THERMCRAFT, INC.

'TECH NOTES"

HANDLING, STARTUP & MAINTENANCE

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ELECTRIC RESISTANCE - HEATING ELEMENTS

INTRODUCTION

Since our establishment in 1971, Thermcraft has supplied high quality, reliable, electric resistance type heaters, for various applications, around the world.

Our expertise allows us to provide products which exceed our customers expectations. From start to finish we coordinate with our customers to produce the ideal product for their applications. This is our way of providing you with the products that will meet your needs at a price based on that value.

Although the use of electrical resistance type heating elements have been around for many years, with new applications occurring daily, there still exists some misunderstood aspects of use and quite frequently mis-use of the elements, due to assumptions or lack of readily available information.

This guide discusses general issues relating to the use, care and maintenance factors relative to obtaining the longevity of Thermcraft products. The complexity of issues relating to resistance type heaters indicates the need for a universal guide as a starting point.

Thus, this guide is just that, a guide only and actual specifications of heating units should be made only after consultation with Thermcraft engineers.

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REVIEW OF APPLICATION AND MAINTENANCE FACTORS

Thermcraft has furnished the following information as a guide only and does not imply or make any guarantees or warranties. It should be obvious that the number of variables in types of applications makes it clearly impossible to provide any absolutes.

ELECTRICAL LEAD CONSIDERATIONS

It is not only important to consider the type of electric heater and placement and wattage requirements, but it is also necessary to consider the types of electrical leads used and the methods by which they exit and terminate the heated area. Some general considerations in selecting various lead types are:

- Temperature of Lead Area
- Flexibility Required
- Relative Cost

* Contaminants in the Lead Area
* Abrasion Resistance Required
* Accessibility to Controls

HEATING ELEMENT LEADS AND POWER CONNECTIONS

Be sure that the line voltage matches the heater's rated voltage. Electric wiring to the heater must be installed in accordance with Local and National Electric Code. Polarity MUST always be observed. Adjacent leads should always be connected to the same polarity. Failure to observe polarity may cause premature heater failure.

LEAD STYLES

Element leads are available in a wide range of styles, but can generally be grouped into a few categories such as:

1. Single Conductor
2. Twisted Pair
3. Rod
4. Pad or Bar

The single conductor concept is quite common and is normally the standard form of supply for ceramic and vacuum formed fiber, heating elements. With this form, the heating element conductor also serves as the lead. Caution must be exercised when this form is used since the lead can become quite hot, especially when the element package is running at or near its maximum rating. The heat generated can create problems with terminations, interactions with lower grades of insulation, and possible overheating of the lead wire itself (SEE ALSO SECTIONS ON TERMINATIONS AND LEAD PROTECTION).

Twisted pair indicates a lead in which the element conductor has been folded back upon itself and then twisted together in a specific manner. In this method, the effective cross-sectional area of the lead has been in effect doubled. This allows the lead to run at substantially reduced temperatures. This feature alone greatly reduces the potential of element failures that can be directly traced to lead or termination problems. This style of lead generally carries a premium over the single conductor form and is generally limited to use with BSA wire gauge sizes of 9 to 10 gauge or smaller. This type of lead configuration is recommended where possible.

Rod leads involve fastening a lead of much heavier cross-sectional area (typically a minimum of twice) to the actual element. Again, this allows the lead to run at much lower temperatures than the actual element. Typically, the rod will be welded to the heating element conductor. Although the rod is heavier than the element, care must be exercised when handling since the welding process will generally result in a fairly brittle area in the immediate area of the weld site. This brittle section is susceptible to cracking or outright mechanical breakage if mishandled. The rod type of connector can be used with either wire or strip heating elements. The material used for the rod type connector can be made of a lower temperature rated but similar chemistry alloy, as that used in the actual heating element.

The pad or bar lead is similar in nature to the rod concept except that either a flat bar is used, or if the element in question uses "strip" rather than wire, the strip is often folded back on itself once or twice to increase the cross-sectional area. It is typically provided with a hole near the end for terminating via bolted connections. If the pad has been welded to the element conductor, the same concerns expressed at the weld site about brittleness with the rod lead apply. This style of lead is often used with fiber based heating packages and if the lead is not long enough to extend through the "back up" insulation, the client is forced to make all his bolted power connections in an area exposed to rather high ambient temperatures (SEE LEAD PROTECTION SECTION AND TERMINATIONS SECTION).

BENDING RADIUS

Lead wire extending from the heater elements usually can be bent to conform to your specific needs. Caution must be taken so that the integrity of the internal connection is maintained to prolong the life of the heating element. To avoid placing excessive stress on this junction, use soft nose pliers to hold the lead wire secure where the wire exits from the heating element and then bend. Note: Some pliers can gouge the wire creating a weak spot.

The minimum bending radius of the wire should be 4 to 8 times the diameter of the wire. This works for both nickel-chrome alloys and iron-chrome-aluminum alloys. However, one should note that in very cold ambient conditions, iron-chrome-aluminum alloys could still crack or break when any bending is done (i.e.: see Brittleness Section).

BRITTLENESS

Many of the high temperature metallic alloys used for heating elements suffer from poor ductility and brittleness, especially after they have been at operating temperature for any length of time. This is especially true for iron-chrome-aluminum based materials, which are often used in higher temperature applications. Traditional iron-chrome-aluminum materials will become very brittle once they have reached a temperature of 950 Deg. C, and this brittleness occurs almost instantaneously. The newer powder metal based ironchrome-aluminum alloys also become brittle once they have been heated but this is a more gradual process and is strictly dependant on time and temperature. Once these alloys are cooled to room temperature, attempting to move them most likely will lead to breakage. Heating these brittle elements to a "color" temperature (above 500 Deg. F) should allow them to be moved or repositioned without mechanical damage.

As indicated in other sections, the iron-chrome-aluminum materials also exhibit a low temperature brittleness phase. This will typically be a problem when the material is below 68 Deg. F and will become more of a problem as the temperature is decreased. Typically, attempting to bend, twist, or flex these materials below 40 Deg. F will cause cracking and breakage. As such, if the units have been stored in an unheated area, allow them to warm up to as least 70 Deg. F and preferably higher, since the higher the temperature the easier they are to work with.

When these alloys are welded, the immediate area in the weld site will become brittle (from the heat of welding). These areas should always be given special treatment when handling, since excessive force or flexing applied to these joints will cause cracking and perhaps breakage. Because of this potential risk, it is often desirable to supply very large size element systems with the rod or pad terminals unattached. Once elements have been permanently secured, the terminals are positioned and TIG welded to the elements.

TERMINATIONS

Proper terminations are critical to a successful heating element application and if not done correctly will adversely effect element life. One of the major goals is to insure that the largest amount of element "lead wire" is in close "hard" physical contact with the actual "termination" as is practical. In cases where insufficient contact exists, either through a lack of material or loose physical contact, a condition known as a "HIGH RESISTANCE JOINT" can develop. This phenomena will cause localized heating in the termination area causing further degradation of the connection, leading to failure at the joint. Generally this will require the replacement of what is otherwise a perfectly good heating element. An added point of consideration is the fact that the termination process requires metals of differing alloys to be joined together. While this joining process may produce chemical reactions at the junction, which can lead to early failure, it can be minimized if kept under 1000 Deg. F.

When terminating small gauge wire leads such as those commonly found on ceramic plate or vacuum formed fiber heater panels, the recommended practice is to use a mechanical compression procedure. This can be a bolt (binding post) with washers and jam nuts, split bolt with washers and nut, or a specialized terminal strip. In all cases, the lead wire should be thoroughly cleaned at the area of contact by the use of steel wool or light sanding, to insure a good electrical connection. Use of chemical cleaners is STRONGLY discouraged, since they may leave a residue that could cause corrosion and early failure. The lead wire must be wrapped completely around the binding post and compressed between the washers and jam nuts or the terminal strip hardware. Insertion through the split bolt and compression between the washers will generally suffice. The preferred terminal material is brass although stainless steel is acceptable in many applications. Note: Excessive and/or repeated bending will cause "work hardening" of the material leading to cracks/breakage.

The use of ring connectors is NOT recommended due to the generally insufficient amount of contact area between the lead wire and ring sleeve and probable lead wire deformation or damage caused during the crimping process. If ring connectors must be used, they should be stainless steel and must be either TIG welded or silver soldered to the lead wire.

The use of joint compounds is NOT recommended. Although this is a common practice for electrical connections when dealing with power wiring, the joint compound could adversely affect the integrity of the termination (generally causing corrosion and thus early failure).

During this process, the lead wire can be bent to conform to your specific situation. Caution must be taken to insure the integrity of the internal connection. To avoid placing excessive stress on this junction, the use of soft nose pliers is recommended to hold the lead wire secure where it exits either the heating panel or furnace. The lead wire can then be bent as required (SEE SECTIONS ON MINIMUM BENDING RADIUS AND BRITTLENESS CONCERNS).

A certain amount of "slack" must be provided in the element leads to allow for expansion and contraction during heat up and cool down cycles. If this is not done, the lead wire may be damaged or break due to mechanical stress. This is a compound problem because in addition to the wire expansion, the furnace shell, insulation, and internal support structures are moving during thermal cycling. However, from a wire standpoint only, 1/8" to 1/4" of slack should be enough for most wire gauges.

For heavier gauge wire elements, a "rod" lead is usually supplied. When this is the case, the rod generally will be machined to allow use of factory specified connection schemes. A common procedure would be to provide the end of the rod threaded for use with washers and jam nuts. Care must be exercised when tightening these connections not to twist or flex the rod since this may cause cracking or complete failure of any welded joints used to connect the rod to the actual element (SEE SECTIONS ON LEAD STYLES AND BRITTLENESS). Other concepts used are slots and/or holes which allow the client to weld other leads of heavy cross section conductors directly to the element using approved procedures. Special mechanical compression connectors can also be used where applicable.

It is recommended that the terminations be checked for tightness after the first eight (8) hours of operation and on a periodic basis thereafter to insure a high resistance joint does not develop through looseness. The length of time for the follow up examinations depends on a variety of factors such as cycle rates, ambient conditions, induced physical vibrations, etc., but should not exceed six (6) months. It should be noted that this is a common practice that should be applied to all electrical power connections. INCOMING ELECTRICAL POWER MUST BE DISCONNECTED AND LOCKED OUT ON THE SYSTEMS TO BE EXAMINED, PER RECOGNIZED ELECTRICAL MAINTENANCE STANDARDS AND CODES.

LEAD PROTECTION

Often it is desirable to provide a protective covering over the element leads. This may be required due to electrical or mechanical considerations. Great care should be taken when selecting a protective shield for the leads. The most common practice is to run the lead either inside a high temperature ceramic tube or place high temperature ceramic beads over the lead. Either of these methods can also have a flexible sleeve (such as NEXTEL) placed over the top for additional protection. In general self sticking tapes should not be used since even the high temperature grades typically use organic based mastic/adhesive which can break down into carbon based substances. These can in turn react with the wire causing corrosion, carbon infiltration, and embrittlement.

Also the grades of insulation used should be examined carefully. Many of the lower rated materials have a significant amount of free silica in them. When iron-chrome-aluminum based alloys are used for heating element conductor (generally higher temperature applications up to 1300 Deg. C) the protective alumina oxide coating formed on the outside of the conductor will react with the free silica starting at temperatures around 1000 Deg. C. This reaction will lead to a eutectic melting phenomena occurring at the point of the reaction. Excessive insulation of the leads could also develop overheating conditions both of the lead and in the area of the terminations.

Fiber based heating systems are traditionally treated on the outside with a substance to make the fiber somewhat rigid and self supporting. However, undo pressure will cause permanent deformation of the fiber surface and/or cracking that will adversely effect the insulation qualities of the refractory fiber pad. Trying to force fit the units will most likely cause the fiber to crack or break off. The leads or terminal pads provided on the fiber pads should be supported to prevent twisting or flexing during the attachment of power leads. This will prevent the fiber being damaged in the lead exit area. As with all refractory fiber based materials, an approved respirator should be worn when handling these types of heater packages, especially if the heater has been at temperature for any length of time and is being replaced.

REPAIRS

In some of the larger elements (rod style) and on certain lead assemblies, it may be possible to repair a break (mechanical in nature or where the conductor is not extensively melted). To do this for nickel-chrome alloys the oxide must be cleaned off, the wires joined together, and then welded using approved methods. For iron-chrome-aluminum alloys, a similar operation is used except material should be heated to "red" color temperature before it is moved. This will allow bending of the conductor segments without causing additional breakage.

HANDLING, STORAGE, ENVIRONMENTAL FACTORS

One of the reasons modern metallic based heating elements can operate at such high temperatures (to 1400 Deg. C) for extended periods of time, is they form a protective oxide on their outer surface. Surface contamination by a variety of substances will interfere with the oxide formation process. (which occurs only at elevated temperatures) This will lead to premature failure of the element. Since most elements are shipped in a "green state" (no oxide on the surface) it is imperative that the material be kept as clean as possible until the element is installed and has been heated to form the oxide.

Another important area of consideration is storage of the elements. They must be protected from the weather and must be stored inside a cool, dry location. Ideally this would also be a low humidity location, but in practice, this is not always possible. Many of the alloys used for heating applications have a high percentage of iron in them and they are susceptible to rust when exposed to high moisture. The rust will interfere with oxide formation and lead to premature failure. In cases where ceramic based or vacuum formed fiber elements are used, the ceramic and fiber can absorb moisture either directly from the air or from direct exposure such as condensation, leaky overhead pipes, or spills. This absorption characteristic can compound the rusting potential since in many cases, the alloy will be embedded and not visible for inspection. (SEE DRY OUT SECTION).

Another area of contamination is body oil present on your hands. It is recommended that clean cotton gloves be worn when handling the exposed elements to protect them. If this is not possible, thoroughly wash hands with soap and water before handling the elements. It should be noted that the smaller the element material, the more significant this contamination becomes, especially for wire sizes below BSA 18 gauge and strip thickness of 0.04 in.

In general, all petroleum based products and most "shop dirt" will adversely effect oxide formation. Therefore, never place the elements directly on the shop floor without first putting down a protective barrier (such as clean paper or cardboard). If there is a lot of oil vapor present in the atmosphere, do not expose the elements to the atmosphere any longer than absolutely necessary.

When heaters are removed from storage, they should be warmed to a minimum of 68 Deg. F before attempting to install. Many of the high temperature alloys show increasing problems with ductility and brittleness at lower temperatures (below room temperature or 68 Deg. F). If the leads or elements are below this temperature, attempting to bend or shape them could lead to cracking or breakage. Note that the danger of this occurring increases dramatically as the temperature also decreases. Although 68 Deg. F is a generally accepted minimum temperature for working with these alloys, in practice, it is very desirable to use a higher temperature (up to 100 Deg. F) if possible. The reason for this is small variations in batch consistency could shift the critical temperature point up or down several degrees.

Ceramic based heater systems by their nature are susceptible to mechanical damage from mechanical shocks and stresses, thus do not drop them or force fit them.

VIBRATIONS

For locations experiencing excessive vibration, it should be a prime consideration for shock mounting using industry standard shock mounting techniques. Excessive vibration can also affect wire connections. Make sure the connectors used will withstand the vibration and remain tight.

LOADING

A 20% reduction in maximum loading should be allowed for if a contactor is used in lieu of an SCR control. Please note that this SCR control is either a phase angle fired or variable time base fired zero cross over unit. Generally, a zero crossover unit is more desirable but actual application will determine the practical choice.

DRYING OUT PROCEDURE: EMBEDDED ELEMENTS

Before the initial heat up of a furnace, check to see if any embedding cement has broken loose from the ceramic heaters and if the heater wire is visible. Apply embedding cement where needed following the instructions given for patching heaters.

DRYING OUT PROCEDURE: REFRACTORY MATERIALS

It is highly recommended to run the temperature up slowly in order to dry the moisture out of the refractory lining. It is suggested that the unit be run up to 200 Deg. F one to two hours, then slowly to 500 Deg. F and kept at this temperature for four to six hours, open to air. Then increase the temperature 150 Deg. F per hour thereafter until normal operating temperature is reached. CAUTION: If steaming appears at any time during run-up, do not increase temperature until steaming stops.

CYCLING

Note: The best way to get long life is to use a large cross sectional area element with moderate watt loading, and never shut it off. The problem with cycling is the oxide will either crack or spall off exposing the base material to further oxidation and eventual failure.

HELPFUL SUGGESTIONS AND PRACTICES

While heating elements do not have a projected service life in most applications, the possibility of ultimate failure should be considered. Provisions should be made for ready replacement if the potential down time will be expensive or critical to production or other operations. Replacement parts should be stocked as necessary so that a failed element can be replaced in a short period of time without completely stopping or disrupting the process.

1. Keep the equipment clean, particularly around the terminals, wiring enclosure, and heater itself, through a regular maintenance program. In highly contaminating environments or in hazardous atmospheric conditions, special attention should be directed to the terminal boxes and electrical enclosures. Heater terminal enclosures can be designed with special fittings to use positive inert gas pressure to prevent the entrance of contaminants or explosive gases. Purging is a low cost solution to many terminal problems where local codes permit the use of continuous purging.

2. Use field wiring suitable for the temperatures involved. Heater terminal boxes and enclosures usually get quite warm during operation and may require special wiring techniques. For field terminal connections inside the heater enclosure, alloy wire with high temperature insulation is recommended unless the instruction sheet specifically states that copper or low temperature insulated wire may be used. Never use rubber, wax impregnated or thermoplastic insulated wire on high temperature heater applications since these materials will deteriorate very quickly with heat. Some insulating materials may give off fumes which could cause injury or damage to the heating equipment. Always check local electrical codes for proper wiring requirements.

3. Use thermal insulation wherever possible to reduce heat losses. Insulation is relatively inexpensive and will pay for itself in a short time by reducing heat losses and operating costs. It is also desirable from the standpoint of personnel comfort and safety.

We certainly hope this information is helpful and we realize that it does not answer all questions that arise. Thus for additional assistance, contact your nearest Thermcraft representative or call our plant direct.