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MODIFICATION OF CP-5 FUEL ASSEMBLIES
FOR FUEL CAPSULE IRRADIATION EXPERIMENTS

by

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W. N. Beck, J. H. Kittel and F. L. Brown*

ABSTRACT

The standard vertical fuel tube assembly of the CP-5 research reactor was modified to permit diversion of heavy water coolant into the thimble for temperature-controlled irradiation experiments of capsules containing fuel specimens. The modification entailed revisions to the thimble, outer top shield plug and center shield plug, and helium sweep system. The modified thimble is provided with inlet and outlet ports which circulate heavy water from the reactor flow system through the thimble cavity. The coolant in the thimble removes fission heat from the encapsulated samples introduced into the thimble cavity. Flow tests of the thimble were first performed on a flow stand, with final flow characteristics being determined in the reactor. A helium purge system was incorporated to remove dissociation gases trapped in the thimble cavity. Four configurations of capsules and capsule baskets were flow tested under conditions simulating operating flow conditions from 2 to 10 Mw reactor power. Irradiation capsules are now being satisfactorily operated in the modified thimbles at 2-Mw reactor power.

INTRODUCTION

In the development of fuel for reactors it is essential to determine experimentally the characteristics of the material under conditions representative of actual in-pile operation. As a means of accomplishing these objectives, fuel samples can be encapsulated, introduced into an operating reactor, and subjected to preselected periods of irradiation. Postirradiation examination of the sample material then serves to establish the operational characteristics of the particular fuel under study.

A capsule, designed several years ago at Argonne National Laboratory,⁽¹⁾ has been used in large numbers with various design modifications by Argonne and by many other groups engaged in fuel-irradiation

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studies. Capsules of this type are highly useful in performing screening tests on untried fuel materials and in evaluating the comparative performance of different fuel compositions, heat treatments, fabrication histories, etc. For experiments of this nature the capsule will usually contain several specimens.

Since the capsules are uninstrumented, there is no means of measuring or controlling temperatures during irradiation. In order to achieve a desired fuel-irradiation temperature, it is necessary before irradiation to perform flux perturbation and heat transfer analyses of the assembly. The unperturbed neutron flux to achieve the desired fuel temperature can then be specified.

However, experience with several hundred such irradiations in MTR-ETR has shown that it is very difficult to locate a capsule in the exact desired flux. Even if this is accomplished, subsequent changes in flux resulting from shim rod movements, reloading of the core, and changes in adjacent experiments result in large changes in the temperature of the fuel specimens.

In order to provide controlled temperatures during irradiation, the basic capsule design has been modified to include thermocouples and auxiliary electrical heaters.

Irradiation experiments of the nature described above require, because of greater complexity, frequent monitoring by operating personnel. For convenience it was therefore decided to perform the instrumented capsule irradiations in the CP-5 reactor, on the Argonne site, rather than in the more remote MTR-ETR.

Although CP-5 contains vertical irradiation thimbles in each fuel assembly, the original design of the thimbles provides only low-velocity air cooling of samples under irradiation. The original design was therefore not suitable to remove the several kilowatts of heat that would be generated in the proposed fuel irradiations.

Water cooling of the outer surface of the capsule appeared to be more feasible than, for example, increasing the air flow. The most convenient source of coolant was the heavy water which flowed outside each thimble to cool the fuel elements surrounding the thimble.

This report describes the changes which were made in the thimble design to divert some of the heavy water coolant into the thimble for cooling the fuel-irradiation capsules. A description is also given of the flow-testing program which was performed to determine the fluid flow characteristics of the modified thimble and cylindrical fuel assembly.

DESCRIPTION OF THE CP-5 RESEARCH REACTOR

CP-5 is a heavy water-moderated and cooled research reactor. It is fueled with cylindrical-type fuel elements⁽²⁾ of aluminum-enriched uranium alloy jacketed with aluminum. The reactor tank is 6 feet in diameter and 9 feet 7 inches in height. A graphite reflector, 2 feet thick, surrounds the tank (see Fig. 1). The graphite is contained in an outer tank made of steel lined with boron carbide. This vessel is surrounded by 4½ feet of dense concrete. Access ports and columns have been provided in strategic points of the reactor which serve as radiation facilities. These ports include (1) vertical D₂O thimbles, (2) vertical graphite thimbles, (3) thermal column, (4) horizontal beam holes and (5) isotope tunnel. The neutron flux at 2-Mw reactor power ranges from 2.4×10^{12} n/cm²/sec in the isotope tunnel to 3.4×10^{13} n/cm²/sec in the vertical thimbles.

The vertical fuel assemblies, one of which is illustrated in Fig. 2, are suspended in the reactor vessel. Heavy water is pumped into a distribution plenum at the bottom of the tank and passes through the orifice in the bottom of the fuel elements. At 2-Mw operation, 1000 gpm of D₂O flow through the 17 fuel assemblies. Under these operating conditions, the inlet temperature of the coolant is 40°C and rises 12.6°C before being discharged into the reactor tank. The velocity of the liquid in each of the fuel tubes is 5.3 feet per second.

MODIFICATIONS MADE TO THE CP-5 FUEL ELEMENT ASSEMBLY

The existing radiation facilities in the fuel element assembly consisted of air-cooled thimble liners, which could not accommodate large amounts of fission heat. Location of the liner relative to the thimble is shown in Fig. 2. The thimble liner is accessible from the top of the pile by removing a center shield plug. The lower portion of the thimble liner is provided with holes which permit forced air circulation between the thimble and the inside cavity of the liner.

In contemplating the use of the heavy water flow to cool a sample container, it became apparent that the liner must be removed and that the thimble, the center shield plug, and the top outer shield plug must be modified.

Opening the thimble cavity to the flow of the reactor process water meant that, upon removing the top shield plug, the reactor D₂O would be open to atmosphere. It also meant that D₂ and O₂ gases from dissociated D₂O would be trapped in the top of the thimble. In modifying the thimbles, these features had to be taken into consideration in terms of the effects on the operating characteristics of the reactor. If at all possible, substitute

FIG. 1
ELEVATION OF CP-5 RESEARCH REACTOR

FIG. 2
CP-5 CYLINDRICAL FUEL ASSEMBLY
BEFORE MODIFICATION

hardware had to conform with existing geometry of the fuel thimble assembly. It was also a prerequisite that new parts be interchangeable with the existing installation. For the purpose of these experiments, six vertical thimble assemblies were allocated and were modified in the following manner:

A. Outer Top Shield Plug

The existing top plug measured $26\frac{3}{4}$ inches in length and $5\frac{1}{16}$ inches in diameter (Fig. 3). The inside hole diameter was $2\frac{45}{64}$ inches on the lower 22 inches, opening to approximately $3\frac{1}{2}$ inches at the top. The plug serves as a radiation barrier and a gas seal. The construction of the barrel consists of two concentric stainless steel tubes, with the annulus filled with heavy concrete. Embedded in the concrete are two $\frac{5}{16}$ inch O.D. tubes which extend the full length of the plug. These tubes terminate in connectors and are used to contain wires leading to a thermocouple and float. The top of the plug is cross drilled with ports which are used for forced air circulation between the thimbles and the thimble liner. The top of the plug is also provided with a shoulder which supports the center shield plug. "O"-ring pressure seals prevent the escape of the helium atmosphere in the reactor vessel. These rings are located on the outside of the plug and seat against the fuel assembly casing. One inside ring seals the inserted thimble.

The new plugs were designed similarly to a plug used by Schiltz.⁽³⁾ This type of plug conserves the basic diameters, but is approximately $1\frac{1}{4}$ inches shorter. It is characterized by a bolt-down flange rather than a solid one-piece "O"-ring retainer. The reduction in length was necessary to accommodate the bulk of the electrical connector which would be attached to the center plug.

In performing this reduction of length, two "O"-ring grooves had to be omitted; previous experience with this seal assured adequate control of leaks in this particular area. Inasmuch as the intended design of the thimble called for the introduction of reactor heavy water into the thimble cavity, an "O"-ring seal for the center shield plug was installed on the flange. The flange was equipped with a helium-vent tube which opened into the thimble cavity in order to continuously purge dissociation gases from the heavy water.

B. Center Shield Plug

The principal function of the original standard center plug was to provide adequate radiation shielding. It was designed to fill the center cavity of the thimble and, as such, fitted the inside contour of the thimble. The plug was approximately 60 inches in length and was constructed with a stainless steel shell filled with limonite, boron carbide and cemented (Fig. 4). The two extremities were filled with lead. When the plug was inserted into the thimble, the expanded flange of the plug seated in a recess of the outer shield plug. A spiral hole extended the full length of the plug and served as an air intake for the thimble liner.

FIG. 3
MODIFICATIONS MADE TO UPPER SHIELD PLUG

STANDARD CENTER SHIELD PLUG

MODIFIED SHIELD PLUG

FIG. 4
MODIFICATION TO CENTER SHIELD PLUG

The revisions which accompanied the modifications of the center plug were directed toward utilizing the plug as a suspension device for the test capsule, as well as to continue using it as a radiation shield and a gas seal. Inasmuch as it became necessary to remove the stem of the plug and incorporate pressure-tight fittings in the center spiral channel, to compensate for the loss of shielding for the stem, the revised plug was filled with lead shot and paraffin. Boral discs were inserted in the lower end. The proposed D₂O-vented thimble required that the plug be provided with pressure seals. This was accomplished by installing an "O"-ring in the flange of the plug which seated against the recess of the outer top plug. The air manifold was removed and a pressure AN-type connector was substituted. Lead wires were then threaded down the spiral channel and through a long extension tube to the experiment capsule. Removal of the capsule was to be accomplished by extracting the plug and, for that purpose, eye-bolts for a cable attachment were provided at the top of the plug. A proposed diagram of the capsule installation for high-temperature irradiation is shown in Fig. 5.

The same facility can also be used for irradiation at ambient temperature by attaching to the extension rod a basket containing capsules. The basket is a ribbed aluminum tube, 29 inches in length, a diagram of which is shown in Fig. 6. Sample capsules are inserted in the basket and locked in place by a compression spring. The ribs of the basket restrict lateral motion of the samples and form an annulus through which the process heavy water can flow. The basket flange is a close-tolerance fit within the thimble, thereby assuring that the circulation of the coolant will be throughout the annulus formed by the capsules and the basket. The quick-detachable twist lock permits easy removal of basket from the restraining rod.

C. Thimble Modifications

The thimbles serve as access ports to the center of the cylindrical fuel assembly. The thimble measures $126\frac{27}{32}$ inches in length and $2\frac{5}{8}$ inches maximum diameter at the top collar. This diameter dimension is conserved for $25\frac{7}{16}$ inches, where it tapers at a 20° angle to $1\frac{13}{16}$ inch. The lower extremity terminates in a tapered cone $2\frac{1}{2}$ inches long. It is tipped with a $\frac{1}{2}$ inch diameter, $1\frac{1}{2}$ inch aluminum plug. At approximately $29\frac{1}{2}$ inches from the top of the thimble there is welded a collar which compresses an "O"-ring to seal the thimble to the intermediate shield plug.

In order to introduce a flow of reactor coolant into the thimble cavity, the tapered end-cone was selected as the logical point of entry. This cone serves as a deflecting surface to the incoming flow of heavy water, distributing the coolant to the fuel tubes. Twelve holes were drilled into this cone. They were located in four rows of three each, spaced 90° apart. The hole diameters varied consecutively in each two and were $\frac{5}{16}$ inch, $\frac{7}{16}$ inch, and $\frac{9}{16}$ inch. A diagram of the intake ports is shown in Fig. 7. An adjustable

FIG. 5
IRRADIATION CAPSULE ATTACHED TO CENTER SHIELD PLUG

FIG. 6
ALUMINUM BASKET DESIGNED FOR IRRADIATIONS AT AMBIENT TEMPERATURE.
SAMPLES ARE CONTAINED IN INDIVIDUAL CAPSULES.

FIG. 7
COMPARATIVE DIAGRAM SHOWING VALVE ASSEMBLY
INCORPORATED IN END OF THIMBLE

tapered cone having identical hole placement was inserted into the thimble cone. The adjustable cone provided a means whereby the total intake opening could be controlled by the degree of alignment of the holes of the two cones. The variation of total aperture with alignment is shown in Fig. 8.

FIG. 8

VALVE SETTING OF THIMBLE VERSUS TOTAL VALVE OPENING.
THE VALVE SETTING IS DETERMINED BY MEASURING THE APERTURE
OF THE LARGE VALVE HOLE

The discharge of heavy water coolant from the thimble cavity is through holes in the upper wall of the thimble. A total of eight $\frac{3}{4}$ inch diameter holes are set in two rows of four each, each row $2\frac{3}{4}$ inches apart. The hole locations are staggered so as not to weaken the thimble well. The locations of the holes coincide with the main discharge openings in the fuel assembly casing. A diagram of the thimble with the ports is shown in Fig. 9.

The presence of the heavy water in the thimble cavity during irradiation presented the possibility of trapping explosive mixtures of D_2 and O_2 at the top of the thimble. To preclude this possibility, it was necessary to sweep helium over the top of the D_2O . A two-line, closed loop, helium-recirculating system was considered for scavenging the gases. This was abandoned, however, in lieu of a system that utilizes the reactor

FIG. 9
MODIFIED THIMBLE SHOWING LOCATION OF VENTS AND PORTS

reservoir supply of helium, pumping it to the thimble cavity and exhausting it into the helium atmosphere of the reactor. Purification of the gas was then performed by the reactor filter and recombiner system.

As previously noted, the outer top shield plug was equipped with a helium inlet line which was sealed to the thimble cavity. This line was connected to a double pump system, located in the sub-floor of the reactor building, which provided a continuous flow of helium to the thimble. One of these pumps is normally in continuous operation, while the other is a standby pump which automatically operates if there is an undue pressure drop in the line to the thimble. The intake to these pumps is coupled directly to the main supply of the reactor.

With the introduction of this single-line system, exhausting of the gas in the thimble became necessary. It was accomplished by drilling eight $\frac{3}{8}$ inch holes in the wall of the thimble, above the coolant discharge holes. The location of these holes can be seen in Fig. 9.

FLOW TESTING OF MODIFIED THIMBLE

The modified thimble was a significant departure from the previously established functions of the thimble and, as such, required evaluation of anticipated in-pile operating characteristics. Although anticipated flow velocities, flow volume, liquid head in the thimble, etc., could be calculated, actual verification by means of flow tests was considered essential. In order to perform these tests a full-scale mock-up of the fuel assembly tube was tested with the modified thimble.

A. Flow System Measurements

An existing flow stand was utilized for these tests. This stand had been previously used to determine flow characteristics of various CP-5 fuel assemblies, and therefore incorporated the majority of the fuel tube components common to the actual reactor assembly.

A diagram of the flow stand is shown in Fig. 10. The flow chamber is a cylindrical casing which houses the fuel tube assembly. The liquid contained in this casing is equivalent to that in the reactor vessel. An overflow line tapped into the casing wall controls the fluid level in the casing. The location of this overflow line was so positioned as to duplicate the actual liquid level of the reactor vessel. The vertical flow of liquid through the assembly was provided by a 130-gpm centrifugal pump coupled to the lower inlet of the casing. A metering valve between the pump and the inlet served to control the liquid flow. A large valved line at the bottom of the casing provided the flow return. This valve also provided a means for

FIG. 10
BLOCK DIAGRAM OF FLOW STAND USED TO
EVALUATE THE OPERATING CHARACTERISTICS
OF THE MODIFIED THIMBLE

adjusting the level of the liquid in the casing. For these particular tests a siphon line was provided for insertion in the thimble cavity. The calculated liquid level inside the thimble indicated that, under certain flow conditions, the head would be higher than the actual physical length of the thimble. By withdrawing liquid from the thimble a nominal head, which was read by a "U"-tube water manometer, could be maintained.

The main flow through the fuel tube assembly was regulated by the inlet and outlet valves. The determination of flow rate was made by actual weight measure of the discharge liquid. All tests were performed using ordinary tap water as the circulating fluid. The use of the siphon pump was limited to tests where the liquid level approached the top of the thimble. In such cases, the flow rate in the siphon line, together with the respective manometer readings, provided the information for determining fluid flow through the thimble.

Flow testing of various valve openings was required to determine the volume of coolant which would be delivered from the reactor fuel tubes. The anticipated effect of this diversion would be to produce a rise in the operating temperature of the fuel elements, and for that reason a maximum thimble valve opening, which would not result in an undesirably large loss of fuel element coolant, had to be established. Another consideration was that there should not be a drastic change in flow distribution whenever capsules or baskets were introduced or removed from the thimble cavity.

The thimble used in the first test was a standard thimble equipped with a conical slide valve. No other ports or openings were provided, inasmuch as the primary objective was to determine the liquid flow through the thimble cavity. Valve openings from 0.5 square inch to a maximum aperture of 1.9 square inches were tested. These openings were tested under flow rates of 875 gpm to 2200 gpm equivalent total reactor flow. The wide range of flow rates was utilized purposely in anticipation of projected modifications to the reactor. At a reactor power level of 2 Mw the coolant pumps circulate 1000 gpm through the core.⁽³⁾

It is planned in the future, to increase the power of the reactor to 4 Mw and eventually to 10 Mw. At 10 Mw the pumps would be delivering in excess of 2000 gpm. It was therefore necessary to consider the operation of the thimble not only at the present reactor power, but also at the proposed increased power levels.

The results obtained under these conditions are plotted in Fig. 11. The curves shown represent data from valve openings of 1.125 square inches and 1.9 square inches.

FIG. 11
FLOW CHART OF VALVED THIMBLE. THE CURVES ARE MARKED IN TERMS OF
TOTAL REACTOR FLOW THROUGH 17 SEPARATE THIMBLES

The dimensions and locations of outlet ports were largely dictated by the hydrostatic head in the thimble cavity. It was advantageous to minimize this hydrostatic head in order to realize a maximum flow through the thimble cavity. The thimble, $\frac{1}{16}$ inch thick, was constructed of 0.063 inch thick 2S aluminum. The ports had to be located in the thimble wall so as not to adversely affect the structural integrity of the unit.

Direct access for discharging the thimble water into the reactor tank was possible in a port area normally used to discharge the coolant from the fuel tube. The introduction of ports in the thimble at this location would provide adequate aperture for exhausting the thimble. The direction

of flow of thimble water, however, would be approximately perpendicular to the flow of the water past the fuel tube. It was not known what the resultant effect would be on the reading of the float of the fuel tube assembly. This float continuously records the rate of flow past the fuel tubes by the position it assumes and an excessive drop in this position alarms the CP-5 reactor control board and shuts down the reactor. Flow test information on various thimble openings in the fuel tube discharge area was obtained on a thimble with three different apertures, with results as listed in Table I.

Table I

Results of Flow Tests on Modified Thimble

Test	Outlet Port Opening	Thimble Valve Opening (in. ²)	Liquid Flow (gpm, 17 thimbles)	Liquid Head in Thimble (in.)
1.	1.76 in. ² (4 $\frac{3}{4}$ in. holes)	1.9	2200	43
		1.125	2200	30
		1.9	1000	13
		1.125	1000	6
2.	2.54 in. ²	1.9	2200	18.5
	(4 $\frac{3}{4}$ in. holes)	1.125	1000	4
	(4 $\frac{1}{2}$ in. holes)			
3.	3.52 in. ² (8 $\frac{3}{4}$ in. holes)	1.9	2200	18
		1.125	2200	12
		1.9	1000	5
		1.125	1000	3

The tests revealed that sufficient reduction in liquid head could be accomplished with 3.52 square inches of outlet opening. Any additional increase in opening, although beneficial in terms of liquid flow, would unduly weaken the thimble wall. For that reason, this aperture was adopted for installation in the reactor. It was decided, however, that in the first in-pile thimble test, the ports would be positioned above the fuel tube discharge ports to preclude the possibility of shutting down the reactor.

Various configurations of capsules and baskets to contain capsules are contemplated for use with the modified thimble. These capsules will contain fissionable material. The fission heat generated during irradiation will be dissipated in the stream of coolant heavy water. The flow rate of the coolant in the fuel assembly and in the thimble with a capsule or basket inserted in the thimble had to be established in order to (1) calculate the heat transfer coefficients of the sample capsules and (2) calculate the effect on the operating temperature of the reactor fuel elements. Four different configurations were tested. Configuration No. 1 represented an instrumented capsule in the thimble. The remaining three configurations represented various arrangements of uninstrumented capsules in baskets. A cross-sectional view of the assemblies formed by the capsules and thimbles is shown in Fig. 12. The data obtained from the capsule tests are included in Fig. 13. The top horizontal line, labeled "top of thimble," represents the thimble head limitations due to the physical length of the thimble.

During these capsule tests it was observed that the fluid motion in the thimble exerted a lifting force, which was as high as 4 kilograms, on the capsules and basket. This value was noted under the most severe condition of maximum fluid flow and minimum capsule annuli. In order to prevent the capsules from being raised by coolant flow, the baskets will be restrained by a rod which couples the baskets to the center shield plug, as shown in Fig. 6. Removal of the basket from the thimble is accomplished by extracting the center shield plug.

B. In-Pile Tests of Thimble

After the out-of-pile flow tests were carried out, a modified thimble was introduced into a vertical fuel tube assembly of the CP-5 reactor. This particular thimble conformed to the intended operational configuration, with the exception of the location of the outlet ports, which were elevated above the discharge ports of the fuel tube. Close observation of the behavior of this fuel assembly during reactor operation revealed only minor rises in fuel tube temperature. The float level in the assembly was, however, noted to be riding abnormally high. The most probable reason for this behavior was that liquid from the thimble was spilling into the float chamber and causing a rise in the float level. A direct measurement of the liquid level inside the thimble while the reactor flow system was in operation revealed a high liquid head, which substantiated the belief that the float chamber was being fed by coolant from the thimble.

A second thimble of identical configuration, but with discharge ports located directly opposite to the existing fuel tube ports, was then tested in the reactor. A marked drop in the float level was noted. The liquid head in the thimble also receded to the value established by the flow stand test. The associated hardware, plugs and shields designed for use with this thimble were then fitted to the fuel assembly preparatory to testing of actual fuel capsules.

CONFIGURATION NO. 1

CONFIGURATION NO. 2

CONFIGURATION NO. 3

CONFIGURATION NO. 4

FIG. 12
CROSS-SECTIONAL VIEW OF CAPSULE CONFIGURATIONS TESTED IN THE MODIFIED THIMBLE

FIG. 13
FLOW TEST RESULTS OF THE FOUR CAPSULE CONFIGURATIONS. THE CURVES ARE MARKED IN TERMS OF TOTAL REACTOR FLOW THROUGH 17 THIMBLES

PRESENT OPERATING EXPERIENCE

Six center holes of the CP-5 research reactor: VT-4, -5, -8, -10, -13, and -14, were allocated for these experiments. The new thimbles and accessories, when substituted for the standard equipment, were functionally interchangeable and compatible. Several capsule configurations have been successfully tested. It has been found that the modified thimbles are quite suitable for testing materials with rates of heat release on the order of several kilowatts.

The installation of a capsule experiment in the reactor is relatively simple, requiring a maximum of 15 minutes to accomplish either insertion or extraction of a capsule assembly. The only connection required is the coupling of a connector to the mating receptacle on the center shield plug. Observation of the operating system has indicated that the capsules are free from any tendency to oscillate, shift, or bind within the thimble cavity.

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REFERENCES

1. J. H. Kittel and P. Tedeschi, A Capsule Design for Experimental High-flux Irradiations of Fuel Materials, ANL-4900 (1952).
2. W. H. McCorkle, Modifying CP-5 for 4-Mw Operation, Nucleonics, 15 (2), 91-92 (1957).
3. R. J. Schiltz, J. H. Monaweck and E. S. Sowa, EBR-II Fuel Irradiation Facilities, ANL-5940 (November, 1958).