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SUBJECT: Temperature Structure in the Midplane Spacer for EGCR Fuel Rod

TO: Distribution

FROM: L. G. Epel
J. K. T. Jung

Abstract

The steady-state temperature structure for a cross-sectional area at the midplane of the EGCR fuel rod is presented. The temperatures are given for the UO_2 as well as for the stainless steel tubing and spacer.

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Introduction

The necessity of having a spacer at the midplane of the EGCR fuel rod to restrain excessive bowing has long been acknowledged. The introduction of such a spacer perturbs the temperature distribution which would ordinarily exist there; an investigation of the temperature field with the spacer in place was undertaken. The lack of complete symmetry and homogeneity made an analytical solution unwieldy to obtain; hence, numerical methods utilizing the IBM-704 were resorted to.[1] The system studied is shown in Fig. 1. It shows the fuel rod and spacer for an outer rod (which is the higher temperature rod) broken up into 129 areas. Due to symmetry considerations, only half the total cross section needed to be studied and for calculational purposes the diameter 1-121 was assumed to be insulated so that the azimuthal gradients were zero.

Procedure — Since the concern here was in the magnitude of various temperatures themselves, rather than the values of the temperature gradients, four conservative boundary conditions were imposed which afforded computational simplification. They were:

(1) The heat transfer coefficient at the outside surface of the clad was considered to be 300 Btu/hr-ft^2-^{o}F, which is the coefficient in effect when the flow is established in the tube bundle. Actually, at flow disrupters such as a spacer the heat transfer coefficient rises significantly.

(2) Heat flow out of the ends of the spacer (normal to Fig. 1) was denied and thus a three-dimensional problem was avoided. In reality the spacer is only 1/4 in. thick (instead of infinitely thick as assumed here) and including this effect would have lowered all temperatures considerably.

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[1] T. B. Fowler and E. R. Volk, Generalized Heat Conduction Code for the IBM-704 Computer, ORNL-2734 (October 16, 1959).

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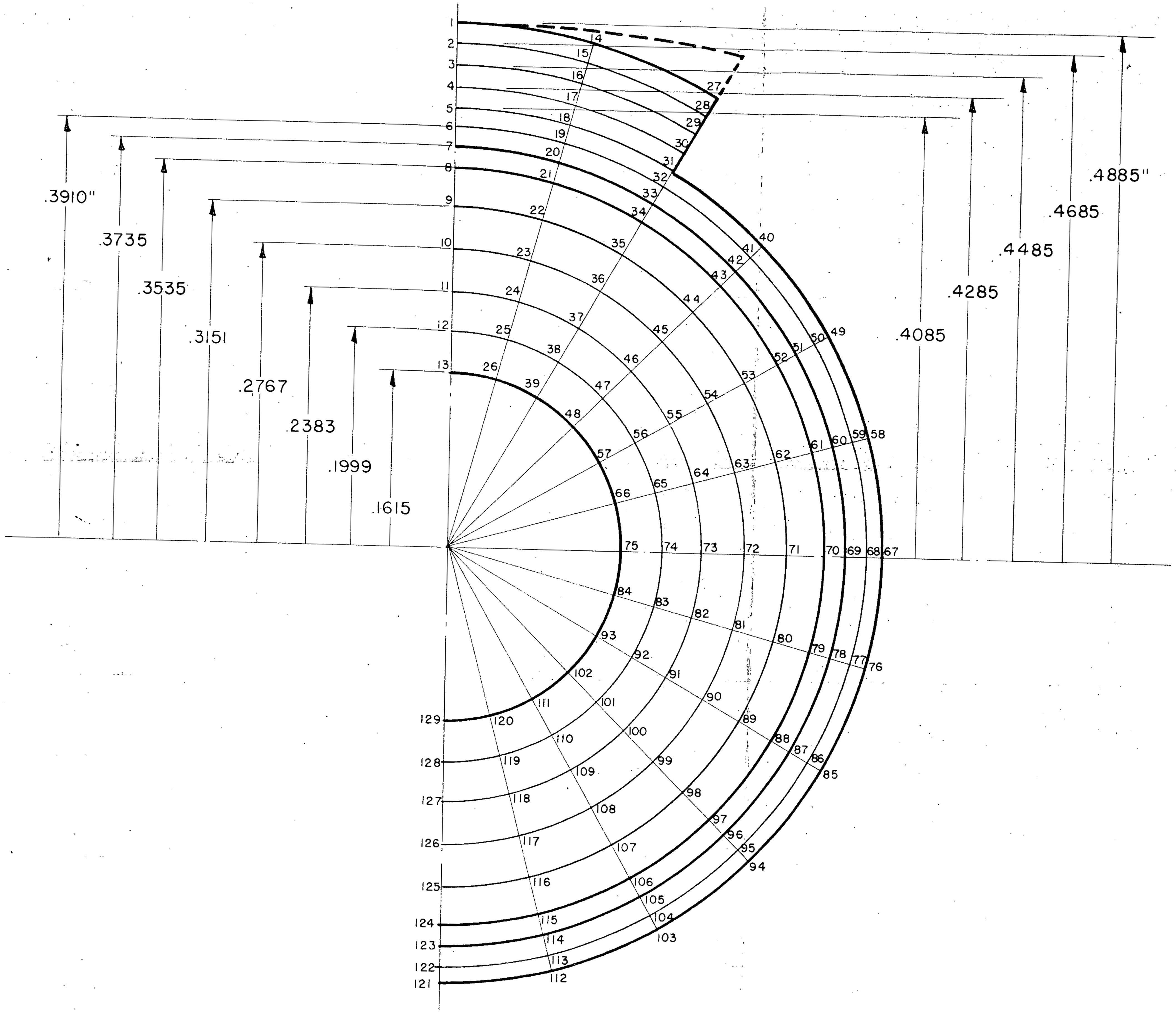

FIG. I. POINT NOMENCLATURE FOR MID-PLANE OF EGCR FUEL ROD

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(3) The fin effect of the two splines that are spaced 120° and 180° from the one touching the graphite sleeve was neglected. Taking this into account would have further reduced the temperature field.

(4) The surface defined by points 1 through 27 in Fig. 1 was assumed to be insulated. In the actual case there will be some heat transferred through this surface causing a further depression of the temperature in that region.

Besides the four conservative approximations noted above, one further simplification was instituted to facilitate computation. The arc 1-27 actually has its center at a point 1.5 in. from point 1 (Fig. 1) instead of at the center of the rod. Had the true radius of curvature been used for arc 1-27, the area 27-31 would have been increased 60% above that shown in the figure (see dotted lines). To avoid unduly penalizing the system by this transformation, the heat transfer coefficient acting on surface 27-31 was raised 60% from 300 to 480 Btu/hr-ft^2-°F.

The heat generation rate distribution that was used is shown in Fig. 2 in normalized form. The zero degree line in Fig. 2 corresponds to line 1-13 in Fig. 1; the inner curve in Fig. 2 refers to the inner surface of the UO_2 pellet while the outer curve relates to the outside surface of the UO_2. Points between the inner and outer surfaces of the oxide have their heat generation rates represented by a point proportionately between the inner and outer curves of Fig. 2. For example, a point half way between the inner and outer surface of the oxide pellet and at 30° from line 1-13 has its generation rate represented by point M in Fig. 2, halfway between points A and B.

The average value of the heat source was taken as 8326 Btu/hr-in.^{3} which corresponds to a point having a generation rate 2.158 times the overall reactor average of 3858 Btu/hr-in.^{3} The maximum power density is not expected to exceed this value.

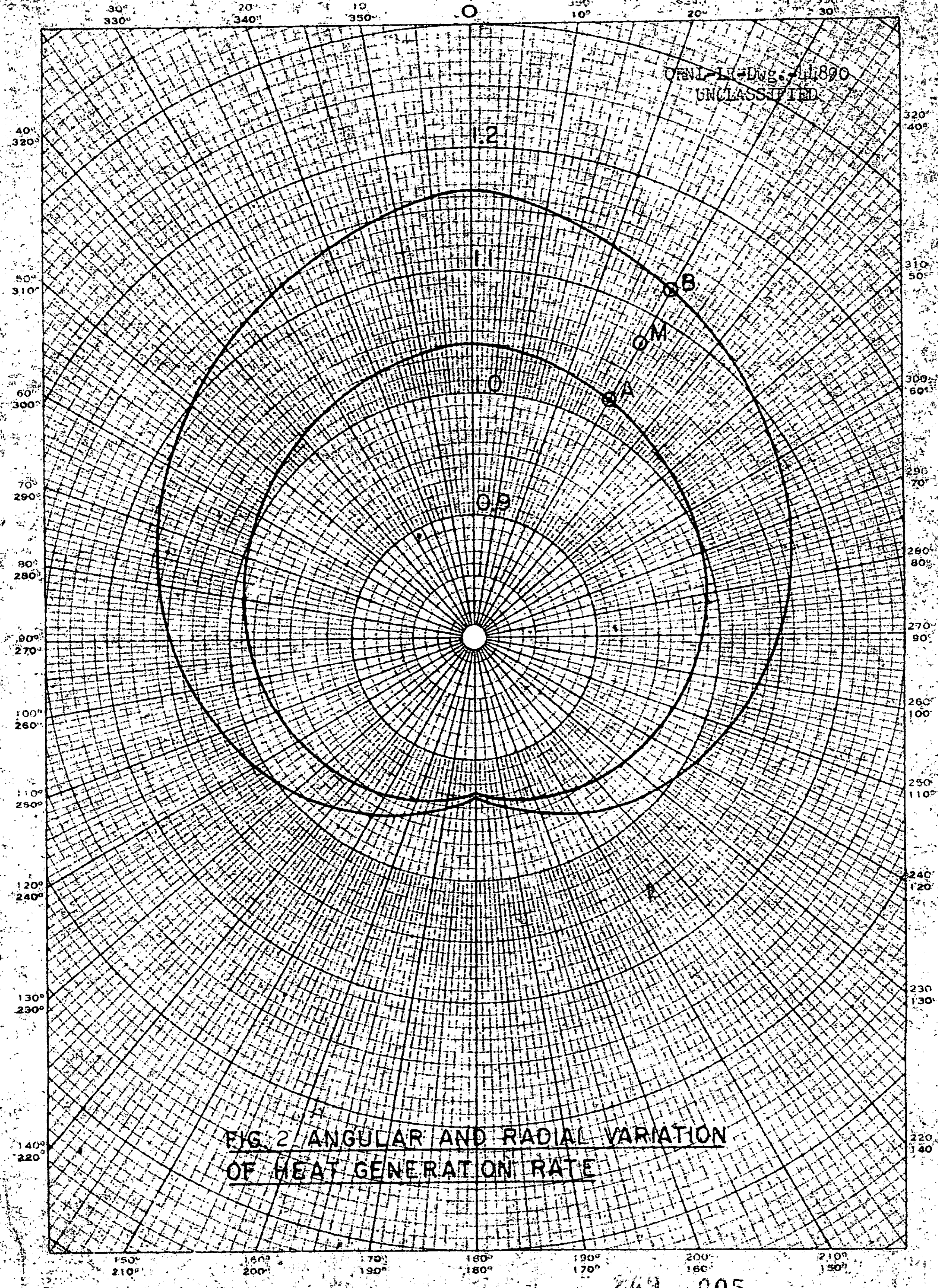

FIG. 2 ANGULAR AND RADIAL VARIATION OF HEAT GENERATION RATE

For purposes of this study the thermal conductivity of the UO_2 was taken as 1.00 Btu/hr-ft-°F and that of the stainless steel was considered to be 12.0 Btu/hr-ft-°F.

Conclusions

The temperature structure is shown in the contour plot of Fig. 3 in which the temperatures noted are in degrees Fahrenheit above the ambient bulk gas temperature. The accompanying table similarly gives the value of the temperature in degrees Fahrenheit above ambient gas temperature for points 1 through 129 in Fig. 1. It is seen that even with the four pessimistic approximations mentioned in the procedure applied to the analysis, the maximum stainless steel temperature existing (point 8) was only 883°F above the ambient gas temperature.

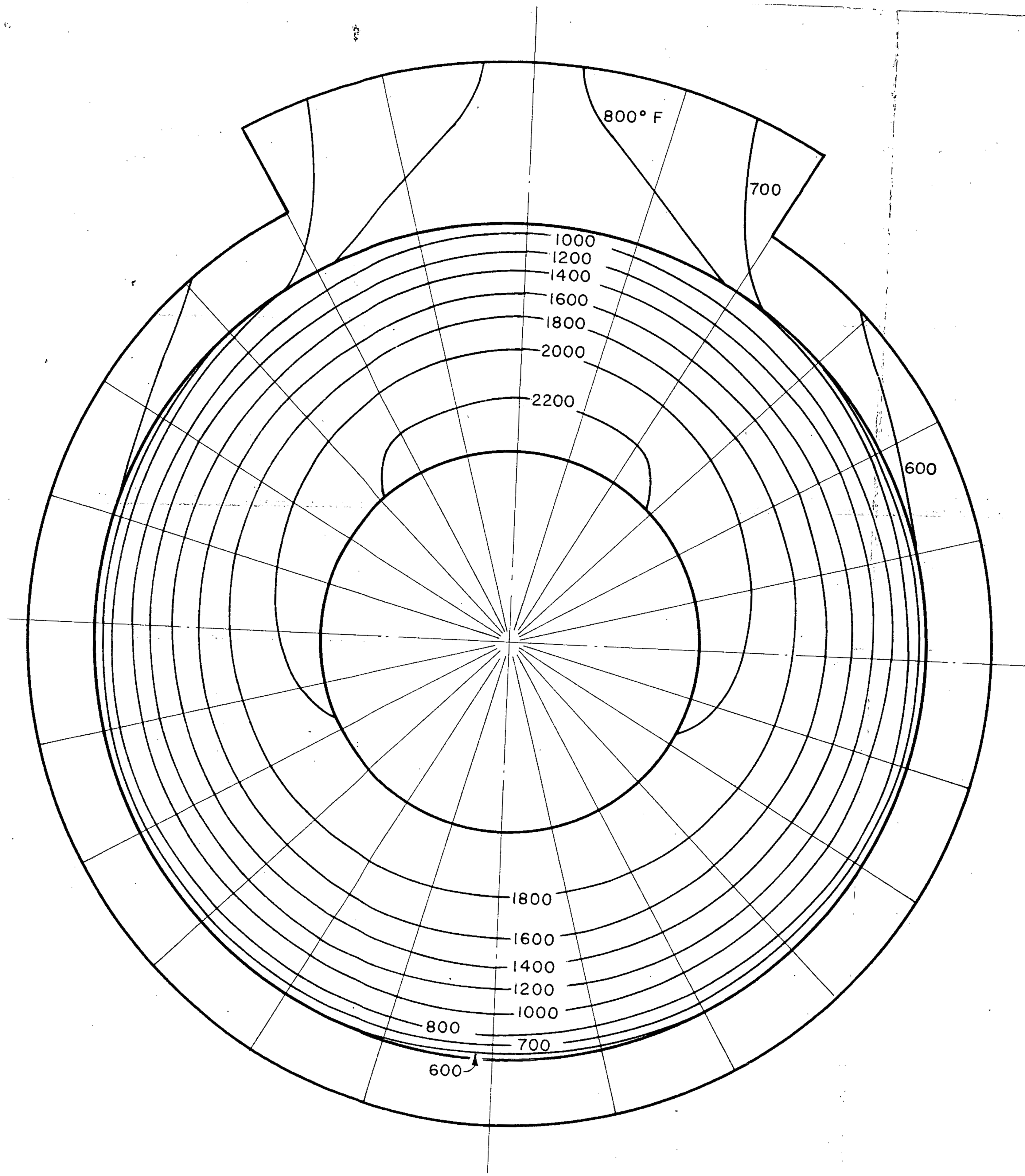

FIG. 3. TEMPERATURE DISTRIBUTION IN MID-PLANE OF AN OUTER ROD IN THE EGCR FUEL CLUSTER.

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STEADY STATE TEMPERATURE DISTRIBUTION AT MIDPLANE OF EGCR FUEL ROD

Point Number	ΔT(°F)	Point Number	ΔT(°F)	Point Number	ΔT(°F)
1	815	44	1192	87	525.7
2	816.1	45	1614	88	548.4
3	819.8	46	1927	89	1040
4	826.4	47	2124	90	1437
5	836.2	48	2195	91	1735
6	847.8	49	554.1	92	1926
7	862.4	50	574.5	93	1996
8	883.3	51	595.4	94	480.8
9	1374	52	619.9	95	498.7
10	1764	53	1143	96	517.3
11	2051	54	1564	97	539.7
12	2230	55	1877	98	1024
13	2293	56	2075	99	1417
14	768.7	57	2147	100	1712
15	770	58	528.8	101	1901
16	774.3	59	548.3	102	1970
17	781.7	60	568.5	103	474.9
18	792.7	61	592.5	104	492.5
19	805.3	62	1108	105	510.9
20	820.8	63	1523	106	533
21	842.3	64	1833	107	1011
22	1340	65	2031	108	1400
23	1738	66	2102	109	1692
24	2031	67	511.4	110	1880
25	2214	68	530.3	111	1949
26	2279	69	550	112	470.9
27	615.4	70	573.5	113	488.4
28	618.1	71	1080	114	506.6
29	626.4	72	1490	115	528.4
30	640.8	73	1796	116	1002
31	662.4	74	1991	117	1388
32	685.3	75	2062	118	1679
33	707.8	76	498.5	119	1866
34	733.1	77	517	120	1935
35	1259	78	536.3	121	469.4
36	1676	79	559.3	122	486.8
37	1982	80	1058	123	504.9
38	2174	81	1461	124	526.6
39	2242	82	1763	125	997.6
40	593.9	83	1956	126	1382
41	615.5	84	2027	127	1673
42	637.4	85	488.6	128	1860
43	662.6	86	506.7	129	1930

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