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Atomics International

NO. TI-036-711-003

PAGE 1. 1

REV	SUMMARY OF CHANGE	APPROVALS AND DATE
1.	<p><u>Change No. 1</u></p> <p>Replace pages 6 through 11</p>	<p><i>John Smith</i> <i>7-8-75</i></p>

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One of the major subtasks of the AI Prototype LMFBR Steam Generator Program is the design, fabrication, and test of a Hydraulic Test Model (HTM) of the Prototype Steam Generator. This model will be used to verify predictions--based on theory and prior AI-MSG test data--of pressure drop, fluid flow, leak detectability, and vibration behavior of the Prototype Steam Generator.

The fabrication of the HTM also provides valuable insight into potential fabrication problems and tooling requirements for the construction of the Prototype and CRBRP plant units.

Essential features of the design of the HTM are shown in Figure 1. A complete Drawing List is presented in Appendix A. The major differences between the HTM and the prototype steam generator are as follows:

1. Overall Length. The HTM is about 20 feet, or 30%, shorter than the prototype steam generator. This foreshortening substantially reduces the cost of the unit and of the facility which will test the HTM in a vertical attitude. The foreshortening was accomplished with essentially no compromise of test objectives by merely removing a section of the center of the steam generator, which is a repetitive structure of tubes and spacers. Calculations have shown that there is a sufficient length of fully developed flow so that the pressure drop and flow distribution measurements may be taken with a high degree of confidence that they are typical of the Prototype unit.
2. Materials. The HTM is made primarily of carbon steel, whereas the prototype unit will be made of 2½ Cr-1 Mo alloy. A clear plastic cylinder is used to simulate a lower thermal liner and

Note: The frontispiece (9042-40102CN) presents the completed HTM as rigged for the move from the AI shop to the Rocketdyne test area.

permits direct observation of flow patterns in the lower end of the HTM. These material substitutions will have no effect on the test data obtained from the HTM, relative to the Prototype Steam Generator.

3. Shell Thickness. The HTM shell is made of steel approximately at 3/4 inch thick, as compared to the 1½ inch thickness of the prototype steam generator shell. Inside dimensions, which are those of interest to the hydraulic test, are identical (except for overall length) with the Prototype Steam Generator.
4. Welding Processes and Joint Configuration. The HTM was fabricated using the processes which were cost-effective for the materials, technical requirements, and quality requirements for the hydraulic test. The joint configurations and welding procedures will, of course, be somewhat different for the prototype/plant units and will be tailored to meet the requirements of the Steam Generator Equipment Specification, RDT E4-16T. A case in point is the fact the rolled joint between the individual steam tubes and the tubesheet in the HTM, whereas this joint will be a critical RDT tube-to-tubesheet butt-weld in the prototype unit.
5. Instruments. The HTM contains a large number of penetrations, pitot tubes, and view ports which are necessary for adequate instrumentation of the test. Obviously, these design features will not be incorporated into the Prototype or production steam generators.

In spite of these differences, many, if not most, of the major fabrication features which were previously unproven were demonstrated during the fabrication of the HTM; namely, (1) insertion and alignment of the tube supports and their spacing in the shroud subassembly; (2) insertion of the shroud subassembly into the shell subassembly and subsequent build-up of the shell; and (3) insertion of the tubes into the spacers and vibration suppressors during the tube lay-up.

The progress of fabrication was followed and, as required, schedule adjustments were made, using a critical path network program available at AI on timeshare computer terminals. The program which was employed, titled FPL PERT (which is written in APL), is based on the activity-on-node concept and is available from Proprietary Computer Systems. The advantages of this program are its simplicity, accessibility, and low computer cost. Appendix B contains the final output report of the FPL PERT program as applied to the HTM fabrication and shows the actual assembly sequence and schedule.

The remainder of this report consists of photographs taken during the course of HTM fabrication and the annotated comments which describe each of the photographs.

Figure 2: Drilling of Spacer Plates with Multiple Drill Press
(9042-4008)

This figure illustrates the set-up used in drilling the spacer plates and the disc and the donut tube holes in the HTM spacer plates. Many of the flow holes in the spacer plates were also drilled using this arrangement. A number of drills pass through a pattern plate which has hardened steel bushings installed to align the drills in proper position; the spacer plate is held securely below the pattern plate.

Figure 3: Spacer Pattern Plate (9035-4061)

Shown here is the pattern plate; several bushings are visible.

Figure 4: Tape-Controlled Drilling of Spacer Plates (9042-4006)

As a backup to the multiple drill press, a milling machine controlled by tape was employed to drill flow holes in the spacer plate assemblies. The program directs the mill to drill one quadrant at a time as seen in this photograph. This machine was found to be fast and reliable, and a greater dependence will be placed on its use in future spacer-drilling operations. Note that the tube holes are already in place, as a result of being drilled with the multiple-drill press.

Figure 5: Disc-Spacer (9042-4027CN)

This photograph shows a spacer having no flow holes in the central region; this is called the "disc."

Figure 6: Donut-Spacer (9042-4028CN)

The other spacer immediately next to the disc in the assembly has flow holes in the central region but none in the periphery; this is called the "donut". These figures illustrate quite dramatically the spacing of the tube support holes and also the spacing of the flow holes which surround each tube support hole.

Figure 7: Tubes in Tube Rack, Overall (9042-4016CN)

This shows the tubes in the storage rack after tube bending.

Figure 8: Tube Bending Tool (9035-4051)

This figure shows the tool used to make the precision bends required of the individual HTM tubes. The scribed radii which define each tube's curvature are visible in this figure.

Figure 9: Central Shell Piece (9035-4057)

This figure shows a typical shell section as it arrived at AI. The piece has been machined to size with weld preparations at the ends.

Figure 10: Welding of Shell Subassemblies (9042-4032CN)

This photograph shows the submerged arc welding of a girth weld of two shell subassembly pieces. The pieces shown in this photograph are of the lower end and the holes for viewports and pitot tube penetrations are apparent.

Figure 11: Completed Submerged-Arc Shell Weld (9042-4036)

This photograph is of a completed weld using the submerged-arc process and shows the very wide bead attainable by this process. A weld of the size and depth, approximately 3/4-inch, of the shell sections can be accomplished in less than four hours (including setup time) using the submerged-arc process.

Figure 12: Shell Section Subassemblies (9042-4017CN)

This photograph shows two completed subassemblies of shell sections. The weldor is adding an eye to be used for lifting and moving one of the subassemblies. This weld will be cut free and the region blended to be smooth with the existing surface after the move has been made.

Figure 13: Test of Air Pallets (9042-4002)

This figure shows the successful test of three air pallets (which will be used for moving the steam generator in the shop) which lifted a total weight of 200,000 pounds. The operator can easily move this assembly using the controls in his hand.

Figure 14: Overall View of Air Pallet Test (9042-4003)

Another view of the air pallet test. The modest amount of patching of the floor required for optimum performance of the air pallets are visible in this photograph, as is the fact that the distribution of weight on the air pallets is typical of the weight distribution of a full-size prototype steam generator.

Figure 15: Shroud Subassembly - Lower End (9035-4055)

Another view of the shroud subassembly is shown in this photograph. This shows the rings around the lower (or outlet) window and the ring which will be used to center the lower end of the shroud assembly using centering bolts from the inside. The threaded hole for that bolt can be seen at the 2:00 o'clock position on the ring which is between the window and the main support ring.

Figure 16: Shroud Subassembly - View of Inside Surface (9035-4056)

This photograph shows the inside of the shroud subassembly before the insertion of the spacers.

Figure 17: Shroud Subassembly - Upper End (9035-4054)

This shows the shroud subassembly on rolls at Atomics International before addition of the spacer plates. The flow straightener rings near the upper windows (toward the right) are readily visible. The lug which spaces the thermal liner off of the shroud and makes it

concentric with the shell may be seen near the main support ring with its bolt holes.

Figure 18: View of Upper Inlet Region (9042-4033CN)

This photograph shows the upper end of the shroud subassembly after all the spacers and the disc have been inserted, but prior to the installation of the donut. Note the rows of heads of the bolts which restrain the ring, which, in turn, hold the spacer plates in position. One of these rings (holding the disc in position) is seen in this photograph. A partial view of a typical spacer plate may be seen through the inlet window.

Figure 19: Upper End of Shell Shroud Subassembly (9042-4038)

This shows the upper end of the shell-shroud subassembly and shows the donut very clearly as well as the centering bolts which align the shroud with the shell at the upper end. The two sets of threaded holes which may be seen in the upper ring will be used to affix 1) the upper shroud piece, and 2) the seal plates.

Figure 20: Shroud-Shell Subassembly Being Built Up (9042-4018CN)

This photograph shows the shroud subassembly with the central shell section in place while the lower thermal liner is being fitted up for welding into position. In this photograph the donut has been placed in position over the disc which was shown in Figure 4.

Figure 21: Shell Shroud Subassembly - Lower End Liner (9042-4039)

This figure shows the lowest tube spacer and the liner which has now been placed in position, with three of the six view port holes clearly visible. One of the outlet nozzle penetrations may also be seen at the 5:00 o'clock position. The line of two-inch pipe thread holes in the shell and the smaller holes in the liner with their grommets in place are also visible on the "minus X" access. Pitot tubes will be inserted in these holes in a later date. The lugs which are welded to the shell will be removed; these are handling aids.

Figure 22: Overall View of Tube Insertion (9042-4040)

At this time almost half of the tubes have been inserted through the built-up shell shroud spacer subassembly. A plastic liner was placed in position between the bottom spacer and the lower tubesheet and the upper tubesheet is in position in the large structure at the far end of the HTM. The tube storage rack is just out of sight around the corner to the right of the submerged-arc welding machine. The mechanic is guiding the pointed leader tube which guides each of the steam tubes in its passage through the network of tube spacers. The insertion of these tubes was done with much greater ease than had been anticipated.

Figure 23: Elbow Region after Tube Insertion (9042-4041)

Shown in this figure are the vibration suppressor rings with the bars that permit longitudinal expansion while suppressing lateral vibration of the tubes. The upper tubesheet is also visible in this photograph. The seal plates which fit between the upper ring in the shroud have been fitted in place to prohibit flow of incoming shell side fluid into the elbow region in the vicinity of the shell.

Figure 24: Overall View of the HTM with Trunnions Being Affixed (9042-4043)

This figure shows the HTM with the fixtures (trunnions), which are used to facilitate lifting and moving of the HTM, being placed in position. The weldor at the left is attaching a handling eye to the first elbow piece which is to be moved into position shortly.

Figure 25: Welding of Lower Trunnion to Lower Tubesheet Support Ring (9042-4046)

This photograph shows the welding using metal electrode inert gas (MIG) welding which is quite rapid compared to conventional covered electrode (or stick) welding and compared to tungsten electrode inert gas (TIG) welding. In this view the tubes have not been set into final position, i.e., with the end of the tube $\frac{1}{2}$ -inch from the back face of tubesheet.

Figure 26: Welding of Upper Trunnion to Shell (9042-4045)

This view shows the welding of the upper trunnion to the shell. The doubler ring around the shell over the rolls behind the weldor was required to keep the weight of the HTM from indenting the shell where it was supported by the rolls; this was due to the fact that the HTM is thinner than the prototype which will not need this added support at the shop roll load points.

Figure 27: View of Elbow Thermal Liner (9042-4044)

This photograph shows the short thermal liner in the elbow and the accelerometer leads which pass through that liner and through the shell section proper. The three white tubes at the top of the picture are those which will be instrumented with accelerometers to obtain vibration data.

Figure 28: Rolling Tubes into the Tubesheet (9042-4059)

This shows the operation of rolling (swaging) of the tubes into the tubesheet. A mandrel is inserted into the tube and rotated and expanded at the time, thereby expanding the tube into the tubesheet and making a solid seal. The white grease used for lubrication is evident in this photograph.

Figure 29: Preparing Tubesheets for Tube Rolling (9042-4056)

This photograph shows the final staking-in-place of the tubes into the tubesheets just prior to the tubes being rolled into position. It may be noted that the lower windows and pitot tube penetrations and leader rods are in place. These latter operations were performed during the period of time that the short leg welds were being made and the upper tubesheet put into position. The drain valve for the water is also evident in this photograph.

Figure 30: Close-up of Windows and Pitot Penetrations - Lower Leg(9042-4053)

This photograph shows the plastic windows in place and the pipe-cap, back-side pitot tube penetrations with the leader tubes in place. At the bottom, slightly out of focus, is the front-side pitot tube pene-

tration. The hole shown in the center of the shell is for the drain valve of the hydraulic model; the drain nozzle of the prototype unit has a window and cover plate assembly affixed. The penetrations of the leader tubes through the pipe-caps may be noted to be away from the center. This is the result of aligning the caps with the pitot tubes as a last step in the assembly operation. Each pipe-cap was matched to the pitot tube location.

Figure 31: Build-up of Elbow Shell (9042-4047)

Here we see the elbow sections being built up and around the tube bundle. The short bars that were used to locate the upper short piece and which are tack-welded across the weld preparation groove are apparent, as are the eye-bolts which were welded to the shell piece to facilitate its handling. The welder seen behind the elbow is filling in a weld groove using the MIG welding gun. The three instrumented tubes have been painted white and are seen in the tube bundle.

Figure 32: Final Assembly of Short Leg (9042-4057)

This photograph shows the upper tubesheet support ring being lowered into position. This ring will be bolted to the tubesheet and welded to the upper shell section shown with the two rows of window openings.

Figure 33: HTM Nearing Completion (9042-4055)

Here we see the hydraulic test model in the final stages of assembly. The tubes have been rolled into place and the upper tubesheet support ring is welded into position, but the windows and pitot tubes are not yet in position in the short leg.

Figure 34: HTM (9042-4097CN)

This shows the completed HTM awaiting shipment to Rocketdyne for testing.

HYDRAULIC TEST MODEL

TI-036-711-003

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FIGURE 1

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FIGURE 6

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APPENDIX A

HYDRAULIC TEST MODEL DRAWING LIST

This Appendix contains a list of the drawings used for the fabrication of the hydraulic test model of the prototype steam generator. The design layout drawings used as the basis for the working drawings is R-N036711001. The working drawings listed below are listed by the last three digits of the drawing number: Each of these drawings is prefixed by "EX-N036711-". The indenturing of the drawing number signifies the relationship between the part shown on the drawing and the next using drawing number. In other words, all of the components of an assembly or subassembly are shown indentured immediately below that assembly or subassembly.

HYDRAULIC TEST MODEL DRAWINGS

(All prefixed by EX-N036711...)

- 006 Instrument Test Assembly-MSG Hydraulic Flow Test
- 040 Adapter, Instrument Probe-MSG Hydraulic Flow Test
- 002 Test Fixture Support Assembly-SG Hydraulic Flow Test
- 039 MSG Hydraulic Model Test Fixture Support Flange
(Matched Set)
- 041 Trunion Assembly-Lower Test Fixture Support-MSG Hydraulic
Flow Test (Matched Set)
- 045 Lifting Bracket-MSG Test Fixture-Hydraulic Flow Test
- 004 Test Assembly-MSG Hydraulic Flow Test
- 005 Shroud and Spacer Assembly-Hydraulic Flow Test
- 007 Split Ring-Spacer Support-Steam Generator Flow Test
- 015 Shroud Assembly-Steam Generator Hydraulic Flow Test
- 021 Tube Spacer-Steam Generator Hydraulic Flow Test
- 022 Disc-Steam Generator Hydraulic Flow Test
- 023 Spacer Ring-Steam Generator Hydraulic Flow Test
- 024 Donut-Steam Generator Hydraulic Flow Test
- 008 Support Flange-Outer Shell-Steam Generator
Hydraulic Flow Test
- 009 Steam Tube-MSG Hydraulic Flow Test
- 010 Tube Sheet-Steam Generator Hydraulic Flow Test

- 036 Outer Shell Subassembly-MSG Hydraulic Flow Test
(Matched Set)
- 011 Section Details-Outer Shell-Steam Generator Hydraulic
Flow Test
- 012 Pipe Section-Outer Shell-MSG Hydraulic Flow Test
- 013 Support Ring-Outer-Steam Generator Hydraulic Flow Test
- 014 Elbow Section-Outer Shell-MSG Hydraulic Flow Test
- 016 Thermal Liner-Outlet Duct-MSG Hydraulic Flow Test
- 017 Thermal Liner Inlet Duct-MSG Hydraulic Flow Test
- 018 Thermal Liner Assembly Steam Generator
- 019 Thermal Liner-Steam Generator-Blower
- 020 Vibration Suppressor Assembly-Steam Generator
Hydraulic Flow Test
- 025 Seal-Steam Generator Drawing Flow Test
- 027 Ring-Shroud Centering-MSG Hydraulic Flow Test
- 028 Details-View Port-MSG Hydraulic Flow Test
- 031 Nozzle-Water Inlet and Water Outlet-Steam Generator
Hydraulic Flow Test
- 032 Drain Nozzle-Steam Generator Hydraulic Flow Test
- 033 Thermal Baffle-Steam Generator Hydraulic Flow Test
- 034 Lug-Vibration Suppressor Support-MSG Hydraulic Flow Test
- 035 Gasket-Thermal Liner-MSG Hydraulic Flow Test

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FINAL TABULATED SCHEDULE OUTPUT
FROM TIME-SHARE CRITICAL PATH PROGRAM

APPENDIX B SHEET 1

ACTIVITY NUMBER	DESCRIPTION	RESPON SIBILITY	POSSIBLE START	POSSIBLE FINISH
20220	FINISH SPACER FABRICATION	789 SHOP		1/30/75α
20225	FABRICATE DISC AND DONUT	789 SHOP	1/31/75α	2/06/75α
20700	SUBARC WLD 36-07/36-06 SHELL	789 SHOP	2/05/75α	2/07/75α
20701	SUBARC WLD 36-04/36-05 SHELL	789 SHOP	2/06/75α	2/10/75α
20612	COMPLETE SHROUD SUB ASSEMBLY	789 SHOP	2/07/75α	2/11/75α
20710	COMPLETE UPPER 17-01 LINER	789 SHOP	2/11/75α	2/12/75α
20720	COMPLETE LOWER 16-01 LINER	789 SHOP	2/11/75α	2/12/75α
20750	ATTACH CENTER SHELL 36-01 TO SHRD	789 SHOP	2/12/75α	2/13/75α
20730	WELD UPPER 17-01 LINER TO SHRD	789 SHOP	2/13/75α	2/17/75α
20740	WELD LOWER 16-01 LINER TO SHRD	789 SHOP	2/13/75α	2/14/75α
20760	SUBARC WLD 36-05 TO 36-01 ON SHRD	789 SHOP	2/18/75α	2/18/75α
20770	SUBARCWLD 36-06 TO 36-01 ON SHRD	789 SHOP	2/19/75α	2/20/75α
20800	WELD INLET NOZZLE 31-02 IN PLACE	789 SHOP	2/19/75α	2/20/75α
20830	ADD CENTERING RING AND SEALS	789 SHOP	2/19/75α	2/25/75α
20810	WELD OUTLET NOZZLE 31-01 IN PLACE	789 SHOP	2/21/75α	2/26/75α
20780	SET UP PLASTIC LINER/LOWER TIS	789 SHOP	2/24/75α	2/25/75α
20790	SUBARC WLD LOWER END CLOSED	789 SHOP	2/26/75α	2/27/75α
20840	PUT SUBASSY, T/S,VIBN SUPPRSR IN PLACE	789 SHOP	2/26/75α	2/28/75α
20850	BEGIN TUBE INSTALLATION	789 SHOP		3/03/75α
20860	INSTALL TUBES	789 SHOP	3/03/75α	3/12/75α
20980	ADD TRUNIONS AND LIFTING BRCKT	789 SHOP	3/13/75α	3/26/75α
20861	INSTALL VIBN SUPPRESSOR RING HALVES	789 SHOP	3/13/75α	3/14/75α
20862	INSTALL ACCELEROMETERS	789 SHOP	3/13/75α	3/17/75α
20940	ALIGN,MACHINE,INSTALLPITOT ADAPTERS	789 SHOP	3/17/75α	4/21/75α
20870	WELD ELBOW LINER 18-01 IN PLACE	789 SHOP	3/18/75α	3/19/75α
20880	WELD FIRST ELBOW SHELL 36-08	789 SHOP	3/20/75α	3/25/75α
20890	WELD SECOND ELBOW SHELL 36-09	789 SHOP	3/26/75α	3/31/75α
20900	WELD THIRD ELBOW SHELL 36-10	789 SHOP	4/01/75α	4/03/75α
20910	WELD SHORT LEG SHELL 36-11	789 SHOP	4/04/75α	4/08/75α
20820	WELD DRAIN NOZZLE IN PLACE	789 SHOP	4/04/75α	4/04/75α
20970	INSTALL WINDOWS	789 SHOP	4/07/75α	4/23/75α
20920	WELD TIS SUPPORT FLANGE 08-01	789 SHOP	4/09/75α	4/14/75α
20930	ROLL TUBES INTO TUBESHEET	PURCH LABOR	4/15/75α	4/21/75α
20960	INSTALL PITOT TUBE LEADER RODS	789 SHOP	4/22/75α	5/09/75α
21000	READY TO SHIP	789 SHOP		5/12/75α
20945	PAINT HTM	789 SHOP	5/12/75α	5/19/75α

APPENDIX B (Continued)

FINAL BAR-CHART SCHEDULE OUTPUT FROM TIME SHARE CRITICAL PATH PROGRAM