

IEEE Recommended Practice for Electrical Impedance, Induction, and Skin Effect Heating of Pipelines and Vessels

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Abstract: Recommended practices are provided for the design, installation, testing, operation, and maintenance of impedance, induction, and skin-effect heating systems. Thermal insulation and control and monitoring are addressed. General considerations for heating systems are discussed, covering selection criteria, design guidelines and considerations, power systems, receiving and storage, installation, testing, operations, and maintenance. These aspects are then discussed for each of the above types of systems, along with special considerations particular to each. These recommended practices are intended to apply to the use of these heating systems in general industry.

Keywords: heating systems, impedance heating, induction heating, process heating, skin-effect heating, thermal insulation

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Foreword

(This Foreword is not a part of IEEE Std 844-1991, IEEE Recommended Practice for Electrical Impedance, Induction, and Skin Effect Heating of Pipelines and Vessels.)

The types of heating systems covered by this recommended practice have been used for a number of years in the petrochemical industry. They were recognized for the first time in the 1981 issue of the National Electrical Code (ANSI/NFPA 70-1990 [1]).

Electrical heating of pipelines and vessels in the petrochemical industry is a growing portion of total heating requirements because of its advantages in temperature control and the rise of energy costs. This recommended practice is a companion document and supplements IEEE Std 515-1989, IEEE Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications. While this recommended practice may be used with IEEE Std 515-1989 to select the type of electrical heating to be used, it is a stand-alone document for the types of heating it covers.

Since electric heating systems are interrelated with electric power, control, and alarm systems, other standards, some of which are listed in Section 2., should be referred to when using this recommended practice. The recommendations here are not intended to supersede any current standards or recommended practices, and sound engineering judgment should always be used when applying this or any other standard.

Suggestions for improvement of this recommended practice are welcomed and should be addressed to the Secretary, IEEE Standards Board, Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08855-1331, USA.

This recommended practice correlates petrochemical industry practices; it is not intended to be a design guide or an exhaustive procedure manual. It may be used to evaluate different heating systems and suppliers of those systems for suitability and performance. The appendixes are included for information only; they are not part of this recommended practice.

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IEEE Recommended Practice for Electrical Impedance, Induction, and Skin Effect Heating of Pipelines and Vessels

1. Scope

This document provides recommended practices for the design, installation, testing, operation, and maintenance of the following types of electrical heating systems: impedance heating systems, induction heating systems, and skin effect heating systems. These recommended practices are intended to apply for use of these heating systems in general industry.

1.1 Limits

These recommended practices, when used with other recognized codes and standards, are intended to cover each heating system in its entirety, including system design, specification, installation, operation, testing, and maintenance of the following:

- 1) Heating systems
- 2) Thermal insulation systems
- 3) Pipeline or vessel electrical isolation systems
- 4) Electric power supply systems
- 5) Electric grounding systems
- 6) Control and monitoring systems

1.2 Purpose

1.2.1

Design information, selection parameters, and data in this document are not intended to provide a complete design of these heating systems. They should be helpful guides when the user is performing the following tasks:

- 1) Selecting the optimum heating system
- 2) Establishing design criteria and constraints for the heated pipeline or vessel to assure system compatibility
- 3) Preparing specifications for heating systems to obtain quotations on equivalent systems
- 4) Developing information on installation, operation, testing, and maintenance of these heating systems

1.2.2

This document is intended to aid the user in specifying, installing, operating, testing, and maintaining heating systems that will

- 1) Maintain design temperature of contained material
- 2) Provide electrical, thermal, and mechanical durability and reliability
- 3) Minimize hazards to the user or the surroundings

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

- [1] ANSI/NFPA 70-1990, National Electrical Code.¹
- [2] IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms.²
- [3] IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book).
- [4] IEEE Std 400-1990, IEEE Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field.
- [5] NFPA-NEC-TCD-1983, National Electrical Code Technical Committee Documentation for 1983 Annual Meeting.
- [6] Federal Energy Administration. "Economic Thickness for Industrial Insulation." *Energy Conservation Paper Number 46*, August 1976.
- [7] Turner, W. C. and Malloy, J. F. *Handbook of Thermal Insulation Design Economics for Pipes and Equipment*. New York: McGraw-Hill, 1980.

3. Definitions

The following definitions apply to the subject matter in this document.

ambient temperature: The environmental temperature surrounding the object under consideration. For objects enclosed in thermal insulation, the ambient temperature is the temperature external to the thermal insulation.

ampere turns: The product of the number of turns and the ac amperes flowing in an induction heating coil.

Curie temperature: The temperature at which the magnetic properties of a substance change from ferromagnetic to paramagnetic.

dead leg: A portion of a piping system, without flow, used to simulate the overall system conditions for control sensing.

eddy current: Current that circulates in a metallic material as a result of electromotive forces induced by a variation of magnetic flux.

¹NFPA publications are available from Publications Sales, National Fire Protection Association, Battery-march Park, Quincy, MA 02269, USA.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

effective flux penetration (P): The distance into a pipeline or a vessel wall that the value of current induced by the magnetic field at the surface would have to penetrate in order to generate the same heat as generated by the actual induced current distribution in the wall.

ferromagnetic material: A material that, in general, exhibits hysteresis phenomena and whose permeability is dependent on the magnetizing force.

heat loss: A quantitative value of energy flow from a pipe, a vessel, or equipment to the surrounding ambient.

heat sink: A part that conducts and dissipates heat away from the pipeline or the vessel. Heat sinks, as related to pipe heating systems, can be pipe supports, valve operators, etc.

impedance heating: An electric heating system where the object to be heated generates heat as a result of an ac current passing through it.

induction heating: The generation of heat in any conducting material by means of magnetic flux-induced currents.

magnetic flux (Φ): A condition in a medium produced by a magnetomotive force such that, when altered in magnitude, a voltage is induced in an electric circuit linked with the flux.

magnetic flux density (β): Flux per unit area through an element of area normal to the direction of flux.

magnetic flux leakage: That portion of the total magnetic flux in a circuit that does not intercept the material that contains the magnetic flux that is heating.

magnetic hysteresis: The property of a magnetic material to convert electric energy to heat by virtue of the fact that the magnetic induction for a given magnetizing force depends upon the previous conditions of magnetization.

maintain temperature: Specified temperature of the fluid or process material that the heating system is designed to hold at equilibrium under specified design conditions. *Syn:* **maintenance temperature**

maximum exposure temperature: The highest temperature to which an object may be exposed continuously.

permeability: (μ). Ratio of the magnetic flux density to the corresponding magnetizing force.

pipeline: A length of pipe, including pumps, valves, flanges, control devices, strainers, or similar equipment for conveying fluids.

power factor: The ratio of the circuit power (watts) to the circuit voltamperes.

runaway pipeline (vessel) temperature: The highest equilibrium temperature on the pipeline or the vessel that can occur when the heating system is continuously energized in the maximum ambient temperature.

saturation flux density (β_s): . The maximum possible magnetic flux density in a material.

skin effect heating: An electric heating system where a conductor inside a ferromagnetic material generates heat via I^2R losses in the conductor and ferromagnetic material.

soft start: The ability of a controlling device to apply power to a load upon energization in a proportional manner, irrespective of values of the controlling signals.

thermal insulation: Material having air- or gas-filled pockets, void spaces, or heat-reflective surfaces that, when properly applied, will reduce the transfer of heat with reasonable effectiveness under ordinary conditions.

vessel: A container such as a barrel, a drum, or a tank for holding fluids or other material.

weather barrier: A material that protects thermal insulation from environmental conditions such as rain, sleet, snow, wind, contamination, and physical damage.

zoning: A division of circuits to minimize different conditions in any one circuit, so the temperature at the location of a sensor is typical for the complete circuit.

4. Thermal Insulation

The primary function of thermal insulation is to reduce the rate of heat transfer from or to a surface that is operating at a temperature other than ambient. Thermal insulation is applied to piping systems for personnel protection and energy conservation. This reduction of energy loss can reduce operating expenses, improve system performance, and increase system output capability. Conversely, improperly applied or maintained thermal insulation may render an electric heating system totally ineffective.

Prior to any heat loss analysis for an electrically heated pipe or vessel, a review of the selection of the insulation is recommended. The principal areas for consideration are

- 1) Selection of insulation material
- 2) Selection of weather barrier or jacketing
- 3) Selection of insulation thickness
- 4) Selection of insulation size

4.1 Selection of Insulation Material

The important aspects to be considered when selecting an insulation material are

- 1) Thermal characteristics
- 2) Mechanical properties
- 3) Chemical compatibility
- 4) Moisture resistance
- 5) Personnel safety characteristics
- 6) Fire resistance
- 7) Cost

Some common insulation materials available are

- Calcium silicate
- Fiberglass
- Polyurethane
- Mineral fiber
- Polyisocyanurate
- Expanded (perlite) silica
- Cellular glass
- Elastomeric foam

4.2 Selection of Weather Barrier

Proper operation of an electrically heated system depends upon the insulation being dry. Electrical heating systems normally have insufficient heat output to dry out wet insulation. Some insulation materials, even removed from the piping and force-dried, never regain their initial properties after once being wet.

Piping may be weather-protected with either metal jacketing or a polymeric system. Smooth metal jacketing should be formed with modified S longitudinal joints. The circumferential end joints should be sealed with closure bands and supplied with sealant on the outer edge or overlapped. See Fig 1.

Metal jacketing should be overlapped such that the longitudinal joints are as shown in Fig 1. These joints should be oriented such that they shed water.

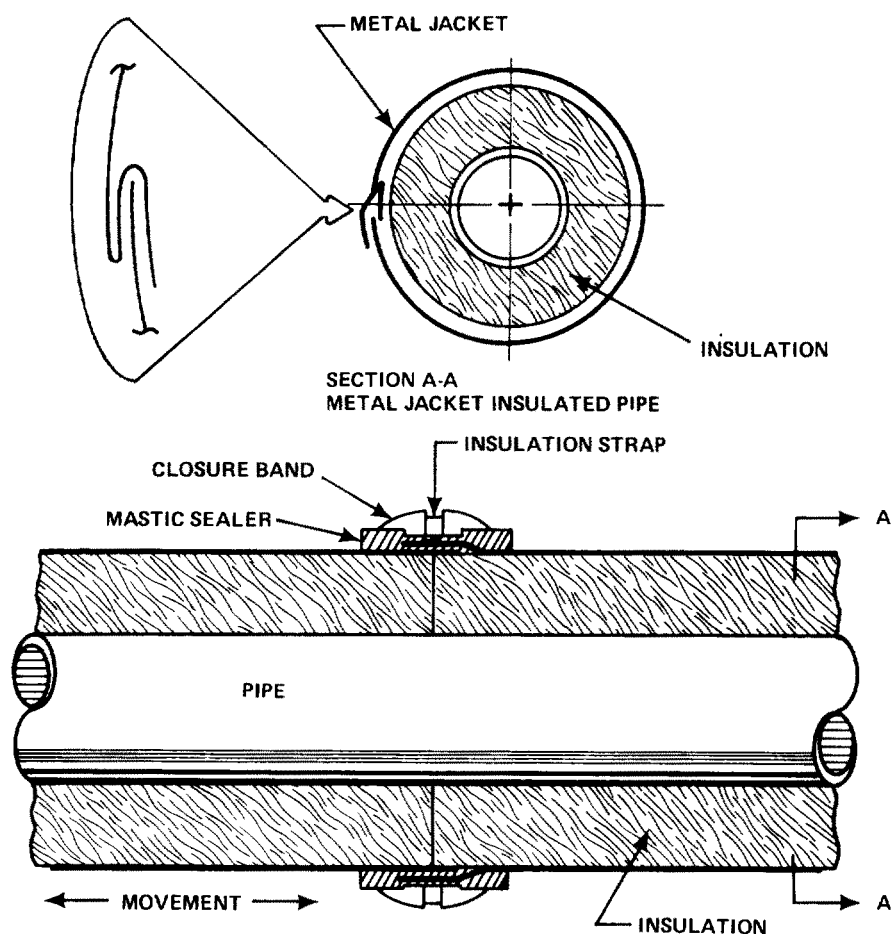


Figure 1 — Thermal Insulation Metal Weather Barrier Installation

Factory-applied thermal insulation and jacketing of a preinsulated piping system can have many configurations. Generally, the techniques used in applying the jacketing, whether in straight sections or spiral wound, are not repeatable under field conditions. The manufacturer's instructions should be followed in supporting the pipeline and sealing field joints to prevent intrusion of moisture.

Jacketing that is not overlapped or otherwise closed without sealant is not effective as a barrier to moisture. A single unsealed joint can allow a considerable amount of water to leak into the insulation.

The type of weather barrier used should be based on a consideration of

- 1) Effectiveness in excluding moisture
- 2) Corrosive nature of chemicals in the area
- 3) Fire protection requirements
- 4) Cost
- 5) Resistance to ultraviolet radiation
- 6) Effective life

4.3 Selection of Insulation Thickness

An economic consideration of the insulation will weigh the initial costs of materials and installation against the energy saved over the life of the insulation. Methods for analyzing the most economic thicknesses are outlined in [6] and [7].³ In all cases thermal insulation thickness should also be sized to provide personnel protection.

4.4 Special Consideration of Thermal Insulation

4.4.1 Uniform Heat Loss

In most piping systems minor local temperature deviations are acceptable, since many fluids are not temperature sensitive to the point where they will affect product quality. In cases where extreme temperature sensitivity does necessitate close temperature control, it is imperative that the thermal insulation maintain uniform heat loss throughout the piping system. The entire heating system may be rendered ineffective if thermal insulation is not properly applied.

This problem is further amplified as temperatures are elevated. Most insulations suitable for use on high-temperature lines are mechanically rigid. Insulation should be cut to fit with minimum gaps. A ceramic wool for the filling of voids and irregularities at joints and heat sinks is preferred over insulating cements, which tend to become brittle after being cured and have poor insulating qualities. Normal thermal cycling of the process will, in time, cause the cements to crack, exposing bare pipes and creating heat losses that are not normally anticipated.

Insulation covers for valves, flanges, pipe supports, and other irregularly shaped objects should be molded for the particular configuration or fabricated from block or several segments of the same material used for adjacent straight piping.

The use of custom-prefabricated removable insulation and weather barriers should also be considered for areas of high maintenance. Where insulation with a thermal conductivity different from that being applied to the pipe is used to insulate totally an irregular surface, the thickness of the insulation must be adjusted to compensate for differences in thermal conductivity and surface area. However, a custom fitting of the equipment with the same type of material is preferred. This is very important when dealing with impedance, induction, or skin effect types of heating systems, since it is often difficult, if not impossible, to provide additional local heat to individual valves, flanges, pipe supports, or other heat sinks to compensate for the heat lost through irregular or exposed surfaces. An example illustrating this point is presented in Appendix C.

4.4.2 Composite Insulation Systems

Insulation systems may be composed of two layers of the same type of insulation that are applied in such a manner to stagger the joints. The staggering of the joints radially and longitudinally would allow the insulation to flex with the thermal cycling of the pipeline. An alternative would be to construct the insulation with the inner layer having a temperature rating that withstands high temperature, and the outer layer having better insulating or moisture characteristics with a lower temperature rating.

These systems are superior to normal, single-layer insulations in terms of heat loss and deterioration with time. They may not be acceptable for every application because of spacing, cost, or other considerations. Other systems are available and should be examined on a case-by-case basis.

On very-high-temperature systems, radiation may be a major mode of heat loss, and insulation experts should be consulted.

³The numbers in brackets correspond to those of the references in Section 2..

4.4.3 Penetrations of the Insulation

When necessary to penetrate the weather barrier and insulation for process instruments, pipetaps, or other reasons, the penetrations should be sealed and oriented such that they shed water due to rain, spills, sprinkler system operations, or routine hosing. Bottom penetrations are desirable. Consideration should be given to the effect of relative motion between the pipe and the weather barrier due to thermal expansion.

4.4.4 Maximum Temperatures

The maximum surface temperature of the pipe or the vessel should be considered to the extent that none of the component ratings are exceeded in the application. This includes electrical insulation and isolation, thermal insulation, pipe wall material, process material, and control instrumentation. The maximum surface temperature of the thermal insulation should also be considered for personnel protection. Typically, the maximum surface temperature of the thermal insulation or weather barrier should not exceed 60°C (140 °F) for personnel protection.

4.4.5 Wet Insulation

Thermal insulations become ineffective when water is present. Hygroscopic insulations, such as calcium silicate, should be avoided for electric heating applications, unless special considerations are taken to exclude moisture.

4.5 Determination of Energy Losses

To determine actual energy losses for a given set of conditions, a complete insulation specification, including the thermal conductivity of the insulant at several mean temperatures, the type of weather barrier specified, insulation size and thickness, desired pipe maintenance temperature, and the minimum ambient temperature and wind conditions, is required.

Given these parameters, the heat loss may be evaluated by the use of Eq 1 in Appendix A. An example of such an evaluation is given in that Appendix.

Eq A1 models heat loss for an ideal system under controlled conditions. Heat losses in a typical installation will differ due to variations in installation techniques, components, and system deterioration. It is sound engineering judgment to add a safety factor to the calculated heat losses when sizing the heating system. This safety-factor approach is typical not only for Eq A1, but for subsequent heat-loss equations referred to in this recommended practice.

4.6 Special Considerations of Energy Loss

4.6.1

It may be necessary to specify that the heating system be capable of raising the temperature of a static product to fluid flow temperature within a certain time period. The heating requirements may be evaluated by the use of Eq B1 in Appendix B. An example of such an evaluation is given in that Appendix.

4.6.2 Classified Locations

For classified areas, the maximum runaway pipe temperature must be calculated for the fault conditions of control failure and/or system overvoltage (ANSI/NFPA 70-1990 [1], Article 501-10). The runaway pipe temperature of the system is calculated at maximum ambient temperature with the circuit continuously energized. The formula for calculating the runaway pipe temperature is a rearrangement of the terms of the heat-loss formula in Eq A1 in Appendix A. See Eq A9, Appendix A.

4.7 Thermal Insulation System Maintenance

The maintenance of thermal insulation systems is essential for lowest cost operation and for reliability. The reliability of an electric heating system is as dependent upon the thermal insulation system as upon the electric power system. A thermal insulation system is a sound investment; good maintenance protects that investment.

4.7.1 Maintenance of Insulation

Maintenance of thermal insulation is needed for two reasons:

- 1) The repair or replacement of damaged or soaked insulation caused by abuse, corrosion, leaks, or weathering.
- 2) The removal and replacement caused by the repair of valves, pumps, or other equipment. In all cases, if the thermal insulation is wet, it must be removed and replaced.

One of the most common problems with maintenance is that, when repairs to equipment necessitate the removal of thermal insulation, the insulation is generally torn off without regard to its re-use. When valves, fittings, and other equipment are insulated with preformed covers, they should be removed carefully to be reinstalled in their original configuration. When repairs are being made, attention should be given to the adjacent insulation so as not to damage it inadvertently. A temporary weather barrier should also be used to protect the insulation from rain, hosing, or spills. In many cases, it is advantageous to install a permanent weather barrier on the ends of insulation adjacent to sections that will be removed frequently for maintenance.

4.7.2 Maintenance of the Weather Barrier

The primary reason for the failure of a thermal insulation system is the failure of the weather barrier to exclude moisture. Weather barrier failures are attributable to the following:

- 1) Spillage of liquids
- 2) Corrosion
- 3) Pipeline leakage
- 4) Gaps or unsealed joints
- 5) Hot projections through the insulation
- 6) Cracks caused by thermal expansion
- 7) Mechanical abuse
- 8) Foot traffic

Minimization of corrosion, spills, and leaks should be an operating goal. The problems they cause to unsealed insulation are significant. Gaps and unsealed joints can be located by inspection during construction. Cracks developing after prolonged operation, due to thermal expansion, indicate the need for an expansion joint in the insulation system. Cracks on smooth protrusions may be eliminated by the use of metal flashing and sealants fitted flush along the protrusion, while irregular objects will require repeated resealing.

In areas of high maintenance, foot traffic, or mechanical abuse, the weather barrier may have to be of additional strength, or an additional sheet of metal covering may need to be installed over the existing weather barrier to provide sufficient protection.

5. Control and Monitoring

5.1 Control Types

5.1.1 On-Off Controls.

On-off is the simplest, least expensive form of control. It can be accomplished manually or automatically from an external signal, usually temperature activated. Contactors are usually used for service switching because of their simplicity and ability to control large amounts of power repetitively. Contactors should be sized for continuous load and inrush currents on cold load starts. Mechanical and contact life considerations may require a larger size contactor than is indicated by the electric load. The temperature control band is a compromise between accuracy of control, limitations on the number of operations of the contactor, and system design, so that the control range is usually broader than with other types of control. Contactors have moving parts, draw arcs when breaking circuits, are noisier, and require more maintenance than solid-state controllers. Use of mercury contactors alleviates noise and life problems. Enclosures must be suitable for the environment. It is critical with on-off control that the heating system match the service voltage available.

5.1.2 Analog (Proportional) Control

Analog control devices match the output power to the needs of the heating system and provide a stable load on the electrical distribution system as long as the heating requirements remain constant. They require a continuous signal whose level varies with measured temperature at the control point. Depending on the accuracy of the sensor and controller, they can control temperature very closely. These devices have no moving parts, are relatively maintenance free, and have a long life provided they are properly installed and electrically protected. They do not mechanically open the circuit, so a switch and contactor, or a shunt trip circuit breaker, should be provided in a series with the controller for overtemperature protection and circuit isolation. The following are commonly used analog control devices for heating applications.

5.1.2.1 Saturable Core Reactors

These devices can vary output voltage from approximately 10% to 100%, in proportion to the current in a dc control winding. The dc source can be controlled to provide *soft-start* capabilities. Reactors are constructed similarly to transformers and have an inherent ability to withstand voltage and current surges and overloads. Losses are dependent on coil and core construction, but generally are similar to losses in a transformer of equal size. Operation in the lower control range will result in a low system power factor. They are large, heavy, and expensive when compared to silicon-controlled rectifiers (SCRs).

5.1.2.2 Phase-Angle-Fired Silicon-Controlled Rectifiers (SCRs)

These devices can continually vary output voltage from 0% to 100% by turning on for a varying portion of each half-cycle. The firing circuit is controlled to vary the firing time and can be equipped with a soft-start option to limit inrush to inductive loads. A current limit circuit is available to limit current to match the load and for control of cold start currents on variable resistance heaters. They require both voltage surge and thermal energy (I^2t) protection because of limited dielectric and thermal capabilities.

The chopping action of the SCR imposes harmonics on the electric system, which can be a problem when this type of load is a large percentage of the total system load. When phase control is adjusted for low output; voltage, the distribution system power factor will be low. Meters that will read rms values of nonsinusoidal waves should be used. The most likely mode of failure is full on. There is usually a 1–2% loss in power in the control package. These devices must be packaged to suit the environment.

NOTE — Zero- (burst)-fired SCRs are an alternative to phase-fired SCRs, but they have limitations on their application, which should be explored with the controller vendor before use.

5.2 Zoning and Sensor Location

To heat and control pipelines or vessels properly, consideration must be given to establishment of heating zones that can be separately controlled. Many factors must be taken into consideration when establishing zones and locating sensors to properly control the zone.

5.2.1 Ambient Conditions

For any single heating zone, the ambient conditions should be nearly uniform or the temperature differentials resulting from different ambient conditions should be acceptable. The complete zone should be either outdoors or indoors. Ambient temperatures and wind and sun loading conditions should be comparable in all portions of the zone.

5.2.2 Physical Conditions

Pipelines or vessels that are to be in a single zone should be of equal size or have uniform heat loss. Consideration should be given to the chimney effect on sloped or vertical pipe runs, which tends to raise the temperature at the top because of convection.

5.2.3 Process Conditions

Required temperatures should be uniform throughout the zone. Flow conditions should be similar in all pipelines heated in a single zone. Varying fluid levels in vessels should be given consideration.

5.2.4 Temperature Control Sensor Location

5.2.4.1

Ambient sensing, although energy inefficient, provides acceptable control to maintain a minimum temperature, such as for freeze protection. The sensor should be located where ambient conditions are typical and should be protected from direct sunlight.

5.2.4.2

The pipeline or vessel temperature sensor should be located so that response is typical for the complete zone. To maintain a minimum temperature, the sensor should be located on the coldest pipeline, at the bottom of vertical runs, in the coldest ambient, and in nonflowing lines. The sensor should be located to avoid any direct temperature effect from skin effect envelope, and approximately 1–1.5 m (3.3–5 ft) from in-line heat sources or heat sinks. If flow patterns are unpredictable, consideration should be given to locating the sensor on a dead leg (a segment of process piping that is not in the flow pattern). Overtemperature must be considered in applying these recommendations.

5.3 Types of Sensors

(See Table 1)

5.3.1 Thermostats

A thermostat is a combined sensor and on-off controller. The bimetal or fluid-filled system senses temperature changes and switches contacts. The sensor may be inside a thermostat housing or extended by a capillary tube for remote sensing. Enclosure anti materials should be suitable for the environment. Thermostats should be inspected, calibrated, and mechanically operated on a scheduled basis.

5.3.2 Thermocouple (tc)

Thermocouples sense temperature and generate a millivolt signal, proportional to the temperature.

5.3.3 Thermistor

Thermistors sense temperature and change resistance very rapidly in the temperature, control range. The change of resistance can be either positive or negative with an increase of temperature.

5.3.4 Resistance Temperature Detector (rtd)

Change of resistance of rtds is uniform over a broad temperature range. Resistance increases as temperature increases. To improve accuracy, three leads are used to compensate for the lead-wire loop resistance and changes in lead resistance with a change in ambient temperature.

5.4 Wiring Considerations

Electrical noise on signal wiring is a common cause of problems with some temperature control systems.

Table 1—Temperature Sensor Characteristics

Sensor Type	Thermostat	tc	Thermistor	rtd
Signal	On-Off	mV	k Ω	Ω
Accuracy	Fair	Good	Very Good	Excellent
Response	Fair	Excellent	Very Good	Good
Interchangeability	Good	Very Good	Good	Very Good
Stability	Fair	Good	Very Good	Excellent
Range	Broad	Broad	Narrow	Broad
NOTE — Table characteristics are for sensors, and users should be aware that system control may be affected by the type of controller used with the sensor.				

Consideration should be given to spacing sensor wiring away from power wiring; using twisted, shielded, or twisted/shielded cable; and using separate ferromagnetic raceways for sensor wiring.

5.5 Special Control Considerations

5.5.1

All heating systems covered in this recommended practice can be designed to heat the system rapidly. The sensors and controllers used should be able to respond quickly to temperature excursions to prevent temperature overruns.

5.5.2

Backup temperature control should be applied to prevent over temperature in case of control failure. For this backup protection, an entirely separate system is recommended, including sensors, controllers, and power interrupting devices such as a shunt-trip circuit breaker or a magnetic contactor. This is especially important when saturable core reactors or SCRs are the primary control device, or when the heater is located in a hazardous (classified) location where the runaway temperature may exceed 80% of the lowest ignition temperature of the flammables in the area.

5.6 Control Specifications

Each respective section of this recommended practice details specifications required for the type of heating system used. The heating system vendor will normally recommend control and monitoring component specifications to meet the required heating system performance. General specifications for control and monitoring should include the following:

5.6.1 Controller Location

Environmental conditions, such as maximum and minimum ambient temperature, indoor or outdoor location, routine hosing, solar heating, corrosives, and classification of the area with description of hazardous substances, should be considered.

5.6.2 Accessibility

Control and monitoring equipment can be floor- or wall-mounted, have front or back access, and have a wiring entrance at the top, the bottom, or the side.

5.6.3 Electrical

Consider available supply voltages and capacity interlocks; local or remote operation and indication; type of indicators desired (lights, meters, alarms, etc); and quantity, type, and location of additional temperature monitoring.

5.6.4 Remote Monitoring

Controllers that can be monitored and tested for proper operation from a remote location, such as a control room, should be considered when there are a large number of electrically heated pipelines or vessels dispersed over a large area.

6. Heating Systems—General

6.1 Introduction

These heating systems are composed of many components; failure of any component to be designed, installed, or maintained as specified can result in failure of the system to function properly. To obtain a successful installation of any of these systems requires coordination and cooperation among piping, insulation, electrical, and support designers, purchasers, fabricators, and erectors, at all stages of a project.

6.2 Categories

Heating systems covered in this recommended practice can be divided into five categories.

6.2.1 Solidification Prevention

Systems may be used to prevent the fluid in a line or a vessel from solidifying. Many materials handled in industry require this protection. These include water, aqueous solutions, heavy fuel oil, pitch, asphalt, metals, sulfur, and other chemicals. The heating system compensates for the heat losses from the pipeline in order to maintain the temperature of the contents above the solidification point.