CONNECTICUT YANKEE ATOMIC POWER COMPANY

BERLIN, CONNECTICUT
P. O. BOX 270 HARTFORD, CONNECTICUT 06101

TELEPHONE
203-666-6911

October 10, 1978

Docket No. 50-213

Director of Nuclear Reactor Regulation
Attn: Mr. D. L. Ziemann, Chief
Operating Reactors Branch #2
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Reference: (1) W. G. Counsil letter to D. L. Ziemann dated August 16, 1978.

Gentlemen:

Haddam Neck Plant
Electrical Penetration Qualification Program

In Reference (1), Connecticut Yankee Atomic Power Company (CYAPCO) informed the NRC Staff of the progress of the environmental qualification test program of the containment electrical penetrations at the Haddam Neck Plant. It was stated that certain anomalies in the program necessitated a revision to the test procedure; the new test procedure was also discussed.

The test program now has been completed, and CYAPCO hereby submits the attached report summarizing that program and the results. CYAPCO has concluded from these results that the safety-related electrical penetrations, as modified by the Raychem heat shrink tubing, would be able to perform their design basis function and so would be qualified for at least the next two years. Within the two-year period, CYAPCO will investigate various options and establish a course of action that will yield acceptable and environmentally qualified electrical penetrations at the Haddam Neck Plant for the remaining life of the plant.

CYAPCO trusts that the NRC Staff will find the attached information adequate.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY

W. G. Counsil

W. G. Counsil
Vice President

Attachment

7810260182 P

DOCKET NO. 50-213

ATTACHMENT

HADDAM NECK PLANT

RESULTS OF THE ELECTRICAL PENETRATION QUALIFICATION PROGRAM

SEPTEMBER, 1978

This report provides a description of the electrical performance of a reactor containment electrical penetration under environmental conditions representative of a loss-of-coolant accident (LOCA). The test specimen included two single conductor 4/0 AWG mineral insulated (MI) cables and four seven conductor #12 AWG MI cables. This testing was performed by Franklin Institute Research Laboratories.

Description of Test Specimen

The penetration assembly consisted of six MI cables passing through a steel cartridge seven (7) inches in diameter and five (5) feet long, with a 13-1/2 inch diameter flange at one end. The six cables protruded approximately two feet beyond each end of the steel cartridge. Four of the penetration cables tested were 7/C #12 AWG, typical of those used for safety related motor operated valves and instrumentation. The remaining two were 1/C 4/0 AWG cables representative of those associated with the containment air recirculation fan circuits.

Mineral insulated metal sheathed cables are terminated with an epoxy filled potting chamber to seal the MgO powder insulation - of the cable itself - against moisture. Normally, fiberglass reinforced silicone rubber sleeving is used to insulate individual conductors from within the potting chamber up to the external connections to other devices or equipments. Because earlier testing had demonstrated some weaknesses with this design, Raychem Thermofit heat shrinkage sleeves were used to provide additional sealing, of the manufacturer's terminations, against the ingress of moisture.

On the 1/C 4/0 AWG cables, the silicone rubber sleeving which is a part of the manufacturer's termination was cut back to within one to one and a half inches of the potting chamber. The newly exposed 4/0 AWG conductor and the region of the cable sheath behind the potting chamber were then cleaned with crocus cloth and ethyl alcohol. Raychem Thermofit sleeves were then shrunk over the cable manufacturer's terminations on the MI cables. The Raychem sleeves were positioned so that they were centered over the potting chamber of the MI cable termination. This configuration is illustrated in attached Figure 1. It should be noted that a minimum of three or four inches of this Raychem sleeve will seal the MI cable termination on both the cable sheath side of the pot and on the conductor side of the pot.

Three of the 7/C #12 AWG cables are illustrated in attached Figure 2. Approximately three inches of the cable manufacturer's silicone rubber sleeving was removed on each of the seven individual conductors. The newly exposed areas of the conductors and the cable sheath were then cleaned with crocus cloth and ethyl alcohol; furthermore, the remaining silicone rubber sleeving was abraded to insure a good seal with the heat shrinkable sleeve. Raychem Thermofit sleeves were then applied to the individual conductors. These sleeves were positioned so that approximately three inches of each sleeve shrunk down on the bare copper conductor and the remaining three inches shrunk down onto the cable manufacturer's silicone rubber sleeving. The application of these sleeves was designed to seal the primary leakage path which would allow moisture to get into the epoxy pot terminating the MI cable. A larger diameter Raychem sleeve was then shrunk down over the bulk of the potting chamber and onto the cable sheath. This sleeve was applied to seal the interface between the copper cable sheath and the brass potting chamber.

The fourth 7/C #12 AWG cable was modified with a Raychem special 7-fingered heat shrinkable cable breakout which was not representative of any presently installed cable penetration at the Haddam Neck Plant. This sample was included in the test for informational purposes and possible future reference.

Preconditioning of Test Specimen

Prior to being put into the autoclave, the penetration was thermally aged and irradiated. The thermal aging was defined using the Arrhenius equation as the basis for accelerated aging. The mineral insulated cable itself is inorganic; therefore, thermal aging is of little, if any, significance. The organic components, which are subject to aging considerations, are limited to the cable terminations, i.e., the epoxy used to fill the potting chamber, the silicone rubber sleeving which insulates individual conductors, and the Raychem heat shrinkable products. Three assumptions were made in connection with the accelerated thermal aging program. The first is that the average containment temperature in the penetration region over a year is 40°C (104°F). The second is that the 4/0 AWG conductors operate at a temperature on the order of 60 to 70°C. And finally, the 7/C penetration cables typical of safety related valve circuits are not normally energized, except for low current indicating lamp circuits, so that they are normally at the containment ambient temperature.

It was recognized, both from our own experience and discussions with Raychem, that when Raychem heat shrinkable products are applied over two different diameters, there are unresolved stresses present at the discontinuity such that the sleeves will tend to migrate in the direction of the smaller diameter. The migration is a function of both time and temperature. Because of this, two separate aging cycles were defined. First, with the Raychem sleeves installed on the two 1/C 4/0 AWG MI cables, the penetration was aged at 150°C for 168 hours. This aged the epoxy, the silicone rubber sleeving and the Raychem products, already installed, for an equivalent of 30 - 40 years assuming an operating conductor temperature on the order of 60 to 70°C. Following this, the Raychem sleeves were installed on the 7/C penetration cables. The penetration was then aged again at 80°C for 400 hours. This provided an equivalent aging of two years at a normal (de-energized) temperature of 40°C. This second aging cycle did, in fact, provide some additional aging to the two 4/0 cables; however, the effects were minimal due to the low aging temperature.

The radiation exposure included allowance for both the normal operating dose and the LOCA dose. The normal operating dose over the plant life in the electrical penetration area is expected to be 8.4×10^3 rads. This is negligible compared to the LOCA dose. Using realistic calculations - based upon 2% of the core inventory being released as per NRC Regulatory Guide 4.2 - the total dose 30 days after a LOCA at the electrical penetration area is expected to be 1.9×10^6 rads. To be conservative, the penetration was irradiated to 5×10^6 rads at a rate of approximately 0.5×10^6 rads per hour using a cobalt 60 source.

Autoclave Environmental Parameters

The environmental parameters called for a rise from initial conditions of 120°F and 0 psig to 286°F and 40 psig in 8 to 10 seconds to conservatively simulate the start of a LOCA. Actual conditions are expected to be a maximum of 260°F and 31 psig. The 286°F figure corresponds to saturated steam at the containment design pressure of 40 psig.

Approximately three minutes into the test, a chemical spray of borated demineralized water was initiated into the autoclave. The borated water was mixed to form a solution of 2640 ppm boron. This corresponds to normal refueling water storage tank values of about 2400 ppm plus 10% margin. The concentration and dissociation of hydrazine were determined to be so low as to be inconsequential; therefore, it was not used as a component of the chemical spray. The spray angle of the chemical spray nozzle was 120° and the spray rate was approximately .3 gallons per minute. The chemical spray was maintained for twelve hours.

After the initial temperature/pressure rise, the conditions of 286°F and 40 psig were held constant for 30 minutes; this is about twice the expected duration of the high temperature/pressure transient that would accompany a LOCA at Connecticut Yankee. Following this, the temperature/pressure was brought down to 232°F and 7 psig in six uniform steps over a three-hour period. These new conditions were then held constant for the remainder of the test.

The autoclave portion of the penetration test got underway Wednesday, August 23, 1978, at 18:16 hours. The test was terminated approximately 111 hours later on Monday morning, August 28, 1978. Termination of the autoclave test was based upon stabilized insulation resistance (IR) data gathered during this portion of the penetration test as discussed with the NRC Staff.

Test Voltages and Currents

During the autoclave portion of the test, all conductors (23) of the five MI Cables within the penetration assembly were continuously energized with voltage or current except for short periods while the circuits were de-energized to allow megger testing. On each of the three seven conductor cables, three peripheral conductors, equidistantly spaced amongst the six peripheral conductors of each cable, were energized with 525 volts (AC) to ground. The remaining three peripheral conductors and the center conductor were wired in series and connected to 20 ampere current source. One leg of each current source was grounded so that 525 volts was present on a conductor to conductor basis as well as conductor to ground. Each individual conductor energized with voltage was individually isolatable. The 525 volts were designed to represent the plant's 480 volt electrical system with margin. The 20 ampere current circuits were designed to represent the 17 ampere locked rotor current typical of a safety related valve with margin.

The two single conductor 4/0 AWG cables were energized with 300 VAC to ground to represent the normal 277 volts plus margin. It should be noted that the 525 volts applied between some individual conductors and the grounded sheath on the 7/C #12 AWG cables is greater - by a factor equal to the square root of 3 - than normal plant operating voltages. This overstressing of the ground insulation was due to limitations in the available test set up.

Pass/Fail Criteria

A failure of a test specimen (individual conductors) is defined as the inability of that specimen to continuously support the applied test voltage or current. There were no failures involving the test set up; the only failure was a specimen under test.

Test Results

The following test results are based strictly upon the previously defined pass/fail criteria. Failure analysis will follow in the next section of this report.

At approximately 25 hours elapsed time into the test, the voltage and current circuits were de-energized to perform megger testing. Following this - elapsed time approximately 26 hours - the voltage and current circuits were re-energized. About thirty seconds later, the circuit breaker was tripped by conductor 4 of cable 4. This was the third time the circuits had been de-energized for, and re-energized after, megger testing. The first of these was at approximately four hours elapsed time, in the chemical spray portion of the autoclave test.

The remaining ten conductors energized with voltage successfully maintained their capability to withstand that voltage throughout the duration of the test. The twelve conductors carrying 20 amps performed flawlessly throughout the test. The failure occurred in a 7/C #12 AWG MI cable. The 1/C 4/0 AWG MI cables performed flawlessly throughout the test.

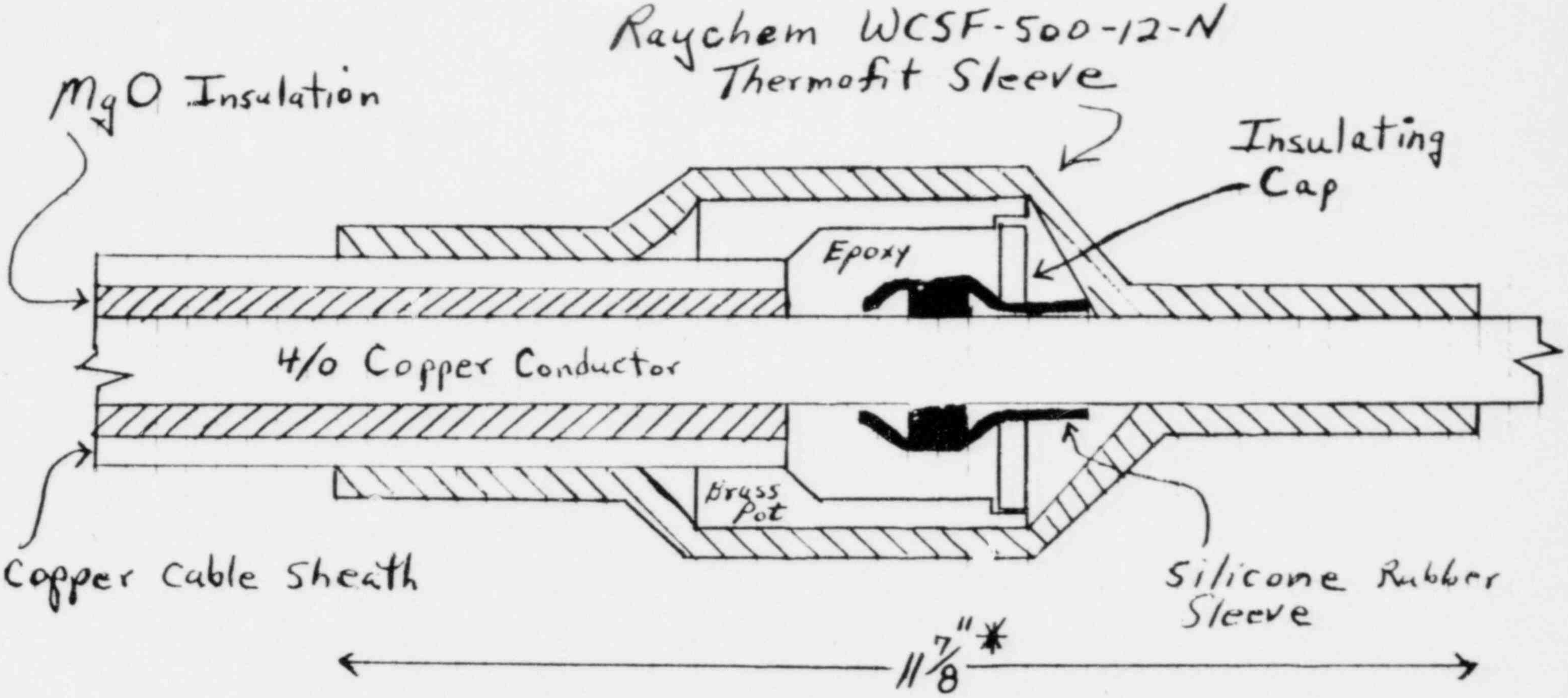
Failure Analysis

Post test examination and testing provided the location, type, and cause of the failure occurring during the test. The failure which occurred in a 7/C #12 AWG MI cable, was a short circuit of a conductor energized with 525 VAC - with respect to ground - to ground. As would be expected, it was one of the peripheral conductors of the cable. The failure occurred within the epoxy filled potting chamber which terminated the MI cable. The fault occurred between one of the six peripheral conductors and the inside diameter of the brass pot just inside the insulating cap which forms the front face of the potting chamber. In this region, there was a very tiny hole in the epoxy, and the surrounding epoxy was charred. It is not known whether the tiny hole may have been a void when the cable was potted or if the arc associated with the fault may have caused it. The ingress of moisture, either through or around the insulating cap, was the cause of the insulation breakdown. However, it must be recognized that due to test set up limitations, the ground insulation was being stressed at very nearly twice (1.73) the normal in-plant condition. It is reasonable to believe this failure would not have occurred had the normal voltage to ground been present. This hypothesis is supported by megger testing results which, in some cases, indicated that the IR of a given conductor was an inverse function of the applied test voltage; the higher the applied megger voltage, the lower the indicated IR value would be. The configuration of the Raychem sleeves on this cable are illustrated in attached Figure 2. This failure occurred approximately 26 hours into the autoclave portion of the penetration environmental test.

Conclusions

The single conductor 4/0 AWG MI cables, modified with Raychem Thermofit sleeving, performed flawlessly throughout a simulated LOCA after being aged and irradiated. The Raychem modified, aged, and irradiated seven conductor #12 AWG MI cables also performed well in the LOCA environment. The unfaulted conductors remained capable of performing their design function, i.e., maintaining voltage and current capability. The CAR fan penetrations, which must remain functional somewhat longer than most of the safety-related equipment in the containment, are now considered qualified for the remaining life of the plant. Because of anomalies involving the use of heat shrinkable sleeves on different diameters, the 7/C cables only were subject to a relatively low accelerated thermal aging temperature indicative of two years of plant operation.

The 7/C cables, used for the generation of the safety injection signal, valve alignments in the ECCS, and air solenoids for the CAR unit dampers, would be required to function for only 30 seconds into the accident, (see D. C. Switzer letter to V. Stello, Jr., dated March 6, 1978). A comparison between the time required for the 7/C penetrations to operate (i.e., 30 seconds) and the time to failure of the one conductor of a 7/C penetration (i.e., 25 hours) establishes a firm basis for concluding that the 7/C penetrations qualified for the next two years. The conservatism in the time factor, in conjunction with conservatisms in the test voltages and currents and the environmental test envelop, relative to specific plant parameters, further assures that the penetration is well qualified to perform its intended function for the next two years.

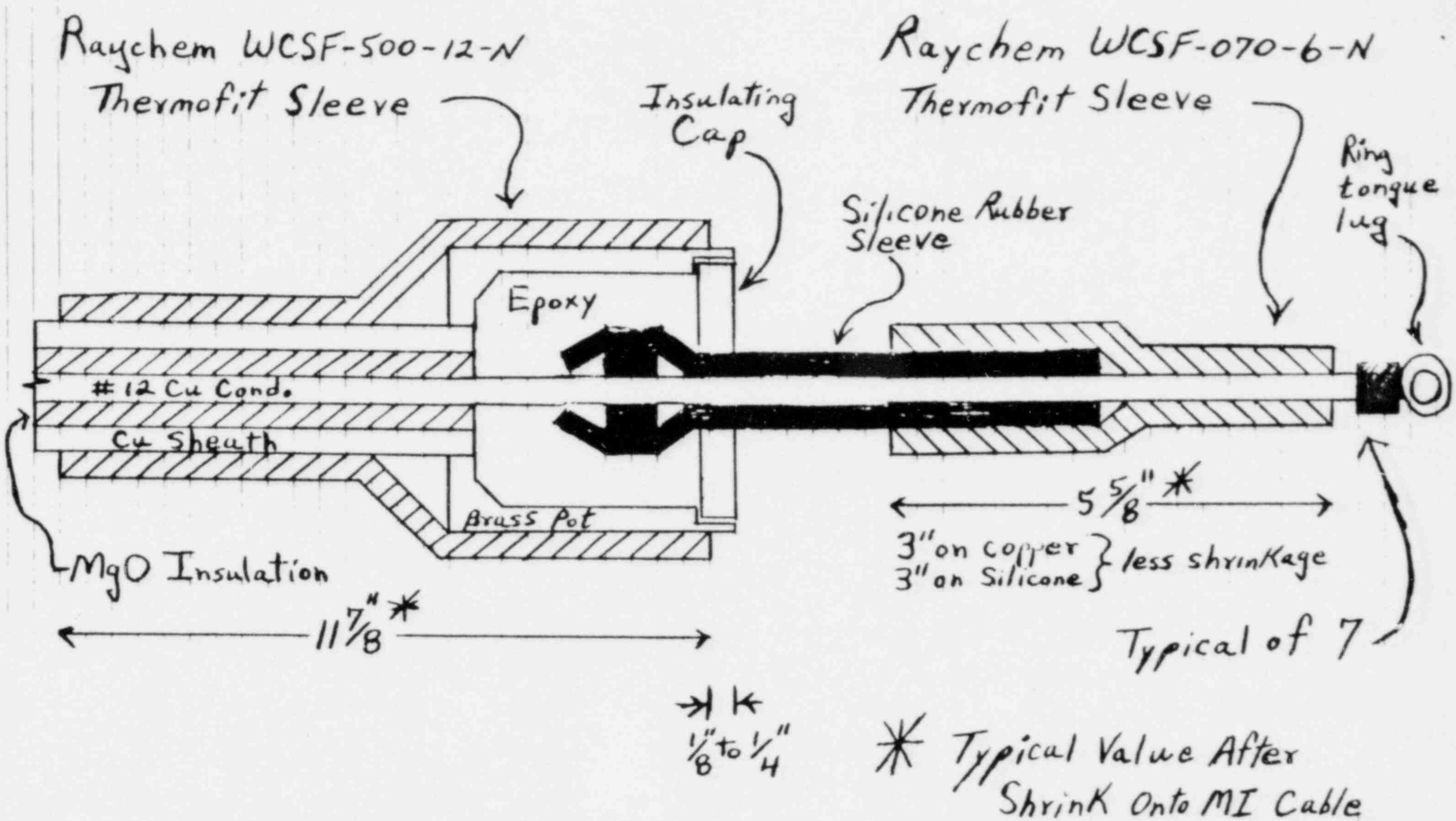


Raychem Thermofit sleeve centered over brass potting chamber

Not to Scale

* Typical value after shrink onto MI cable

Figure 1



Not to Scale

Figure 2