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**RADIAL VANE
STEAM SEPARATOR DEVELOPMENT
TENTH QUARTERLY REPORT
PHASE II
OCTOBER-DECEMBER**

R.H. MOEN
J.E. GIFFORD

U.S. ATOMIC ENERGY COMMISSION
CONTRACT AT(04-3)-189
PROJECT AGREEMENT 42

ATOMIC POWER EQUIPMENT DEPARTMENT

GENERAL ELECTRIC

SAN JOSE, CALIFORNIA

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RADIAL VANE STEAM SEPARATOR DEVELOPMENT

Tenth Quarterly Report
Phase II
October - December 1967

R. H. Moen

J. E. Gifford

Prepared for the
U. S. Atomic Energy Commission
Contract AT(04-3)-189
Project Agreement 42

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TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	v
1.0 SUMMARY	-1-
2.0 PRINCIPAL INVESTIGATORS AND REPORTS ISSUED	-1-
2.1 Principal Investigators	-1-
2.2 Reports Issued	-1-
2.3 Background Report	-1-
3.0 STATEMENT OF PROBLEM	-2-
3.1 Task 1 - Larger Model Separator Test	-2-
3.2 Task 2 - Reactor Separator and Dryer Design	-2-
3.3 Task 3 - Test Program Planning	-2-
3.4 Task 4 - Instrumentation Design	-3-
3.5 Task 5 - Model Vibration Tests	-3-
4.0 DESCRIPTION OF THE RADIAL VANE STEAM SEPARATOR, TEST EQUIPMENT, AND TEST FACILITIES	-3-
4.1 Nomenclature and Description	-3-
4.2 Test Equipment and Test Facilities	-5-
4.2.1 Test Equipment	-5-
4.2.2 Test Facilities	-8-
5.0 ACCOMPLISHMENTS DURING THE REPORT PERIOD	-10-
5.1 Task 1 - Larger Model Separator Test	-10-
5.2 Task 2 - Reactor Separator and Dryer Design	-10-
5.2.1 Plenum Deflector Tests	-17-
5.2.2 Reactor Separator Cost Estimates	-24-
5.3 Task 3 - Test Program Planning	-28-
5.4 Task 4 - Instrumentation Design	-28-
5.5 Task 5 - Model Vibration Tests	-28-
6.0 FUTURE WORK	-33-
APPENDIX A - REPORT ON TRIP TO EUROPE TO DISCUSS PHASES II AND III OF THE RADIAL VANE STEAM SEPARATOR DEVELOPMENT PROGRAM	-34-
DISTRIBUTION LIST	-42-
	-44-
	-51-

LIST OF ILLUSTRATIONS

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1	Sketch of the Full-Circle Radial Vane Separator, FCRV-2	-4-
2	Sketch of the Flows in the Separator	-6-
3	FCRV-4 Plenum Deflectors	-11-
4	Radial Vane Steam Separator for KRB - New Design	-15-

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
I	Some Model Separator Design Data	-7-
II	Some Design Numbers for the Steam-Water Test Facilities	-9-
III	FCRV-4 Plenum Deflector Test Data	-12-

FOREWORD

The United States and the European Atomic Energy Community (Euratom), on May 29, and June 18, 1958, signed an agreement which provides a basis for co-operation in programs for the advancement of the peaceful applications of atomic energy. This agreement, in part, provides for the establishment of a Joint U.S. - Euratom research and development program which is aimed at reactors to be constructed in Europe under the Joint Program.

The work described in this report represents the Joint U.S. - Euratom effort which is in keeping with the spirit of co-operation in contributing to the common good by the sharing of scientific and technical information and minimizing the duplication of effort by the limited pool of technical talent available in Western Europe and the United States.

1.0 SUMMARY

Air-water tests of FCRV-4 conducted for the purpose of determining the effect of plenum deflector design on performance and a trip to Europe to discuss the current status of the development program constituted the major accomplishments during the report period. Contract problems have delayed the program, so an alternate reduced program has been proposed while a solution to the problems is sought.

EURAEC
Number

GEAP
Number

Title

1533

4967

Radial Vane Steam Separator Development, Fifth Quarterly Report, July-September 1965

1585

4935

Radial Vane Steam Separator Development - Experimental Study of Carryunder Sources in a Radial Vane Separator, A. A. Kudirka and J. E. Gifford

2.0 PRINCIPAL INVESTAGATORS AND REPORTS ISSUED

1598

5084

Radial Vane Steam Separator Development, Sixth Quarterly Report, October-December 1965

2.1 PRINCIPAL INVESTAGATORS

R. H. Moen Project Engineer
E. Kiss Vibration Analysis and Testing
A. A. Kudirka Analysis and Task 1 Testing
J. E. Gifford Test Engineer

1656

5149

Radial Vane Steam Separator Development, Seventh Quarterly Report, January-March 1966

2.2 REPORTS ISSUED

1854

5283

Radial Vane Steam Separator Development, Final Report - Phase I, January 1967

EURAEC
Number

GEAP
Number

Title

1253

4728

Radial Vane Steam Separator Development, First Quarterly Report, June-September 1964

1931

5524

Radial Vane Steam Separator Development, Eighth Quarterly Report - Phase II, November 1966 - June 1967.

1301

4783

Radial Vane Steam Separator Development, Second Quarterly Report, October-December 1964

-

5567

Radial Vane Steam Separator Development, Ninth Quarterly Report - Phase II, July - September 1967

1365

4847

Radial Vane Steam Separator Development, Third Quarterly Report, January-March 1965

1450

4914

Radial Vane Steam Separator Development, Fourth Quarterly Report, April-June 1965

2.3 BACKGROUND REPORT

GEAP-4272, "Nuclear Superheat Project, Internal Steam Separation, Development of Radial Vane Steam Separators, "R. H. Moen, May 31, 1963.

3.0 STATEMENT OF PROBLEM

The basic purpose of the Phase II portion of the Radial Vane Steam Separator Development Program, with which this report is concerned, is to design a radial vane steam separator and related equipment for test in a boiling water reactor. Present planning is to design for test in the KRB reactor built for Rheinisch-Westfaelisches Elektrizitätswerk (RWE) and Bayernwerk (BAG) at Gundremmingen, West Germany by the General Electric Company and the German electrical equipment manufacturing firm, Allgemeine Elektrizitäts-Gesellschaft (AEG). A Phase III program has been proposed for the purpose of constructing the radial vane separator and related equipment and testing this in the KRB reactor. AEG has agreed to work on Phase III with General Electric. The Phase II program includes the design mentioned above, testing of model full-circle radial vane separators in the new Large Steam-Water Test Facility of the General Electric Company, planning of the test program, test instrumentation design, and model tests to determine design data to aid in designing the reactor separator to have no vibration problems. This program is discussed in more detail in subsections 3.1 through 3.5.

The design will utilize the data and experience obtained during the Phase I program which was directed toward the development of the radial vane separator concept. Phase I work was reported in the first seven quarterly reports, a topical report, and a final report (see subsection 2.2 for list of reports). The Phase I development work was preceded by development work carried out under the Nuclear Superheat Program (Project Agreement 13 of the same contract which covers this Phase II program). The final report of this earlier work is listed in subsection 2.3.

3.1 TASK 1 - LARGER MODEL SEPARATOR TEST

Full-circle model radial vane steam separator tests at reactor conditions will be carried out for the purpose of demonstrating performance in a larger scale than has been possible in the past. Various nozzle and vane configurations will be tested with flow from all nozzles and vanes. These tests will give scale-up information to verify the reactor separator design. The tests will be performed utilizing three radial vane separators identified as RVSM-1, -2, and -3, and described in subsection 4.2.1. The test will be carried out in the newly expanded Large Steam-Water Test Facility of the General Electric Company. A wide range of inlet qualities will be tested, and the normal performance indicators (carryunder, carryover, and pressure drop) will be measured.

3.2 TASK 2 - REACTOR SEPARATOR AND DRYER DESIGN

Detailed hydraulic and mechanical design of the separator and dryer system required to meet the existing design and operating requirements of the KRB reactor will be carried out. All necessary safety and operating aspects will be considered during this effort. Plans will be prepared for procurement of the separator and related equipment.

3.3 TASK 3 - TEST PROGRAM PLANNING

A test program will be set up in advance which will best demonstrate the performance of the radial vane steam separator and prove the feasibility of operation of a radial vane steam separator in an operating boiling water reactor. Further, the test program will be designed so that the performance of the separator may be compared with the other

types of steam separators if data are available. This Task will include maintaining contact with the German firm (AEG), which will work with General Electric and the reactor owners and operators (KRB, RWE, and Bayernwerk) for the purpose of coordinating work on the development program.

3.4 TASK 4 - INSTRUMENTATION DESIGN

Design and specify the instrumentation required to measure the performance of the radial vane steam separator to accomplish the needs of the test program. As a minimum, the tests will measure nozzle pressure differential, separator vibration, water level in the lower vortex, carryover from the dryers, and carryunder from the separators.

3.5 TASK 5 - MODEL VIBRATION TESTS

Carry out model tests in the Large Air-Water Test Facility of the General Electric Company to aid in the proper design of the reactor separator. Vibration tests will be performed utilizing FCRV-4 and a new radial vane separator model in the air-water facility to analyze vibration problems which may be encountered during the KRB test. The new model separator design will be based on findings from Task 5 tests of FCRV-4 and a new mechanical design for the KRB separator developed from Task 2.

4.0 DESCRIPTION OF THE RADIAL VANE STEAM SEPARATOR, TEST EQUIPMENT, AND TEST FACILITIES

A description of the radial vane steam separator and the principle of operation are given in this section. This description uses much of the nomenclature of the program. In addition, some of the test equipment and test facilities which are likely to be mentioned in these reports are described. The purpose is to allow one to familiarize one's self with the nomenclature used without reviewing all the preceding reports.

4.1 NOMENCLATURE AND DESCRIPTION

On Figure 1 is shown a sketch of a model radial vane separator called FCRV-2 (FCRV stands for Full-Circle, Radial Vane) which was built under the Nuclear Superheat Program and modified under the United States-Euratom Program (Phase I). The nomenclature associated with the radial vane separator will be discussed using this figure and Figure 2 which represents an idealized sketch of a section through the separator axis and the water flow on the wall (wall flow). The steam-water mixture (black arrow for water, white arrow for steam) entering the steam separator plenum at the bottom is shown in Figure 1. The diameter of this plenum is quite small in this model, but is larger in other models, and very large in reactors. In the region of the nozzles, through which the flow of the steam-water mixture is directed onto the concave surfaces of the vanes, are located plenum deflectors or flow guides to change the mixture flow from axially upward to radially outward. These plenum deflectors are not necessary in all cases. On the vanes the water flows on the concave surface while the steam moves away from the water due to the effect of the centrifugal force resulting from flow on the curved surface of the vane. The separated steam flows between the water surface and the next vane, and the water tends to drag the steam along as it flows along the vane. The steam flows radially and turns upward, some between the vanes and some outside the outer edge of the vanes. This steam tends to carry water droplets with it under some conditions, and these water droplets are referred to as carryover.* Once the water leaves the nozzle, it is accelerated downward under the influence of gravity. The water flowing off the vanes forms the vane jets which flow onto the wall cylinder or cylindrical vessel

* Carryover is reported as weight percent moisture in the separated steam flow.

FIGURE 1. SKETCH OF THE FULL-CIRCLE RADIAL VANE SEPARATOR, FCRV-2

wall liner and form a rotating water layer (see Figure 2). The rotating water flow on the wall, called the upper vortex, increases in thickness as the distance below the top of the nozzles increases because of the input of water from the vane jets. Below the nozzle region the thickness of the upper vortex decreases because no more water is put in and the downward velocity is increasing because of the acceleration of gravity. The tangential component of velocity established when the vane jet hits the wall cylinder remains nearly constant in the upper vortex, thus maintaining a centrifugal field which causes separation of steam or air which has been unseparated in the vane flow or re-entrained when the vane jets hit the upper vortex surface. The falling upper vortex flows into the reactor water reservoir below the vanes. This water reservoir, called the lower vortex, rotates because of the rotation of the upper vortex when the two meet; however, it rotates at a lower tangential velocity. After the upper vortex enters the lower vortex, it forms a rotating, annular, expanding jet. The area between the annular jet and the steam separator plenum forms a rotating eddy. The centrifugal field caused by the rotating flow in the lower vortex tends to move the carry-under** bubbles (these are steam or air bubbles carried into the water regions) radially inward where they are moved upward toward the surface of the lower vortex by the eddy. At the surface of the lower vortex, separation of the carryunder steam occurs and this steam joins the main steam flow and flows out the top of the separator. The water continues downward to the downcomer for recirculation.

4.2 TEST EQUIPMENT AND TEST FACILITIES

The Phase I development program was carried out with the aid of several pieces of test equipment which were tested in different

** Carryunder is reported as weight percent steam in the separated water flow.

test facilities. Since several of these test units or facilities will probably be referred to in this and subsequent reports, a brief description of them is given in this section.

4.2.1 Test Equipment

Three model full-circle radial vane separators and two 2-vane test units used in Phase I development work will be described along with two full-circle units and one partial-circle unit to be tested in Phase II. These last-mentioned units are referred to as Radial Vane Separator Modules, RVSM, which are described in subsection 5.1. Drawings of the Phase I units may be found in the Phase I Final Report, Volume II (see subsection 2.2). Drawings of the Phase II units may be found in Appendix A of the Eighth Quarterly Report (see subsection 2.2).

a. Three Model Full-Circle Radial Vane Separators for Phase I

The three model full-circle radial vane separators are designated FCRV-2, -3, and -4. Each has vanes with a 4-inch radius and an arc length of about 130 degrees. The nozzle directs flow onto the vane in the same manner in all units. FCRV-2, built originally for the Nuclear Superheat Program, consists of a plenum having a 10-1/4-inch inside diameter; eighteen 18-inch by 1/4-inch nozzles, thirty-six 42-inch vanes with a nominal 1-inch spacing between the vanes having nozzles and a greater spacing between the vanes not having nozzles, and a wall cylinder having an inside diameter of 28 inches. The vanes and nozzles were arranged symmetrically about the plenum wall. It operates with six 18-inch or eighteen 6-inch nozzles because of the limitations of the Small Air-Water Test Facility or the Small Steam-Water Test Facility in which it was built to be tested.

The FCRV-3, built for the primary purpose of having all vanes active which FCRV-2 does not have, consists of a plenum

FIGURE 2. SKETCH OF THE FLOWS IN THE SEPARATOR

having an inside diameter of 10-1/4 inches in the vane and nozzle region and an inside diameter of 15-1/4 inches below the nozzle region, forty-eight 30-inch by 1/4-inch nozzles, forty-eight 36-inch vanes with a nominal 1-inch spacing, and with wall cylinders having inside diameters of 36 inches and 42 inches. It was built for testing with air-water mixtures only in the Large Air-Water Test Facility.

plenum having an inside diameter of 42 inches, seventy-two 30-inch by 1/4-inch nozzles (there are actually 144 nozzles, but a minimum of 72 are completely plugged), one-hundred forty-four 36-inch vanes with a nominal 1-inch spacing between all vanes whether or not a nozzle is between the vanes, and wall cylinders having inside diameters of 68 inches and 73 inches. It is designed for testing in the Large Air-Water Test Facility.

The FCRV-4, built for the primary purpose of measuring the effect of wall cylinder diameter on separation of entrained carryunder in the wall flow, consists of a

Some comparative design data for the FCRV-2, FCRV-3, and FCRV-4 are shown in Table I.

TABLE I
SOME MODEL SEPARATOR DESIGN DATA

Item	RVSM-1	RVSM-2	RVSM-3	FCRV-2	FCRV-3	FCRV-4
Number of Nozzles*	34	9	9	18	48	72
Nozzle Width (inch)	1/4	1/4	1/4	1/4	1/4	1/4
Nozzle Length (inch)	3/4	3/4	3/4	3/4	3/4	3/4
Nozzle Height* (inches)	10.5	40	40	18	30	30
Number of Vanes	34	18	10	36	48	144
Vane Radius (inches)	4	4	4	4	4	4
Vane Height (inches)	22.5	52	52	42	36	36
Vane Arc (degrees)	130	130	130	130	130	130
Nominal Vane Spacing (inches)	1-1/2	1-1/2	1-1/2	1	1	1
Plenum Diameter (inches)	11	11	11	10-1/4	15-1/4 below vanes 10-1/4 in vane region	42
Wall Cylinder Diameter (inches)	36 and 41	36 and 41	36	28	36 and 42	68 and 72

*The nozzle height and number of active nozzles may be changed by plugging off the unwanted portions.

b. Two 2-Vane Tests Units for Phase I

Two-vane test units were built to study the operation of the vane-nozzle combinations in more detail. The Two-Vane Test Unit was built for the purpose of studying the effect of

vertical steam velocity between the vanes, the effect of nozzle length, and the effect of vane spacing on separation performance. The design of this unit assures that all or nearly all of the steam must flow upward between the vanes, and therefore will allow determination

of limiting flows for a nozzle-and-vane pair of the radial vane steam separator. Plenum baffles were also included in the design to study the effect of plenum velocity on the limiting flow rates. The unit was built for testing in the Small Steam-Water Test Facility. Nozzle lengths of 18, 30, 42, and 54 inches and vane spacings of nominally 1, 1-1/16, 1-1/4, 1-1/2, 2, and 3 inches may be tested. The plenum velocity may be adjusted for any nozzle-vane combination by using appropriate plenum baffles. All the steam must flow from the top of the vane pair into a duct attached to the top of the vanes. The carryover performance of the two-vane unit is measured by taking moisture samples in the steam duct.

The Clear Plastic Two-Vane Test Unit was designed for visual and photographic studies of flow on a radial vane to study separation of air from water on the vane. The unit consists of a clear plastic vane of 4-inch radius and 130-degree-arc length, and a 4.5- x 4.5-inch-square plenum containing an 18-inch-high by 1/4-inch-wide nozzle. The Small Air-Water Test Facility was used for the tests of this unit.

c. Radial Vane Separator Modules

Three radial-vane separator modules have been built using nozzle and vane geometries similar to the proposed design for KRB reactor. These units, referred to as RVSM-1, -2, and -3, were built for the purpose of determining performance of this design at reactor conditions in the Large Steam-Water Test Facility. These units are referred to as modules since the discharge from the lower vortex is into a pool of water and these units could be used as one of several radial vane separator modules for steam separation in a reactor. This discharge arrangement also simulates the KRB discharge geometry. There is no plan at the present time to use more than a single radial vane separator

for steam separation in a reactor and KRB will have a single unit.

d. Description of Radial Vane Separator Modules

The RVSM-1 was designed to study the operation of a full circle of active vanes with nominal 1-1/2-inch spacing between them. The capacity of the Large Steam-Water Test Facility limits the height of the 34 nozzles in RVSM-1 to 10.5 inches. The nozzles are 1/4-inch wide and they operate from an 11-inch-diameter plenum.

The RVSM-2 was built to investigate the operation of 40-inch-high nozzles in a radial vane separator. Due to the capacity limitations of the steam-water test facility, nine symmetrically spaced 1/4-inch-wide nozzles with a vane on each side were used. The spacing between active vanes is nominally 1-1/2 inches, and the space between the inactive vanes is covered to improve the simulation of steam escape velocities. The inlet plenum of the RVSM-2 is 11 inches in diameter.

The RVSM-3 was designed to study the operation of 40-inch-high nozzles with their vanes spaced nominally 1-1/2 inches apart. Nine nozzles with ten vanes spaced in a 90-degree sector of the 11-inch separator plenum are used. The design also provides for baffling the steam flow from this separator through a 90-degree sector to simulate steam exit velocities that would exist in a full-circle separator with these nozzles and vanes. More detailed design data for the RVSM units are presented in Table I and in Appendix A of the Eighth Quarterly Report (see subsection 2.2).

4.2.2 Test Facilities

The Air-Water and Steam-Water Test Facilities built and financed by the General

Electric Company and the modification to the Large Air-Water Test Facility carried out as part of the Phase I program have been used for radial vane steam separator development. The most important test facilities are the Steam-Water Test Facilities located at the Moss Landing, California, Power Plant of the Pacific Gas and Electric Company; the most-used test facilities are the Air-Water Test Facilities of the General Electric Company located at San Jose, California. These facilities are used most because they are much less expensive to operate than the Steam-Water Test Facilities, much more convenient, and the performance of the equipment can be observed visually and recorded photographically.

a. Steam-Water Test Facilities

The Small and Large Steam-Water Test Facilities are basically the same when used

for testing steam separators; i.e., they consist of a pressure vessel, a water recirculation pump, a water supply, a steam supply, and a common instrumentation system. This instrumentation system is used for sampling and measuring carryover, measuring carry-under, flow rates, pressures, and pressure drops. Normal operating pressure is 1000 psig, saturated. The Large Steam-Water Test Facility began operation in June 1967. On Table II is a comparison of some of the important design numbers for the two test facilities. The small facility was used for steam-water tests at reactor conditions of FCRV-2 and the Two-Vane Test Unit. The large facility will be used for the radial vane separator modules tested during Phase II.

b. Air-Water Test Facilities

The Small Air-Water Test Facility is a mock-up of the Small Steam-Water Test

TABLE II

SOME DESIGN NUMBERS FOR THE STEAM-WATER TEST FACILITIES

<u>Item</u>	<u>Small Facility</u>	<u>Large Facility</u>
Pressure Vessel		
Inside Diameter (inches)	36	42
Inside Length on Axis (feet)	17	34
Recirculation Pump		
Hot Water Flow (gpm)	1,700	4,500
Head, (lb _f -ft/lb)	150	820
Steam Flow (lb/h)	60,000	200,000

Facility. It is operated at ambient temperature and atmospheric pressure at about the same volumetric flow rates as the small steam-water facility. This facility was used for air-water tests of FCRV-2 and various two-vane

test units. The Large Air-Water Test Facility is similar to the small facility, but has water flows of 10,000 gpm and corresponding air flows. This facility was modified using USAEC funds for the purpose of testing FCRV-3 and

FCRV-4. Drawings of this loop are presented in Volume II of the Phase I Final Report (see subsection 2. 2).

5.0 ACCOMPLISHMENTS DURING THE REPORT PERIOD

Air-water tests of FCRV-4 conducted for the purpose of determining the effect of plenum deflector design on performance and a trip to Europe to discuss the current status of the development program constituted the major accomplishments during the report period.

5.1 TASK 1 - LARGER MODEL SEPARATOR TEST

No progress was made on this task during the report period.

5.2 TASK 2 - REACTOR SEPARATOR AND DRYER DESIGN

5.2.1 Plenum Deflector Tests

Air-water tests of the FCRV-4 were conducted to determine the need for a turning deflector at the top of the plenum. The cost of the curved plenum deflector for KRB is quite high, perhaps \$15,000 if purchased from an American vendor. The tests, which are discussed below, showed that the deflector is not needed. Test results showed that:

- a.) carryover and vane jet spread are about the same for the curved plenum deflector and the flat plate (no deflector),
- b.) pressure drop is slightly less for the flat plate,
- c.) excessively high vane jet spread and carryover result from use of a straight cone-shaped deflector, and
- d.) there is no detectable difference in carryunder for any of the three deflector geometries.

5.2.1.1 Test Equipment and Procedure

The FCRV-4 with seventy-two 6-inch nozzles and a 72-inch-diameter wall cylinder

was used to test three plenum deflectors. The deflectors, shown on Figure 3, are curve shaped, straight cone shaped, and a flat plate. Separator performance for each type of plenum deflector was determined by measurements of the air and water flow rates, carryunder, plenum pressure, lower vortex level, and height of the upper vortex. A qualitative estimate of carryover was determined by visual observations. Wall water layer thickness, velocity, and angle of flow are measured with a velocity probe connected to manometers. The velocity probe was located approximately 6 inches below the bottom of the nozzles.

Each plenum deflector was tested at inlet qualities of approximately 6 and 14 percent at the maximum flow obtainable from the loop equipment. The curve-shaped deflector, which was used for all previous FCRV-4 tests, was tested first to establish base data.

5.2.1.2 Discussion of Test Data

Test data are shown on Table III except for carryunder, which was zero for each test, and carryover, which is discussed below.

The data are arranged so the separator performance for each deflector may be compared at each flow rate. As shown, the plenum pressure drop is slightly lower for the flat plate. The plenum pressure tap in the plenum wall located approximately 6 inches below the level of the vane bottoms was used for the comparisons.

Carryover is high for the flow rates of Run No. 1, regardless of the type of plenum deflector used. This is caused by vane jet spread hitting the vane support at the top outer edge of the vanes. This support is located only 3 inches above the top of the nozzles in the FCRV-4. This would not be a problem in reactor operation because the support would be located well above the spread of the vane jet. The level of the

FIGURE 3. FCRV PLENUM DEFLECTORS

TABLE III

FCRV-4 PLENUM DEFLECTOR TEST DATADecember 1967

Item	Run No. 1			Run No. 2		
	Curve	Cone	Flat	Curve	Cone	Flat
Type of plenum deflector used						
Total volumetric flow rate (10^3 ft ³ /h)	125.4	133.9	133.2	154.9	167.6	164.4
Volumetric flow rate of water (10^3 ft ³ /h)	54.9	54.6	55.4	34.1	35.6	35.6
Equivalent inlet quality ⁽¹⁾ (weight-percent steam)	6.0	6.8	6.6	14.1	15.6	15.3
Plenum differential pressure ⁽²⁾	9.2	8.8	8.5	5.4	5.4	4.9
Plenum head loss (feet of mixture)	48.5	49.7	47.1	53.2	58.5	51.9
Plenum velocity (ft/sec)	3.6	3.9	3.8	4.5	4.8	4.7
Nozzle velocity (ft/sec)	46.4	49.6	49.3	57.3	62.1	60.9
Lower vortex level at radius = 32.5 inches (inches below bottom of vanes)	30	44	23	37	43	33
Vertical position of velocity probe (inches below nozzle bottoms)	5.4	5.4	5.4	5.4	5.4	5.4
Horizontal position of velocity probe (inches from wall cylinder inside diameter)	0.60	0.65	0.65	0.40	0.35	0.45
Wall water layer thickness (inches)	1.2	1.3	1.3	0.80	0.70	0.90
Angle of flow on the wall (degrees from horizontal)	21	22	22	21.5	25	22
Axial velocity of water on wall (ft/sec)	6.5	6.1	6.7	5.6	5.6	5.3
Tangential velocity of water on wall (ft/sec)	16.9	15.1	16.5	14.1	12.1	13.1
Level of upper vortex above top of vanes (inches)	7.8	11.8	6.0	0.8	4.3	1.0

(1) Assumes homogeneous flow.

(2) Measured at the plenum wall 6 inches below level of vane bottoms.

GEAP-5597

upper vortex indicates that vane jet spread is about the same for the curved deflector and the flat plate, but is higher for the cone deflector. This occurs in both runs.

For Run No. 2, carryover is acceptable when using the curved deflector or flat plate, but is excessive when using the cone deflector. During Run No. 2, carryover from the cone deflector was in excess to the extent of almost obscuring measurement of the level of the upper vortex.

Measurements from the velocity probe, i. e., wall water layer thickness, velocity, and angle of flow, show very little difference in performance for the three deflectors. The small differences shown are not detectable with the velocity probe when used with manometers. This means that the carryover observation and measurement of the upper vortex level (an indication of spread) must be relied upon as indicators of difference in separator performance.

5.2.1.3 Conclusion

The use of a flat-top plenum, i. e., no plenum deflector, is justified and advantage can be taken of the cost saving due to not having to buy a shaped deflector.

5.2.2 Reactor Separator Cost Estimates

Estimated construction costs for the radial vane separator were received from one West German and one Dutch manufacturer following a request by AEG. Another bid was received from the same Dutch firm through an American agent in San Jose. These estimates are for about \$30,000, including transportation and assembly. This is about one-fourth the cost of the equipment plus transportation from the American vendor. The Dutch manufacturing firm is the one which assembled the original KRB dryer and separator. This

firm has the templates from which the guide ring and hold-down lugs were made. The use of these templates in the manufacture of the radial vane separator is necessary if the separator installation time in the KRB reactor is to be kept low whether the original KRB design is to be used or the larger diameter separator requested by KRB. This installation time must be minimized because of the large downtime charges for a power reactor.

5.3 TEST PROGRAM PLANNING

In Appendix A is presented the trip report covering the December 1967 trip to Europe to discuss the development program. The primary findings of this trip were that KRB will allow the test only if the separator can be designed so that refueling can be carried out without removing the separator, but only with removing the top cover. RWE and Bayernwerk, who have agreed conditionally to the test and have agreed to furnish up to 28 days of downtime for the test, will not proceed without unlimited guarantees against losses due to downtime beyond 28 days and against losses due to damages to the plant. Currently the program is stalled while awaiting resolution of this problem by Euratom or others. An extension of the development program contract has been requested after consultation with the USAEC to look for resolution of the guarantee problem and to design a separator to meet the needs of KRB.

New design numbers for the radial vane steam separator for KRB were calculated to determine the possibility of meeting the new KRB design requirements. It was assumed that a new dryer shroud would be built. The design numbers showed that a separator could be built to meet the KRB requirements if the vane-to-wall clearance could be set at about 1 inch greater than the maximum calculated upper vortex thickness. An additional

problem which arises is the presence of core spray pipes and feedwater spargers in the lower vortex region. Test data have not been obtained at corresponding conditions. The new design has a separator plenum inside diameter of 114-1/2 inches compared to 68 inches for the current design. Nozzle length would be 30 inches. It is proposed that two banks of about one dozen 42-inch nozzles be included to demonstrate performance of 42-inch nozzles. In this case, there would be twenty-four 42-inch nozzles and two hundred two 25-inch nozzles with about 1-1/2-inch vane spacing. This compares with one hundred forty-four 42-inch nozzles with 1-1/2-inch vane spacing in the current design. A sketch of this is shown on Figure 4.

5.4 TASK 4 - INSTRUMENTATION DESIGN

No progress was made on this task during the report period.

5.5 TASK 5 - MODEL VIBRATION TESTS

No progress was made on this task during the report period.

6.0 FUTURE WORK

The development program has been stalled because KRB is only interested in the test if a new separator geometry is provided, and RWE and Bayernwerk will only agree to the test if full responsibility for downtime and damages is assumed by someone else. Until such time as these problems are resolved, the development program has been delayed and the following program proposed. Extend the current contract date from December 31, 1967, to June 30, 1968, with no additional funding. If the downtime problem can be solved, then the program would be restarted in June 1968, and Phase II completed. A new proposal for Phase III would be submitted with the work to start about October 1968. The over-all objective would be to complete Phase III during calendar year 1969. The exact timing of the Phase III program can only be set once the KRB refueling schedule is firmed up. As requested by KRB, an analysis will be made of a separator which will allow refueling without removing the separator during the next quarter.

FIGURE 4. RADIAL VANE STEAM SEPARATOR FOR KRB - NEW DESIGN

APPENDIX A

REPORT ON TRIP TO EUROPE TO DISCUSS PHASES III AND III
OF THE RADIAL VANE STEAM SEPARATOR DEVELOPMENT PROGRAM

The following is a copy of the trip report submitted to the USAEC.

January 10, 1968

H. B. Fry, Director (9)
Contracts Division
U.S. Atomic Energy Commission
San Francisco Operations Office
2111 Bancroft Way
Berkeley, California

SUBJECT: REPORT ON TRIP OF R. H. MOEN TO EUROPE TO DISCUSS PHASES II AND III
OF P. A. 42 — CONTRACT NUMBER AT(04-3)-189

This letter is a report of a trip to West Germany and Belgium by R. H. Moen of the Atomic Power Equipment Department of the General Electric Company made in connection with the proposal for a Phase III program of Project Agreement 42 of Contract Number AT(04-3)-189. The primary purposes of the trip were: (1) to discuss the progress and future of P.A. 42 with Euratom, (2) to discuss the progress and future of the P.A. 42 and to discuss the technical aspects of cooperation in carrying out the Phase III tests and other problems related to Phase III with AEG, the German firm cooperating with General Electric on this project, and (3) to discuss the technical problems of the Phase III testing and the conditions under which these tests will be permitted with KRB, RWE, and Bayernwerk. Attachment A shows a summary of the places, dates, purposes, results, and attendees of the various discussions along with their affiliation.

Of the purposes of the trip listed above, the most important was the meeting with the owners and operators of KRB. Two major conclusions were reached at the meeting with these people. The first is that KRB will consider allowing the test only under the condition that KRB derives some immediate benefit from the test and the immediate benefit desired is that the radial vane separator to be used in the test be designed in such a manner that the main body of the separator need not be removed for refueling. The second is that RWE, which favors the test to the extent of allowing 28 days of downtime for this test, will not proceed unless someone other than RWE, KRB, and Bayernwerk assumes unlimited liability against the losses due to downtime and damages. Another significant conclusion comes from the meeting with Euratom and this is that Euratom favors the program and has found funds to support the German work and travel and living expenses for an AEG man to work on the project in San Jose, but at the time of the trip had not yet received approval from the Euratom Council. AEG exhibited still considerable interest in the Phase III tests and one measure of this is the number of personnel who participated in the meetings.

With regard to the desires of KRB for a separator which cannot be removed for refueling, it was proposed that the writer return to San Jose and do the design work necessary to establish whether or not such a separator would be possible for KRB. It was stated at the meeting by the writer that designing this separator would require removing all design margins from the vane-to-wall clearance and reducing the probability of success of the experiment due to this reason and due also to the presence of core spray and feedwater sparger pipes in the lower vortex region. It was also proposed that following the analysis to see if the separator could be built that discussions would be held at the USAEC to determine whether or not the contract would be extended in view of the problems of designing a new separator and the problem of obtaining some guarantor of the type required by RWE. Euratom and the German Government are possible guarantors, but the probability of funds being budgeted for this purpose is small.

Concerning the status of work in the field of interest, the following may be said. AEG has developed a steam separator for use in reactor plants offered by them, e.g., the Lingen plant will use an earlier form of the separators and Wuergassen plant is expected to use a more advanced model of the separator. They have also carried out a dryer development program. They have very competent technical people assigned to this development. Their laboratory facilities are currently being expanded to increase the capability of testing from that with

H. B. Fry

January 10, 1968

air-water mixtures to that with steam-water mixtures at high pressures. These facilities while not as large as those available in the United States and particularly at General Electric are quite substantial. Consequently, AEG has the ability of making a great technical contribution to further development work and testing and they have shown considerable interest in the project.

The above (including Attachment A), adequately covers the requirements of Section 3 of the "Conditions for Approval of Foreign Travel" as requested by you in your letter dated September 29, 1967 to D. Eldred in which authorization for this trip was received. The requirements of Section 5 have been met by reporting a breakdown of expenditures in foreign countries in the SAN 68 report for December 1967. Should you desire more information please contact me.

Sincerely,

(original signed by R.H. Moen)

R.H. Moen, Principal Development Engineer
Mechanical & Equipment Development
M/C 521

RHM:vjf

cc. A. Colling) Euratom
P. Kruys
R. Stella USAEC-Brussels

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ATTACHMENT A

<u>DATE</u>	<u>PLACE</u>	<u>PURPOSE AND RESULTS</u>	<u>ATTENDEES</u>	<u>AFFILIATION</u>
Dec. 2	Brussels, Belgium	<p>To discuss current status and future course of Phases II and III of P. A. 42 and to review plans for discussions with AEG, KRB, RWE, and Bayernwerk.</p> <p>Discussions were carried out as planned. Euratom favors carrying on P. A. 42, probably has funds to carry out European part of Phase III and pay travel and living expenses for an AEG man at APED, and has no funds to guarantee downtime or damages. There is a small probability that guarantee funds could become available in the 1968-72 budget or as a result of discussions with the West German Government. Euratom offered helpful comments on plans for discussions in West Germany. Colling of Euratom and Stella of the USAEC Mission at Brussels joined me at the meetings in Germany.</p>	<p>Kruys Colling Stella Moen</p>	<p>Euratom Euratom USAEC APED</p>
Dec. 4	Frankfurt, West Germany	<p>To discuss current status and future course of Phases II and III and to plan for discussions with KRB, RWE, and Bayernwerk. To discuss in detail the pre-installation, installation, and removal of the KRB separator to be sure that existing design for the separator and plan for using it are satisfactory. To discuss other technical questions concerning Phase III.</p> <p>Discussions were carried out as planned. The separator design and plan for use were found to be adequate and arrangements were made to discuss these with KRB people. A review of the division of work between AEG and GE was carried out. Answers to all technical questions raised were resolved.</p>	<p>Colling Stella Voigt Vollradt Jahn Scholz</p>	<p>Euratom USAEC AEG AEG AEG AEG</p>

<u>DATE</u>	<u>PLACE</u>	<u>PURPOSE AND RESULTS</u>	<u>ATTENDEES</u>	<u>AFFILIATION</u>
Dec. 5	Gundremmingen, West Germany	<p>To discuss in detail the pre-installation, installation, and removal of the radial vane separator.</p> <p>The discussions were carried out with Stahl of KRB. The current design of the radial vane separator and plans for the use of it in KRB were found to be adequate and facilities and storage areas for carrying out the work were found to be available. It was found that two-shift operation would be required to accomplish the installation and removal in a reasonable length of time.</p>	Colling Defosses Stella Stahl Turner Moen	Euratom Euratom USAEC KRB APED APED
Dec. 6	Gundremmingen, West Germany	<p>To review the program and discuss conditions under which the Phase III testing can be carried out, schedule for testing, the incentives for KRB and the use of the KRB dryer.</p> <p>The program and schedule were reviewed briefly in addition to the incentives for KRB and future power plants. The need for the use of the KRB dryer was stated as was the lack of guarantees for downtime. Knoerzer said that KRB would consider the test program only if KRB received some direct benefit in which case also the downtime charges possibly could be reduced a little and other financial incentives be considered. The direct benefit that KRB wants is a separator which need not be removed for refueling. Ellmer said that the test would be allowed only if unlimited liability for downtime and damages were to rest with someone other than KRB, RWE, and Bayernwerk.</p> <p>I stated that I thought that a separator could be designed to meet the demands of KRB, but only if all design margin in vane-to-wall spacing were removed. The probability of success of the test would be much reduced because of this and because of the presence of the core spray and feedwater sparger pipes in the lower vortex region. Knoerzer said that this condition for allowing the test is necessary. I said that I would consider the design of such a separator and a new dryer which would be required for this after returning to San Jose and would then discuss the program with the USAEC.</p>	Colling Defosses Stella Ellmer Schober Maierhofer Knoerzer Jahn Loehr Turner Moen	Euratom Euratom USAEC RWE Bayernwerk Bayernwerk KRB AEG AEG APED APED

GEAP-5597

<u>DATE</u>	<u>PLACE</u>	<u>PURPOSE AND RESULTS</u>	<u>ATTENDEES</u>	<u>AFFILIATION</u>
		With regard to downtime guarantees there remains a small possibility that such guarantees would be included in the 1968-72 budget of Euratom as stated by Colling. His emphasis was on "small." There appeared to be a further small possibility that the German Government might in the future, perhaps 1968, consider such guarantees.		
Dec. 7	Grosswelzheim, West Germany	To visit the AEG steam separation test facilities. Problems of the test were briefly discussed with Kirchenmayer, the AEG steam separation program and new test facilities were discussed, and a brief tour of the facilities carried out.	Colling Stella Kirchenmayer Vollradt Schueler Tischer	Euratom USAEC AEG AEG AEG AEG
Dec. 7	Frankfurt, West Germany	To discuss results of trip. This was done. AEG awaits word of the results of the separator redesign, the future of the program, and the need for an AEG man on the program at San Jose. The AEG dryer development program was also discussed.	Voigt Jahn Molitor Moen	AEG AEG AEG APED

GEAR-5597

Approved:

D. H. Imhoff, Manager
Development Engineering

C. H. Robbins, Manager
Mechanical and Equipment Development

R. H. Moen, Project Engineer
Radial Vane Steam Separator Development Project

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