;
- The thickness of insulation needed for condensation control;
- The thickness of insulation needed for personnel protection;
- Heat loss efficiencies versus bare pipe;
- Payback period or Return on Investment (ROI);
- Emission reductions (CO_2 and NO_x); and
- Much more.

Heat transfer calculations are based on the American Society for Testing and Materials (ASTM) C680 Standard Practice for Determination of Heat Gain or Loss on Bare and Insulated Surfaces of Piping and Equipment.

Economic thickness is defined as the thickness that minimizes the total cost of an insulation system.

The 3E Plus program allows users to supply:
- Custom insulation thermal conductivity curves;
- Custom fuel types; and
- Custom jacket material emittance values.

Entering Data and Using Worksheets

The next step in the appraisal process is taking the data acquired during the on-site interview and facility walk-through and inputting data for each of the lines and equipment surfaces inventoried into 3E Plus (each system will be calculated separately).

Manually transfer the data from the 3E Plus Questionnaire and/or the Field Survey into the appropriate 3E Plus program screens and allow the program to make the necessary calculations. There will be a number of different calculations made based on the findings during the walk-through and the various materials used throughout the facility.

Once all of the calculations have been made, this data is manually entered into a final spreadsheet that will calculate the total savings in dollars and Btu. This information is then entered into a format that you will use for the Insulation Energy Appraisal Final Report, which contains a summary, a display of savings to be effected, and appropriate backup data.

Transferring Data to the Spreadsheet

Use MS Excel to create worksheets produced by the 3E Plus program. Final spreadsheets have already been created and the formulas have been entered. Therefore, when you enter data from the calculations sheets produced by the 3E Plus program, final calculations are made automatically for you.

Move the cursor to the cell in which you wish to enter data, and then enter the appropriate data. Continue doing this horizontally until you have transferred all of the data from the calculation sheets into the appropriate spreadsheet cells. Continue entering data on successive horizontal lines until you have transferred data from all of the calculation sheets produced by the 3E Plus program.

The information should be automatically totaled in the appropriate cells and transferred to the summary totals at the bottom of the spreadsheet.

Objective of the Final Report

The objective of the final report is to recommend insulation system improvements that will save energy and reduce emissions, and to provide clients with the information they need to implement these recommendations. The report should also provide background information on the insulation system and the assessment process. The final report should summarize the results of the Insulation Energy Appraisal in a clear and concise manner.

The report should describe:

- The objective/scope of the assessment;
- The approach used;
- The condition of the existing insulation system;
- Areas where the insulation system can be upgraded;
- Estimates of the savings likely from the upgrade (energy [Btus], economics [$], environment [pounds of CO_2];
- Estimated cost of the upgrades; and
- Estimated payback period and/or ROI.

The Final Report

An Insulation Energy Appraisal Final Report should contain the following information.

Executive Summary

An executive summary is an effective way to highlight the report findings for the decision maker. Summarizing all the facts on one page is important because an energy user's report can be extensive for a large facility. The written report may be more than the energy user wants to read or can fully comprehend. Furthermore, an executive may want to skip to the bottom line.

- **Introduction, Objective, and Scope of the Appraisal**
  - Describe the overall objective and scope of the appraisal, what systems were inspected, what systems were not inspected, and why.
- **Approach**
  - Briefly describe the appraisal process and the computer software used to make calculations.
- **The Condition of the Existing Insulation System**
  - A brief overall description of the condition of the existing insulation system is useful to set the stage for the recommendations that follow.
- **Summarize Energy and Financial Savings**
  - Estimated fuel savings (in Btus and units of fuel)

- Financial benefits associated with the proposed insulation upgrades
- Report the estimated financial savings:
  - Annual Energy Savings, $/yr
  - Simple Payback Period = First Cost/Annual Savings
  - Return on Investment (ROI), % = (Annual Savings/First Cost) x 100

- **Describe Environmental Savings**
  - Report savings in terms of reduced combustion product gases (CO_2, NO_x, and other greenhouses gases) resulting from reduced fuel consumption.
- **Highlight other Applicable Insulation Benefits**
  - ***Safety/Worker Comfort Benefits***
    - Lower surface temperatures may translate to increased worker safety and better working conditions.
  - ***Process Control***
    - In some processes, insulation provides a vital role in providing process control.
  - ***Noise Reduction***
    - Noise reduction is often a significant benefit of insulation.
- **Note Ancillary Issues**
  - Mention specific issues or situations that may have been noted during the appraisal process but are not necessarily related to insulation and the scope of the appraisal (i.e., steam traps, leaks, etc.).
- **Disclaimer**
  - Include a disclaimer or warranty.

Marketing Your Appraisal Service

There are a number of basic marketing methods available for contacting energy users to introduce appraisals. For example:

- Personal visits;
- Personalized letters;
- Telephone calls; and
- Networking.

Identify Facility Decision-Makers Responsible for Energy Usage

These may be past and present insulation customers or new contacts.

Identify the Decision-Maker

If you are unfamiliar with a facility, the best person to contact may be the plant manager. Other potential contacts may include: the maintenance coordinator, director, manager, maintenance supervisor, project engineer, plant engineer, engineering manager, or engineering superintendent.

Purchasing Decision Makers

According to a recent study, maintenance and engineering most often have the final say on purchasing insulation. Engineering appears to have a greater impact on the final purchase decision in companies that focus on new capital projects.

Why Energy Users Purchase Insulation
The same study cited a number of reasons why energy users purchase insulation (in order of importance):

- Routine maintenance;
- Plant expansion;
- Process change or modification;
- Reduction of energy consumption; and
- Laws or regulations.

Presenting the Program to Potential Customers

Develop a professional presentation so that you do not waste the energy user's time. Find a common thread that can be used in the initial call or visit. This common thread could be energy consumption, environmental concerns, or knowledge of insulation performance.

Explain that the final report will:

- Describe opportunities for improvement;
- Highlight properly insulated systems; and
- Document savings in actual costs.

Explain the Benefits of an Appraisal

- Increase energy savings
- Protect equipment and personnel
- Increase process efficiency
- Prevent condensation
- Prevent excessive heat in fire hazard areas
- Control noise
- Maintain temperature
- Reduce greenhouse gases

An Insulation Energy Appraisal can demonstrate how to:

- Save hundreds of thousands of Btu;
- Improve process control and efficiency; and
- Decrease fuel consumption, thereby reducing fuel bills and a plant's impact on the environment.

The Value of Your Service
Appraisals have been completed:

- For free as a customer service;
- For a fixed fee; and
- On an hourly cost basis as part of a future job.

Additional Resource:

- The **Insulation Science Glossary** contains a list of basic and advanced insulation industry terms and their definitions. It is reviewed quarterly by NIA's Technical Information Committee.