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SNAP-8

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DIVISION

TECHNICAL MEMORANDUM

PREPARED BY: E. F. Perez, J. Edberg

ABSTRACT

CYLINDRICAL RADIATOR ANALYSIS WITH INTERIOR INSULATED

An investigation was made to evaluate the sizes and weights of cylindrical radiators for use in the SNAP-8 heat rejection system. In this investigation the radiators were sized to provide the required heat rejection, while operating with the maximum external heat load from solar and planetary sources, using OS-124 or NaK as the cooling fluids.

The interiors of the cylinders were considered to be insulated with heat radiating from the outside surface of the radiation only.

The resulting optimum radiator sizes were compared to an optimum flat radiator configuration.

APPROVED:

DEPARTMENT HEAD P. I. Wood

P. I. Wood

NOTE: This document is considered preliminary and is subject to revision as analysis progresses and additional data are acquired. The general reader may encounter internal reference not available to him.

CYLINDRICAL RADIATOR ANALYSIS WITH INTERIOR INSULATED

I. INTRODUCTION

The flat, hinged radiator, conceived early in the design phase of the SNAP-8 has several drawbacks. These drawbacks include hinges which are difficult to fabricate for space applications because of the possibility of cold welding. The second drawback is that in order to connect the moving radiator panels to the fixed components in the PCS, it is necessary to use some type of flexible bellows connection and a mechanical deploying mechanism which would affect system reliability. Also the lack of rigidity due to the flexible joints could possibly cause problems in maneuvering in space.

Consequently, it was decided to investigate the possibility of using a rigid cylindrical radiator which would fit within the envelope of the aerodynamic fairing of the S-IV stage of the Saturn C-1 Booster.

Heat rejection from this radiator configuration would be from the outside surface only, with the interior being insulated to prevent irradiation from the main radiator onto the lube and cool radiator section, the NS, the PCS and the payload.

II. TECHNICAL DISCUSSION

A. RADIATOR DESIGN CRITERIA

The main heat rejection radiator was designed to provide the necessary area to reject approximately 330 kilowatts (thermal), at temperature levels corresponding to the current system design points with the radiator inlet and outlet temperatures at 665°F and 495°F, respectively. The lube and cool loop radiator was designed to reject 17.3 kw (thermal) with the radiator inlet and outlet temperatures at 250°F and 220°F, respectively. It was further assumed that the cylindrical radiators would reject heat by radiation from the outer surface only. Adequate insulation would be provided internally to minimize heat radiation from hot to cold surfaces. It was assumed that the radiator would be designed for the maximum external heat flux with the axis of the cylindrical perpendicular to the solar flux.

Two fluids were considered in the analysis; OS-124 and NaK, the first being a hydrocarbon and the second an inorganic liquid metal.

B. BASIC ASSUMPTIONS

The analyses were conducted by making certain simplifying assumptions and approximations. Some of the more important assumptions are noted below:

1. The main heat rejection radiator and the L/C loop radiator were assumed to be contained within the 20-ft diameter of the Saturn C-4 envelope. It was further assumed that the ends of the cylindrical radiators were closed and no heat would be transferred through them.

2. The minimum fin thickness was assumed to be 0.015 in. from fabrication and strength considerations. The fin profile was assumed to be either rectangular or trapezoidal as indicated in the results of this analysis.

3. Calculations of radiator heat rejection were performed using data, equations and tables developed for flat radiators. Conversion to cylindrical radiators was accomplished by assuming that the tube and fin could be sectioned as shown in Figure 1.

4. The micrometeorite armor was assumed to be 0.320 inch thick and made of castable aluminum. The heat rejection from the fins was determined using data, curves and equations of Mackay and Bacha, Reference 1. The effects of mutual irradiation between tubes and fins was not considered.

5. Longitudinal heat conduction along tubes and fins was not considered.

6. Fin dimensions were assumed to be constant along the length of the radiator.

III. METHOD OF ANALYSIS

The method of analysis was similar to that performed in the flat folding radiator. The procedure followed approximately the following steps.

A. The heat rejected from the fin was based on at the armor surface temperature for each of the 7 nodes into which the entire main heat rejection radiator was divided. After determining the length of fin required per node, sum up all the lengths.

B. The weight per unit length of the tube and fin was calculated, then radiator weight was calculated using the total lengths evaluated previously. These weights do not include the weight of manifolds or tubes connecting the radiators to the PCS.

C. The calculations were repeated for radiators having different fin dimensions.

IV. RESULTS AND CONCLUSIONS

A. The results of calculations for cylindrical radiators using OS-124, were plotted in Figure 2 which shows radiator weights as a function of fin dimensions and radiator area.

B. Results of the calculation for cylindrical radiators using NaK are shown plotted in Figure 4. It is noted that, in all cases calculated in this study, the fin width of approximately 3.0 inches invariably resulted in the lightest configurations.

C. A comparison of the weights of the main radiator in cylindrical configuration for OS-124 and NaK are shown in Figure 3.

D. It may be concluded that cylindrical radiators using NaK coolant can replace the hinged flat radiator with a very small weight penalty. For comparison, Table I shows a summary of fin dimension, weights of tubes and fins and radiator areas for the optimum flat radiators and cylindrical radiators.

TABLE I

Radiator Configuration	Flat Radiator	Cylindrical Radiators		
Coolant	NaK	NaK	NaK	OS-124
Fin width - inches	4.55	3.0	3.0	3.0
Fin thickness at root $\sim\delta_H$ inches	.064	.060	.040	.060
Fin thickness at tip $\sim\delta_c$ inches	.016	.030	.020	.030
Total projected area - ft^2	1360*	1000**	1110**	1100**
Weight of tubes and fins ~lb	880	1120	1050	1240

* Projected area on both sides of flat radiator

** Outside area of cylinder

Reference

D. B. Makay, C. P. Bacha, Space Radiator Design and Analysis, Part I, ASD Technical Report 61-30, dated October 1961.

TYPICAL CYLINDRICAL RADIATOR FIN SECTION

(Cylindrical Radiator Fin is Obtained by Cutting Flat Radiator Fin Along "Cut" Line.)

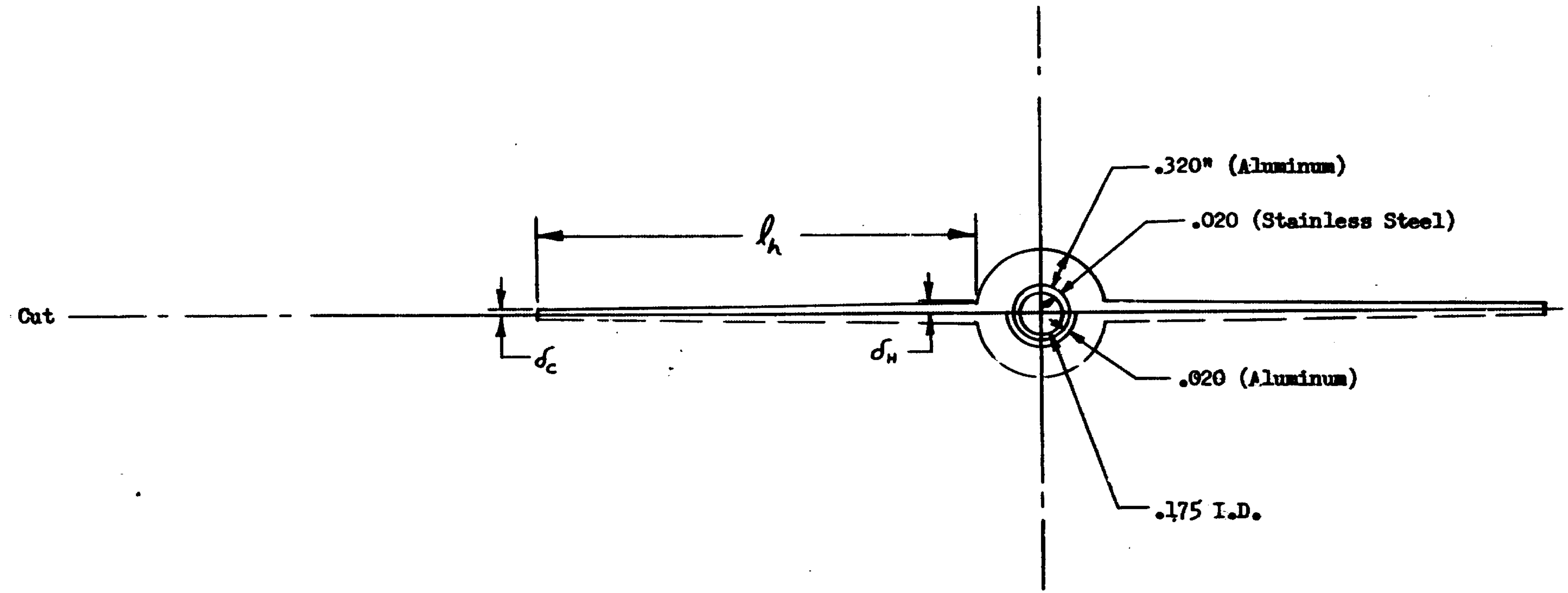

FIGURE I

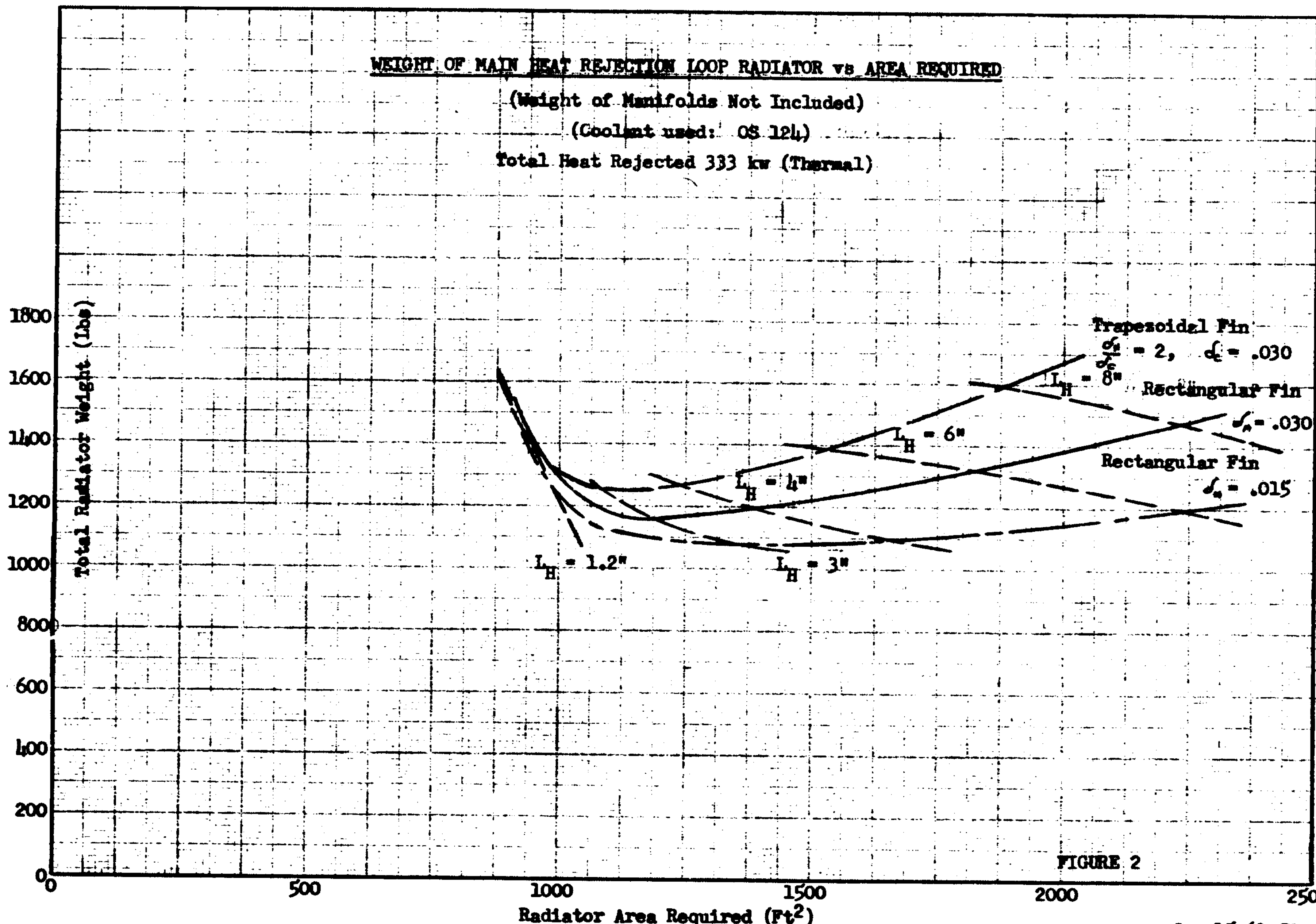

FIGURE 2

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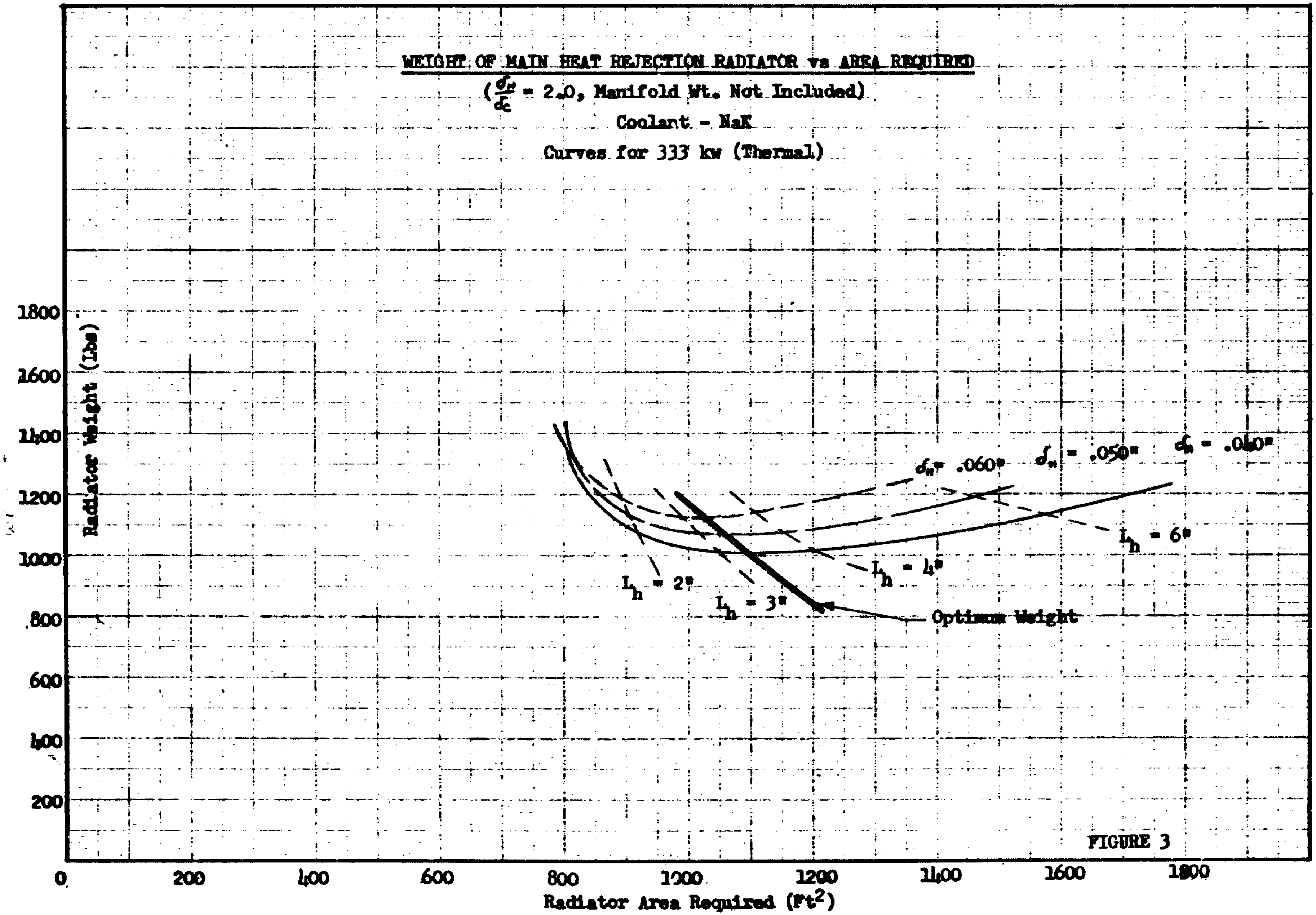
WEIGHT OF MAIN HEAT REJECTION RADIATOR vs AREA REQUIRED
($\frac{d_H}{d_C}$ = 2.0, Manifold Wt. Not Included)
Coolant - NaK
Curves for 333 kw (Thermal)
Radiator Weight (Lbs)
1800
1600
1400
1200
1000
800
600
400
200
0
200
400
600
800
1000
1200
1400
1600
1800
Radiator Area Required (Ft²)
d_H = .060"
d_H = .050"
d_H = .040"
L_h = 2"
L_h = 3"
L_h = 4"
L_h = 6"
Optimum Weight

FIGURE 3

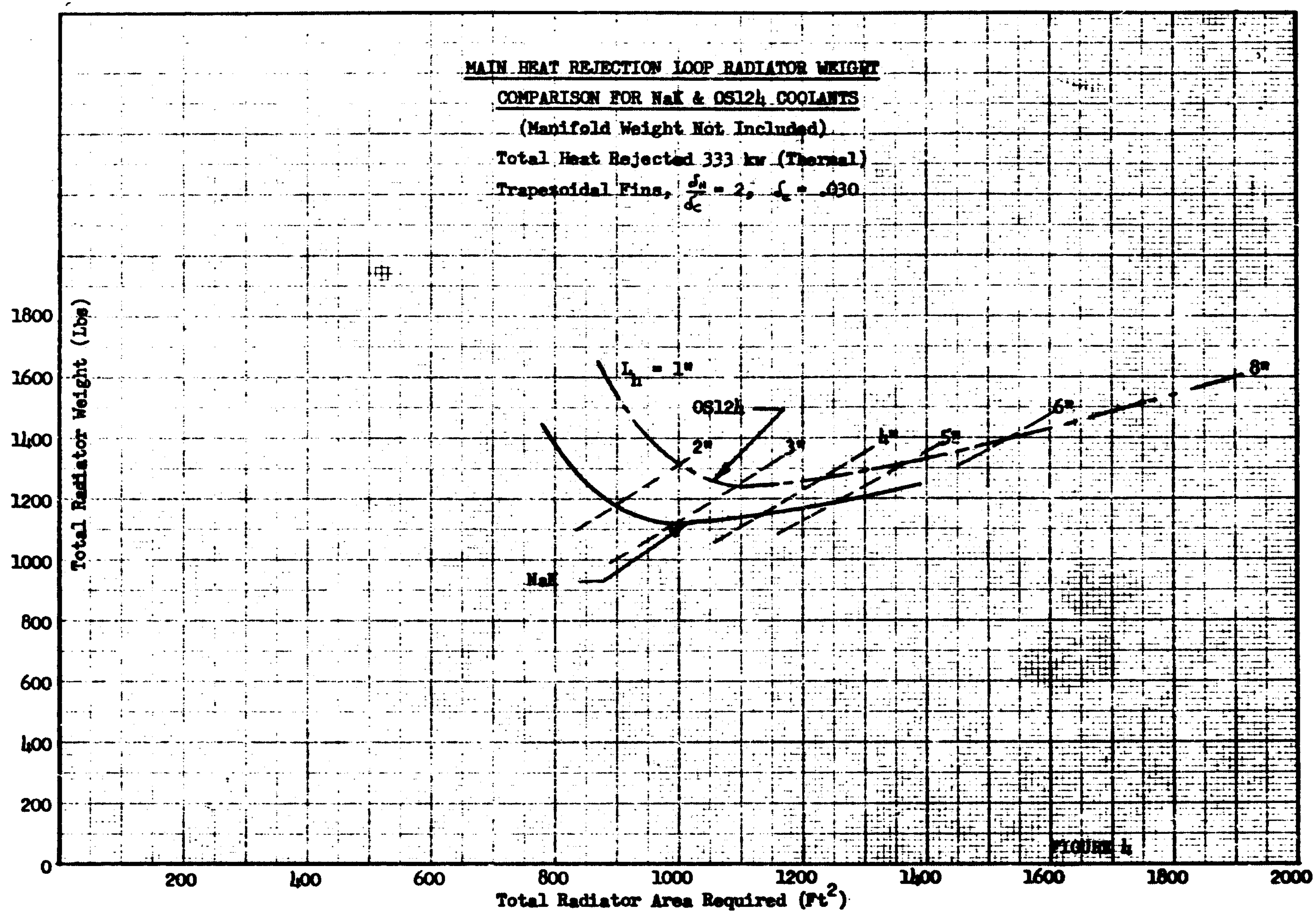
MAIN HEAT REJECTION LOOP RADIATOR WEIGHT
COMPARISON FOR NaK & OS124 COOLANTS
(Manifold Weight Not Included)
Total Heat Rejected 333 kw (Thermal)
Trapezoidal Fins, $\frac{\delta_H}{\delta_C} = 2$, $\delta_C = .030$
L_H = 1"
OS124
2"
3"
4"
5"
6"
8"
NaK
Total Radiator Weight (Lbs)
Total Radiator Area Required (Ft^2)
0
200
400
600
800
1000
1200
1400
1600
1800
2000

FIGURE 4