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GULF GENERAL ATOMIC

AEC RESEARCH AND
DEVELOPMENT REPORT

GA-10502

40-MW(E) PROTOTYPE HIGH-TEMPERATURE
GAS-COOLED REACTOR
POSTCONSTRUCTION RESEARCH AND DEVELOPMENT PROGRAM

QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING
JANUARY 31, 1971

Prepared under
Contract AT(04-3)-314
for the
San Francisco Operations Office
U.S. Atomic Energy Commission

February 26, 1971

MASTER

GULF GENERAL ATOMIC COMPANY, P.O. BOX 608, SAN DIEGO, CALIFORNIA 92112

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INTRODUCTION AND SUMMARY

This report, which covers the work performed during the quarter ending January 31, 1971, concludes the series of quarterly reports on the Peach Bottom Postconstruction Research and Development Program prepared under Contract AT(04-3)-314 for the U.S. Atomic Energy Commission. The overall objective of this program has been to develop information concerning the performance features of the Peach Bottom 40-MW(e) prototype high-temperature gas-cooled reactor plant.

Planning for the postconstruction phase of the program began in early 1964. The loading of Core 1 began February 5, 1966 and proceeded until a critical configuration was achieved on March 3, 1966. Core 1, which continued in service until October 1969, supplied much useful information on the operation of high-temperature gas-cooled reactors.

Core 2, which has similar characteristics to Core 1 but contains improved fuel, was installed in the reactor in July 1970, and this core is currently supplying power for Philadelphia Electric Company on a regular basis. The Peach Bottom reactor has successfully demonstrated the practicality of high-temperature gas-cooled reactors for power generation as base-loaded and load-following plants and has provided the information required by the program.

Peach Bottom Atomic Power Station operated at essentially full power during this quarter except for four brief outages. The plant parameters were all well within normal range before and after the outage transients, indicating no unusual occurrences in the reactor system. In particular, main coolant system activity stayed at or below 0.5 Ci, with Core 2 having operated for 182 effective full power days (EFPD). This clearly indicates improved fuel element performance compared to Core 1 at a similar point

in its operating history. The electrical and thermal power histories covering the operation of core 2 to date are given in Figs. 1 and 2. The main loop activity level for the same period is given in Fig. 3.

A brief power reduction was made on November 28 in anticipation of a reactor shutdown because of an apparent drop in rod hydraulic reservoir level. It was found, however, that no hydraulic leak existed, the level change being due to a sharp change in the sub-pile room temperature that resulted from turning on the room cooling unit.

The only drop from full-power operation during December occurred when a 19-hr shutdown was performed to permit testing of the main loop moisture monitors. Two of the hygrometer elements were replaced and the plant continued normal power operation. On January 18, when a similar shutdown was made during a work outage on the main transmission lines, two moisture monitors were replaced.

The first forced outage of the quarter resulted on January 25 from a full load loss caused by transmission-line switching that also involved the nearby Conowingo hydroelectric plant. With both plants separated from their load, frequency and voltage swings occurred that precipitated an overspeed trip of the main Peach Bottom turbine-generator set. As in the last quarter (see GA-10400), a loop isolation and reactor setback occurred, and the operator manually scrammed the plant as an added precaution due to the loss of system power and frequency regulation. Within 5 hr the plant was resynchronized and went back into power operation.

Early on January 26 another trip occurred. During instrument maintenance work, an operator error caused the turbine-driven boiler feed pump to trip, which also resulted in a loop isolation and reactor setback. In both these isolations, the main steam electrically operated relief valves opened, and one failed to reclose until the steam pressure dropped to about 600 psig. The plant was again operating at power within 7 hr, however, and normal full-power operation continued to the end of the reporting period.

Fig. 1. Electrical power history for Core 2

Fig. 2. Thermal power history for Core 2

Fig. 3. Main loop activity history for Core 2

TASK 2
EXPERIMENTS DURING APPROACH TO POWER AND AT POWER

LONG-TERM REACTIVITY BEHAVIOR

An analysis of the effects of spectral changes during depletion on reactivity predictions has been completed. It was determined that for nuclides with narrow resonances in the thermal energy range it is necessary to periodically reaverage the cross sections over the changing spectrum during depletion in order to assure proper time dependence of the affected nuclide concentration. The nuclides most affected with the present thermal group structure are Pa-233 and Rh-103. The correction involved in using constant cross sections in a four-thermal-group depletion calculation is only $0.006 \Delta\rho$ by the end of Core 2 life. This correction has been applied to the reactivity prediction for Core 2, the resulting predicted core reactivity being about $0.0008 \Delta\rho$ lower than that measured at about 175 EFPD.

CORE 2 PHYSICS

The results of the Core 2 loading and startup physics testing indicate that the methods in use for HTGR physics analysis are adequate to accurately describe the behavior of the Peach Bottom core. As reported in earlier quarterly reports GA-10300 and GA-10400, measurements of core reactivity, rod worth, temperature defect, and xenon reactivity at the beginning of life were very close to the values predicted.

Continued operation of the reactor to about 200 EFPD has resulted in a reactivity discrepancy of less than $0.001 \Delta\rho$ when normalized to the beginning of life value. The good agreement between calculated and measured reactivity changes during depletion shows that the burnup of fuel and poison is well understood and accurately described by the diffusion codes now in use.

The performance of the Peach Bottom reactor to date lends increased confidence to the physics analysis methods developed for the HTGR program and previously verified by critical experiments.

TASK 3
REACTOR MATERIALS BEHAVIOR

TEST JM-19, "DISTRIBUTION OF FISSION PRODUCTS IN FUEL ELEMENTS"

Information on the loss of fission products from Peach Bottom fuel elements was obtained by investigating the fuel. Pieces of compacts from fuel element D06-01 were counted using a lithium-drifted germanium detector. Concentration values (in units of atoms per sample) for the observed species were derived from the counting data, and these values were normalized to log-averaged values for the nonreleasing fission products (Zr-95, Nb-95, Ru-103, Ru-106, and Ce-144) to obtain relative concentration data in units of atoms per fission.

The results, presented in Fig. 4, show that the concentrations for the observed species, except those for the activation products Pa-233 and Cs-134, varied little with axial position in the fuel element.

The data for Pa-233 and Cs-134, on the other hand, show a distinct attenuation at the ends of the element. This is believed caused by the softening neutron flux at the ends of the active fuel element caused by the graphite reflectors (i.e., relatively more fission and less neutron capture by Th-232 and Cs-133).

An important species to consider is Cs-137. A relatively high fission-gas release of Xe-137 or a relatively high diffusional release of Cs-137 could occur as a function of position in the element because of variation in, for example, temperature or fuel condition. This behavior would show up as a trend in the Cs-137 data. There does appear to be a slight attenuation of the relative concentration as one traces from the lower end of the element to the top. This behavior is generally in line with the temperature behavior.

Fig. 4. Relative fission-product concentrations (atoms/fission) in element D06-01 fuel compacts

This attenuation is only 10%, however, and may be coincidental. In any event, these data strongly suggest high retentions of Cs-137 within the fueled compacts.

TASK 5

DETERMINATION OF EFFECTIVENESS OF HELIUM PURIFICATION SYSTEM

TEST JM-1, "GASEOUS FISSION PRODUCT RELEASE MEASUREMENTS"

Core 2 average fission-product release (R/B) values remain well below Core 1 values as shown in Fig. 5.

A comparison of Kr-85m R/B data for Core 1 and Core 2 shows that initial R/Bs began at approximately the same level, but as expected, Core 2 values have not shown the pronounced increase evident at a comparable point in Core 1 operation. This behavior demonstrates the improved irradiation stability of the Core 2 coated fuel particles.

Recent R/B values for the various krypton and xenon isotopes are given in Table 1. The data were obtained from samples taken by Philadelphia Electric Company and counted. The gamma spectrometry data were recorded on punched paper tapes that were forwarded along with other necessary data to Gulf General Atomic, where the spectral analyses and R/B calculations were performed with the aid of a Sigma 2 computer and the PB R/B code.

TEST JM-14, "REMOVAL AND ANALYSIS OF MAIN LOOP PARTICULATE MATTER"

Radiation monitors opposite the two main loop dust separators have shown that during Core 2 operation there has been relatively little activity associated with particulate matter in the primary coolant gas. Typically, readings are comparable to those obtained during early Core 1 operation.

TEST JM-16 "SURVEILLANCE OF LOW-LEVEL CHEMICAL IMPURITIES"

Core 2 primary coolant impurity levels in general have remained below the technical specification limits. During the latter part of November 1970,

Fig. 5. Kr-85m R/B data for Core 1 and Core 2

TABLE 1
CORE 2 AVERAGE R/B VALUES DETERMINED FROM MAIN PURGE (A-301) SAMPLES

Date	Time	Total Reactor Thermal Energy (MW-hr)	Power Level (%)	R/B						
				Kr-85m 4.4h	Kr-88 2.8h	Kr-87 76m	Kr-89 3.2m	Xe-133 5.27d	Xe-135 9.2h	Xe-138 17m
10-06-70	0933	195,190	97.4	2.5×10^{-4}	1.2×10^{-4}	9.4×10^{-5}	---	1.1×10^{-3}	1.7×10^{-4}	---
10-15-70	0921	219,590	97.3	2.6×10^{-4}	1.2×10^{-4}	9.1×10^{-5}	1.1×10^{-5}	1.1×10^{-3}	1.9×10^{-4}	2.1×10^{-5}
10-19-70	0928	230,460	97.4	2.6×10^{-4}	1.2×10^{-4}	9.5×10^{-5}	1.3×10^{-5}	1.1×10^{-3}	2.0×10^{-4}	2.5×10^{-5}
10-26-70	0921	249,490	97.3	2.3×10^{-4}	1.1×10^{-4}	9.1×10^{-5}	1.2×10^{-5}	1.2×10^{-3}	2.0×10^{-4}	2.3×10^{-5}
11-03-70	0930	268,740	97.4	2.6×10^{-4}	1.3×10^{-4}	9.3×10^{-5}	1.0×10^{-5}	1.1×10^{-3}	2.0×10^{-4}	2.1×10^{-5}
11-10-70	0933	287,680	97.7	2.6×10^{-4}	1.3×10^{-4}	9.6×10^{-5}	1.1×10^{-5}	1.3×10^{-3}	2.1×10^{-4}	2.3×10^{-5}
11-19-70	0945	312,040	97.5	2.9×10^{-4}	1.4×10^{-4}	9.3×10^{-5}	1.1×10^{-5}	1.2×10^{-3}	2.2×10^{-4}	2.3×10^{-5}
11-25-70	0947	328,430	97.5	2.8×10^{-4}	1.4×10^{-4}	9.6×10^{-5}	1.3×10^{-5}	1.2×10^{-3}	2.3×10^{-4}	2.6×10^{-5}
12-01-70	0938	343,550	97.4	3.1×10^{-4}	1.5×10^{-4}	1.1×10^{-4}	1.3×10^{-5}	1.5×10^{-3}	2.5×10^{-4}	2.7×10^{-5}
12-07-70	1110	359,750	97.6	3.1×10^{-4}	1.5×10^{-4}	1.0×10^{-4}	1.1×10^{-5}	1.4×10^{-3}	2.5×10^{-4}	2.5×10^{-5}
12-14-70	1417	379,080	97.4	2.8×10^{-4}	1.4×10^{-4}	9.8×10^{-5}	1.1×10^{-5}	1.2×10^{-3}	2.3×10^{-4}	---
12-24-70	1028	404,730	98.4	2.6×10^{-4}	1.4×10^{-4}	1.0×10^{-4}	---	1.4×10^{-3}	---	---
12-30-70	0909	418,060	98.3	2.6×10^{-4}	1.3×10^{-4}	9.5×10^{-5}	---	1.2×10^{-3}	2.2×10^{-4}	---
1-06-71	0849	436,820	98.9	2.2×10^{-4}	1.2×10^{-4}	9.8×10^{-5}	1.3×10^{-5}	1.3×10^{-3}	2.2×10^{-4}	2.5×10^{-5}
1-13-71	0941	455,370	98.1	2.5×10^{-4}	1.2×10^{-4}	---	---	9.4×10^{-4}	2.1×10^{-4}	---
1-20-71	0936	471,070	96.0	2.2×10^{-4}	1.2×10^{-4}	7.7×10^{-5}	1.1×10^{-5}	9.7×10^{-4}	1.8×10^{-4}	2.0×10^{-5}

hydrogen levels in the main loop were observed to increase to around 100 ppm by volume. The H_2 concentration in the oxidizer effluent was also found to be high, and it was deduced that the Cu/CuO catalyst in the oxidizer unit was in need of regeneration. It is of interest, however, that whereas the CuO bed had failed with respect to oxidation of H_2 , the unit was still effective in CO oxidation and removal. This was determined by comparing the CO concentration in the main loop, 0.4 ppm by volume, to that in the oxidizer effluent, <0.05 ppm by volume. Another indication of CO oxidation and removal by the system was the observation that CO levels in the main loop had not increased above the normal level of about 0.5 ppm.

During the latter part of December 1970, the oxidizer was regenerated by the addition of oxygen, after which hydrogen levels were observed to drop to about 10 to 15 ppm by volume. This regeneration proved to be insufficient, and during the early part of January, hydrogen in the main loop was again observed to increase. This was not totally unexpected, because the regeneration process was known to be less than complete due to oxygen leakage from the oxygen manifold. The oxidizer was again partially regenerated in January, and H_2 levels once again decreased and remained low for several days. On January 26, 1971, the H_2 concentration started to increase again and leveled off at about 140 ppm by volume. A more complete oxidizer regeneration is planned for February. Gaseous impurity concentrations as a function of time are given in Table 2. Most of these data were furnished by Philadelphia Electric Company.

TABLE 2
GASEOUS IMPURITY CONCENTRATIONS

Date	Impurity Concentration (ppm by vol)			
	H ₂	N ₂	CH ₄	CO
11-25-70	86	1.4	2.2	0.4
11-30-70	110	1.5	2.0	< 0.04
12-15-70	--	2.9	1.6	0.7
12-18-70 ^(a)	106	1.7	2.2	0.4
12-24-70	46	2.2	0.6	0.4
12-29-70	20	1.8	0.6	0.9
1-6-71 ^(a)	60	1.6	0.8	0.6
1-12-71	15	1.0	0.7	0.6
1-18-71	11	1.7	0.7	0.7
1-26-71	12	--	--	--
1-27-71	30	1.7	1.0	0.4
2-4-71	90	--	--	--
2-8-71	140	--	--	--

(a) The oxidizer bed was partially regenerated after December 18, 1970 and January 6, 1971.

Appendix A
PROJECT PERSONNEL

This postconstruction research and development program on the 40-MW(e) prototype HTGR is being carried out by the following project personnel:

C. L. Allen	V. J. Lab
E. E. Anderson	R. K. Lane
W. E. Bell	R. J. Lansley
G. E. Besenbruch	W. L. Lefler
J. R. Brown	P. T. Mattson
R. D. Burnette	J. W. McLean
D. D. Busch	R. E. Norman
G. Buzzelli	R. Riley
H. R. W. Cobb	D. I. Roberts
B. P. Cross	W. J. Scheffel
R. C. Dahlberg	A. S. Schwartz
S. E. Donelson	P. Schleifer
R. R. Frost	R. H. Smith
J. N. Graves	O. M. Stansfield
A. S. Hilbert	K. R. Van Howe
E. L. Hill	F. E. Vanslager
L. J. Hull	W. H. Weitzel
J. F. Hildebrand	G. L. Wessman
M. E. Kantor	P. Winchell