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SUBJECT: Transverse Pressure Difference Across Staggered and Inclined Spacers in the ART Fuel-to-NaK Heat Exchanger

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SUMMARY

The ART fuel-to-NaK heat exchanger[1] was modified with six 60° staggered spacers and six 60° inclined spacers alternately placed. Transverse pressure taps were installed across one spacer of each type. The average transverse pressure difference across each instrumented spacer was expressed in terms of the ratio of the transverse pressure difference to the quantity, $\frac{\rho u^2}{2g_c}$, over the Reynolds modulus range of 3,000 to 8,000. For the inclined spacer, this term fell between 1.4 and 1.1; for the staggered spacer, the data varied randomly between 0.01 and 0.3 with no definite trend established. The tube bundle friction factor was also determined and fell about 10% below the data previously obtained using vertical spacers.

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NOMENCLATURE

D	hydraulic diameter, defined by four times the cross-sectional flow area divided by the total wetted perimeter, ft
f	friction factor defined by $f = \Delta P_t \Big/ \frac{L}{D}\frac{\rho u^2}{2g_c}$
g_c	gravitational conversion factor, $4.170 \times 10^8 \frac{lb_m - ft}{lb_f - hr^2}$
L	tube bundle length, ft.
N_{Re}	Reynolds modulus, $Du\rho/\mu$
u	mean fluid velocity, ft/hr
ρ	mean fluid density, lb_m/ft^3
μ	dynamic viscosity, $lb_m/hr - ft$
ΔP_t	measured static pressure drop through tube bundle, lb_f/ft^2
ΔP_u	velocity pressure defined by $\Delta P_u = \frac{\rho u^2}{2g_c}$, lb_f/ft^2
ΔP_i	average transverse pressure difference across the inclined spacer, lb_f/ft^2
ΔP_s	average transverse pressure difference across the staggered spacer, lb_f/ft^2

[redacted]

[redacted]

INTRODUCTION

In order to determine the transverse pressure characteristics resulting from the use of staggered spacers and inclined spacers in the ART fuel-to-NaK heat exchanger, the experimental heat exchanger[1] previously tested was modified with six 60° staggered spacers and six 60° inclined spacers alternately placed at six inch intervals. Three sets of transverse pressure taps were installed across one of each type of spacer well downstream of the entrance region: one set across the center of the spacer and one set each 1-1/2 inches upstream and 1-1/2 inches downstream of the center pressure taps (shown in Figure 1).

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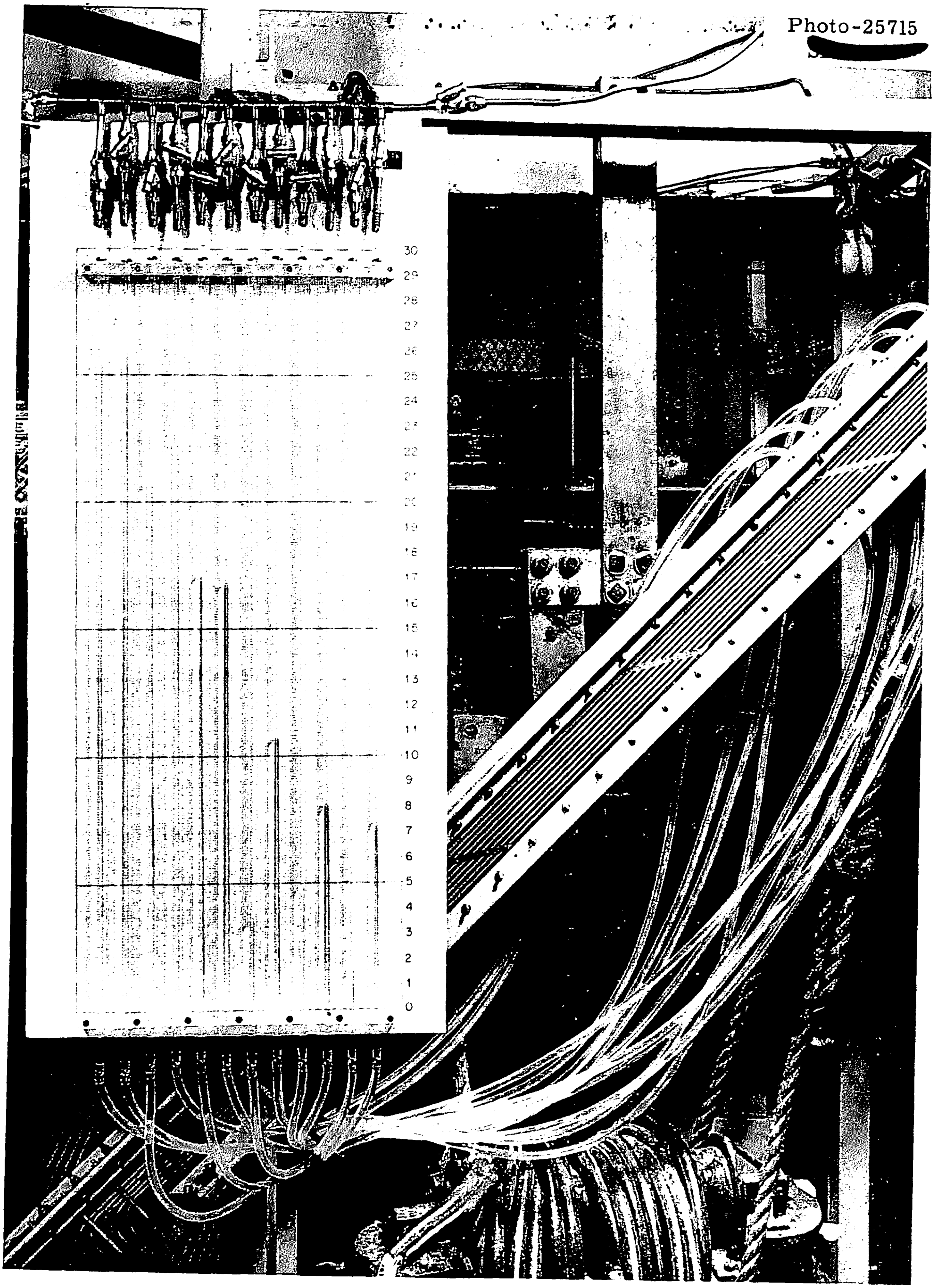

Fig. 1 Photograph of heat exchanger showing transverse pressure measuring taps and manometer.

EXPERIMENTATION

The experimental procedure was similar to that used to determine the isothermal friction characteristics described in Reference 1. The transverse pressure manometer (Figure 1) consisted of twelve glass tubes each connected to a transverse pressure tap at the bottom and to a common manifold at the top. The manifold was connected to a compressed air line and a bleed line so that the average water level in the manometer could be varied to suit the working range used. For each run, the average pressure difference across each of the two instrumented spacers was determined and converted to lb_f/ft^2. The velocity head was calculated and converted to lb_f/ft^2 in order that a dimensionless pressure parameter could be used as the correlating term.

The tube bundle friction factor was determined by the method previously used.

RESULTS

Due to edge effects in the region between the spacer and heat exchanger shell wall, fluctuations in flow, and the small magnitude of the pressure differences to be measured, the results were to some extent erratic. This was particularly true for the staggered spacer.

For this spacer, the downstream pressure taps indicated a transverse pressure difference opposite in sign to that which would be expected.

As a result, the data for the staggered spacer varied randomly between 0.01 and 0.3 with no definite trend established. For this reason, the data for the staggered spacer are not plotted.

The transverse pressure parameter for the inclined spacer is shown in Figure 2. When plotted logarithmically, this term varies inversely with the Reynolds modulus. The scatter below N_{Re} = 5,000 results from the difficulty in measuring accurately the small pressure differences involved.

The tube bundle friction factor is shown in Figure 3. The data fall about 10% lower than those determined using vertical spacers placed at 5 inch intervals. This is probably due to the decreased spacer density, the "streamlined" effect of the inclined spacers and the possibility of cross flow through the staggered spacers.

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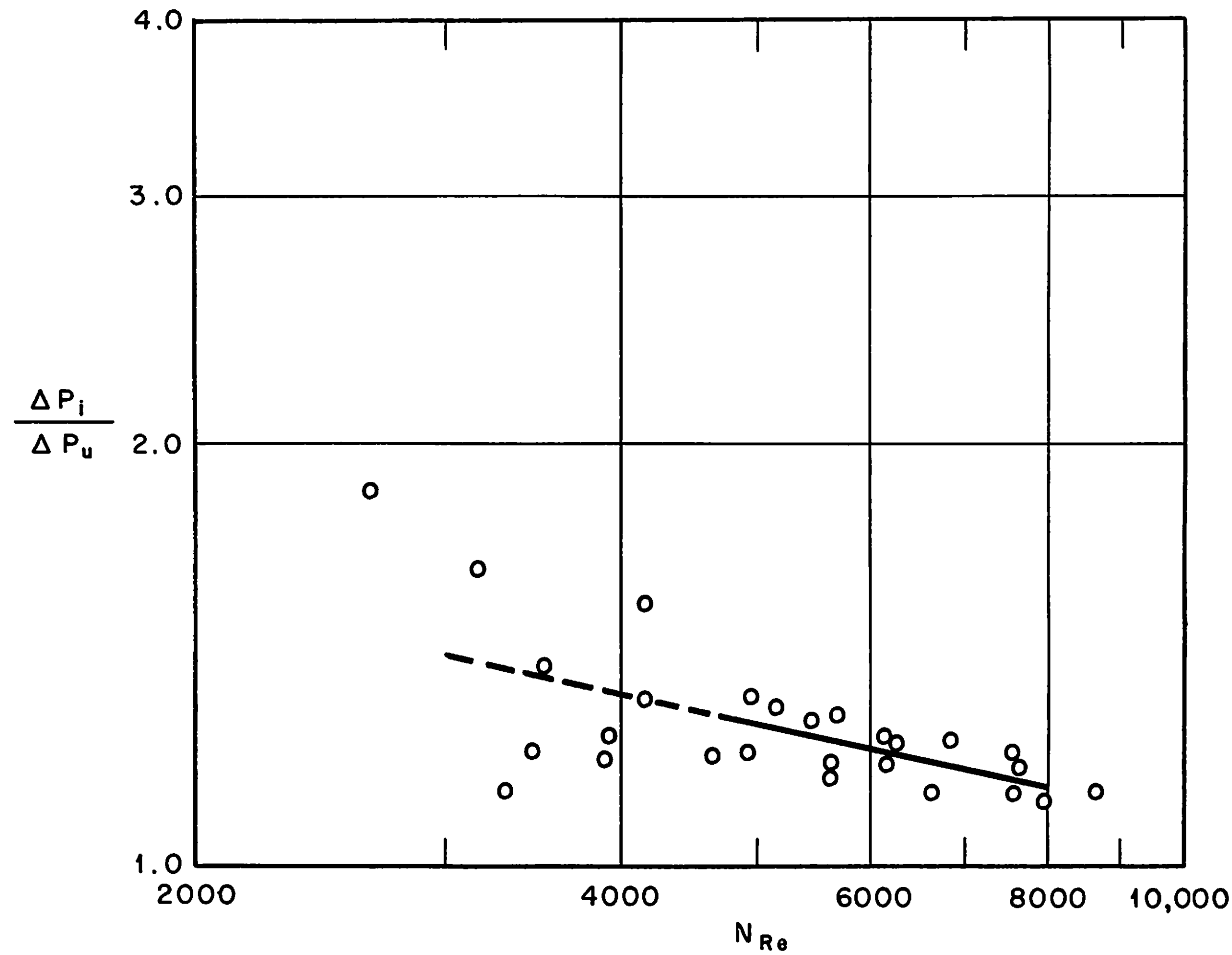

Fig. 2. Transverse Pressure Parameter of a 60° Inclined Spacer in the ART Fuel-to-NaK Heat Exchanger.

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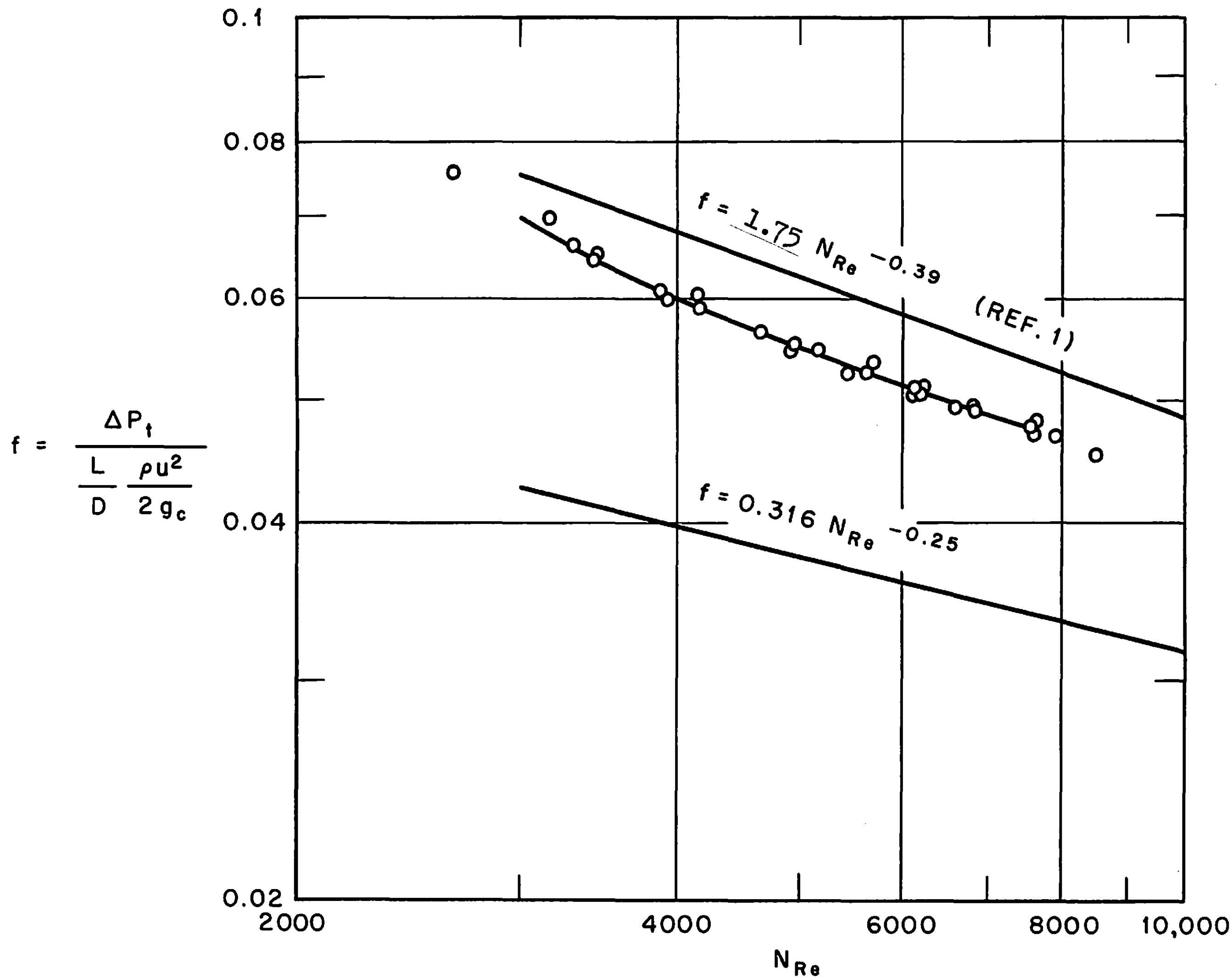

Fig. 3. Friction Characteristics of 60° Staggered Spacers and 60° Inclined Spacers in the ART Fuel-to-NaK Heat Exchanger.

REFERENCES

1. Wantland, J. L., Thermal Characteristics of the ART Fuel-to-NaK Heat Exchanger, ORNL-CF 55-12-120, Dec. 1955.