Furnace Insulation Module User's Guide **March 8, 2017**

General Description

ZIRCAR Ceramics' Furnace Insulation Modules Type FIM are pre-assembled insulation systems constructed of premium grade ZIRCAR Ceramics fibrous ceramic insulation layers, encased in a rugged shell.

These complete units require only the addition of a protective furnace enclosure and power supply, with temperature controller, to build a complete rapid cycle furnace. Easy to use, they facilitate rapid furnace construction and use components that are easily replaced.

Set-Up

Furnace Insulation Modules should be installed and operated properly to avoid damage to the lining, elements, and user. Make sure to follow these steps:

UNCRATING: Remove packing from furnace chamber. Take care during removal not to damage the Hot-Face insulation. Inspect lining for damage and report to carrier immediately.

POSITIONING: The module should be located with the roof level, to assure that the elements hang true. It should be positioned within a proper enclosure, which will provide electrical and thermal protection to the operator. DO NOT ADD ADDITIONAL INSULATION TO THE OUTSIDE OF THE MODULE! Modules requires a cage around element terminals to protect the operator from electrical hazards.

POWER SUPPLY / CONTROL INSTRUMENTATION: ZIRCAR Ceramics' FIMs are not supplied with power supplies or controllers on a regular basis. It is critical that the power supply the end user integrates with an FIM provides the proper electrical supply to the elements. Failure to do so can result in overheating of the chamber and possible lining failure as well as damage to the elements.

Check that the power supply used is of the type recommended and is functioning properly at all times. See Appendix I and Appendix II for typical wiring diagrams.

Heating Elements are composed of molybdenum disilicide ($MoSi_2$) cermet. This material is extremely brittle and exhibits a positive temperature coefficient of resistivity. These elements have low (negligible) resistance at room temperatures. Because of these

unique characteristics it is important to utilize a properly designed power supply which provides a proportional controlled, phase angle fired electric energy source with current limiting capability. The use of non proportioning on/off, or "burst" fired power systems can damage the heating elements and are not recommended.

The power supply should provide a maximum power rating to the heating elements as specified by the manufacturer. Refer to Appendix III for tables listing electrical characteristics of the elements. The following considerations are important:

Maximum Output Voltage:

The power supply should be sized to provide the maximum voltage recommended by the manufacturer of the elements at operating temperature. This specified total voltage relates to the permissible surface loading of the element and should not be exceeded to prevent overheating and possible damage to the elements and lining.

Maximum Output Current:

This will occur upon initial heating when the elements are at (or near) room temperature. The current limit feature of the SCR power controller will be required to limit the current during this initial heat-up phase. Maximum current at start-up should be limited as follows:

ELEMENT SIZE	MAXIMUM CURRENT
3/6	75A
6/12	200A
9/18	350A

Sizing the power supply to provide current of 1.5x to 2x the maximum rated element current (at operating temperature) has proven to be adequate for most installations.

As the elements heat-up and increase in resistivity they will become self-limiting with respect to current provided the maximum recommended operating voltage is not exceeded.

ACCESSORY INSTALLATION

Hearth Plates: Locate hearth plates in floor of furnace on top of hearth posts. Install ceramic fiber blanket or "wad" material to cushion and level the plates. Do not operate furnace with load without hearth plates or other support mechanism.

Heating Elements: Carefully remove elements from packaging. Remove wooden spacers by snipping the cable ties or tape by cutting with sharp knife or razor blade. *DO NOT STRESS ELEMENTS IN HANDLING* *HEATING ELEMENTS ARE COMPOSED OF $MoSi_2$ CERMET AND ARE EXTREMELY BRITTLE*

3/6mm MOSI2 Elements

Place element in Type H-6 fibrous ceramic holder. Locate 6mm to 3mm transition point even with or up to 1/4 " past end of insulation tab. Proper positioning will place the transition point at or slightly below the furnace roofline. *DO NOT LOCATE TRANSITION POINT ABOVE OR MORE THAN 1/4" BELOW FURNACE ROOF LINE* Tighten element holder nut so that the element is securely held in place.

Insert elements in furnace roof. Elements should slide smoothly into place. Use a file to slightly enlarge slot if needed. DO NOT FORCE ELEMENTS INTO POSITION

Check that end of insulation tab is located at furnace roofline Do not operate furnace if insulation tabs are not properly positioned.

Wrap element strap around top of element terminal. Leave enough slack so that the strap does not pull on element.

Secure element strap with manual terminal clamp. Be careful not to stress element terminals while installing terminal clamp.

6/12mm MOSI2 Elements

Place element in Type H-12 fibrous ceramic element holder. Locate 6mm to 12mm transition point even with the end of the insulation tab on the element holder and the conical section below the roofline. Proper positioning will place the 6/12 transition point at the furnace roofline. DO NOT LOCATE TRANSITION POINT ABOVE OR MORE THAN 1/4" BELOW FURNACE ROOF LINE

Connect element straps to element terminals. Loosen nut of terminal end of strap. Remove and discard PVC spacer. Slip strap end over element terminal. Tighten nut.

Insert elements in furnace roof. Elements should slide smoothly into place. DO NOT FORCE ELEMENTS INTO POSITION

Check that end of insulation tab is located at the furnace roofline. Do not operate furnace if insulation tabs are not properly positioned.

Connect post end of element strap to bolts on terminal boards. Secure with aluminum nut, lock washer and flat washer.

Check that element strap excess is folded out of contact from neighboring strap.

Custom Configuration MOSI2 Elements

Check outside view drawing for proper element position.

Thermocouple: The thermocouple should be located as shown on the outside view drawing or as supplied. Check that the thermocouple is functioning properly to avoid over firing. Over firing will accelerate furnace-lining failure.

OPERATION

INITIAL START-UP: The elements sometimes have residual stresses from their manufacturing process and will bend on initial heat-up to relieve them. If the bending is severe enough the elements will contact the furnace lining. In the case of alumina lined chambers, the element will react with the insulation and usually break and damage the insulation.

It is recommended that elements be heated to 1500° C for the first time to allow for the initial deformation in the heating elements.

Heat the furnace to 1500° C as fast as possible to allow elements with residual stresses to deform. Hold for approximately 15 minutes.

Allow the furnace to cool and examine the elements. Rotate 180 degrees any elements bending towards the wall. During subsequent firings the elements will sag and straighten themselves.

SAFETY PRECAUTION

Use dark glasses when watching glowing heating elements. The eyes are subjected to great strain when observing above 1400°C (2550° F)

HEATING ELEMENTS: After operation at high temperatures, a protective layer of vitreous silica (SiO_2) will form on the surface of MOSI2 heating Elements.

The ability of elements to withstand oxidation at high temperatures depends on the formation of this protective layer of vitreous silica on the surface. When molybdenum disilicide reacts with oxygen in the atmosphere, the layer of glass is formed and under this a thin layer of molybdenum silicide with a lower silicon content ($Mo_5 Si_3$).

The protective silica layer may spall off the elements. This is normally due to:

The contamination of the surface layer by foreign oxides, which change the terminal expansion of the glass layer and cause spalling. In new furnaces this may be caused by volatiles released by insulation materials. Spalling should subside with the depletion of these volatiles. Contamination may be caused by volatiles released from the furnace load. In this case spalling will probably not change.

When elements are operated at high temperatures for extended periods, the thickness of the protective layer increases and may exhibit a tendency to flake off when cooled down. The protective layer is, however, reformed as soon as the element re-attains a high temperature.

On an unprotected element surface, e.g. the surface from which the layer has flaked off, a yellowish, powdery layer (MoO_3) is formed. This, however, does not affect the formation of a new silica skin at temperatures above 800° C (1470° F). This yellowish layer comes off in the form of smoke when the silica skin is re-formed.

Heating elements which have been operating for a long time at a high temperature and have then cooled down, sometimes have internal stresses which cause the glaze to splinter into small fragments. There have been instances where elements, which have been cold for several days, have emitted a shower of fine glaze particles when touched.

Always use eye protection when handling heating elements that have cooled-down.

FURNACE LINING: The stability of the fibrous ceramic thermal insulation relies on a delicate chemical balance. It is important that materials which will contaminate and react with the furnace lining be removed prior to heating the chamber.

New furnace linings are organic-free but contain a certain amount of absorbed volatiles which will be driven out of the lining on initial heating. These absorbed volatiles are present in minor concentrations and do not affect the porous insulation's ability to be rapidly cycled. Initial bake out is not required.

The furnace chambers are designed for rapid cycling. It should be noted that the slower the cycling the longer the expected lining life. For this reason it is recommended that

the user avoid opening the furnace door while the chamber is hot. This practice will result in decreased life of the door insulation.

MAINTENANCE

Remove foreign materials which will react with the fibrous ceramic insulation prior to firing. These will damage and possibly contribute to the eventual failure of the lining. Foreign material can consist of:

Load remnants

Vitreous silica which has spalled from elements.

Any other material not supplied with the furnace lining.

Inspect wall and roof panels after first few firings and at regular intervals. Fibrous ceramic insulation will crack with normal service. These hairline cracks which don't open up will not affect overall performance.

Cracks and voids which open up after severe cycling or over temperature operation should be repaired. Alumina linings which have been damaged by heating element contact can be repaired by patching with SALI moldable. Remove all foreign or sintered material from the affected spot prior to patching. It is important to prevent direct-line radiation and excess temperature from reaching and damaging the back-up insulation.

Inspect insulation tabs after first few cycles and at regular intervals. Broken or poorly fitted tabs will provide sources of lost heat and can accelerate lining failure.

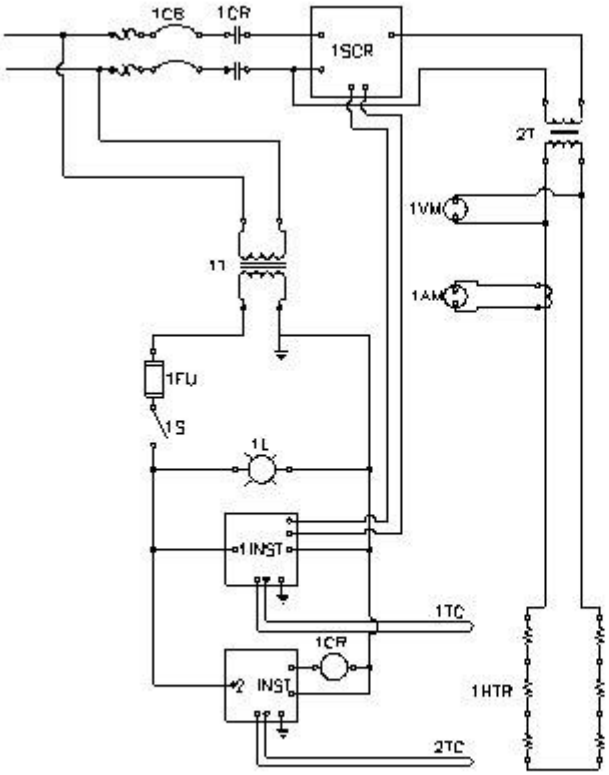
When replacing broken heating elements, inspect fibrous ceramic insulation tabs on the element holders. Tabs should not be broken. Tabs should be the same length as the roof thickness and fill the space between element terminals completely. Replace broken or "sintered" tabs.

Inspect roof and door support hanger rods after first few firings and at regular intervals. Loose or misaligned support rods should be corrected immediately. Using an Allen key, loosen the shaft collar until it will slip freely on the rod. Pull the rod back into the correct position and retighten the shaft collar. Do not rotate or stress the rods when repositioning. This may damage the internal supports. Check alignment carefully.

Inspect element electrical connections after first few cycles and at regular intervals. Check that connections are tight and free of accumulated dust or oxidation.

APPENDIX I

Typical Single Phase Furnace Power Supply Wiring Diagram

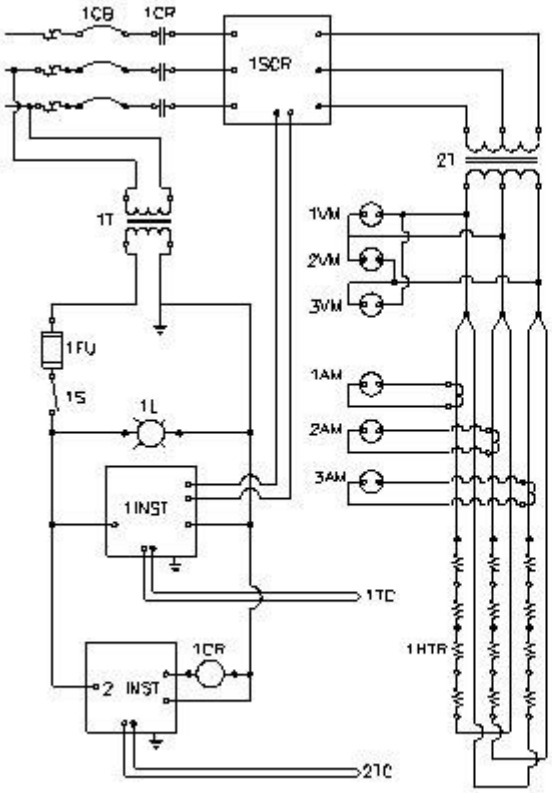


LEGEND

1AM	–	AMMETER
1CB	–	CIRCUIT BREAKER, MAIN
1CR	–	CONTROL RELAY, OVERTEMP
1FU	–	FUSE, CONTROL CIRCUIT
1HTR	–	HEATING ELEMENTS
1INST	–	CONTROLLER/PROGRAMMER
2INST	–	CONTROLLER, OVERTEMP
1L	–	INDICATING LIGHT
1S	–	SWITCH, CONTROL CIRCUIT
1SCR	–	SCR, PHASE ANGLE FIRED WITH CURRENT LIMIT
1T	–	ISOLATION TRANSFORMER CONTROL CIRCUIT
2T	–	TRANSFORMER, POWER CIRCUIT
1TC	–	THERMOCOUPLE, CONTROLLER
2TC	–	THERMOCOUPLE, OVERTEMP CONTROLLER
1VM	–	VOLTMETER

APPENDIX II

Typical Three Phase Furnace Power Supply Wiring Diagram



LEGEND

1,2,3AM	–	AMMETER
1CB	–	CIRCUIT BREAKER, MAIN
1CR	–	CONTROL RELAY, OVERTEMP
1FU	–	FUSE, CONTROL CIRCUIT
1HTR	–	HEATING ELEMENTS
1INST	–	CONTROLLER/PROGRAMMER
2INST	–	CONTROLLER, OVERTEMP
1L	–	INDICATING LIGHT
1S	–	SWITCH, CONTROL CIRCUIT
1SCR	–	SCR, PHASE ANGLE FIRED WITH CURRENT LIMIT
1T	–	ISOLATION TRANSFORMER CONTROL CIRCUIT
2T	–	TRANSFORMER, POWER CIRCUIT
1TC	–	THERMOCOUPLE, CONTROLLER
2TC	–	THERMOCOUPLE, OVERTEMP CONTROLLER
1,2,3VM	–	VOLTMETER

APPENDIX III

Electrical Characteristics of Heating Element

MOSI2, 18-6/12-12-10-1.97in.

PHYSICAL DATA

D TERMINAL LENGTH LU= 10.00 in/ 254.00 mm
G LEG SPACING A= 1.97 in/50.04 mm
E HOT ZONE LENGTH LE= 12.00 in/ 304.80 mm
H 2 SHANKS
F HOT ZONE AREA = 18.47 in.^2 /119.16 cm^2
I 0.00746 OHMS @ 25 C

TEMPERATURE DATA

J FURNACE TEMPERATURE=3000 F/1649 C
K ELEMENT TEMPERATURE=3250 F/1788 C
L WATT LOADING=120.5 W/IN^2/ 18.7 W/CM^2
M CONVECTION CORRECTION = 0 F/ 0 C

ELECTRICAL DATA HOT

U 15.0 VOLTS / 158.3 AMPS / 2373.3 WATTS TOTAL
0.09467 OHMS HOT /W 2225.7 WATTS EFFECTIVE
0.00589 OHMS TERMINAL / 147.6 WATTS TERMINAL LOSS
0.08878 OHMS HOT ZONE / 6.2 % TERMINAL LOSS

ELEMENT DATA WITH THREE WATT LOADINGS
USING A CONVECTION CORRECTION FACTOR OF 0 DEGREES FAHRENHEIT

FURNACE TEMP F	LOWER WATT LOADING 100 W/IN^2			AVERAGE WATT LOADING 75 W/IN^2			HIGHER WATT LOADING 50 W/IN^2		
FURN<-TEMP->ELEM	ELEM	AMPS	VOLTS	ELEM	AMPS	VOLTS	ELEM	AMPS	VOLTS
5072	5128	113.2	18.4	5114	98.2	15.9	5100	80.3	12.9
5162	5215	112.2	18.5	5202	97.3	16.0	5189	79.5	13.1
5252	5303	111.2	18.7	5290	96.4	16.2	5278	78.8	13.2
5342	5390	110.3	18.9	5378	95.6	16.3	5366	78.1	13.3
5432	5478	109.3	19.0	5467	94.8	16.5	5455	77.5	13.4
5522	5566	108.4	19.2	5555	94.0	16.6	5544	76.8	13.5
5612	5654	107.5	19.4	5644	93.2	16.8	5633	76.2	13.7

ELEMENT DATA WITH A CONSTANT 12.0 VOLTS

FURNACE TEMP F	ELEMENT TEMP F	WATT LOADING W/IN^2	CURRENT AMPS	TOTAL POWER WATTS
2800	3012	84.8	138	1661.0
2900	3091	82.2	134	1611.5
3000	3172	80.0	131	1567.9
3100	3255	77.9	127	1525.4
3200	3340	75.8	124	1484.2

This information is presented for illustration purposes only and is not to be taken as technical specifications. ZIRCAR Ceramics, Inc. extends no warranty, expressed or implied, and accepts no liability, relative to the application of this information.