UNITED STATES
DEPARTMENT OF INTERIOR
BUREAU OF MINES
SYNTHETIC FUELS DEMONSTRATION PLANT
LOUISIANA, MO.

T.O.M. Reel 252
Frames 884-896

T-120
W. M. Sternberg

H.O.L.D. HEAT EXCHANGE

5/19/43

Appendix 1 shows three cases of H.O.L.D. heat exchange calculated to Upper Silesian conditions:

1. Thick paste is heated in the heat exchanger consisting of two tubes side by side and welded together (70 mm. diameter) in accordance with a suggestion of Dr. Josenhans.
2. An auxiliary liquid is used in jacket surrounding the high-pressure tube; the H.O.L.D. heat is therefore first absorbed by this auxiliary liquid (oil), and this heat is next transferred in the second system to the paste.

Appendix 2 shows α values for twin tubes. At present no liquid was yet found to give the high value of α = 500, as used in table 1.

3. Similar to 2, but H.O.L.D. more strongly cooled to 262° C. as in 1, to permit direct comparison. Thick paste is correspondingly heated to higher temperature.

Computation of heat transfer in twin tubes

$$\frac{\alpha \cdot d}{\lambda} = 0.024 \cdot \left(\frac{w \cdot d \cdot \gamma}{\eta \cdot g}\right)^{0.8} \cdot \left(\frac{\eta \cdot g \cdot c}{\lambda'}\right)^{0.37}$$

The free cross section F = 0.00657 m.^{2} for jacket tubes 70/102-137/146.

TABLE 1

Tube dimensions	Two tubes, 70 mm.	Jacket tubes 70/102-137/146		Jacket tubes 70/102-137/146	
Case	1	2 (with auxiliary liquid)		3 (with auxiliary liquid)	
Exchanger forward pass .... T./hr..	20 (paste)	20 (oil, paste)	20 (oil)	20 (paste)	27 (oil)
m.^{3}/hr..	4,000 (gas) 1/	4,000 (gas)	-	4,000 (gas)	-
Heat coefficient .... kcal./°C..	11,920	11,920	12,000	11,920	16,200
α value .... kcal./°C.,hr.,m.^{2}..	300	300	500	300	500
Weight (total) .... T./hr..	21	21	20	21	27
Volume .... m.^{3}/hr..	22+12.3=34.3	34.3	22	34.3	30
Sp. gr .... kg./m.^{3}..	615	615	900	615	900
Velocity .... m./sec..	2.47	2.47	1.58	2.47	2.17
Δp/m. tube .... atm..	0.0107				
Heat exchanger return pass .... T./hr..	32 (H.O.L.D.)	20 (oil)	32 (H.O.L.D.)	27 (oil)	32 (H.O.L.D.)
Heat coefficient .... kcal./°C..	18,550	12,00	18,550	16,200	18,550
α value .... kcal./°C.,m.^{2},hr..	400	500	400	500	400
Weight .... T./hr..	32	20	32	27	32
Volume .... m.^{3}/hr..	35.5	22	35.5	30	33.5
Sp. gr .... kg./m.^{3}..	900	900	900	900	900
Velocity .... m./sec..	2.55	1.58	2.55	2.17	2.55
Δp/m. tube .... atm..	0.0167			0.0121	0.0167
Temperature changes .... °C..	262 ← 420 100 → 330	170 ← 340 100 → 255	300 ← 420 170 → 340	180 ← 350 100 → 315	262 ← 420 180 → 350
Δt .... °C..	122	77	103	54	76
Heat transfer .... 10^3 kcal./hr..	2,740	1,840	2,040	2,550	2,750
Radiation .... 10^3 kcal./hr..	200	200	200	200	200
K value .... kcal./°C.,hr.,m.^{2}..	147·0.60=87	160	180	160	180
Area .... m.^{2}..	260	150	112	300	200
Tube length .... m..	1,200	700	510	1,370	930
Δp forward pass, 2/ .... atm..	15				
Δp return pass .... atm..	23				

1/ Δp about 50% larger for 8,000 m.^{3} gas/hr.
2/ +15% for stall.

For 20 m.^{3}/hr. in twin tubes the velocity $w = 0.85$ m./sec.

$d = 0.137 - 0.102 = 0.035$ m.

For 200° C.:

$\lambda = 0.117$ kcal./°C.,m.,hr.

$\lambda' = 0.117/3600 = 0.325 \times 10^{-4}$ kcal./°C.,m.,sec.

$\gamma = 900$ kg./m.^{3}

$c = 0.55$ kcal./kg.,°C.

$\eta = 40 \times 10^{-6}$ kg. · sec./m.^{2}

$$\alpha = \frac{0.117}{0.035} \cdot 0.024 \cdot \left(\frac{0.85 \cdot 0.035 \cdot 900}{40 \cdot 10^{-6} \cdot 10}\right)^{0.8} \cdot \left(\frac{40 \cdot 10^{-6} \cdot 10 \cdot 0.55}{0.325 \cdot 10^{-4}}\right)^{0.37}$$

$$= 0.08 \quad 6700^{0.8} \quad 6.8^{0.37}$$

$$= 0.08 \quad 1150 \quad \cdot \quad 2.3$$

$$= 187 \text{ kcal./°C.,m.}^2\text{,hr.}$$

Determinations were run in six models composed of:

1. Two concentric tubes
2. Twinned tubes
3. Triplet tubes
4. Two tubes cast in aluminum
5. Two tubes with oil for heat transfer
6. Four tubes cast in lead

The length of the heat transferring parts was 2 m. in all models. Heat was transferred from hot to cold water. All models were operated countercurrently. The amounts of water were measured at the outlet in units of 20 liters. Temperatures were measured with thermometers divided to 1/10 degree. The experimental results are shown in figures 1 to 6.

The values were:

1. Two concentric tubes, figure 1. Tube diameter 6 x 14 and 17 x 33 mm.

Amount of water: a. Warm water $Q_w = 295$ l./hr. (through annular space)

b. Cold water $Q_c = 375$ l./hr. (through inner tube)

Velocities: a. Warm water $V_w = 1.12$ m./sec.

b. Cold water $V_c = 3.69$ m./sec.

Temperatures: a. Warm water $95.6 \longrightarrow 67.6$

b. Cold water $\underline{33.6 \longleftarrow 13.2}$ $\Delta t = 20.4^\circ$ C.

$62.0 \quad 54.4$

Average temperature difference: $\vartheta_m = 58.2^\circ$ C.

Inner surface of inside tubes: $F = 3.77 \times 10^{-2}$ m.^{2}

Heat transfer number:

$$k = \frac{20.4 \cdot 375}{3.77 \cdot 10^{-2} \cdot 58.2} = 3480 \text{ kcal./m.}^2\text{,hr.,}^\circ\text{C.}$$

Control determinations: $Q_w = 312$ l./hr.

$Q_c = 371$ l./hr.

$V_w = 1.19$ m./sec.

$V_c = 3.65$ m./sec.

Temperatures: $97.3 \longrightarrow 70.5$

$\underline{34.8 \longleftarrow 13.2}$ $\Delta t = 21.6^\circ$ C.

$62.5 \quad 57.3$

$\vartheta_m = 59.9$

$$k = \frac{371 \cdot 21.6}{3.77 \cdot 10^{-2} \cdot 59.9} = 3560$$

Calculations: For $V_w = 1.12$ m./sec.; $\alpha_w = 6{,}800$

For $V_c = 3.69$ m./sec.; $\alpha_c = 14{,}000$

Resistance to heat transfer of a thick wall tube is

$$\frac{1}{k} = \frac{1}{c} + \frac{\frac{d_1}{2} \cdot \ln \frac{d_2}{d_1}}{\lambda} + \frac{1}{\alpha_w \frac{d_2}{d_1}},$$

where d_1 and d_2 are respectively the inner and outer diameters of the inside tube. Substituting the values given above,

$$\frac{1}{k} = \frac{1}{14,000} + \frac{3 \cdot 10^{-3} \ln \frac{14}{6}}{\lambda} + \frac{1}{6800 \cdot \frac{14}{6}}, \text{ from which } \lambda = 17.4.$$

No depositions were considered in the computations. The k values are lowered by them, and as a result the values for λ are too small.

The λ values from the k values for H.O.L.D. and thick paste are calculated with

$\alpha_1 = 500$ for H.O.L.D.

$\alpha_2 = 250$ for thick paste.

Assuming that H.O.L.D. is led through the inner tube and the thick paste through the annular space, we get

$$\frac{1}{k} = \frac{1}{500} + \frac{3 \cdot 10^{-3} \ln \frac{14}{6}}{17.4} + \frac{1}{250 \cdot \frac{14}{6}} = (2 + 0.146 + 1.71) \cdot 10^{-3} = 3.86 \cdot 10^{-3}$$

$k = 259$

2. Twinning arrangement, figure 2.

Two tubes 10 x 18 joined together by autogenous welding.

Amounts of water: $Q_w = 610$ l./hr.

$Q_c = 366$ l./hr.

Velocities: a. $V_w = 2.16$ m./sec.

$V_c = 1.295$ m./sec.

Temperatures: 60.2 ⟶ 57.5

18.9 ⟵ 14.8 $\Delta t = 4.1^\circ$ C.

41.3 42.7

$\vartheta_m = 42$

$$k = \frac{366 \cdot 4.1}{6.28 \cdot 10^{-2} \cdot 42} = 568 \text{ (= 16\% of the concentric arrangement)}$$

Control determinations: $Q_w = 261$ l./hr.

$Q_c = 610$ l./hr.

Temperatures: 64.3 → 61.8

20.3 ← 14.8 $\Delta t = 5.5^\circ$ C.

44.0 47.0

$\vartheta_m = 45.5$

$$k = \frac{261 \cdot 5.5}{6.28 \cdot 10^{-2} \cdot 45.5} = 502$$

For $V_w = 2.16$ m./sec.; $\alpha_w = 11{,}000$ m./sec.

$V_c = 1.29$ m./sec.; $\alpha_c = 5{,}400$ m./sec.

By analogy the electrical capacities of two cylindrical conductors at a distance **a** from each other (figs. 4a and 4b). The resistance to heat transfer of this arrangement $C = 1/2\ C_1$ where C_1 is the capacity of two cylindrical conductors with radii a and r.

The heat conductivity of the concentric cylinders is

$$\frac{1}{k'} = \frac{\frac{d}{2} \ln \frac{a}{r}}{\lambda}$$

and the corresponding resistance to heat conductivity of the two parallel cylinders is also

$$\frac{1}{k''} = \frac{d \ln \frac{a}{r}}{\lambda} = \frac{d \ln \frac{2a}{d}}{\lambda}$$

The heat resistance for the whole arrangement is then

$$\frac{1}{k} = \frac{1}{\alpha_1} + \frac{d \ln \frac{2a}{d}}{\lambda} + \frac{1}{\alpha_2}$$

In this case,

$$a = 2 \cdot 9 + 1 = 19 \text{ mm.} = 19 \cdot 10^{-3} \text{ m.}$$

$$\frac{1}{k} = \frac{1}{11{,}000} + \frac{10 \cdot 10^{-3} \cdot \ln \frac{2 \cdot 19 \cdot 10^{-3}}{10 \cdot 10^{-3}}}{\lambda} + \frac{1}{5400} =$$

$$= 0.000091 + \frac{10 \cdot 10^{-3} \ln 3.8}{\lambda} + 0.000185 =$$

$$= 0.000276 + \frac{10 \cdot 10^{-3} \cdot 1.33}{\lambda} =$$

$$= 0.000276 + \frac{13.3 \cdot 10^{-3}}{\lambda}$$

It follows therefore that

$$0.000276 + \frac{13.3 \cdot 10^{-3}}{\lambda} = \frac{1}{568} \text{ and}$$

$$\lambda = \frac{13.3 \cdot 10^{-3}}{1.48 \cdot 10^{-3}} = 9$$

This low λ value indicates that, unlike electrical capacity, not the whole space participates in the heat transfer, but only the tube material and the welding material of the weld.

Using the α values for H.O.L.D. and thick paste, we get

$$\frac{1}{k} = \frac{1}{500} + \frac{1}{250} + \frac{13.3 \cdot 10^{-3}}{9} = (2 + 4 + 1.48) \cdot 10^{-3} = 7.5 \cdot 10^{-3}$$

k = 133.5 (about 50% of the k values with concentric arrangement)

3. Triplet tubes.

Three tubes 10 x 18 joined by autogenous welding (hot water in the two outer tubes, cold water in the inside tube).

Amounts of water: Q_{w_1} = 485 l./hr. (left side)

Q_{w_2} = 442 l./hr. (right side)

$Q_w = 927$ l./hr.

$Q_c = 945$ l./hr.

Velocities: $V_{w_1} = 1.718$ m./sec.

$V_{w_2} = 1.568$ m./sec.

$V_c = 3.35$ m./sec.

Temperatures: 50.4 → 48.3

19.8 ← 17.4 $\Delta t = 2.4^\circ$ C.

<u>50.4 → 47.6</u>

30.6 30.9

or 30.2

$\vartheta_m = 30.55$

$$k = \frac{945 \cdot 2.4}{6.28 \cdot 10^{-2} \cdot 30.55} = 1335$$

Control determinations: Amount of water: $Q_{w_1} = 482$ l./hr.

$Q_{w_2} = 438$ l./hr.

$Q_c = 937$ l./hr.

Velocities: $V_{w_1} = 1.705$ m./sec.

$V_{w_2} = 1.55$ m./sec.

$V_c = 3.32$ m./sec.

Temperatures: 63.3 → 59.1

20.8 ← 17.4 $\Delta t = 3.4^\circ$ C.

<u>63.3 → 59.2</u>

42.5 41.75

$\vartheta_m = 42.1$

$$k = \frac{937 \cdot 3.4}{6.28 \cdot 10^{-2} \cdot 42.13} = 1205$$

Calculations: α values found for above water velocities are:

$$\alpha_1 = 8000 \qquad \alpha_w = 7750$$
$$\alpha_2 = 7500$$
$$\alpha_3 = 9800$$

The heat transfer surfaces in the warm and in the cold tubes are in proportion of 2:1.

Resistance to heat transfer

$$\frac{1}{k'} = \frac{\frac{d}{2} \ln \frac{2a}{d}}{\lambda}$$

and the total resistance to heat transfer is

$$\frac{1}{k} = \frac{1}{2 \cdot 7750} + \frac{1}{9800} + \frac{\frac{10 \cdot 10^{-3}}{2} \ln \frac{38}{10}}{\lambda} =$$

$$= 0.0645 \cdot 10^{-3} + 0.104 \cdot 10^{-3} + \frac{5 \cdot 10^{-3} \cdot 1.33}{\lambda} =$$

$$= 0.169 \cdot 10^{-3} + \frac{6.65 \cdot 10^{-3}}{\lambda} = \frac{1}{1335}$$

$$\lambda = \frac{6.65}{0.58} = 11.5$$

With the α values for thick paste and H.O.L.D., the two possible values are figured to

1. H.O.L.D. on the outside:

$$\frac{1}{k} = \frac{1}{250} + \frac{1}{2 \cdot 500} + \frac{6.65 \cdot 10^{-3}}{11.5} =$$

$$= (4 + 1 + 0.58) \cdot 10^{-3} =$$

$$= 5.58 \cdot 10^{-3}$$

$$k = 179 \; (= 70\%)$$

2. H.O.L.D. on the inside:

$$\frac{1}{k} = \frac{1}{2 \cdot 250} + \frac{1}{500} + \frac{6.65 \cdot 10^{-3}}{11.5} =$$

$$= (2 + 2 + 0.58) \cdot 10^{-3} =$$

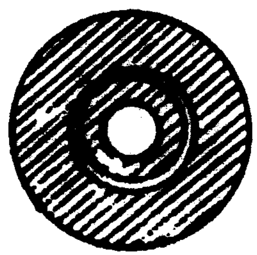
$$= 4.58 \cdot 10^{-3}$$

$$k = 218 \; (= 84\%)$$

Measurements on additional models will follow.

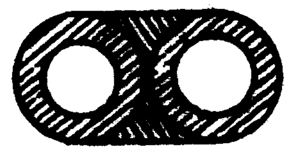
/s/ Hamacher

Fig. 1



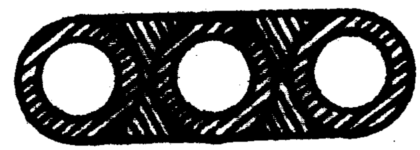
Annular space Warm water	Inner tube Cold water
V_w = 1.12 m./sec.	V_c = 3.69 m./sec.
K, measured = 3500	
α_w = 6800	α_c = 14,000
Calculated λ = 17.4	
Thick paste	H.O.L.D.
with λ = 17.4	
Assumed α_2 = 250	α_1 = 500
Calculated K = 259	

Fig. 2



Warm water	Cold water
2.16 m./sec.	1.23 m./sec.
K = 568 (16%)	
α_w = 11,000	α_c = 5400
λ = 9	
Thick paste	H.O.L.D.
with λ = 9	
α_2 = 500	α_1 = 500
K = 133 (50%)	

Fig. 3

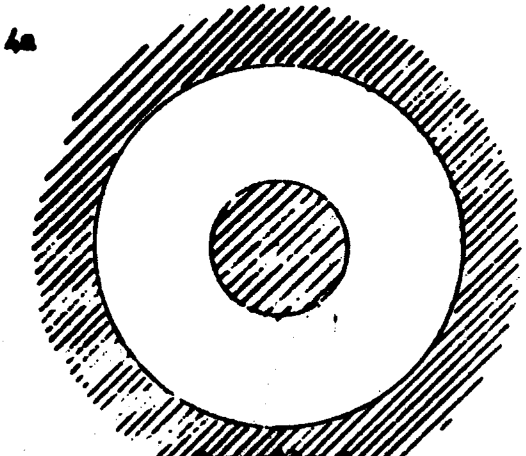


Warm water	Cold water
1.64 m./sec.	3.35 m./sec.
K = 1335 (30%)	
α_w = 7750	α_c = 9800
λ = 11.5	
Thick paste	H.O.L.D.
with λ = 11.5	
α_2 = 250	α_1 = 500

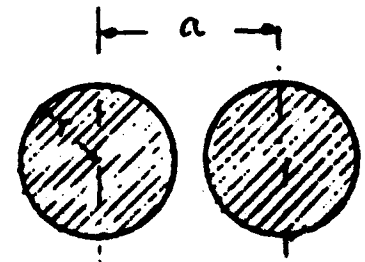
K = 179 (70%) H.O.L.D. on the inside

K = 218 (64%) H.O.L.D. on the outside

Fig. 4a

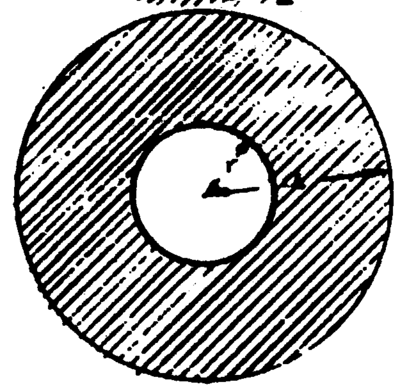


Capacity C_1



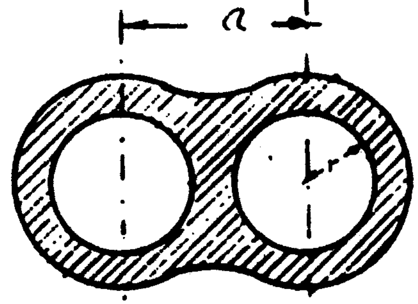
Capacity $C = 1/2\ C_1$

Fig. 4b



Resistance to heat transfer

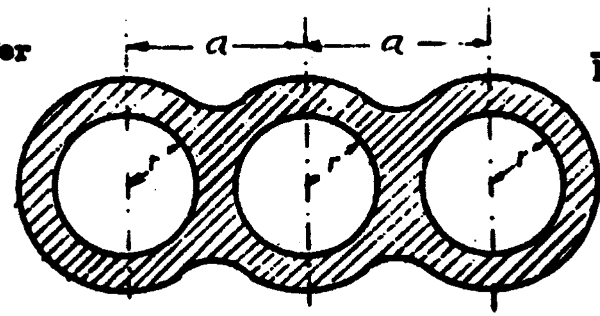
$$\frac{1}{k'} = \frac{r \ln \frac{a}{r}}{\lambda}$$



Resistance to heat transfer

$$\frac{1}{k'} = \frac{2r \ln \frac{a}{r}}{\lambda}$$

Fig. 4c



$$\frac{1}{k_1} = \frac{r \ln \frac{a}{r}}{\lambda}$$

Frames 897-923

Experiments on steam-distilling phenols from l.t.car. products and effluent water, by Dr. Durrfeld, Leuna, 9/21/31.

Summary

Report of experiments on steam-distilling phenols from gasification water effluent. Operating conditions were determined for waters containing various concentrations of phenols and a plant is described. Depending on operating conditions, 1 T. of low pressure steam can drive out 90% of the phenols from 1.9-2.2 $m.^3$ of water.

Frames 924-925

Separation of residual oils. January 6, 1944.

In the phenol production from middle oils by liquefied ammonia, the ammonia-phenol mixture must be freed from entrained or dissolved neutral oils. This can be most easily accomplished with light gasoline (distillation range below 110° C.). When the light gasoline extract is evaporated, a so-called residual oil stays behind which contains 20-40% of phenols, and the neutral oil components of which consist mostly of aromatic hydrocarbons. A phenol-free residual oil has an aniline point of -35° C., while the aniline point of a neutral oil from the same raw materials and the same distillation range, which remained undissolved in the ammonia extraction is 17. The residual oil contains, therefore, the aromatic constituents of the neutral oil which are preferentially extracted by the ammonia-phenol mixture.

One attempt to separate a residual oil with 22% phenols (4.2 liters) obtained from the Navy fuel oil from Blechhammer 200-300° C. fraction with a 10% sodium hydroxide solution produced an almost phenol-free middle oil (0.8 liter), while phenol was enriched to 50%. This illustrates the ease with which certain aromatic neutral oils are separated by alkaline phenol solutions. To judge from this experiment it seems impossible to recycle the residual oil; a special procedure will have to be worked out. In order to obtain a further enrichment with phenols, an excess of sodium hydroxide was added to the phenol mixture and the neutral oil constituents were driven out with steam. A light blue neutral oil was obtained in that way (1.0 liter) which still contained 5% phenol, and which distilled within a rather narrow range. Steam distillation was continued until no more neutral oil was driven out. Two layers were formed in the distillation flask, the upper layer (0.06 liter) consisting of a high-boiling oil with 7% phenol. The lower layer was a phenol mixture with 8% neutral oil, 98% of which distilled below 230°, while only 75% distilled from the 275-300° fraction.

These results show that no steam distillation at atmospheric pressure is possible to drive out neutral oils boiling above 250° C. to separate neutral oil from phenol. Phenol-free constituents are obtained in such steam distillation even from an alkaline solution. No sharp separation of residual oil into acid and neutral constituents is possible in a single operation, and this separation procedure must be repeated.

/s/ (unreadable)

Frames 926-938

Processing of creosote oil S. December 4, 1935.

Preliminary estimate before the start of production in Leuna.