MAR 28 1963

IID-18258

Study No. II-226, Supplement 1
EGCR

APPROVED

OAK RIDGE OPERATIONS OFFICE

ATOMIC ENERGY COMMISSION

MASTER

STUDY NO. II-226, Supplement No. 1

TEMPERATURE DISTRIBUTION
MODERATOR AND REFLECTOR
REACTOR CORE

EXPERIMENTAL GAS COOLED REACTOR

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Prepared By
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N O T I C E

This report summarizes as of the date of the study the status of this phase of the design of the Experimental Gas Cooled Reactor under construction in the Oak Ridge Area. Since the data was developed prior to completion of all design, fabrication and construction, the information is subject to modification during the evolution of the complete design of the entire facility and no attempt has been made to revise, rewrite, edit or otherwise modify the study to maintain the data current with related research and development programs or subsequent design revisions. Users are cautioned to avoid interpretations and conclusions based on the incomplete data contained herein.

TEMPERATURE DISTRIBUTION MODERATOR AND REFLECTOR
REACTOR CORE

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APPROVED

Dec. 22, 1960

I. OBJECTIVE

The purpose of this study is to determine revised moderator coolant flow requirements in the EGCR core for the latest design using the heat generation distributions given in Reference 2. The temperature distribution in the graphite columns is also determined.

II. CONCLUSIONS

A. The moderator is primarily cooled by coolant flowing in the 1/8 inch annulus formed by the fuel assembly sleeves and the fuel channel holes in the graphite moderator core columns. With the exception of the small experimental tubes, other components, (e.g. flux scanner tubes, control rods, etc.) do not require coolant flow from the reactor lower plenum. The coolant flows required for each of the three zones in the reactor core at full power and maximum anticipated power operation for any column (defined in Reference 2) are as follows:

TABLE 1, FULL POWER
(See Figure 1 for Zone Configuration)

<u>Zone</u>	<u>Coolant Flow Per Channel Lb/hr</u>	<u>Number of Moderator Channels</u>	<u>Total Flow Each Zone Lb/hr</u>
1	131	80	10,480
2	103	88	9,064
3	70	64	4,480

The total moderator annulus coolant flow is 24,024 lb/hr.

TABLE 2, MAXIMUM ANTICIPATED POWER
(See Figure 2 for Zone Configuration)

<u>Zone</u>	<u>Coolant Flow Per Channel Lb/hr</u>	<u>Number of Moderator Channel</u>	<u>Total Flow Each Zone Lb/hr</u>
1	150	28	4,200
2	135	124	16,740
3	126	80	10,080

The total moderator annulus coolant flow is 31,020 lb/hr.

B. The maximum moderator temperature (1220 F average over the cross section) at full power operation, occurs near the peak heat flux, at a location 6.25 to 7.25 feet from the bottom of the active core. The temperature in most of the graphite columns varies from 555 F to 1150 F over the lower half of the column and 1150 F to 990 F over the top half of the column. The maximum graphite surface temperature (exposed to the coolant) is less than 1110 F.

Moderator coolant, small experimental tube coolant, graphite surface and graphite temperature distribution over the entire core for full power and maximum anticipated power operation are presented in Table 1 to 12 and Table 1-A to 10-A respectively.

III. RECOMMENDATIONS

A. The moderator annulus orifices at the bottom dummy fuel assemblies (Ref. 5) should be sized to give flow required for maximum anticipated power in any core column. The flow requirements for the maximum anticipated power conditions are given under Section II-A. Thus, it will not be necessary to change these orifices for any anticipated control rod and fuel programs. The flows given in Table 2 include that portion of the total that permeates through the graphite column. This procedure is in accordance with the recommendations given in Reference 6.

B. For the purpose of estimating total coolant flow by-pass around fuel channels (Ref. 4) it is recommended that the design total flow to moderator annuli be increased by 5% to allow for inaccuracies in sizing and fabricating the unconventional orifices. Thus total coolant by-pass is a maximum of 32,600 lb/hr.

IV. GIVEN DATA

A. Core Component Dimensions and reactor operating conditions as given in Reference 4.

B. Graphite heat generation from Reference 2.

C. Coolant flow for small experimental tubes from Reference 4.

D. Method of Analysis from Reference 3.

V. ASSUMPTIONS

A. Heat is transferred from fully inserted control rod and graphite plugs in large loop facility to adjacent graphite columns, where it is removed by moderator annulus coolant. The heat is assumed to be uniformly distributed over a column cross section.

B. In calculating maximum anticipated heating in any column, the heating valves for a quadrant of a column and for the sleeves were assumed to be proportional to the fuel channel power of that quadrant.

VI. METHOD OF ANALYSIS

The method of analysis is the same as in Ref. 3. The effect on the graphite temperature of irregular block and coolant channel geometries, different coolant temperature in experimental tube and moderator annuli, variation of radial and axial volumetric heat generation, variation of heat transfer coefficients (Figure 3) and method of control rod programming are included in the analysis.

A comparison was made for graphite column no. 1 of the axial temperature distribution for three positions of control rods (see Figure 4):

- (a) 62-inch bank insertion
- (b) 47-inch bank insertion
- (c) Zero bank insertion (Chopped cosine distribution)

The cosine flux distribution gives the highest calculated graphite surface temperature for Column 1. However, the flux distribution for 62-inch bank insertion was selected for all temperature distribution analyses. This selection was made for the following reasons. The highest calculated surface temperature for the cosine distribution occurs at the top of the active column where axial heat conduction in the column will reduce actual temperatures somewhat. Furthermore for the 62-inch insertion, the average graphite surface temperature over the entire column is greater than that of the cosine distribution. Preliminary comparison of maximum surface temperatures in graphite columns other than in Column 1 shows that the 62-inch control rod insertion results in higher graphite surface temperature than for the chopped cosine.

The analysis is based on maintaining fuel channel exposed graphite surface temperature below 1100 F, to prevent rapid oxidation of the graphite in the event of a reactor coolant system rupture. Some of the other column surface temperatures (such as large experimental channel and control rod channels) will exceed 1100 F. However, temperatures higher than 1100 F on these surfaces are acceptable since it would require a much longer time for oxygen to come in contact with these surfaces and the total amount of surface area is smaller.

VII. REFERENCES

1. Memo: C. A. Preskitt to M. Bender, August 8, 1960.
2. ORNL CF 60-10-122, "Gamma-Ray and Fast Neutron Heat Deposition in the EGCR Core", E. A. Nephew.
3. Study II-226, Approved, "Temperature Distribution, Moderator and Reflector".
4. Study II-179-1, Approved, "Reactor Core Coolant Flow Distribution".
5. Study II-176, Approved, "Dummy Fuel Assembly Design and Analysis".
6. Study II-179-2, Approved, "Permeation of Coolant Through Graphite".

VIII. NOMENCLATURE USED IN TABLES 1 TO 12 AND 1-A TO 10-A

Δt Moderator	Moderator annulus coolant temperature above coolant inlet temperature, °F
Δt Experimental Tube	Experimental Tube coolant temperature above coolant inlet temperature, °F
Δt Graphite	Average graphite temperature over cross section above coolant inlet temperature, °F

All tables are for 62-inch bank insertion of control rods, excepted as noted.

FIGURE 1 CORE QUADRANT SHOWING GRAPHITE COLUMNS BY NUMBERS AND MODERATOR CHANNELS BY ZONE NUMBERS AT FULL POWER

<u>ZONE</u>	<u>CONTROLLING COLUMN</u>
1	NO. 1
2	NO. 6
3	NO. 4

SIMILAR TO

DR'N *F.C. 11/5* CH'D APP'D SCALE = 12 SHEET OF ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

FIGURE 2 CORE QUADRANT SHOWING GRAPHITE COLUMNS BY NUMBER AND MODERATOR CHANNELS BY ZONE NUMBERS AT MAXIMUM ANTICIPATED POWER

<u>ZONE</u>	<u>CONTROLLING COLUMN</u>
1	NO. 8
2	NO. 1
3	NO. 4

DR'N <i>F.C 12/5</i>	CH'D	APP'D	SCALE = 12	SHEET <i>1</i> OF	ISSUE
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Figure 3 Heat Transfer Coefficient vs. Mass Rate

FIGURE 4 MODERATOR ANNULI GRAPHITE SURFACE TEMPERATURE VS. CORE HEIGHT

Table I

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 0

Zone 2

Moderator Annulus Flow Rate = 103 lb/hr

Coolant Inlet Temperature = 510 °F

Small Experimental-tube Flow Rate = 103 lb/hr

Axial Position Ft.	Δt Moderator F	Δt Experimental Tube F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	2	44	47
1.25	24	29	148	159
2.25	67	79	256	273
3.25	123	145	363	385
4.25	186	274	459	487
5.25	249	307	533	566
6.25	307	387	580	618
7.25	357	457	598	638
8.25	393	510	581	621
9.25	416	542	538	576
10.25	426	553	485	521
11.25	431	552	478	506
12.25	438	545	457	486
13.25	447	534	468	486
14.25	461	528	471	487
14.50	465	525	478	489

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Table 2

Graphite Column No. 1

Zone 1

Moderator Annulus Flow Rate = 131 lb/hr
Coolant Inlet Temperature = 510⁰ F

Axial Position Ft.	Δt moderator F	Δt graphite surface F	$\bar{\Delta t}$ graphite F
0.25	2	45	58
1.25	24	153	190
2.25	67	262	318
3.25	123	369	439
4.25	186	465	545
5.25	251	538	620
6.25	310	584	662
7.25	360	598	666
8.25	398	577	629
9.25	419	531	563
10.25	428	476	490
11.25	430	461	470
12.25	433	443	446
13.25	439	446	448
14.25	448	451	452
14.50	451	454	455

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Table 3

Graphite Column No. 2

Zone I

Moderator Annulus Flow Rate = 131 lb/hr
Coolant Inlet Temperature = 510 °F

Axial Position Ft.	Δt Moderator F	Δt graphite surface F	$\bar{\Delta t}$ graphite F
0.25	2	42	53
1.25	22	140	173
2.25	62	241	290
5.25	114	340	402
4.25	174	430	500
5.25	234	498	570
6.25	291	542	610
7.25	339	557	617
8.25	375	540	585
9.25	397	500	528
10.25	407	451	463
11.25	412	440	448
12.25	417	427	429
13.25	425	432	433
14.25	436	439	440
14.50	440	442	443

FULL POWER

Table 4 MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 3

Zone 2

Moderator Annulus Flow Rate = 103 lb/hr

Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ graphite F
0.25	2	40	47
1.25	21	133	154
2.25	61	230	262
3.25	112	326	366
4.25	169	411	457
5.25	227	477	523
6.25	280	517	562
7.25	325	532	570
8.25	359	515	544
9.25	380	477	495
10.25	390	432	440
11.25	397	424	429
12.25	405	414	416
13.25	417	423	424
14.25	432	435	435
14.50	437	440	440

Table 5 FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 4

Zone 3

Moderator Annulus Flow Rate = 70 lb/hr
Coolant Inlet Temperature = 510⁰F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite F
0.25	2	42	73
1.25	29	146	237
2.25	81	258	396
3.25	144	369	543
4.25	214	467	664
5.25	279	541	743
6.25	336	585	777
7.25	380	597	764
8.25	409	573	699
9.25	422	524	603
10.25	423	467	501
11.25	423	451	473
12.25	427	437	443
13.25	438	444	449
13.25	455	457	459
14.50	460	463	465

Table 6

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 5

Zone 1

Moderator Annulus Flow Rate = 131 lb/hr
Coolant Inlet Temperature = 510 °F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite F
0.25	2	44	61
1.25	23	147	198
2.25	64	252	329
3.25	119	356	452
4.25	180	448	558
5.25	242	519	632
6.25	301	564	671
7.25	350	579	672
8.25	387	560	630
9.25	409	516	560
10.25	418	464	483
11.25	422	452	464
12.25	426	435	439
13.25	432	439	442
14.25	443	445	446
14.50	446	449	450

Table 7

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 6

Zone 2

Moderator Annulus Flow Rate = 103 lb/hr
Coolant Inlet Temperature = 510 °F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	46	55
1.25	25	155	180
2.25	69	266	305
3.25	126	375	424
4.25	190	471	527
5.25	253	543	610
6.25	311	587	642
7.25	359	599	647
8.25	393	575	611
9.25	413	526	548
10.25	419	468	478
11.25	422	453	460
12.25	426	436	438
13.25	434	441	443
14.25	446	449	450
14.50	451	453	454

Table 8

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 7

Zone 3

Moderator Annulus Flow Rate = 70 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	37	44
1.25	26	128	149
2.25	73	228	259
3.25	132	328	367
4.25	196	417	462
5.25	257	485	531
6.25	311	528	572
7.25	354	543	581
8.25	383	526	555
9.25	399	488	505
10.25	404	442	450
11.25	408	432	437
12.25	416	424	425
13.25	429	435	436
14.25	448	450	451
14.50	454	456	457

Table 9 FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 8

Zone 2

Moderator Annulus Flow Rate = 103 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite F
0.25	2	42	53
1.25	22	141	173
2.25	63	244	291
3.25	116	344	404
4.25	176	433	501
5.25	235	501	571
6.25	290	543	609
7.25	336	555	614
8.25	370	536	580
9.25	390	494	521
10.25	399	444	456
11.25	405	434	441
12.25	412	421	424
13.25	422	429	430
14.25	437	439	440
14.50	441	444	445

Table 10

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 9

Zone 3

Moderator Annulus Flow Rate = 70 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	39	64
1.25	27	136	210
2.25	76	241	352
3.25	136	346	486
4.25	202	438	597
5.25	265	509	672
6.25	320	551	707
7.25	363	565	700
8.25	392	544	647
9.25	407	502	565
10.25	410	451	479
11.25	413	439	457
12.25	420	428	434
13.25	432	438	442
14.25	451	453	455
14.50	456	459	460

Table II

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 1

Zone 1

Moderator Annulus Flow Rate = 131 lb/hr
Coolant Inlet Temperature = 510° F
47-inch bank insertion of Control Rods

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite F
0.25	2	42	54
1.25	21	126	156
2.25	57	220	266
3.25	106	313	373
4.25	162	402	470
5.25	222	476	549
6.25	280	534	607
7.25	333	573	642
9.25	411	571	617
10.25	433	538	568
11.25	444	492	506
12.25	449	477	485
13.25	455	463	466
14.25	462	470	472
14.50	465	470	471

Table 12

FULL POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 1

Zone 1

Moderator Annulus Flow Rate = 131 lb/hr

Coolant Inlet Temperature = 510° F

Chopped Cosine Axial Flux Distribution (Max. to Avg. = 1.28)

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	Δt Graphite F
0.25	5	87	110
1.25	28	129	158
2.25	58	181	216
3.25	94	236	277
4.25	135	293	339
5.25	178	349	398
6.25	223	402	453
7.25	268	449	501
8.25	312	491	541
9.25	354	525	573
10.25	392	551	596
11.25	427	570	610
12.25	458	581	616
13.25	485	586	615
14.25	508	590	613
14.50	514	608	635

MAXIMUM ANTICIPATED POWER
Table 1-A MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 0

Zone 2

Moderator Annulus Flow Rate = 135 lb/hr

Coolant Inlet Temperature = 510⁰F

Small Experimental Tube Flow Rate = 135 lb/hr

Axial Position Ft.	Δt Moderator F	Δt Experimental Tube F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite
0.25	2	2	41	48
1.25	22	28	136	158
2.25	62	76	236	269
3.25	115	141	335	379
4.25	176	217	425	478
5.25	238	298	497	554
6.25	297	377	545	603
7.25	347	447	565	622
8.25	385	500	554	605
9.25	410	535	519	561
10.25	422	548	473	508
11.25	428	549	468	495
12.25	435	545	450	477
13.25	443	538	460	478
14.25	454	532	463	479
14.50	457	530	469	481

MAXIMUM ANTICIPATED POWER

Table 2-A MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 1

Zone 2

Moderator Annulus Flow Rate = 135 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\bar{\Delta t}$ Graphite F
0.25	2	45	58
1.25	24	150	189
2.25	67	258	318
3.25	120	364	440
4.25	188	460	546
5.25	254	533	622
6.25	314	580	664
7.25	365	596	670
8.25	402	577	633
9.25	424	533	568
10.25	432	479	494
11.25	435	465	475
12.25	437	447	450
13.25	442	449	451
14.25	451	454	455
14.50	454	457	458

Table 3-A

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 2

Zone2

Moderator Annulus Flow Rate = 135 lb/hr
Coolant Inlet Temperature = 510⁰ F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	Δt Graphite F
0.25	2	43	55
1.25	23	143	180
2.25	65	247	302
3.25	120	349	419
4.25	182	441	521
5.25	245	513	594
6.25	304	558	636
7.25	353	575	642
8.25	390	558	609
9.25	413'	517	549
10.25	421	466	480
11.25	425	454	463
12.25	429	438	441
13.25	435	441	443
14.25	444	447	448
14.50	448	450	451

Table 4-A

**MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION**

Graphite Column No. 3

Zone 3

Moderator Annulus Flow Rate = 126 lb/hr
Coolant Inlet Temperature = 510° F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	45	55
1.25	22	150	178
2.25	63	256	298
3.25	116	359	413
4.25	176	451	512
5.25	237	520	583
6.25	293	563	623
7.25	341	576	628
8.25	377	555	594
9.25	399	509	534
10.25	408	456	467
11.25	413	444	451
12.25	418	428	431
13.25	426	433	435
14.25	438	441	441
14.50	442	444	445

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Table 5-A

Graphite Column No. 4

Zone 3

Moderator Annulus Flow Rate = 126 lb/hr
Coolant Inlet Temperature = 510^o F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	Δt Graphite F
0.25	2	48	85
1.25	23	157	267
2.25	65	268	435
3.25	120	375	587
4.25	182	472	710
5.25	244	543	789
6.25	303	587	820
7.25	351	599	802
8.25	388	575	729
9.25	409	526	621
10.25	418	468	510
11.25	422	454	480
12.25	426	436	445
13.25	433	440	446
14.25	443	446	449
14.50	448	450	452

**MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION**

Table 6-A

Graphite Column No. 5

Zone 2

Moderator Annulus Flow Rate = 135 lb/hr
Coolant Inlet Temperature = 510 °F

Axial Position Ft.	Δt Moderator F	Δt GRAPHITE Surface F	Δt Graphite F
0.25	2	44	62
1.25	24	146	200
2.25	66	252	334
3.25	122	356	460
4.25	185	450	567
5.25	249	522	643
6.25	309	568	683
7.25	359	585	685
8.25	396	567	643
9.25	418	524	572
10.25	427	473	493
11.25	430	459	472
12.25	433	442	447
13.25	438	445	448
14.25	447	450	451
14.50	451	453	455

Table 7-A

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 6

Zone 2

Moderator Annulus Flow Rate = 135 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	Δt Graphite F
0.25	2	44	57
1.25	24	147	187
2.25	67	254	313
3.25	123	359	434
4.25	186	453	538
5.25	251	526	613
6.25	310	572	655
7.25	361	589	661
8.25	398	570	625
9.25	420	527	562
10.25	428	474	489
11.25	431	461	470
12.25	434	444	447
13.25	439	446	448
14.25	448	451	452
14.50	452	454	455

Table 8-A

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 7

Zone 3

Moderator Annulus Flow Rate = 126 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	Δt Graphite F
0.25	2	43	52
1.25	21	142	170
2.25	60	243	286
3.25	111	342	396
4.25	169	430	491
5.25	228	497	560
6.25	283	539	598
7.25	330	553	604
8.25	365	534	573
9.25	387	492	517
10.25	398	443	454
11.25	404	433	440
12.25	410	420	422
13.25	419	426	427
14.25	432	435	435
14.50	436	439	439

Table 9-A

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 8

Zone 1

Moderator Annulus Flow Rate = 150 lb/hr
Coolant Inlet Temperature = 510°F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	42	59
1.25	25	141	191
2.25	69	245	321
3.25	127	349	445
4.25	193	445	553
5.25	262	521	632
6.25	326	572	678
7.25	380	595	687
8.25	421	583	653
9.25	445	546	589
10.25	454	498	516
11.25	456	484	496
12.25	457	466	470
13.25	459	465	468
14.25	464	467	468
14.50	466	469	470

Table 10-A

MAXIMUM ANTICIPATED POWER
MODERATOR TEMPERATURE DISTRIBUTION

Graphite Column No. 9

Zone 1

Moderator Annulus Flow Rate = 150 lb/hr
Coolant Inlet Temperature = 510 F

Axial Position Ft.	Δt Moderator F	Δt Graphite Surface F	$\overline{\Delta t}$ Graphite F
0.25	2	40	73
1.25	24	134	231
2.25	66	234	381
3.25	122	333	519
4.25	185	425	635
5.25	251	497	714
6.25	312	546	752
7.25	363	567	747
8.25	402	556	691
9.25	425	520	605
10.25	434	475	511
11.25	436	463	487
12.25	439	447	455
13.25	443	449	455
14.25	451	453	456
14.50	454	456	458

← 5.0 →
← 5.25 →

$$\frac{15}{\text{inches}} = 720$$

From Study II - 226
Calculation sheet 2 to 3

$$\text{Coolant Rate } W = 125 \frac{\text{lb}}{\text{HR}}$$

$$N_{Re} = (2.17)(10^3) \quad (\text{Transition region})$$

$$h = 24 \text{ BTU} / \text{ft}^2 \cdot \text{HR} \cdot \text{F}$$

$$G = \frac{W}{A}$$

$$N_{Re} = \frac{De G}{\mu} = 0.24615 (G)$$

$$h = J G (C_p) \left(\frac{G \cdot De}{k} \right)^{1/3} = (J)(G) (1.25) (1.122)$$

W	$G \left(\frac{\text{LB}}{\text{HR} \cdot \text{FT}^2} \right)$	N_{Re}	J	h
100	7067 (10^3)	1.7395 (10^3) ✓	0.00195	21.00 ✓
110	7774 (10^3)	1.914 (10^3) ✓	0.00182	21.58 ✓
125	9187 (10^3)	2.261 (10^3) ✓	0.00185	25.93 ✓
130	9894 (10^3)	2.435 (10^3) ✓	0.00205	30.78 ✓
140	10,600 (10^3)	2.609 (10^3) ✓	0.00225	36.37 ✓
150	11,307 (10^3)	2.748 (10^3) ✓	0.00242	41.73 ✓
		(2.78)		
80	5.654 (10^3)	1.392 (10^3) ✓	0.00285	19.40 ✓
60	4.240 (10^3)	1.044 (10^3) ✓	0.0028	18.10 ✓
40	2.827 (10^3)	0.597 (10^3)		
		(.695)		

Reference: MC-ADAMS, Figure 9-22 & "Colburn" J equation

EGCR Moderator Temperature Distribution

SIMILAR TO

DR'N F.C. 11/5 CH'D FERRATT 12/5 APP'D *[Signature]* SCALE = 12 SHEET 1 OF 17 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

Reference to STUDY II - 226 Calculation sheet 38 to 40

The effect of variation of flow rate on temperature difference between Graphite moderator and coolant is considered below

Laminar Flow From Figure — in subsequent section

W = 40	$h = 16.7$
W = 60	$h = 18.1$
W = 90	$h = 20.25$
W = 110	$h = 21.70$

But Teddell's Model was constructed based on $W = 125 \frac{\text{LB}}{\text{HR}}$ and the Length of film coefficient, $L = \frac{h}{h_c} = \frac{15}{24} = 0.625$

Hence the effective conductivity of graphite for lower flow rate is

W = 110	$k_{110} = 0.625 (21.70) = 13.56$
W = 90	$k_{90} = 0.625 (20.25) = 12.66$
W = 60	$k_{60} = 0.625 (18.1) = 11.31$
W = 40	$k_{40} = 0.625 (16.7) = 10.44$

The Overall Heat Transfer Coefficient is

$$x_{\text{graphite}} = 1.5''$$

$$U = \frac{1}{\frac{1}{h} + \frac{x}{k}}$$

$$U_{125} = \frac{1}{\frac{1}{24} + \frac{1.5}{12.66}} = \frac{1}{0.041667 + 0.008333} = 20.0$$

EGCR Moderator Temperature Distribution

SIMILAR TO

DR'N F.C. 11/15/1 CH'D FERRATT 11/18 APP'D *[Signature]* SCALE = 12 SHEET 2 OF 17 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

$$U_{110} = \frac{1}{0.0544162} = 18.38$$

$$U_{90} = \frac{1}{0.057716} = 17.33$$

$$U_{60} = \frac{1}{0.0635819} = 15.73$$

$$U_{40} = \frac{1}{0.0678214} = 14.74$$

$$Q_{125} = U A \Delta T$$

$$Q_{110} = U_{110} A \Delta T$$

$$\frac{Q_{125}}{Q} = \frac{U_{125}}{U_{110}} \frac{\Delta T_{125}}{\Delta T_{110}}$$

$$1 = \frac{20}{18.38} \frac{\Delta T_{125}}{\Delta T_{110}}$$

$$\Delta T_{110} = 1.0881 \Delta T_{125}$$

$$\Delta T_{90} = 1.1541 \Delta T_{125}$$

$$\Delta T_{60} = 1.2714 \Delta T_{125}$$

$$\Delta T_{40} = 1.3568 \Delta T_{125}$$

DR'N F.C. 11/16	CH'D FERRATT 12/8	APP'D <i>HK</i>	SCALE = 12	SHEET 3 OF 17	ISSUE
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ALLIS-CHALMERS MFG. CO. DEPT.

SIMILAR TO

From Figure A

$$\begin{array}{ll} W = 130 & h = 25.92 \\ W = 140 & h = 20.78 \\ W = 150 & h = 36.37 \end{array}$$

$$U_{130} = \frac{1}{\frac{1}{28.93} + 0.0083333} = \frac{1}{0.0468986} = 21.32$$

$$U_{140} = \frac{1}{\frac{1}{30.78} + 0.0083333} = \frac{1}{0.0408219} = 24.50$$

$$U_{150} = \frac{1}{\frac{1}{36.37} + 0.0083333} = \frac{1}{0.035828} = 27.91$$

$$\Delta t_{130} = \frac{20.0}{21.32} \Delta t_{125}$$

$$\Delta t_{130} = 0.9381 \Delta t_{125}$$

$$\Delta t_{140} = 0.8163 \Delta t_{125}$$

$$\Delta t_{150} = 0.7166 \Delta t_{125}$$

Above correction factors for calculating graphite temperatures are plotted on sheet 4A

DR'N	F.C. 11/16	CH'D	FERRATT 12/8	APP'D	SCALE	= 12	SHEET	4 OF 17	ISSUE
ALLIS-CHALMERS MFG. CO.				DEPT.					

SIMILAR TO

TOTAL GAMMA and FAST NEUTRONS HEATING OF GRANITE COLUMNS
(Reference to E. A. NEPHEW Report, "Gamma-Ray
and Fast Neutron Heat Deposition in HLEGCR Core")

BASED ON FIGURE 7 & 16 OF E. A. NEPHEW

BLOCK No	(KW)	BTH HR	g' (BTH HR-FT)	ADDITIONAL HEAT ★ ★	TOTAL HEAT BTH HR-FT	INPUT NUMBER FOR COMPUTER
0	66.846	228,145	15,734	1,118	16,852	16,852
1	88.946	303,573	20,936		20,936	20,936
2	81.703	278,869	19,232		19,232	19,232
3	61.182	208,814	14,400		14,400	14,400
4	28.421	97,000	6,690		6,690	6,690
5	85.551	291,985	20,137		20,137	5,034
6	71.138	242,794	16,744		16,744	16,744
7	49.658	169,483	11,688		11,688	11,688
8	45.934	156,772	10,812	669	11,481	5741
9	23.657	80,741	5,568	669	6,237	6,237

★ ★ Information From Study II-179-1, Approved

(a) BLOCK NO. 0 From Inserted Central Control Rod = 19 KW
(Only Quarter of heat experienced by Block) = 4.75 KW

(b) BLOCK NO. 9 From GRANITE PLUGS = 38,807 BTH/HR
only $\frac{1}{4}$ of it goes to #9 = 9,700

SIMILAR TO

DR'N F.C. 11/18 CH'D FERRATT, 1/8 APP'D [Signature] SCALE = 12 SHEET 5 OF 17 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

BASED on Figure 8 & 15 of E.A. Nephew

	Per Sleeve (KW)	$\frac{BTU}{HR}$	Q_s''' $\frac{BTU}{HR-FT^3}$	Q_s' $\frac{BTU}{HR-FT}$	
0	7.1843	24,520	14,718	1,635	
1	8.6448	29,505	22,523	1,967	
2	7.6480	26,103	19,926	1,740	
3	5.7548	19,641	14,993	1,309	
4	4.7130	16,085	12,278	1,072	
5	8.1673	27,875	21,279	1,858	
6	6.6628	23,740	17,359	1,516	
7	4.9660	16,949	12,938	1,130	
8	5.1440	17,556	13,402	1,170	
9	3.7265	12,719	9,709	848	

From sheet 24 Report II - 226

Cross sectional Area of Graphite meat sleeve = 0.0873 FT²

Column Volume of Graphite must sleeve = 1.31 FT³

Total Length = 15.0 FT

$$g''' = \frac{g}{FT^3}$$

$$g' = \frac{g}{F_I}$$

SIMILAR TO

DR'N F.C. 11/18/60

CH'D FERRATT, 2/8

APP'D

SCALE = 12

SHEET 6 OF 17

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

①

1

ISSUE

DEPT.

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Reference Figure 7, A-1 and 2

Gamma heat deposition in Graphite Column AT MAXIMUM
ANTICIPATED BULK GENERATION

0	15.643 13.033 13.033 9.6609*				
16	13.272 13.068 14.239 14.225	13.458 14.291 14.291 14.433			
32	14.493 14.496 13.467 13.485	14.523 14.485 14.049 14.507	13.993 13.031 13.031 7.340		
48	12.993 12.965 11.860 11.713	13.467 12.780 10.195 8.952	11.358 4.555* 7.369 2.859*		
64	8.631 7.272 3.048* 2.633*				
80	4				

SIMILAR TO

DR'N F.C 11/24 CH'D FERRATT 148 APP'D *[Signature]* SCALE = 12 SHEET 8 OF 17 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

A

B

C

Reference Figure 15, A-1 and 2

Fast Neutron Heat Deposition (KW) in Graphite Fuel Assembly Sleeves at Maximum Anticipated Power Generation.

0	2.836 2.836 2.836 0				
16	2.836 2.836 2.836 2.836	2.836 2.836 2.836 2.836			
32	2.836 2.836 2.836 2.836	2.836 2.836 2.836 2.836	2.836 2.836 2.836 2.836		
48	2.521 2.626 2.310 2.415	2.626 2.521 2.415 2.310	2.626 2.521 2.415 2.310	8	
64	2.205 2.205 4			9	
80					

SIMILAR TO

DR'N F. 11/25

CH'D FERRATT, 2/8

APP'D

SCALE

= 12

SHEET 9 OF 17

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Reference : Figure 8, A1, and 2

Gamma Heat Deposition (KW) in Graphite Fuel Element Sleeves, At Maximum Anticipated Power Generation.

0	5.845 5.845 5.845 0				
16	5.845 5.845 5.845 5.845	5.845 5.845 5.845 5.845			
32	5.845 5.845 5.412 5.412	5.845 5.845 5.629 5.845	5.845 5.845 5.845 8		
48	5.196 5.412 4.763 4.979	5.412 5.196 4.979 4.763	5.412 4.763 9		
64	4.546 4.546				
80	4				

DR'N F.C. 11/05	CH'D FERRATT 12/8	APP'D <i>HK</i>	SCALE = 12	SHEET 10 OF 17	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.					

SIMILAR TO

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

Total Gamma and Fast Neutron average heat deposition in Sleeves at Maximum Anticipated Heat Generation.

		G_2	G_3	
	Power Level (KW)	$\frac{BTU}{HR}$	$\frac{BTU}{HR-FT^3}$	$\frac{BTU}{HR-FT}$
0	8.681	29,625	22,617	1,975
1	8.6810	29,625	22,617	1,975
2	8.3595	28,531	21,779	1,902
3	7.5555	25,787	19,685	1,719
4	6.7510	23,041	17,589	1,536
5	8.6810	29,625	22,617	1,975
6	8.6668	29,355	22,408	1,957
7	7.5555	25,787	19,685	1,719
8	8.6810	29,628	22,617	1,975
9	7.5555	25,787	19,685	1,719

SIMILAR TO

DR'N *FC* *H/20* CH'D *FERRATT* *12/8* APP'D *[Signature]* SCALE = 12 SHEET *12* OF *17* ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

FROM: E. A. NEPHEW "Gamma-Ray and Fast Neutron
Heat Deposition in The EGCR CORE"

SUMMARY OF TOTAL HEAT DEPOSITION (KW) IN COLUMNS AND SLEEVES

66.846 *82.546 [7.1843] *8.6810				
88.946 *89.312 [8.6448] *8.6810	85.551 *90.981 [8.1673] *8.6810			
81.708 *89.171 [7.6480] *8.3595	71.138 *91.750 [6.6628] *8.6008	45.934 *78.185 [5.1440] *8.6810		
61.182 *79.505 [5.7548] *7.5555	49.658 *75.428 [4.9660] *7.5555	23.657 *48.007 [3.7265] *7.5555		
28.421 *40.729 [4.7130] *6.7510				

UNBRACKETED NUMBERS : GRAPHITE COLUMNS POWER

BRACKETED NUMBERS : FUEL ASSEMBLY SLEEVES POWER

* : MAXIMUM ANTICIPATED POWER

SIMILAR TO

DR'N FC 411	CH'D FERRATT 12/8	APP'D <i>[Signature]</i>	SCALE = 12	SHEET 13 OF 17	ISSUE
ALLIS-CHALMERS MFG. CO.			DEPT.		

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

INPUT NUMBERS

BLOCK NO. 1, 6 & 7,

NORMAL OPERATION

BLOCK NO. LOCATION		No. 1	No. 6	No. 7
[350]	$\bar{Q}_s$ (Stator)	55.22, 523	55.17359	55.12938
[351]	$\bar{Q}_B$ (Block)	55.20, 936	55.16744	55.11, 688
[352]	$\bar{Q}_s$ (Stator)	54.1, 967	54.1516	54.1130
[361]	C_{11}	48.878	→ Same	→ Same
[362]	C_{12}	-49.61053	→ Same	→ Same
[372]	$\frac{\Delta T}{Q}$ (at $\frac{1}{2} \rho_0$)	-48.97	→ Same	→ Same
[379]	(W) Annulus	53.115	53.110	53.100
[390]	Number of Channels/Node	51.40	→ Same	→

MAXIMUM ANTICIPATED HEAT GENERATION

	No. 1	No. 6	No. 7
[350]	55.22617	55.22468	55.19685
[351]	55.21936	55.21, 596	55.17754
[352]	54.1975	54.1975 57	54.1719
[379]	53.120	53.120	53.100
[390]	51.4	51.4	51.4

Note: Effect of error in input number of Block NO. 1 and Block NO. 6 are negligible

SIMILAR TO

DR'N F.C 12/11 CH'D Ferrara 12/8 APP'D *[Signature]* SCALE = 12 SHEET 14 OF 17 ISSUE

ALLIS-CHALMERS MFG. CO. DEPT.

INPUT NUMBERS

BLOCK NUMBER 2 & 3

NORMAL HEAT GENERATION

		No. 2	No. 3
[350]	$\bar{Q}_s$	55.19926	55.14993
[351]	$\bar{Q}_B$	55.19232	55.14400 ✓
[352]	$\bar{Q}_s$	54.1740 ✓	54.1309 ✓
[361]	C_{11}	48.875 ✓	→
[362]	C_{12}	-49.59524	→
[372]	ΔT_a	-48.9000	→
[379]	Wannulus	100	82.90
[390]	No. of channels in Model	51 4	51.40

MAXIMUM ANTICIPATED HEAT

		No. 2	No. 3
[350]		55.21779	55.19685
[351]		55.20989	55.18714 ✓
[352]		54.1902	54.1719
[379]			

SIMILAR TO

DR'N

F.C. 12/2

CH'D

FERGATT 12/8

APP'D

[Signature]

SCALE

=12

SHEET 15 OF 17

ISSUE

ALLIS-CHALMERS MFG. CO.

DEPT.

A

B

A-C MFG. CO., MILWAUKEE, WIS. FORM NO. 6833-3

INPUT NUMBERS

NORMAL POWER

BLOCK NO. LOCATION		BLOCK NO. 4	BLOCK NO. 8	NO. 9
[350]	$\bar{Q}_s$	55.12278 ✓	55.13402 ✓	54.9709 ✓
[351]	$\bar{Q}_b$	54.6690 ✓	54.5741 ✓	54.6237 ✓
[352]	$\bar{Q}_s$	54.1072 ✓	54.1170 ✓	53.848 ✓
[361]	C_{11}	49.207 ✓	49.1645 ✓	49.1525 ✓
[362]	C_{12}	-50.280 ✓	-50.21591 ✓	-50.33333 ✓
[372]	ΔT_a	-49.250 ✓	-49.368 ✓	-49.325 ✓
[379]	W_{ANN}	5 ✓	52 ✓	
[390]	No. of channels in net	51.2000	51.15	51.200

MAXIMUM ANTICIPATED POWER

		BLOCK NO. 4	NO. 8	NO. 9
[350]	$\bar{Q}_s$	55.17589 ✓	55.22617 ✓	55.19685 ✓
[351]	$\bar{Q}_b$	54.9587 ✓	54.9653 ✓	55.12203 ✓
[352]	$\bar{Q}_s$	54.1536 ✓	54.1719 ✓	54.1719 ✓
[379]	W_{ANN}		1975 ✓	

NOTE: Effect of error in input number for loc 352 of Block No. 8 is negligible. F. H. H.

DR'N <i>F.C. 12/2</i>	CH'D <i>F.H. H. 12/2</i>	APP'D <i>[Signature]</i>	SCALE = 12	SHEET 16 OF 17	ISSUE
ALLIS-CHALMERS MFG. CO.			DEPT.		

SIMILAR TO

A INPUT NUMBER BLOCK NO. 0		B FULL POWER	C MAXIMUM ANTICIPATED POWER
[349]	$\bar{Q}$ channel	53.772 ✓	54.1109
[350]	$\bar{Q}_5$	55.18718 ✓	55.22617 ✓
[351]	$\bar{Q}_{13}$	55.16852 ✓	55.20940 ✓
[352]	$\bar{Q}_5$	54.1635 ✓	54.1975 ✓
[353]	C ₄	50.2875	
[354]	C ₅	52.1415	
[361]	C ₁₁	48.795	
[362]	C ₁₂	-50.325 ✓	
[364]	W channel	53.100 ✓	53.100
[379]	W channel	53.103 ✓	53.135
[390]		51.30	51.30

DR'N F.C. 12/21		CH'D FERRATT 12/96	APP'D <i>ML</i>	SCALE = 12	SIMILAR TO	SHEET 17 OF 17	ISSUE
ALLIS-CHALMERS MFG. CO. DEPT.							