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MODERATOR EVALUATION FOR THE K PILES — AGHT (CHF) AND 185 W GRAPHITE.

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INTRODUCTION

At the time that the Atomic Energy Commission authorized the construction of the K piles, about 1200 tons of graphite were available for moderator use in the Hanford inventory. Contracts were immediately let with the National Carbon Company for procurement of additional moderator material. At the suggestion of the Atomic Energy Commission, an examination was made of graphite of appropriate dimension for K pile use that was stored at Oak Ridge. Because this graphite could be made available before the material from National Carbon, it appeared that its use would permit completion of machining and pile lay up at an earlier date.

About 200 tons of AGHT* and about 200 tons of graphite designated 185-W were available. Samples of these materials were sent to Hanford for pile moderator and pile material evaluation. Apparent density and nuclear purity were tested for pile moderator evaluation. It was also necessary to test thermal conductivity in this regard because graphite temperature affects pile reactivity and graphite temperature is partially determined by graphite thermal conductivity. Radiation induced dimensional instability, thermal expansion, and machinability were tested for pile material evaluation. Because only about five months were available for testing between the time that samples of these materials were procured and the time that machining would begin for the K piles, these materials could be evaluated only for pile positions in which large radiation damage induced physical property changes were either not expected or could not impair pile operation (1). AGHT graphite was actually utilized as central filler block material in KW pile.

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* After purification AGHT graphite was renamed CH [redacted]

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AGHT graphite was purified in the National Carbon Company's Clarksburg furnaces and utilized in the KW pile. The 185-W grade graphite was not used but might be utilized in other reactors.

SUMMARY

This report describes the evaluation of physical properties of AGHT and 185-W graphites that are important to pile construction and operation.

On the basis of these data, purified AGHT graphite was allocated to either filler block positions in the central regions of the K piles or to the upper or lower reflectors. This decision was based on the similarities of physical properties between AGHT graphite and the other moderator components. A similar allocation could be made for 185-W graphite for some future pile if it can be successfully purified or if purification is not required.

EXPERIMENTAL RESULTS AND DISCUSSION.

In order to evaluate AGHT and 185-W graphites for use in the K piles, measured physical properties were directly compared to physical properties of other graphite components of the pile moderator. The results of this study indicated that neither of these graphites were significantly different in physical properties from graphites to which they were being compared. However, the exposure periods in Hanford piles for the determination of radiation induced physical property changes were short with respect to exposure periods for the evaluation of other graphites to be used as portions of the K pile stacking.

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The evaluation with respect to individual physical properties is discussed in detail below.

I. PILE MODERATOR EVALUATION

As indicated by the introduction, an evaluation of a graphite as a pile moderator must include information concerning apparent density, nuclear purity, thermal conductivity, and irradiation induced changes in thermal conductivity.

Apparent Density and Nuclear Purity.

The nuclear purity as measured in the 305 test pile of purified AGHT graphite and the average density of AGHT(2) and 185-W graphites are compared with production grade TS-GBF graphite in Table I. The similarity in these pile moderator properties should be noted.

Thermal Conductivity Prior to Irradiation.

The thermal conductivity at pile start up is of importance in the determination of graphite temperatures which in turn have a significant effect on pile reactivity. Values of thermal conductivity before irradiation for AGHT and 185-W graphites and other graphites utilized in the K piles are presented in Table II. Because initial thermal conductivity depends upon graphitization temperature, the comparison is made between graphites that have been subjected to the same maximum graphitization temperature. All graphites in Table II were graphitized at 2800 C. It will be noted from Table III, that AGHT graphite appears to have higher thermal conductivity than the other materials. Computations carried out by the Heat Transfer Sub-Unit of Pile Technology indicated that the difference was not sufficient to cause any appreciable effects during operation (3). Therefore AGHT graphite may be considered comparable to CSF in this respect.

Radiation Induced Thermal Conductivity Changes.

Changes in thermal conductivity caused by low temperature irradiation in a water cooled test facility of AGHT and 185-W graphites are compared to similar changes of other K pile graphites in Table II . It will be noted from the table that very little difference exists between the graphites after an irradiation period of 445 MD/CT in a cold test hole. It should be remembered that the changes in a cold test hole indicate the worst possible temperature condition for radiation damage to which a graphite could be subjected in the K piles.

Because AGHT and 185-W graphites were being evaluated for filler block positions, irradiation was carried out in a test facility such that the sample temperature was equivalent to ambient pile temperature, Table III indicates thermal conductivity changes induced by irradiation at such a temperature. It is expected that K pile temperatures will be comparable to temperatures used in this experiment. Again the similarity between the results for various materials should be noted.

II. EVALUATION OF AGHT AND 185-W GRAPHITES AS PILE MATERIALS.

In order to evaluate a graphite as a pile material, it is necessary to test the thermal expansion, machinability, and dimensional stability under irradiation.

Thermal Expansion.

The thermal expansion coefficient of AGHT and 185-W graphites have been measured using a dial gauge dilatometer. The results over a temperature range of 20 C to 300 C are presented along with similar measurements on CSF graphite in Table IV. It is apparent that AGHT and 185-W graphites show a greater thermal expansion in the direction parallel to the axis of extrusion than does CSF graphite. A similar expansion on TS-GBF graphite in the direction parallel to the axis of extrusion has been noted.

Machinability.

The machinability of AGHT and 135-W graphites have been compared to TS-GBF and CSF graphite in Table V. Determinations were carried out by measuring the depth of penetration of a drill into the graphite sample that occurs in five seconds under a given load (4). From the table it is observed that AGHT and 185-W graphites are at least as machinable as other graphites for the K piles.

Dimensional Stability Under Irradiation.

In order to obtain an evaluation of the radiation stability of AGHT and 185-W graphites in a minimum amount of time irradiation was carried out in Hanford piles and also at the MTR. The Hanford irradiations were carried out in both water cooled test facilities in order to determine dimensional changes caused by irradiation at the worst possible pile temperature conditions and at ambient pile temperature in order to determine the instability that might be associated with filler blocks in the K piles.

Irradiation in Hanford Cold Test Hole. Results of the irradiations carried out in water cooled test holes are presented in Table VI. These data indicate that the expansion of transverse samples of AGHT graphite is similar to that of CSF graphite. The 185-W material appears to have less expansion than CSF graphite. An expansion in the direction parallel to the axis of extrusion was noted in both AGHT and 185-W graphites. This expansion is of the same order of magnitude as the parallel expansion associated with TS-GBF graphite. K pile design is such that such expansion in the parallel direction will not cause operating difficulties.

Hanford Irradiated Ambient Pile Temperature. The data obtained from hot test hole irradiation of AGHT and 185-W graphite is compared with CSF graphite in Table VII. Results indicated that no appreciable dimensional instability could be associated with these graphites at low exposures.

Exposures in the MTR Because of the limited time available for evaluation, it was considered advantageous to utilize the rapid exposure that could be attained in the MTR. It should be noted, however, that no direct correlation is available between MTR exposure and Hanford exposure. Not only does a difference exist in the neutron flux energy spectrum, but a difference in temperature of irradiation of water cooled samples also exists (5). Therefore, each graphite being evaluated was compared directly to samples of CSF and TS-GBF graphites. Samples of the "unknown" graphite were exposed along side samples of the "standard" graphites. Results are presented in Tables VIII through XI. An equivalent Hanford exposures is listed. In order to determine this exposure, the percent distortion of CSF samples from the MTR were assigned an exposure based on the exposure associated with that percent expansion in a Hanford cold test hole. It will be noted from the tables that 185-W graphite is more stable than CSF graphite. AGHT graphite appears less stable than either CSF or TS-GBF in the transverse direction. However, the differences are not considered large enough to prevent the use of this material in [redacted] the K piles [redacted]

Despite the limited time available for evaluation, these data indicated that the use of AGHT graphite as filler block material in the central zones of the K piles would not lead to operational difficulties. Had additional time been available for evaluation, it is quite possible that an unlimited use of AGHT graphite might have been authorized.

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TABLE I

NUCLEAR PURITY AND APPARENT DENSITY OF GRAPHITE EVALUATED FOR THE K PILES

TYPE OF GRAPHITE	NUMBER OF HEATS TESTED IN 305 PILE	AVERAGE PURITY dih	AVERAGE APPARENT DENSITY g/cc	RANGE OF APPARENT DENSITY g/cc
AGHT	56	0.93	1.67	1.62 - 1.69
185-W	0	----	1.64	----
TS-GBF*	899	0.98	1.65	1.60 - 1.66

* Material produced by National Carbon under the G-5 contract.

TABLE II

THERMAL CONDUCTIVITY OF AGHT AND 185-W GRAPHITES BEFORE AND AFTER COLD TEST HOLE IRRADIATION

TYPE OF GRAPHITE	ORIENTATION TO EXTRUSION AXIS	AVERAGE THERMAL CONDUCTIVITY cal/cm/sec/°C			
		0 MD/CT	212 MD/CT	287 MD/CT	445 MD/CT
AGHT	Transverse	0.33	0.020	0.017	0.013
185-W	Transverse	0.25	0.017	0.014	
CSF	Transverse	0.26	0.017	0.014	0.011
AGHT	Parallel	0.44	0.023	0.021	0.017
185-W	Parallel	0.32	0.021	——	0.015
CSF	Parallel	0.41	0.022	0.020	0.015

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TABLE III

THERMAL CONDUCTIVITY OF AGHT AND 185-W GRAPHITES BEFORE AND AFTER IRRADIATION AT AMBIENT PILE TEMPERATURE

TYPE OF GRAPHITE	ORIENTATION TO EXTRUSION AXIS	AVERAGE THERMAL CONDUCTIVITY cal/cm/sec/°C		
		0 MD/CT	AFTER 430 MD/CT	742 MD/CT
AGHT	Transverse	0.33	0.15	0.14
185-W	Transverse	0.25	0.12	——
CSF	Transverse	0.26	0.13	0.12
AGHT	Parallel	0.44	0.23	——
185-W	Parallel	0.32	0.16	——
CSF	Parallel	0.41	0.20	0.16

TABLE IV

THERMAL EXPANSION OF AGHT AND 185-W GRAPHITES

TYPE OF GRAPHITE	ORIENTATION TO EXTRUSION AXIS	THERMAL EXPANSION COEFFICIENT OVER TEMPERATURE RANGE 20 C TO 300 C x 10^6		
		MAXIMUM	MINIMUM	AVERAGE
AGHT	Transverse	4.4	4.0	4.2
185-W	Transverse	3.7	3.5	3.6
CSF	Transverse	5.1	4.2	4.8
AGHT	Parallel	1.7	1.4	1.5
185-W	Parallel	2.2	1.7	1.9
CSF	Parallel	1.2	0.8	1.0

TABLE V

MACHINABILITY OF AGHT AND 185-W GRAPHITES

TYPE OF GRAPHITE	MACHINABILITY INDEX *
TS-GBF	18
AGHT	28
185-W	39
CSF	31

* Higher index indicates graphite is more readily machinable.

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TABLE VI

PHYSICAL DISTORTION OF AGHT AND 185-W GRAPHITES CAUSED BY IRRADIATION IN HANFORD COLD TEST HOLES

TYPE OF GRAPHITE	ORIENTATION TO EXTRUSION AXIS	PERCENT PHYSICAL EXPANSION AFTER		
		212 MD/CT	287 MD/CT	445 MD/CT
AGHT	Transverse	0.12	0.18	0.27
185-W	Transverse	0.10	0.16	0.25
CSF	Transverse	0.13	0.21	0.26
AGHT	Parallel	0.04	0.05	0.09
185-W	Parallel	0.02	0.05	0.08
CSF	Parallel	0.01	0.01	0.03

TABLE VII

PHYSICAL DISTORTION OF AGHT AND 185-W GRAPHITES CAUSED BY IRRADIATION AT AMBIENT PILE TEMPERATURE IN HANFORD PILES

TYPE OF GRAPHITE	ORIENTATION TO EXTRUSION AXIS	PERCENT DISTORTION AFTER 430 MD/CT	742 MD/CT
AGHT	Transverse	0.03	0.01
185-W	Transverse	0.02	----
CSF	Transverse	0.01	-0.01
AGHT	Parallel	0.0	----
185-W	Parallel	0.0	----
CSF	Parallel	-0.02	-0.03

TABLE VIII
IRRADIATION OF AGHT GRAPHITE WITH TRANSVERSE ORIENTATION TO AXIS OF EXTRUSION AT THE MATERIALS TESTING REACTOR

AVERAGE PERCENT EXPANSION AGHT	 CSF	 TS-GRF	EQUIVALENT HANFORD EXPOSURE MD/CT
0.13	0.13	0.11	225
0.27	0.28	0.24	490
0.33	0.36	0.27	620
0.85	0.65	0.55	1065
1.47	1.08	0.83	1635
1.27	1.21	0.88	1785
2.59	2.07	1.44	2795

TABLE IX

IRRADIATION OF AGHT GRAPHITE WITH PARALLEL ORIENTATION TO AXIS OF EXTRUSION AT THE MATERIALS TESTING REACTOR

AVERAGE PERCENT EXPANSION			EQUIVALENT HANFORD CTH EXPOSURE - MD/CT
AGHT	CSF	TS-GBF	
0.19	0.03	0.13	400
0.09	-0.04	0.06	1140
0.17	-0.23	0.08	1950
-0.04	-0.45	-0.23	3810

TABLE X

IRRADIATION OF 185-W GRAPHITE WITH TRANSVERSE ORIENTATION TO AXIS OF EXTRUSION AT THE MATERIALS TESTING REACTOR

AVERAGE PERCENT EXPANSION			EQUIVALENT HANFORD CTH EXPOSURE MD/CT
185-W	CSF	TS-GBF	
0.07	0.07	0.05	125
0.13	0.16	0.12	280
0.17	0.21	0.16	365
0.29	0.33	0.30	575
0.35	0.43	0.34	745
0.71	0.84	0.67	1320
0.79	1.01	0.81	1545
0.81	1.05	0.78	1600
0.76	1.12	0.80	1680
1.49	1.94	1.10	2645
1.25	1.97	1.04	2675
2.36	3.01	1.89	4005

IRRADIATION OF 185-W GRAPHITE WITH PARALLEL ORIENTATION TO AXIS OF EXTRUSION AT THE MATERIALS TESTING REACTOR

	AVERAGE PERCENT EXPANSION		
185-W	CSF	TS-GBF	EQUIVALENT HANFORD CTH EXPOSURE - MD/CT
0.07	0.02	0.10	550
0.13	-0.10	0.14	1425
-0.22	-0.43	-0.23	2730
-0.26	-0.49	-0.32	2970

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