FABRICATION DETAILS FOR WIRE WRAPPED
FUEL ASSEMBLY COMPONENTS

by

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ABSTRACT

Extensive hydraulic testing of simulated LMFBR blanket and fuel assemblies is being carried out under this MIT program. The fabrication of these test assemblies has involved development of manufacturing procedures involving the wire wrapped pins and the flow housing. The procedures are described in detail in this report.

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Reports Issued Under This ContractB. Topical Reports

E. Khan and N. Todreas, "A Review of Recent Analytical and Experimental Studies Applicable to LMFBR Fuel and Blanket Assembly Design," COO-2245-4TR, MIT, Sept. 1973.

E. Khan, W. Rohsenow, A. Sonin and N. Todreas, "A Simplified Approach for Predicting Temperature Distribution in Wire Wrapped Assemblies," COO-2245-5TR, MIT, September 1973.

T. Eaton and N. Todreas, "Instrumentation Methods for Interchannel Coolant Mixing Studies in Wire-Wrap Spaced Nuclear Fuel Assemblies," COO-2245-9TR, MIT, June 1974.

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B. Chen and N. Todreas, "Prediction of Coolant Temperature Field in a Breeder Reactor Including Interassembly Heat Transfer," COO-2245-20TR, MIT, May 1975.

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Chapter 1

FLOW HOUSING CONSTRUCTION

(Taken in part from the thesis of C. Oosterman)

The initial flow housing constructed in this program (Fig. 1) was made of aluminum and plexiglas and modeled fuel assemblies. Because of corrosion problems experienced with this housing when used with stainless steel fuel pins, it was decided to eliminate aluminum as the housing material in the blanket flow housing. Brass and stainless steel were considered, but a housing of these materials as designed in Fig. 1 would have weighed 250 pounds. This added to the blanket pin weight, would have made a total of 460 pounds, a weight considered too high for easy laboratory operations. Also brass or stainless steel stock of the required size is not a standard stock item and, therefore, requires a long lead time and extra expense to procure. The design shown in cross-section in Fig. 2 reduces the weight of the flow housing and eliminates the material procurement problems. This design has a flow housing weight of 125 pounds and a total test section weight of 335 pounds. Considerable less machining time and complication is involved, and standard 1/2 inch stainless steel plate is used. Stainless steel is chosen over brass due to its superior strength. Type 303 has good machineability. The cap screws holding the plexiglas to the metal sides are spaced every 2 inches. The outer

row on one side is spaced every 6 inches. All other screws are spaced every 4 inches.

A static pressure tap is placed in each face of the hexagonal flow housing at the 1 foot and 3-1/2 foot levels below the top of the 5 foot long flow housing as shown in Fig. 3. These pressure taps are to monitor both axial and circumferential pressure drops. The levels are chosen to minimize any entrance or exit effects. Flow is assumed to be fully developed after one wire wrap lead length.

Time and expense are saved by following the proper sequence in constructing a flow housing such as this one. First, the plexiglas sides are machined and holes are drilled in them. The metal pieces are machined, but the holes to connect the plexiglas to the metal sides are not drilled. Two hexagonal jigs are machined to the inner dimensions of the flow housing. All the pieces are assembled around the jigs using the jigs to ensure that proper positioning of the pieces is maintained. The cap screw holes in the metal sides to hold on the plexiglas sides are marked with a center-punch, since all parts are properly aligned. Before disassembly, dowel pin holes are drilled through the plexiglas into the metal sides to ensure proper alignment each time the housing is assembled. The flow housing is disassembled, and the holes for the cap screws for the plexiglas are drilled.

In constructing any future flow housing, it is advantageous to cut the o-ring slot in the metal side rather than in the plexiglas. Plexiglas has very poor dimensional tolerances, and a proper slot depth cannot be maintained unless the face of the plexiglas is machined.

Vertical rod positioning is provided by 2 sets of 9 rows of horizontal rods as shown in Fig. 4. The first set of 1/4 inch rods is 1.5 inches above the bottom of the housing. The second set is 2.5 inches above the bottom. The rods must be drilled accordingly.

The two flow housing end plates are shown in Fig. 5. Two dowel pins are placed in each end of the flow housing in the metal sides to match the holes in the end plates. These provide alignment of the flow housing with the end plates. The end plates mate with the flow loop.

Chapter 2

CHANGING THE FLOW HOUSING FROM A FULL WIRE CONFIGURATION TO A HALF WIRE CONFIGURATION

Hydraulic tests which involve shaved peripheral fuel rods require that the flow housing is slightly decreased in size. Referring to Fig. 6, the distance across the flats of the hexagonal housing is 4.266" for the full wire configuration. For the half wire case, the distance across the flats is 4.234", as shown in Fig. 7.

One approach to produce this change would be to machine the mating faces of the metal sides and redrill the hole pattern in the plexiglas window. This, however, would not allow the section to be converted back to a full wire configuration without shimming the machined metal sides.

Thus, the approach shown in Fig. 8 was selected in preference to machining the metal sides. As shown, the plexiglas face - plexiglas face dimension is decreased by a protruding dovetail. The metal face - metal face dimensions are decreased by moving the metal sides slightly closer together. The exact dimensions of the dovetail are shown in Fig. 9.

To change the flow housing from a full wire configuration to a half wire configuration, the original flat windows are replaced with the dovetailed windows. Assemble the flow housing with the dovetailed windows as follows:

1. Cut four equal lengths of O-ring seals. Each seal should be $1/8$ inch longer than the flow housing length.
2. Feed the O-ring seals into the slots in the plexiglas windows. Each seal should extend about $1/16$ inch beyond each end of the window.
3. Using several cap screws, attach one plexiglas window to the two metal sides of the flow housing. Use extreme care in attaching the window so as not to chip the dovetail. Do not force the dovetail over the metal edges but rather slide the two metal sides into and against the dovetail. Tap in all dowel pins for alignment.
4. Load the fuel rods into the housing.
5. Attach the other plexiglas window to the flow housing. Again, use care in attaching the window so as not to chip the dovetail. Tap in all dowel pins for alignment.
6. Secure both plexiglas windows in place using all the cap screws provided for each window.

The flow housing is now ready for installation on its test rig.

Chapter 3

PREPARATION OF STAINLESS STEEL

RODS FOR WIRE WRAPPING

As received stainless steel rods must be cut, trimmed, and drilled prior to wire wrapping. The procedure to be described has been used in machining 85 rods with no mistakes and a fast turnover time. It has been found that it is better to work the whole lot of rods operation by operation rather than to complete rods individually. The procedure follows:

- 1) Cut the stainless steel stock to a length of 60-1/8" to 60-1/4". The 1/8" - 1/4" oversize is for trimming.
- 2) Chuck the cut rod in a lathe and face the end. Center the tool properly to avoid raising a burr in the center. After the face has been completely machined, chamfer the edge with a file.
- 3) Insert the faced end of the rod into the drill jig as shown in Figs. 10 & 11. Be sure the rod contacts the 1/4" dowel pin stop in the drill jig. Clamp the rod in the jig by tightening the two 1/4-20 nuts on the bottom of the drill jig. Drill the two 1/4" diameter holes in the rod. Use cutting oil. (Note that the drill bushings, which are made of hardened tool steel, will automatically guide the drill.)

Rotate the jig 180° (bottom up) and countersink the holes to break the edges. The countersink will have to be gripped close to the end of its shank to avoid hitting the drill jig with the drill press chuck, as shown in Fig. 12. File off any burrs. Loosen the rod in the drill jig. Rotate the rod 180° (visually) in the drill jig. Hold the rod and countersink the other side of the 1/4" dia. holes. File any burrs and blow out the chips with an airgun, and remove the rod.

4) The next procedure is to mill the rods to length. While the exact setup method is at the discretion of the individual, the following has been found to be an easy approach: obtain two 1/2" thick aluminum plates. One plate should be at least 24" long by 3" wide. The other plate should be about 6" by 3". Drill and ream the hole patterns shown in Fig. 13 in each plate. Insert 1/4" dia. dowel pins into each hole (4 total). The dowel pins should be at least 1" long. Clamp the plates onto a Bridgeport milling machine table as shown in Fig. 14. The drilled fuel rods can now be loaded into the milling machine for trimming. The drilled ends of the two rods should be laced onto the dowel pins located in the 24" aluminum plate, as shown in Fig. 15. The other two ends of the rods should be placed between the dowel pins located in the 6" plate, such that the

rods will be held "captive" (see Fig. 15). Clamp the "captive" ends of the two rods down with a milling strap. The milling head of the bridgeport should be rotated into proximity of the rod ends. An end mill can be used to machine the ends of the rod. Setting a table stop on the machine's longitudinal travel will insure that the rods will be machined to the same length. After trimming, loosen the milling strap and remove the two rods.

- 5) Next, the 1/4" dia. axial hole is drilled. It is best to perform this operation on a turret lathe. Such a machine is located in the Mechanical Engineering Material Processing Lab, (building 35-135). Permission to use the turret lathe should first be acquired from the technical supervisor of the lab, Ralph Whittimore. Ralph is also familiar with the operation and machine setup. Setting up the turret lathe requires the following:
 - a) Establishing a stop to position the rod end in the chuck.
 - b) Setting up a 5/16" dia. center drill.
 - c) Setting up a 15/64" dia. drill
 - d) Setting up a 1/4" dia. reamer.

Once the above items are chucked in the turret of the lathe, depth stops are set for each operation. The depth of the center drill should be such that the resulting outer cone dia. is greater than $1/4"$. This provides for a countersunk hole, and eliminates an otherwise additional operation. Drill depth should be at least $1-1/8"$, while reamer depth is $1"$. After the hole is drilled, a file should be run over the rotating rod to break the edge of the previously milled end. (If a turret lathe is not available, the operations will have to be performed individually on an engine lathe.)

- 6) The final operation is drilling the starting hole for the wire. It is best to use a Bridgeport milling machine for the operation and a jig. As in the fourth operation, a $1/2"$ thick plate of aluminum can be used for the jig. The plate should be about $3"$ by $9"$. Clamp the aluminum plate onto the milling machine table with a strap and drill and ream the hole pattern shown in Fig. 16. Dowel pins, $1/4"$ dia. by $1"$ long, should be inserted into the holes of the aluminum plate. Next, the milling machine spindle is located with respect to the dowel pin positions for the correct hole location. The exact spindle

location is on the hole centerline and 6" from the end of the rod (or 4.500" from the first dowel pin or 3.500" from the second dowel pin, as shown in Fig. 17). Fuel rods may be loaded into the machine for drilling by lacing the rods onto and in between the four dowel pins (Fig. 17). Clamp the rod with a milling strap. Rather than drilling the 1/32" diameter hole with a #67 drill, use the pilot point of a #0 center drill. The center drill is stronger than a drill and will not break as easily. Drill at the highest spindle speed possible (~3000 RPM) and use cutting oil. Do not push hard on the center drill. Remove the rod after drilling. The fuel rods are now ready for wire wrapping.

Chapter 4

WIRE WRAPPING

4.1 Introduction

Prepared fuel rods, as shown in Fig. 18 (from Oosterman's thesis), are wire wrapped using the apparatus shown in Figs. 19, 20, 21, 22 and 23. Basically, the mechanism is very similar to a lathe, in that both have a carriage or shuttle which is driven by a leadscrew. The rotational speed of the leadscrew is related to the rotational speed of the work, or in this case, the fuel rod, through a set of gears. Referring back to Fig. 19, on the top of the page the gear train used for wrapping 4" lead lengths is shown. Note that one turn of the fuel rod (CCW) requires the gear box shaft to rotate five turns (CW). Five turns of the gear box shaft (CW) results in 40 turns of the leadscrew (CCW). Since the leadscrew has ten threads per inch, one turn of the leadscrew would advance the shuttle $1/10"$, or, for 40 turns, 4". Thus, for 1 turn of the fuel rod, the shuttle advances 4". Note also that the "hand" of the wire wrap is the same as the "hand" of the leadscrew, since both rotate in the same direction. In other words, a right hand leadscrew produces a right hand wire wrap and a left hand leadscrew produces a left hand wrap. Currently, the machine is set up for right

hand wraps. Wire wrapping is performed by hand using the crank fastened to the 120 tooth gear of the gear box assembly. The actual mechanism of wrapping is due to the action of the shuttle, which translates forward while laying the wire down onto the rotating rod. Wire tension is produced through dead weights.

4.2 Procedure for Wire Wrapping

The following procedure should be followed in using the apparatus:

1. Slip Part A (see Figs. 19 & 20), a brass bushing, onto the fuel rod, at the end of the rod containing the two radial holes.
2. Run the shuttle all the way back against the rod end support, such that the shuttle will not interfere with the insertion of the fuel rod. (see Fig. 23)
3. Slip the end of the rod containing the radial holes through the brass bearing in the mounting plate. The rod will have to be cocked somewhat as it is inserted. As the end of the rod comes through the bearing, slip gear B on the rod (see Fig. 19 & 20). The gear should be slipped on such that the gear hub is touching the bearing in the mounting plate.
4. Push the rod far enough into the mounting plate, such that the other end of the rod, containing the axial hole, can be inserted onto the rod end support (see Figs. 19 & 23).

5. Align the radial hole in the brass bushing (Part A) with the second radial hole in the fuel rod (that is, the radial hole furthest away from the end of the rod). Insert a 1/4" diameter dowel pin, 1" long, through the bushing and rod. (see Figs. 19 & 20)
6. Rotate the rod so that the wire start hole is facing vertically upward. Clean the area around the hole in preparation of brazing.
7. Bring the shuttle to within 4" of the start hole by turning the crank on the gear box.
8. Cut off a piece of wire approximately 7 ft. long. Thread an end of the wire through the slot in the rod end support and the hole in the shuttle die (see Figs. 19 & 23). Make sure the end of the wire is not bent or flattened, or threading will be difficult.
9. Gently tap the rod end support spindle to insure the dowel pinned bushing (Part A) is firmly seated against the bearing in the mounting plate (see Figs. 19, 20 & 23).
10. Bend the end of the wire 90° to form a sharp hook which is then inserted into the wire start hole. This operation will require practice! The hook cannot be longer than the depth of the wire start

hole ($\sim 3/32$ "- $1/8$ ") or the wire will not lie flat against the rod. If the hook is too small, it will never stay in the hole.

11. Hold down the wire near the start hole and advance the shuttle towards the start position. The edge of the shuttle die, (the edge where the wire exits from the die and is wrapped onto the rod) should be brought to the center of the wire start hole, such that half the hole is covered by the die and the other half is not covered.
12. Gear B (see Figs. 19 & 20) should be disengaged from its mating gear in the gear box assembly by slipping it slightly down the end of the fuel rod. (Do not take it off the rod.) Rotate Gear B until access is gained to the setscrew on it. Engage the gear back with its mate. Be sure to push Gear B firmly against the bearing in the mounting plate, then tighten the setscrew, locking the gear to the fuel rod.
13. Carefully hang the tensioning weight (~ 10 lbs) onto the free end of the wire (see Fig. 19). Allow the weight to free hang.
14. Start wire wrapping by turning the crank in the appropriate direction. Note that the wire is being held in merely by the hook. In the beginning, be

sure that the hook does not come out of the wire start hole. After several lead lengths have been wrapped ($\sim$ half the rod), continue wrapping slowly just until the start hole is in a vertical position. Stop wrapping.

15. Apply a silver solder flux to the cleaned surfaces around the wire start position. Using an oxyacetylene torch, heat the area around the wire start position until it is red. Do not apply the torch directly to the area, but rather heat the area by concentrating the flame on the underside of the rod. This method will avoid oxidizing the surface to be soldered. When the rod is bright red hot, apply silver solder to the area around the hole. The solder should flow easily and completely wet the area. If the silver solder balls up, either the area was not clean to start or the gas mixture in the torch was not correct. Let the rod cool down, clean the area, and try again. After the solder has set, continue wrapping until the shuttle die has passed over the end of the rod and is approximately $1/4$ " from the end as shown in Fig. 19.

16. Clean the area around the end of the rod and the wire. Using the same procedure as described in 15, solder the wire to the end of the rod. Be very

careful when heating the rod not to apply the torch directly to the wire. Since the wire is sustaining a fairly large tensile stress ($\sim 13,000$ psi for a tensioning weight of 10 lbs) accidental direct heating of wire will result in rapid creep failure. After the solder has set, cut the excess wire off near the end of the rod with diagonal cutters. Remember to remove the tensioning weight first, or at least rest it on a stool. Also, remember that the soldered areas are still very hot, even though they may not be glowing red.

17. Knock the dowel pin out of the brass bushing, Part A (see Figs. 19 & 20), and the rod. Slide the rod towards the mounting plate in order to disengage Gear B from its mating gear in the gear box assembly. Rotate the fuel rod until access is gained to the setscrew in Gear B (see Fig. 19 & 20). Loosen the setscrew, thus freeing the fuel rod from the gear.
18. Push the rod far enough into the mounting plate bearing to free the end of the rod from the rod end support. Cock the rod slightly to clear the rod end support and remove the fuel rod.
19. Cool the soldered areas gradually with running tap water.

20. File off any excess silver solder or protruding wire.
21. Repeat procedure with another rod or, if finished, tie all loose details (Gear B, brass bushing, tensioning weight) to the wire wrap apparatus with a waste end of wire to avoid losing them. Small items such as dowel pins may be taped to the frame of the apparatus. Also, turn off the valves on the tanks of the oxyacetylene torch.

Chapter 5

METHOD OF SHAVING WIRE ON WIRE WRAPPED SIMULATED FUEL RODS

Half wire tests of the LMFBR flow housing require that the wire spacer on the peripheral rods of the fuel bundle is shaved to half the wire diameter at all flow housing contact points. A procedure for shaving the wire spacer follows:

First, note that the wire flats have a specific angular orientation to the wire start position (see Fig. 24). These are: 30°, 90°, 150°, 210°, 270° and 330°. Observe also on Fig. 24 that the wire start position lies on the centerline of the two 1/4" diameter radial support holes.

To angularly orient the rod for filing, the locator shown in Fig. 25 should be used. As seen from Fig. 25 the locator is simply a bar of stock with a center hole for accepting the rod, and a set of flats and 1/4" diameter holes, which are used for orienting the rod.

Orientation of the rod is accomplished by aligning the 1/4" diameter holes in the rod with the correct set of 1/4" diameter holes in the locator, then lancing the two together with two 1/4" diameter dowel pins.

Each of the six wire start-wire flat positions shown in Fig. 24 can be duplicated with the locator as shown in Fig. 26. Note that the wire flat position is 180° out of phase with the locator flat, as shown in Fig. 26.

After the rod has been correctly aligned, the rod and locator should be clamped down either to a five to six foot milling machine table or a straight, flat piece of steel. The arrangement shown in Fig. 27 was found to be quite satisfactory for filing the rods. Note that the locator is clamped down to the steel flat. On each side of the area to be filed a C-clamp should be used to hold the rod down. The C-clamp should be placed over the spot where the wire spacer contacts the steel flat, to avoid springing the rod.

The file used for shaving the wire is mounted on height blocks (see Fig. 27). These blocks control the depth of the cut. For shaving to a depth of one half the wire diameter, the block height should be:

$$\text{Wire Dia.} + \text{Rod Dia.} + \frac{\text{Wire Dia.}}{2} = H$$

or, for the given case:

$$.031 + .501 + \frac{.031}{2} = .548"$$

For shaving the wire, use a sharp mill file and a draw filing type motion. Try to keep the file forces in line with the wire, to avoid moving the wire. If the wire does move,

try repositioning it, then apply a thin layer of 10 second epoxy. Even if the wire does not move, a small amount of epoxy at each flat location is recommended.

File each spot until the rod is finished. Note that for corner rods, (see Fig. 24), the rods will have to be filed twice because of the two angular contact points.

Flow Housing Design Option

Figure 1

Flow Housing Design
Figure 2

Pressure Tap Locations
12 Inches Below Flow Housing Exit

Figure 3

Rod Support Scheme
 Figure 4

Flow Housing End Plate

Figure 5

Figure 6 - Flow Housing Dimension - Full Wire

Figure 7 - Flow Housing Dimension - Half Wire

Figure 8 - Flow Housing Configuration for Half Wire Testing

Figure 9 - Dovetail Dimensions

Figure 10 - Drill Jig

Figure 11 - Drill Jig Set-up

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Figure 12 - Method of Countersinking Holes

Figure 13 - Jig Plates for Milling Set-up

Figure 14 - Setting Jig Plates on Milling Machine

Figure 15 - Machining Ends of Rods

Figure 16 - Setting Up Jig Plate for Drilling Wire Start Hole

Figure 17 - Drilling Wire Start Hole

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type 304 stainless steel
rod diameter = 1/4-inch
rod length = 60 inches

Rod Support Holes

Figure 18

Figure 19 - Wire Wrap Apparatus

Front View

Side View

Basic Mechanism For Wire Wrap Apparatus

Figure 20

Basic Mechanism:

Gears A and B

4-inch lead, 40:1 gear ratio:

Gears A, B, C, D

6-inch lead, 60:1 gear ratio:

Gears A, B, E, F

Gear Combinations For 4 and 6 Inch Leads

Figure 21

Gear Box For 4-Inch Lead

Figure 22

Wire Wrap Apparatus
Rod End Support and Shuttle

Figure 23

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Figure 24 - Wire Start - Wire Flat Geometry

Figure 25 - Locator for Establishing Angle Between Wire Start Position and Intended Wire Flat Position During Filing.

Figure 26 - Setting Angle Between Wire Start and Wire Flat with Locator

Figure 27 - Filing Arrangement