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SNAP-8

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TECHNICAL MEMORANDUM

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ABSTRACT

WEIGHT-AREA TRADE-OFF STUDY FOR A FLAT SNAP-8 RADIATOR

An analysis was made to permit evaluation of the trade off between radiator area and weight. A method was developed to determine the optimum manner in which the radiator projected area can be reduced with a minimum increase in radiator weight.

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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.

WEIGHT-AREA TRADE-OFF STUDY FOR A FLAT SNAP-8 RADIATOR

I. INTRODUCTION

The radiator area of the four-loop system is significantly greater than the area for the former two-loop system for the following reasons:

More heat is being rejected

Cycle heat rejection is accomplished at a lower average temperature

Two low-temperature sections have been added for component cooling.

Therefore, for system and vehicle integration considerations, there is interest in determining the weight penalties associated with a reduction in radiator area.

This study is based on a tube-and-fin type radiator with the use of OS-124 as the radiator heat-transfer fluid.

II. DISCUSSION

An analysis has been made to permit evaluation of the trade off between radiator area and weight. A method was developed for determining the optimum manner in which the radiator projected area can be reduced with a minimum increase in radiator weight. The development of this method is included in the Appendix and is described briefly as follows:

The radiator is considered to consist of several equal heat-rejection nodes of decreasing temperature. The average tube surface temperature for each node is used for evaluating the heat radiated to space. The number of nodes is determined by the accuracy desired. Heat rejection from the fins is evaluated by using the data of Mackay and Bacha, Reference 1. The parameters for each node, including tube length and fin dimensions, are optimized for a specified heat rejection, temperature level, tube diameter, fin taper ratio, and several projected areas. Weights are calculated and plotted as a function of projected area. This procedure is repeated for each of the nodes. Data for the main radiator are presented in Figure 1. Next a locus of points having equal $\frac{dw}{da}$ are plotted and a composite radiator is constructed in which each node has an equal weight-for-area trade off. The weight and area for each composite radiator are computed and weight is plotted as a function of area. Figure 2 is a plot for the main radiator, which shows that for a 25% decrease in area from the optimum weight configuration, the weight increase in approximately 8%.

WEIGHT-AREA TRADE OFF FOR FLAT SNAP-8 MAIN RADIATOR

COOLANT OS 124

T_h = FIN ROOT TEMPERATURE

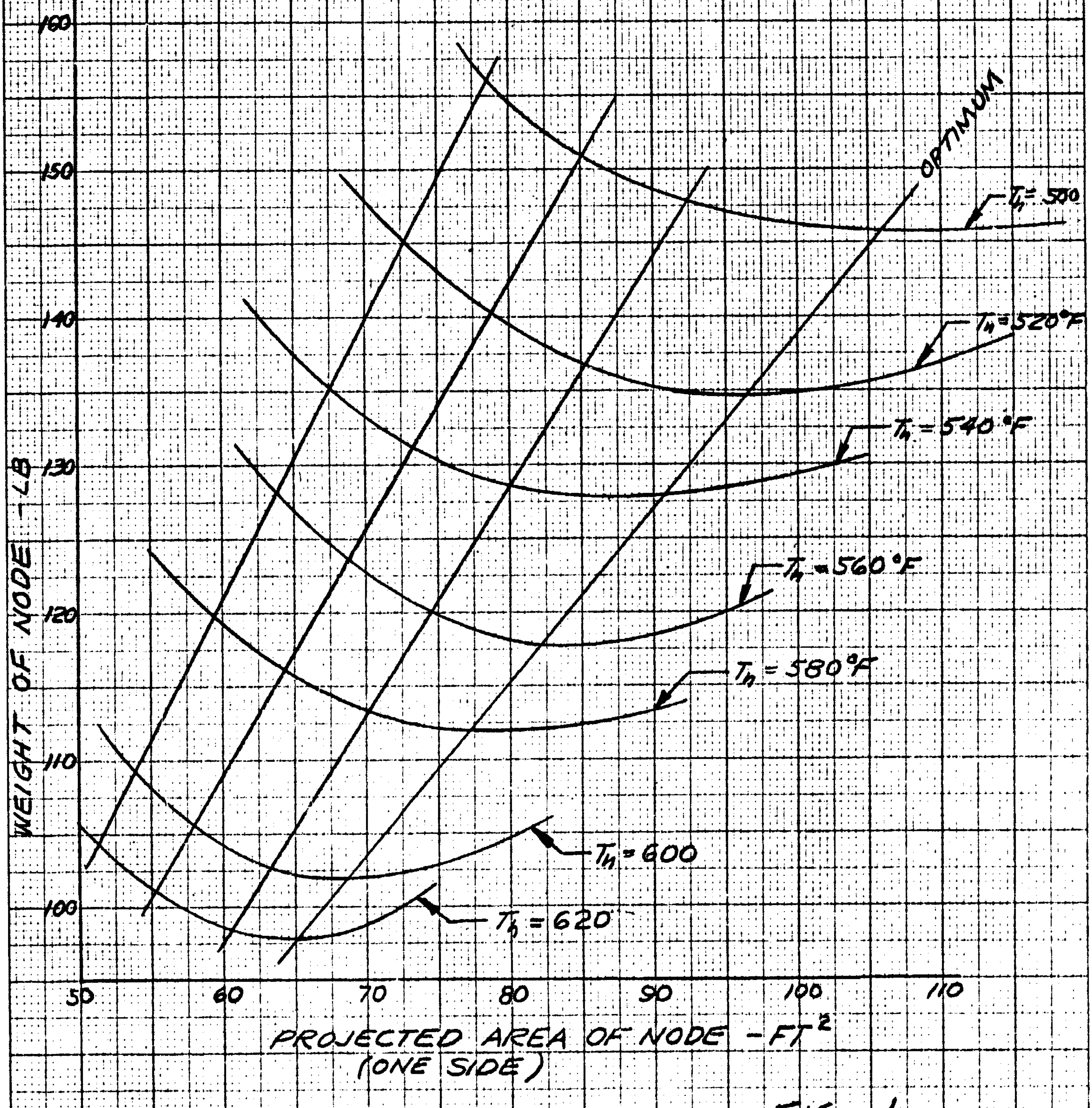
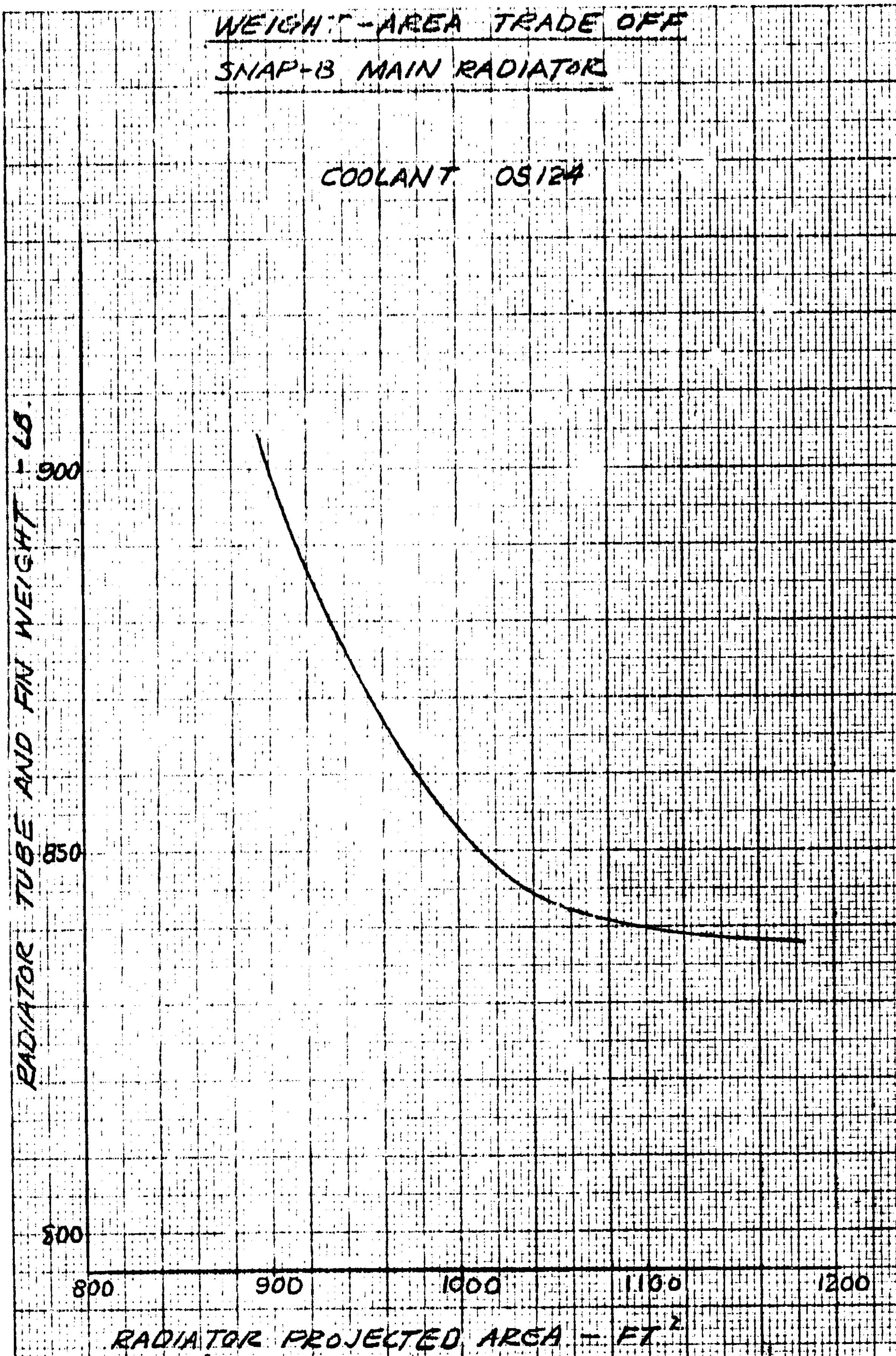


FIG. 1



WEIGHT-AREA TRADE OFF
SNAP-8 MAIN RADIATOR
COOLANT OS124
RADIATOR TUBE AND FIN WEIGHT - LB.
900
850
800
800
900
1000
1100
1200
RADIATOR PROJECTED AREA - FT²
(BOTH SIDES)

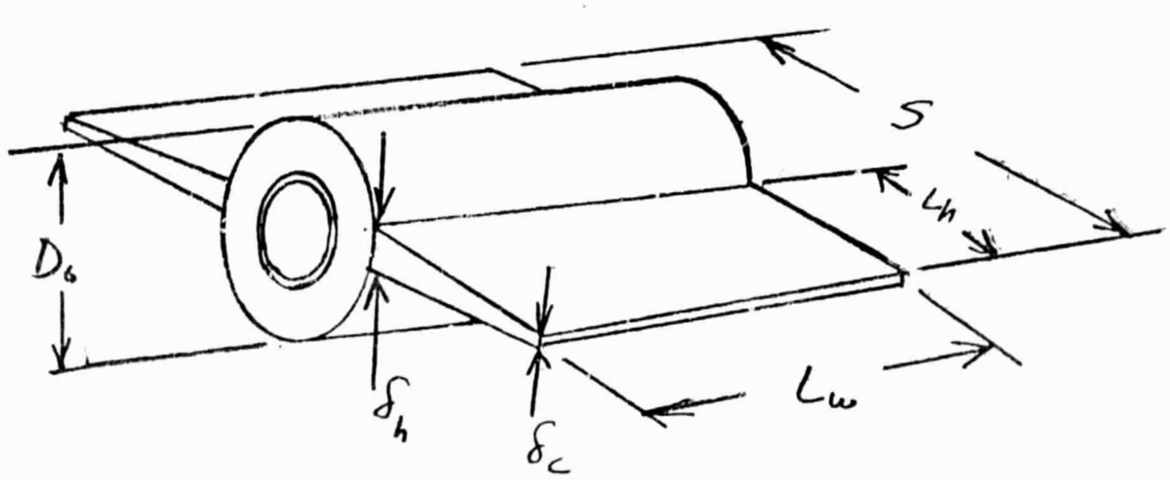
FIG. 2

APPENDIX

RADIATOR WEIGHT FOR AREA TRADE OFF ANALYSIS

IN THIS ANALYSIS A METHOD IS DEVELOPED FOR MODIFYING THE RADIATOR PROJECTED AREA, FROM THE OPTIMUM WEIGHT CONFIGURATION, WITH A MINIMUM INCREASE IN WEIGHT.

IF WE CONSIDER THAT THE RADIATOR IS MADE UP OF SEVERAL EQUAL HEAT REJECTION NODES, FOR WHICH THE AVERAGE TEMP. WILL ACCURATELY DESCRIBE THE HEAT RADIATION, AND THAT HEAT REJECTION FROM THE FINS CAN BE DETERMINED BY USING THE DATA OF MACKAY & BACH REF. 1, THEN THE RADIATOR MAY BE ANALAYZED IN THE FOLLOWING MANNER



PROJECTED AREA

$$A = (D_o + 2L_h) L_w = \qquad (1)$$

$$S = D_o + 2L_h \qquad \text{(SPAN BETWEEN TUBES)}$$

REF. 1. D.B. MACKAY, C.P. BACHA "SPACE RADIATOR DESIGN & ANALYSIS PART I" ASD TECH. REPORT 61-30 OCT. 1961

NOMENCLATURE

A RADIATOR PROJECTED AREA (ONE SIDE)

B VARIABLE DEFINED IN EQN. 4a

C_1 PARAMETER USED IN REFERENCE (1)

C_2 PARAMETER USED IN REFERENCE (1)

E ENVIRONMENTAL PARAMETER

K THERMAL CONDUCTIVITY OF FIN MATERIAL

L_h FIN HALF WIDTH

L_w LENGTH OF FIN AND TUBE

q HEAT REJECTED FROM THE FLUID IN THE RADIATOR

S SPAN BETWEEN TUBES

T_h TEMPERATURE AT ROOT OF FIN

W_R WEIGHT OF RADIATOR TUBE AND FINS

W_T WEIGHT PER FOOT OF TUBE AND ARMOR

δ_h THICKNESS OF FIN AT ROOT

δ_c THICKNESS OF FIN AT TIP

ρ DENSITY OF FIN MATERIAL

ξ PARAMETER DEFINED IN REF (1)

IF WE SPECIFY $q, A, W_T, D_o, \frac{\delta_c}{\delta_h}, T_h, E = \frac{C_2}{C_1 T_h^4}$

$A = \text{CONST}$

$$W_R = W_T L_w + \rho_1 L_h L_w \delta_h \left(1 + \frac{\delta_c}{\delta_h}\right) \qquad (2)$$

FROM REF 1

$$\delta_h = \frac{C_1 T_h^3 L_h^2}{K_{AL} \xi_p} \qquad (3)$$

SUBSTITUTING (3) INTO (2)

$$W_R = \left[W_T + \frac{K_1 C_1 T_h^3}{K \xi_p}\left(1 + \frac{\delta_c}{\delta_H}\right) L_h^3\right] L_w \qquad (4)$$

LET

$$B = \frac{K_1 C_1 T_h^3}{K_{AL} \xi_p}\left(1 + \frac{\delta_c}{\delta_H}\right) \qquad (4a)$$

$$W_R = \left(W_T + B L_h^3\right) L_w$$

$$\frac{dW_R}{dL_w} = W_T + B L_h^3 + 3B L_h^2 L_w \frac{dL_h}{dL_w} \qquad (5)$$

$$A = D_o L_w + 2 L_h L_w$$

$$\frac{dA}{dL_w} = 0 = D_o + 2L_h + 2L_w \frac{dL_h}{dL_w}$$

$$\frac{dL_h}{dL_w} = \frac{S}{2L_w}$$

SUBSTITUTING INTO (5) AND EQUATING TO ZERO FOR OPTIMUM WEIGHT.

$$B L_h^2 - \frac{3}{2} B L_h^2 S + W_T = 0$$

SUBSTITUTING FOR S AND REARRANGING

$$L_h^3 + \frac{3}{4} D_0 L_h^2 - \frac{W_T}{2B} = 0 \qquad (6)$$

TYPICAL NUMBERS FOR D_0 AND B INDICATE ONE POSITIVE REAL ROOT FOR (6)

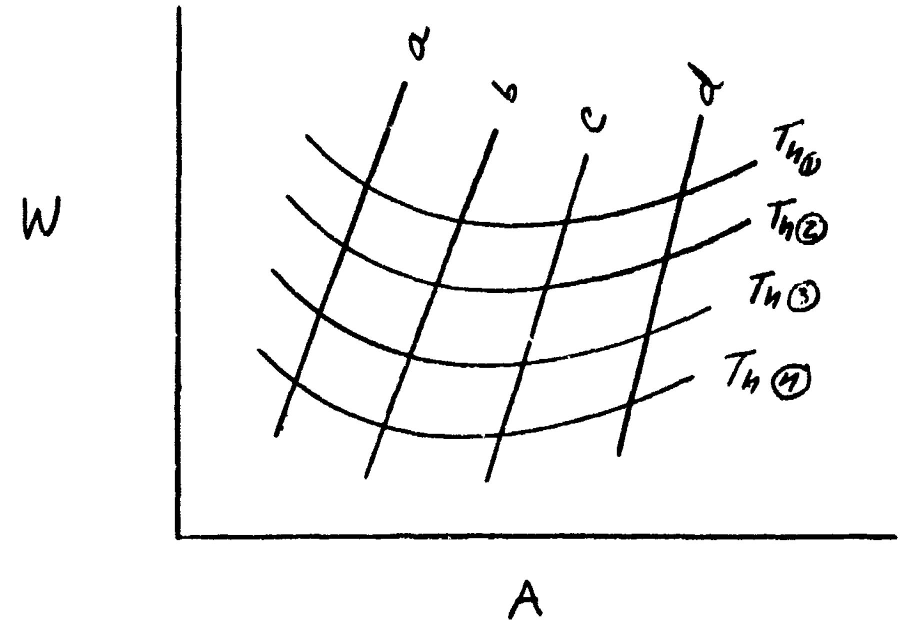
HEAT REJECTED FROM THE FLUID

$$q = \frac{\pi}{2} D_0 C_1 T_h^4 L_w + 2 C_1 T_h^4 \Omega L_h L_w - C_2 L_w$$

$$L_w = \frac{q}{\left[\left(\frac{\pi}{2} - \epsilon\right) D_0 + 2 \Omega L_h\right] C_1 T_h^4} \qquad (7)$$

THEREFORE IF WE TAKE A TUBE AND FIN SECTION WITH n NODES AND EACH NODE IS AT AN AVERAGE TEMPERATURE $T_{h(n)}$, AND WE SPECIFY $q, W_T, D_0, \frac{\delta_c}{\delta_h}$ WE CAN CALCULATE WEIGHT AS A FUNCTION OF AREA USING EQUATIONS (1), (3), (4), (4a), (6) AND (7)

AS SHOWN IN THE FOLLOWING SKETCH



WE CAN THEREFORE CONSTRUCT A RADIATOR IN WHICH ALL THE SECTIONS HAVE EQUAL $\frac{dW}{dA}$ AND THE FIN DIMENSIONS AND TUBE LENGTH HAVE BEEN OPTIMIZED FOR MINIMUM WEIGHT

THIS IMPLYS THAT THE FIN THICKNESS AND WIDTH WILL VARY ALONG THE LENGTH.

IF WE TAKE ALTERNATE CONFIGURATIONS DIFFERENT FROM THE OPTIMUM (LINE C) WE CAN DO SO WITH A MINIMUM INCREASE IN WEIGHT