GEAP-10055
AEC RESEARCH AND
DEVELOPMENT REPORT
APRIL 1969

RECEIVED BY DTIC OCT 1 5 1969

MASTER

**TWO-PHASE FLOW
AND HEAT TRANSFER
IN MULTIROD GEOMETRIES
FOURTEENTH
QUARTERLY PROGRESS REPORT
JANUARY 1 - MARCH 31, 1969**

U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT (04-3)-189
PROJECT AGREEMENT 44

ATOMIC POWER EQUIPMENT DEPARTMENT
GENERAL ELECTRIC
SAN JOSE, CALIFORNIA

CONTINUATION OF THE DEVELOPMENT OF NUCLEAR

DISCLAIMER

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

DISCLAIMER

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

TWO-PHASE FLOW AND HEAT TRANSFER
IN MULTIROD GEOMETRIES
FOURTEENTH QUARTERLY PROGRESS REPORT
JANUARY 1—MARCH 31, 1969

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:
A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.
As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Approved:

E. Janssen
E. Janssen
Project Engineer

F. A. Schraub / E/8-569
F. A. Schraub, Manager
Core Development

U. S. Atomic Energy Commission
Contract AT(03-4)-189
Project Agreement 44

*Printed in U.S.A. Available from the
Clearing House for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia
Price: \$3.00 per copy*

ATOMIC POWER EQUIPMENT DEPARTMENT
GENERAL ELECTRIC
SAN JOSE, CALIFORNIA

flg

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or*
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.*

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Table of Contents

	ACKNOWLEDGMENTS	1
	SUMMARY	1
1.	INTRODUCTION	1
2.	DESCRIPTION OF TEST	2
3.	DATA REDUCTION	4
4.	INITIAL TESTS	5
5.	SINGLE-PHASE SAMPLING DATA	5
6.	TWO-PHASE SAMPLING DATA	5
7.	PRESSURE DROP DATA	13
	DISTRIBUTION LIST	16

List of Illustrations

Figure No.	Title	Page
1	Dimensions of Nine-Rod Array	2
2	Schematic of Loop Showing Sampling Circuit	3
3	Calibration for Isokinetic Setting	6
4	Corner Subchannel Cold Data	7
5	Variation of Channel Flow with Pressure Differential	8
6	Variation of Channel Enthalpy with Differential Pressure	9
7	Variation of Channel Flow and Enthalpy Versus Average Quality	10
8	Total Static Pressure Drop Versus Heated Length	14
9	Total Static Pressure Drop Versus Heated Length	15

ACKNOWLEDGMENTS

This program is sponsored by the Atomic Energy Commission and conducted by the General Electric Company, with the following individuals contributing to the program during the current reporting period:

Project Engineer:
Engineers:

E. Janssen
R. T. Lahey
D. W. Radcliffe
B. S. Shiralkar
Y. H. Kong

Engineering Assistant:

SUMMARY

Task C

Work connected with subchannel flow tests in the nine-rod test section is described. The work includes calibration of calorimeter (i. e., determination of heat loss), determination of ΔP setting for isokinetic sampling in the corner subchannel, single- and two-phase sampling of corner subchannel flow, and single- and two-phase pressure drop. Results are given in tables, and typical results are plotted.

The results show that in the range of conditions tested, both the mass velocity and the quality in the corner subchannel are less than the average for the channel. The mass velocity in the corner subchannel appears to approach the average channel value at qualities corresponding to transition from slug to annular flow. Pressure drop results are not yet ready to report.

1. INTRODUCTION

This is the fourteenth quarterly report on the work done under Contract AT(04-3)-189, Project Agreement No. 44, and covers the period from January 1 to March 31, 1969.

The objectives for Phase 1 of the program were as follows.

Task A

1. Obtain detailed measurements of flow structure (pressure drop, liquid film thickness, wall shear stress, local mass flux, local impact pressure) for air-water and steam-water mixtures.
2. Carry on an analytical effort in parallel with the air-water tests.

Task B

1. Measure the critical heat flux for a vertical nine-rod geometry, under forced convection conditions, with water at high pressure (600 to 1400 psia) and flow upward. Tests should be performed with a "clean" multirod geometry (as little disturbance as possible to the flow by the provisions for maintaining the rods in correct relative alignment).
2. Investigate the effect of certain parameters; specifically, quality, flow rate, heated length, pressure, and rod-wall spacing.

3. Use the results to evaluate one or more computer models as a basis for CHF prediction.

The work under Phase I has been reported in Quarterly Reports Nos. 1 through 10, plus certain topical reports and summary reports, either issued or to be issued soon.

The objectives for Phase 2 are as follows.

Task C

1. Make measurements of both fully-developed and developing two-phase flow (steam-water at 600 to 1400 psia, adiabatic and with heat addition, flow vertical upward) from which can be determined rates of mass and energy transfer in the transverse direction, such measurements to be made in a circular tube, eccentric annulus, and nine-rod channel. The nine-rod channel measurements should include representative measurements of subchannel flow and enthalpy from which can be deduced information concerning cross flow and mixing.
2. Determine the relationships between rate and driving potential, or potential gradient, and the effect of certain parameters (e.g., total flow, pressure, local void) on these relationships. In particular, determine the effect of grid-type spacers in the nine-rod channel.

3. Analyze the results to evaluate existing models of two-phase flow. Endeavor to develop an improved model in light of the results. Such a model should be useful in the prediction of flow structure, pressure drop, and critical heat flux in developing two-phase flow in multirod geometries, both "clean" and with grid-type spacers.

Task D

1. Measure critical heat flux in a nine-rod channel fitted with grid-type spacers characteristic of modern water-cooled reactors.
2. Determine, if possible, whether, and to what degree, the effect of spacers on the CHF is caused by a redistribu-

bution of the flow among the various subchannels, or by a highly localized disturbance which might, for example, disrupt the liquid film.

3. Modify the prediction methods developed in Task C as appropriate, and check them against the data obtained under Item 1.

Tests were performed under the scope of Task C during the current reporting period to determine the flow and quality distribution within the corner subchannel of the nine-rod test section. Single-phase and two-phase pressure drop measurements were also made during this period of testing. A description of the work follows.

2. DESCRIPTION OF TEST

A detailed description of the nine-rod test section can be found in the Thirteenth Quarterly Progress Report. For purposes of continuity, the part of the setup relevant to this test will be described briefly here. In Figure 1 is shown the dimensions of the nine-rod array and the location of the corner subchannel. This subchannel was physically separated from the rest of the channel at the end of the heated length by means of two "flow splitters." The flow splitters consist of 0.010-inch-thick metal pieces, 2 inches long and

0.218 inch wide, that slide into grooves, one on the rod and one in the channel wall. The flow is then removed through a tube which hooks up with the sample line. Details of the sampling circuit are shown in Figure 2. The two-phase mixture is condensed in a Helicoil heat exchanger, which is used as a calorimeter to determine the enthalpy of the sample. The sample flow is monitored by a turbine flowmeter; two turbine meters of different capacity are used in conjunction with the different subchannels being sampled.

SECTION "A-A"
(NOTE SPLITTER POSITIONS FOR THE VARIOUS SUBCHANNELS)

FIGURE 1. DIMENSIONS OF NINE-ROD ARRAY

FIGURE 2. SCHEMATIC OF LOOP SHOWING SAMPLING CIRCUIT

A flow control valve is used to set the sample flow to the desired amount.

The sample flow rate is set so as to obtain a particular value of static pressure difference between pressure taps located inside and outside the subchannel at the same axial location. Four pressure taps, referred to as C1, C2, W1, and W2, are available for this purpose, and their peripheral locations are shown in Figure 1. Axially, they are located at the leading edge of the flow splitters. When sampling the corner subchannel, C1 and C2 or W2 can be used. Similarly, W1 and W2 can be used for the side subchannel. A special arrangement is required for the center subchannel and will be detailed in the next report. When this pressure difference is set to the value that exists when the sample tube is removed and the subchannel flow is not being taken off, the sampling is termed "isokinetic." This pressure difference was generally zero or close to it. "Non-isokinetic" data were also taken, since they yield additional information such as estimates of the enthalpy of crossflow between sub-

channels. The static pressure differences were measured by a 0.2-psi-capacity Pace ΔP cell.

The sample enthalpy is determined by a heat balance on the calorimeter. For this purpose, cooling water from a city water line is used and its flow rate is measured with another turbine flowmeter. The inlet and outlet temperatures of the cooling water are measured by chromel-alumel thermocouples. Three thermocouples are located at each place and their differential output is also recorded to obtain better accuracy on the rise in temperature of the cooling water. The outlet thermocouples are inserted beyond a right-angle bend in the piping to ensure good mixing in the water. The outlet temperature of the condensed sample was also measured with three chromel-alumel thermocouples.

Pressure drop measurements were also made during the tests. These were taken with Pace ΔP transducers over six 1-foot lengths and a Pace cell and a manometer over the whole 6-foot heated length.

3. DATA REDUCTION

Most of the data were obtained in the form of paper tape output from the DYMEC data acquisition system. The raw data consist of (a) the main flow rate and inlet temperature, (b) electrical power to the test section, (c) the system pressure and pressure differential between subchannels, (d) the temperatures in the heat exchanger, (e) pressure drop along the test section, and (f) temperatures along the vessel wall for calculation of the hydrostatic head. A computer program was written to reduce them to the engineering quantities of interest.

The system flow rate is obtained from the main loop turbine meter, as well as a 1-inch orifice in conjunction with a 60-inch high-pressure manometer. The bundle average exit equilibrium quality is calculated from the first law of thermodynamics as:

$$\bar{X}_e = [(3413 \times W - Q_L) / F_M \cdot H_{sub}] / H_{fg}$$

where

$$\begin{aligned} W &= \text{Total power, kW,} \\ Q_L &= \text{Heat loss, Btu/h} \\ &= 0.13 (Gr \cdot Pr)^{1/3} \cdot A_H \cdot (T_{avg} - T_{room}), \end{aligned}$$

where

$$\begin{aligned} Gr &= \text{Grashof number,} \\ Pr &= \text{Prandtl number,} \end{aligned}$$

$$\begin{aligned} A_H &= \text{Test Vessel Surface Area, ft}^2 \\ T_{avg} &= \text{Average test vessel temperature, } ^\circ\text{F, and} \\ T_{room} &= \text{Room temperature, } ^\circ\text{F;} \end{aligned}$$

also

$$\begin{aligned} F_M &= \text{System flow, lb/h,} \\ H_{sub} &= \text{Inlet subcooling, Btu/lb, and} \\ H_{fg} &= \text{Latent heat of evaporation, Btu/lb.} \end{aligned}$$

The sample or subchannel quality is calculated as:

$$X_{CH} = \left(\frac{F_{cw} \cdot C_p \Delta T_{cw} - H_{sat} + H_{out} + \frac{Q'}{F_s}}{F_s} \right) / H_{fg},$$

where

$$\begin{aligned} F_{cw} &= \text{Cooling water flow, lb/h,} \\ F_s &= \text{Sample flow, lb/h,} \\ \Delta T_{cw} &= \text{Temperature rise of cooling water, } ^\circ\text{F,} \\ H_{sat} &= \text{Enthalpy of saturated liquid, Btu/lb,} \\ H_{out} &= \text{Enthalpy of sample at heat exchanger outlet, Btu/lb, and} \\ Q' &= \text{Sample heat loss, to be determined experimentally, Btu/h.} \end{aligned}$$

All pressure drop measurements were corrected for the hydrostatic head, based on the average density of water between the relevant pressure taps.

4. INITIAL TESTS

Initial tests were performed to determine:

- The heat loss from the sample pipe and calorimeter.
- The isokinetic setting of the pressure differential.

Heat balance tests were run with single-phase water between 400 to 500°F at pressures of 1100 to 1200 psi to obtain higher accuracy in the estimation of the subchannel quality (i.e., to estimate Q' in the equation for X_{CH}). It was found that there was negligible heat loss in the sample piping between the test section exit and heat exchanger inlet. However, the heat balances were in error by as much as $\pm 5\%$ of the total sample energy transfer. This was well above the upper limit indicated by an error analysis, but the reason for the discrepancy could not be determined exactly. During the course of a day's run, the variation in the error was much smaller, of the order of $\pm 1\%$. For this reason, the following procedure was adopted during the two-phase runs: while heating up, heat loss checks were

made with single-phase water and the discrepancy in heat balance was used as Q' for that particular series of tests.

The isokinetic setting for the corner subchannel was experimentally found to be a fraction of the average dynamic head at the exit, indicating probable static pressure tap impacting. The dynamic head was evaluated as:

$$\frac{\bar{G}^2}{2g_c} (v_f + X_e v_{fg})$$

where

v_f = Specific volume of liquid, and
 v_{fg} = Difference in specific volumes between vapor and liquid.

A plot of the pressure difference versus dynamic head is shown in Figure 3. At high flow rates and qualities, the pressure difference is seen to be appreciable. This plot was used in setting the isokinetic sampling settings for the corner subchannel.

5. SINGLE-PHASE SAMPLING DATA

Shown in Figure 4 are the results obtained for single-phase sampling in the corner subchannel. The pressure differential on the vertical coordinate is plotted with respect to the

isokinetic setting, so that the intersection with the horizontal axis yields the natural flow split. The trends are as expected and add confidence to the two-phase data.

6. TWO-PHASE SAMPLING DATA

Some typical trends in the two-phase data are shown in Figures 5 and 6. In this series of runs, all nine rods were equally heated; the heated length was 6 feet. A comparison of these plots shows that as the subchannel flow is increased, the subchannel enthalpy generally increases, indicating that the enthalpy of flow diversion is higher than the enthalpy of the subchannel. Shown in Figure 7 is the variation in subchannel flow and enthalpy with average quality for three runs—2E1, 2E2, 2E3—which differ only in inlet subcooling. Hence, this plot also represents the change in subchannel flow and enthalpy along the heated length of the channel, assuming always fully developed flow at the end of the subcooled region. The apparent trend of the

subchannel mass flux to approach the bundle average mass flux in the quality region corresponding to the slug-annular transition is consistent with the steam-water data of other investigators.*

In general, the corner subchannel data show that the mass flux in the subchannel is lower than the average flow rate, and that the subchannel quality is lower than the average quality, except at the highest mass flux.

Some of the isokinetic data for single- and two-phase flow are shown in Table 1. The detailed test conditions for the different test points are shown in Table 2.

* (Rowe, D. S., Angle, C. W., "Crossflow Mixing Between Parallel Flow Channels During Boiling, Part II," BNWL-371 PT2, December 1967.
 (Rowe, D. S., Angle, C. W., "Crossflow Mixing Between Parallel Flow Channels During Boiling, Part III," BNWL-371 PT3, January 1969.)

FIGURE 3. CALIBRATION FOR ISOKINETIC SETTING

FIGURE 4. CORNER SUBCHANNEL COLD DATA

FIGURE 5. VARIATION OF CHANNEL FLOW WITH PRESSURE DIFFERENTIAL

FIGURE 6. VARIATION OF CHANNEL ENTHALPY WITH DIFFERENTIAL PRESSURE

FIGURE 7. VARIATION OF CHANNEL FLOW AND ENTHALPY VERSUS AVERAGE QUALITY

Table 1

CORNER SUBCHANNEL RESULTS
(P = 1000 psia)

Test Point	$\bar{G}/10^6$	$\bar{X}_e$	$G_{CH}/10^6$	X_{CH}	$\frac{G_{CH} - \bar{G}}{\bar{G}}$	$\frac{H_{CH} - \bar{H}}{\bar{H}}$
1B	0.480	-	0.311	-	-0.351	-
1C	0.990	-	0.701	-	-0.292	-
1D	1.510	-	1.095	-	-0.275	-
1E	1.97	-	1.62	-	-0.177	-
2B2	0.530	0.029	0.372	0.003	-0.298	-0.030
2B3	0.535	0.090	0.550	0.072	+0.028	-0.0793
2B4	0.535	0.176	0.524	0.133	-0.021	-0.0423
2C1	1.060	0.042	0.965	0.029	-0.0896	-0.0140
2C2	1.068	0.075	0.968	0.063	-0.0936	-0.0131
2D1	0.540	0.110	0.425	0.083	-0.213	-0.028
2D3	0.540	0.318	0.490	0.260	-0.926	-0.050
2E1	1.080	0.035	0.950	0.004	-0.121	-0.0355
2E2	1.080	0.106	1.046	0.049	-0.032	-0.0602
2E3	1.060	0.215	0.965	0.160	-0.095	-0.0521
2F1	2.07	0.042	1.53	0.120	-0.261	+0.0883
2F2	2.07	0.108	1.62	0.160	-0.218	+0.055
2G1	1.070	0.038	0.882	0.032	-0.176	-0.007
2G2	1.080	0.090	1.00	0.020	-0.074	-0.0753
2H1	2.12	0.031	1.87	0.020	-0.119	-0.0126
2H2	2.12	0.099	1.75	0.146	-0.175	+0.020
2I2	1.06	0.104	1.035	0.110	-0.024	+0.0064

Table 2

TEST CONDITIONS
(P = 1000 psi)

Test Point	$\bar{G}/10^6$ (lb/ft ² -h)	Power (kW)	Heat Flux (Btu/ft ² -h)	Subcooling (Btu/lb)	$\bar{X}_e$
1B	0.480	0	0	504.6	-
1C	0.990	0	0	504.6	-
1D	1.510	0	0	504.6	-
1E	1.97	0	0	504.6	-
2B2	0.530	532	225,000	149.6	0.029
2B3	0.535	532	225,000	108.7	0.090
2B4	0.535	532	225,000	52.8	0.176
2C1	1.060	532	225,000	57.2	0.042
2C2	1.068	532	225,000	35.1	0.075
2D1	0.540	1064	450,000	259.2	0.110
2D3	0.540	1064	450,000	124.4	0.318
2E1	1.080	1064	450,000	142.9	0.035
2E2	1.080	1064	450,000	96.7	0.106
2E3	1.060	1064	450,000	29.1	0.215
2F1	2.07	1064	450,000	59.6	0.040
2F2	2.07	1064	450,000	17.4	0.109
2G1	1.07	1064	450,000	142.2	0.038
2G2	1.080	1596	675,000	189.8	0.090
2H1	2.12	1560	660,000	102.6	0.031
2H2	2.12	1596	675,000	59.2	0.099
2I2	1.06	1880	800,000	227.5	0.104

7. PRESSURE DROP DATA

Both single-phase and two-phase pressure drop data are being accumulated and reduced. These data will be used to calculate the single-phase friction factor for the test geometry, and the two-phase multiplier (Φ^2_{LO}). Some of

the preliminary total static pressure drop (including density head) data are shown in Figures 8 and 9 for two values of the average mass velocity.

FIGURE 8. TOTAL STATIC PRESSURE DROP VERSUS HEATED LENGTH

FIGURE 9. TOTAL STATIC PRESSURE DROP VERSUS HEATED LENGTH

DISTRIBUTION LIST

Aerojet-General Corporation Nuclear Products and Services Group P. O. Box 77 San Ramon, California 94583 Attn: H. Jaffe	1	Dynatech Corporation 17 Tudor Street Cambridge, Massachusetts 02139 Attn: A. Bergles	1
Argonne National Laboratory Reactor Engineering Division 9700 South Cass Avenue Argonne, Illinois 60439 Attn: Dr. Paul Lottes	1	General Electric Company Research and Development Center P. O. Box 8 Schenectady, New York 12301 Attn: Fred Staub	1
Argonne National Laboratory Reactor Engineering Division 9700 South Cass Avenue Argonne, Illinois 60439 Attn: M. Petrick	1	Knolls Atomic Power Laboratory General Electric Company P. O. Box 1072 Schenectady, New York 12301 Attn: Document Librarian	1
Atomics International P. O. Box 309 Canoga Park, California 91305 Attn: L. Bernath	1	Geoscience Limited 410 South Cedros Solano Beach, California Attn: H. Poppendick	1
Babcock & Wilcox Company Atomic Energy Division P. O. Box 1260 Lynchburg, Virginia 24505 Attn: D. F. Judd	1	Massachusetts Institute of Technology Department of Mechanical Engineering Cambridge, Massachusetts 02139 Attn: Dr. W. Rohsenow	1
Brookhaven National Laboratory Chemical Engineering Division Upton, New York 11973 Attn: Dr. O. E. Dwyer	1	Massachusetts Institute of Technology Department of Mechanical Engineering Cambridge, Massachusetts 02139 Attn: Dr. P. Griffith	1
Columbia University Department of Chemical Engineering New York, New York 10027 Attn: J. Casterline	1	New York University Department of Mechanical Engineering University Heights New York, New York 10453 Attn: Dr. Novak Zuber	1
Combustion Engineering, Inc. Nuclear Division P. O. Box 500 Windsor, Connecticut 06095 Attn: Dr. P. Zmola	1	North Carolina State University Department of Chemical Engineering Raleigh, North Carolina 27607 Attn: Dr. J. K. Ferrell	1
E. I. du Pont de Nemours and Company Wilmington, Delaware 19898 Attn: J. S. Neill	1	Oak Ridge National Laboratory P. O. Box X Oak Ridge, Tennessee 37830 Attn: H. W. Hoffman	1

GEAP-10055

Pacific Northwest Laboratory P. O. Box 999 Richland, Washington 99352 Attn: J. Batch	1	A. Amorosi, Director LMFBR Program Office Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439	1
Rutgers, The State University College of Engineering New Brunswick, New Jersey 08903 Attn: Dr. R. L. Peskin	1	Atomic Energy of Canada Limited Chalk River, Ontario, Canada Attn: G. A. Wikhammer	1
Stanford University Department of Mechanical Engineering Stanford, California 94305 Attn: Dr. G. Leppert	1	U. S. Atomic Energy Commission Division of Reactor Development and Technology Washington, D. C. 20545 Attn: R. M. Scroggins	2
TRW, Inc. TRW Systems Group One Space Park Redondo Beach, California 90278 Attn: S. M. Zivi	1	U. S. Atomic Energy Commission Division of Reactor Development and Technology Washington, D. C. 20545 Attn: N. Todreas	1
University of Michigan Department of Chemical and Metallurgical Engineering Ann Arbor, Michigan 48103 Attn: R. Balzhiser	1	U. S. Atomic Energy Commission Division of Reactor Development and Technology Washington, D. C. 20545 Attn: Water Projects Branch	1
Westinghouse Electric Corporation Atomic Power Division Box 355 Pittsburgh, Pennsylvania 15230 Attn: L. S. Tong	2	U. S. Atomic Energy Commission Division of Reactor Development and Technology Washington, D. C. 20545 Attn: Research & Development Branch	1
Westinghouse Electric Corporation Bettis Atomic Power Laboratory P. O. Box 79 West Mifflin, Pennsylvania 15122 Attn: S. Green	1	U. S. Atomic Energy Commission Division of Safety Standards Washington, D. C. 20545 Attn: R. Impara	1
National Aeronautics & Space Admin. Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135 Attn: R. Weltmann (SEPO)	2	U. S. Atomic Energy Commission DTIE P. O. Box 62 Oak Ridge, Tennessee	3
National Aeronautics & Space Admin. Lewis Research Center 21000 Brookpark Road Cleveland, Ohio 44135 Attn: Librarian	3	Centre d'Etudes Nucleaires Chemin des Martyrs Grenoble (Isere) France Attn: M. Mondin	1

CISE Casella Postale 3986 Milano (Segrate) Italy Attn: Prof. M. Silvestri	1	Centre d'Etudes Nucleaires de Saclay B. P. no 2 Gif-sur-Yvette (S&O) France Attn: M. J. Horowitz	1
MAN Abhofach Nurnberg 2 Germany Attn: Dr. Mayinger	1	FIAT Sezione Energia Nucleare Via Settembrini 235 Torino Italy Attn: M. G. Cesoni	1
SNECMA Division Atomique 22, Quai Gallieni Suresnes (Seine) France Attn: M. Foure	1	Reactor Centrum Nederland 112 Scheveningseweg 's Gravenhage Netherlands Attn: Prof. Dr. M. Bogaardt	1
Technische Hogeschool Eindhoven P. O. Box 313 Eindhoven Netherlands Attn: Prof. Dr. M. Bogaardt	1	ANSALDO Direzione Generale Piazza Carignano 2 Genova Italy Attn: Dr. F. Cristofori	1
AEG-Kernenergieversuchsanlage 8752 Grosswelzheim (Unterfranken) Germany Attn: Dr. Kirchenmayer	1	EURATOM Direction Generale R&E 51, rue Belliard Bruxelles Belgium Attn: Dr. P. Kruys	2
CNEN Rome Via Belisario, 15 Italy Attn: M. Bianchi	1	EURATOM Casella Postale 1 Ispra (Varese) Italy Attn: M. R. Morin	1
Alsthom 38 avenue Kleber Paris 16e France Attn: M. P. Domenjoud	1		