UNCLASSIFIED
SECRET COVER SHEET

X-426 (Rev. 8-55)

OAK RIDGE NATIONAL LABORATORY
Operated By
UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

delete
IC-84 Aircraft Reactors

ORNL
CENTRAL FILES NUMBER
56-10-39

DATE: October 10, 1956

SUBJECT: Effect of Spacer Density on Heat Transfer
and Pressure Drop in the *delete* **AFR Fuel-to-Nak**
Heat Exchanger

TO: Distribution

FROM: J. L. Wantland

EXTERNAL TRANSMITTAL AUTHORIZED

Classification cancelled (or changed to) **UNCLASSIFIED**

by authority of *9/15/59*

by *JB* TIE, date *9/24/59*

RESTRICTED DATA

This document contains information of a preliminary nature and was prepared primarily for internal use of the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

This document contains information of a preliminary nature and was prepared primarily for internal use of the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

SECRET COVER SHEET
UNCLASSIFIED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

UNCLASSIFIED

- 2 -

SUMMARY

delete
Heat transfer and isothermal friction characteristics of the experimental
ART fuel-to-NaK heat exchanger have been determined for three degrees of
spacer density. The data appear to indicate that for a given heat ex-
changer pressure drop, the heat transfer coefficient is almost independent
of the spacer density; as the spacer density is decreased, the Reynolds
modulus increases to such an extent that the Nusselt modulus does not change
significantly. For a given available pressure drop, with decreased spacer
density, a larger flow rate exists allowing the same heat removal rate with
a lower axial temperature change or a greater heat removal rate with the
same axial temperature change.

NOMENCLATURE

c	specific heat of water, Btu/lb _m -°F
D _h	equivalent heated diameter = 4 (cross-sectional flow area/heated perimeter), used in N _{Nu} , ft
D _w	equivalent wetted diameter = 4 (cross-sectional flow area/wetted perimeter), used in N _{Re} , ft
f	friction factor defined by $f = \frac{\Delta P}{\frac{L}{D_w} \frac{\rho u^2}{2g_c}}$
g _c	gravitational conversion factor = 4.170 x 10 ⁸ lb _m -ft/lb _f -hr ²
h	surface coefficient of heat transfer, Btu/hr-ft ² -°F
k	thermal conductivity of water, Btu/hr-ft-°F
L	total length of tube bundle parallel to axis of shell, ft
ΔP	static pressure drop through the tube bundle, lb _f /ft ²
u	average water velocity around the tube bundle, ft/hr
μ	dynamic viscosity of water, lb _m /hr-ft
ρ	density of water, lb _m /ft ³
N _{Pr}	Prandtl modulus, cμ/k
N _{Nu}	Nusselt modulus, h D _h /k
N _{Re}	Reynolds modulus, D _w uρ/μ

SECRET

INTRODUCTION

It was desired to determine the effectiveness of the tube spacers as turbulators to increase the possible heat transfer for a given pressure drop and to determine if there would be an optimum spacer density from this standpoint. The experimental ART ^{delete} fuel-to-NaK heat exchanger has undergone experimentation with 25 sets of spacers at 2-1/2 inch intervals and 9 sets of spacers at 7-1/2 inch intervals as well as with the normal spacer density of 13 sets of spacers at 5 inch intervals as reported in Reference 1.

The experimental results with the three spacer densities, as well as a portion of the data extrapolated to zero spacers, are presented in Figures 1 and 2. As would be expected, an increase in the number of spacers increases both the heat transfer characteristics and fluid friction characteristics of the fuel side of the system.

SECRET

SECRET
ORNL-LR-DWG 12602

Fig. 1 Heat Transfer Characteristics of the Experimental ^{ART} Fuel-to-NaK Heat Exchanger for Three Spacer Densities.

DECLASSIFIED 5

delete

Fig. 2 Isothermal Friction Characteristics of the Experimental ART delete
Fuel-to-NaK Heat Exchanger for Three Spacer Densities.

ANALYSIS

In order to analyze the effect of spacer density on the heat transfer characteristics, Figure 2 was re-plotted as $f N_{Re}^2$ vs. N_{Re} to establish a pressure drop parameter since for a given configuration, fluid, and operating condition, $\Delta P \sim f N_{Re}^2$. From this graph, data were taken at three conditions of constant pressure drop: $f N_{Re}^2 = 6.0 \times 10^5$, $f N_{Re}^2 = 1.0 \times 10^6$, and $f N_{Re}^2 = 1.7 \times 10^6$. At each of these conditions, the corresponding Reynolds modulus was found, and from Figure 1 at each spacer density and Reynolds modulus, the appropriate heat transfer parameter ($N_{Nu}/N_{Pr}^{0.4}$) was located. The results of these determinations (shown in Table 1) appear to indicate that the coefficient of heat transfer decreases by about 8% from the spacer density with 25 spacers to the extrapolated data for zero spacers. It should be emphasized that the data presented in Table 1 are taken from the "faired" curves of Figure 1 and 2, both of which are reported with a precision of $\pm 10\%$. A slightly different interpretation of the original data could easily reverse the slight trend indicated by Table 1.

TABLE 1

COMPARISON OF HEAT TRANSFER PARAMETERS FOR DIFFERENT SPACER DENSITIES
AT THREE CONDITIONS OF CONSTANT PRESSURE DROP

$f N_{Re}^2$	Number of Spacers	N_{Re}	$N_{Nu}/N_{Pr}^{0.4}$
6.0×10^5	25	2550	9.0
↓	13	2810	9.0
↓	9	2880	8.0
↓	0	3120	7.9
1.0×10^6	25	3540	11.6
↓	13	3780	11.4
↓	9	4000	10.5
↓	0	4250	11.2
1.7×10^6	25	5000	14.1
↓	13	5260	14.6
↓	9	5680	13.9
↓	0	5880	12.9

SECRET

CONCLUSIONS

For a given available pressure drop, in the range investigated, variation in spacer density has no large effect on the heat transfer characteristics. A slight affect may well exist but within the limits of precision of the experimental data it would be imprudent to state even the direction of this trend.

For a given pressure drop with decreased spacer density, a larger flow rate exists allowing the same heat removal rate with a lower axial temperature change or a greater heat removal rate with the same axial temperature change.

It is therefore recommended that the spacers not be thought of as turbulators to improve the heat transfer, but merely as devices to maintain the proper tube spacing, and the minimum number of spacers that will properly serve this purpose should be utilized.

UNCLASSIFIED

- 10 -

BIBLIOGRAPHY

1. Wantland, J. L., "Thermal Characteristics of the ~~ART~~ ^{delete} Fuel-to-NaK Heat Exchanger," ORNL CF 55-12-120, December 1955.

UNCLASSIFIED

DECLASSIFIED 10