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USE OF HYDRAULIC MODELS
IN NUCLEAR REACTOR DESIGN
NYO-3250-2

CONNECTICUT YANKEE ATOMIC POWER COMPANY
HADDAM, CONNECTICUT

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USE OF HYDRAULIC MODELS IN NUCLEAR REACTOR DESIGN NYO-3250-2

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by
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Appendices

The work reported herein was
done under the supervision of
A. G. Thorp II. It is dedicated
to his memory.

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Abstract

Experimental studies were conducted on a scaled hydraulic model of the Connecticut-Yankee Reactor. Various configurations were tested and compared with regard to pressure drop due to different components and with regard to the distribution of the flow at the inlet to the core. Based on these studies the geometry of the Connecticut-Yankee Reactor vessel internals was determined and the estimates of the pressure drops in the vessel was revised.

In addition, the flow distribution in the thermal shield annuli and in the lower plenum was studied and is described in the report.

Nomenclature

<u>Symbol</u>	<u>Definition</u>	<u>Units</u>
A	Cross flow area	ft ²
C	Numerical constant	-
D _e	Equivalent hydraulic diameter	ft
E	$\Delta p / (\rho v^2 / 2g_c)$ Euler number	-
f	Moody s friction factor	-
g _c	Gravitational constant(=32.174)	lb _m ft/lb sec ²
h	Manometer head	in
L	Characteristic length	ft
p	Pressure	lb/in ²
q	volumetric flow rate	ft ³ /sec
R _e	vD_e / ν Reynolds number	-
TH	Total heat (static + velocity head)	lb/in ²
v	Velocity	ft/sec
v ¹	Fluctuating component of velocity	ft/sec
VH	$\rho v^2 / 2g_c$ Velocity head	lb in ²
Δ	Increment of change	-
ϵ	Root mean square roughness	μ in
ν	Kinematic viscosity	ft ² /sec
π	3.14159	-
Π_i	i th dimensionless group	-
ρ	Density	lb _m /ft ³
$\emptyset$	Functional relationship	-
ψ	Functional relationship	-

Subscripts

d	Dynamic
Hg	Mercury
H ₂ O	Water
i	Dummy index
M	Refers to the model
P	Refers to the prototype
s or st	Static

1. Introduction

Improvements in the design of the pressurized water reactors frequently result in changes of the geometry of various components inside the pressure-vessel. Since it is desired to reduce the uncertainties involved in the hydrodynamic design, the effect of the various geometries must be accounted for. In particular, it is desired to determine the flow distribution hot channel factor and the pressure drop due to various components of the vessel.

Since the mathematical formulation of the flow patterns in the reactor vessel is overly complex, one has to revert to experimental techniques. Of these techniques, the one involving a hydraulic model was considered the most feasible and quite reliable.

The investigation reported herein was focused on the non-statistical hot channel subfactor associated with flow maldistribution at the inlet to the core.

The inlet flow distribution subfactor has been progressively revised as more knowledge is acquired on the subject. For example, subfactor of 1.07 was used for Yankee Core I. Computer code analysis helped in reducing this subfactor to 1.05, for Yankee Core III. Tests of hydraulic models aided in a further reduction to 1.03 for the current generation of large plants. However, changes in geometry of the lower plenum and other components in the vessel make model tests necessary in order to assure the designer of the accuracy of his estimates.

2. Objectives

The objectives of the studies conducted with the Connecticut-Yankee hydraulic model were:

- a) To substantiate the hydraulic design of the Connecticut-Yankee reactor vessel and internal components with reference to the

distribution of coolant at the inlet to the core.

- b) To measure pressure drops in the hydraulic model and calculate the Euler numbers associated with the various components in order to refine the pressure drop calculations of the prototype.
- c) To investigate the hydrodynamic effects of the dummy instrumentation guide tubes projecting from the bottom support plate to the bottom of the vessel.

3. Design Principles

The use of small scale models is a very powerful research tool, and is particularly valuable in two cases:

- a) Exploration of the fundamental behavior of a particular system which is little understood.
- b) Obtaining quantitative data for use in prototype design problems, particularly when the mathematical model is nonexistent or is overly complex.

The validity of scale model experiments depends on the supposition that the same physical laws govern the phenomena under consideration in the prototype as in the model. Suppose also, that for the prototype these laws are described by a general relationship of the form:

$$\psi(x_1, x_2, \dots, x_n) = 0 \quad (3.1)$$

If this equation is unique, then the need for dimensional homogeneity leads to the requirement for an equivalent relation

$$\phi(\pi_1, \pi_2, \dots, \pi_m) = 0 \quad (3.2)$$

among a set of independent dimensionless groups π_i of the original parameters

x_1 . For the four physical dimensions (mass, time, length, and temperature) necessary for describing the n parameters, $m \geq n-4$.

This is a brief and general statement of the Buckingham Π theorem [7]¹. The theorem also defines a model as a physical system with characteristics uniquely related to those of the prototype such that measurements of the characteristics of the model accurately predict the characteristics of the prototype. It is always desirable to attain a model for which the dimensionless groups Π_i are equal to those of the prototype, viz.

$$\Pi_{i_M} = \Pi_{i_P} \quad (3.3)$$

For a hydraulic model, the parameters of principal importance are included in the equation:

$$\Psi(p, v, \rho, \nu, L, D_e, \epsilon, v') = 0 \quad (3.4)$$

These eight parameters can be reduced, according to the Π theorem, to five dimensionless groups, i.e.,

$$\Phi[L/D_e; \epsilon/D_e; \nu D_e/\nu; \Delta H/(\rho v^2/2g_c); \sqrt{v'^2}/v] = 0 \quad (3.5)$$

These dimensionless groups are: the geometry; the relative roughness; the Reynolds number; the Euler number and the degree of turbulence. The geometry, roughness, and Reynolds number form the independent groups; while the Euler number and degree of turbulence are dependent variables.

The first of the independent dimensionless groups concerns the geometry. It was decided to maintain geometrical similarity between the model and prototype

¹Numbers in brackets designate references at the end of the report.

wherever possible. Much thought was given to the scale factor because large scale factors result in compact models that are relatively inexpensive to fabricate and test. However, the small flow passages involved result in amplification of boundary layer effects and may thus cause a flow that is in a different regime than the one encountered in the prototype. Also, inaccuracies in model fabrication may cause erroneous results. Large models, like the one described by Flanigan et al [2] or Hazard and Allen [5], are expensive and require extensive testing facilities. A one-seventh scale model was previously used by the Westinghouse Atomic Power Division and was found satisfactory. Also, various components of the previous model were available, with considerable savings in cost. In order to utilize these components, and keep geometric similarity with the Connecticut Yankee Reactor, 1:7.518 was adopted as the scaling factor for the characteristic length.

A similar procedure was adopted for the relative roughness. Wherever the relative roughness was considered of primary importance (as in the thermal shield region) it was scaled down by the factor 1:7.518. At large flow passages, this restriction was alleviated.

It is well known that complete similarity as defined by Equation (3.3), is sometimes impractical. Some of the independent dimensionless variables, which are believed to exert secondary influence or which affect the phenomenon in a known manner, may be allowed to deviate from their precise values. In particular, the effect of the Reynolds number on the Euler number is rather small for sufficiently high Reynolds numbers. In the region of interest, it is found that

$$f \propto Re^{-0.1}$$

Moreover, research on turbulent flow [6] has shown that the form loss coefficient is nearly independent of the Reynolds number at values above 5000, except within boundary layers.

In Table 1, the relevant information concerning the Reynolds numbers at various locations is summarized. It is noted that the Reynolds numbers are sufficiently large in all places to assume that dynamic similarity is assured.

The discussion presented above leads to the conclusion that the dependent variables, i.e., the Euler number and the turbulence intensity, should satisfy Equation (3.3). Therefore, a model designed according to these principles should yield useful quantitative data for designing an improved prototype.

Table 1. DESIGN DATA FOR THE CONNECTICUT YANKEE HYDRAULIC MODEL

	<u>Model</u>	<u>Prototype</u>
Flow Rate lb/hr	2.0×10^6	93.6×10^6
Temperature °F	70	546 588
Specific Volume ft ³ /lb	0.01604	0.02127 0.02272
Kinematic Viscosity ft ² /sec	10.5×10^{-6}	1.48×10^{-6} 1.40×10^{-6}
<u>Inlet Nozzles</u> ⁽¹⁾		
Flow Area, ft ²	0.3377	16.50
Re $\times 10^{-6}$	0.824	51.98
Velocity Head, psi	4.68	5.34
<u>Thermal Shield</u> ⁽²⁾		
Flow Area, ft ²	0.3173	17.97
Re $\times 10^{-6}$	0.337	9.98
Velocity Head, psi	5.41	4.80
<u>Flow Skirt</u> ⁽³⁾		
Flow Area, ft ²	0.3173	17.97
Re $\times 10^{-6}$	0.337	19.49
Velocity Head, psi	5.41	4.80
<u>Lower Plenum</u> ⁽⁴⁾		
Flow Area, ft ²	1.5582	87.75
Re $\times 10^{-6}$	0.24	14.4
Velocity Head, psi	0.22	0.20
<u>Core</u> ⁽⁵⁾		
Flow Area, ft ²	0.6556	38.77
Re $\times 10^{-5}$	0.944	4.09
Velocity Head, psi	1.24	0.893
<u>Upper Plenum</u> ⁽⁶⁾		
Flow Area, ft ²	1.5563	75.0
Re $\times 10^{-6}$	0.24	18.98
Velocity Head, psi	0.22	0.29

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- (1) The flow area and Reynolds number of the inlet nozzles are calculated at a location corresponding to the location of the pressure taps in the model.
- (2) The flow area of the thermal shield is the combined area of the two annuli. The Reynolds number is based on an average velocity through the thermal shield.
- (3) The flow area of the thermal shield was also used for the flow skirt. The Reynolds number is therefore based on the velocity of flow entering the flow-skirt region.
- (4) The term "lower plenum" as used in this report includes the flow passage from the skirt to the top of the support columns. The flow velocity and Reynolds number are calculated for the inside area of the skirt, at the location of the pressure taps on the support columns.
- (5) The Reynolds number in the core of the prototype is based on the velocity and hydraulic diameter of an area bound by four fuel rods.
- (6) The term "outlet nozzles" as used in this report includes the upper plenum as well as the outlet nozzles. The Reynolds' number is based in the flow velocity and diameter at the outlet nozzles at the location of the pressure taps.

4. Description of the Model and Test Loop

4.1. Description of the Model

4.1.1. Hydrodynamic Design

Based on the design principles described in Section 3 of this report, it was decided to maintain exact geometric similarity between the model (Fig. 1) and the Connecticut-Yankee Plant. This similarity was maintained throughout except for the core and certain other minor changes discussed below.

- a) The core was simulated by 157 dummy fuel assemblies. This core was previously used by Westinghouse Atomic Power Division and is described by Hetsroni [4]. The pressure drop across the simulated core was equal to that of the prototype, and dynamic similarity was assumed to exist. However, since the simulated core had been used for previous model studies, the core, vessel and thermal shield were 3.175 in. shorter than the scaled-down prototype. This discrepancy was considered insignificant since most pressure drops in the core and along the thermal shield are due to form losses.
- b) No attempt was made to simulate the Rod Cluster Control in the guide tubes or core. Instead, the flow area in the walls of the guide tubes was reduced from 50% to 40% and the flow area in the upper core plate was reduced by an amount proportional to the area occupied by the control rods.

Figure 1. The hydraulic model used in the experimental studies

c) The holes in the lower core plate were in the form of four slots, rather than four round holes per fuel assembly. This change was made in order to obtain sufficient flow area and to maintain the same pressure drop as in the prototype.

4.1.2 Mechanical Design

Some special features included in the mechanical design of the model were as follows:

- a) The model was constructed entirely of 6060 T-6 aluminum alloy except for stainless steel fasteners. All aluminum parts were anodized by Alumilite 204 process in order to minimize galvanic corrosion in the vessel.
- b) The vessel was designed to withstand a static pressure of 80 psig, and was hydrostatically tested at 100 psig.
- c) The vessel outlet nozzles were provided with liners mating in an "O" ring joint with the upper core barrel. This arrangement eliminated bypass flow at the joint between the core barrel and outlet nozzle. In the prototype, the seal is provided by differential thermal expansion between the core barrel and vessel -- a phenomenon not present in the model.

In addition, all bolted joints between the sections of the core barrel, baffle, and skirt were tightly fitted to minimize bypass flow.

- d) The inlet and outlet nozzles section is removable, to permit replacement or modification of the nozzles, if desired.

- e) The upper barrel section was fabricated in a special way to permit removal of the barrel without disturbing the instrumentation tubes in the core.
- f) A clamping flange was installed between the internals and the upper vessel head to permit removal of the upper head and internals without disturbing the core's instrumentation.
- g) The relative roughness of the thermal shield, vessel and core barrel was scaled down by the same scaling factor as for the characteristic length.

The fabrication of the model was subcontracted to an outside vendor. Fabrication procedures at the vendor's shop were followed closely. Before delivery, the vessel and internals were carefully inspected and checked for accuracy of fabrication. The tolerances of all the components were found to meet specifications except for the upper barrel assembly. This assembly was rejected and subsequently refabricated.

The drawings describing the assembly of the model and details of construction are presented in Appendix B (Figs. 28 through 30).

4.2 Description of the Test Loop

The special loop designed for the experimental studies of the hydraulic model is shown in Figs. 2 and 3. The loop consisted of four centrifugal pumps, storage tanks, water treatment equipment and piping.

Four 6-in. inlet lines connected the pumps to the inlet nozzles of the vessel. Each inlet line was equipped with flow straighteners and orifice plates (I.D. = 4.735 in. $\beta = 0.739$) for flow velocity measurements.

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Figure 2. The hydraulic model installed in the test loop

PERMANENT HYDRAULIC FACILITY (AT WALTZ MILL)

Figure 3

The pumps were driven by 150 H.P. motors and were capable of pumping 2000 gpm against a 95 psi head.

By-pass flow from the pumps was channeled through heat exchangers in order to maintain constant temperature of the fluid. Also, an ion exchange column was installed in the loop for maintaining high water resistivity and reducing galvanic corrosion in the model.

4.3 Description of the Instrumentation

4.3.1. Instrumentation of the Simulated Fuel Assemblies

All simulated fuel assemblies were instrumented for measurement of flow rates. A square-edged orifice plate, 0.725-in. I.D., was installed at the lower part of each assembly. Pressure taps were located 0.325-in. upstream and 0.325-in. downstream of the orifice.

The simulated fuel assemblies were calibrated in a loop specifically designed for this purpose. Some 35 assemblies were calibrated in place inside the model in order to confirm the calibration curves previously obtained.

The simulated fuel assemblies and their calibration are described in more detail elsewhere [4].

The pressure taps in the simulated fuel assemblies were connected to manometer boards by means of stainless steel tubing (0.045-in. I.D.) and vinyl tubing.

Special manometer boards were designed to facilitate simultaneous recording of all the static pressures. Since the pressure at various locations in the vessel varied by more than 60 psi, and since pressure difference between adjacent pressure taps was as low as 0.01 psi,

it was decided to employ water as the manometer fluid and connect the manometers in banks of 10 to pressurized manifolds. The pressure difference between the various manifolds was measured by means of U-tubes manometers filled with mercury. The manometer boards are shown in Fig. 4.

A special photographic technique was devised to simultaneously record all manometer readings and other relevant information. This technique minimized any erroneous readings caused by temporal fluctuations. The accuracy of this method was judged satisfactory.

4.3.2. Instrumentation of the Vessel

Static pressure taps were located at various locations in the vessel and internals of the model. The location of the taps was chosen in such a manner that pressure drop due to the various components of the model could be ascertained. The locations of the pressure taps are shown in Figs. 28, 29, and 30 and in Table 2.

The pressure taps were connected to the manometer boards described previously by means of stainless steel tubing (0.045-in. I.D.) and vinyl tubing.

In addition, total head impact tubes were located in the two annuli created by the thermal shield. The total head tubes were located at two elevations: one group at the top of the thermal shield, and another group close to the bottom. In each elevation there were 16 total head tubes--8 in the inner annulus and 8 in the outer annulus. The total head tubes were placed in the center of the annuli, adjacent to static pressure taps at the walls of the annuli. The velocity head could thus be ascertained and the velocity at each location was calculated.

Figure 4. Typical photo of the manometer board

Table 2

LOCATION OF PRESSURE TAPS

<u>Location</u>		<u>No. of Pressure Taps</u>	<u>Type of Pressure Taps</u>
Inlet Nozzles		4	Static Head
Thermal Shield	Upper Region	16	Static Head
	Lower Region	16	Static Head
	Upper Region	16	Total Head
	Lower Region	16	Total Head
Skirt	Lower Region	16	Static Head
Support Columns		21	Static Head
Fuel Assemblies		314	Flow Rate
Upper Pleunum	Guide Tubes	24	Static Head
Outlet Nozzles		<u>4</u>	Static Head
Total		447	

5. Testing and Analysis Procedures

5.1 Testing Procedure

At the beginning of each test, the desired flow rate was established in each loop by throttling the inlet and outlet valves. After steady state conditions were established, the manometer boards were connected to the pressure taps. The air pressures in the manifolds above the manometers were adjusted until the manometer fluid was visible in all manometers. The pressure difference between the various manifolds was then measured by means of the mercury filled manometers. The pressure difference between the various manifolds, together with other relevant information such as room and loop temperatures, were all recorded on a chalkboard.

The water level in all 447 water manometers was recorded simultaneously together with the information on the chalkboard, by means of three Press cameras operated by a single shutter actuator. A typical photo is shown in Fig. 4.

Upon completion of the test, the air pressure in all manifolds was reduced. Water was then allowed to flow through the manometers to prevent air bubbles from becoming trapped in the pressure lines.

5.2. Data Reduction

The water level in all the manometer was established from the photographs by means of a Benson-Lehner analog to digital data reader. This reader was first calibrated for each photograph and the hairline was then set on each manometer to obtain the water column height. The height, in inches, was converted to voltage and then to frequency. The decimalized manometer level was then punched on digital-computer cards in

proper format.

Computer codes NØRM (Flow Normalization Code) and DARE (Data Reduction Code) were specifically developed for reducing the data and for calculating the relevant velocities and pressure drops.

5.2.1. Pressure Drop

The static pressure at various locations in the vessel, as measured by the pressure taps and recorded by the photographic technique, was used to determine the pressure drops due to various components in the model.

All static pressures were referred to the static pressure at the inlet nozzles. The static pressure at each location was determined by subtracting the difference of water levels from the difference in air pressure in the corresponding manifolds; i.e.,

$$\Delta p_{st_1} = C_1 \Delta h_{Hg} - C_2 \Delta h_{H_2O} \quad (5.1)$$

where

C_1 and C_2 are temperature dependent coefficients for mercury and water, respectively

Δh_{Hg} is the difference in pressure, in inches of mercury, between the air pressure in some particular manifold and the air pressure in manifold "A" (above the manometers connected to the inlet nozzles).

Δh_{H_2O} is the difference in pressure, in inches of water, between the particular manometer and the manometers connected to the taps in the inlet nozzles.

The static pressure drop Δp_{si} due to component i of the vessel was established by subtracting the pressure drop $\Delta p_{st_{i-1}}$

from the inlet nozzle to the taps upstream, from the pressure drop Δp_{st_1} from the inlet nozzles to the taps downstream of the component "1", i.e.

$$\Delta p_{s_1} = \Delta p_{st_1} - \Delta p_{st_{1-1}} \quad (5.2)$$

For example, the pressure drop due to the lower plenum was ascertained by subtracting the pressure drop from the inlet nozzles to the bottom of the flow skirt from the pressure drop from the inlet nozzles to the support columns.

After the static pressure drop was established, the total pressure drop was calculated by accounting for the change in the velocity head (Δp_{d_1}).

The total pressure drop across some component "1" was then determined by adding the dynamic pressure drop to the static pressure drop, i.e.

$$\Delta p_1 = \Delta p_{s_1} + \Delta p_{d_1} \quad (5.3)$$

These calculations were all performed by the computer code DARE, described in the Appendix A to this report.

The total pressure drops due to the various components were plotted versus the flow rate on a logarithmic paper. Straight lines, with slopes close to 2.0, fitted the data points very closely. The Euler numbers were calculated from these lines at a flow rate of 4,000 gpm.

5.2.2. Flow Rate

The pressure drops across the orifice plates in the simulated fuel assemblies were determined, in inches of water, from the photographs of the manometers. The readings were converted to pressure drop in psi

through multiplication by a temperature dependent coefficient.

The flow rate through each assembly was established by converting the pressure drop to flow rate by means of the calibration curves for each assembly.

The flow rates through each simulated fuel assembly were then normalized by dividing each flow rate by the average flow rate through all the assemblies.

From the normalized flow data, a histogram was prepared to represent the number of fuel assemblies having flow rates of various magnitudes. The histogram presentation is not conclusive since the location and relative distribution of partially starved assemblies is of great importance. For most regions of the core, normalized flow rates of less than 0.95 are not desirable; however, in the periphery much smaller normalized flow rates can be tolerated due to the low power generated in this region.

The flow rates, normalized flow rates, and histograms were computed by the digital computer program NORM, described in a previous report [4].

5.2.3. Velocity

The velocity in the thermal shield annuli was calculated by the computer code DARE, from the data obtained during the experiments. The velocity at each point was obtained by subtracting the static head, measured at the vessel and/or core barrel walls, from the total head measured at the centers of the annuli by means of the total head impact tubes,

$$V = C \sqrt{\frac{2g_c}{\rho} (TH_i - \Delta p_{st_i})} \quad (5.4)$$

where TH_i is the total-pressure difference between the inlet nozzle and the i^{th} total head impact tube; and where C is the ratio between the velocity at the centerline of the annulus to the average velocity in the annulus, at that location.

Note that the assumption was made that the static pressure is uniform in the radial direction in each annulus.

6. Results and Discussion

6.1 Preliminary Tests

Preliminary tests were conducted with the hydraulic model in order to establish the testing procedures and to eliminate any unforeseen difficulties in design and operation.

During the preliminary tests, failure was encountered in some of the instrumentation tubes extending from the bottom support plate to the bottom of the vessel. Ostensibly, vibrations in the model and loop were the cause for the failure. New instrumentation tubes were fabricated from stainless steel and press-fitted into the bottom support plate and testing was resumed. Although some of the instrumentation tubes were noted to vibrate, no failure occurred.

6.2 Tests with Dummy Instrumentation Tubes

Some of the newer Westinghouse designed reactor plants employ instrumentation tubes which extend from the bottom support plate to penetrations in the bottom of the vessel. Occasionally, these tubes are not symmetrically located. It may be necessary, for example, to have one quadrant of the core instrumented

intensively, while the other quadrants have only one or two instrumentation tubes. In particular, in the Connecticut Yankee Reactor, thirteen instrumentation tubes were located in one quadrant of the core. Yet only one or two tubes were located in all other quadrants. The problem thus arises as to whether the asymmetry of the instrumentation tubes in the lower plenum may affect the flow distribution at the inlet to the core.

In order to solve this problem, simulated instrumentation tubes were installed in the model. In addition, dummy tubes were installed in the model such that the tube arrangement was symmetrical around the center-line of the model.

Several tests were conducted with this configuration. The flow distribution at the inlet to the core, velocities and pressure drops were measured with various flow rates. It was determined that the distribution of flow at the inlet to the core is rather independent of the flow rate.

The flow distribution at the inlet to the core for this configuration is depicted in Figs. 5 & 6. Fig. 5 demonstrates the normalized flow distribution as printed out by the computer. This distribution is considered satisfactory since most fuel assemblies have normalized flow rates close to 1.00. A few simulated assemblies have flow rates considerably less than unity--however, these assemblies are widely scattered and it was demonstrated that their low flow rate can be attributed to experimental errors, since these assemblies had constantly low flow rate under any flow conditions and for all tested configurations.

Fig. 6 is a representation of the flow histogram for the same configuration.

Normalized Flow Distribution With Four Loops Operating

[illegible]

CONN. YANKEE MODEL TEST - RUN 33'R - 4 LUDPS - 4811 GPM=30.64GPM/ASS'

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	
0.79 - 0.81	
0.81 - 0.83	
0.83 - 0.85	*
0.85 - 0.87	***
0.87 - 0.89	*****\$*
0.89 - 0.91	*****\$**
0.91 - 0.93	*****
0.93 - 0.95	*****\$*****\$*****\$*
0.95 - 0.97	*****\$*****
0.97 - 0.99	*****\$*****\$*****\$*****\$
0.99 - 1.01	*****\$*****\$*****\$*****\$*****\$*
1.01 - 1.03	*****\$*****\$*
1.03 - 1.05	*****\$*****\$**
1.05 - 1.07	*****\$*****\$**
1.07 - 1.09	*****\$*****\$
1.09 - 1.11	*****\$
1.11 - 1.13	*****\$*
1.13 - 1.15	
1.15 - 1.17	*
1.17 - 1.19	
1.19 - 1.21	*
1.21 - 1.23	

Flow Histogram With Four Loops Operating With Dummy Instrumentation Tubes

6.3. Tests Without Dummy Instrumentation Tubes

6.3.1. Flow Distribution

In order to establish whether the dummy instrumentation tubes were essential to the hydrodynamic performance of the Connecticut-Yankee Reactor, it was decided to remove them and retest.

The flow distribution at the inlet to the core was measured for various flow rates subsequent to removing the dummy instrumentation tubes. A sample of the normalized flow distribution is depicted in Fig. 7. The histogram associated with this configuration is given in Fig. 8.

Close examination of Fig. 7 and comparison with Fig. 5 reveals that the flow distribution at the inlet to the core was not adversely affected by the removal of the dummy instrumentation tubes. The flow distribution obtained with this configuration also compares favorably with those during experimental studies of other reactors [1,4].

The subsequent experimental studies were conducted without the dummy instrumentation tubes.

6.3.2. Pressure Drop

The static pressures at different locations were measured by means of the probes described previously. The pressure drops due to the various components were calculated by the computer code DARE.

Pressure drops were plotted on log-log paper (Fig. 9 through 15) versus the flow rate. Straight lines with a slope of approximately 2.0 fitted the data very well in most cases.

Note that the pressure drops depicted in Figs. 9 through 15 are

CONN. YANKEE MODEL TEST - RUN 81 - 4 LOOPS (EQUAL)

29.10 GPM/ASS¹

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	*
0.79 - 0.81	
0.81 - 0.83	*
0.83 - 0.85	**
0.85 - 0.87	*
0.87 - 0.89	****\$
0.89 - 0.91	****\$
0.91 - 0.93	****\$*****\$
0.93 - 0.95	****\$*****\$****
0.95 - 0.97	****\$*****\$*****\$****
0.97 - 0.99	****\$*****\$*****\$**
0.99 - 1.01	****\$*****\$*****\$*****\$***
1.01 - 1.03	****\$*****\$***
1.03 - 1.05	****\$*****\$**
1.05 - 1.07	****\$***
1.07 - 1.09	****\$***
1.09 - 1.11	****\$***
1.11 - 1.13	****
1.13 - 1.15	*
1.15 - 1.17	
1.17 - 1.19	*
1.19 - 1.21	*
1.21 - 1.23	

Flow Histogram With Four Loops Operating
Without The Dummy Instrumentation Tubes

FIG. 9

FIG. 10

FIG. 11

PRESSURE DROP DUE TO THERMAL SHIELD SUPPORT
LUGS AND FLOW SKIRT

FIG. 13

FIG. 14

FIG. 15

arithmetic averages, i.e., the individual measurements at any elevation were averaged to produce a mean value. Variations between the individual measurements at the inlet nozzles, the flow skirt, the support columns, the guide tubes and at the outlet nozzles, proved very small. At the thermal shield regions, however, the variations in static pressures were more noticable, due to variations in local velocities. The velocity distribution in the thermal shield regions is discussed in a later section of this report.

The pressure drops at a 4,000 gpm flow rate were used in determining the Euler numbers associated with the various components. Since the straight lines drawn through the data points have a slope of approximately 2.0, the pressure drop at any other flow rate could have been used.

The pressure drops and Euler numbers for the various components are summarized in Table 3.

Table 3

SUMMARY OF PRESSURE DROPS AND EULER NUMBERS

Component	Flow Area ft ²	Velocity Head psi	Pressure Drop at 4,000 gpm psi	Euler Number
Inlet Nozzles ⁽¹⁾	0.3377	4.68	2.47	0.53
Thermal Shield ⁽²⁾	0.3173	5.41	3.09	0.57
Support Lugs & Flow Skirt ⁽³⁾	0.3173	5.41	1.56	0.29
Lower Plenum ⁽⁴⁾	1.5582	0.22	4.22	19.18
Core & End Plates ⁽⁵⁾	0.6556	1.24	32.90	26.53
Upper Plenum & Outlet Nozzles ⁽⁶⁾	1.5563	0.22	0.66	3.00
Total ⁽⁷⁾	0.6556	1.24	44.90	36.21

- (1) The pressure drop associated with the inlet nozzles is the difference between the pressure at the inlet nozzles and the pressure measured by means of the taps at the upper region of the thermal shield.
- (2) The pressure drop associated with the thermal shield is the difference between the pressure at the upper taps of the thermal shield and the pressure at the taps located at the bottom of the thermal shield.
- (3) This pressure drop is due to the support lugs and the expansion losses from the thermal shield annuli.
- (4) This pressure drop is the difference between the pressure taps on the bottom of the flow skirt and the pressure at the top of the support columns.
- (5) The pressure drop due to the core and end plate was measured by means of the taps on the guide tubes and on the support columns.
- (6) The pressure drop associated with the upper plenum and outlet nozzles is the difference between the pressure measured at the guide tubes and the pressure at the outlet nozzles.
- (7) The total Euler number was based on the velocity in the simulated fuel assemblies.

6.4. Three Loops Operation

Upon completion of the tests with four loops the investigation was focused on three-loops operation. This case is of practical interest since it may be desirable to restart the reactor after a pump-caused scram has occurred and to continue plant operation with only three loops in service.

Two cases were studied:

- a) All loops having equal flow rate - this case corresponds to a reactor plant equipped with valves in the inlet and outlet lines. In case of operation with three loops the valves in one loop are closed and that loop is isolated from the vessel.
- b) Two loops have an equal flow rate and one loop has about 65% of the flow rate in any other loop. This case corresponds to a reactor plant not having valves in the inlet and outlet lines, or when those valves are not closed (to keep the inactive loop warm). In this case back-flow will occur in the inoperative loop. It may be assumed that under these conditions some 35% of the flow in the adjacent loop will pass through the inlet nozzle of the inoperative loop.

The distribution of the flow at the inlet to the core under case "a" (all loops having equal flow) is depicted in Fig. 16. It can be noted from the figure that the flow distribution is almost as uniform as in the case of four operative loops.

Fig. 18 demonstrates the distribution of the flow at the inlet to the core for case "b". Although this distribution is similar to the ones shown before, it is somewhat less uniform.

CONN. YANKEE MODEL TEST - RUN 71 - 3 LOOPS (1,3+4 EQUAL) 23.91GPM/ASS'

Normalized Flow Distribution With Three Loops Operating
(Equal Flows), Without Dummy Instrumentation Tubes

CONN. YANKEE MODEL TEST - RUN 71 - 3 LOOPS (1,3+4 EQUAL) 23.91GPM/ASS'

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	
0.79 - 0.81	*
0.81 - 0.83	
0.83 - 0.85	
0.85 - 0.87	
0.87 - 0.89	****\$
0.89 - 0.91	****
0.91 - 0.93	****\$****
0.93 - 0.95	****\$****\$****
0.95 - 0.97	****\$****\$**
0.97 - 0.99	****\$****\$****\$****\$****\$****
0.99 - 1.01	****\$****\$****\$****\$****\$
1.01 - 1.03	****\$****\$****\$****
1.03 - 1.05	****\$****\$****
1.05 - 1.07	****\$
1.07 - 1.09	****\$****\$*
1.09 - 1.11	****
1.11 - 1.13	***
1.13 - 1.15	***
1.15 - 1.17	
1.17 - 1.19	*
1.19 - 1.21	
1.21 - 1.23	

Flow Histogram With Three Loops Operating (Equal Flow Rates),
Without Dummy Instrumentation Tubes

Normalized Flow Distribution with Three Loops Operating (unequal flow rates), without Dummy Instrumentation Tubes

1505

1547

[illegible]

FIG. 18

CONN. YANKEE MODEL TEST - RUN 77 - 3 LOOPS(1,3+4 NOT EQ) 26.75GPM/ASS'

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	*
0.79 - 0.81	
0.81 - 0.83	*
0.83 - 0.85	****
0.85 - 0.87	*
0.87 - 0.89	****
0.89 - 0.91	***
0.91 - 0.93	*****\$*****\$
0.93 - 0.95	*****\$*****\$*****\$
0.95 - 0.97	*****\$*****\$*****
0.97 - 0.99	*****\$*****\$***
0.99 - 1.01	*****\$*****\$
1.01 - 1.03	*****\$*****\$*****\$*****
1.03 - 1.05	*****\$*****\$*****
1.05 - 1.07	*****\$*****\$***
1.07 - 1.09	*****\$**
1.09 - 1.11	*****\$**
1.11 - 1.13	*****\$*
1.13 - 1.15	*****\$
1.15 - 1.17	*
1.17 - 1.19	*
1.19 - 1.21	
1.21 - 1.23	*

Flow Histogram With Three Loops Operating
(unequal flow rates), Without Instrumentation Tubes

6.5. Two Loops Operation

Occasionally, it may be desirable to operate the reactor plant at low power conditions with only two operating loops. Therefore, it is of interest to observe the flow distribution at the inlet to the core with only two operative, loops.

Three sets of tests were conducted for two-loops operation:

- a) two inlets at 45° apart
- b) two inlets at 180° apart
- c) two inlets at 225° apart

In Fig. 20 the normalized flow distribution at the inlet to core is presented for case "a" of the above. It is apparent from the figure that zones of partially starved fuel assemblies exist at the center of the north-east and the south-east (the top of the figure being the north) quadrants of the core.

Fig. 22 demonstrates the normalized flow distribution for case "b". Examination of this figure reveals that a rather large zone of partially starved fuel assemblies exists in the center of the southern half of the core.

In Fig. 24 the normalized flow distribution at the inlet to the core is depicted for the case when the operative inlet nozzles are 225° apart. Here zones of partially starved fuel assemblies exist at the north-west and south-west quadrants of the core.

It can be summarized from the above that the normalized flow distribution for two operating loops is not as uniform as for three and four operating loops. Therefore, the hot channel factor associated with the distribution

CONN. YANKEE MODEL TEST - RUN 61 - 2 LOOPS (1+2 EQUAL) 21.00GPM/ASS¹

***** NORMALIZED FLOW DISTRIBUTION *****

						1.05	0.94	0.85						
					1.08	1.02	0.98	0.95	1.08	0.95	0.97			
			1.03	1.04	1.11	0.	0.79	1.00	0.	0.95	0.90			
		0.	1.12	1.07	0.97	1.00	1.02	0.99	1.01	0.96	0.93	1.12		
	1.00	1.00	1.03	1.03	1.08	0.99	1.02	1.01	0.99	0.89	0.97	1.03	0.90	
	0.98	1.07	0.98	0.94	1.06	1.09	1.12	0.93	0.83	0.98	0.93	1.03	1.14	
0.92	0.95	1.01	1.07	1.09	1.09	1.02	1.12	0.92	0.99	0.86	0.95	1.04	0.94	0.90
0.92	0.90	0.87	1.05	0.97	1.12	1.06	1.02	1.14	0.91	0.99	1.00	0.99	1.07	1.07
1.26	0.98	1.00	1.03	1.07	0.97	1.07	1.07	0.95	1.05	0.97	1.04	1.02	1.02	0.99
	0.96	1.05	1.06	1.06	0.93	0.95	0.93	1.01	0.96	0.88	1.07	1.02	1.09	
	0.98	1.09	1.06	1.01	1.04	0.98	0.99	0.90	0.92	0.85	0.91	1.13	1.30	
		0.97	1.03	1.01	0.98	0.94	0.96	0.94	0.88	1.04	1.15	0.86		
			1.03	1.02	1.01	0.99	1.05	0.91	0.90	1.08	0.94			
				0.95	1.02	1.02	1.08	0.95	1.02	0.90				
						0.96	1.06	0.84						

1640

1665

1640

1660

Normalized Flow Distribution With Two Loops Operating (1 & 2),
Without Dummy Instrumentation Tubes

CONN. YANKEE MODEL TEST - RUN 61 - 2 LOOPS (1+2 EQUAL) 21.00GPM/ASS'

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	*
0.79 - 0.81	
0.81 - 0.83	
0.83 - 0.85	***
0.85 - 0.87	****
0.87 - 0.89	**
0.89 - 0.91	*****\$*****
0.91 - 0.93	*****\$***
0.93 - 0.95	*****\$*****\$***
0.95 - 0.97	*****\$*****\$*****
0.97 - 0.99	*****\$*****\$*****\$
0.99 - 1.01	*****\$*****\$*****
1.01 - 1.03	*****\$*****\$*****\$*****\$**
1.03 - 1.05	*****\$*****\$
1.05 - 1.07	*****\$*****\$*****
1.07 - 1.09	*****\$*****\$*****
1.09 - 1.11	*
1.11 - 1.13	*****\$**
1.13 - 1.15	**
1.15 - 1.17	*
1.17 - 1.19	
1.19 - 1.21	
1.21 - 1.23	

Flow Histogram With Two Loops Operating (1 & 2),
Without Dummy Instrumentation Tubes

Normalized Flow Distribution with Two Loops Operating (1 & 3),
Without Downy Instrumentation Tubes

1645

1.06 1.01 0.99 0.99 1.06 0.98 1.02

1670

1.00 1.01 1.05 0.94 1.02 1.02 1.01 0.96 0.94

0.98 1.10 1.05 0.98 1.04 1.08 1.03 1.07 1.00 0.92 1.05

0.99 0.99 1.03 0.99 1.10 1.04 1.10 1.09 1.07 0.95 1.00 0.96 0.88

0.96 1.10 1.03 0.93 1.04 1.11 1.14 0.98 0.90 1.03 0.96 1.00 1.06

0.94 0.98 0.99 0.95 1.07 1.04 1.01 0. 0.96 1.01 0.91 0.96 1.01 0.92 0.88

0.87 0.95 0.86 1.01 0.85 1.02 1.06 1.05 1.52 0.98 0.99 1.00 0.95 1.06 1.06

1.26 1.02 0.97 0.97 0.96 0.82 0.99 1.05 0.96 1.05 1.03 1.04 1.02 1.01 1.00

1.02 1.07 1.02 1.02 0.93 0.92 0.89 0.96 1.00 0.90 1.10 1.02 1.07

1.02 1.08 1.06 0.98 0.99 0.91 0.90 0.90 0.91 0.87 0.97 1.15 0.91

0.99 1.04 1.01 0.99 0.90 0.90 0.91 0.90 1.11 1.20 0.91

1.07 1.05 1.03 0.93 1.10 0.90 0.91 1.12 0.98

0.93 1.03 1.01 1.10 0.94 1.09 1.00

0.86 0.92 0.85

1680

1675

CONN. YANKEE MODEL TEST - RUN 64 - 2 LOOPS (1+3 EQUAL) 21.24GPM/ASS¹

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	
0.79 - 0.81	
0.81 - 0.83	*
0.83 - 0.85	**
0.85 - 0.87	**
0.87 - 0.89	****
0.89 - 0.91	****\$*****\$*****
0.91 - 0.93	****\$*****\$
0.93 - 0.95	****\$****
0.95 - 0.97	****\$*****\$****
0.97 - 0.99	****\$*****\$**
0.99 - 1.01	****\$*****\$*****\$*****\$**
1.01 - 1.03	****\$*****\$*****\$****
1.03 - 1.05	****\$*****\$*****\$
1.05 - 1.07	****\$*****\$*****
1.07 - 1.09	****\$*
1.09 - 1.11	****\$**
1.11 - 1.13	***
1.13 - 1.15	**
1.15 - 1.17	
1.17 - 1.19	
1.19 - 1.21	*
1.21 - 1.23	

Flow Histogram With Two Loops Operating (1 & 3),
Without Dummy Instrumentation Tubes

Normalized Flow Distribution with Two Loops Operating (1 & 4), Without Turbulence Intermittency Index

1665

0.99 0.97 0.94 0.96 1.09 0.99 1.01

0.97 0.99 0.98 0.87 0.98 1.03 1.04 0.98 0.98

0.99 1.04 0.96 0.90 0.94 1.05 1.06 1.09 1.03 0.96 1.15

0.97 0.97 0.96 0.90 0.97 0.95 1.08 1.07 1.11 1.00 1.05 1.02 0.99

1.01 1.10 1.01 0.85 0.96 1.05 1.11 1.01 0.96 1.10 1.03 1.05 0.99

0.97 1.02 0.99 1.01 1.00 1.03 0.94 1.07 1.00 1.05 0.96 1.02 1.05 0.95 0.84

0.94 0.95 0.91 1.00 0.91 1.01 1.04 1.07 1.18 1.06 1.05 1.05 1.01 1.03 1.06

1.28 1.02 0.98 0.97 1.01 0.93 1.02 1.07 1.02 1.09 1.15 1.09 0.99 0.97 1.00

0.99 1.03 0.99 0.97 0.91 0.91 0.93 1.08 1.11 0.94 1.13 1.00 1.02

0.98 1.02 0.99 0.93 0.94 0.98 1.03 0.99 1.04 0.97 0.95 1.04 0.91

0.92 0.96 0.91 0.98 0.95 1.03 1.01 1.02 1.15 1.12 0.85

0.95 0.95 0.94 0.97 1.16 0.95 0.97 1.06 0.95

0.89 0.98 0.97 1.05 0.96 1.04 0.97

0.87 1.00 0.94

1658

CONN. YANKEE MODEL TEST - RUN 67 - 2 LOOPS (1+4 EQUAL) 21.14GPM/ASS'

***** FLOW HISTOGRAM *****

0.75 - 0.77	
0.77 - 0.79	
0.79 - 0.81	
0.81 - 0.83	
0.83 - 0.85	**
0.85 - 0.87	**
0.87 - 0.89	*
0.89 - 0.91	*****\$****
0.91 - 0.93	*****\$***
0.93 - 0.95	*****\$*****\$*****
0.95 - 0.97	*****\$*****\$*****\$***
0.97 - 0.99	*****\$*****\$*****\$*****\$*****\$*
0.99 - 1.01	*****\$*****\$*****\$***
1.01 - 1.03	*****\$*****\$*****\$***
1.03 - 1.05	*****\$*****\$*****\$*
1.05 - 1.07	*****\$*****
1.07 - 1.09	*****\$*
1.09 - 1.11	*****\$*
1.11 - 1.13	**
1.13 - 1.15	***
1.15 - 1.17	**
1.17 - 1.19	*
1.19 - 1.21	
1.21 - 1.23	

Flow Histogram With Two Loops Operating (1 & 4),
Without Dummy Instrumentation Tubes

of flow at the inlet to the core must be considerably lower for the two-loop case than for the four loops.

6.6. Velocity Distribution in The Thermal Shield Annuli

The velocity distribution in the thermal shield annuli was ascertained by means of thirty-two total head impact tubes located at two levels in the two annuli. Thus, in each annulus the total head was measured at two different distances from the inlet nozzle and at eight points in each level.

The velocity at each measuring station was determined by subtracting the static pressure, as measured by means of the pressure taps at the vessel wall and core barrel, from the total head.

Great care was exercised to center the total head tubes in the annuli in order to ascertain an accurate measurement of the radial maximum velocity. The average velocity was determined by multiplying the radial-maximum velocity in the inner annulus by 0.8360 and the radial-maximum velocity in the outer annulus by 0.8276, based on the velocity distribution between two infinite plates [3].

Fig. 26 depicts the distribution of the radial average velocity and normalized radial average velocity.

The velocity is plotted for the various angular locations. The locations of the inlet nozzles are also shown in the figure.

It can be noted that the velocity attains a maximum value underneath the inlet nozzles at the higher level. For level II, the maximum subsides and a minimum velocity is occasionally noted underneath the inlet nozzles.

In order to confirm the accuracy of these measurements, the velocity

VELOCITY DISTRIBUTION IN THE THERMAL SHIELD ANNULI

distributions curves were integrated and the mass flow rate thus obtained were compared against the flow rates measured in the inlet nozzles. The agreement was usually within two per cent.

7. Conclusions

Based on a careful examination of the data and results presented herein, the following conclusions may be drawn:

- 1) The flow distribution at the inlet to the core is similar to that observed for other reactors [4].
- 2) There is no hydrodynamic advantage in the dummy instrumentation tubes in the lower plenum.
- 3) The size and geometry of the lower plenum seem to be adequate.
- 4) The flow distribution for two operating loops is not as uniform as for three and four operating loops.

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Appendix A - Computer Code DARE

1. General Description

The computer code DARE was developed to expedite the reduction of the data obtained during the experimental procedures. Specifically, it was developed to calculate pressure drops and velocities as measured by means of the static pressure taps and the total head impact tubes, respectively.

During the experimental procedures, photographs were taken of the manometer boards. These photos were then used to abstract static pressures and the total head by means of the analog to digital data converter described previously. The decimalized pressures were punched on computer cards, which served as data input for the code.

In its present form, the code can be used only for the particular arrangement of pressure taps and manometer boards. Modification in the experimental setup will require slight modification of the code.

2. Algorithm

The static pressure drop from the inlet nozzles to k^{th} pressure tap in the vessel is given by:

$$\text{DELP}(K) = \text{COEF} \times \text{PRESHG}(I) - (\text{RHOW}/15552.0) \times (\text{PRES}(K) - \text{AAPRES})$$

where

$\text{DELP}(K)$ is the pressure drop from the inlet nozzles to the k^{th} pressure tap in psi.

COEF is a temperature dependent coefficient for converting in. of mercury to psi. This coefficient is determined by the code at the input temperature.

PRESHG is the pressure difference between the manifold over the manometer connected to the k^{th} pressure tap and the manifold over the manometers connected to the inlet nozzles, in in. of mercury.

RHOW is the density of the experimental fluid (water), in $\text{lb}_m/\text{cu ft.}$ The density is determined by the code at the input temperature.

PRES(K) is the pressure at the k^{th} pressure tap, in in. of water.

AAPRES is the average pressure at the pressure taps in the operative inlet nozzles, in in. of water.

The velocity at the J^{th} total head impact tube is given by

$$V(J) = 12.0 \times (64.348/\text{RHOW}) \times (\text{DELP}(K) - \text{DELP}(J))$$

where K is the static pressure tap at the wall adjacent to the J^{th} total head impact tube.

The change in dynamic head between the inlet nozzles and the J^{th} total head tube in psi is:

$$\text{DVH}(J) = \text{VHIN} - V(J) \times V(J) \times \text{RHOW}/9266.112$$

where VHIN is the velocity head at the inlet nozzles, in psi.

Finally, the total pressure loss between the inlet nozzles and the K^{th} pressure tap, in psi, is:

$$\text{DP}(K) = \text{DELP}(K) + \text{DVH}(J)$$

3. Input Cards

Card Type 1 (1H015 x 65H Format)

This card may include up to 70 alpha-numeric characters in columns 16 to 80.

Card Type 2 (I3, 5x, F6.1 Format)

NTEMP - the ambient temperature during the test is entered in columns 1 to 3.

FLOW - the total flow rate, in gpm, is entered in columns 9 to 15.

Card Type 3 (F5.1, 9F6.1 Format)

PRES(K) - the static pressure from the manometer boards are entered on the cards, in counts (each count is equivalent to one ninth of an inch of water column). There have to be 14 cards, 13 of which contain 10 pieces of information. The last one contains 4 pieces of information.

Card Type 4 (757.2 Format)

PRESHG(I) - the difference in pressure, in in. of mercury, between the manifold over the manometers connected to the taps in the inlet nozzles and the manifold over the other manometers. Presently there are eight manifolds, i.e., seven pieces of information are entered in this card.

Problems may be stacked.

The listing of the code follows, together with a sample problem.

*CYWB-26-HETSRONI	439HS 054000	02	54655FORTSYST
* HETSRONI, REACTOR ENGINEERING SECTION, APD			DARE 10
* XEQ			DARE 15
* NO SYMBOL TABLE			DARE 20
C DARE - DATA REDUCING CODE FOR FLOW MODEL TESTS			DARE 25
DIMENSION PRES(134), PRESHG(7), TH(84), V(84), DP(134),DVH(84),			DARE 30
1 DELP(134)			DARE 35
C FORMATS			DARE 40
1000 FORMAT (1H1)			DARE 45
1005 FORMAT (34H0 FLOW MODEL TESTS, DATA ANALYSIS)			DARE 50
1010 FORMAT (109H0 ***** INPUT			DARE 55
1 *****)			DARE 60
1015 FORMAT (109H0 ***** OUTPUT			DARE 65
1 *****)			DARE 70
1020 FORMAT (F5.1,9F6.1)			DARE 75
1025 FORMAT (I3,5X,F6.1)			DARE 80
1030 FORMAT (6X,7HNTEMP = I3,10X, 7H FLOW = F6.1)			DARE 85
1035 FORMAT (29H0 TEMPERATURE IS OUT OF RANGE)			DARE 90
1040 FORMAT (42H0 PRESSURE DROPS AND VELOCITIES AT LEVEL I)			DARE 95
1045 FORMAT (43H0 PRESSURE DROPS AND VELOCITIES AT LEVEL II)			DARE 100
1050 FORMAT (29H0 PRESSURE DROPS AT LEVEL III)			DARE 105
1055 FORMAT (35H0 PRESSURE DROPS AT SUPPORT COLUMNS)			DARE 110
1060 FORMAT (31H0 PRESSURE DROPS AT GUIDE TUBES)			DARE 115
1065 FORMAT (1H015X70H			DARE 120
1)			DARE 125
1070 FORMAT (1H)			DARE 130
1075 FORMAT (7F7.2)			DARE 135
10 RIPT 5, 1065			DARE 140
RIPT 5, 1025, NTEMP , FLOW			DARE 145
RIPT 5, 1020, (PRES(K),K=1,134)			DARE 150
RIPT 5, 1075, (PRESHG(I),I=1,7)			DARE 155
15 WOT6,1000			DARE 160
WOT6,1005			DARE 165
WOT6,1070			DARE 170
WOT6,1065			DARE 175
WOT6,1070			DARE 180
WOT6,1030,NTEMP,FLOW			DARE 185
WOT6,1070			DARE 190
CALL TIMEX			DARE 195
WOT6,1070			DARE 200
WOT6,1070			DARE 205

```

WOT6,1010
WOT6,1070
OUTPUT PRES( ), PRESHG( )
20 IF(NTEMP-66) 25,30,35
25 WOT 6, 1035
GO TO 315
30 RHOW = 62.337
COEF =0.49067
GO TO 100
35 KETEMP = NTEMP - 66
GO TO (40,45,50,55,60,65,70,75,80,85,90,95),KETEMP
40 RHOW = 62.330
COEF =0.49062
GO TO 100
45 RHOW = 62.323
COEF =0.49057
GO TO 100
50 RHOW = 62.318
COEF =0.49052
GO TO 100
55 RHOW = 62.310
COEF =0.49047
GO TO 100
60 RHOW = 62.304
COEF =0.49042
GO TO 100
65 RHOW = 62.297
COEF =0.49037
GO TO 100
70 RHOW = 62.290
COEF =0.49032
GO TO 100
75 RHOW = 62.282
COEF =0.49027
GO TO 100
80 RHOW = 62.273
COEF =0.49022
GO TO 100
85 RHOW = 62.265
COEF =0.49017
GO TO 100

```

```

DARE 210
DARE 215
DARE 220
DARE 225
DARE 230
DARE 235
DARE 240
DARE 245
DARE 250
DARE 255
DARE 260
DARE 265
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DARE 360
DARE 365
DARE 370
DARE 375
DARE 380
DARE 385
DARE 390
DARE 395
DARE 400
DARE 405
DARE 410

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90	RHOW = 62.256	DARE 415
	COEF = 0.49012	DARE 420
	GO TO 100	DARE 425
95	RHOW = 62.247	DARE 430
	COEF = 0.49008	DARE 435
100	CONTINUE	DARE 440
	FLOWW = FLOW * 2.228E-3	DARE 445
	FLOS = FLOWW * FLOWW * RHOW / 9266.112	DARE 450
	SAPRES = 0.0	DARE 451
	B = 0.0	DARE 452
101	DO 103 K=1,4	DARE 453
	IF (PRES(K)) 103,103,102	DARE 454
102	B = B + 1.	DARE 455
	SAPRES = SAPRES + PRES(K)	DARE 456
103	CONTINUE	DARE 457
	AAPRES = SAPRES / B	DARE 458
	VHIN = (FLOS / 0.11405) * 4. / B	DARE 460
	SDELP = 0.0	DARE 465
	B = 0.0	DARE 470
105	DO 120 K=21,36	DARE 475
	IF (PRES(K)) 115,115,110	DARE 480
110	B = B + 1.	DARE 485
	DELP(K) = COEF * PRES HG(1) - (RHOW/15552.)*(PRES(K)-AAPRES)	DARE 490
	SDELP = SDELP + DELP(K)	DARE 495
	GO TO 120	DARE 500
115	DELP(K) = 0.	DARE 505
120	CONTINUE	DARE 510
	ADELP1 = SDELP / B	DARE 515
	SDELP = 0.0	DARE 520
	B = 0.0	DARE 525
	DO 135 K=37,52	DARE 530
	IF (PRES(K)) 130,130,125	DARE 535
125	B = B + 1.	DARE 540
	DELP(K) = COEF * PRES HG(2) - (RHOW/15552.)*(PRES(K)-AAPRES)	DARE 545
	SDELP = SDELP + DELP(K)	DARE 550
	GO TO 135	DARE 555
130	DELP(K) = 0.	DARE 560
135	CONTINUE	DARE 565
	ADELP2 = SDELP / B	DARE 570
	DO 155 K=69,84	DARE 575
	IF (PRES(K)) 145,145,140	DARE 580

140 IF (PRES(K-48)) 145,145,150	DARE 585
145 TH(K) = 0.	DARE 590
V(K) = 0.	DARE 595
GO TO 155	DARE 600
150 TH(K) = COEF*PRESHG(4) - (RHOW/15552.) * (PRES(K) - AAPRES)	DARE 605
V(K) = SQRTF((64.348/RHOW)*(-(TH(K)- DELP(K-48))))*12.	DARE 610
155 CONTINUE	DARE 615
B = 0.	DARE 620
SDP1 = 0.	DARE 625
160 DO 180 K=21,36	DARE 630
IF (V(K+48)) 175,175,165	DARE 635
165 IF (PRES(K))175,175,170	DARE 640
170 B = B + 1.	DARE 645
DVH(K)=-(V(K+48)*V(K+48)*RHOW /9266.112)+ VHIN	DARE 650
DP(K) = DELP(K) + DVH(K)	DARE 655
SDP1 =SDP1 + DP(K)	DARE 660
GO TO 180	DARE 665
175 DVH(K) = 0.	DARE 670
DP(K) = 0.	DARE 675
180 CONTINUE	DARE 680
ADP1 = SDP1 / B	DARE 685
185 DO 205 K=5,20	DARE 690
IF(PRES(K)) 195,195,190	DARE 695
190 IF(PRES(K+32))195,195,200	DARE 700
195 TH(K) = 0.	DARE 705
V(K) = 0.	DARE 710
GO TO 205	DARE 715
200 TH(K) = (RHOW/15552.) * (PRES(K) - AAPRES)	DARE 720
V(K) = SQRTF((64.348/RHOW)*(TH(K) + DELP(K+32))) * 12.	DARE 725
205 CONTINUE	DARE 730
B = 0.	DARE 735
SDP2 = 0.	DARE 740
210 DO 230 K=37,52	DARE 745
IF (PRES(K)) 225,225,215	DARE 750
215 IF (V(K-32)) 225,225,220	DARE 755
220 B = B + 1.	DARE 760
DVH(K) = VHIN - (V(K-32)*V(K-32)*RHOW / 9266.112)	DARE 765
DP(K) = DELP(K) + DVH(K)	DARE 770
SDP2 = SDP2 + DP(K)	DARE 775
GO TO 230	DARE 780
225 DVH(K) = 0.	DARE 785

DP(K) = 0.	DARE 790
230 CONTINUE	DARE 795
ADP2 = SDP2 / B	DARE 800
SDELP = 0.0	DARE 805
B = 0.0	DARE 810
VH3 = FLOS / 0.28692	DARE 815
DVH3 = VHIN - VH3	DARE 820
235 DO 250 K=53,68	DARE 825
IF (PRES(K))245,245,240	DARE 830
240 B = B + 1.	DARE 835
DELP(K) = COEF*PRESHG(3) -(RHOW/15552.)*(PRES(K)-AAPRES)	DARE 840
DP(K) = DELP(K) + DVH3	DARE 845
SDELP = SDELP + DELP(K)	DARE 850
GO TO 250	DARE 855
245 DELP(K) = 0.	DARE 860
DP(K) = 0.	DARE 865
250 CONTINUE	DARE 870
ADELP3 = SDELP / B	DARE 875
ADP3 = ADELP3 + DVH3	DARE 880
SDELP = 0.0	DARE 885
B = 0.0	DARE 890
VH4 = FLOS / 2.42805	DARE 895
DVH4 = VHIN - VH4	DARE 900
255 DO 270 K=85,106	DARE 905
IF (PRES(K)) 265,265,260	DARE 910
260 B = B +1.	DARE 915
DELP(K) = COEF*PRESHG(5) -(RHOW/15552.)*(PRES(K)-AAPRES)	DARE 920
DP(K) = DELP(K) + DVH4	DARE 925
SDELP = SDELP + DELP(K)	DARE 930
GO TO 270	DARE 935
265 DELP(K) = 0.	DARE 940
DP(K) = 0.	DARE 945
270 CONTINUE	DARE 950
ADELP4 = SDELP / B	DARE 955
ADP4 = ADELP4 + DVH4	DARE 960
SDELP = 0.0	DARE 965
B = 0.0	DARE 970
VH5 = FLOS / 2.42207	DARE 975
DVH5 = VHIN - VH5	DARE 980
275 DO 290 K=107,130	DARE 985
IF (PRES(K)) 285,285,280	DARE 990

280	B = B + 1.	DARE 995
	DELP(K) = COEF*PRESHG(6) -(RHOW/15552.)*(PRES(K)-AAPRES)	DARE1000
	DP(K) = DELP(K) + DVH5	DARE1005
	SDELP = SDELP + DELP(K)	DARE1010
	GO TO 290	DARE1015
285	DELP(K) = 0.	DARE1020
	DP(K) = 0.	DARE1025
290	CONTINUE	DARE1030
	ADELP5 = SDELP / B	DARE1035
	ADP5 = ADELP5 + DVH5	DARE1040
	SDELP = 0.	DARE1045
	B = 0.	DARE1050
295	DO 310 K=131,134	DARE1055
	IF (PRES(K))305,305,300	DARE1060
300	B = B + 1.	DARE1065
	DELP(K) = COEF*PRESHG(7) -(RHOW/15552.)*(PRES(K)-AAPRES)	DARE1070
	SDELP = SDELP + DELP(K)	DARE1075
	GO TO 310	DARE1080
305	DELP(K) = 0.	DARE1085
	DP(K) = 0.	DARE1090
310	CONTINUE	DARE1095
	ADELP6 = SDELP / B	DARE1100
	WOT6,1000	DARE1105
	WOT6,1015	DARE1110
	WOT6,1070	DARE1115
	WOT6,1070	DARE1120
	WOT6,1040	DARE1125
	WOT6,1070	DARE1130
	OUTPUT (DELP(I),I=21,36),ADELP1,VHIN,(V(I),I=69,84),(DVH(I),I=21,	DARE1135
	1 36),(DP(I),I=21,36), ADP1	DARE1140
	WOT6,1070	DARE1145
	WOT6,1070	DARE1150
	WOT6,1045	DARE1155
	WOT6,1070	DARE1160
	OUTPUT (DELP(I),I=37,52),ADELP2, VHIN, (V(I),I=5,20),(DVH(I),I=37,	DARE1165
	1 52),(DP(I),I=37,52), ADP2	DARE1170
	WOT6,1070	DARE1175
	WOT6,1070	DARE1180
	WOT6,1050	DARE1185
	WOT6,1070	DARE1190
	OUTPUT (DELP(I),I=53,68),ADELP3,VHIN,DVH3,(DP(I),I=53,68), ADP3	DARE1195

WOT6,1070	DARE1200
WOT6,1070	DARE1205
WOT6,1055	DARE1210
WOT6,1070	DARE1215
OUTPUT (DELP(I),I=85,106),ADELP4, VHIN, DVH4,(DP(I),I=85,106),	DARE1220
1 ADP4	DARE1225
WOT6,1070	DARE1230
WOT6,1070	DARE1235
WOT6,1060	DARE1240
WOT6,1070	DARE1245
OUTPUT (DELP(I),I=107,130), ADELP5, VHIN, DVH5, (DP(I),I=107,130)	DARE1250
1 ,ADP5	DARE1255
WOT6,1070	DARE1260
WOT6,1070	DARE1265
OUTPUT (DELP(I),I=131,134), ADELP6, VHIN	DARE1270
WOT 6, 1070	DARE1275
CALL TIMEX	DARE1280
315 GO TO 10	DARE1285
END	DARE1290
* DATA	DARE1295

STORAGE NOT USED BY PROGRAM

DEC OCT
3317 06365

DEC OCT
32561 77461

STORAGE LOCATIONS FOR VARIABLES APPEARING IN DIMENSION AND EQUIVALENCE STATEMENTS

DEC OCT
DELP 2789 05345
PRESHG 3182 06156

DEC OCT
DP 3007 05677
PRES 3316 06364

DEC OCT
DVH 2873 05471
TH 3175 06147

DEC OCT
I0000A 2655 05137
V 3091 06023

STORAGE LOCATIONS FOR VARIABLES NOT APPEARING IN COMMON, DIMENSION, OR EQUIVALENCE STATEMENT

DEC OCT
AAPRES 2649 05131
ADELP4 2645 05125
ADP2 2641 05121
B 2637 05115
DVH5 2633 05111
I00000 2629 05105
I00004 2625 05101
SAPRES 2621 05075
VH3 2617 05071

DEC OCT
ADELP1 2648 05130
ADELP5 2644 05124
ADP3 2640 05120
COEF 2636 05114
FLUS 2632 05110
I00001 2628 05104
KETEMP 2624 05100
SDELP 2620 05074
VH4 2616 05070

DEC OCT
ADELP2 2647 05127
ADELP6 2643 05123
ADP4 2639 05117
DVH3 2635 05113
FLOW 2631 05107
I00002 2627 05103
NTEMP 2623 05077
SDP1 2619 05073
VH5 2615 05067

DEC OCT
ADELP3 2646 05126
ADP1 2642 05122
ADP5 2638 05116
DVH4 2634 05112
FLOWW 2630 05106
I00003 2626 05102
RHOW 2622 05076
SDP2 2618 05072
VHIN 2614 05066

SYMBOLS AND LOCATIONS FOR SOURCE PROGRAM FORMAT STATEMENTS

EFN LOC
8)V8 1000 05060
8)VS 1020 05000
8)10G 1040 04755
8)114 1060 04717
8)T5V 29887 04234
8)T65 29893 04251
8)T6A 29898 04265
8)T6F 29903 04311
8)T6L 29909 04330
8)T6R 29915 04354
8)T71 29921 04371
8)T76 29926 04405
8)T7B 29931 04431

EFN LOC
8)VD 1005 05057
8)101 1025 04775
8)10L 1045 04745
8)119 1065 04710
8)T60 29888 04237
8)T66 29894 04255
8)T6C 29900 04272
8)T6H 29905 04314
8)T6M 29910 04332
8)T6S 29916 04357
8)T72 29922 04375
8)T78 29928 04412
8)T7D 29933 04434

EFN LOC
8)VI 1010 05050
8)106 1030 04772
8)10Q 1050 04734
8)11E 1070 04672
8)T61 29889 04241
8)T67 29895 04260
8)T6D 29901 04304
8)T6J 29907 04321
8)T60 29912 04335
8)T6T 29917 04361
8)T73 29923 04400
8)T79 29929 04424
8)T7F 29935 04441

EFN LOC
8)VN 1015 05024
8)10B 1035 04763
8)10V 1055 04726
8)11J 1075 04671
8)T63 29891 04244
8)T68 29896 04262
8)T6E 29902 04307
8)T6K 29908 04325
8)T6Q 29914 04342
8)T6V 29919 04364
8)T74 29924 04402
8)T7A 29930 04427
8)T7G 29936 04445

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8)T7H 29937 04450	8)T7I 29938 04452	8)T7K 29940 04455	8)T7M 29942 04462
8)T7N 29943 04465	8)T7O 29944 04467	8)T7Q 29946 04472	8)T7S 29948 04477
8)T7T 29949 04502	8)T7U 29950 04504	8)T80 29952 04507	8)T82 29954 04513
8)T83 29955 04522	8)T84 29956 04525	8)T85 29957 04527	8)T87 29959 04532
8)T89 29961 04537	8)T8A 29962 04543	8)T8B 29963 04546	8)T8C 29964 04550
8)T8E 29966 04553	8)T8G 29968 04560	8)T8H 29969 04563	8)T8I 29970 04565
8)T8K 29972 04570	8)T8M 29974 04575	8)T8N 29975 04600	8)T8O 29976 04602
8)T8Q 29978 04605	8)T8S 29980 04611	8)T8T 29981 04620	8)T8U 29982 04623
8)T8V 29983 04625	8)T91 29985 04630	8)T93 29987 04635	8)T94 29988 04640
8)T95 29989 04642	8)T97 29991 04645	8)T99 29993 04652	8)T9A 29994 04655
8)T9B 29995 04657	8)T9D 29997 04662	8)T9F 29999 04667	

LOCATIONS FOR OTHER SYMBOLS NOT APPEARING IN SOURCE PROGRAM

[illegible]

LOCATIONS OF NAMES IN TRANSFER VECTOR

	DEC	OCT		DEC	OCT		DEC	OCT		DEC	OCT
SQRT	6	00006	TIMEX	5	00005	(FIL)	4	00004	(FPT)	0	00000
(RTN)	2	00002	(STH)	3	00003	(TSH)	1	00001			

ENTRY POINTS TO SUBROUTINES NOT OUTPUT FROM LIBRARY

SQRT	TIMEX	(FIL)	(FPT)	(RTN)	(STH)	(TSH)
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EXTERNAL FORMULA NUMBERS WITH CORRESPONDING INTERNAL FORMULA NUMBERS AND OCTAL LOCATIONS

EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN	IFN	LOC	EFN
10	99	00015	15	112	00071	29996	131	00245	29998	137	00273	
29990	148	00356	29992	154	00404	20	159	00426	25	160	00432	
30	162	00441	35	165	00446	40	167	00467	45	170	00475	
50	173	00503	55	176	00511	60	179	00517	65	182	00525	
70	185	00533	75	188	00541	80	191	00547	85	194	00554	

DARE - DATA REDUCING CODE FOR FLOW MODEL TESTS

5/05/65

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90	197	00562	95	200	00570	100	202	00574	101	207	00610
102	209	00615	103	211	00623	105	216	00642	110	218	00647
115	222	00671	120	223	00673	125	229	00711	130	233	00733
135	234	00735	140	238	00747	145	239	00752	150	242	00757
155	244	01011	160	247	01017	165	249	01024	170	250	01030
175	255	01051	180	257	01055	185	259	01062	190	261	01067
195	262	01072	200	265	01077	205	267	01124	210	270	01132
215	272	01137	220	273	01143	225	278	01164	230	280	01170
235	286	01207	240	288	01214	245	293	01241	250	295	01245
255	302	01267	260	304	01274	265	309	01321	270	311	01325
275	318	01347	280	320	01354	285	325	01401	290	327	01405
295	332	01421	300	334	01426	305	338	01450	310	340	01454
29984	354	01566	29986	360	01614	29977	373	01713	29979	379	01741
29971	390	02024	29973	396	02052	29965	407	02135	29967	413	02163
29958	430	02310	29960	436	02336	29951	449	02435	29953	455	02463
29945	466	02546	29947	472	02574	29939	483	02657	29941	489	02705
29932	506	03032	29934	512	03060	29925	525	03161	29927	531	03207
29918	548	03334	29920	554	03362	29911	567	03463	29913	573	03511
29904	587	03617	29906	593	03645	29897	603	03722	29899	609	03750
29890	621	04035	29892	627	04063	315	636	04125			

BEGIN LOAD TIME 22.826

ENTRY POINTS TO SUBROUTINES REQUESTED FROM LIBRARY,

(FPT) (TSHM) (RTN) (STHM) (FIL) TIMEX SQRT

SUBROUTINE ENTRY POINTS AND STARTING LOCATIONS UPPER PROGRAM 13423 LOWER COMMON 77461

	ENTRY	START		ENTRY	START		ENTRY	START		ENTRY	START
MAIN-P	00153	00144	SQRT	06534	06531	TIMEX1	06613	06610	TIMEX	06616	
ANYER	07423	06752	SBRER	07421		DVFLW	07414		UNFLW	07417	
BRCDE	07401		EPMD	07372		(SVN)	06757		(SIX)	06756	
(FPT)	06760		ERROR	07107		ERTRP	07433		ERSIN	07425	
(TSHM)	07463	07453	(TSH)	07463		(BLOK)	10143	07524	(STHD)	07540	
(STHM)	07535		(STH)	07535		(WTC)	10266	10215	(WER)	10227	
(RDC)	10345	10314	(RER)	10323		(RTN)	11212	10361	(FIL)	11201	
(IOH)	11342		(TCO)	12375	12266	(TEF)	12374		(RCH)	12373	
(ETT)	12372		(REW)	12371		(WEF)	12370		(BSR)	12367	
(WRS)	12366		(RDS)	12365		(IOS)	12271		STCH)	12407	
(TCN)	12406		(LCH)	12405		(CHR)	12404		(RUN)	12403	
(BSF)	12402		(SDL)	12401		(SDH)	12400		(BTT)	12377	
(TRC)	12376		(IOU)	12433	12430	(FT)	12457	12451	(EXEM)	12460	
(EXE)	12460		EXIT	13410	13406	(TES)	13422	13422			

EXECUTION TIME 22.828

FLOW MODEL TESTS, DATA ANALYSIS

CONN. YANKEE MODEL - RUN 84 - 4 LOOPS

DARE

NTEMP = 74

FLOW =2323.0

05/05/65

TIME= 22.829

***** INPUT *****

THE PRES ARRAY IS

SUBSCRIPT=

1	2	3	4	5	6
363.00000	269.00000	365.00000	349.00000	355.00000	367.00000
7	8	9	10	11	12
370.00000	417.00000	371.00000	421.00000	0	490.00000
13	14	15	16	17	18
345.00000	426.00000	327.00000	462.00000	395.00000	551.00000
19	20	21	22	23	24
382.00000	429.00000	507.00000	479.00000	433.00000	446.00000
25	26	27	28	29	30
915.00000	747.00000	930.00000	730.00000	430.00000	394.00000
31	32	33	34	35	36
478.00000	513.00000	954.00000	699.00000	919.00000	764.00000
37	38	39	40	41	42
776.00000	839.00000	782.00000	837.00000	709.00000	761.00000
43	44	45	46	47	48
684.00000	711.00000	684.00000	700.00000	669.00000	709.00000
49	50	51	52	53	54
686.00000	601.00000	726.00000	761.00000	782.00000	795.00000
55	56	57	58	59	60
781.00000	815.00000	782.00000	699.00000	683.00000	869.00000
61	62	63	64	65	66

676.00000	641.00000	687.00000	670.00000	640.00000	638.00000
67	68	69	70	71	72
778.00000	866.00000	971.00000	811.00000	991.00000	821.00000
73	74	75	76	77	78
833.00000	917.00000	841.00000	908.00000	787.00000	977.00000
79	80	81	82	83	84
968.00000	811.00000	854.00000	920.00000	875.00000	879.00000
85	86	87	88	89	90
0	646.00000	653.00000	640.00000	882.00000	625.00000
91	92	93	94	95	96
781.00000	638.00000	651.00000	659.00000	666.00000	654.00000
97	98	99	100	101	102
645.00000	649.00000	633.00000	0	639.00000	642.00000
103	104	105	106	107	108
650.00000	640.00000	0	0	823.00000	757.00000
109	110	111	112	113	114
771.00000	829.00000	795.00000	765.00000	826.00000	797.00000
115	116	117	118	119	120
805.00000	835.00000	831.00000	777.00000	825.00000	822.00000
121	122	123	124	125	126
835.00000	861.00000	836.00000	820.00000	837.00000	832.00000
127	128	129	130	131	132
834.00000	838.00000	840.00000	839.00000	410.00000	422.00000
133	134				
449.00000	381.00000				

THE PRESHG ARRAY IS

SUBSCRIPT=

1	2	3	4	5	6
4.6500000	7.5100000	6.2300000	0.4700000	7.3500000	31.500000
7					
31.500000					

***** OUTPUT *****

PRESSURE DROPS AND VELOCITIES AT LEVEL I

THE DELP ARRAY IS

SUBSCRIPT=

21	22	23	24	25	26
1.5969442	1.7090774	1.8932963	1.8412344	-3.6997139E-02	0.6358022
27	28	29	30	31	32
-9.7068518E-02	0.7038831	1.9053106	2.0494819	1.7130822	1.5729156
33	34	35	36		
-0.1931827	0.8280306	-5.3016156E-02	0.5677214		

ADELP1 1.0397822 VHIN 1.5786960

THE V ARRAY IS

SUBSCRIPT=

69	70	71	72	73	74
24.111210	22.421037	25.245931	22.985276	16.001111	20.153930
75	76	77	78	79	80
15.870251	20.271838	22.750786	25.539232	24.430342	21.964635
81	82	83	84		
15.662404	20.894197	16.693608	19.323848		

THE DVH ARRAY IS

SUBSCRIPT=

21	22	23	24	25	26
----	----	----	----	----	----

-2.3288403	-1.8002121	-2.7052873	-1.9724166	-0.1422423	-1.1514413
27	28	29	30	31	32
-0.1142091	-1.1834794	-1.9003311	-2.8054063	-2.4329638	-1.6640503
33	34	35	36		
-7.0156723E-02	-1.3556840	-0.2944232	-0.9311797		

THE DP ARRAY IS

SUBSCRIPT=

21	22	23	24	25	26
-0.7318961	-9.1134712E-02	-0.8119910	-0.1311822	-0.1792395	-0.5156391
27	28	29	30	31	32
-0.2112776	-0.4795962	4.9794912E-03	-0.7559245	-0.7198817	-9.1134697E-02
33	34	35	36		
-0.2633394	-0.5276534	-0.3474393	-0.3634584		

ADP1 -0.3884880

PRESSURE DROPS AND VELOCITIES AT LEVEL II

THE DELP ARRAY IS

SUBSCRIPT=

37	38	39	40	41	42
1.9218365	1.6695367	1.8978079	1.6775462	2.1901552	1.9819078
43	44	45	46	47	48
2.2902742	2.1821457	2.2902742	2.2261981	2.3503456	2.1901552
49	50	51	52		
2.2822647	2.6226691	2.1220744	1.9819078		

ADELP2 2.1173186

VHIN 1.5786960

THE V ARRAY IS

SUBSCRIPT=

5	6	7	8	9	10
17.232153	16.326682	17.387048	17.249432	18.611816	18.579776
11	12	13	14	15	16
0	20.398776	18.595803	19.609484	18.547681	20.015466
17	18	19	20		
19.349497	22.759490	18.515529	18.707608		

THE DVH ARRAY IS

SUBSCRIPT=

37	38	39	40	41	42
-0.4172284	-0.2129858	-0.4532712	-0.4212332	-0.7496232	-0.7416137
43	44	45	46	47	48
0	-1.2181800	-0.7456186	-1.0059278	-0.7336043	-1.1140563
49	50	51	52		
-0.9378470	-1.9029936	-0.7255947	-0.7736519		

THE DP ARRAY IS

SUBSCRIPT=

37	38	39	40	41	42
1.5046080	1.4565509	1.4445367	1.2563130	1.4405320	1.2402941
43	44	45	46	47	48
0	0.9639657	1.5446557	1.2202702	1.6167413	1.0760989
49	50	51	52		
1.3444177	0.7196756	1.3964796	1.2082559		

ADP2 1.2955596

PRESSURE DROPS AT LEVEL III

THE DELP ARRAY IS

SUBSCRIPT=

53	54	55	56	57	58
1.2702623	1.2182004	1.2742670	1.1381053	1.2702623	1.6026572
59	60	61	62	63	64
1.6667334	0.9218483	1.6947667	1.8349332	1.6507143	1.7187952
65	66	67	68		
1.8389380	1.8469475	1.2862813	0.9338626		

ADELP3 1.4479734 VHIN 1.5786960 DVH3 0.9511682

THE DP ARRAY IS

SUBSCRIPT=

53	54	55	56	57	58
2.2214305	2.1693686	2.2254352	2.0892734	2.2214305	2.5538254
59	60	61	62	63	64
2.6179015	1.8730165	2.6459348	2.7861013	2.6018825	2.6699634
65	66	67	68		
2.7901061	2.7981156	2.2374495	1.8850308		

ADP3 2.3991415

PRESSURE DROPS AT SUPPORT COLUMNS

THE DELP ARRAY IS

SUBSCRIPT=

85	86	87	88	89	90
0	2.3640118	2.3359785	2.3880404	1.4188889	2.4481117

91	92	93	94	95	96
1.8233695	2.3960499	2.3439880	2.3119500	2.2839167	2.3319738
97	98	99	100	101	102
2.3680166	2.3519976	2.4160737	0	2.3920451	2.3800308
103	104	105	106		
2.3479928	2.3880404	0	0		

ADELP4 2.2828041 VHIN 1.5786960 DVH4 1.5045417

THE DP ARRAY IS

SUBSCRIPT=

85	86	87	88	89	90
0	3.8685535	3.8405202	3.8925820	2.9234306	3.9526534
91	92	93	94	95	96
3.3279111	3.9005916	3.8485297	3.8164916	3.7884583	3.8365154
97	98	99	100	101	102
3.8725582	3.8565392	3.9206153	0	3.8965868	3.8845725
103	104	105	106		
3.8525344	3.8925820	0	0		

ADP4 3.7873457

PRESSURE DROPS AT GUIDE TUBES

THE DELP ARRAY IS

SUBSCRIPT=

10					
13.495190	13.759504	13.703437	13.471161	13.607323	13.727466
13.483176	13.599314	13.567276	13.447133	13.463152	13.679409
13.487180	13.499195	13.447133	13.343009	13.443128	13.507204
13.439123	13.459147	13.451138	13.435119	13.427109	13.431114

ADELP5 13.515547

VHIN 1.5786960

DVH5 1.5043586

THE DP ARRAY IS

SUBSCRIPT=

10

14.999549	15.263863	15.207796	14.975520	15.111682	15.231825
14.987534	15.103672	15.071634	14.951491	14.967510	15.183767
14.991539	15.003553	14.951491	14.847368	14.947487	15.011563
14.943482	14.963506	14.955496	14.939477	14.931468	14.935472

ADP5 15.019905

THE DELP ARRAY IS

SUBSCRIPT=

10

15.149155	15.101098	14.992970	15.265293
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ADELP6 15.127129

VHIN 1.5786960

05/05/65

TIME= 22.829

Appendix B - Mechanical Design Drawings

<u>Figure Number</u>	<u>Drawing N°</u>	<u>Title</u>
28	647J272	General Assembly
29	647J267	Pressure Vessel and Thermal Shield Details
30	647J269	Internals Assembly and Details