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Centimeter

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DECLASSIFIEDBy Authority of RM:ltanCGNMP-101 5-12-94By J. E. Savelly 5-12-94Verified By J. E. Savelly
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- 1 - File 1 (OHG, ODG, RW) - Hanford
- 2 - File 2 (ODG, Tech.) - H. Worthington

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- 10 - Chronological
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INV.

D-47

May 9, 1944

MEMORANDUM

TO: FILE

FROM: T. B. DREW & W. K. WOODS

REDUCTION OF SIZE OF WATER PASSAGES
BY THERMAL EXPANSION - W FILE

In connection with an inquiry into the extent of oversize that might be tolerable in the outside diameter of finished slugs, the effect of thermal expansion on the clearance between the slugs and the aluminum tubes has been estimated. It appears that the extent of the contraction of this clearance on heating to operating conditions is such that the cold outside diameter of the slugs might more wisely have been specified as $1.438" \begin{cases} +0.000 \\ -0.006 \end{cases}$ instead of the current $1.440" \pm 0.002"$.

Over the middle four feet of the nominal peak tube (330 kw/tube - 21 gpm., in at 5°C ., out at 65°C), when using unbonded slugs with $0.350"$ caps and bottoms, the clearance in the upper quadrant under operating conditions is 4 mils less than at room temperature. Reduction in this clearance to the extent of 3 mils or more is found over the middle 12 feet. Further details are provided in the attached table. For bonded slugs the reduction in clearance in the upper quadrant is about 80% of that for unbonded slugs. In both cases the governing factor is the expansion of the filler; its effective mean temperature is enough higher than that of the coating to more than compensate for its lesser coefficient of expansion. Except in the last foot of the tube the coating is under tension.

A review of the assumptions on which the flow computations have been hitherto based shows that the dimensions of the tube and slugs, now currently regarded as official, were intended to correspond to water passage dimensions measured under operating conditions, not at room temperature.

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File

#2

5/9/44

The dimensional specifications,

Vertical I.D. of Tube	1.598 ± 0.003
Rib Height	0.086 ± 0.002
Slug O.D.	1.440 ± 0.002

when measured at room temperature correspond to 72 mils and 65 mils respectively for the nominal and for the minimum clearance in the upper quadrant at room temperature. At operating conditions, however, the two figures are replaced by 68-69 mils and 61-62 mils if the specifications are understood to refer to room temperature measurements as is usually to be expected. It appears that, for nominal slugs in a nominal tube, at the peak tube load the exit temperature of the water in the upper quadrant of the annulus will be about 10°C. above the average, a circumstance hitherto supposed to correspond to nominal slugs in an undersized tube. The worst case of oversize slugs in an undersized tube, formerly supposed to give an excess temperature of 13°C., actually gives 22°C. It is to be noted that no bowing has been allowed for.

NOTE

In view of these facts it is certainly unwise to relax the oversize tolerance on the diameter of the slug, on the undersize diameter of the tube, or oversize height of the rib. Indeed, consideration might well be given to reducing the oversize tolerance on the slugs if it is still feasible so to do. Surely current plans for unbonded slugs should be based on a slug outside diameter of 1.438 $\begin{cases} +0.000 \\ -0.000 \end{cases}$, measured at room temperature.

TECHNICAL DIVISION

Thomas B. Deen
W. K. Woods
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TBD & WKN/11

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Appendix

4-

5/9/44

Kuh-1001

At the midplane of the hottest tube

$$\lambda = \frac{42,500}{2\pi(0.0566)(12)(22.3)(0.7669)} = 582^\circ\text{C}.$$

Here the thermal conductivity has been somewhat conservatively taken as 12.

Temperature Difference Between Axis and Surface of Filler

At the middle of the tube

$$T_0 - T_s = \lambda [I_0(\mu R) - 1] = 582(0.4411) = 257^\circ\text{C}.$$

At distance z ft. from the middle,

$$T_0 - T_s = 257 \cos \frac{\pi z}{2Z_0} = 257 \cos \theta$$

Average Temperatures of FillerThe true cross-sectional mean temperature of the heavy metal measured above its surface temperature T_s is:

$$\begin{aligned} T_{av} - T_s &= \frac{1}{\pi R^2} \int_0^R 2\pi r (T - T_s) dr \\ &= \lambda \left[I_0(\mu R) - \frac{2I_1(\mu R)}{\mu R} \right] \end{aligned}$$

(Note that this differs from the calorimetric mean temperature, which is affected by the variation of specific heat with temperature)

$$I_0(\mu R) = 1.4411$$

$$I_1(\mu R) = 0.7669$$

$$\frac{T_{av} - T_s}{T_0 - T_s} = 0.520$$

$$T_{av} - T_s = 134 \cos \frac{\pi z}{2Z_0} = 134 \cos \theta \quad ^\circ\text{C}.$$

The mean temperature across a diameter of the filler, above its surface temperature T_s is:

$$\begin{aligned} T_{AD} - T_s &= \frac{1}{R} \int_0^R (T - T_s) dr \\ &= \lambda \left\{ I_0(\mu R) - \frac{2}{\mu R} [I_1(\mu R) - I_3(\mu R) + I_5(\mu R) \dots] \right\} \end{aligned}$$

$$\frac{T_{AD} - T_s}{T_0 - T_s} = 0.683$$

$$T_{AD} - T_s = 175.4 \cos \frac{\pi z}{2Z_0} = 175.4 \cos \theta \quad ^\circ\text{C}.$$

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It is the mean temperature on a diameter that determines the expansion of the filler.

Appendix

5/9/44 Sub-1001

VI. Official Dimensions as of May 1, 1944

Tubing

Vertical I.D.	$1.598 \pm 0.003"$
Rib Height	$0.086 \pm 0.002"$

Slug, Bonded Type

O. D. finished	$1.440 \pm 0.002"$
O. D. filler	$1.360 \pm 0.001"$
Thickness of coating plus bond	$0.040"$
Nominal jacket thickness	$0.035"$

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8/18/94

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