RECORD COPY

SNPO C.

Astronuclear
Laboratory

WANL-TME-1205

TITLE: INTERNAL INSTRUMENTATION CABLE TRANSITIONING

Date: June 29, 1965

Author(s):

G. M. Chambers

G. M. Chambers

Sensor Application Engineering

MASTER

Approved by:

R. R. Swope

R. R. Swope, Supervisor

Sensor Application Engineering

Instrumentation and Control

R. W. Kaisner

R. W. Kaisner, Manager

Instrumentation Systems and Facilities Support

Instrumentation and Control

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

INFORMATION CATEGORY

UNCLASSIFIED

R. W. Kaisner
Authorized Classifier Date

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

INTERNAL INSTRUMENTATION CABLE TRANSITIONING

1.0 SCOPE

This preliminary report describes the progress made on a technique for transitioning (splicing) instrumentation cables which will withstand radiation levels and temperature conditions internal to the NERVA reactors.

2.0 INTRODUCTION

During the assembly of NRX-A3, an instrumentation problem was encountered which involved the tie rod strain gages. Each gage contained three small (.025/.028 dia.) integral metal sheathed cables. During or immediately after seal block brazing, four of the small cables from various gages were broken immediately above the braze area in the vicinity of the braze fillet. A number of causes are suspected, the exact one not definitely known. Each suspected cause basically indicates that the diameter of the cables are so small that they permit a catastrophic problem to occur during brazing. Therefore, it was decided that in future reactors it was necessary to transition the small strain gage cables to a larger diameter cable to avoid this problem. A photograph and more detail account of the cables broken during NRX-A3 assembly is given in WANL-TMI-1420.

3.0 SUMMARY

A transition was established to splice three .025/.028 diameter single conductor cables to a .088/.090 diameter three conductor cable. This transition, which can initially be assembled on a bench and then placed in the reactor appears to satisfy the environmental requirements for operation in the core support plate (dome end) region of the reactor. The transition shown in Figure 1, is basically a sealed metal box which contains the spliced conductors electrically insulated with a ceramic cement.

The transition is comprised of the following materials:

1. Stainless steel, type 304.

2. Sauereisen DW 30 electrical cement, PDS 30174.
3. Silver braze, AMS 4769 and AMS 4770S.
4. Glass, Westinghouse Research type A508, PDS 30173.
5. The stainless steel sheathed, MgO insulated, copper conductor cables being transitioned.

A detailed technique has been developed for assembly of the transitions and has been incorporated in WANL Process Specification, PS-294649, of which a copy is attached.

4.0 TECHNIQUE DEVELOPMENT

4.1 Transition Requirements

It was first necessary to obtain information related to environmental conditions in which the transition would be operating. Since it was decided that the best possible location for the strain gage transition would be in the core support plate (dome end) area, the environmental requirements for this location were first considered. Operation in a temperature range of approximately 200°R to ambient would be required. Radiation levels for this area required operation in $<10^{15}$ NVT (fast) for neutron flux fields and $<10^{12}$ ergs/gram(c)-hr for gamma. Since cleanliness is one of the prime requirements in assembling a reactor, it was felt that assembly of a strain gage splice in the core support area could possibly cause contamination. Design of a transition that would be assembled on the bench appeared more desirable. Investigation revealed that if the transition size would permit it to pass through a cluster nut along with three of the small integral leads to the other gage installed on the tie rod, then it could be assembled on a bench after the cluster was assembled. The cluster could then be stacked in the core, the transition routed through the core support plate and a cluster nut and then secured to the plate.

4.2 Transitioning Cable Selection

It was decided that the metal sheath cable to which the three small strain gage cables would be transitioned to would have an .090 outer diameter with three conductors.

This type of cable (WANL P/N 945C964) had been used successfully as an integral sheath on other reactor instruments and an ample supply was already in NERVA stores.

4.3 Transition Container and Accompanying Electrical Cement Selection

In the past, instrumentation transitions were located external to the reactor/pressure vessel in a comparatively low radiation field and used organic epoxy* as an electrical insulator. Because of the relatively high radiation requirements for the internal transition, epoxy could no longer be used. It was now necessary to go to inorganic materials with ceramics in general appearing that they would satisfy the established requirements. The first type of ceramic tested was Bean Type H cement which employs aluminum phosphate as a binder. This cement had been used successfully in radiation fields and had good insulating qualities.

To confine the cement around the transition, a cylindrical potting boot of the type already used for making external-to-the-reactor transitions was tried. Extreme difficulty was encountered in curing the H cement after injecting it into the potting boot. It appeared that the volatiles in the cement would concentrate into a bubble and push the cement along with it as it escaped from the boot. Varying the curing time and temperature did not improve this condition.

It appeared that a possible cure for this problem would be to design a potting boot which would leave more area of the cement exposed during curing so that the volatiles could escape more readily without concentrating and moving the cement. A rectangular potting boot shown in Figure 2, was designed for this purpose. It was designed so that a lid, shown in Figure 3, could later be attached after cement curing. This did not completely remedy the problem, however, for the volatiles still concentrated somewhat permitting voids to exist. Applying small thin layers of the Type H cement in the boot and curing each layer before applying a new layer was tried and was successful, but it was a very time-consuming operation (> one hour per layer). Applying the cement layer-by-layer also endangered

* See CD-2639 for permissible radiation level of epoxys.

damaging the transitioned wires which were contained in the boot. Other available ceramic materials were tried and the one found to be most suitable was Sauereisen DW 30 electrical cement. It should be noted that ceramics, such as Sauereisen, in general, withstand relatively high radiation levels well. Battelle Memorial Institute has used Sauereisen for strain gage bonding in neutron fluxes up to 10^{17} NVT.

Sauereisen DW 30 is basically MgO , $MgSO_4$ and SiO_2 in powder form which can be mixed with water to the desired consistency. The cement can be readily applied by pouring and hardens with a setting action within 18 to 24 hours at room temperature. The curing action can be considerably speeded up through application of heat.

It was found that the DW 30 generally took 2-1/2 hours to cure when heated to $150^{\circ}F$ with a heatlamp. This was with a weight ratio of four parts DW 30 and one part water. It was decided that a heatlamp would be the most advantageous way of applying the heat for curing because of the proximity (6 to 8 inches) of the transition to a fueled cluster which can only be placed in special criticality zones. It was found during the determination of curing requirements that the time required for the insulation resistance of this cement to reach the one megohm value would vary above and below the two hour mark when heated at $150^{\circ}F$; but after the insulation resistance reached the one megohm point, they took 1/2 hour or less for the resistance to increase to maximum ($> 200K$ megohms) at which the cement was satisfactorily cured. After reaching the one megohm point, it was never found to take longer than 1/2 hour for the cement to cure.

It was therefore concluded that if the cement was heated to $150^{\circ}F$ until the insulation resistance reached one megohm, then 1/2 hour of continued heating will cure the cement. Samples were cured following this procedure and found satisfactory after sectioning.

The effects of differential expansion were checked between the Sauereisen cement and stainless parts. Completed transitions were dunked in LN_2 (approximately $140^{\circ}R$) for sustained periods and then sectioned. No adverse effects were observed.

As previously stated, the main reason for going to a transition boot was to facilitate the escape of the volatiles during curing. Another advantage of this boot is that the

transitioned wires can easily be seen and assured they are separated when filling the cement. The DW 30 cement flows easily around the wires and has no tendency to force the wires toward the metal boot. The transition boot shown in Figure 2 was designed such that it would fit through the reactor core supply plate and along with the other three leads from an opposite gage have a cluster nut passed over it. This permits initial assembly of the transition on a bench and not necessarily over the core.

4.4 Conductor Splicing and Remaining Technique Selection

For the splicing of the .025 cable CU conductors to the CU conductors of the .090 cable various types of splices were tried. This included the helix method now used in external transitioning. A common lap splice was found to be adequate as to strength and electrical qualities when splicing with silver braze. A technique is employed here which permits the splicing to be made external to the transition boot, which is later slid over the splice, see Figure 5.

It was found that the .090 and .025 cables required a temporary moisture seal for the transitioning period. If no seal were applied, the water which was mixed with the Sauereisen cement would be driven into the cable during curing, causing a low insulation resistance. An epoxy seal could not be used due to the radiation levels present. The Aero seal method could not be used since the Aero seal out gases when heated, which hinders both brazing and cement curing procedures. The glass preform method* appears to be the only one available that would do the job. All indications show the glass preforms will hold up under the present radiation level, however, no test data at the time of this report completely confirms this. Tests on the glass are scheduled to be run in the future Plum Brook tests and results should be known before the transitions are made for NRX-A4. It should be noted the glass is only a temporary seal for the transition will be completely sealed off upon transition completion. Since the glass will be confined in the transition, any outcome of the glass will not be detrimental to the reactor.

* See WANL Process Specification, PS-294624-2.

To insure the .025 cable conductors are spaced far enough apart for working ease and provide a means of establishing a specific orientation, the transition adapter shown in Figure 4 was designed. By brazing the .025 cables to the adapter and then brazing the adapter to the boot, the .025 cables become securely connected to the boot and at the other end of the transition the .090 cable is also secured to the boot by brazing. The transition boot and adapter has been designed to become completely sealed after transitioning by brazing in the areas shown in Figure 5. It was decided that silver braze of the type AMS 4770S and AMS 4769 would be adequate for all sealing operations. This silver braze, which consists of Ag, Cu, Zn and Cd, has a melting point $> 1000^{\circ}\text{F}$.

The remaining technique development involved determining procedures to be used to insure the proper conductor identity, electrical requirements and cement curing are met. A copy of this procedure is attached.

*Areas Which are Silver Brazed

SECTIONED VIEW OF THE INTERNAL TRANSITION

Figure 1

TRANSITION BOOT

Fig. 2

Material: SS 304
SAE Sketch No.: 117
George Chambers 4/6/65

TRANSITION BOOT LID

Fig. 3

Material: SS 304
SAE Sketch No.: 117
George Chambers 4/6/65

TRANSITION ADAPTER

Figure 4

Material: SS 304
 SAE Sketch No.: 118
 George Chambers 4/6/65

(A)

(B)

(C)

- A-1 With the transition boot positioned up cable, conductors are spliced by brazing.
- A-2 The strain gage leads are then brazed to adapter.
- B-1 The transition boot is positioned over splice, and brazed to adapter.
- B-2 The transition boot is then also brazed to .090 cable.
- C-1 Boot is filled with cement and cured. The lid is then brazed to the boot completely sealing the container.

GENERAL BRAZING SEQUENCE DURING TRANSITION ASSEMBLY

Figure 5

Westinghouse Electric Corporation

Astronuclear Laboratory
P. O. Box 10864
Pittsburgh, Pa. 15236
(Fed. Ident. Code No. 14683)

PROCESS SPECIFICATION 294649
(Not for Publication)

May 27, 1965

INSTRUMENTATION CABLE TRANSITIONING -
NUCLEAR ENVIRONMENT

1. SCOPE

This specification covers requirements for making instrumentation cable transitions which will be in a nuclear environment internal to the reactors, designated as follows:

<u>Designation</u>	<u>Description</u>
294649-1	Transitioning one 0.090-inch diameter three conductor (3/c) cable to three 0.025-inch diameter one conductor (1/c) cables.

2. APPLICABLE DOCUMENTS

The following documents, of the issue in effect, shall form a part of this specification to the extent specified herein.

PS 294624	PS 294625	PDS 30174
AMS 4769	AMS 4770	

3. REQUIREMENTS

3.1 MATERIAL AND EQUIPMENT

Sauereisen No. DW 30 Electrical Cement - PDS 30174
Transition Boot, P/N 946C330
Transition Lid, P/N 964B348
Transition Adapter, P/N 964B349
Microflame Torch Set, Model B
Acetylene Torch, No. 1 Tip or Waterwelded Gas Generator Model SD with No. 21 and No. 25 Tips

Printed in U.S.A.

P S 294649
Page 1 of 9 Pages

AMS 4769 Silver Braze Alloy Wire approximately 0.020-inch diameter

AMS 4770 Silver Braze Alloy, powdered, No. 200 mesh

Flux, Aircosil Low Temperature, No. 904 1250 or equivalent

Metal Sheath Stripping Tools, Sizes 0.090 inch and 0.025 inch

Transition holding jig

Acetone

Spring Clamp (No. 1 Hargrave)

Mixing Dish and Spatula

Scales - Gram, Balance

Heat Lamp, 250 or 375 watt

Megohmmeter, 50 volt, General Radio Co., Model 1862B or equivalent

Resistance Bridge

7X - magnifying glass

Grit Paper No. 400, No. 180 and No. 100

Dental Tweezers

Six Inch Graduated Rule

200°F Thermometer

Small File

NOTE: The instruments used for electrical measurements shall be under the control of the facility Instrumentation Standard Laboratory and have a current approved calibration sticker attached.

3.2 CLEANLINESS: In addition to any specific cleaning instructions detailed in this specification, the following general cleaning precautions shall apply:

3.2.1 Prior to cable transitioning the material and equipment shall be free of all dirt, scale, grease, oil or any foreign material.

3.2.2 Contamination of a transition by sanding, brazing or general shop atmosphere shall be prevented by the use of a vacuum hose placed in such a manner that all grit, smoke and fumes are removed from the assembly.

3.2.3 Upon completion of the transition the components shall be visually inspected to assure conformance with Section 3.2.1.

3.3 PREPARATION OF 0.090-INCH DIA. CABLE:

3.3.1 Select one end of the specified 0.090-inch dia. 3/c cable to be the readout end of the cable. This end will hereafter be called the readout end and the end opposite will be called the transition end. Strip and moisture seal the readout end per 294624-2.

3.3.2 Strip the transition end of the 0.090-inch 3/c cable to expose 3/4-inch of conductor and moisture seal per 294624-2. The requirements of Section 3.6 of 294624-2 shall not apply.

3.3.3 Measure the insulation resistance between all conductors in parallel and the metal sheath using a 50-volt megohmmeter. Insulation resistance shall be no less than 200 megohms. Record the value on the applicable history sheet for the sensor being transitioned.

3.3.4 The resistance of each conductor shall be measured using a resistance bridge. Record the "A", "B", and "C" (see Figure 1) conductor resistance on the applicable history sheets.

Figure 1

3.3.5 Clean any remaining MgO from the 3/4-inch length of exposed conductors at the transition end of the cable using No. 400-grit paper. Clean approximately two inches of the cable sheath, at the transition end with 400-grit paper and acetone. The conductors shall then be cut to the following lengths ($\pm 1/32$ "): See Figure 2.

Figure 2

3.3.6 Place the transition end of the 0.090-inch cable in the holding jig leaving approximately 2-3/4 to 3 inches of cable transition end protruding from the clamp. The boot and the adapter shall be trial fitted to assure that the adapter will slide into the boot. Insert the smallest diameter hole of the transition boot over the cable transition end and slide the boot onto the cable.

3.4 PREPARATION OF 0.025-INCH DIA. CABLES

3.4.1 The 0.025-inch dia. 1/c cables shall be cut to length as specified by the control drawing. The A cable shall then be cut 1/4 inch $\pm 1/32$ shorter than the C cable and the B cable cut 1/8 inch $\pm 1/32$ shorter than the C cable.

NOTE: Insure the "A", "B", and "C" identities of the 0.025-inch cables are not lost during cutting. Immediately reidentify each cable with letter type markings after cutting.

3.4.2 The "A" cable shall be stripped to expose 1/2-inch $\pm 1/32$ of conductor length and inserted into any hole in transition adapter. The hole selected shall then become the guide or reference.

3.4.3 The "A" cable shall be pushed through the adapter until approximately six inches protrudes on the other side and moisture sealed per 294624-2. The requirements of Section 3.6 of 294624-2 shall not apply. After sealing, the adapter shall be repositioned so that approximately $\frac{3}{4}$ inch of cable protrudes from the adapter.

3.4.4 The "B" and "C" cables shall be prepared as specified in Section 3.4.2 and 3.4.3 except that the "B" cable shall be inserted in the first hole counter-clockwise from the "A" cable and the "C" cable inserted in the remaining hole. (see Figure 3)

Figure 3

3.4.5 Clean any remaining MgO from each conductor using No. 400-grit paper and approximately two inches of the cable sheath, at the transition end, with 400-grit paper and acetone.

3.4.6 Electrical measurements, in accordance with the applicable designation of P S 294625, shall be secured for the sensor being transitioned. Record all measurements on the applicable history sheet.

3.4.7 Position the 0.025-inch 1/c cables in reference to the adapter as follows ($\pm 1/32$): (see Figure 4)

Figure 4

3.4.8 Place the transition adapter in the holding jig leaving approximately $5/8$ inch of the transition end protruding. Rotate the adapter so that the "A", "B", and "C" 0.025-inch 1/c cables will line up with the "A", "B", and "C" conductors of the 0.090-inch 3/c cable respectively. The relative position of the cables, in respect to the adapter, shall not be shifted.

3.5 TRANSITIONING:

3.5.1 Reposition the 0.090-inch cable so that the "A", "B", and "C" conductors of the 0.090-inch cable will overlap the "A", "B", and "C" conductors of the 0.025-inch cables respectively by $1/8$ inch $\pm 1/32$. Conductors shall be spaced at least $1/32$ inch apart for transitioning. (see Figure 5) The cable shall then be secured in the transition jig.

Figure 5

3.5.2 Transition the "A" conductor of the 0.090-inch cable to the "A" conductor of the 0.025-inch cable by lap-brazing the conductors. (see Figure 6) The braze area shall be coated with flux and the powdered silver braze alloy. Heat shall then be applied with a microflame or a waterwelder torch with a No. 25 tip until the silver braze alloy has flowed. The flux shall be removed with water after the braze has been completed. A visual examination with 7X or greater magnifying glass shall be made on the transition to insure a satisfactory joint has been made.

3.5.3 Repeat Section 3.5.2 for transitioning the "B" and "C" conductors.

3.5.4 The 0.025-inch cables shall be brazed to the transition end of the adapter using the flux, wire braze alloy and an acetylene or a waterwelder torch with a No. 21 tip. The flux shall be removed with water and the braze area cleaned with abrasive paper. (see Figure 6)

3.5.5 The transition adapter shall be marked with a small file $3/8$ inch $\pm 1/16$ from the transition side. The transition boot shall then be positioned over the adapter so that it overlaps to this mark. (see Figure 6)

3.5.6 The adapter shall be brazed to the transition boot using the flux, wire braze alloy and an acetylene or a waterwelder torch with a No. 21 tip. (see Figure 6) The flux shall be removed with water and the braze area cleaned with abrasive paper.

NOTE: Thermal expansion may result in changing of the relative position of the conductors with respect to one another. If this condition occurs the 0.090-inch cable shall be repositioned to place the conductors back to their prebrazed position.

3.5.7 The 0.090-inch cable shall be brazed to the transition boot using the flux, wire braze alloy and an acetylene or a waterwelder torch with a No. 21 tip. (see Figure 6) Slight tension may be applied during brazing to prevent the conductors from spreading due to thermal expansion. The flux shall be removed with water and the braze area cleaned with abrasive paper.

Figure 6

3.5.8 The transitioned cables shall be visually examined to assure that all brazed joints completely unite mating parts and are free of pinholes, voids etc.

3.5.9 The transitioned cables shall be removed from the transition jig and the 0.090-inch cable placed in a holding device approximately four-inches from the transition. Caution shall be exercised to avoid crushing or damage to the cable.

3.6 CEMENTING INSTRUCTIONS:

3.6.1 The 30174-1 cement shall be prepared for cementing by thoroughly mixing, on a weight basis, four parts of 30174-1 to one part of water (four grams of 30174-1 and one gram of water will pot one boot).

3.6.2 Examine the conductors to assure they are separated by at least 1/32 inch and apply small quantities of the 30174-1 mixture to the transition boot. The cement shall be agitated slightly with a small spatula to assure flow of the mixture around the conductors and into all small gaps. The boot shall be filled slightly above the rim and permitted to air cure for ten minutes minimum.

3.6.3 The transition boot shall be heated with a 250 or a 375-watt heatlamp for a minimum of one hour at $125 \pm 10^{\circ}\text{F}$ followed by heating to $175 \pm 10^{\circ}\text{F}$ for a minimum of one hour. Heating shall be from underneath and directed on the bottom of the boot. A 200°F thermometer, placed in contact with the boot, shall be used to monitor the curing temperature.

3.6.4 After the two hour curing cycle, the insulation resistance between the conductors and the 0.090-inch metal sheath shall be measured using a 50-volt megohmmeter. If the insulation resistance is greater than one megohm the cement shall be cured for an additional $3/4$ hour at $175 +25, -10^{\circ}\text{F}$. If the insulation resistance is less than one megohm curing shall continue at $175 +25, -10^{\circ}\text{F}$ until the resistance has increased to greater than one megohm and then continue for an additional $3/4$ hour.

3.6.5 If the level of the cement falls below the rim of the boot an additional layer shall be applied to raise it slightly above the rim. The layer shall be heat cured at $175 \pm 10^{\circ}\text{F}$ until hardened.

3.6.6 The cement in the boot shall be level with the rim of the boot. Excess cement shall be removed by filing or sanding with No. 180-grit paper.

3.6.7 The transition lid shall be trial fitted on the boot to assure that the lid completely contacts the rim of the boot.

3.6.8 The lid shall be positioned on the boot so that it overlaps equally on all sides and secured to the boot with a small spring clamp.

3.6.9 The lid shall be brazed to the boot using the flux, wire braze alloy, and an acetylene or a waterwelder torch with a No. 21 tip. (see Figure 7)

Figure 7

3.6.10 The completed transition shall be cleaned with abrasive paper and a clean, lint-free cloth wetted with acetone. A visual examination, at 7X magnification or greater, shall be made to assure that the brazed joint is free of pin holes, voids etc.

3.7 FINAL ELECTRICAL MEASUREMENT:

3.7.1 The resistance between each conductor, at the readout end, shall be measured using a resistance bridge. The measurement shall be within two percent of the sum of the measurements made in Section 3.3.4 and 3.4.6.

3.7.2 The insulation resistance shall be measured between all conductors in parallel and the 0.090-inch metal-sheath cable. A minimum of 200 megohms shall be required.

3.7.3 Record all measurements on the applicable history sheet. The bridge leads resistance shall be subtracted before the measurement of 3.7.1 is recorded.

4. QUALITY ASSURANCE

4.1 SURVEILLANCE: Adherence to the provisions of this specification shall be under the surveillance of a WANL Quality representative.

4.2 COMPLIANCE: No change shall be made from these procedures without first obtaining WANL approval.

4.3 QUALIFICATION: Prior to making transitions for reactor use, the operator shall produce a qualifying transition which meets the requirements of this specification.