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LABORATORY MANUAL FOR SALT MIXING TEST
IN ROD BUNDLES

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ABSTRACT

This report is a Laboratory Manual dealing with the procedure employed during Salt Tracer Experiments, which are used for evaluating the hydraulic characteristics of a rod bundle. A description of the standard equipment used is given together with details of manufacture of non-standard items i.e. probes used for detecting the salt-concentration. Details of bundle construction have not been included as they are available in the references cited. An attempt has also been made to point out potential trouble areas and procedures.

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CHAPTER 1: Introduction

The analysis of energy transfer within the sub-channels of a Reactor rod bundle, fuel or blanket, requires a correlation for determining the coolant mixing within the bundle. Such correlations are based on the data obtained from, among other methods, Salt Tracer Experiments; wherein a salt solution is injected into the bundle. The salt is injected by means of an Injector into the different sub-channel types; i.e., central, edge and corner. The spread of the salt is detected by means of probes located in a flow separator at the top of the bundle. The salt concentration determines the conductivity of the water, the property which is measured by the probes. The injection of the salt solution is done in such a manner that the main flow is not disturbed; i.e., the injection velocity equals the flow velocity in the channel where injection is taking place.

This report deals with the description of the equipment, set-up and running procedure for the Salt Tracer Experiment, also referred to as the Mixing Test. The test sections are models of 61 pin LMFBR bundles, both fuel and blanket, and have a hexagonal shape with wire-wrapped rods arranged in a triangular lattice.

CHAPTER 2: General Equipment Description

2.1 Blanket Assembly

For a complete detail of the construction and development of the test section consult Reference 3.

Diameter of the rod = 0.50"

Diameter of the wire = 0.0314"

Length of the rod = 60"

Note: The wire wrapping lead is varied by the experimenter. Details of wire wrapping are available in References 1, 2.

2.2 Fuel Assembly

For a complete detail of the construction and development of the test section consult Reference 4.

Diameter of the rod = 0.250"

Diameter of the wire = 0.0625"

Length of the rod = 60"

Note: Here too the wire wrapping lead is variable.

Note: The Injection Rods as described in Reference 4 are different from those described below. The Rods now being used are those described below.

2.3 Injection Rods (Fig. 2a)

The injection rods are of the same diameter and length as the main rods; i.e., 0.5" and 0.250" respectively for the

Blanket and Fuel Assemblies. These are hollow tubes with 0.03125" diameter holes drilled along the length of the tube at an angle of 30° to the vertical axis. The bottom of the tube is sealed and they are wrapped with the same lead and lead as the main rods. The wrapping is done in such a manner that the holes are aligned with the channel where injection is desired.

	<u>Blanket</u>	<u>Fuel</u>
Outer diameter of Injection Rod	0.50"	0.250"
Inner diameter of Injection Rod	27/64"	9/64"

2.4 Injectors (Fig. 2b)

As shown in the figure they are hollow cylinders, closed at one end and the other end is connected to a long tube which helps in placing them at the desired depth in the bundle. They have four grooves, two on either side on the central injection hole, where O-rings are fitted. These O-rings are required for obtaining a tight fit in the injector rod and thereby ensure that the flow of the salt solution is in the desired direction. The following are the dimensions.

	<u>Blanket (inch)</u>	<u>Fuel (inch)</u>
Diameter of Injector =	27/64	9/64
Dimension A =	25/64	8/64

		<u>Blanket (inch)</u>	<u>Fuel (inch)</u>
Dimension B	=	33/64	14/64
C	=	41/64	20/64
D	=	44.5/64	22.5/64
E	=	48/64	25/64
F	=	56/64	31/64
G	=	1.0	38/64
H	=	1 $\frac{22}{64}$	44/64
Depth of Groove	=	5/64	2/64
Width of Groove	=	5/64	4/64

2.5 Main Flow Loop (Fig. 3)

The figure shows the flow loops for both bundles, i.e., Blanket and Fuel. Water is drawn from the canal by pump P1 and is pumped into the Tank. A filter is employed in the line so that debris from the canal do not pass into the Tank. Large pieces of debris are liable to stick in the bundle and block the flow passages. Pump P2 draws water from the Tank and circulates it through the bundles.

When operating the Fuel bundle B2, at high flow rates, the valves 2, 4 and 5 are closed. Valve 1 is always open and Valve 3 is partially open such that, with Valves 4, 5 & 6 closed, the level of the water in the tank does not drop.

During the experiment the flow through the bundle is controlled by Valve 6 and is metered by the Venturimeter V2 and indicated by the Rotometer R2. For operating at low flow rates, below 30 gpm, Valve 6 is closed and Valve 4 is opened. This allows the use of metering and indicating system M3. The outlet pipe of this system is connected to a point after Valve 6 but before the lower plenum.

When operating the Blanket Assembly B1 at high flow rates, the Valves 6,7,8 and 9 are closed together with Valve 10. During this operation Valve 10 is used only for draining the bundle when desired. Valve 4 is fully opened and the flow is regulated by Valve 5. The metering and indication is done by system M1 comprising of the venturimeter V1 and Rotometer R1. For low flow rate operations Valve 5 is closed and Valve 7 fully opened. Valves 8 and 9 are employed depending on the flow meter being used and are used for controlling the flow rate. The outlet of metering system M3 is now connected to Valve 10, which thus forms the entrance point into the bundle. Flow meters R3.1 and R3.2, comprising the metering system M3, are of a type which do not require the use of a separate venturimeter for measuring purposes.

The principal components used are described below,

- a) Pumps P1 and P2 -- Both these pumps are similar and are manufactured by the Bell and Gascett Company.

Each pump has a maximum capacity of 300 gpm at 180 ft water head pressure.

Note: It is absolutely essential that the priming water should be opened before the pumps are turned on. This water should remain open if the pumps are being turned on and off quickly.

b) Metering System M1 -- This comprises of

Venturimeter V1: which is a TEFCO 3" meter No. A-105-2 KKM.

Rotometer R1: which is a Fischer & Porter meter No. 7404 A0514 A1 of 370 gpm capacity and using the tube FP-1/2-27-G-10/55.

c) Metering System M2 -- This comprises of

Venturimeter V2: which is a TEFCO 3" meter No. 300 A-105-2 KKM.

Rotometer R2: which is a Fischer & Porter meter No. 7303 A3749A1 of 360 gpm capacity and using the Tube FP-1/2-27-G-10/55.

Note: Both venturimeters V1 and V2 are factory calibrated and we need to check only the Rotometers. Rotometer R2 does not give correct readings; i.e., the indicated gpm is not the true gpm. The calibration graph is shown in Fig. 7.

d) Metering System M3 -- This comprises of

Rotometer R3.1: which is a Fischer & Porter meter of 19 gpm capacity and

using the Tube FP-1-1/2-G-10/83.

Rotometer R3.2: which is a Fischer & Porter
meter of 37 gpm capacity and
using the Tube FP-2-27-G-10/83

e) Valves

The valves 1,2,3,4,5 and 6 are identical 3", solid-wedge gate valves manufactured by the Jenkins Co. They are specified as 125 WSP, 200 OWG.

Valve 7 is a 2" solid-wedge gate valve manufactured by the Jenkins Co. and specified as 125 WSP, 150 OWG.

Valves 8 and 9 are identical 1 1/2" solid-wedge gate valves manufactured by the Jenkins Co. and specified as 125 WSP, 200 OWG.

2.6 Injection System (Fig. 4)

The injection system consists essentially of a large Tank, capable of being pressurized to above 120 psi, connected to the injector through a flow meter. As there is no flow measuring device incorporated so the flow-meters have to be calibrated. The calibration curves of Rotometers R4 and R5 are shown in Fig. 8 and 9.

Rotometer R4 is a Fischer & Porter meter employing the tube FP-1/8-12-G-5/81.

Rotometer R5 is a Fischer & Porter meter employing the tube FP-1/4-20-G-5/81.

2.7 Detection System (Figure 5)

The salt concentration at various points of the bundle is detected by means of an electronic system based on an "Inter-data Computer System". The probes (see Appendix A for details of construction and location) are fitted in the flow separator made of brass. Platinum is used for the electrodes because of its chemical inertness and high electrical conductivity. Details of the Computer System are available in Reference 5.

NOTE: The flow housing is so small that the probe tips, when located in position, have a tendency to touch the sides and so short-circuit. To overcome this, the inside of the channels in the housing have been painted with Scotch-clad coating (Black), No. 1706. This paint should be inspected every time the probes are removed from the housing and new paint put on if it starts to flake.

CHAPTER 3: Set-Up and Running Procedure

3.1 Setting Up the Bundle

1. Assemble the bundle and ensure that all aligning pins (dowell pins) are in place. (For assembly procedure see Reference 3 or 4).

2. Clean all the mating surfaces of the bundle and the locating plate on the lower plenum.

3. Ensure that the rubber gasket is in place.

NOTE: For the fuel bundle there is a recess cut in the lower securing plate for receiving the bundle. The gasket is placed in this recess. For the blanket bundle, there is no recess and the gasket is positioned over the opening in the plate.

4. Lift the bundle and place it upright over the gasket.

NOTE: The fuel bundle can be lifted easily by two persons but the blanket should be lifted with the block-and-tackle. Make sure the screws of the lifting plate are fully tight before operating the tackle.

5. Place the top holding plate on the bundle.

NOTE: The top plate of fuel bundle has a recess similar to the bottom plate and the gasket is fitted in place inside the recess. For the blanket assembly the top plate also has a recess, but this does not go against the bundle. In this case the recess is for fixing the flow separator. A gasket is put over the bundle before the top plate is fitted.

6. a. For the blanket assembly, secure the top plate in place. Also ensure that the bundle remains vertical during the tightening

operation.

b. For the fuel bundle place the top plenum over the plate before tightening the nuts. The plenum has an o-ring fitted; ensure that it is in place. Make sure the bundle is vertical and sealed properly in both the top and bottom plate. Secure the assembly.

NOTE: If the gasket has to be replaced, make sure that the next gasket is made of stiff rubber. The weight of the bundle is considerable and it can cause "walking" in soft rubber. This leads to blocked flow passage and excessive leakage. Use vacuum grease to hold the gasket in place when positioning the bundle and the top plate.

7. For the blanket assembly place the top plenum in place over the bundle and secure it by means of the holding bolts. These are not the same as those holding the top plate.

8. Connect the drain pipes to the plenum.

9. Run water through the bundle and check for leaking joints. Small leaks can be stopped by applying RTV-108 (or even RTV-106) to the joint and allowing to set for 2-3 hours. For large leakage check the tightness of the securing bolts and the positioning of the gaskets and the bundle.

3.2. Setting up the Experiment

1. For the blanket assembly place the injector in the injection rods allowing approximately 1 1/2 feet of the rod to remain above the bundle top. For the fuel bundle the injectors can be

placed in position even after the flow separator has been fitted in place.

2. Plug the top of the injector rod not being used. This can be done either by a rubber cork or by using a solid rod of the same size as the injector. An unplugged rod will cause appreciable flow deviations.

3. Place the flow separator assembly (i.e., flow separator with the probes fitted) in place.

NOTE: For the fuel bundle the separator assembly has to be bolted to the top plate. The locating holes are provided in the top plate. This operation is done most easily by first removing the top plenum and then fixing the separator assembly. The plenum can then be put back easily. For the blanket bundle the separator fits into a recess and so the plenum does not have to be removed. In both cases seal the joints with RTV.

4. For the fuel bundle the injectors can now be placed in position.

5. Connect the probes to the junction box. It should be ensured that correspondingly numbered labels are connected together and that the 16-pin plugs are correctly put in the sockets, i.e., the pin numbers correspond.

6. Check to see that all outlets of the junction box are correctly plugged into the white box (MPX). The connecting scheme is as shown in Figure 5.

7. Connect the MPX to the computer by means of the 16 pin connector cable marked "white box". This cable should be oriented

such that the red lining of the cable is on the side of the red dot on the MPX box.

8. Connect the video terminal to the computer.
9. Plug in the MPX, video-terminal and the computer.
10. Switch on the system.

NOTE: The MPX should always be switched off when the cables are being plugged in or the probes are being replaced.

11. Initialize the system as per the method given in Reference 5.

3.3 Calibration of Probes;

1. On a sensitive laboratory balance, e.g., like the one in Nuclear Engineering Department, weights 0.6 gm., 2.0 gms., 5.0 gms., 10.0 gms., and 20.0 gms. of common salt. The accuracy of measurement is $\pm .000001$.

NOTE: The salt is obtained in bulk quantities from chemistry stock room (Bldg. 18, sub-basement).

2. Flush the bundle with water flowing at a rate of 70-100 gpm. A few minutes of flushing is sufficient.
3. Open the drain valve and allow the water to drain completely.
4. Close the drain valve.
5. Dissolve 0.5 gms of salt in 100 lbs of water in a large barrel. Stir thoroughly to ensure that all the salt has dissolved.
6. Using a small pump or a bucket put the solution into the bundle. Ensure that the probe tips are fully covered by the saline solution.

7. Using the computer, take and store the probe readings.
This data is stored on the floppy disc.

8. Drain the bundle.

9. Flush the bundle again.

10. With fresh water in the bundle, take a set of data and store it. This will form the background reading.

11. Thoroughly clean the bucket in which the salt solution is prepared. Dissolve 1.0 gm of salt in 100 lbs of water and repeat steps 6 to 10.

NOTE: The bucket should be thoroughly cleaned otherwise any salt left from the previous solution will effect the following data.

12. Repeat data with solutions of the different concentrations obtained by dissolving 2.0 gms., 3.0 gms., 5.0 gms., 10.0 gms., and 20.0 gms. of salt in 100 lbs of water.

NOTE: The range of solutions selected is such that the readings remain below the electrical saturation point.

13. After taking the data, remove floppy disk from the computer and take it to the Mechanical Engineering Computer Room. The calibrations curves can now be plotted as indicated in Reference 5.

3.4 Experimental Procedures

1. Drain the injection tank and flush it thoroughly with water.

2. Thoroughly wash the plastic bucket.

3. Measure 1 kg. of salt and dissolve it completely in 100

lbs. of water.

NOTE: This concentration of the solution is sufficient for injecting depths of 24". A greater injecting depth will require a higher concentration for effective detection by the probes.

4. Fill the Injector Tank with the solution using a small pump or a bucket and funnel.

5. Close the inlet valve.

6. Pressurize the tank by opening the air valve. The maximum pressure is 110 psig.

7. Turn on the main pumps and allow water to flow through the bundle.

8. Align the injector with the hole in the injection rod at the required injecting depth.

NOTE: This is done by initially placing the injector at the required depth and then slowly moving it up and down till a steady stream of water flows out of the connecting tube. The alignment of the hole will also be indicated by a rise in the indicator ball of the rotameter. This occurs because now the water is flowing through the rotameter and pressure is released. At this point the hole in the injector is aligned with the hole in the injection rod. The depth of the injector is found from measuring the length of injector tube above the top of the bundle. Knowing the length of the injector, the depth can be calculated.

9. Connect the injector to the injection system. See Figure 4.

10. Take the background reading.

11. Read the water temperature.
12. Adjust the main valve to get the desired flow rate.
13. After the main flow becomes steady open the injection valve and set it to get the desired flow rate of injection mixture.
14. After allowing time for injection flow to become steady and reach the bundle, take and store the data.
15. Close the injection valve.
16. Allow the water to run for some time so that all traces of the salt injected are washed away.
17. Repeat steps 10 to 16 for each flow rate desired.
18. After completing the experiment at one injecting location shut off the main pumps. Remove the injector and place it in its new position. Make sure that tops of the injector rods not being used are plugged. You are now ready to repeat the experiment.

NOTE: Probe calibration procedure should be repeated if the experiment is being done after a gap of a few days.

NOTE: Depending on the size of the bundle it may be found that the arrangement indicated above will cause a substantial pressure drop/flow blockage in the flow separator housing. If this does occur, pulling the probes upwards and re-locating them so that only the tips of the electrodes are in the flow separator housing will alleviate the difficulty. For a very small bundle, it may be necessary to discard the flow separator housing and locate the probes only on a skeleton frame. The skeleton frame will also have to be used for very low Reynolds number flow, i.e.,

APPENDIX A

I. Construction of the probes.

1. Cut the red/white wire into approximately 3 foot lengths.
One length required for each probe.

2. Strip approximately 1/2" of the coating at one end.

3. Cut the platinum wire into .75" segments; two segments are required for each probe.

4. Using the wire wrapping gun wrap the exposed wire onto approximately 1/4" of the platinum wire.

5. Solder the wire onto the platinum wire.

6. Cut heat shrink tubing to a length sufficient to cover the soldered portion and allow some overlap. A length of 1" is found sufficient.

7. Put the heat shrink tubing in place over the joint and seal it in place using a heat gun.

8. Cut the stainless steel tubing (.125" OD and .095 ID) into 4" lengths.

9. Mount tubing into lathe collet and face off both ends. Next, apply center drill to taper the inside edge of one of the ends. This prevents damage of the wire during assembly of probe.

10. Pull the wire through the tapered end of the S.S. tube so that only the platinum leads are sticking out. Be careful not to tear the wire insulation or heat shrink tubing (Figure 6).

11. Using a voltmeter, check for short-circuit of either wire to case or to each other.

12. Set all probes upright in the wooden holder.

13. Mix a batch of structural cement as per the directions on the box. Drop a small amount over the end of the tube and allow to dry. Reverse the probes in the holder and similarly seal the other end of the tube. This will hold the platinum leads and wire in place.

14. Strip away excess cement carefully. A sharp knife may be used. Any excess cement at the end with the platinum leads will cause problems during assembly in the flow separator unit.

15. Again check for shorts by using a voltmeter.

The individual probes are now ready. They have to be connected in groups of eight to the ribbon cable and platinized before assembly in the flow separator unit. The following procedure is employed.

1. Strip the coating off the ends of the wires in the 16-wire Ribbon cable.

2. Slip on heat shrink tubing pieces onto the free ends of the probe wires.

3. Connect the probes to the ribbon cable after ensuring that the two wires of a probe are connected to adjacent wires on the cable.

4. Solder the joints and seal the heat shrink tubing in place over the joint, after allowing for overlap on both sides.

A good joint is formed by twisting the wire together before soldering.

5. Check each ribbon cable with a voltmeter. Each probe should also be checked individually.

6. Label the probes (1 to 8) to correspond to the number on the 16 pin connector of the ribbon cable. Wrong numbering will lead to unknown connections with the interfacing computer. The labelling can easily be done by visual inspections. Alternately the computer system can also be employed. When using the computer system, plug in the ribbon into one of the connecting joints in the white box after ensuring that the first pin of connector fits into the first socket and so on. Switch on the system. Place the probe in water and by taking one probe at a time out of water, it can be labelled according to the indication on the computer terminal. The reading is different in water and in air.

7. Using waxed string, tie the wires of the two probes together leaving about 6-8" for placement of the probes in the flow separator.

8. The next step is the platinizing of the probes. This is done in the following manner:

a. Prepare a cleaning solution consisting of 100 ml isopropyl alcohol, 100 ml ethyl ether, 50 ml concentrated HCl and 50 ml distilled water in a small beaker and place the probes, 8 at a time, into this solution. Allow to remain for 2-3 minutes and then rinse in distilled water. It is suggested that gloves and apron be employed during the mixing, which should be carried out in a well ventilated area.

b. Place the platinizing solution in the small 50 ml beaker and attach it to the clip on the platinizing Kit #3139/.

c. Place the probes in the solution and attach the ribbon cable to the kit.

d. Turn on the current to 50 mA. Platinize for 3-4 min. while changing the polarity of the current every 30 sec. or so by the help of the switch provided on the kit. The probes should be shaken periodically to prevent the formation of bare spots due to the rising bubbles. This platinizing will result in a uniform black coating of the platinum tips of the probes.

e. Rinse the probes in running water for about 5 minutes.

f. The platinized probes should be stored in water till required for use.

The following items are available from places shown below:

Red/white wire: 30 guage, 7/38 stand, type B TWPR
C.E. Scrymgeour Co. 13 Grant Ave., Burlington, MA 01803
(and heat shrink tubing)

16 Wire Ribbon Cable: 5 foot lengths with connecting
plugs #7P16-3T60-1, Augat Inc., 33 Perry Ave. Attleboro,
Mass. 02703

Platinum wire: EE stock-room or Erglehart industries,
New Jersey

Structural Cement: Scotch-weld structural Adhesive
#2216, 3M company, John G. Shelly Co. 16 Mia Lane,
Wellesley Hills, Mass.

Platinizing Kit; Kit #3139 Available from Yellow

Spring Instrument Co.

II. Placement of Probe in Flow Separators:

1. Screw in the separator/locating pins into the flow separator housing.
2. Place the locating plexiglass plate in position, over the separator housing, and tighten in place.
3. Label the ribbon cables from 1 to 16.
4. Using the numbering scheme shown in Figure 10, place the probes in the flow separator. Start by placing probe #1 of ribbon cable #1 in Channel No. 1 and continue by placing probe #2 of Cable #1 into channel No. 2 and so on. After fixing all probes Cable #1 move on to Cable #2 and so on till all probes are fixed. The probes should be fixed such that only about a 1/4" of the S.S. tube is inside the flow separator. It may be necessary to fix the probes in the locating plate. Use RTV-106 for this purpose. This does not form as strong a bond as RTV-108 and so replacement of the probes is easy.
5. After completing the assembly place the unit in water so that the tips of the probes are immersed.
6. Connect the ribbon cables of the probes to the junction box, ensuring that the number on the ribbon cable corresponds to the number on the junction box connecting cables. The numbering on the 16-pin plug should also correspond to that on the pocket. The computer system can now be used for checking any shorts. Replace any bad probes.

7. For the fuel bundle, the probes should be positioned such that only the tips of the platinum wire are in the separator housing otherwise excessive flow blockage will result.

FIG. 1 FUEL ROD TEST SECTION
FULLY ASSEMBLED

FIG. 2a

FIG. 2b

FIG. 2a Injector Rod

FIG. 2b Injector

FIG. 3 Flow Diagram of the Main Water Circulation Loop

FIG. 4 Injection System

FIG. 5: Detection System

FIG. 6 Showing the Construction of Probe and the Joint with the Ribbon System

FIG. 7. Graph of Calibration for Rotometer R1
Fischer and Porter Meter No. 7404 A0514 A1

FIG. 8. Calibration Graph of Rotometer R4
Fischer and Porter Meter using tube FP-1/8-12-G-5/81.

FIG. 9. Calibration Graph of Rotometer R5

Fischer and Porter Meter using tube FP-1/4-20-G-5/81

FIG. 10 Number Scheme for Locating the Probes in the Flow Separator

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