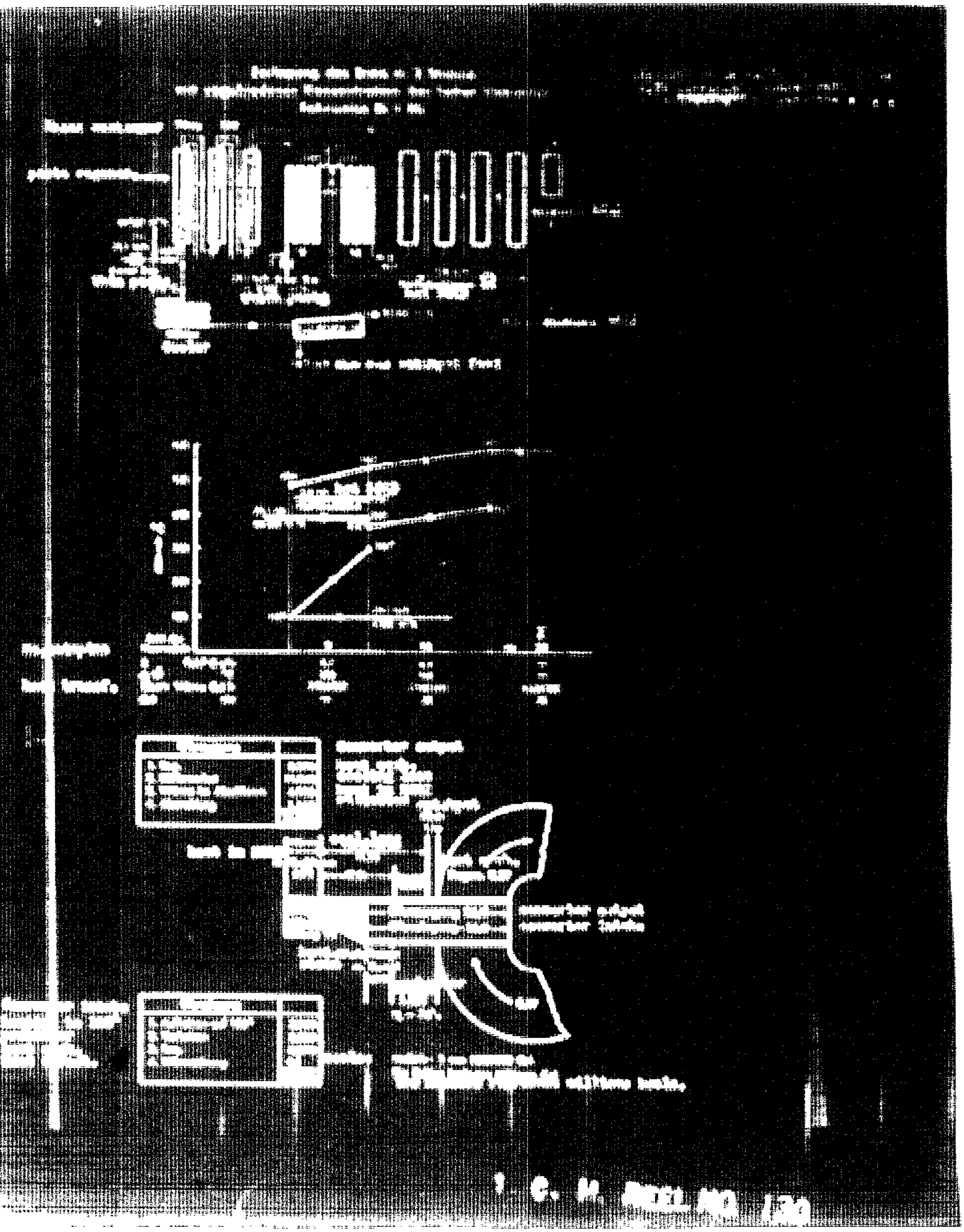
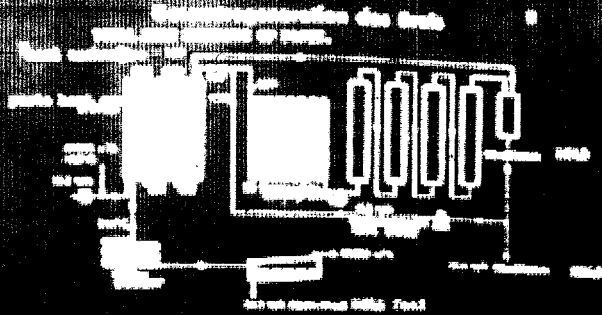
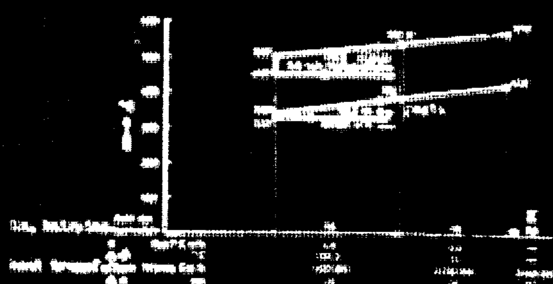
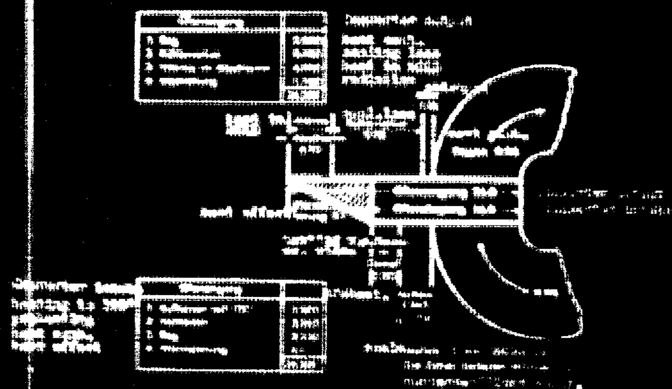


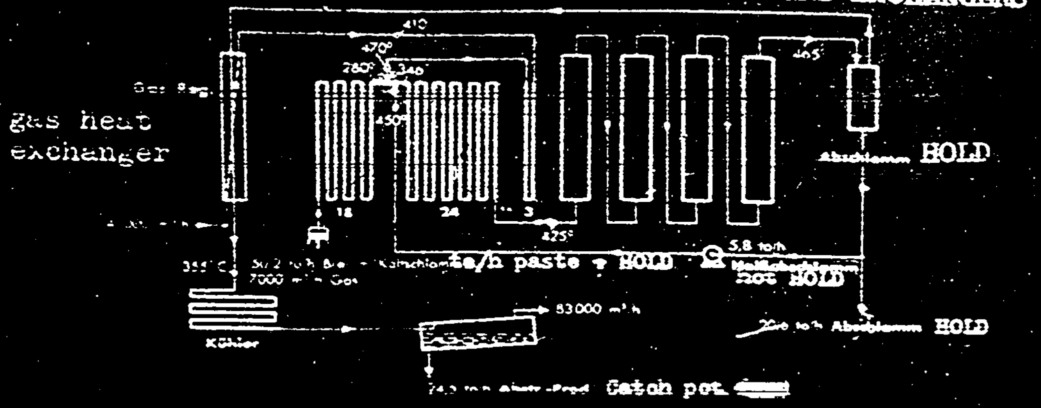


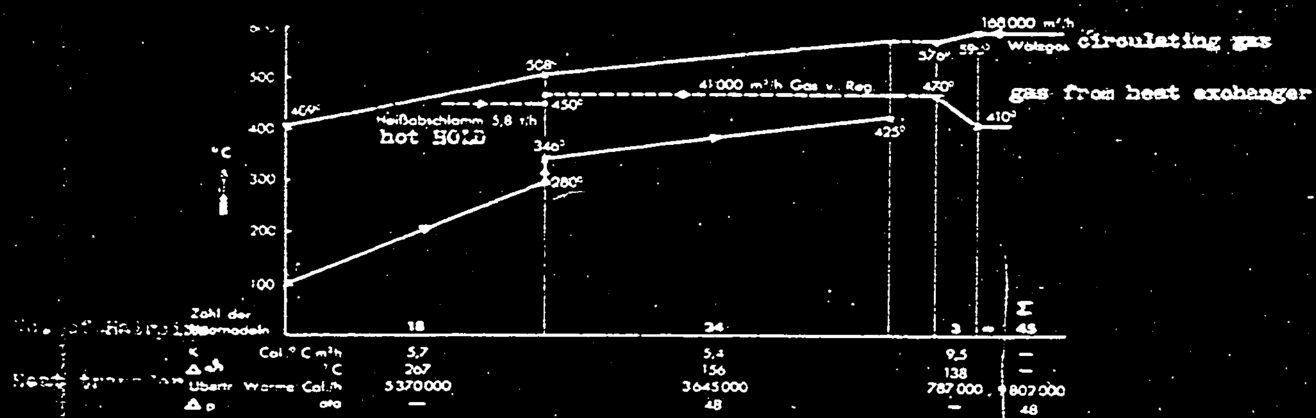




Gasregeneration

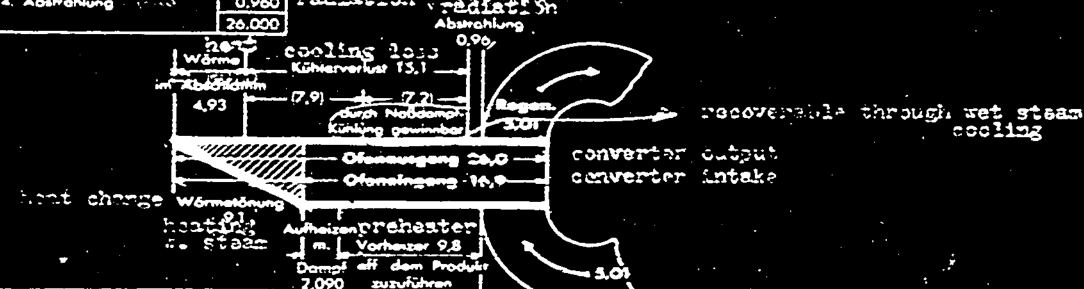
GAS HEAT EXCHANGERS





Ofenausgang	
1. Reg.	5,010
2. Kühlerverlust	15,100
3. Wärme im Abschlamm	4,930
4. Abstrahlung	0,960
	26,000

converter outlet
heat exchanger
cooling loss
heat in HOLD
radiation



Maßstb. 5 mm 1000000 Cal Scale

Die Zahlen bedeuten Millionen Cal.

The numbers represent million Kcals.

CONVERTER INLET

Ofeneingang	
1. Aufheizen auf 100°	2,090
2. Vorheizen	9,800
3. Reg.	5,010
4. Wärmetönung	9,100
	26,000

Heating to 100°
Preheating
Heat exchanger
heat change

T.O.M. Reel No. 11
Target No. 30/4.09
Bag No. 2247

Ludwigshafen, Feb. 14, 1940

HEAT EXCHANGE AND PREHEATER OF THE 700 ATM.
LIQUID PHASE HYDROGENATION AT BLECHHAMMER

The tables below and the temperature diagrams show the conditions during the paste heating in the 700 atm. stalls of the Upper Silesian installation.

I. Process: Gasoline Production from Coal (4-phase Stall).

1. Without heat exchange of paste with cold HOLD.

1-a. Without coal paste heat exchange with hot HOLD in path II.

2. With heat exchange of thin paste with cold HOLD.

3. With heat exchange of all the paste including the cold HOLD.

3-a. With heat exchange of all the paste without the cold HOLD but with hot HOLD, between heat exchangers I and II.

II. Process: Gasoline + Fuel Oil from Coal (4-phase Stall).

1. With heat exchange of coal paste including cold HOLD.

2. With heat exchange of the coal paste including 1/3 of the cold HOLD combined with 2/3 hot HOLD between heat exchangers I and II.

II-a. Process: Gasoline + Fuel Oil from Coal (3-phase Stall).

1. With heat exchange of coal paste including cold HOLD.

2. With heat exchange of the coal paste including 1/3 of the cold HOLD combined with 2/3 hot HOLD between heat exchangers I and II.

The calculations based on the temperature diagrams are drawn from the following data:

Temperature of the Distillate - Gas Mixture in the Outlet of the Catch Pot 465°C

Specific heat of coal paste	(100° - 425°)	0.55 kcal/kg. °C
" " " " "	(100° - 300°)	0.53 " " "
" " " " "	(300° - 425°)	0.57 " " "
" " " distillate	(300° - 465°)	0.7 " " "
" " " "	(200° - 465°)	0.66 " " "
" " " circulating gas	(100° - 425°)	0.32 " " "
" " " " "	(300° - 465°)	0.33 " " "
" " " fuel gas	(560° - 450°)	0.35 " " "

v. stall scheme N 7775-2

The heating surface calculations are based on the K values of Stall 2 of Nordstern which have recently been evaluated. Suitable intermediate values have been calculated for temperature intervals which do not conform to those in the Nordstern preheater (Report #913).

The 600 heat exchangers with 199 small tubes 14/23 diameter with an average heating surface of 188 m² have been used for the paste heat exchanger.

Whenever the process is carried out without paste heat exchange the gas coming from the 600 units and heated to 410° in the gas heat exchanger is also preheated by passing through a "gas hairpin" to 440° for the sake of uniformity.

In processes involving paste heat regeneration, the total gas is preheated in these gas hairpins from 30° to about 100° in order to prevent too much cooling of the paste at 110° when mixed with the gas.

In the last case, the gas hairpin is best located in the cold path and the temperature of the compressed gas would be reduced here by around 10°.

Remarks to sheet I. The smallest heating surface is found in the preheater for the process of regeneration of thin paste, because -

a. The heating of the thick paste in the paste part of the preheater is done at a high average temperature difference, and -

b. The region of the poor heat transfer is bridged over.

The preheater with the lowest heat consumption is found in the process of total heat exchange of the paste, but it is however not yet settled whether the paste with 48% total solids can be heated up to around 340° in small tube heat exchangers.

In the table headed Outlet Temperatures of the "Heat Exchanger, Return Part", the temperatures entered permitted one to judge the usefulness of the suggested wet steam cooling in connection with the heat values which have also been entered. Should the process be selected for the production of gasoline from coal by the methods 1 or 1a, i.e., omitting the paste heat exchange, there is available in the wet steam cooling with a temperature fall from 346° to 240°.

30,800 x 146 + 4,500,000 kcal/h

which is the minimum of the reduction in amount of heat brought to the preheater, because the steam produced in the boiler room cannot be produced without heat losses. It can be seen that wet steam cooling will be economical from the standpoint of amount of heat involved even in the most favorable case of 3a.

Remarks to sheet II. The higher thru-put in the production of fuel oil requires heat exchange of the paste in all cases. The heat exchange of the total paste brings about a disadvantage when passing through the interval of the poor heat transfer between 320 and 375° of having nearly one-half the preheater in that interval of low heat transfer (4.5 kcal/m², °C, h, and occasionally still lower, Report No. 913). This necessitates the large number of hairpins.

It remains yet to investigate at what temperature to work during the maximum HOLD amount and the minimum of the cold gas in the heat exchanger, because that will determine the size of the preheater.

The calculation of the resistance of the preheater is also based on the Report No. 913, in which a λ value of 0.024 for Stall 1 and 0.037 for Stall 2 has been calculated. As a safety factor, the higher value of 0.037 has been used in the computations for Upper Silesia. The gas circulating pumps have already been ordered for a maximum pressure difference of 60 atm., and one may notice that for the sake of economy they should have been ordered for a 100 atm. pressure difference, which shows that case II can only be operated when at least the preheater is connected in parallel. The experience with the liquid phase preheaters and considerations of the swelling properties of the cold paste requires these two preheater systems to be positively fed, i.e., the heat exchangers must also be connected in parallel.

The following questions remain to be answered:

1. Can the measuring-out of the coal paste be carried out from combination piping? An accuracy of ± 5% is sufficient.

2. The hot HOLD pumping suggested in the case II 2 must also be determined for two streams, because but one heat exchanger is built into each stream in front of the regenerator. May we assume such a distribution of the stream from the hot circulating pump with the possibly unequal pressure differences?

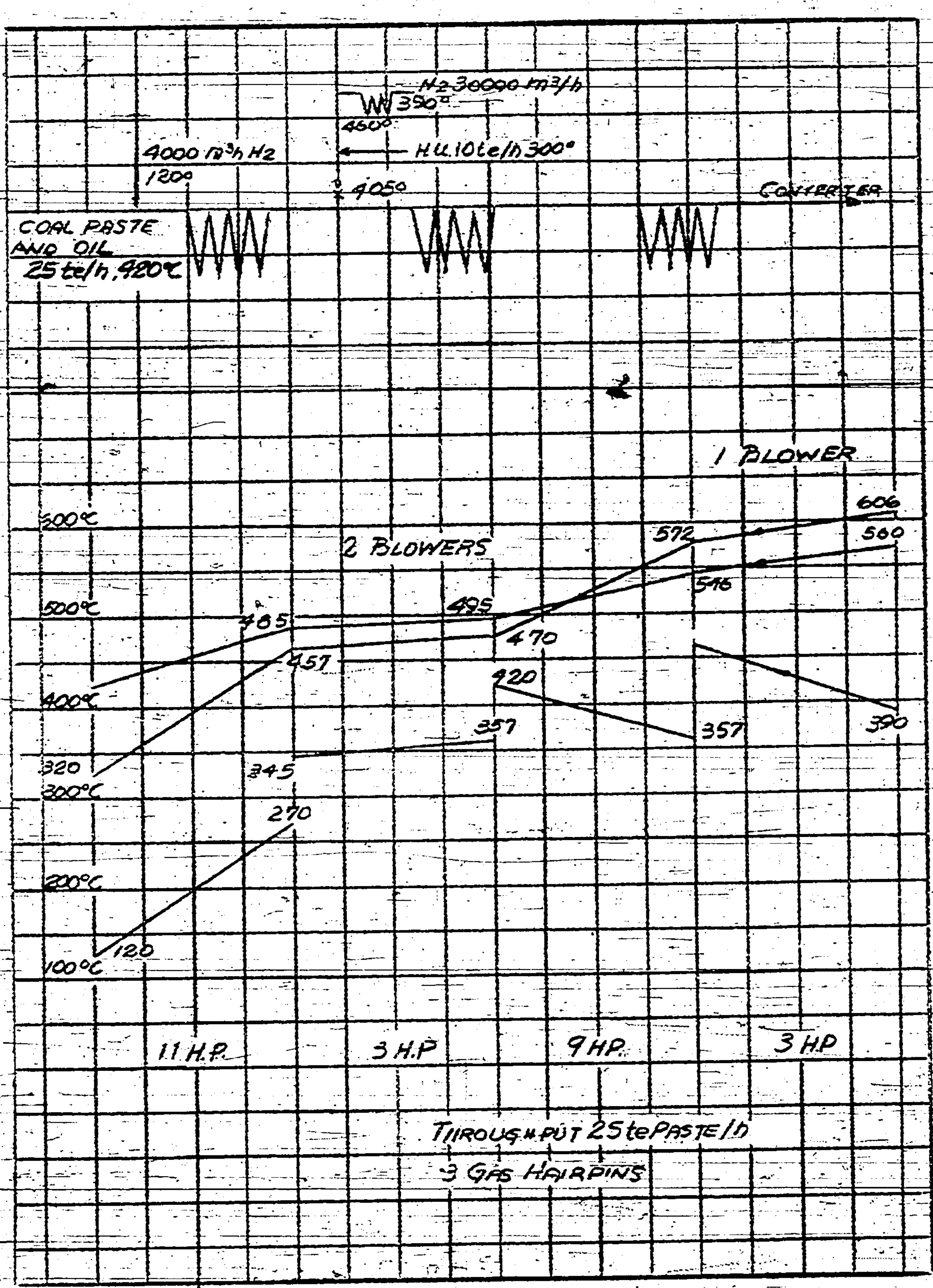
3. When using the 600 heat exchangers with parallel connections, velocities of the (outer) intake way are obtained of only 0.25 - 0.4 m/sec. which are very unfavorable for heat transfer. Are such low velocities practical, or should one change over to narrower hairpins?

4. Is the distribution on the return part of both heat exchangers through a check valve (? Drosselkolben) behind the heat exchangers safe in operation?

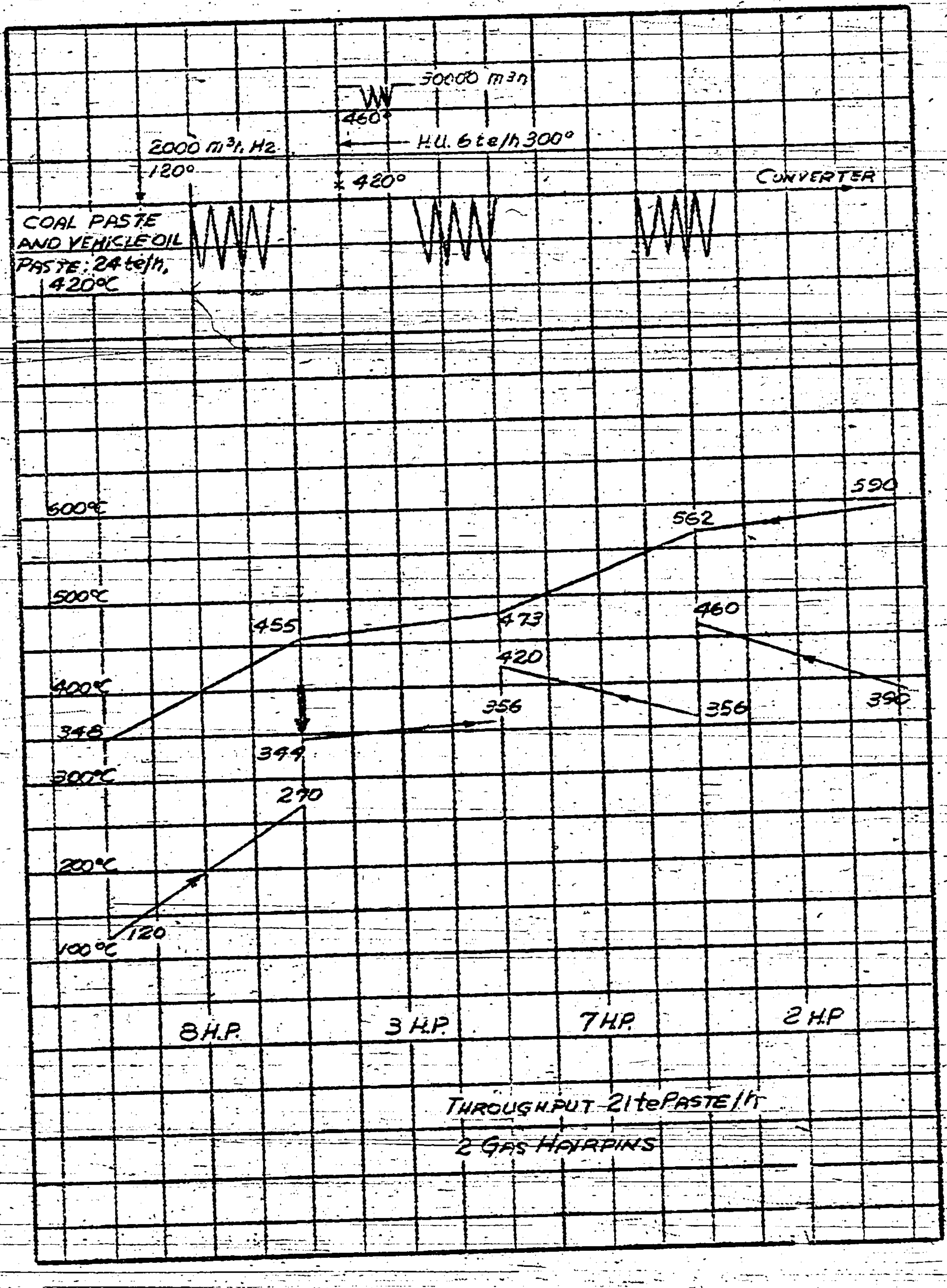
There are other questions: Distribution of the inlet gases, the connection in series of the last three hairpins for the possible equalization of non-uniform heating in the individual streams, etc., are here of lesser importance.

It has been shown that the 4-phase stall offers difficulties in the process for fuel oil, which caused us to calculate the case IIa for a 3-phase stall. One may see that the preheater has only 19 hairpins and that the pressure difference of the stall of 34 atm. permits ready operations with 60 atm. circulating pumps. However, when designing the high pressure cycle, we will have to use now instead of four 4-phase stalls in the gasoline production five 3-phase stalls for gasoline + fuel oil production, and the as yet missing converter No. 16 will be more than equalized by the total larger preheater volume of the five stalls.

Sternberg/mc/pkl



H2 30000 m3/h
350°
450°
4000 m3/h H2
120°
HU. 10 te/h 300°
405°
CONVERTER
COAL PASTE
AND OIL
25 te/h, 420°C
1 BLOWER
2 BLOWERS
600°C
500°C
400°C
300°C
200°C
100°C
606
572
560
516
495
485
470
457
420
357
357
390
345
320
270
120
11 H.P.
3 H.P
9 HP.
3 HP
THROUGHPUT 25 te PASTE/h
3 GAS HAIRPINS



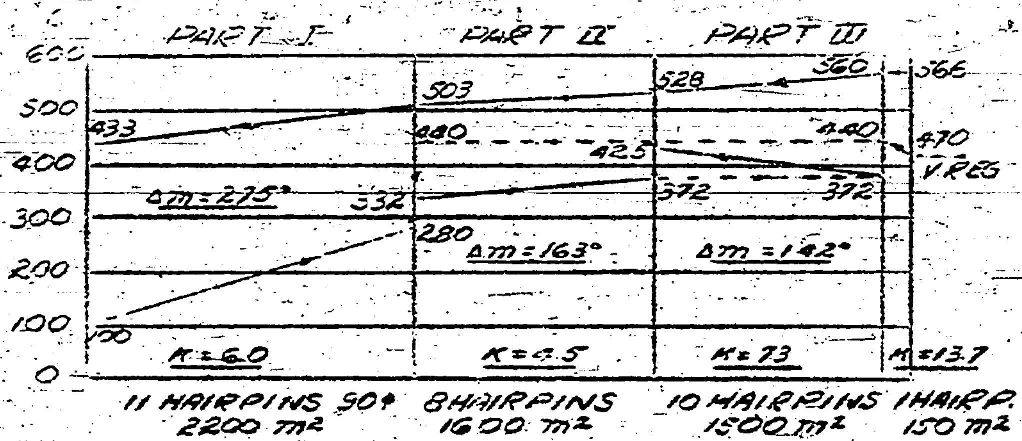
30000 m3n
460°
H.U. 6 te/h 300°
2000 m³/h H2
120°
420°
CONVERTER
COAL PASTE
AND VEHICLE OIL
PASTE: 24 te/h,
420°C
600°C
500°C
400°C
300°C
200°C
100°C
590
562
455
473
460
420
356
356
390
348
349
270
120
8 H.P.
3 H.P.
7 H.P.
2 H.P.
THROUGHPUT 21 te PASTE/h
2 GAS HAIRPINS

I) 700 Atm. Gas Preheater For the Upper Silesian Installation
for Gasoline from Coal (3 Unit Stall)

Throughput: 29.4 te/h coal paste) 47.6% total solids
4.0 te/h HOLD return)
4500 m^3/h paste gas
29,500 m^3/h injection gas from heat exchangers

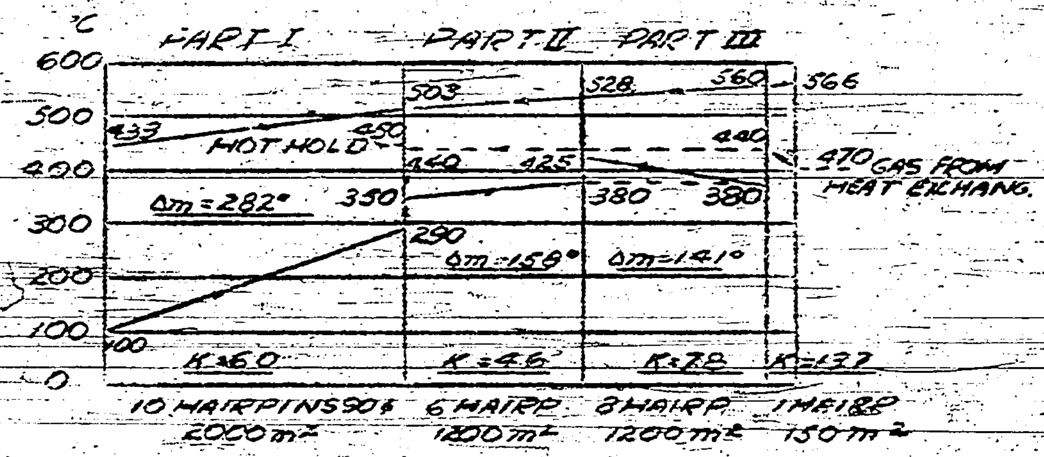
1) Without Paste Heat Exchange with Cold HOLD

$\Delta p = 20$ atm. for parts II and III ($\lambda = 0.037$)



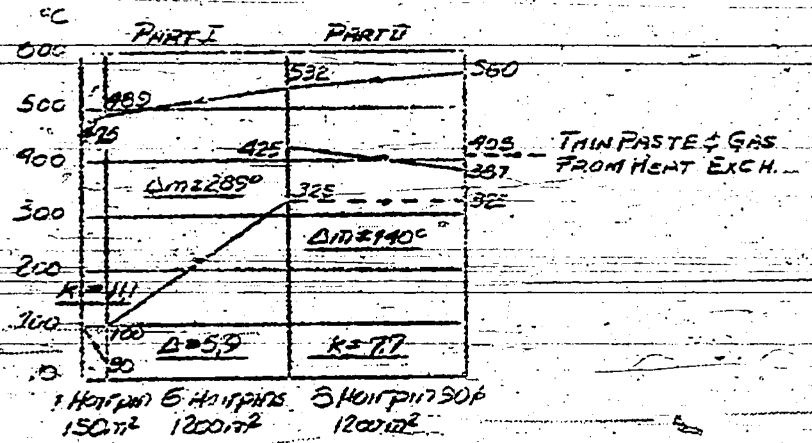
1a) With no Paste Heat Exchange, Hot HOLD in Part II

$\Delta p = 16$ atm. for Parts II and III ($\lambda = 0.037$)



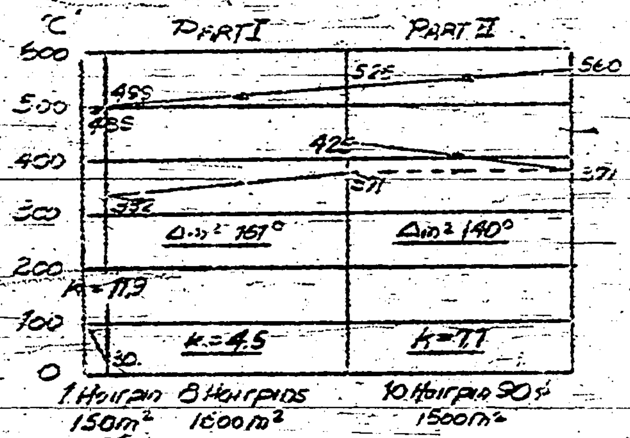
Coal Stall Preheater in Upper Silesia 3278-16

2) with Heat Exch. of thin paste and Cold HOLD.
Δ p = 9 at. in II
(λ = 0.037)
14.7 te/h coal paste (56.% tot.sol.)
14.7 te/h reg. coal paste) 41.0%
+ 4.0 te/h cold HOLD) tot.sol.
3,000 m^3/h paste gas
31,000 m^3/h injection gas



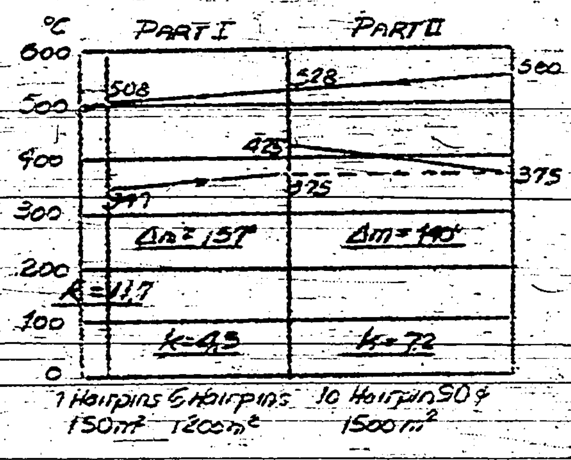
3) Heat Exchange of all the paste including cold HOLD
Δ p = 20 atm (λ = 0.037)

29.4 te/h coal paste
4.0 te/h cold HOLD
34,000 m^3/h injection gas



3a) With Heat Exch. of Total Paste, without the cold HOLD, with hot HOLD between exchangers II and I
Δ p = 17 atm. (λ = 0.037)

29.4 te/h coal paste
4.0 te/h hot HOLD
34,000 m^3/h injection gas

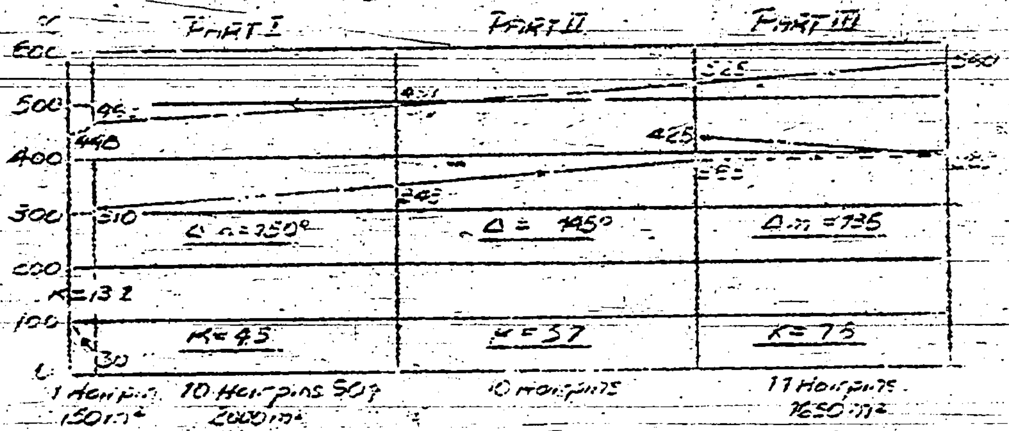


II) 700 atm Gas Preheater, Upper Silesia, for Fuel Oil & L gas from coal (4-phase Stall)

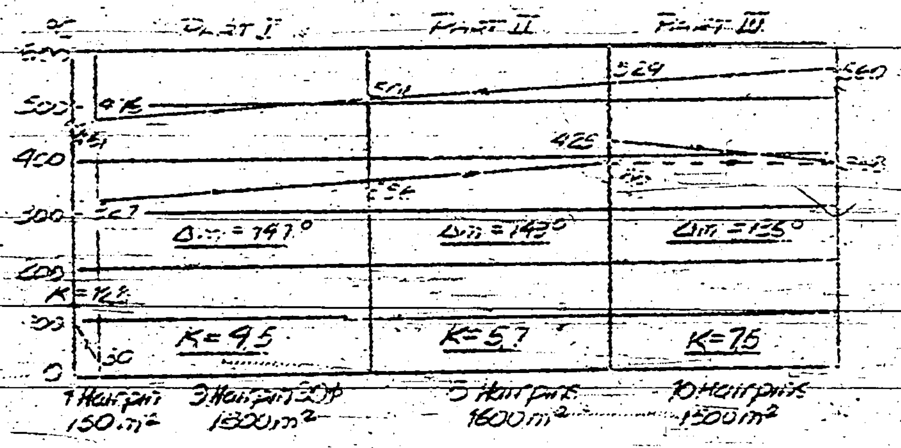
Thruput: 43.8 to/h Coal Paste) 8.4 to/h return HOLD) 48.1% Tot.Sol. 35,600 m^3/h injection gas)

1) With heat exchange of all the paste, including cold HOLD:

$\Delta p = 55$ at ($\lambda = 0.037$)



2) With heat exchange of all the paste, including 1/3 cold HOLD and 2/3 hot HOLD between exchangers II and I.



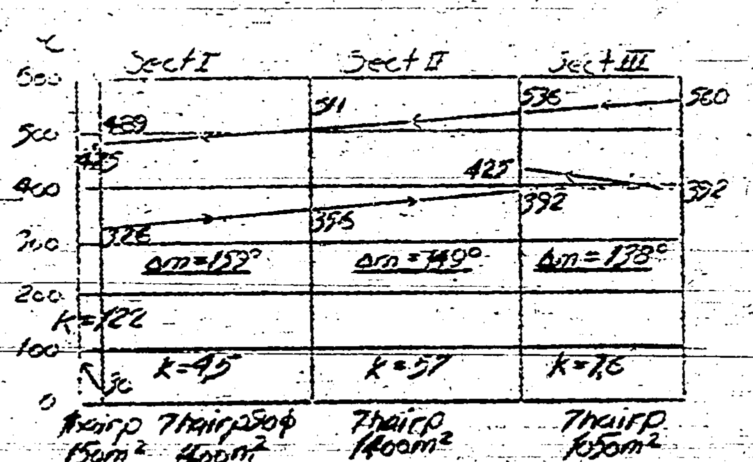
Coal Stall Preheater, Upper Silesia N3230-16

IIa) 700 at. Gas Preheater in Upper Silesia for Fuel Oil and I-gasol. from Coal (3 Phase Stall)

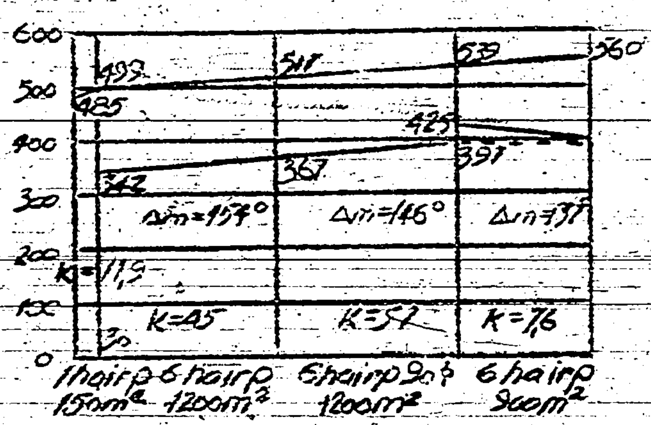
Thruput: 32.8 te/h coal paste) 48.1% G.K.
6.3 te/h return HOLD)
35,000 m^3/h injection gas

1) With heat exchange of all paste, including cold catch pot:

$\Delta p = 27$ at. ($\lambda = 0.037$)



2) With heat exchange of all paste, also 1/3 cold HOLD and 2/3 hot HOLD between exchangers II and I.



Ludwigshafen, Feb. 14, 1940

HEAT EXCHANGERS AND PREHEATERS OF THE COAL STALL AT BLECHHAMMER

Production of:		I. Gasoline from coal (four phase stall)					II. Fuel oil + L gasoline from coal (four phase stall)		IIa. Fuel oil + L gasoline from coal (three phase stall)	
Method		1) With no paste heat exch., with cold HOLD	1a) No paste heat exch., with hot HOLD in part II of preheater	2) With heat exch. of thin paste and cold HOLD	3) With heat exchange of total paste including cold HOLD	3a) With heat exchange of total paste with hot HOLD between exchangers II & I, without cold HOLD	1) With heat exch. of total paste and cold HOLD	2) With heat exch. of total paste, 1/3 cold HOLD and 2/3 hot HOLD between exchangers II and I	1) With heat exch. of total paste including cold HOLD	2) With heat exch. of the paste and 1/3 cold HOLD and 2/3 hot HOLD between exchangers II and I
THROUGHPUTS										
Coal paste	te/h	29.4	29.4	14.7 (50% purified coal) 14.7	29.4	29.4	43.8	43.8	32.8	32.8
Cold HOLD	"	4.0	—	4.0 (41% purified coal)	4.0	—	8.4	2.8	6.3	2.1
Hot HOLD (150°)	"	—	4.0	—	—	4.0	—	5.6	—	4.2
Injection gas	m³/h	29,500	29,500	31,000	34,000	34,000	35,600	35,600	35,000	35,000
Cold gas	"	23,000	23,000	23,000	23,000	23,000	43,000	43,000	31,000	31,000
Paste gas	"	4,500	4,500	3,000	—		—	—		—
HEAT EXCHANGERS										
Number of heat exchangers		1	1	2	2	2	2	2	2	2
Surface	m²	188	188	376	376	376	376	376	376	376
Heat value, forward pass	kcal/h, °C	9,450	9,450	20,200	28,600	II) 26,500 I) 28,700	39,100	II) 36,100 I) 39,100	31,900	II) 29,700 I) 31,900
Inlet temperature	°C	30	30	100	100	100 247	100	100 238	100	100 244
Outlet temperature	°C	410	410	405	332	230 347	310	220 327	326	229 342
Heating to	°C	380	380	305	232	130 100	210	120 89	226	129 88
Heat value, return pass	kcal/h, °C	30,800	30,800	30,100	30,100	30,100	45,200	45,200	36,200	36,200
Inlet temperature	°C	465	465	465	465	387 465	465	386 465	465	377 465
Outlet temperature	°C	346	346	255	240	250 367	280	288 386	262	269 377
Cooling	°C	119	119	210	225	117 93	185	98 79	203	108 88
Average temperature difference	°C	150	150	100	136	143 119	167	177 143	150	158 128
k heat exchangers	kcal/m², h, °C	127	127	164	129	128 128	130	130 130	128	129 130
PREHEATERS										
Feed temp. outlet	°C	425	425	425	425	425	425	425	425	425 425
Useful heat requirements	10⁶ kcal/h	6.55	5.8	4.04	3.55	3.1	5.5	4.8	4.1	3.55
Actual heat requirements	10⁶ kcal/h	8.5 (η = 0.77)	7.0 (η = 0.76)	5.5 (η = 0.73)	4.9 (η = 0.73)	4.4 (η = 0.71)	7.2 (η = 0.76)	6.4 (η = 0.75)	5.6 (η = 0.73)	4.9 (η = 0.73)
Amount of circulating gas (15°C, 1 atm.)	m³/h	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000	150,000
Cir. gas inlet temp.		566	566	560	560	560	560	560	560	560
" " outlet "		433	448	476	485	494	448	461	475	483
Number of hairpins 60 mm diameter		29 + 1 gas hairpin	24 + 1	14 + 1	18 + 1	16 + 1	31 + 1	27 + 1	21 + 1	18 + 1
Δp preheater atm.		20	16	9	20	17	55	48	27	24
Δp of the stall (exch., preheater, conv.) atm.		30	26	24	36	32	75	65	38	34

Sternberg/mz

T. O. M. Reel 11

Ludwigshafen/Rhein, April 18, 1939

REPORT

Re: - Spec. Heat of Coal Paste and Middle Oil.

The following tables 1 and 2 show results of experiments on Scholven coal and gasoline stalls.

A presentation of the heat balance in the individual preheater gases is not possible with the measured values. On the one hand the amount of circulation gas cannot be definitely measured, on the other hand the measured temperature of the mixture of paste and gas is wrong. It is always too high.

The total balance of coal stall II gives the following spec. heat for the paste:

2,000 m^3/h paste gas absorb in the preheater:		
2,000 x 0.32 x (396 - 34)	=	232,000 kcal/h
27,000 m^3/h work gas give up in the preheater:		
27,000 x 0.32 x (409 - 396)	=	112,000 "
Power gas volume:		930 m^3/h
Air volume assumed:	5 x 930 =	4,650 "
Waste gas into atmosphere:		5,580 "
Waste gas loss: 5580 x 0.32 x (398 - 10)	=	694,000 kcal/h
Radiation:		200,000 "
Paste gas:		232,000 "
		1,126,000 "
Added by the power gas:		4,460,000 "
Added by the work gas		112,000 "
		4,572,000 kcal/h
Remain for paste and filmoil:		3,446,000 kcal/h
The spec. heat for paste with 4.25% filmoil becomes:		0.506 kcal/kg °C
The same balance gives for coal stall III:		0.493 kcal/kg °C
for coal stall IV:		0.565 kcal/kg °C

but with coal paste and oil injection in the ratio of 1:1
for gasoline stall 9: 0.836 kcal/kg °C for middle oil

<u>Remarks:</u> From the balance for the year 1938 for Scholven I the spec. heat of the coal paste without filmoil becomes 0.545 kcal/kg °C.

<u>Tables 1 and 2 follow:</u>

Ludwigshafen/Rhein, April 18, 1939

Coal Stall 300 at in Scholven I.

Table 1.

Stall	Coal II	Coal III	Coal IV
Date	3/20/39	3/20/39	3/21/39
Time	10^{30}	11^{00}	12^{00}
Paste gas entering passage I m^3/h	2,000	2,000	2,000
Paste gas entering temp. °C	34°	51°	41°
Work gas entering passage II m^3/h	27,000	27,000	27,000
Work gas entering temp. °C	409°	416°	409°
Paste injection kg/h	23,500	23,500	10,000
Oil injection "	1,000	1,000	10,000
Entering temp. of paste and oil °C	118°	109°	134°
Temp. after preheater-part I °C	215°	208°	300°
" " " " II °C	354°	348°	385°
" " " " III "	396°	399°	428°
Measured temp. of the mixture °C of paste and work gas	368°	370°	322°
Flue gas entering preheater	586°	586°	586°
" " after part III	497°	470°	511°
" " " II	465°	428°	457°
" " leaving preheater	398°	388°	365°
Power gas volume m^3/h	930	950	980
Heat value kcal/m^3	4,800	4,800	4,800
Circulating gas volume m^3/h	81,000	80,000	70,000
Static pressure, mm water gage,	230	240	275
Work - amps.	34	33	33.5
Work - KW	232	226	243

Y cos Θ = 0.79

Ludwigshafen/Rhein, April 18, 1939

Gasoline Stall 9 in Scholven I

Table 2.

Gasoline Stall	9
Date	3/22/39
Time	12 h
Gas entering - m^3/h	30,000
Middle oil injection t/h	12
Entering temp. of oil and gas °C	352°
Temp. at end of passage I °C	373°
Product leaving preheater °C	394°
Flue gas entering °C	457°
After part II "	407°
Flue gas leaving "	375°
Power gas volume m^3/h	250
Heat value $kcal/m^3$	4,600
Work done by motor - KW	215
At Amp.	25.5
Heating surface	2 x 800 m^3

Braun/fkp

T.O.M. Reel No. 5
Target No. 30/4.08
Bag No. 2747
Item No. 18

March 29, 1938

COMPUTATIONS OF THE SPLITTING STALLS
WITH CATALYST 6434, HYDROGENATION WORKS
SCHOLVEN

A splitting stall is equipped with:

1. **3 Converters:** 1000 mm diameter, 18 m long, volume of catalyst 8 m^3/converter

2. **2 Heat Exchangers:**

Heat Exchanger I: 600 mm diameter, 18 m long, 241 tubes 14 x 23 mm diameter, spacing 29.5 mm, average heating surface 228 m^2,

Heat Exchanger II: 600 mm diameter, 18 m long, 301 tubes 14 x 23 mm diameter, spacing 27 mm, average heating surface 286 m^2

3. **1 Gas Heated Preheater:**

8 hairpins 90 mm diameter, 28 m long, heating surface 1280 m^2, inlet temperature of the circulating heating gas 560°C.

The 6 hottest hairpins of the 8 are made of N10 material and the 2 cold hairpins of N8 material. The catalyst 6434 is moved downward in the gasoline converter and no waste pipe is provided.

4. **1 Gas Cooler:** 60 tubes of S2 steel, nominal width 70 mm, 23280 mm long.

The cooler is connected as follows: The upper 20 tubes may be operated with fresh water, while the bottom 40 are cooled with return water. It is, however, possible to operate the whole cooler with return water.

The inlet temperature of the fresh water was assumed to be 15° and of the return cooling water at 32°. The outlet temperature of the cooling water is 55°C.

The Thru-put/stall is:

23.7 te/h of middle oil

The Amount of Injection Gas is:

40,000 m^3/h (at 15°C and 1 at).

(over)

This corresponds to:

1,700 m^3 gas/te of feed

Temperatures:

Converter inlet 375°
Converter outlet 385°

Heat exchanger inlet 30°

Part I.

a. Computation of Amount of Cold Gas in the Gasoline Converter.

The heat of the reaction is:

80 kcal/kg feed

The amount of heat produced in a converter is:

Q = 23700 x 80 = 1,900,000 kcal/h.

This heat is taken up:

1. By the radiation of the converter:

If converter radiates about:
q = 150000 kcal/h.
The total radiation of the 3 converters:
QI = 3 x 150000 = 450,000 kcal/h.

2. Heating of the middle oil and the injection gas.
Temperature rises 10° in the converter, namely from 375° to 385°C.

This heat is QII = Ww x Δt (2)
Ww = the heat value in kcal/h/°C; Δt = 10°C
The specific heat of the middle oil C_M = 0.7 kcal/kg/°C:
Ww = 23700 x 0.7 = 16,600 kcal/h/°C
The heat value of the circulating flue gas with a specific heat of cg = 0.33 kcal/m^3/°C
Wwg = 40000 x 0.33 = 13,200 kcal/h/°C
Σ Heating Value = 29,800 kcal/h/°C

The amount of heat from the heat of the reaction absorbed by the middle oil and in heating gas is then, according to equation (2):

QII = 29800 x 10 = 298,000 kcal/h

3. By the Cold Gas

The amount of cold gas is:

$$Vk = \frac{Q'}{ck \times \Delta t} \quad (m^3/h)$$

$Q' = Q - QI - QII$
$= 1,900,000 - 450,000 - 298,000$
$Q' = 1,152,000$ kcal/h.
$ck = 0.31$ kcal/m^3/°C
$\Delta t = t_2 - t_1 = 385 - 40 = 345$°C
$$Vk = \frac{1,152,000}{0.31 \times 345}$$
$Vk = 10,800$ m^3/h of cold gas (15°, 1 at).

According to past experience, with 3 converters half of the cold gas is used up in Converter I.

b. Computation of heat exchangers.
(Temperature diagram N 2012-15)

The intake of the heat exchangers on the converter side:
1) 23700 kg/h of distillate at 385°C,
2) 50800 m^3/h of gas at 385°C.

With c = 0.7 kcal/kg/°C, the heat value is,
23,700 x 0.7 = 16,600 kcal/h/°C
The heat value in 2) with c = 0.33 kcal/m^3/°C:
50,800 x 0.33 = 16,800 kcal/h/°C

Σ Heat value (return pass) = 33,400 kcal/h/°C

The amounts to be heated in the heat exchangers should be:
(1 page missing in the microfilm. The text continues as follows:)

$$\Delta m = \frac{53}{\ln \frac{128}{75}} = \frac{53}{2.3 \times 0.232}$$

$F = 228 + 286 = 514$ m^2,

$$k = \frac{7,450,000}{514 \times 99} \quad \Delta m = 99°C$$

$k = 146$ kcal/m^2/h/°C (to be used as a minimum K value)

Addition to the Heat Exchanger Computations.

Were the stall 6434 built with new heat exchangers of 199 and 249 tubes and an average heating surface of 188 m^2 and 236 m^2, the k value of 175 kcal/m^2/h/°C would be obtained with the same temperature conditions. One should expect to obtain this value of 175 kcal/m^2/h/°C because of an increase in the velocity in the heat exchanger of about 20%.

(over)

c. Computation of the Preheater
(Temperature diagram N1917-16)

The preheater is composed of 2 sections:

Section 1. 4 hairpins 90 mm diameter x 30 m, arranged co-currently, average heating surface 4 x 160 m^2 = 640 m^2.

Section 2. 4 hairpins 19 mm diameter x 30 m, counter-currently, average heating surface 4 x 160 m^2 = 640 m^2.

Computation of the Heating Gas Blowers

To be heated in the preheater:

Part 1. 23.7 te/h of middle oil, from 310°C to 375°C.

Part 2. 40,000 m^3/h of injection gas, from 310°C to 375°C.

The heating values are

For 1, with c = 0.65 kcal/kg/°C

23,700 x 0.65 = 15,400 kcal/h/°C

For 2, with c = 0.32 kcal/m^3/°C:

40,000 x 0.32 = 12,800 kcal/h/°C

Σ Heat Value = 28,200 kcal/h/°C

The amount of heating to be delivered by the circulating flue gas:

Q = 28200 x (375 - 310) = 1,830,000 kcal/h,

Radiation: = 150,000 Kcal/h

Q' 1,980,000 kcal/h.

The inlet temperature of the flue gas is 560°C, and the temperature of the circulating flue gas should drop in the preheater by 165°C, from 560 to 395°C.

The amount of flue gas then is

$$V = \frac{Q'}{c \times \Delta t} \ (m^3/h); \ c = 0.36 \ kcal/m^3/°C,$$

$$\Delta t = 165°C.$$

$$V = \frac{1,980,000}{0.35 \times 165}$$

V = 34,300 m^3/h (15°C, 1 at).

The flue gas blower selected is of 35,000 m^3/h capacity, at 15°C and 1 at.

Calculation of Temperatures in Sections 1 and 2

Section 1 is the co-current part, heating surface 640 m^2. The rise in temperature is 42°C, from 333 to 375°C. In that case:

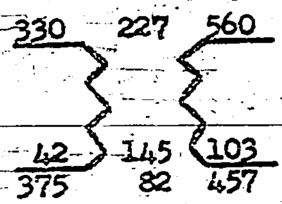
Q I = 28,200 x 42	= 1,185,000 kcal/h
Radiation	= 75,000 kcal/h
Q' I	= 1,260,000 kcal/h

Drop in Temperature of the Circulating Flue Gas:

The heat value of circulating flue gas is:

35,000 x 0.35 = 12,300 kcal/h/°C

$$A = \frac{1,260,000}{12,300} = 103°C$$



$$k = \frac{Q\ I}{F \times \Delta m} \text{ kcal/m}^2\text{/h/°C}; \quad \Delta m = \frac{145}{\ln \frac{227}{82}} = 142°C$$

F = 640 m^2

$$k = \frac{1,185,000}{640 \times 142} = 13 \text{ kcal/m}^2\text{/h/°C}$$

Section 2 is counter-current, heating surface 640 m^2. The increase in temperature amounts to 23°C, from 310° to 333°C. In that case:

Q II is 28,200 x 23	= 645,000 kcal/h
Radiation	= 75,000 kcal/h
Q' II	= 720,000 kcal/h

The drop in temperature of the circulating gas is:

$$A = \frac{720,000}{12,300} = 59$$

(over)

$k = \frac{Q\ II}{F \times \Delta m}$ kcal/m²/h/°C

$F = 640\ m^2$

$k = \frac{645{,}000}{640 \times 105}$

333	124	457
	36	
23	88	59
310		398

$\Delta m = \frac{36}{\ln \frac{124}{88}} = 105°$

k = 9.6 kcal/m²/h/°C

The average value for Sections 1 and 2 is:

$k\ average = \frac{13 + 9.6}{2} = 11.3$ kcal/m²/h/°C

Computation of Tube Wall Temperatures in Section 1.

The amount of heat transferred during the temperature drop from 560° to 333°C is:

$Q' = \frac{q \times (560 - 333)}{\Delta m}$ $\Delta m = 142°$

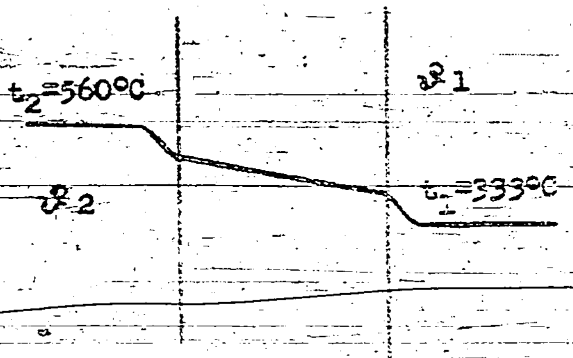
$q = \frac{Q\ I}{L}$ $L = 4 \times \pi \times a$

$a = 28\ m$

$q = \frac{1{,}185{,}000}{4 \times \pi \times 28} = 3{,}380$

$Q' = \frac{3{,}380 \times 227}{142} = 5{,}400$

$Q' = \frac{\vartheta_1 - t_1}{\frac{1}{\alpha_1 \times i.d.}}$ $\Delta t = \vartheta_1 - t_1$



$\alpha_1 = 700$ kcal/m²/h/°C

i.d. = 90 mm

o.d. = 127 mm

$\Delta t = \frac{5400}{700 \times 0.09} = 86°$

$$\vartheta_1 = \Delta t + t_1 = 86 + 333 = 419°C$$

$$Q' = \frac{\vartheta_1 - t_1}{\frac{1}{2\lambda} \times \ln \frac{o.d.}{i.d.}}$$

$\lambda = 40$ kcal/m²/h/°C

$\Delta t_1 = \vartheta_2 - \vartheta_1$

$$\Delta t = \frac{5{,}400 \times \ln \frac{127}{90}}{2 \times 40} = 23°C$$

$$\vartheta_2 = \Delta t_1 - \vartheta_1$$

$$\vartheta_2 = 23 + 419 = 442°$$

The amount of heat transferred with a temperature fall from 457 to 375° is:

$$Q' = \frac{q \times (457 - 375)}{\Delta m}$$

$\Delta m = 142°C$

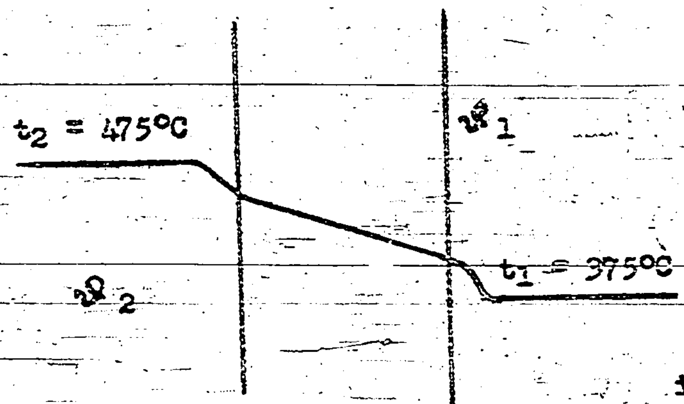
$q = 3{,}380$

$$Q' = \frac{3{,}380 \times 82}{142} = 1{,}950$$

$$Q' = \frac{\vartheta_1 - t_1}{\frac{1}{\alpha_1 \times i.d.}}$$

$\alpha_1 = 70$ kcal/m²/h/°C

$\Delta t = \vartheta_1 - t_1$



$$\Delta t = \frac{Q'}{\alpha_1 \times i.d.} = \frac{1{,}950}{700 \times 0.09} = 31°C$$

i.d. = 90 mm

o.d. = 127 mm

$$\vartheta_1 = \Delta t + t_1$$

$$\vartheta_1 = 31 + 375 = 406°C$$

$\lambda = 40$ kcal/m²/h/°C

$$\Delta t = \vartheta_2 - \vartheta_1$$

(over)

$$Q = \frac{\vartheta_2 - \vartheta_1}{\frac{1}{2\lambda} \times \ln \frac{o.d.}{i.d.}}$$

$$\Delta t = \frac{1{,}950 \times \ln \frac{127}{90}}{2.40}$$

$\Delta t_1 = 8°C$

$\vartheta_2 = \Delta t_1 + \vartheta_1$

$\vartheta_2 = 8 + 406 = 414°C$

Part II

Calculations of the Coolers (Temperature Diagram N 2014-16)

The cooler is calculated for the least favorable heat of reaction, 120 kcal/kg feed.

Feed: 23.7 te/h of middle oil
40,000 m³/h of injection gas (at 15°C and 1 at)

a. The amount of heat set free in the converter:

Q = 23,700 x 120 = 2,850,000 kcal/h.

This heat is taken up by:

1. Radiation of the Converter

Each converter radiates about:

q = 150,000 kcal/h.

The radiation for the 3 converters is:

Q I = 3 x 150,000 = 450,000 kcal/h

2. Heating of the Middle Oil and of the Injection Gas in the converter by 10°C

This heat is: Q II = $\Sigma W \times \Delta t$

The heat value is:

For middle oil with c_M = 0.7 kcal/kg/°C = 23,700 x 0.7 = 16,600 kcal/h/°C

For injection gas with c_g = 0.33 kcal/m3/°C = 40,000 x 0.33 = 13,200 kcal/h/°C

Total heat value 29,800 kcal/h/°C

The middle oil and the injection gas take therefore from the heat of the reaction:

Q II = 29,800 x 10 = 298,000 kcal/h

3. **The Cold Gas**

The amount of cold gas is:

$$V_k = \frac{Q'}{ck \times \Delta t} \ (m^3/h); \quad ck = 0.31\ kcal/m^3/°C$$

$$\Delta t = 385 - 40 = 345°C$$

Q' = Q - Q I - Q II = 2,850,000 - 450,000 - 298,000 = 2,102,000 kcal/h

$$Vk = \frac{2,102,000}{0.31 \times 345}$$

Vk = 19,700 m³/h

b. **Heat Exchangers**

The heat exchangers receive from the converters:

1) 23.7 te/h of distillate at 385°C; Ww = 23,700 x 0.7 = 16,600 kcal/h/°C

2) 59,700 m³/h of gas at 385°C;

Ww = 59,700 x 0.33 = 19,700 kcal/h/°C

Total heat value 36,300 kcal/h/°C

The amounts to be heated in the heat exchanger:

1) 23.7 te/h of middle oil at 30°;

Ww = 23,700 x 0.6 = 14,200 kcal/h/°C

2) 40,000 m³/h of injection gas at 30°;

Ww = 40,000 x 0.31 = 12,400 Kcal/h/°C

Total heat value 26,600 kcal/h/ C

The material is heated 290°, from 30° to 320°, and the total amount of heat transmitted is

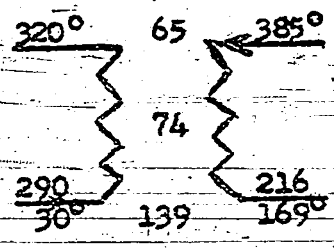
Q = 26,000 x 290 = 7,720,000 kcal/h

Radiation = 140,000 kcal/h

Q' = 7,860,000 kcal/h

(over)

The temperature fall on the hot side is then:



$$A = \frac{7,860,000}{36,300} = 216°C$$

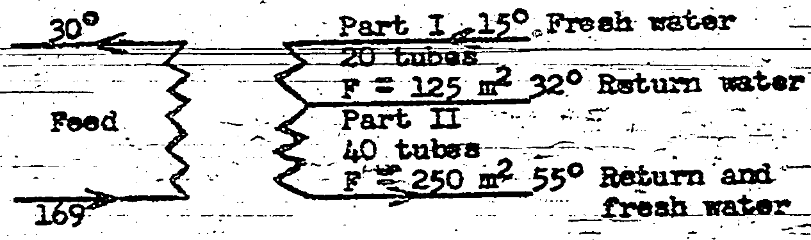
$$F = 514 \ m^2$$

$$k = \frac{7,720,000}{514 \times 97} = 155 \ kcal/m^2/h/°C$$

$$m = \frac{74}{\ln \frac{139}{65}} = 97°C$$

c. Water Cooler

Connections:



Cooler Intake:

1) 23.7 te/h of distillate at 169°, Ww = 23,700 x 0.6 = 14,200 kcal/h/°C

2) 59,700 m³/h of gas at 169°, Ww = 59,700 x 0.31 = 18,500 kcal/h/°C

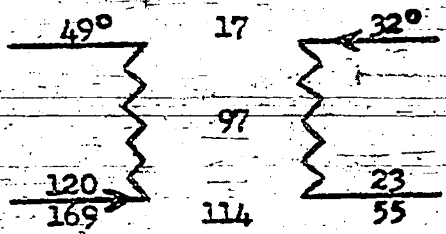
Total heat value = 32,700 kcal/h/°C

1) In the lower part of section 2 the product must be cooled 120°C, from 169°C to 49°C.

The amount of heat removed is

Q = 32,700 x 120 = 3,930,000 kcal/h

For section 2, 40 tubes have been selected with a normal width of 70 mm and a heating surface f = 6.25 m²



$$F = 40 \times 6.25 = 250 \ m^2$$

$$k = \frac{3,930,000}{250 \times 51} = 309 \ kcal/m^2/h/°C$$

$$\Delta m = \frac{97}{\ln \frac{114}{17}} = 51°C$$

2) In section 1 (tip) the product has to be cooled by 19°, from 49°C to 30°C.

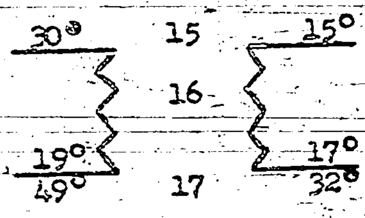
The amount of heat is:

Q = 32,700 x 19 = 620,000 kcal/h

20 tubes with normal width, 70 mm, and with a heating surface $f = 6.25\ m^2$ have been selected for Section 1.

$F = 20 \times 6.25 = 125\ m^2.$

$$k = \frac{620,000}{125 \times 16} = 310\ kcal/m^2/h/°C$$



$\Delta m = 16°C$

3) Amounts of Water

Part 1 requires:

$$V_1 = \frac{Q}{c \times \Delta t} = \frac{620,000}{1000 \times 17} = 37\ m^3/h \text{ of fresh water at } 15°C$$

Section 2 requires:

$$V_2 = \frac{3,930,000}{1000 \times 23} = 171\ m^3/h$$

Of this total amount 37 m^3/h are obtained from Section 1, and the total amount of return cooling water required is:

$V_2 = 134\ m^3/h$ of cooling water at 32°C.

4) Velocity of Water

The free cross section in the cooling tube is:

$$f = \frac{d_a^2 \pi}{4} - \frac{d_i^2 \pi}{4}$$

$d_a = 137$ mm, $d_i = 102$ mm, d_i

$f = 0.0148 - 0.0082 = 0.0066\ m^2$

With 5 tubes connected in parallel:

$F = 0.033\ m^2.$

$$v1 = \frac{37}{0.033 \times 3600} = 0.3\ m/sec.$$

$$v2 = \frac{171}{0.033 \times 3600} = 1.4\ m/sec.$$

(over)

5) Calculation of Pressure Drops (Diagrams N 2024-16 and N 2025-16)

The average temperature of the cooling water is about 40°C and it flows through a jacket and tube of diameters D1 = 137 mm and D2 = 102 mm. The velocity of water in Section 2 is 1.4 m/sec. The pressure drop is determined from:

$$\Delta p = \lambda' \times \rho \times \frac{v^2}{2} \times l \times \frac{U}{F}$$

Here:

λ' is a function of the Reynolds number $R = 2 \times \frac{V \times F}{U \times \nu}$

ν is the kinematic viscosity

ρ is the density

V is the velocity

l is the length of the tube

F is the free cross section

U is the active circumference of the tube

Diagram 1 shows that:

$\nu = 0.66 \times 10^{-6} (m^2/sec)$

$\rho = 101.1\ (kg.sec^2/m^4)$

$U = 0.137 \times \pi + 0.102 \times \pi = 0.75\ m$

$F = \frac{0.137^2\ \pi}{4} - \frac{0.102^2\ \pi}{4} = 0.0066\ m^2$

$R = 2 \times \frac{1.4 \times 0.0066 \times 10^6}{0.75 \times 0.66} = 37,400$

Diagram 2:

$\lambda' = 0.0042$

The total tube length for each bundle in the cooler when cooling with 171 m^3/h of return water

$l = 12 \times 22.56 = 275\ m$

We have therefore:

$$\Delta p = 0.0042 \times 101.1 \times \frac{1.4^2}{2} \times 275 \times \frac{0.75}{0.0066} = 13,000\ kg/m^2$$

Adding about 50% for the inlet and the connecting pieces, the drop in pressure in the cooler, Δ P, is about 2 maximum.

Part-III

Computation of Piping (Diagram N5027-2)

1) Piping from the circulation system (pressure side) up to the outlet of cold gas:

V_0 = 40 m^3/h of injection gas + 10,800 m^3/h of cold gas, 15°, 1 atm.

Temperature 30°C, pressure 300 atm., k = 1.19 (from diagram)

$$V = V_0 \times \frac{p_0}{p} \times \frac{T}{T_0}$$

$$V = (40{,}000 + 10{,}800) \times \frac{1}{300} \times \frac{303}{288} \times 1.19$$

$V = 212\ m^3/h$

The piping selected is of S2 steel, 127 x 90 diameter = 9.2 m/sec.

2) Piping up to feed inlet:

V_0 = 40,000 m^3/h of injection gas, 15°, 1 atm.

Temperature 30°C, pressure 300 atm., k = 1.19

$$V = 40{,}000 \times \frac{1}{300} \times \frac{303}{288} \times 1.19$$

$V = 167\ m^3/h$

Selected: Piping, S2 material, 127 x 90 diameter

v = 7.3 m/sec.

3) Feed formation in front of heat exchanger II:

V = 169 m^3/h of injection gas at 30° and 300 atm. + 24 m^3/h of new material.

V = 193 m^3/h

With the 127 tubes of S2 steel, 90 mm diameter

v = 8.4 m/sec.

4) Feed piping between heat exchangers II and I:

V_0 = 40,000 m^3/h of injection gas, 15°C, 1 atm., + 24 m^3/h of new material.

Temperature 160°C, pressure 300 atm., k = 1.14

$$V = 40{,}000 \times \frac{1}{300} \times \frac{433}{288} \times 1.14 + 24 = 228 + 24$$

V = 252 m^3/h

(over)

With 127 tubes of N8 steel, 90 mm diameter

$v = 11$ m/sec.

5) Piping for feed between heat exchanger I and preheater:

$V_o = 40{,}000$ m^3/h of injection gas, 15°C, 1 atm. + 24 m^3/h of new material.

Temperature 310°C, pressure 300 atm., $k = 1.1$

$$V = 40{,}000 \times \frac{1}{300} \times \frac{583}{288} \times 1.1 + 24 = 297 + 24$$

$$\underline{V = 321 \text{ m}^3/\text{h}}$$

With 127 tubes of N8 steel, 90 mm diameter

$v = 14$ m/sec.

6) Feed piping between preheater and Converter I:

$V_o = 40{,}000$ m^3/h of injection gas, 15°C, 1 atm. + 24 m^3/h of new material.

Temperature 375°C, pressure 300 atm., $k = 1.09$

$$V = 40{,}000 \times \frac{1}{300} \times \frac{648}{288} \times 1.09 + 24 = 327 + 24$$

$$\underline{V = 351 \text{ m}^3/\text{h}}$$

With the 127 tubes of N8 steel, 90 mm diameter.

$v = 15.2$ m/sec.

7) Piping between Converters I and II:

It is assumed that one-half of the total cold gas is introduced into Converter I.

$V_e = 40{,}000$ m^3/h of injection gas + 0.5 x 10,800 m^3/h at 15°C and 1 atm. pressure + 24 m^3/h of fresh material.

Temperature 385°C, pressure 300 atm., $k = 1.085$

$$V = (40{,}000 + 0.5 \times 10{,}800) \times \frac{1}{300} \times \frac{658}{288} \times 1.085 + 24 = 376 + 24$$

$$V = 400 \text{ m}^3/\text{h}$$

With 171 tubes of N8 steel, with 120 mm diameter

$v = 9.8$ m/sec.

8) Piping between Converter II and Converter III:

It is assumed that one-third of the total cold gas is introduced into Converter II.

V_o = 400 m³/h feed at 385°C and 300 atm. + $\frac{1}{3}$ x 10,800 m³/h of cold gas at 15°C and 1 atm.

Temperature 385°C, pressure 300 atm.,   k = 1.085

$V = 400 + \frac{1}{3} \times 10{,}800 \times \frac{1}{300} \times \frac{658}{288} \times 1.085 = 400 + 30$

$V = 430\ m^3/h$

With 171 tubes of N8 steel, 120 mm diameter

v = 105 m/sec.

9) Piping between Converter III and heat exchanger I:

V_o = 40,000 m³/h of injection gas + 10,800 m³/h of cold gas at 15°C and 1 atm. + 24 m³/h of new material.

Temperature of 385°C, pressure 300 atm.,   k = 1.085

$V = (40{,}000 + \quad \times 10{,}800) \times \frac{1}{300} \times \frac{658}{288} \times 1.085 + 24$

$V = 420 + 24$

$V = 444\ m^3/h$

With 171 tubes of N8 steel, 120 mm diameter,

v = 10.9 m/sec.

10) Piping between heat exchanger I and II:

V_o = 50,800 m³/h of gas at 15°C and 1 atm. + 24 m³/h of new material.

Temperature 263°C, pressure 300 atm.,   k = 1.11

$V = 50{,}000 \times \frac{1}{300} \times \frac{536}{288} \times 1.11 + \quad = 350 + 24$

$V = 374\ m^3/h$

With 171 tubes of N8 steel, with 125 mm diameter,

v = 9.2 m/sec.

(over)

11) Piping between heat exchanger II and water cooler:

V_o = 50,800 m³/h of gas at 15°C + 1 atm. + 24 m³/h of new material.

Temperature 158°C, pressure 300 atm., k = 1.14

$$V = 50{,}800 \times \frac{1}{300} \times \frac{431}{288} \times 1.14 + 24 = 290 + 24$$

V = 314 m³/h

With 127 tubes of S2 steel, with 90 mm diameter,

v = 13.6 m/sec.

12) Average velocity in water cooler:

V_o = 50,800 m³/h of gas, 15°C, 1 atm. + 24 m³/h of new material.

Average temperature: $\frac{158 + 30}{2}$ = 94°C, pressure 30 atm., k = 1.16

$$V = 50{,}800 \times \frac{1}{300} \times \frac{367}{288} \times 1.16 + 24 = 250 + 24$$

V = 2.74 m³/h

The cross section of 5 tubes, 70 mm diameter, is equal to 193 cm²

v_m = 3.9 m/sec.

13) Piping from cooler to catch pot:

V_o = 50,800 m³/h, 15°C, 1 atm. + 24 m³/h of new product.

Temperature 30°C, pressure 300 atm., k = 1.19

$$V = 50{,}800 \times \frac{1}{300} \times \frac{303}{288} \times 1.19 + 24 = 212 + 24$$

V = 236 m³/h

With 127 tubes of S2 steel, 90 mm diameter,

v = 10 m/sec.

14) Average velocity in heat exchanger II:

a) Feed side (around group of tubes)

V_o = 40,000 m³/h injection gas at 15°C and 1 atm. + 24 m³/h of new material.

Average temperature: $\frac{30 + 160}{2}$ = 95°C, pressure 300 atm., k = 1.16

$$V = 40{,}000 \times \frac{1}{300} \times \frac{368}{288} \times 1.16 + 24 = 198 + 24$$

$V = 222\ m^3/h$

The free cross section around the tubes is $f = 0.071\ m^2$

$v_m = 0.87$ m/sec.

b) Distillation side

$V_o = 50,800\ m^3/h$ of gas at 15°C, 1 atm. + $24\ m^3/h$ of new material.

Average temperature: $\frac{263 + 158}{2} = 210°$, pressure 300 atm., k = 1.12

$$V = 40,000 \times \frac{1}{300} \times \frac{483}{288} \times 1.12 + 24 = 251 + 24$$

$V = 275\ m^3/h$

The free cross section of the tubes is $f = 0.0462\ m^2$

$v_m = 1.7$ m/sec.

15) Average velocities in heat exchanger I:

a) Feed side

$V_o = 40,000\ m^3/h$ of injection gas, 15°C, 1 atm., + $24\ m^3/h$ of new material.

Average temperature: $\frac{160 + 310}{2} = 235°C$, pressure 300 atm., k = 1.12

$$V = 40,000 \times \frac{1}{300} \times \frac{508}{288} \times 1.12 + 24 = 264 + 24$$

$V = 288\ m^3/h$

The free cross section around the tubes is $f = 0.0962\ m^2$

$v_m = 0.83$ m/sec.

b) Distillation side

$V_o = 50,800\ m^3/h$ of gas at 15°C, 1 atm. + $24\ m^3/h$ of new material.

Average temperature: $\frac{263 + 385}{2} = 324°C$, pressure 300 atm., k = 1.095

$$V = 50,800 \times \frac{1}{300} \times \frac{597}{288} \times 1.095 = 385 + 24$$

$V = 409\ m^3/h$

The free cross section around the tubes is $f = 0.0371\ m^2$

$v_m = 3.1$ m/sec.

(over)

16) Thru-put velocity in the converter referred to the free cross section $f = 0.346^2 \times \frac{\pi}{4} = 0.65\ m^2$

Converter I: $V = 400\ m^3/h$ $v_m = 0.2$ m/sec.

Converter II: $V = 430\ m^3/h$ $v = 0.21$ m/sec.

Converter III: $V = 444\ m^3/h$ $v = 0.22$ m/sec.

17) Cold gas piping:

$V_o = 10,800\ m^3/h$ of cold gas at 15° and 1 atm.

Temperature 30°C, pressure 300 atm., $k = 1.19$

$V = 10,800 \times \frac{1}{300} \times \frac{303}{288} \times 1.19$

$V = 45\ m^3/h$

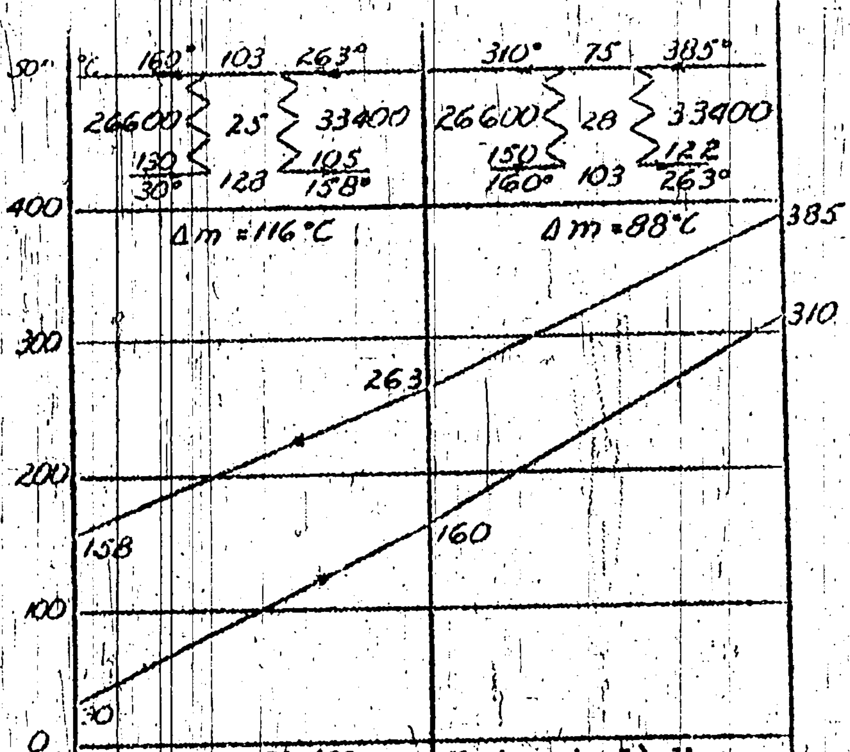
Piping selected of S2 steel, diameter 45 mm.

$v = 7.8$ m/sec.

Sternberg/mc/fkp

Q = 3,460,000 kcal/h   Q = 3,990,000 kcal/h

k_2 = 104 kcal/m²/h/°C k_1 = 198 kcal/m²/h/°C



Heat exch. 2), 600 mm diam., 18 m. long	Heat exch. 1), diam. 600, 18 m. long
301 tubes, 14x23 ϕ,, spaced 27 mm.	241 tubes, 14x23 ϕ, spaced 29.5 mm.
Av. heat. surf. 286 m²	Av. heat. surf. 228 m²

To be heated:

23,700 kg/h middle oil from 30 to 310°C

40,000 m3/h injection gas from 30 to 310°C

= 7,450,000 kcal/h

+ Radiation = 140,000 "

Σ = 7,590,000 kcal/h

Temperature drop on the hot side:

$A = \frac{7,590,000}{33,400} = 227°C$

$k = \frac{7,450,000}{574 \times 99} = 146$ kcal/m²/h/°C

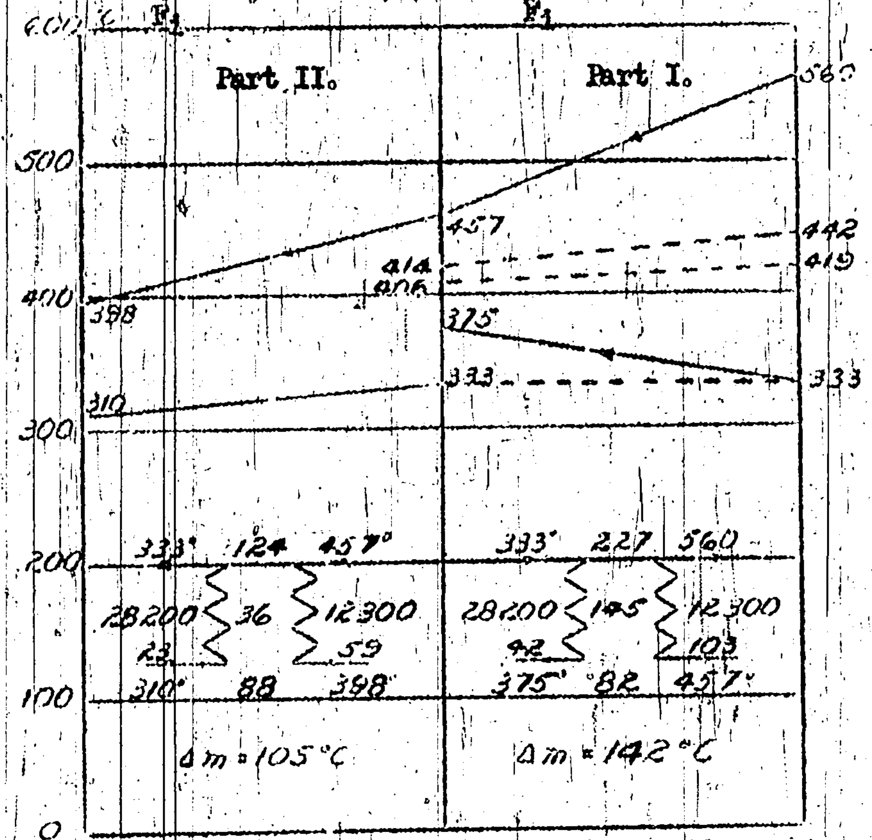
HEAT EXCHANGER OF THE SPLITTING STALL, SCHOLVEN, CATALYST 6434, 23.7 te/h middle oil.

N2012-16

PREHEATER OF THE SPLITTING STALL IN SCHOLVEN, for 6434.
23.7 ts/h middle oil.

H.917-16

Part II.	Part I.
$Q = 645,000$ kcal/h	$Q = 1,185,000$ kcal/h
$k = 9.6$ kcal/m²/h/°C	$k = 13$ kcal/m²/h/°C
$\frac{Q}{F_1} = 20,100$ kcal/h/m²	$\frac{Q}{F_1} = 37,000$ kcal/h/m²



40 hairpins, 90 mm	4 hairpins, 90 mm
$F_a = 640\ m^2$, $F_1 = 32\ m^2$	$F_a = 640\ m^2$, $F_1 = 32\ m^2$

To be heated:

23,700 kg/h middle oil from 310 to 375°C

40,000 m³/h injection gas from 310 to 375°C

$Q = 1,830,006$ kcal/h

Radiation: $Q' = 150,000$ kcal/h

Hot circulating gas:

$V = \frac{1,980,000}{0.35 \times 162} = 35,000\ m^3/h$ at 15°C and 1 atm.

$= 88,500\ m^3/h$ " 398°C " 1 "

Fuel gas requirements:

$K = \frac{1,980,000}{0.83 \times 4,000} = 600\ m^3/h$ (4000 H.U./m²)

Air requirements:

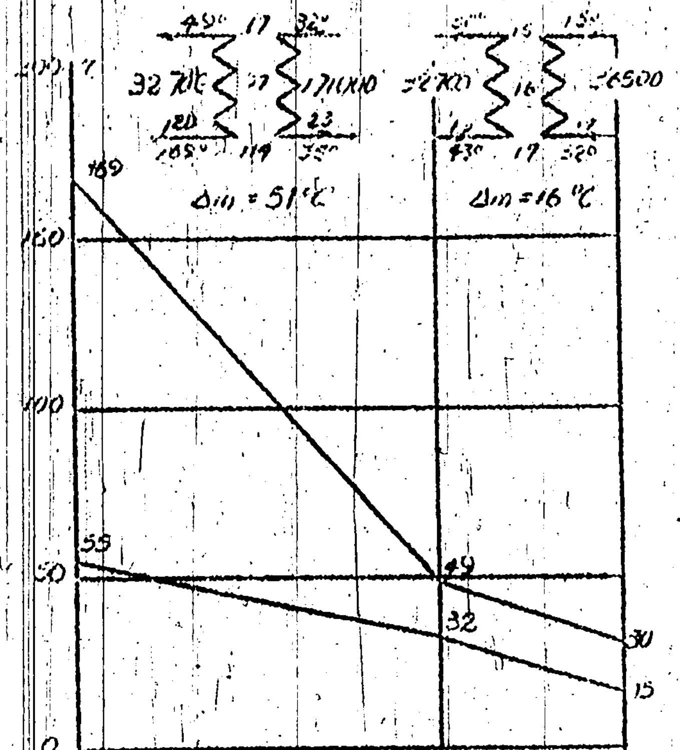
$L = 5.5\ K = 3,300\ m^3/h$

Sheet 3 - T-35

WATER COOLER FOR SPLITTING STALL, SCHOLVEN, 6434,
23.7 te/h middle oil.

$Q = 3{,}930{,}000$ kcal/h $k_2 = 309$ kcal/m²/h/°C

$Q = 620{,}000$ kcal/h $k_2 = 310$ kcal/m²/h/°C



Part 2) 40 tubes 70 mm inside diameter, average cooling surface 250 m²	Part 1), Top: 20 tubes 70 mm inside diameter, average cooling surface 125 m²

To be cooled:

1) 23,700 kg/h distillate from 169 to 30°C

2) 59,700 m³/h gas " 169 " 30°C

$Q = 4{,}550{,}000$ kcal/h

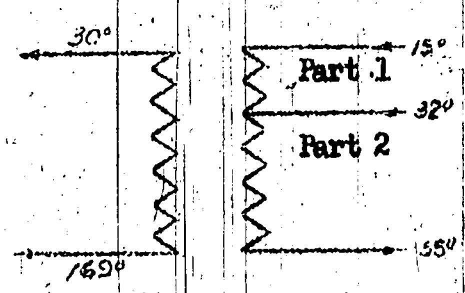
(heat of reaction = 120 kcal/kg feed)

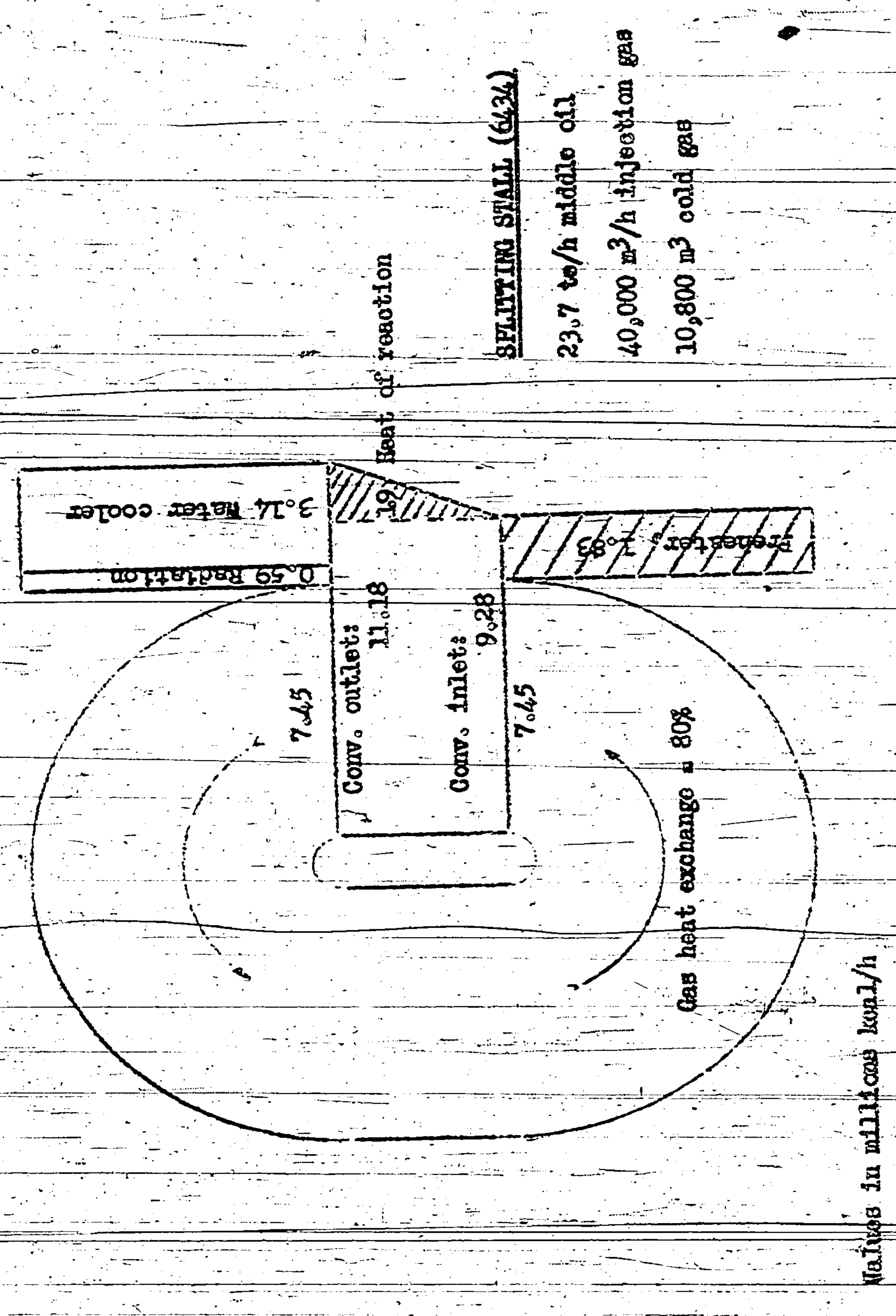
Amounts of water:

$V_1 = 37\ m^3/h$ of fresh water, at 15°C

$V_2 = 134\ m^3/h$ return cooling water at 32°C

Piping:

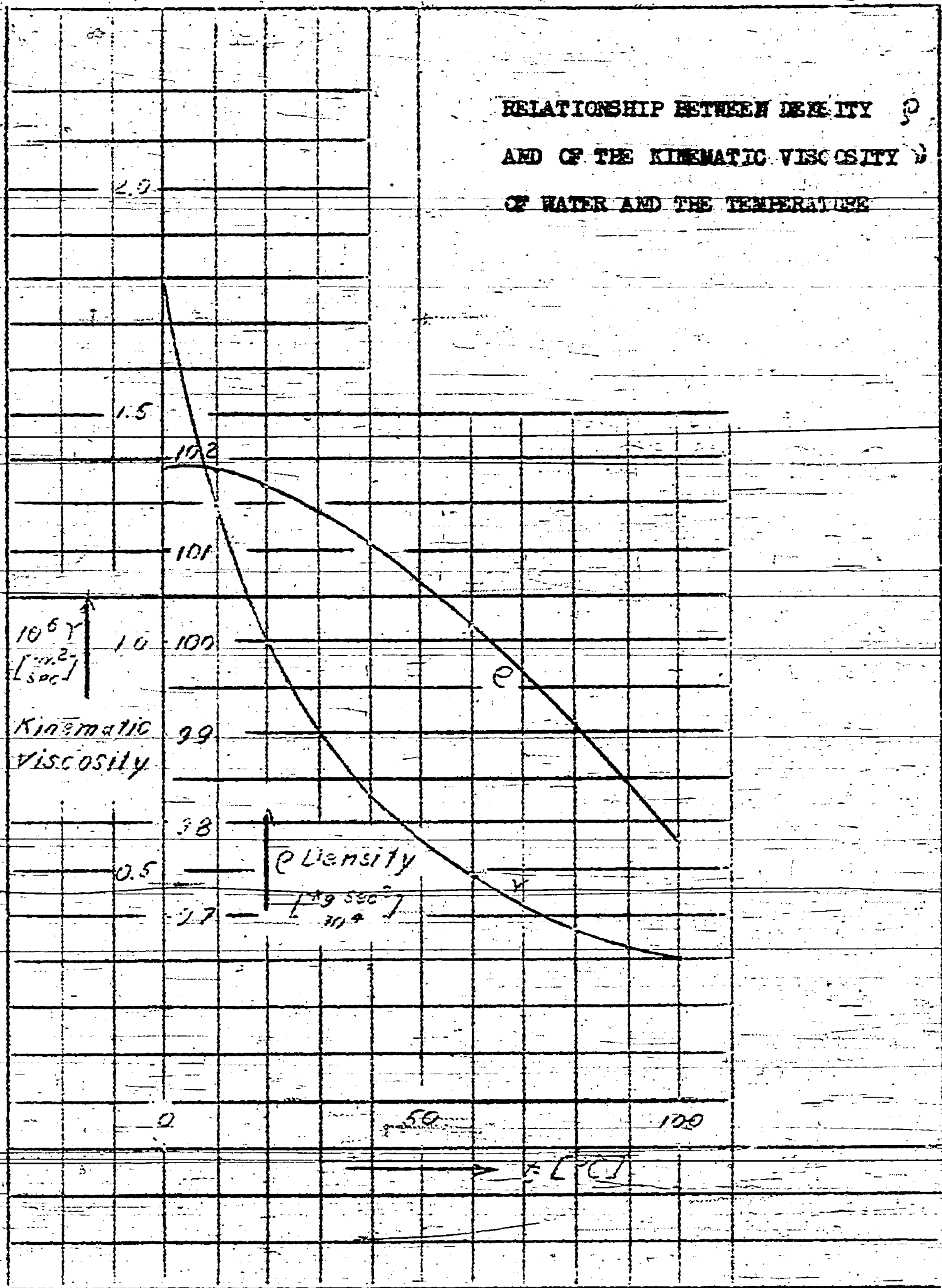




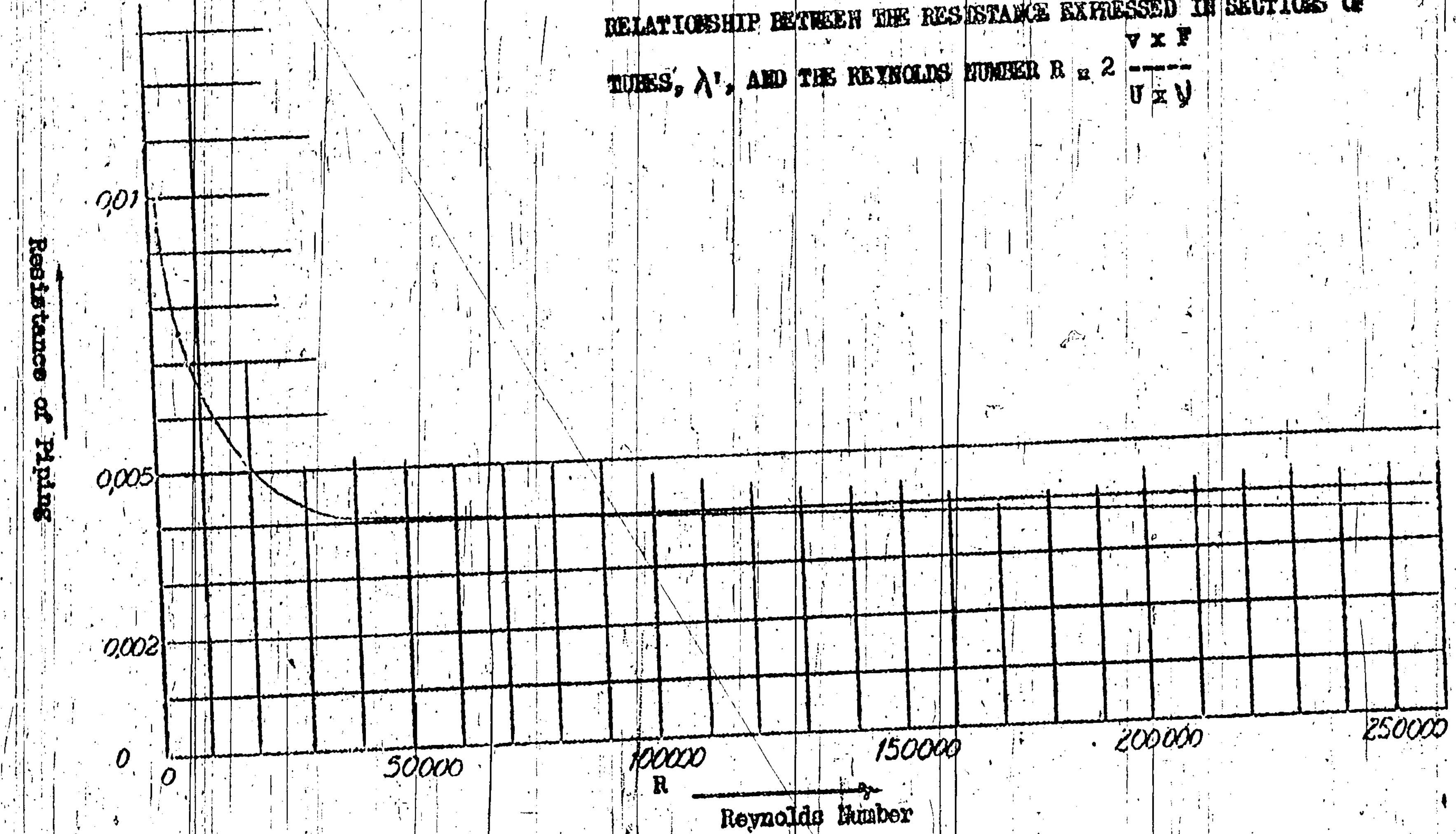
HEAT BALANCE OF THE SPLITTING STALL (CATALYST 6434), SCHOLVEN.

32013-16

RELATIONSHIP BETWEEN DENSITY ρ AND OF THE KINEMATIC VISCOSITY ν OF WATER AND THE TEMPERATURE



RELATIONSHIP BETWEEN THE RESISTANCE EXPRESSED IN SECTIONS OF TUBES, λ', AND THE REYNOLDS NUMBER $R = 2\frac{v \times F}{U \times \nu}$



T.O.M. Reel No. 5
Target No. 30/4.08
Bag No. 2747 pp 4-14
Item 13

INSTALLATION OF THE SPLITTING STALL
AND CONSTRUCTION STEPS 20 AND 21,
LAYOUT OF SPLITTING STALL 6434,
SCHEME N 6151-2, NORDSTERN

A 3-phase stall is provided for the construction Step 20, and 2 2-phase stalls for the construction Step 21. Operations are planned immediately for the construction Step 21, and the stall was calculated for this step. Each stall contains:

a). 2 converters, 1000 mm inside diameter, 18 m long
b). 2 heat exchangers, 1000 mm inside diameter, 18 m long, 199 tubes
c). 1 gas heated preheater
d). 1 cooler

The thru-put per stall is

18 te/h of middle oil 28000 m^3/h of operating gas 395°C inlet temperature Converter I	Data from Nordstern confirmed by high-pressure experiments

1. Calculation of amount of cold gas.

Heat of reaction 80 kcal/kg

Heat liberated in the converter:

$$Q = 18,000 \times 80 = 1,440,000 \text{ kcal/h}$$

This heat is used up:

a. By radiation
$2 \times 150,000 = 300,000$ kcal/h

b. By raising 10° the temperature of the middle oil and injection gas

$$(18,000 \times 0.7 + 28,000 \times 0.33) \times 10 = 218,000 \text{ kcal/h}$$

c. By cold gas
Inlet temperature 40°
Outlet temperature 405°

$$V = \frac{1,440,000 - 300,000 - 218,000}{0.31 \times 365} = 8,150 \text{ m}^3\text{/h}$$

The amount of cold gas provided for was

$$9,000 \; m^3/h$$

2. Calculation of Heat Exchangers.

18 te/h of middle oil and 28,000 m^3/h of injection gas will have to be heated from 30 to 320° in the heat exchangers.

Required amount of heat:

$$(18,000 \times 0.6 + 28,000 \times 0.31) \times 980 = 5,640,000 \text{ kcal/h}$$

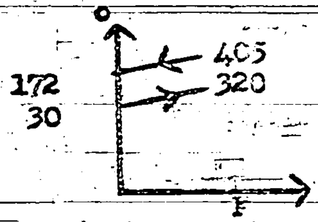
Radiation from 2 heat exchangers = 140,000

5,780,000 kcal/h

The value of available heat on the converter side is

$$18,000 \times 0.7 + (28,000 + 9,000) \times 0.33 = 24,800 \text{ kcal/h/°C}$$

The drop in temperature therefore is



$$\Delta t = \frac{5,780,000}{24,800} = 233°,$$

or from 405° down to 172°

The heating surface of each heat exchanger is 188 m^2.

The heat transfer number is calculated to

$$K = 133 \text{ kcal/m}^2\text{/h}$$

This represents a reserve which may be utilized in case of any difficulties obtained in the heat exchanger (carrying-over of the catalyst).

3. Preheater

The preheater is composed of 2 sections,

Section 1: 4 hairpins, co-currently, 90/127

Section 2: 4 hairpins, counter-currently, 90/127

Amounts heated are

18 te/h of middle oil and 28,000 m^3/h of injection gas from 320 to 395°

The required amount of heat is

$$(18,000 \times 0.65 + 28,000 \times 0.32) \times (395 - 320) = 1,550,000 \text{ kcal/h}$$

The heating gas furnishes

	1,550,000 kcal/h
Radiation	150,000 "
	1,700,000 kcal/h

The inlet temperature of the heating gas is 560°, the outlet temperature is 420°, and the volume figures to

$$V = \frac{1,700,000}{0.35 \times 140} = 34,700 \text{ m}^3/\text{h}$$

The projected pumps should have a capacity of

35,000 m^3/h, 15°, 735 mm

It remains to be considered whether it isn't preferable to order 2 pumps each of 25,000 m^3/h capacity, both of which would be run throttled-down. In case of stoppage, 1 pump could keep the preheater running, by maintaining temporarily a somewhat higher temperature of the heating gas. It may also be suggested to extend the preheater path to 10 hairpins, to permit taking immediate care of Steps 30 and 31.

Calculation of Temperature Changes (See N 2282-16).

Part 1 Co-current; temperature rise of 45° from 350 to 395°

Required amount of heat	932,000 kcal/h
Radiation	75,000
	1,007,000 kcal/h

The temperature fall of circulating heating gas

$$\Delta t = \frac{1,007,000}{35,000 \times 0.35} = 82^\circ$$

i.e., from 560 to 478°.

The heat transfer number   F = 640 m^2

$$K = \frac{932,000}{640, 137} = 10.6 \text{ kcal/m}^2/\text{h}$$

Part 2. Counter-current.

Temperature rise of 30°, from 320 to 350°

Required amount of heat	620,000 kcal/h
Radiation	75,000 "
	695,000 kcal/h

Drop in temperature of circulating heating gas:

$$\Delta t = \frac{695{,}000}{35{,}000 \times 0.35} = 57^\circ$$

or from 478 to 421°.

Heat transfer number

$$K = \frac{640{,}000}{640 \times 140} = 9.5 \text{ kcal/m}^2\text{/h}$$

The two K values are within entirely permissible limits, according to our experience.

Wall Temperature of the Tubes:

Section 1.

The temperature of the feed is 350° and of the flue gas 560°, from which the inside wall temperatures of the tubes is calculated to 415° and the outside wall temperature to 427°.

Computations of Strength

It is necessary to evaluate the safety factor against the resistance to creep strength of the N 8 V material at these temperatures.

The strains on the inside fibers (hypothesis of energy of changes of shape):

$$S_i = 1325 \text{ kg/cm}^2$$

Strain on the outer fibers

$$S_a = 760 \text{ kg/cm}^2$$

Stress through heat tension

On the inside fibers 316 kg/cm²

On the outer fibers — 263 "

Total strains

$$S_i \text{ total} = 1325 + 316 = 1641 \text{ kg/cm}^2$$

$$S_a \text{ total} = 760 - 263 = 497 \text{ "}$$

The average strain amounts therefore to

$$S_{ave} = 1069 \text{ kg/cm}^2$$

Creep resistance strength of the N 8 V materials at the highest wall temperature of the tubes of $432^{\circ} = 28\ kg/mm^2$

The safety factor with respect to the creep resistance is therefore

$$\frac{28}{10.69} = 2.62$$

According to our experience this value may be considered as entirely sufficient, even at the product temperature of 400°C the difference against creep strength resistance would still be sufficiently large.

4. Water Cooler

The cooler is fed with water at 15 or 30°.

In Section 1 the feed is cooled from 172 to 50°.

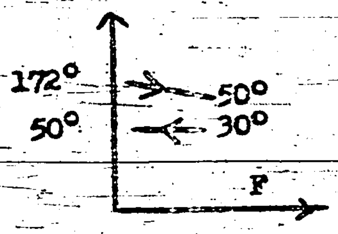
The heat removed amounts to

$$[18,000 \times 0.6 + (28,000 + 9,000) \times 0.31] \times (172 - 50) = 2,720,000\ kcal/h$$

We use 32 tubes, 70 mm, with a cooling surface of 200 mm^2

Heat transfer number

$$K = \frac{2,720,000}{200 \times 55} = 248\ kcal/m^2/h$$



The feed is cooled from 50° to 30° in part 2.

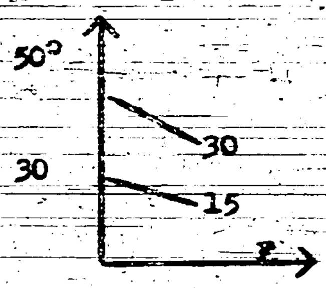
The amount of heat removed is

$$[18,000 \times 96 + (28,000 + 9,000) \times 0.31] \times (50 - 30) = 446,000\ kcal/h$$

16 tubes, i.d. 70 mm, with a cooling surface of 100 m^2 are used.

Heat transfer number

$$K = \frac{446,000}{100 \times 17.5} = 255\ kcal/m^2/h$$



The total cooling surface is

300 m^2, consisting of

4 x 12 units = 48 tubes, 70 mm. i.d.

Heat transfer numbers point to the presence of reserves, and cooling with these coolers may be done even if the heats of reaction are higher.

Amount of water

Section 2 $V = \frac{446,000}{1000 \times 15} = 30$ m^3/h water at 15°

Section 1 $V = \frac{2,720,000}{1000 \times 25} = 109$ m^3/h water at 30°

However, 30 m^3/h are obtained from part 2, and the amount required of return cooling water is only 109 - 30 = 79 m^3/h.

<u>Summary</u>

<u>Thru-put:</u> 18 te/h of middle oil
28,000 m^3/h of operating gas
9,000 m^3/h of cold gas

Temperatures: 30° at the heat exchanger inlet) forward pass
320° at the heat exchanger outlet)

320° preheater inlet
345° " outlet
345° converter inlet
405° " outlet

405° heat exchanger inlet) return pass
172° " " outlet)

172° cooler inlet
30° " outlet

<u>Heat Exchangers:</u> 2 with 109 tubes each
a heating surface of 186 m^2 each
Heat thru-put 133 kcal/m^2/h

Preheater: Section 1, 4 hairpins, co-current 90/127
Section 2, 4 hairpins, counter-current 90/127
N 8 V material for the hairpins
2,62 safety factor for creep resistance strength with maximum wall temperature of the tubes
560° inlet temperature of the heating gas
420° outlet temperature of the heating gas
35,000 m^3/h, at 15°, 735, required capacity of pumps

Suggested: 2 pumps of 25,000 m^3h each
Laying out of passes for building-in of 10 hairpins

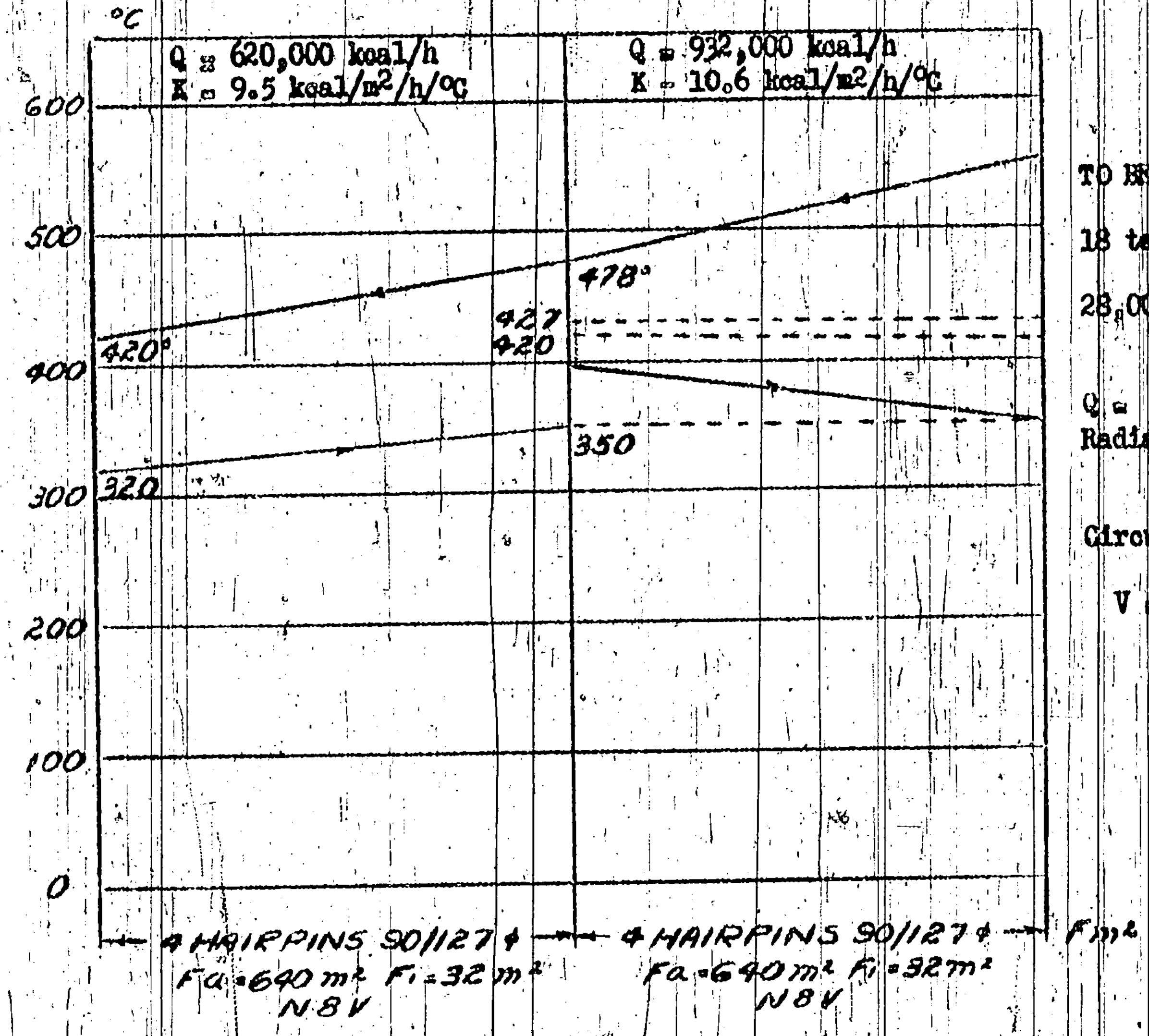
Converter: 2 converters 1000 mm inside diameter, 18 m long

Cooler: 300 m^2 cooler surface = 4 x 12 units, corresponds to 48 tubes of 70 mm i.d.

30 m^3/h of low temperature cooling water, maximum temperature 15°

79 m^3/h of return cooling water, maximum temperature 30°

Sternberg/mc/pkl



TO BE HEATED:

18 te/h middle oil from 320-395°C

28,000 m^3/h injection gas, 320-395°C

Q =	1,550,000 kcal/h	
Radiation =	150,000	"
	1,700,000 kcal/h	

Circulating heating gas

V = 35,000 m^3/h, 15°C, 735 mm

PREHEATER FOR THE NORDSTERN SPLITTING STALL, CATALYST 6434

Throughput 18 te/h middle oil.

32282-16

T.O.M. Reel No. 11
Bag No. 2247
Target 30/4.09

Technical Dept. Group 53 Hy-Werk (Scholven ?) Feb. 23, 1942

LIQUID PHASE STALL PREHEATER:

1 - Heat Requirements and Construction

The liquid phase stall preheater was rechecked with Dr. Wilde and Dipl. Ing. Schappert. The final calculations showed that the figures of the first Scholven calculations were correct.

3-phase stall without paste regeneration,
heat requirement - 9.5×10^6 Heat Units,
34 hairpin coils.

3-phase stall with paste regeneration,
heat requirement - 6.2×10^6 Heat Units,
22 hairpin coils.

4-phase stall with paste regeneration,
heat requirements - 7.9-8×10^6 Heat Units,
28 hairpin coils.

The probable construction of the preheater was discussed with the Combustion Department (Riegemann-Ledig). Attached sketch 10 shows a design of it. (Sketch not available.)

The preheater is built only with 2 passes, arranged in parallel for the circulating gases. Three burners of a capacity of 3,000,000 heat units each are arranged at ground level and heat 1/3 of the height of the preheater each. Opposed to the fear that the gas distribution may not be uniform are the comparatively long pass and the increased resistance against the triple parallel arrangement. In addition there are regulators in the suction outlets. The preheater is sketched for 33 hairpin coils. However, for expediency, 28-29 coils are used. In doing so, 700 mm. are saved in the total length of 8182 mm. The path of the circulating gas is also simple and, in my opinion, favorable. Taken as a whole the design may be evaluated as very suitable.

#2 - Resistance of Circulating Gas System.

The circulating gas system for the triple stall may be designed for a resistance of about 200 mm. W.G. These 200 mm. are distributed as follows:

50 mm. for the hairpin pass
50 mm. for the burners
80 mm. for the ducts
20 mm. additional mixing loss.

For the quadruple stalls the resistance for the hairpin pass is increased by 10-20 mm., so that the probable pressure loss for the system will be between 200-220.

On Tuesday, March 3, Messrs. Schappert, Wilde, Riegemann and Ledig will be in Stettin to study the DHD-Preheater there. This preheater has its fluegas passes arranged in parallel, so that it will be of interest to know the conditions there.

Technical Dept.
Group 53
(Signed) X

KCBraun/pkl

T.C.M. Reel No. 11
Target No. 30/4.09
Bag No. 2247

T-38

Ludwigshafen, March 29, 1939

PREHEATER AND BLOWER FOR 700 ATM.
LIQUID PHASE, SCHOLVEN III/266

131.4 te/h of paste injection is intended for 250,000 te/yr of gasoline production. The 3 or 4 phase coal stalls must be arranged to conform with the capacity of the converters (either 18 or 15 m long) and the provisional arrangement of the 3 or 4 phase coal stalls is:

1. 5 stalls, reaction volume 150 m^3
   Two 3 phase stalls; three 18 m converters; 25 te of paste/h/stall
   Two 4 phase stalls; one 18 m, three 15 m converters; 29 te of paste/h/stall
   One 3 phase stall; two 18 m, one 15 m converters; 23.4 te of paste/h

2. 4 stalls, reaction volume 150 m^3
   Four 4 phase stalls; four 18 m converters; 33 te of paste/h/stall

3. 4 stalls, reaction volume 151 m^3
   Three 4 phase stalls; three 18 m, one 15 m converters; 33.6 te of paste/h/stall
   One 4 phase stall; one 18 m, three 15 m converters; 30.8 te of paste/h

For the present, the distribution shown under 3 is the most promising; it offers the largest paste thru-put (33.6 te/h against 33 te/h in 2 and 29 te/h in 1); the preheaters of all 3 stalls are built in the same way and the preheaters must be designed for 33.6 te/h of coal paste thru-put.

Accordingly the preheaters must heat up:

33.6 te/h of coal paste from 100°C to 440°C
4,000 m^3/h of paste gas from 40° to 440°C
26,000 m^3/h injection gas from 400° to 440°C

Heat consumption:

$33.6 \times 10^3 \times 0.6 \times 340$	=	6,850,000 kcal/h
$4,000 \times 0.32 \times 400$	=	512,000 "
$26,000 \times 0.33 \times 40$	=	343,000 "
Total		7,705,000 kcal/h

76.5% efficiency assumed for the preheater would require:

Heat consumption:	10,200,000 kcal/h
m^3/h of heating gas with 4000 kcal/m^3:	2,500 m^3/h
" " air 5 x 2500 =	12,500 "
Off-gas about:	15,000 "

If the circulating heating gas blower is laid out for 150,000 m^3/h (15°C, 735 mm) for a static pressure of 300 mm water column, the heating gas outlet temperature, when the inlet temperature is 560°, will be

$$\left(\frac{8,000,000}{150,000 \times 0.35} = 153^\circ\right) \longrightarrow 407^\circ C$$

The 15,000 m^3/h of purge gas at 407°C contain:

15,000 x 0.35 x 387 = 2,030,000 kcal/h of sensible heat

There remains 365,000 kcal/h for the radiation of the preheater

Sternberg/mc/Krp

T.O.M. Reel No. 11
Target No. 30/4.09
Bag No. 2247

Ludwigshafen, April 7, 1939

HEAT BALANCE AND TEMPERATURE RELATIONSHIPS
OF THE LIQUID PHASE, SCHOLVEN-EXI/266

The accompanying diagram R-2738-16 shows a heating balance for a 4-phase stall of the coal phase with the following thru-puts:

33.6 to/h of coal paste

26,000 m^3/h of injection gas } 30,000 m^3/h through the preheater
4,000 m^3/h of paste gas }

36,000 m^3/h of cold gas

without radiation tubes between the converters.

For an arrangement of the stalls into four 4-phase coal stalls with converters only 18 m long. With other subdivisions (see T-39), these thru-puts are somewhat reduced.

The amounts of heat are calculated from 0° C.

The amounts introduced into the preheater or exchanger are as follows at the indicated temperatures:

33.6 to/h of paste at 100° into the preheater:	2,004,000 kcal/h
4,000 m^3/h of paste gas at 40°C into the preheater:	51,000 "
26,000 m^3/h of injection gas at 40°C into the heat exchanger:	335,000 "
Total	2,390,000 kcal/h

The circulating gas is heated from 40° C to 400° C in the heat exchanger.

Required heat supply:	3,000,000 kcal/h
The heat consumption of the preheater gas determined from:	
Total heat of fuel gas:	10,100,000 "
Off gas:	- 2,030,000 "
Radiations	- 365,000 "
Useful heat:	7,705,000 "

The heat content of the converter intake at [illegible]° inlet temperature:	2,390,000 kcal/h
	+ 7,705,000 "
	+ 3,000,000 "
	13,095,000 "

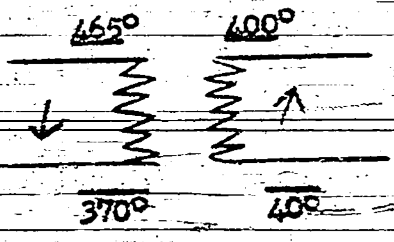
33.6 te/h of paste correspond to about 14.2 te of pure coal/h which requires a heat of reaction in the converter of:	6,250,000 kcal/h
	19,345,000 "
The heat supplied by the heat of the reaction will result in:	
1. A temperature rise of the converter product from 440° to maximum 480° (assumed), which would require:	1,200,000 kcal/h
2. A temperature rise of the coal gas from 40 to 480°C, which would require:	5,050,000 "
The radiation for 4 converters amounts to about	500,000 "
The cold gas entering the converter at 40°C (36,000 m^3/h) carries the amount of heat:	465,000 "
In the hot catch pot the heat contents are 19,345,000 + 465,000 − 500,000 =	19,310,000 "
10.6 te/h of HOLD (water value 6400 kcal/°C) removed:	3,000,000 "
Behind hot catch pot:	16,310,000 "

The heat exchanger bring: about 24 te/h of distillate including 3.6 te/h of water and about 50,000 m^3/h of circulating gas. (We must count on a 1,000 m^3 hydrogen consumption/te of pure coal, or 66,000 m^3/h of total gas/converter, from which we subtract 14.2 x 1,000, which gives around 50,000 m^3/h of circulating gas.)

The water value of the above product is: 31,000 kcal/°C

The converter outlet temperature is 480°C, and we assume 465° as the temperature in the heat exchanger inlet. The output will be

Q = 3,000,000 kcal/h



$$\frac{3,000,000}{31,000} = 95°C$$

Heat exchanger output: $465^\circ - 95 = 370^\circ C$
The average temperature difference in heat exchanger: Δ m = 164°C
With a bundle of 199 tubes, the average heat exchange surface is: 188 m^2
The heat transfer number referred to this surface is: K = 98 kcal/m^2/h/°C
Assuming 100,000 kcal/h loss in the heat exchanger (radiation), there will remain behind of the heat exchanger: 13,210,000 k/cal/h

After we introduce the feed at 200°C into the water cooler, the circulating gas and the distillate must be cooled from 370 to 200°C. There is no condensation of water (in the distillate) above 200°C.

50,000 m^3/h of circulating gas:		50,000 m^3
20.4 te/h of distillate:	= about	2,040 "
3.6 te/h of water:	= about	720 "
Total		52,760 m^3
(Corrected in ink :		50,740.4 ? Transl.)

including 720 m^3 of water = about 1.36%
At 670 atm. total pressure this will amount to 9.0 atm. of steam pressure; the condensation point is 180°C
with a water value of 31,000 kcal/°C,
there will be removed 5,300,000 kcal/h

It would be uneconomical to cool to 200° in an air cooler (the cooler would be too large). However, a waste heat boiler will produce 8-10 te/h of steam.

The cooling surface of the wet steam cooler, with K = 400 kcal/m^2/h/°C and with (?vm) = about 120°C (for steam under 4 atm.) would be about 110 m^2. The feed water cooler connected after it should be planned for a temperature lowering from 200° to 55°C. The total heat removed with 30,000 kcal/°C : 6,400,000 kcal/h.

This will include 1,950,000 kcal/h of heat of vaporization of water set free.

Behind heat exchanger:		13,210,000 kcal/h
Feed wet steam cooler	–	5,300,000 "
Feed water cooler:	–	6,400,000 "
There remain in the product at 55° calculated to 0°.		1,510,000 "

The water value of this amount of heat is 27,500 kcal/°C for the catch pot feed. Considering that the specific heat of the product drops with the temperature, this water value appears to be right.

Should an air cooler be used instead of a waste heat boiler, the following conditions will be obtained: With 820° m^2 outer surface of the air cooler, about 1,200,000 kcal/h could be removed. With 31,000 kcal/°C of water value, the temperature drop would be 39°, from 370 to 311°C. With 12 tubes, 15 m long, these coolers for 820 m^2 surface will weigh 28 te with a total height of 2,775 mm (?). Increasing the surface by 1/3 to 16 tubes (3,425 mm. high, 36 te weight), would result in a temperature drop of about 50°, to 320°C. The gain from the increase in surface is relatively small; the feed water cooler introduced after it would have to be figured to a temperature drop from 300°C to 55°C.

The amount of heat would be removed: 10,500,000 kcal/h. Conditions prevailing with the air cooler are shown in drawing N-2744-16.

Sternberg/mc/pkl

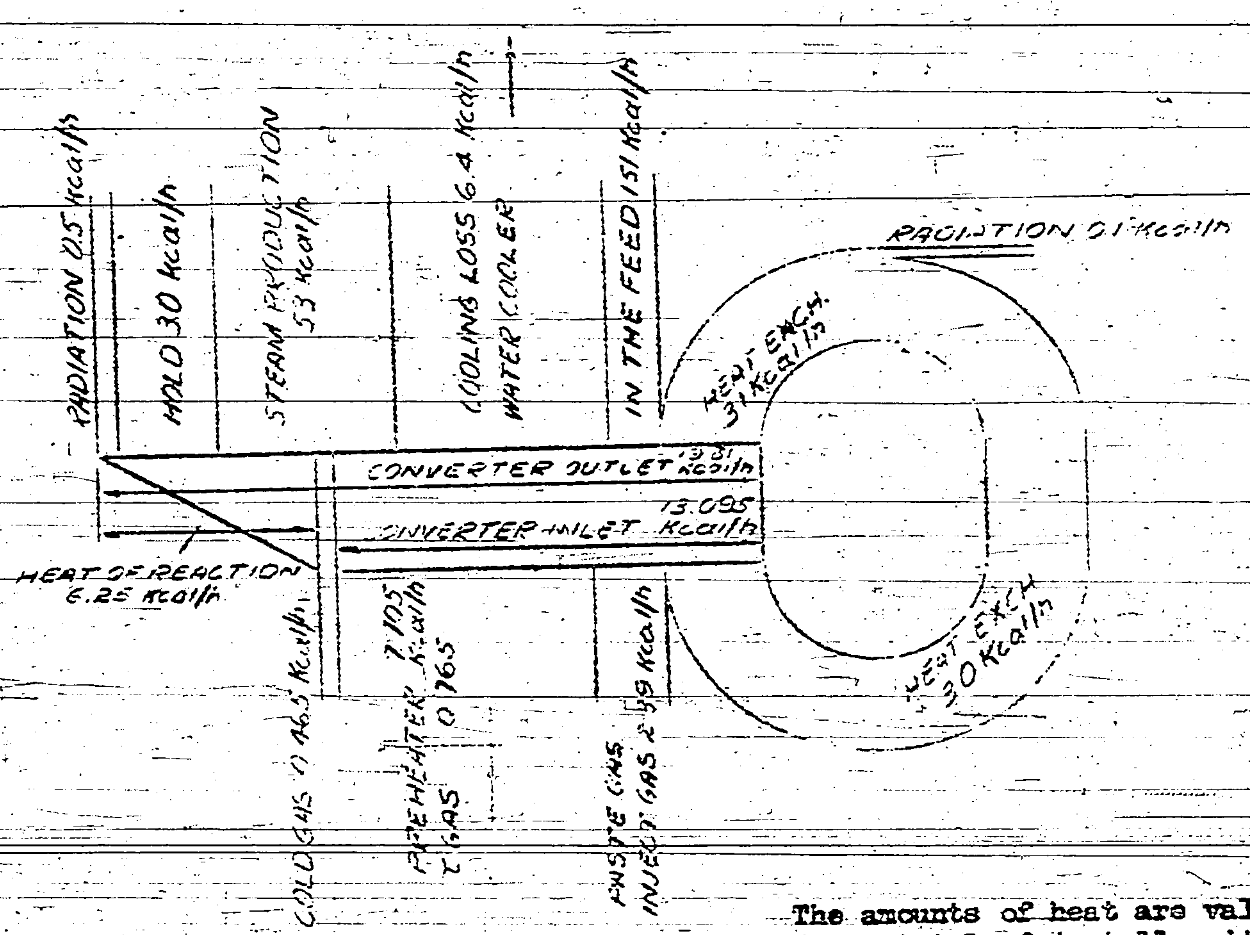
HEAT BALANCE FOR A BITUMINOUS COAL STALL

700 ATM., SCHOLVEN III, WITH STEAM PRODUCTION

Thru-put: Paste 33.6 te/h
Paste gas 4,000 m³/h
Injection gas 26,000 m³/h
Cold gas 36,000 m³/h

Amounts of heat calculated from °C,

and are expressed in millions kcal.



The amounts of heat are valid for a total of 4 stalls with 150 m³ reaction space and the above thru-puts per stall.

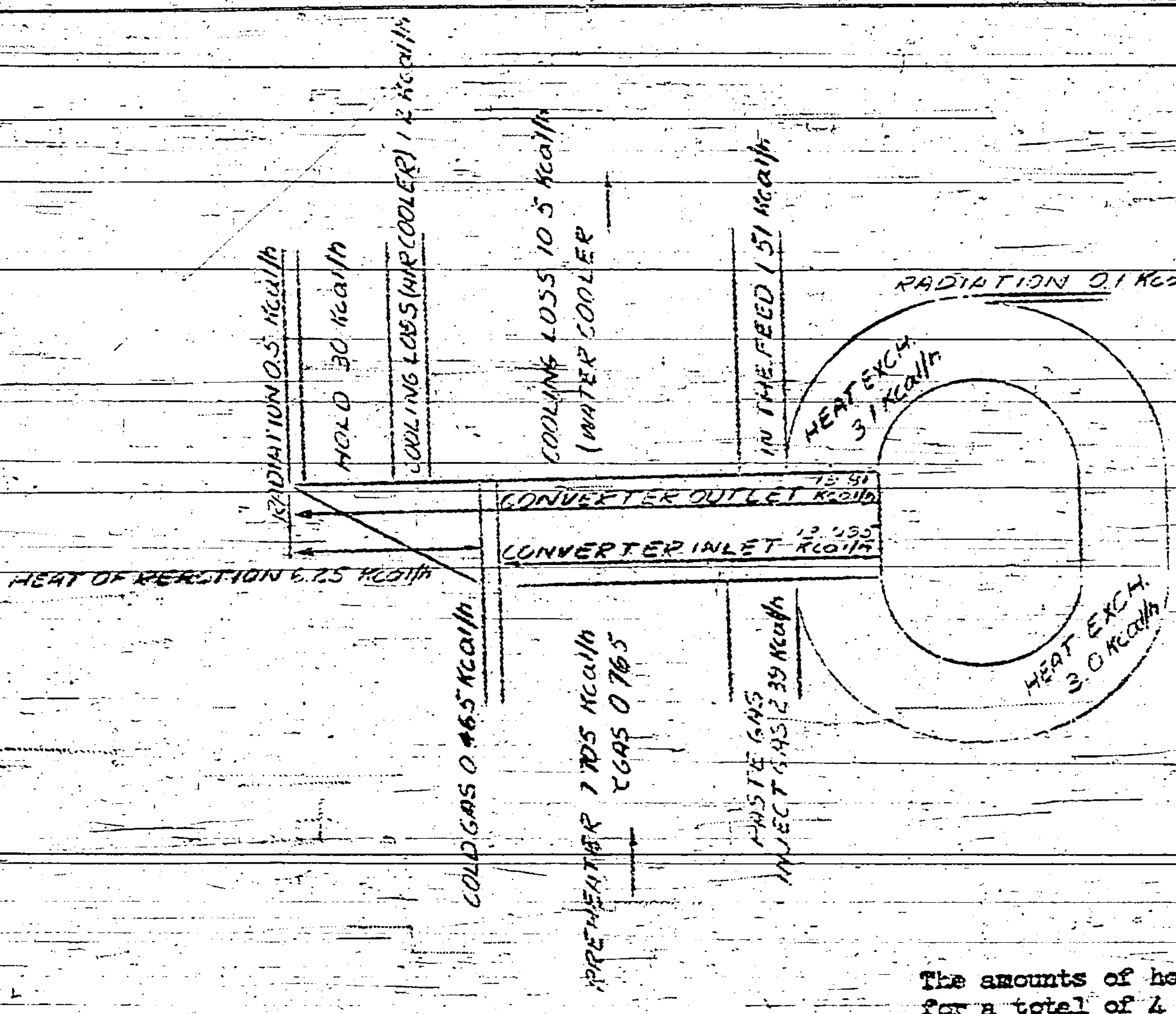
HEAT BALANCE FOR A BITUMINOUS COAL STALL

700 ATM., SCHOLVEN III

Thru-put:	Paste	33.6 te/h
	Paste gas	4,000 m^3/h
	Injection gas	26,000 m^3/h
	Cold gas	36,000 m^3/h

Amounts of heat calculated from °C,

and are expressed in millions kcal.



The amounts of heat are valid for a total of 4 stalls with 150 m^3 reaction space and the above thru-puts per stall.

T-40

T.O.M. Reel No. 103
Bag No. - -
Target 30/4.03

I. G. Farbenindustrie, A.G., Ludwigshafen a.Rhein

Technical Experiment Station, Oppau 200

Report # 421

Pages 1 to 10, Incl.

REPORT ON THE MEASUREMENT OF HEAT CONDUCTIVITY OF REFRACTORY BRICK FOR THE INNER INSULATION OF HIGH PRESSURE CONVERTERS

INDEX

Technical Experiment Station Oppau 200

OPPAU 27 MAY 1940

Report on the Measurement of Heat Conductivity of Refractory Brick for the inner insulation of high pressure converters.

SUMMARY

Experiments were made for heat conductivity on two diatomite bricks and two light refractory bricks in hydrogen at atmospheric pressures of 200 and 750 atms., as well as in nitrogen at atmospheric pressure and at 200 atmospheres. The heat conductivity in hydrogen at a pressure of 750 atmospheres is 0.8 kilogram calories per hour per meter, per degree C. for both diatomites, (Kcal/hm°C) and for the two refractory brick 1.6 to 1.5 Kcal/hm°C. The compressive strength of the diatomites has an average value of 20 to 30 kg/cm^2.

INTRODUCTION

Because of our working with higher temperatures and because of the difficulties of procuring asbestos, the use of fire brick as inner insulation of high pressure catalyst converters must be considered here. Fire brick was already used on the first converters, but because of its high heat conductivity was replaced by diatomite, which was later replaced by cement asbestos because of certain advantages in the hydrogenation converters.

The now proposed light fire bricks are better suited for insulation (have a lower heat conductivity) than the formerly used regular fire brick and have a greater compressive strength than the diatomites.

The following four bricks were examined

(1) Special diatomite "DO.7" by Grünzweig and Hartmann

(2) Diatomite "F" by Grünzweig and Hartmann

(3) Light Fire Brick "LL" from Keramchemie Berggarten

(4) Light Fire Brick "SL 2" from the Siegersdorfer Werke.

Experimental Methods

A spherical autoclave for 1000 atm. and two (2) autoclaves for 200 atm. were available for the measurements. The experiments were made in hydrogen, one each with rising temperature at atmospheric pressure, at 200 atm., and at 750 atm., then at constant average temperature (t_m) of 75°C. and falling pressure. In nitrogen the experiments were carried only to 200 atm.

Results of Experiment

The most important results of the measurements are found in the following 9 tables.

TABLE 1 DENSITY, POROSITY AND COMPRESSIVE STRENGTH

Brick	Density Brick kg/m³	Density Spheres (balls) kg/m³	Porosity Vol. %	Compressive Strength Maximum kg/cm²	Compressive Strength Minimum Kg/cm²	Compressive Strength Average Kg/cm²
DO.7	575	590	77	38	13	29
F	790	790	69	25	13	22
LL	790	775	72	57	33	44
SL 2	1250	1215	50	160	91	141

TABLE 2 - HEAT CONDUCTIVITY IN HYDROGEN BASED ON TEMPERATURE DIFFERENCE

Refractory Brick	Pressure in Atmospheres	Temperature Difference Degrees C. 0	100	200	300	400
DO.7	750	0.440	0.700	0.845	0.865	0.810
F		0.425	0.935	1.00	0.995	--
LL		0.440	1.86	1.85	1.58	--
SL 2		0.680	1.61	1.68	1.66	--
DO.7	200	0.355	0.390	0.410	0.430	0.465
F		0.420	0.545	0.575	--	--
LL		0.430	0.520	0.570	0.585	--
SL 2		0.650	0.815	0.830	0.840	--
DO. 7	1	0.255	0.270	0.285	0.300	0.320
F		0.420	0.475	0.525	--	--
LL		0.380	0.435	0.490	--	--
SL 2		0.635	0.675	0.710	0.755	--

TABLE 3 - HEAT CONDUCTIVITY IN HYDROGEN BASED ON PRESSURE AT t_m 75°C.

Refractory Brick	Pressure in Atmospheres 750	200	1
DO.7	0.744	0.400	0.265
F	0.862	0.531	0.465
LL	0.68	0.502	0.420
SL 2	1.53	0.804	0.661

TABLE 4 - HEAT CONDUCTIVITY IN NITROGEN BASED ON TEMPERATURE DIFFERENCES

Refractory Brick	Pressure in Atmospheres	Temperature Difference in Degrees C. 0	100	200	300	400
DO.7	200	0.150	0.445	0.475	—	—
F		0.220	0.555	0.490	0.475	—
LL		0.200	0.755	0.745	0.270	0.700
SL 2		0.320	0.680	0.675	—	—
DO.7	1	0.115	0.125	0.135	0.145	0.155
F		0.220	0.245	0.210	0.295	0.320
LL		0.200	0.235	0.270	0.365	—
SL 2		0.320	0.410	0.500	0.575	—

TABLE 5 - HEAT CONDUCTIVITY IN NITROGEN BASED ON PRESSURE AT t_m 75°C

Refractory Brick	Pressure in Atmospheres 200	1
DO.7	0.350	0.125
F	0.560	0.250
LL	0.748	0.230
SL 2	0.658	0.385

TABLE 6 - (Zahlentafel 1) Results of Measurements on Special Diatomite "DO.7" by Grünzweig & Hartmann Density 575 kg/m³

Experiment No.	Experiment Date	GAS Kind	GAS Pressure in Atms.	TEMP. DROP From °C	TEMP. DROP To °C	Average Temp. °C.	Coefficient of heat transmission kcal/hm°C	REMARKS
7	29.12.39	Hydrogen	750	278.1	32.4	152.2	0.874	1000 atm. autoclave
8	30.12.39	"	740	517.0	45.8	281.4	0.757	
9	3. 1.40	"	760	143.5	13.1	78.3	0.756	
10	4. 1.40	"	770	27.5	2.9	15.2	0.530	
1	16. 2.40	Hydrogen	202	46.3	24.3	35.3	0.358	200 atm. autoclave
2	17. 2.40	"	214	115.0	31.5	73.2	0.394	
3	19. 2.40	"	206	254.0	43.4	148.8	0.415	
4	20. 2.40	"	185	424.7	57.8	241.2	0.439	
6	22. 2.40	Hydrogen	0	112.9	29.7	71.3	0.262	200 atm. autoclave
7	23. 2.40	"	0	262.4	39.3	150.9	0.290	
9	26. 2.40	"	0	438.7	58.0	248.4	0.317	
15	21. 3.40	Nitrogen	220	134.5	36.3	85.4	0.447	200 atm. autoclave
16	26. 3.40	"	216	295.7	53.7	174.7	0.453	
17	28. 3.40	"	198	77.6	28.5	53.2	0.358	
18	29. 3.40	"	199	42.6	23.8	33.2	0.236	
19	30. 3.40	"	200	31.5	24.6	28.0	0.199	
21	1. 4.40	Nitrogen	0	139.1	27.5	83.3	0.123	200 atm. autoclave
22	2. 4.40	"	0	267.9	32.2	150.0	0.138	
23	4. 4.40	"	0	475.6	40.7	258.2	0.159	
25	6. 4.40	"	0	128.9	28.3	78.6	0.121	
26	8. 4.40	"	0	293.4	33.1	163.2	0.142	
27	9. 4.40	"	0	463.9	40.6	252.3	0.156	

TABLE 7 - (Zahlentafel 2) Results of Measurements on Diatomite "F" by Grünzweig & Hartmann
Density 790 kg/m^3

EXPERIMENT		GAS		TEMP. DROP				
No.	Date	Kind	Pressure in Atms.	From °C	To °C	Average Temp. °C	Coefficient of heat transmission kcal/hm°C	REMARKS
1	22. 5.40	Hydrogen	755	28.6	16.5	22.5	0.566	1000 Atm.
2	23. 5.40	"	760	40.6	20.5	30.6	0.688	autoclave
3	24. 5.40	"	758	72.3	25.6	49.0	0.786	
4	25. 5.40	"	749	148.2	33.7	90.9	0.962	
5	26. 5.40	"	755	252.2	51.5	151.3	1.01	
6	27. 5.40	"	740	354.6	65.5	210.0	1.00	
1	6. 1.40	Hydrogen	192	39.5	21.3	30.4	0.459	200 Atm.
2	8. 1.40	"	190	114.6	31.4	73.0	0.527	autoclave
3	9. 1.40	"	200	247.5	47.2	147.4	0.565	
6	12. 1.40	Hydrogen	0	41.3	22.4	31.9	0.428	200 Atm.
7	13. 1.40	"	0	116.6	31.2	73.9	0.451	autoclave
10	17. 1.40	Nitrogen	201	334.8	52.7	193.8	0.470	200 Atm.
13	20. 1.40	"	185	101.2	30.9	66.1	0.565	autoclave
14	22. 1.40	"	202	247.5	45.9	146.7	0.505	
15	23. 1.40	"	184	169.0	38.7	130.3	0.527	
17	25. 1.40	"	197	30.2	21.8	26.0	0.305	
18	26. 1.40	"	201	64.0	26.9	45.4	0.340	
19	27. 1.40	"	201	33.0	22.1	28.5	0.358	
20	29. 1.40	"	190	36.6	23.3	29.0	0.365	
21	29. 1.40	"	192	49.0	23.2	36.2	0.466	
22	30. 1.40	Nitrogen	0	34.7	21.1	27.9	0.216	200 Atm.
23	31. 1.40	"	0	124.1	28.0	76.0	0.252	autoclave
24	1. 2.40	"	0	283.0	39.5	161.3	0.282	
	2. 2.40	"	0	415.3	49.7	232.5	0.311	

TABLE 8 - (Zahlentafel 3) Results of Measurements on Light Fire Brick "LL" by Keramchemie - Berggarten
Density 790 kg/m^3

EXPERIMENT No.	Date	GAS Kind	Pressure in Atm.	TEMP. DROP From °C	To °C	Average Temp. °C	Coefficient of heat transmission kcal/hm°C	REMARKS
1	3. 4.40	Hydrogen	755	20.5	9.6	13.0	0.591	1000 Atm. autoclave
2	5. 4.40	"	753	32.4	13.0	22.2	0.792	
3	6. 4.40	"	760	56.1	18.6	32.3	0.23	
4	7. 4.40	"	775	101.0	43.3	72.2	2.04	
5	8. 4.40	"	755	302.9	75.3	189.1	1.88	
1	3. 4.40	Hydrogen	745	21.9	13.3	17.6	0.575	1000 Atm. autoclave
2	4. 4.40	"	740	34.1	13.7	23.9	0.767	
3	5. 4.40	"	750	62.7	20.2	41.4	0.19	
4	6. 4.40	"	765	148.0	40.3	94.1	0.76	
5	8. 4.40	"	740	324.3	67.0	195.7	0.55	
6	9. 4.40	"	748	376.8	75.4	226.1	0.45	
1	16. 1.40	Hydrogen	200	46.8	23.3	35.0	0.463	200 Atm. autoclave
2	17. 1.40	"	205	117.4	32.4	74.9	0.518	
3	18. 1.40	"	177	258.7	49.2	153.9	0.551	
4	19. 1.40	"	175	421.3	65.0	243.2	0.590	
6	22. 1.40	Hydrogen	0	38.7	21.7	30.2	0.393	200 Atm. autoclave
7	23. 1.40	"	0	114.6	29.2	71.8	0.430	
8	24. 1.40	Nitrogen	188	84.0	31.6	57.8	0.663	200 Atm. autoclave
12	3. 2.40	"	212	27.2	21.9	24.5	0.399	
13	12. 2.40	"	198	47.7	24.7	36.2	0.651	
2-	14. 2.40	"	190	28.5	22.8	25.6	0.347	
25	22. 2.40	"	206	535.4	88.5	312.0	0.697	
26	23. 2.40	"	194	409.0	75.3	242.2	0.7	
28	26. 2.40	"	189	241.5	48.9	145.2	0.745	
9	26. 4.40	Nitrogen	200	39.0	27.6	33.3	0.357	200 Atm. autoclave
10	27. 4.40	"	203	68.4	33.2	50.8	0.637	
11	29. 4.40	"	220	186.8	43.4	114.7	0.780	
12	30. 4.40	"	224	331.8	68.9	200.3	0.720	
7	24. 4.40	Nitrogen	0	128.5	31.1	74.8	0.229	200 Atm. autoclave
8	25. 4.40	"	0	278.5	22.2	150.3	0.280	

TABLE 9 - (Zahlentafel 4) Results of Measurements on
Light Fire Brick "SL 2" by Siegersdorfer Werke
Density 1250 kg/m^3

EXPERIMENT		GAS		TEMP. DROP		Average Temp. °C	Coefficient of heat transmission kcal/hm°C	REMARKS
No.	Date	Kind	Pressure in Atms.	From °C	To °C			
2	7. 5.40	Hydrogen	730	25.9	15.7	20.8	0.977	1000 Atm. autoclave
3	8. 5.40	"	750	42.3	19.6	31.0	1.10	
4	9. 5.40	"	755	107.3	33.7	70.5	1.53	
5	10. 5.40	"	760	257.7	61.7	159.7	1.68	
6	11. 5.40	"	760	343.3	75.0	209.2	1.67	
1	30. 4.40	Hydrogen	205	32.5	25.9	29.2	0.688	200 Atm. autoclave
2	2. 5.40	"	202	83.3	35.9	59.6	0.794	
3	3. 5.40	"	209	142.8	43.6	93.2	0.617	
4	4. 5.40	"	210	261.2	60.2	160.7	0.633	
5	6. 5.40	"	210	369.6	73.2	221.4	0.838	
7	8. 5.40	Hydrogen	0	112.9	38.4	75.6	0.661	200 Atm. autoclave
8	9. 5.40	"	0	250.5	54.3	152.5	0.708	
9	10. 5.40	"	0	359.0	68.2	213.6	0.758	
13	8. 5.40	Nitrogen	195	29.6	24.7	27.1	0.471	200 Atm. autoclave
14	20. 5.40	"	200	56.0	27.9	42.0	0.551	
15	21. 5.40	"	210	148.0	20.5	84.3	0.606	
16	22. 5.40	"	210	298.5	82.6	180.6	0.664	
11	4. 5.40	Hydrogen	0	114.2	32.2	73.2	0.395	200 Atm. autoclave
12	5. 5.40	"	0	263.9	48.4	166.2	0.511	

According to their construction the four examined bricks may be divided into two different kinds, namely, in burnt Kisselgur (diatomaceous) brick and light fire brick. The diatomites are lighter than the light fire brick; at a density of 800 kg/m^3, the two kinds of bricks approach each other in density. (sic)

The measurements of porosity showed that in the special diatomite DO.7 a high porosity, fine pored, product is available. The diatomite "F" and the light fire brick "LL" have almost the same porosity in spite of their different characters. The light fire brick "SL 2", because of its considerably higher density, has a considerably lower porosity, which lies between diatomite and regular fire brick. But in general the total porosity permits of no evaluation of high pressure insulations. According to the coefficient of heat conductivity in hydrogen the two groups are divergent at 750 atm. and temperatures over 75°C, while they approach each other at 200 atm. and atmospheric pressures as well as at temperatures below 75°C., here the heavier light fire brick "SL 2" is in sharp contrast with the others. Because of lack of time no measurements were made at first in nitrogen at 750 atm. Here the differences are also somewhat sharper only at 200 atm. and t_m 75°C., while at t_m 75°C. and atmospheric pressure the lighter special diatomite "DO.7" stands our sharply. The curves and diagrams show that the heat conductivity in nitrogen which at one atmosphere lies considerably below that in hydrogen exceeds that in hydrogen at 100 to 300 atm. The pressure at which this occurs is a maximum with the comparatively light special diatomite "DO.7". (The curves and diagrams referred to are not available).

It is apparent that the heavier light fire brick "SL 2" has equalled the lighter "LL" at 750 atm. One can say that the higher the pressure a correspondingly heavier brick should be used, since it will, in general, have a higher strength, as is especially marked here.

The special diatomite "DO.7", which shows the lowest coefficient of heat conductivity and is also superior in strength to the heavier diatomite "F" deserves special considerations.

Note: The report from here on is unreadable, but seems to contain a discussion of the tabular values, which should speak for themselves. Much of this report is very difficult to read on the film and some of the figures in the tables were arrived at by interpolation.

KGBraun/mra/pkl

T.O.M. Reel No. 11
Bag 2247
Target 30/4.09
Pages 1 to 8, Incl.

Technical Dept. Group 53 — Hy-Werk, March 11, 1942

PREHEATER FOR COAL STALL - GLADBECK.

The following pages show the temperature diagrams for three (3) cases:

Case 1: 3-phase stall without paste regeneration. The preheater requires 34 hairpin coils for one gas heat exchanger.

Case 2: 3-phase stall with paste regeneration. Using two (2) paste heat exchangers, one preheater with 22 hairpin coils is required.

Case 3: 4-phase stall with paste regeneration. With an assumed paste thruput of 55 t/h and a total gas volume of 90,000 m^3/h, the preheater requires 28 hairpin coils. The regeneration is equipped with three (3) paste heat exchangers.

A 2-phase fluegas preheater, arranged in parallel, requires a fan capacity of 125,000 m^3/h at a pressure of 220-220 mm W.G.

CASE 1 — 3-Phase Stall without Paste Regeneration

Thruput	t/h	45	(0.55)
Film Oil	"	2	
Gas thru heat exchanger	m^3/h	30,000	(0.32)
Paste gas	m^3/h	9,000	(0.32)
Heat Values			
Paste Section	Kcal/°C	28,680	
Mixture Section	"	38,280	
Heat Exchange			
Heat value, inlet pass	Kcal/°C	9,600	
Heat value, return pass	"	42,900	
Temperature diagram °C		440 ⟶ 355 410 ⟵ 40	
Temperature Difference	°C	124°	
Heat Exchanger surface	m^2	188	
K-value	Kcal/°C/m^2/h	152	
Heat output	Kcal/h	3.55×10^6	
Preheater			
Circulating gas volume	m^3/h	150,000	
Circulating gas velocity	m/sec	20	

Temperature Diagram °C

	Gas Tubes	Paste Section	Mixture Section	Gas Tubes
	403 ⟵ 412 40 ⟶ 205	412 ⟵ 524 115 ⟶ 305	524 ⟵ 589 343 ⟶ 425	589 ⟵ 600 410 ⟶ 470
Temp. Difference °C	280	258	171	153
K-Value Kcal/°C/m^2/h	8.5	5.85	6.9	9.4
Absorbed Heat WE/h (Heat Units per hr)	476,000	5.45×10^6	3.06×10^6	576,000
Number of Tubes (Hairpin coils ?)	1	18	13	2

Resistance in Preheater

Passes	6.2 x 17 = 105)	
	)	= 255 mm. W.G.
Burners & Pipes	150)	

CASE 2: 3-Phase Stall with Paste Regeneration

Thruput:			
Thin Paste	t/h	23	(40%; 0.58)
Thick Paste	t/h	22	(54%; 0.52)
Film oil	t/h	2	
Gas thru heat exchanger	m^3/h	30,000	(0.32)
Gas thru preheater	"	9,000	(0.32)
Total gas	"	77,000	
Catchpot	t/h	28.1	(0.65)

Heat Values:		
Heat Exch. - Inlet pass	Kcal/°C	22,900
Heat Exch. - Return pass	"	42,900
Preheater, paste section	"	15,300
Preheater, mixture section	"	38,200

Temperatures:

Paste	°C	105
Gas	°C	40
Heat Exchange Temperature Diagram	°C	288 ⟵ 440 115 ⟶ 395
Temp. Difference	°C	94
Surface	m^2	376
K	Kcal/m^2/h/°C	180
Heat transmitted	Kcal/h	6.4×10^6
Radiation	Kcal/h	200,000

Preheater:

Circulating gas volume	m^3/h	125,000
Width of pass	mm	710

CASE 3: 4-Phase Stall with Paste Regeneration

Throughput:			
Thin Paste	t/h	28	(40%; 0.58)
Thick paste	t/h	27	(54%; 0.52)
Film oil	t/h	2	
Gas thru heat exchanger	m^3/h	35,000	(0.32)
Gas thru preheater	m^3/h	10,000	(0.32)
Total gas	m^3/h	90,000	
Catchpot	t/h	34.4	(0.65)
Heat Values:		27,400	
Heat Exch. - Inlet pass	Kcal/°C	51,200	
Heat Exch. - Return pass	"	18,300	
Preheater, paste section	"	45,700	
Preheater, mixture section	"		
Temperatures:			
Paste	°C	205	
Gas	°C	40	
Heat exchange			
Temperature diagram	°C	287 ⟵ 440 115 ⟶ 395	
Temp. Difference	°C	93	
Surface	m^2	564	
K	Kcal/m^2/h/°C	146	
Heat transmitted	Kcal/h	7.65×10^6	
Radiation	"	300,000	

CASE 3: 4-Phase Stall (Cont'd)

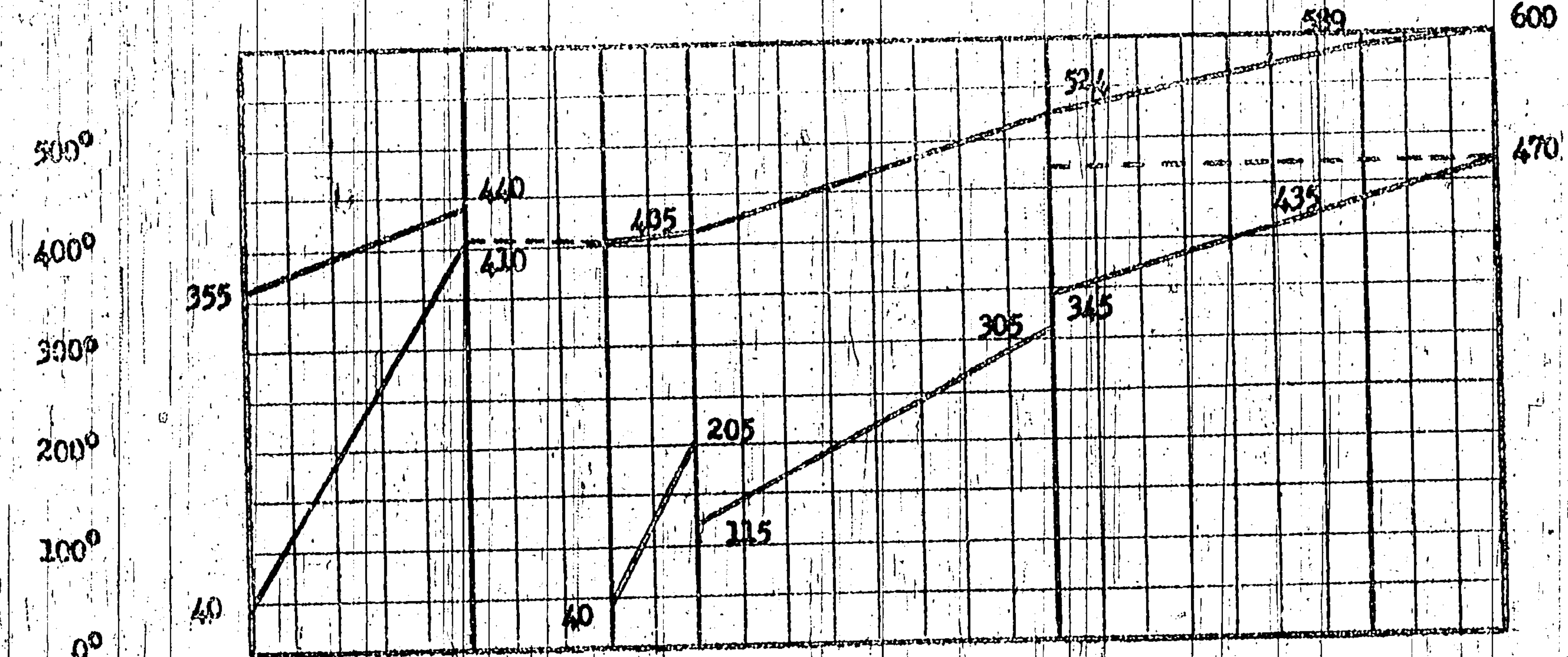
Preheater		
Circulating gas volume	m^3/h	125,000
Width of pass	mm	710
Width of baffle	mm	70
Free cross-section	m^2	2 x 3.3
Maximum velocity of circulating gas	m/sec	17

Temperature Diagram °C

	Gas Tubes	Paste Section	Mixture Section
	400 ⟵ 431	431 ⟵ 520	520 ⟵ 600
	40 ⟶ 130	109 ⟶ 300	356 ⟶ 425
Temperature Difference °C	330	265	169
K-value, Kcal/m^2/°C/h	9.8	5.5	7.65
Absorbed heat, Kcal/h	1.29×10^6	3.5×10^6	3.15×10^6
Number of Tubes (Hairpin coils ?)	2	12	14

Resistances			
In the passes	14 x 5.3 =	60)	
Burners and pipes		130)	210 mm W.G.
Mixing loss		20)	

KCBraun/pkl
fko



Case 1

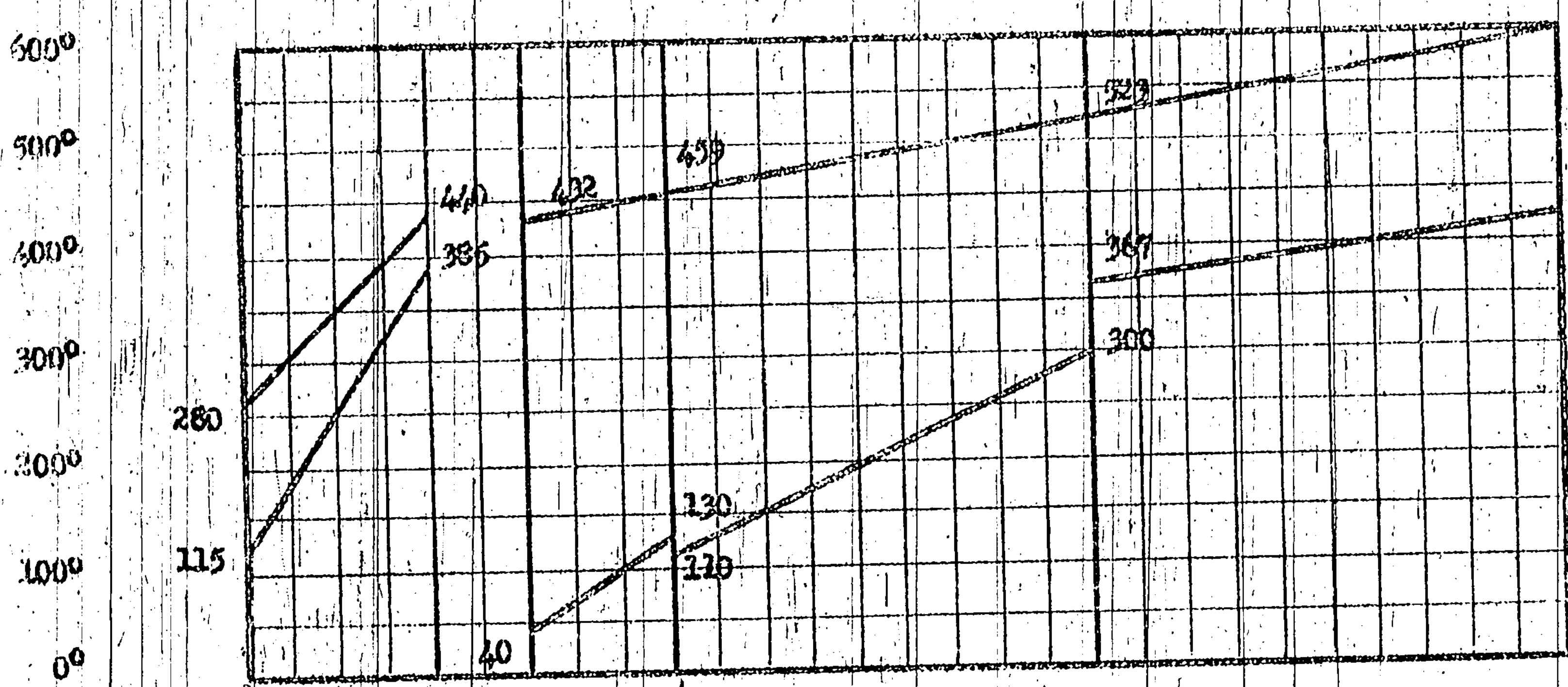
Temperature diagram for heat exchanger and preheater for 3-phase stall without paste heat exchanger.

	Heat Exch.	Gas Tubes	Paste Section	Mixture Section	Gas Tubes
K Value	1.52	8.5	5.85	6.8	8.4
$F = m^2$	188	400	3600	2600	400
$\Delta T = {}^{\circ}C$	124	280	258	171	153
Heat Absorbed	3.5×10^6	0.476×10^6	5.45×10^6	3.06×10^6	0.576×10^6

(F = Heating Surface m^2)

Paste Thruput: 45 t/h
(Workgas 30,000 m^3/h
(Secondary paste gas)

Hydrierwerk Scholven A.G.
Gelsenkirchen-Buer



	Heat Exch.	Gas Tubes	Paste Section	Mixture Section
K Value	180	7.8	5.6	6.75
F = m²	376	400	1800	2200
Δt = °C	94	360	286	175
Heat Absorbed	6.4×10^6	1.42×10^6	2.9×10^6	2.6×10^6

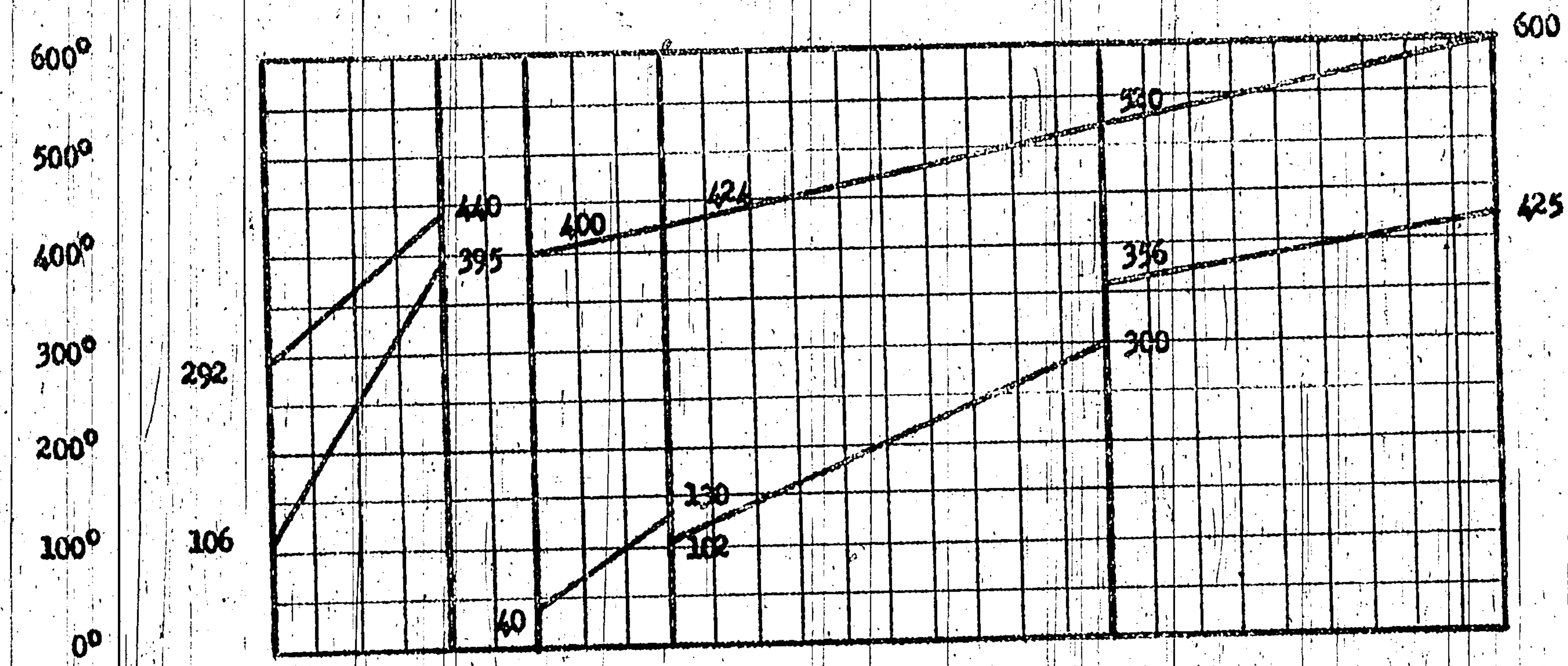
(F = Heating Surface – m²)

Case 2

Temperature diagram for heat exchanger and preheater for 3-phase stall with paste heat exchangers

Paste Thruput:
Thin paste 23 t/h
Thick paste 22 t/h
(Workgas 39,000 m³/h
(Secondary paste gas)

Hydrierwerk Scholven A.G.
Gelsenkirchen-Buer



	Heat Exch.	Gas Tubes	Paste Section	Mixture Section
K Value	146	8.8	5.3	6.65
$F = m^2$	564	400	2400	2800
T = °C	93	330	265	163
Heat Absorbed	$7.65 x 10^6$	1.49×10^6	3.5×10^6	3.45×10^6

Case 3

Temperature diagram for heat exchanger and preheater for 4-phase stall with paste heat exchanger.

Paste Thruput:
Thin paste 28 t/h
Thick paste 27 t/h
(Workgas 45,000 m^3/h
(Secondary paste gas)

Hydrierwerk Scholven A.G.
Gelsenkirchen-Buer

T.O.M. Reel No. 9
Target No. 30/4.11
Bag No. 2733

DR. FRESE REPORT OF APRIL 24, 1939 IN SCHOLVEN.

OPERATING EXPERIENCE WITH THE 700 ATM. INSTALLATION. THE CHLORINE INSTALLATION. CORROSION, ADDITION OF SODIUM SULPHIDE AND INCREASED THE H_2S PARTIAL PRESSURE IN THE CIRCULATING GAS.

During the first months of operations of our liquid stall we had two stall shutdowns because of short circuits in the heat exchangers. The first one was on the heat exchanger II of the 3 exchangers in operation, in the second case the exchanger I of the two remaining exchangers in operation broke down after only 14 days of operation.

Both shutdowns were caused by corrosion, probably as a result of the presence of concentrated NH_4Cl in the water solution. The corrosion began where the injected water, which formed about 6-7% of the catch pot, was condensed. The temperature of the principal corrosion places was in the interval of 350 to 250°. Our injection feed had a varying chlorine content of between 0.05 to 0.12%. The catch pot contained fine black flakes which settled on the surface upon longer standing. The corrosion difficulties were at first overcome by the addition to the feed of somewhat more than the theoretical amount of finely pulverized soda. The chlorine content of the catch pot water, which amounted to 500 mg/li and over before the addition, dropped to about 10 mg/li and lower. No more corrosion spots have been found since.

It is of interest that the stall production with the 11,002 catalyst (Coke/grudel with 2% Mo), which was in series with the HOLD, did not suffer in spite of the alkaline reaction.

In later experiments the soda was replaced with sodium sulfide which was obtained finely ground from the firm Leverkusen under the name of sulfigran. This was done in the expectation of an additional improvement of the catalyst efficiency through the hydrogen sulfide liberated even though it amounted to but about 7% of the total hydrogen sulfide formed in the injection feed. In later experiments the partial pressure of hydrogen sulfide in the circulating gas was found increased by operating at a higher circulating density and by raising the temperature of the catch pot from 27° to 42°.

The hydrogen content in the gas inlet was lowered from 75% to 61%, which raised the hydrogen sulfide content in the inlet of the circulating gas into the stall from 0.05 to 0.15%, corresponding to a partial pressure of hydrogen sulfide of about 1 atm.

In spite of the lowering of the partial pressure of hydrogen, there was a distinct increase in the stall production caused in this case by the increase in the hydrogen sulfide concentration. There was in addition a not inconsiderable saving in hydrogen because a smaller amount of circulating gas was purged. Only 9% fresh hydrogen had to be purged instead of the original

13%, which is of considerable importance when there is no Linde gas installation available. One could not observe a larger amount of iron sulfide formation, in excess of the normal, even after 100 days of operation under such conditions.

I will mention in conclusion a rather unattractive disturbance in operations which has been observed for the first time. Additional water was added to the circulating gas at 25° between the catch pot and the washer for complete washing out of the salts formed as well as of ammonia and CO_2. This created friction which was later found to have been caused by a complete plugging up of the piping with ethane and propane hydrates. The difficulty was overcome by completely avoiding any injection of water into the circuit and also by maintaining a higher gas temperature than the catch pot temperature by heating a few degrees to prevent any condensation.

It is recommended to provide heating of the whole circuit in new installation by introducing a bypass pipe and, in particular, of all the dead spots such as the returns to the gas circulating pumps etc., to avoid a condensation of ethane and propane which moreover thin out lubricating oils and produce undesirable pump disturbances.

Sternberg/mc/pkl

T.O.M. Reel No. 9
Target No. 30/4.11
Bag No. 2733, Under Item 10, "Miscellaneous Information".

COMPARISON OF THE CIRCULATION WASHING AND CIRCULATION PURGE AT 700 ATM.

By Dr. Frese (Ruhröl) on April 24, 1939 in Scholven.

You are familiar with the fact that when such raw materials as coal, pitch or tar are hydrogenated, there are some liquid products as well as a conversion of a small proportion of the feed into less desirable gaseous products, such as C_1, C_2, C_3 and C_4, which are only in part absorbed in the liquid portion of the HOLD or in the catch pot (depending on the amount of gasification), and enter the hydrogenating gas circulating system when they are brought to atmospheric pressure. Another part remains in the circulating gas, becomes enriched there and lowers the partial pressure of hydrogen, unless care is taken for the removal of these gases from the circuit.

There are different means to remove these hydrocarbons and nitrogen from the circuit:

1) By washing with oil or with HOLD.

2) By continuous removal of part of the circuit by purging to a desirable density (in which case the high-hydrogen relief gases are advantageously carried over to the gas decomposition installation of Linde).

3) By low-temperature cooling of the circulating gas or a part of it and by removal of the condensed parts.

These three methods may also be used in combination with each other.

The most commonly used method for removal of the circulating gas hydrocarbons, especially in the 200-300 atm. installations, has been the washing of the circulating gas. However, in 500, 600 or even 700 atm. installations the results are not as desirable as in 200 atm. installations, for reason of greater losses of hydrogen at higher pressures. Should we release the pressure of a catch pot or of an oil wash feed from 700 atm. in steps down to 0 atm., we shall see (1) that during the dropping through the first 300 atm., that is from 700 to 400 atm. hydrogen chiefly, with some methane and nitrogen, are set free, the amount of hydrogen being 2-1/2 times greater than of methane. Only beginning with 400 atm. large amounts of ethane are released, and from 220 atm. down larger amounts of propane, while butane and pentane are set free only below 100 atm.

The 2) is obtained on the assumption that the absorption of gases proceeds in exactly the same way during the washing as during drop in pressure. The curve shows that the most favorable washing effect is at 200-250 atm. At this pressure practically all the hydrocarbons above C_2 and a large proportion of C_1 are washed out, while the proportion of hydrogen absorbed is relatively small. At pressures above 250 atm. relatively large amounts of hydrogen with only small amounts of methane, CO and N_2 are removed, because washing proceeds in accordance with the Henry-Dalton law, and the partial pressure of hydrogen exceeds by much that of the other gases, while the absorption coefficients of H_2 and N_2 are almost the same.

The curve has been constructed for about 6 m^3 catch pot (the catch pot operated of about 80% of fresh additions (tar and tar distillate)), and with about 15 m^3 of wash oil (the washer used counter-current), that is, with 2½ times greater amount of oil than of the catch pot. The temperature of the catch pot wash oil was around 35°. A lower temperature would have been more favorable, but impossible for operating reasons.

A further disadvantage consists in that the pressure of the wash oil was released together with the catch pot in a catch pot tank. There was no special drawing off of the wash oil into a special circuit for a complete removal of the absorbed hydrocarbons, and the catch pot wash oil returned to the circuit still contained hydrocarbons, which affected the effect of washing adversely.

It was interesting under these conditions to perform experiments which would give a comparison of hydrogen losses in the circulation washing with that in a partial circuit purge when the gas in that part of the circuit was kept the same.

The theory would require that the amount of gas given off in a unit time should be equal to the weight of the gas of the purged circuit, reduced by the amount of hydrogen, of which more is removed in the latter case. Theoretical considerations agree rather well with experimental results.

3) shows that the savings in hydrogen in the circuit washing are the greatest at high densities and low hydrogen partial pressures, that the amount returned into the circuit is continuously reduced the higher the hydrogen concentration, and with about 86% hydrogen gas intake both curves practically coincide. The hydrogen removed per ton of fresh addition is the following for the 2 cases:

GAS INTAKE		% LOSS OF HYDROGEN TO FRESH HYDROGEN ADDITION	
Density	% H_2	Washing	Circuit Purge
0.450	61	1.68	9.59
0.350	71	3.87	11.30
0.250	81	9.05	15.68
0.225	83.5	12.35	18.26
0.200	86	20.00	23.59

With a hydrogen content excess of 86% hydrogen, losses in both cases are barely permissible in practice when the purges are not sent to a Linde installation, as will be done shortly in the Ruhröl installation.

The absorption coefficients in terms of m^3 of gas/m^3/catchpot/atm are summarized in the tables at the end of the article.

The table gives information on the volumes of wash oil proper. To maintain a hydrogen concentration of 83% in the circuit an amount of wash oil about four times greater than of new addition must be maintained.

One may see from this consideration that the circuit purge, when operating at 700 atm. is less favorable than the circuit washing, but still is although entirely possible especially when the purged gas is returned to a Linde installation, in which case even the return of 20% of the added hydrogen, which carries only the compression costs, will increase the cost per m^3 of hydrogen by only about 0.1 pfg., entirely independently from the oil fraction recoverable in the Linde installation.

There is one advantage inherent to the circulation purge which lessens the above disadvantages, and which consists in that the fresh hydrogen need not have the same degree of purity with the circulation purge as in washing, because the purification of the circuit from N_2 and CO by washing is done with a large amount of washing oil at a cost of high hydrogen losses. I wish to add that the approximate values given apply only to the conditions used in the process. Changes in the composition of the feed, of the converter temperature, etc., will bring about different gasification and therefore also different proportions of washing and solubility; however, in my opinion, it will differ more in degree than in principle when brown coal or petroleum products are used, which have not the aromatic character of the above catch pot and wash oils.

ABSORPTION COEFFICIENTS

	m^3 of gas/m^3 of catch pot/atm.	m^3 of gas/m^3 of purge/atm.
H_2	0.063	0.074
CH_4	0.178	0.111
C_2H_6	0.364	0.098
C_3H_8	0.645	0.117
C_4H_{10}	0.985	0.171
C_5H_{12}	4.89	1.382
CO_2	4.94	---
H_2S	2.30	0.461
NH_3	3.47	1.645
CO	0.152	0.078
N_2	0.066	0.086

Hydrogen from Purged Feed

(Catch Pot and HOLD) referred to fresh hydrogen when the density of the gas intake is 0.430 equivalent to 63% H_2.

Catch Pot-Purge	600 atm.-60 atm.:	2.62% H_2
Catch Pot-Purge	60 atm.- 0 atm.:	0.20% H_2
HOLD-Purge	600 atm.- 0 atm.:	1.65% H_2
	Total	4.47% H_2

COMPARISON OF AMOUNTS OF H_2 WITH CIRCULATION WASHING AND WITH CIRCULATION PURGE AT DIFFERENT GAS INLET DENSITIES.

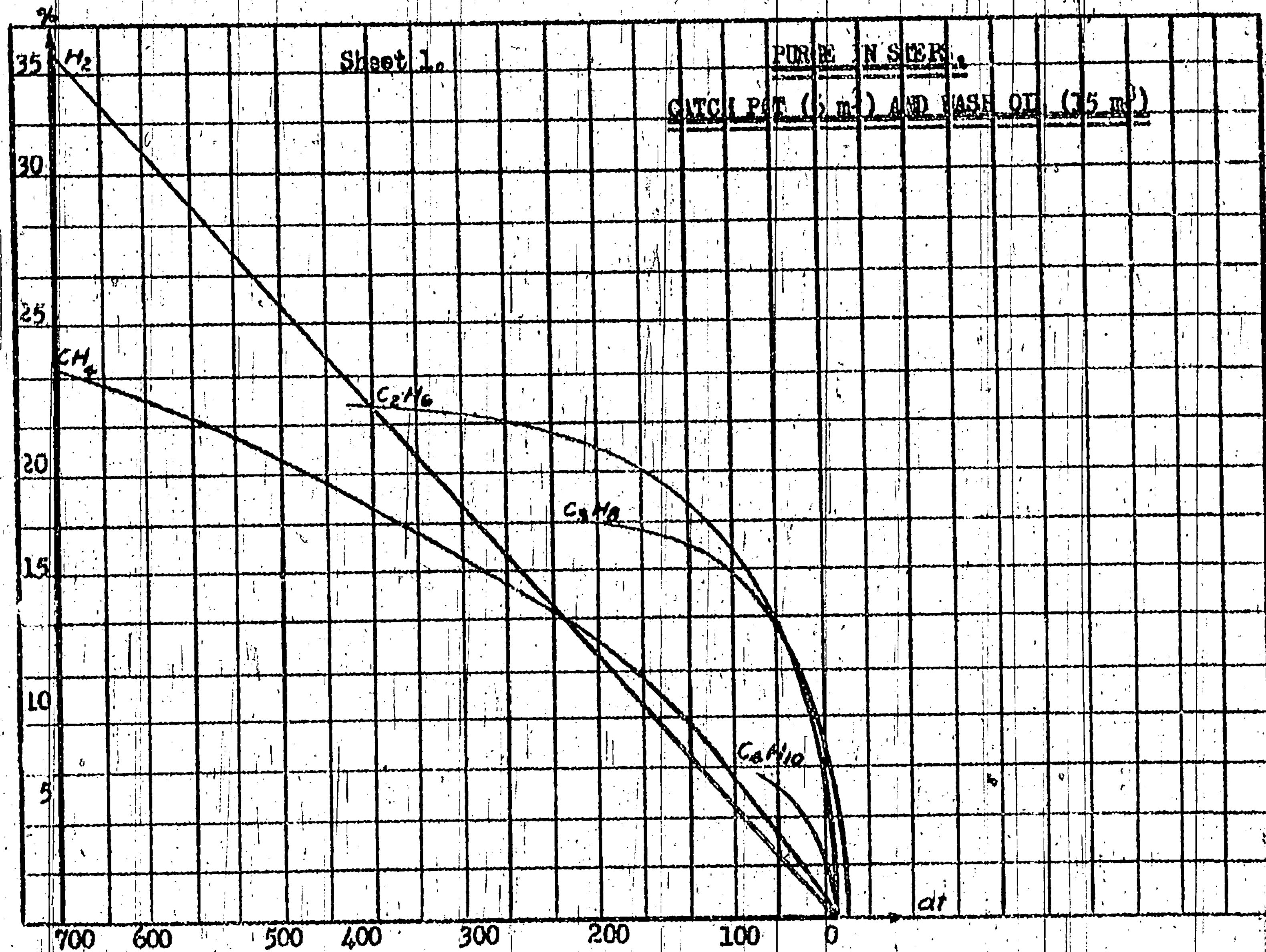
Density	% Hydrogen	% of Purged Hydrogen in Washing (Referred to fresh hydrogen)	% of Purged Hydrogen in Purge (Referred to fresh hydrogen)
0.450	61	1.68	9.59
0.400	66	2.51	10.20
0.350	71	3.87	11.30
0.300	76	5.66	12.96
0.250	81	9.05	15.68
0.225	83.5	12.33	18.26
0.200	86	20.00	23.39

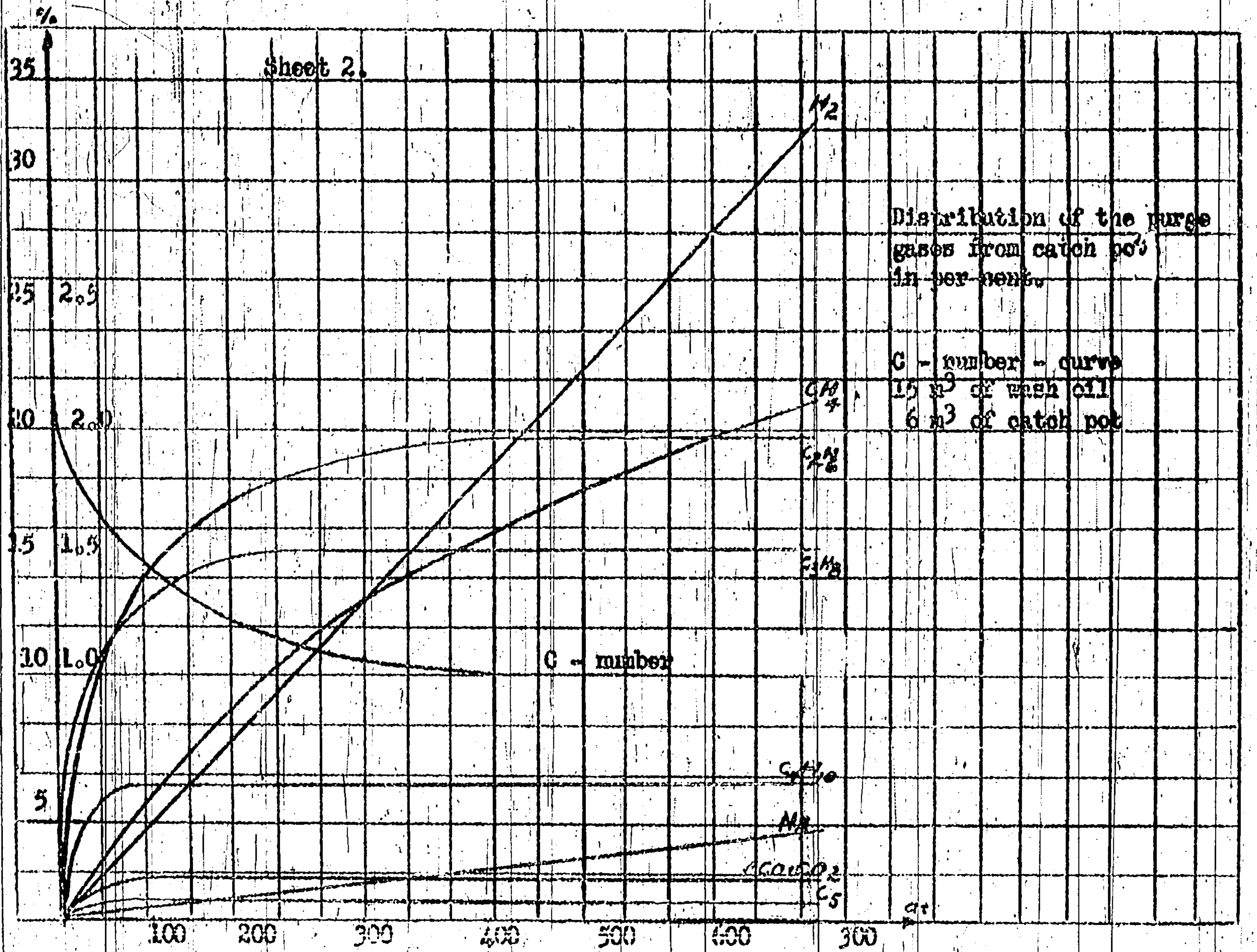
Hydrogen from Purged Products

(Catch Pot and HOLD) referred to fresh hydrogen when the density of the gas intake is 0.430 equivalent to 63% H_2.

Catch Pot-Purge	600 atm.-60 atm.:	2.62% H_2
Catch Pot-Purge	60 atm.- 0 atm.:	0.20% H_2
HOLD-Purge	600 atm.- 0 atm.:	1.65% H_2
		4.47% H_2

Sternberg/mc/pkl

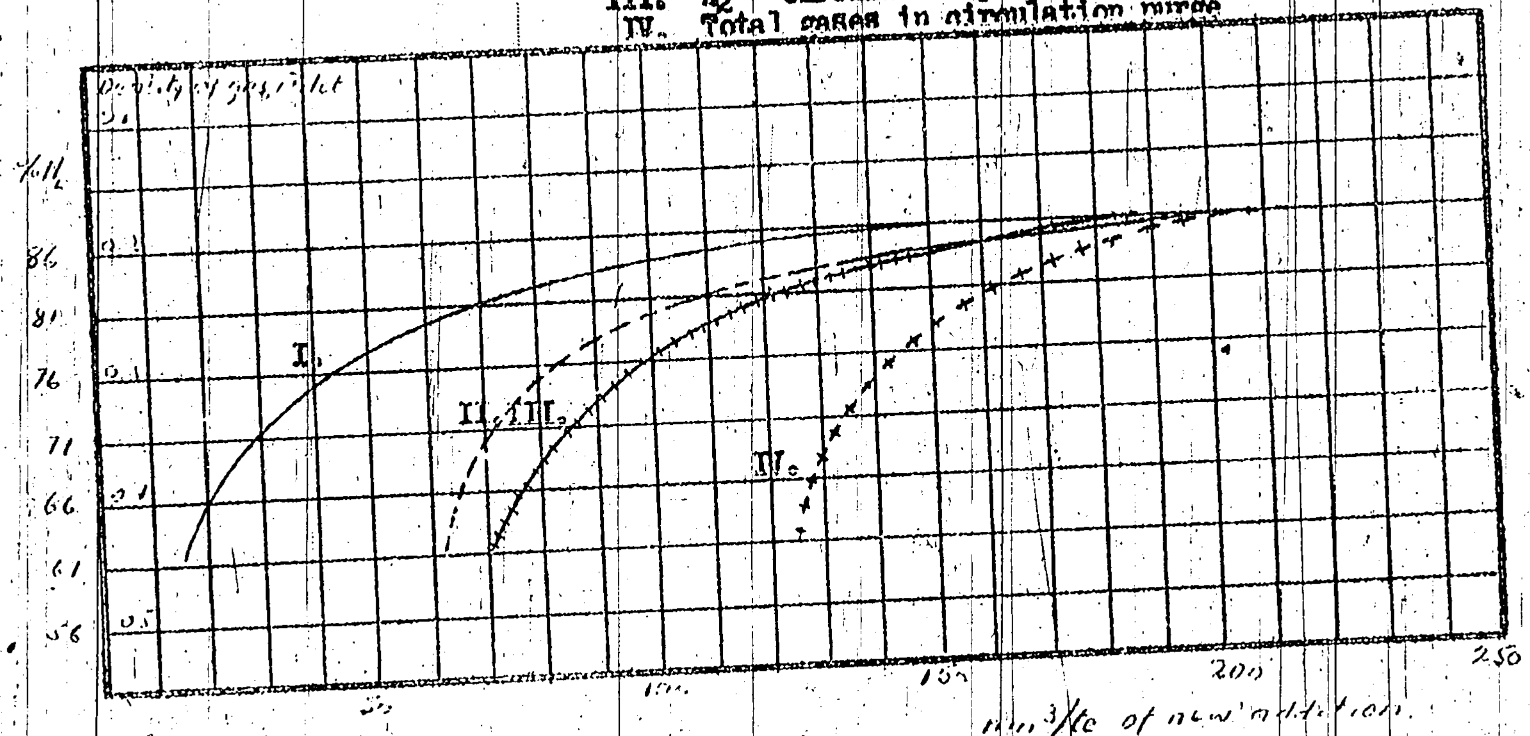

Sheet 1.
PURGE IN STEPS.
CATCH POT (5 m³) AND WASH OIL (15 m³)
%
35
30
25
20
15
10
5
H_2
CH_4
C_2H_6
C_3H_8
C_4H_{10}
700
600
500
400
300
200
100
0
at

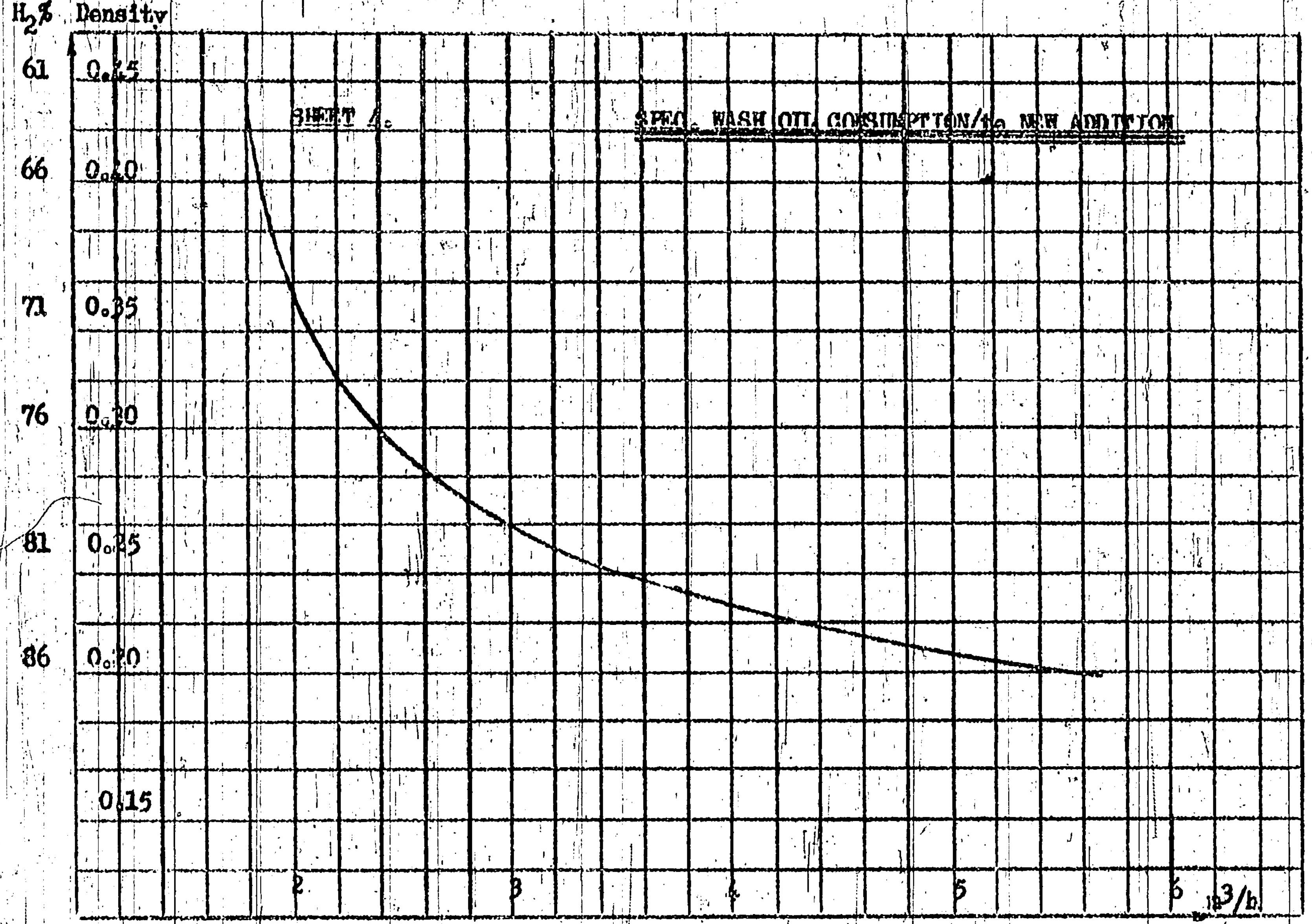

%
35
30
25
2.5
20
2.0
15
1.5
10
1.0
5
Sheet 2.
H_2
CH_4
C_2H_6
C_3H_8
C - number
C_4H_{10}
N_2
$CO + CO_2$
C_5
100
200
300
400
500
600
700
at
Distribution of the purge gases from catch pot in per cent.
C - number - curve
15 m³ of wash oil
6 m³ of catch pot

Sheet 3.

COMPARISON OF CURVES, CIRCUIT PURGE AND CIRCUIT WASHING

I. H_2 in expanded gases of circuit washing
II. Total expanded gases of circuit washing
III. H_2 - Circulation purge
IV. Total gases in circulation purge




SHEET 4.
SPEC. WASH OIL CONSUMPTION/to NEW ADDITION
H2% Density
61 0.45
66 0.40
71 0.35
76 0.30
81 0.25
86 0.20
0.15
2
3
4
5
6 m3/h

T-44

T.O.M. Reel 103
Bag No. - -
Target 30/4.03
Report No. H26-430

I. G. FARBENINDUSTRIE, A.G.
LUDWIGSHAFEN/RHEIN

24 August 1940

Technical Experiment Station Op. 200
Report 430
(Pages 1 to 10 incl.)

REPORT ON THE TESTING OF TWO
ASBESTOS CEMENTS FOR HIGH PRESSURE
INSULATION

INDEX -

KCBraun/ara/pkl

Technical Experiment Station
Oppau - 200
Report No. 430

REPORT ON THE TESTING OF TWO ASBESTOS CEMENTS FOR HIGH PRESSURE INSULATION

Summary

Asbestos cements, which differ in the kind of asbestos fibres and in the amount of water content, were tested for high pressure insulation. The greatest coefficients of heat transmission at 750 atm. hydrogen are 0.87 and 0.68, respectively, kcal/hr/m°C. These values may be considered as very favorable.

Introduction

Samples of asbestos cement, which are still the property of Works Gelsenberg and Wesseling, were made of alumina cement and blue asbestos fibres and these were tested for their thermal conductivity. For the sake of brevity, the two samples are herein designated as "Asbestos-Cement Gelsenberg" and "Asbestos-Cement Wesseling". Both contain, for every ten (10) parts by weight of blue asbestos fibres, 100 parts by weight of alumina. The different nature of the asbestos fibres requires that to the Asbestos-Cement Wesseling" considerably more water must be added than to the "Asbestos-Cement Gelsenberg" to obtain a pourable mass. The asbestos from Gelsenberg consists of moderately coarse and of fine fibres and feels moderately hard, the length of fibres is very nearly 20 mm. The asbestos from Wesseling contains only fine, very soft, fibres of about 10 mm. length. These fine fibres absorb so much water that, compared to the asbestos from Gelsenberg and the formerly used still coarser asbestos, more than twice the amount of water must be added. The composition of the mixtures is shown in the following Table 1.

TABLE 1

Composition of the Asbestos Cements

Asbestos-Cements	Gelsenberg	Wesseling
Blue Asbestos Fibres, Parts by Weight	10	10
Alumina Cement, Parts by Weight	100	100
Water, Parts by Weight	90	200
Asbestos - % of the total Mass	5.0	3.2
Asbestos - % of the Dry Substance	9.1	9.1
Dry Substance - % of the Total Mass	55.0	35.5

The most important physical data of both asbestos-cements are as follows:

Asbestos-Cements	Gelsenberg	Wesseling
Density of the balls, kg/m^3	1140	655
Compressive strength, maximum, kg/cm^2	-	64.5
Compressive strength, minimum, kg/cm^2	-	11.0
Compressive strength, average, kg/cm^2	-	-
Tensile strength, maximum, kg/cm^2	-	12.0
Tensile strength, minimum, kg/cm^2	-	3.3
Tensile strength, average, kg/cm^2	-	-
Coefficient of thermal expansion between 20° and 300°C.	-	7.6×10^{-6}

Results of Tests

The tests were conducted in hydrogen at pressures of one atm. to 210 atm. in the 200 atm. autoclave and at 400 and 760 atm. in the 1000 atm. autoclave. The tests were made based on temperature difference as well as on t_m = 750°C. (constant average temperature of 750°C). In addition a test was made based on one atm. nitrogen (in place of a test in air at atmospheric pressure). The measured coefficients of thermal conductivity are shown in the attached tables 5 and 6 and Diagrams 1, 2, 3 and 4.

Characteristic values are also summarized in the following tables 2 and 3.

TABLE 2

THERMAL CONDUCTIVITY IN HYDROGEN BASED ON TEMPERATURE DIFFERENCE

Asbestos Cement	Pressure in Atm.	Temperature difference in °C 0	100	200	300
Gelsenberg	750	0.600	0.790	0.855	0.870
	400	0.540	0.680	0.730	0.735
	200	0.420	0.540	0.585	0.590
	1	0.300	0.375	0.405	0.420
Wesseling	750	0.360	0.565	0.630	0.665
	400	0.310	0.480	0.520	0.555
	200	0.235	0.300	0.330	0.350
	1	0.200	0.220	0.240	0.260

TABLE 3

THERMAL CONDUCTIVITY IN HYDROGEN BASED ON PRESSURE AT t_m = 75°C

Asbestos-Cement	Pressure in Atm. 750	400	200	100	50	1
Gelsenberg	0.800	0.625	0.530	0.480	0.455	0.358
Wesseling	0.525	0.430	0.340	0.285	0.250	0.215

Up until now only a Leuna asbestos cement (whose coefficient heat transmission/pressure curves are shown in Diagrams 1 and 3), was tested at 75 atm. by the technical experiment station at Oppau. As is apparent, both the above samples of asbestos cement are more faborable than the Leuna asbestos cement, which is made by the tamping method and consists of a mixture of 44 parts blue asbestos, 100 parts alumina cement and 48 parts water. The "Asbestos-Cement Wesseling" has, at 750 atm. hydrogen, with a maximum coefficient of heat transmission = 0.67 kcal/hm°C., the lowest thermal conductivity of all the high pressure insulations which have been tested so far.

The Asbestos-Cement Gelsenberg" approximately corresponds in its thermal conductivity at 200 atm. hydrogen to a former cement asbestos made in the same mixture by the pouring method but with coarser blue asbestos fibres. (This is shown in Diagram 1, see report of the 18 October 1934).

It is difficult to judge how much of the difference between the various asbestos cements may be attributed to the various compositions of the mixtures, the various natures of the blue asbestos fibres, or the difference between the pouring method (Lu) and the tamping method (Leuna). It may also be assumed that each asbestos cement mixture has somewhat different characteristics, according to whether it was formed in the test block or in the lower or upper part of the oven.

The favorable coefficients of thermal expansion of both the asbestos cements can probably be explained by the use of finer blue asbestos fibres, in the case of Wesseling especially fine and soft. The "Asbestos Cement Wesseling" is obviously more porous because of the more than double water content. The dependence of the coefficient of thermal expansion on pressure and on temperature difference is weak for both the above samples (flat slope of the coefficient Heat Transmission/Pressure and coefficient Heat Transmission/Temperature Difference curves), so that exceptionally small unit pores can be assumed.

Figures for strength are at present available only for "Asbestos-Cement Wesseling" which show an extraordinarly great difference of values and can hardly be considered representative. It has the appearance as if the strength relations in the "Asbestos Cement Wesseling" were not very favorable; which may be attributed to the fineness, shortness and uniformity of the fibres. The demand for uniform, very fine, pores contradicts the demand for the best strength relations. Also the uncommonly low density of only 655 kg/m^3 for cement asbestos points to lower strengths. It is intended that further strength tests of "Asbestos Cement Wesseling" as well as of Asbestos Cement Gelsenberg" be made, of which a separate report will be made.

It is to be pointed out here, however, that, according to the form of the test, differences in strength have appeared. The strength samples were made, in one case, from lamellar particles of 25 mm thickness, in the other case, from more stony particles of 80 mm thickness. Results so arrived at are summarised for Wesseling in the following Table 4.

TABLE 4

STRENGTH TESTS ON "ASBESTOS CEMENT WESSELING"

Test	Unit No.	Compressive Strength kg/cm²	Tensile Strength kg/cm²	Bending Strength kg/cm²	Thermal Expansion x 10⁻⁶
Stone	1	11.0	3.6	3.97	
Sample	2	13.6	3.3	--	6.88
	3	--	3.3	--	
Lamellar	1	48.3	11.8	4.8	8.23
Sample	2	64.5	12.0	7.07	
	3	61.2	8.3	4.8	

It should be expressly pointed out here, that both samples were made of the same mixture and by the same method. Differences in hardness could even be noted externally. Of course the possibility exists that differences may also be shown in the determination of the coefficients of thermal conductivity, although perhaps not in the same order of magnitude.

The coefficient of thermal expansion for "Asbestos-Cement Wesseling" approaches that of iron and may be considered satisfactory.

Technical Experiment Station Oppau 200
Report No. 430

TABLE 5 (Zahlentafel 1)

RESULTS OF TESTS ON "ASBESTOS CEMENT GEISENBERG"

(Density 1140 kg/m^3)

Test No.	Date 1940	Kind of Gas	Pressure Atm.	Temperature Drops From °C	Temperature Drops To °C	Average Temp. °C	Coefficient of Thermal Conductivity kcal/hm °C	Remarks
1	18.7	Hydrogen	755	31.4	19.0	25.2	0.603	1000 atm. autoclave
2	19.7	"	755	182.5	36.4	109.4	0.786	
3	20.7	"	760	322.9	53.8	188.4	0.827	
4	25.7	"	790	199.7	39.4	119.6	0.897	
5	26.7	"	745	411.0	61.6	251.3	0.900	
6	27.7	Hydrogen	400	417.2	55.8	236.5	0.739	1000 atm. autoclave
7	29.7	"	400	107.2	24.9	65.1	0.669	
1	20.7	Hydrogen	200	37.6	27.5	32.6	0.437	200 atm. autoclave
2	22.7	"	208	123.4	38.1	80.7	0.517	
3	23.7	"	212	285.0	53.7	169.3	0.574	
4	26.7	"	210	211.7	48.8	130.2	0.593	
5	27.7	"	204	420.6	69.6	245.1	0.602	
6	29.7	Hydrogen	110	107.9	36.1	72.0	0.480	200 atm. autoclave
7	30.7	Hydrogen	55	112.2	35.9	74.1	0.478	200 atm. autoclave
8	31.7	Hydrogen	0	114.0	33.1	73.6	0.358	200 atm. autoclave
9	1.8	"	0	270.9	45.9	158.4	0.397	
10	2.8	"	0	37.8	26.2	32.0	0.306	
11	3.8	"	0	235.4	44.2	139.8	0.405	
12	5.8	"	0	438.7	61.9	250.3	0.434	
13	6.8	Nitrogen	0	132.5	33.9	83.2	0.220	200 atm. autoclave
14	7.8	"	0	363.7	47.9	205.8	0.284	

Technical Experiment Station Oppau 200
Report No. 430

TABLE 6 (Zahlentafel 2)

RESULTS OF TESTS ON "ASBESTOS CEMENT WESSELING"

(Density 655 kg/m^3)

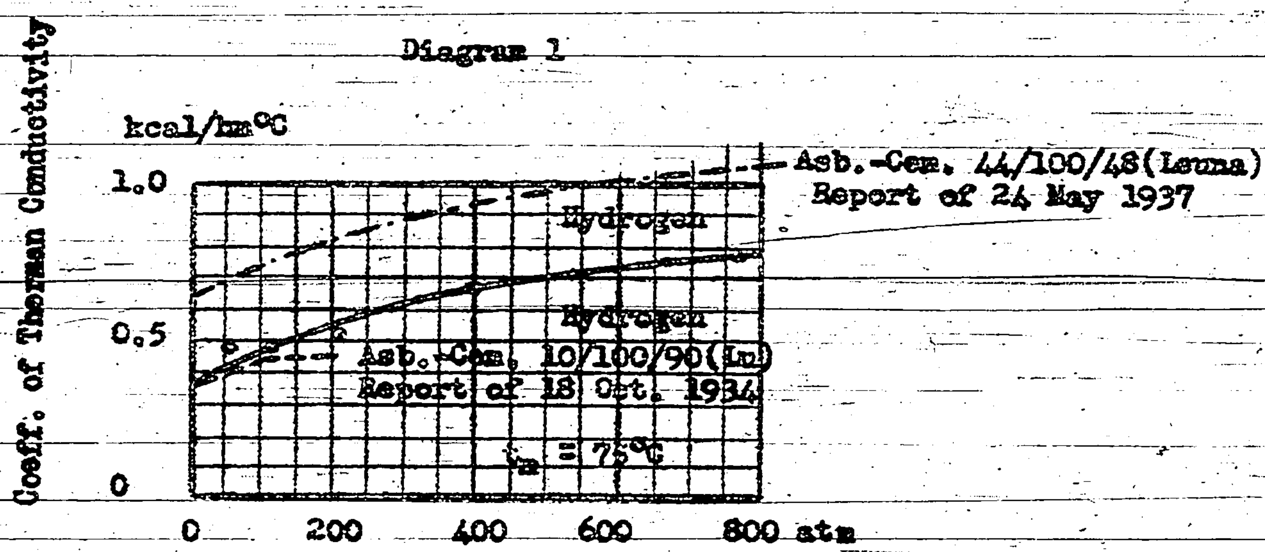
Test No.	Date 1940	Kind of Gas	Pressure Atm.	Temperature Drops From °C.	Temperature Drops To °C.	Average Temp. °C	Coefficient of Thermal Conductivity kcal/hm°C	Remarks
1	1.8	Hydrogen	770	32.2	20.1	26.2	0.395	1000 atm. autoclave
2	2.8	"	755	144.6	30.3	87.4	0.558	
3	3.8	"	760	312.1	46.4	178.2	0.602	
4	8.8	"	770	244.7	44.6	144.6	0.670	
5	9.8	"	760	407.2	58.8	233.0	0.687	
6	10.8	Hydrogen	455	112.3	29.0	70.7	0.470	1000 atm. autoclave
7	12.8	"	400	114.8	27.0	70.9	0.466	
8	13.8	"	400	307.3	41.6	174.4	0.541	
9	14.8	"	410	102.4	24.3	63.4	0.466	
10	15.8	"	420	245.8	38.2	142.0	0.536	
1	31.8	Hydrogen	200	44.2	27.0	35.6	0.248	200 atm. autoclave
2	1.8	"	215	132.9	33.9	84.4	0.301	
3	2.8	"	215	277.7	44.0	160.9	0.338	
4	3.8	"	210	421.3	56.8	239.0	0.359	
5	5.8	Hydrogen	98	110.0	33.7	71.8	0.283	200 atm. autoclave
6	6.8	Hydrogen	51	113.3	33.5	73.4	0.270	200 atm. autoclave
7	7.8	Hydrogen	0	114.0	32.7	73.2	0.215	200 atm. autoclave
8	8.8	"	0	261.1	41.5	151.3	0.242	
9	9.8	"	0	384.0	47.9	215.9	0.264	
10	10.8	Nitrogen	0	149.7	30.5	89.6	0.096	200 atm. autoclave
11	12.8	"	0	360.5	38.1	199.3	0.110	
12	13.8	"	0	206.5	31.6	119.1	0.126	
13	14.8	"	0	115.9	29.0	72.5	0.116	

T-44

Tech. Experiment Sta. Oppau 200

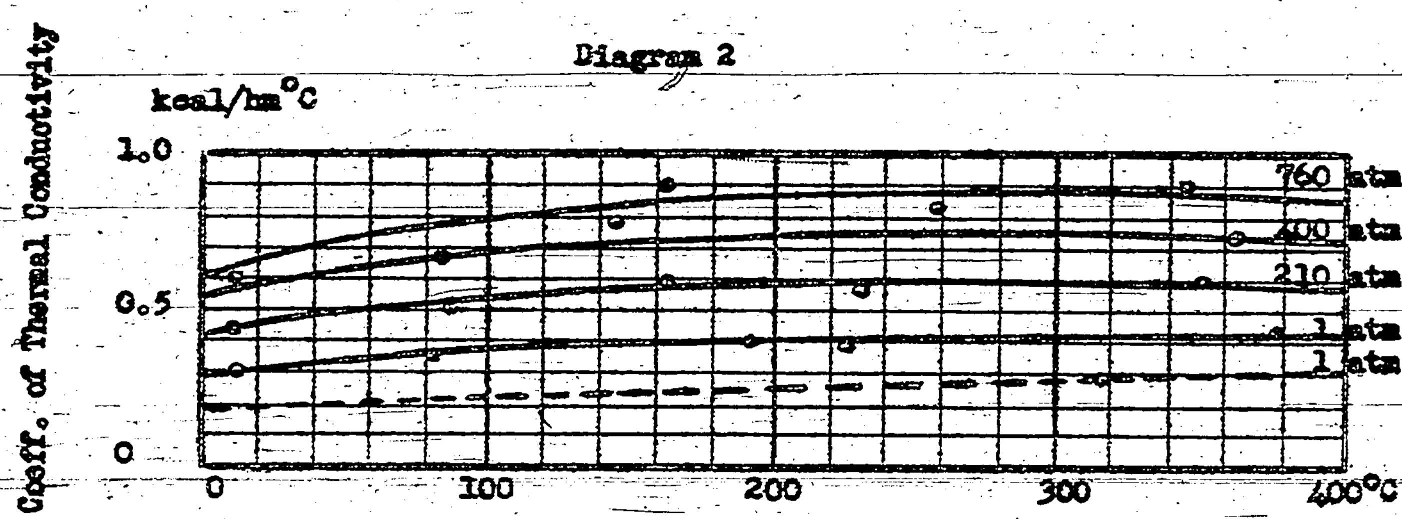
Thermal Conductivity of "Asbestos-Cement - Gelsenberg"

Diagram 1



Pressure - Atm.

Diagram 2



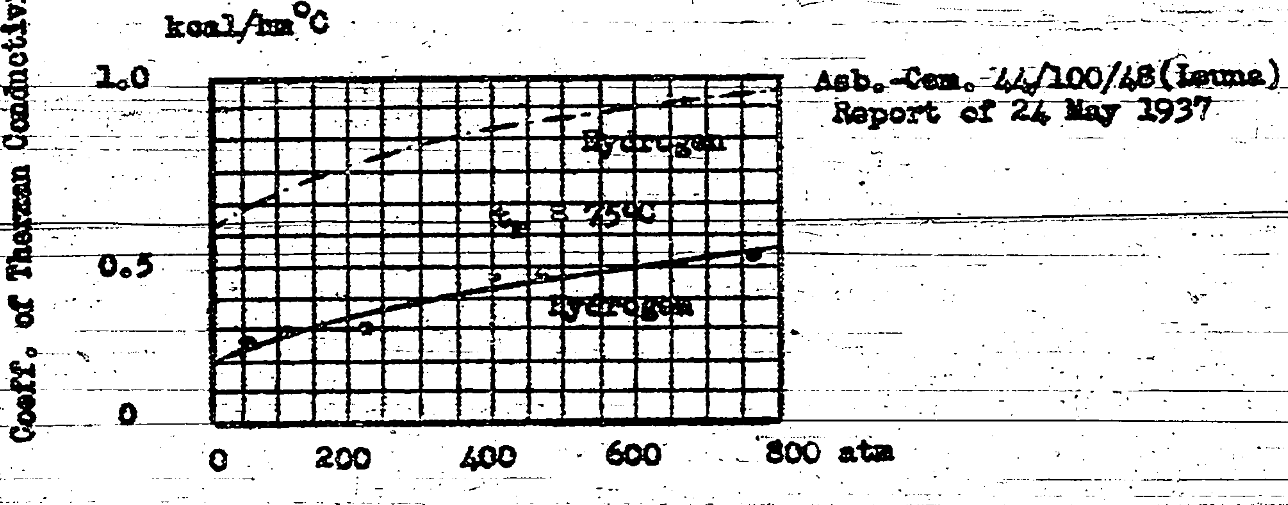
Temperature Difference - °C

Hydrogen
Nitrogen

Tech. Experiment Sta. Oppau 200 T-44

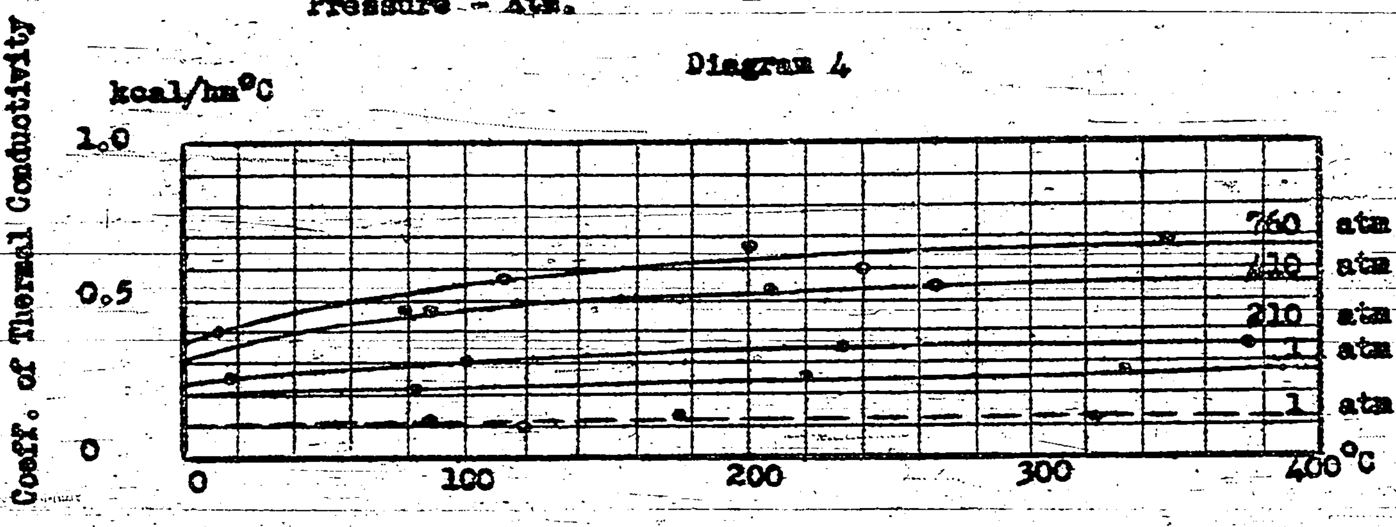
Thermal Conductivity of "Asbestos-Cement - Wesseling"

Diagram 3



Pressure - Atm.

Diagram 4



Temperature Difference - °C

——— Hydrogen

- - - - - Nitrogen

U. S. Bureau of Mines

Coal Hydro. Demon. Plant Div.

T-45

T.O.M. Reel No. 130
pp. 639 to 761

REPORT ON

A VISIT TO THE LEUNA

WORKS HYDROGENATION PLANT

(From the 12 August to the 3 September, 1937)

\- - - - -

REPORT ENG. TD1030. 27 DECEMBER 1937

\- - - - - -

Visitors: From Anic, Messrs. Brusgo and Piana
From I.G., Messrs. Amon and Küppinger
From IGECC, Mr. Walkate

Translation - Part I K. C. Braun
Part II E. M. Sternberg

INTRODUCTION

In the following statements, made on the occasion of the visit of Messrs. Piana and Brusgo of Anic to the Leuna Works, only experiences and constructive details, which have been made or applied in the Leuna plant, are related. Where tar and lignite hydrogenation in Leuna is delt with, these statements may not be applied without qualifications to oil hydrogenation plants. This report contains no suggestions or recommendations for the Anic plant.

INDEX

A. BUILDING OF A STALL, ARRANGEMENT OF VESSELS AND PIPE LINES.

I. G. builds the stall foundation and the walls of one piece; that is, in any sinking of the soil the walls sink with the foundation. The advantage of this construction is that since the supports of the hot pipe lines are partly anchored into the walls of the stall they do not affect the pipe lines and flange connections which might otherwise become loose.

In the stalls the pipe lines must be supported and guided. Among others the vertical hot pipes are supported between the vessels. The lower support is constructed as shown in Figure 1. The support of the pipe lines is at the same level as the lower vessel support.

Other kinds of pipe supports are shown in Figures 2 and 2a.

At one or two places the long vertical pipes, 10 to 18 m long are guided as shown in Figure 3. The pipe can thus expand freely toward the top.

The expansion, which the long pipe lines in the stall are subjected to during operations, must be calculated as closely as possible and taken into consideration in the laying of the lines. The difference in expansion of stall wall and pipe line must be taken up in the horizontal part of the line. To avoid a high bending stress which might lead to loosening of the flanges, the long pipe lines are always laid with intermediate bends so that the bending stress may be reduced as much as possible and transformed into torsion. This latter stress causes a turning of the pipes in the flanges whereby the friction of the flange surfaces must be overcome (indicates a conical flange surface, see Figure 4).

Example: Mean converter wall temperature 150°C at 450°C inside temperature, pipe line temperature 450°C, Δt = 450°C - 150°C = 300°C.
Expansion of N8 = about 1.2 mm/m/100°C.
The true vertical distance between 2 flanges (= pipe length) is 18,000 mm. The expected expansion of this pipe =

$$\frac{300}{100} \times 1.2 \times 18 = 64.8 \text{ mm or about } 65 \text{ mm.}$$

The pipe is then given a pre-tension of about 35 mm; that is, the pipe length must be equal to 18,000 mm - 35 mm = 17,965 mm. The pretension is usually taken as somewhat more than one-half of the expansion. The calculated length of the pipe is shown in a sketch of all stall lines. When all lengths of the new pipe lines are known, a sketch of these lines is submitted to the corresponding installation engineer for approval. The pipe lines are all completely fabricated in the pipe shop. The flange surfaces of pipes and fittings must be protected during transportation. Slight damages to the flange surfaces are corrected by means of a pneumatic grinding machine (see figure 5). The normal wall temperature of a converter with a 65 mm layer of asbestos cement insulation at 450°C inside temperature is about 180°C. When the pipe lines are completed in the pipe shop their installation can be started. The upper and lower horizontal lines are first installed (see figure 4) and then the vertical lines are hung on, which thereby rest on the guides. The weight of the pipe springs the horizontal line enough to permit the tightening of the bolts on the lower flange of the vertical pipe. The bolts of the flange connections must be greased before tightening with Grassimet or a machine oil-graphite mixture to prevent freezing of the bolts and nuts. It is proper that the work of installation be done from the top towards the bottom. The necessary safety measures must be taken so that the men working on the lower part of the stall can work safely.

In vapor phase stalls the converters filled with catalysts must be connected to the nitrogen line during installation. It is proper that this connection (1/2" pipe) be made on the lower cover.

INSTALLATION AND DISMANTLING OF VESSELS.

The laying down and setting up of high pressure vessels is done at Leuna by means of a mounting car which runs on tracks behind the stalls. The car is provided with a ring in which the vessels rest. This ring might be made interchangeable to fit other apparatus. (for drawing of car see Int. Eng. No. 504199, at end of chapter). The laying down and setting up of converters, etc., at the dismantling of a stall, would also be possible without mounting car, namely, as follows:

Using a pit of sufficient depth and a width smaller than the vessel diameter. The converter then rests with the lower cover on heavy oaken beams (see figure 6). I. G. prefers the mounting car and does not use the pits any more.

The converter is laid down on 2 wooden or iron bases provided either with rolls or fitted plates (see figure 7). The vessels may be laid either on the flange rings or on the jacket itself. For the pulling off of covers and the pulling out of converter liners, I.G. has built in hinged rolls at various points between the tracks of the stalls. These hinged rolls can take a maximum load of 40 to 50 te (see figure 8). The weight of the concrete foundation is about 80 tons. The fixture for lifting the vessels consists of a bail which is attached to the cover trunnions (see figure 9). The hoisting speed of the I. G. cranes (150 tons) is about 1 m/minute. This speed seems very low, but I. G. prefers this because the greatest precaution must be taken in the laying down and setting up of vessels. Regulating gears on the hoisting gear should be avoided.

The horizontal transportation to the machine shop is done on special 2-section cars. The high pressure vessels can also be transported by crane. In the latter case the vessel is hung on 2 rope slings and properly balanced. A rope is attached at the end of the vessel for steering, which may be guided from the floor.

For the installation or dismantling of heat exchanger tube bundles and converter liners a maximum lift of 50 tons may be required. The strain on the pulling rope is measured by means of a spring scale so that the rope will not be overloaded (see figure 41).

The cover bolts of high pressure vessels in the stalls are pulled tight by means of a pneumatic machine (see figure 10). For a converter of 1,200 mm inside diameter an air cylinder diameter of 300 mm with a lever arm of 765 mm would be required at an air pressure of 5 to 6 atms. For a converter of 1,000 mm inside diameter an air cylinder diameter of 250 mm would suffice. The operating pressure would be assumed to be 325 atms. and the test pressure 450 atms. The bolt pre-tension possible with these cylinders equals approximately 25 percent of the tension on the volts if the cover were loaded with test pressure.

(over)

The dismantling and installation of a coal stall takes about 7 to 14 days. When a stall is to be in operation in 8 to 9 days, about 60 to 70 men must work on it during the day. At night about 10 men are employed. The work of insulation is done by a day shift of 40 to 50 men. If more time for the installation and dismantling is available, the number of workers may be correspondingly reduced. The foregoing times can only be reached when reserve vessels for installation are available.

The department of operations control removes the thermo-elements after the stall is down, disconnects the wires and connects them again after the stall has been rebuilt. Installation possibilities of thermo-elements in pipe lines are shown in figure 11. This department tests the pressure gauges and other measuring devices.

After all the lines and fittings have been installed in a stall all parts of alloy steel are again tested for material before the stall is turned over to production. (see material control, Chapter K).

It is to be recommended that a space be left free alongside of the stalls where the vessels may be placed for installation or dismantling of a stall. This is of particular importance for the vapor phase converters. To reduce the time during which a stall is down the spare converters in this space alongside of the stalls are filled with catalysts. The converter must be held in a vertical position after filling and closing and must be so transported to the stalls.

Fig. 1

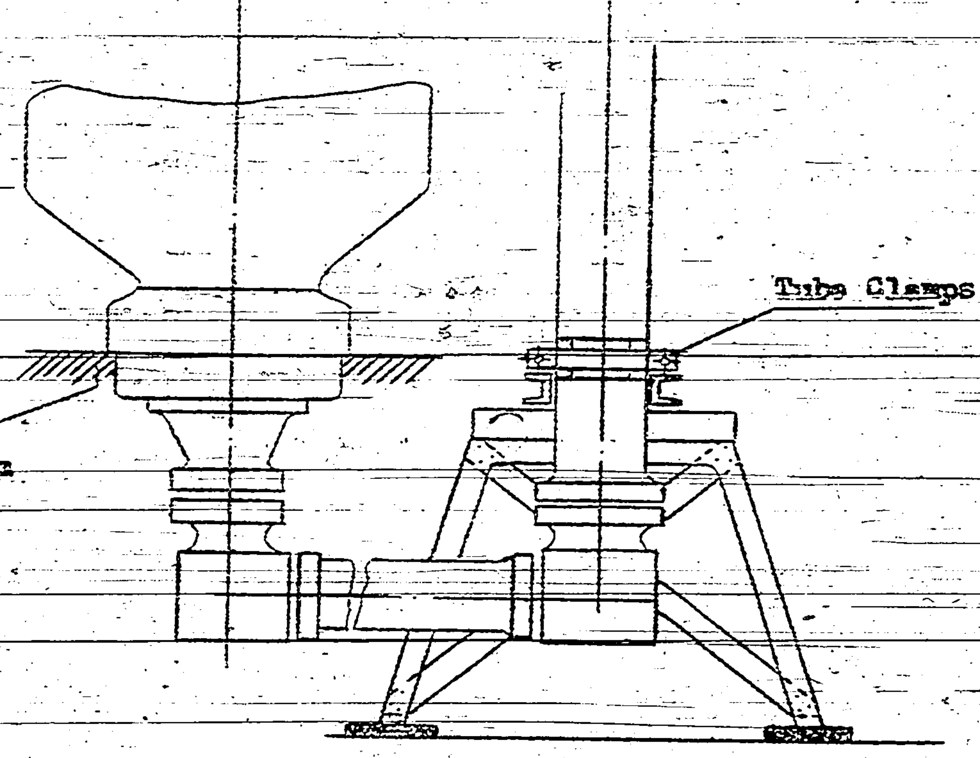


Fig. 2

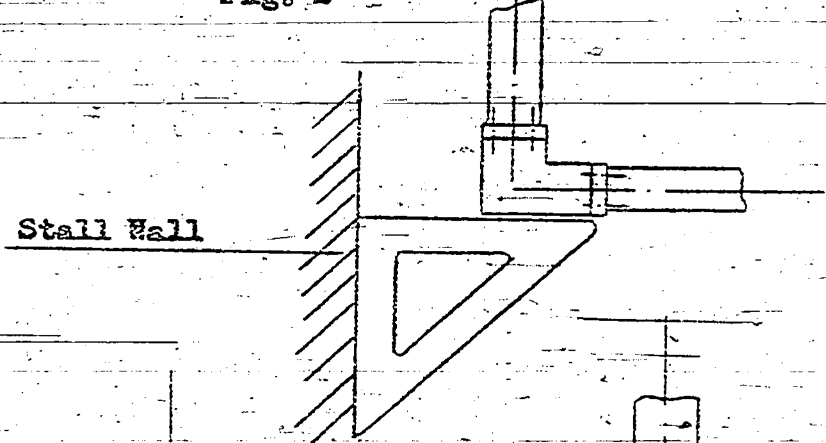


Fig. 2a

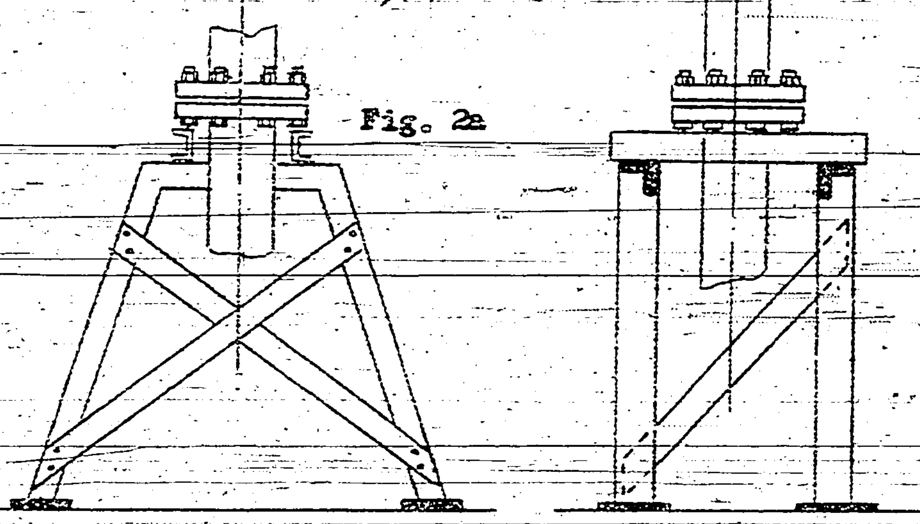


Fig. 3

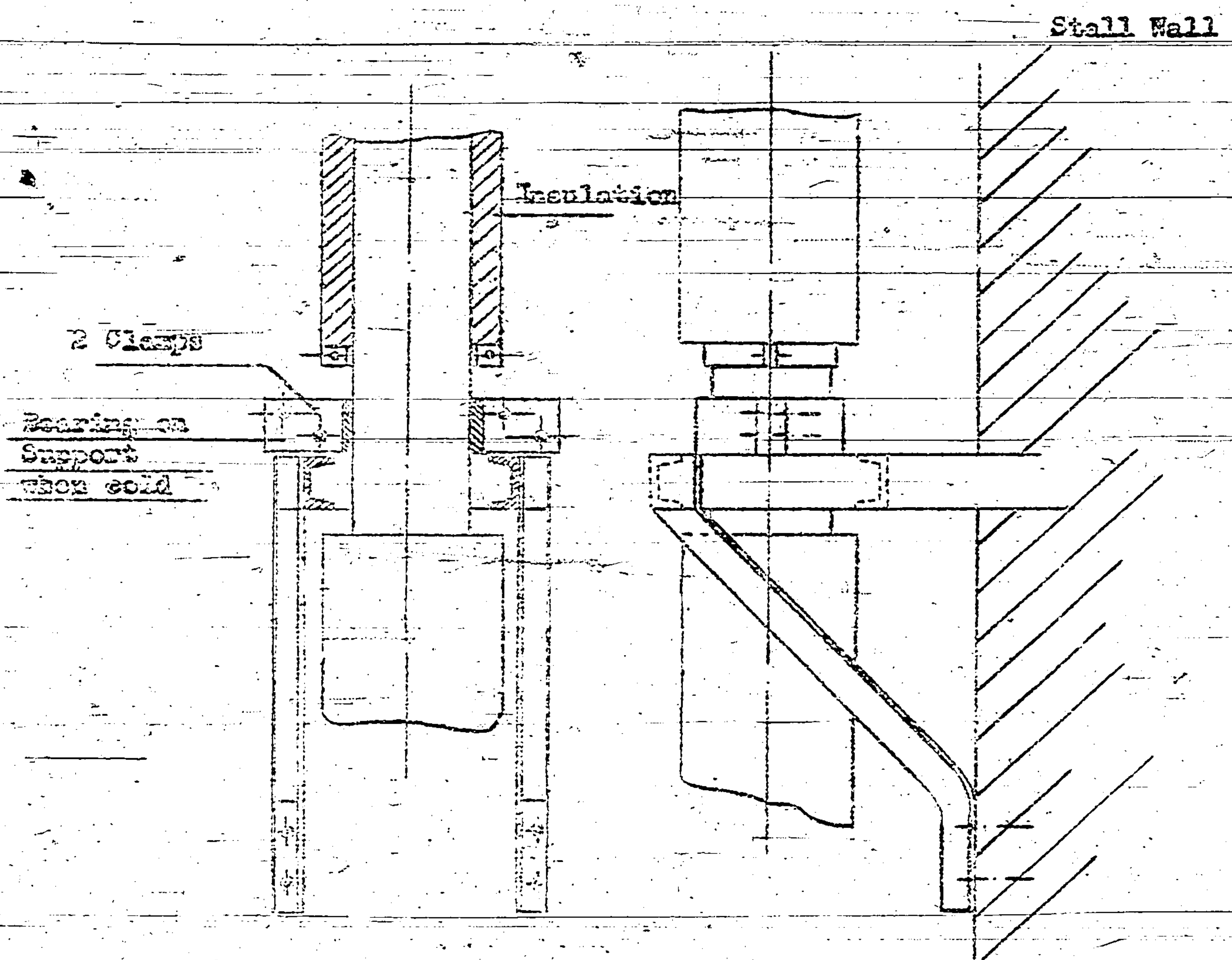

Stall Wall
Insulation
2 Clamps
Bearing on
Support
when cold

FIG. 4.

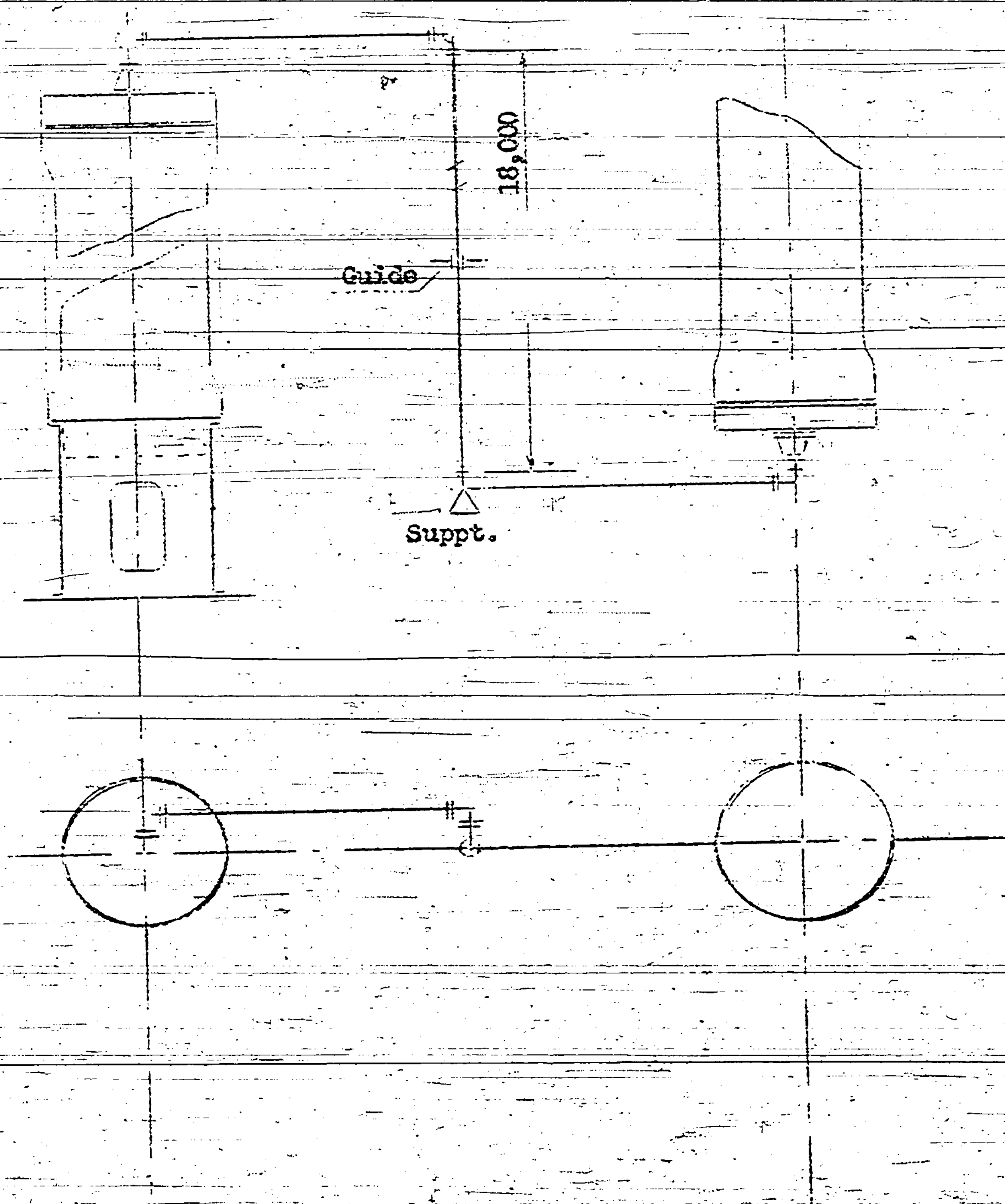


FIG. 5.

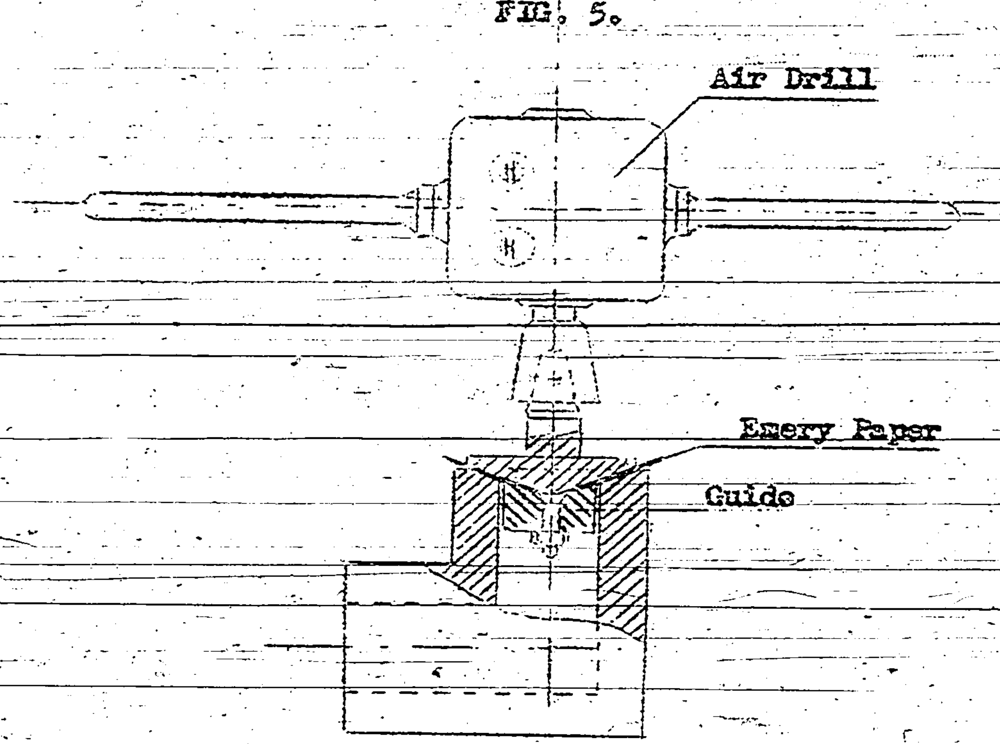

Air Drill
Emery Paper
Guide

FIG. 6.

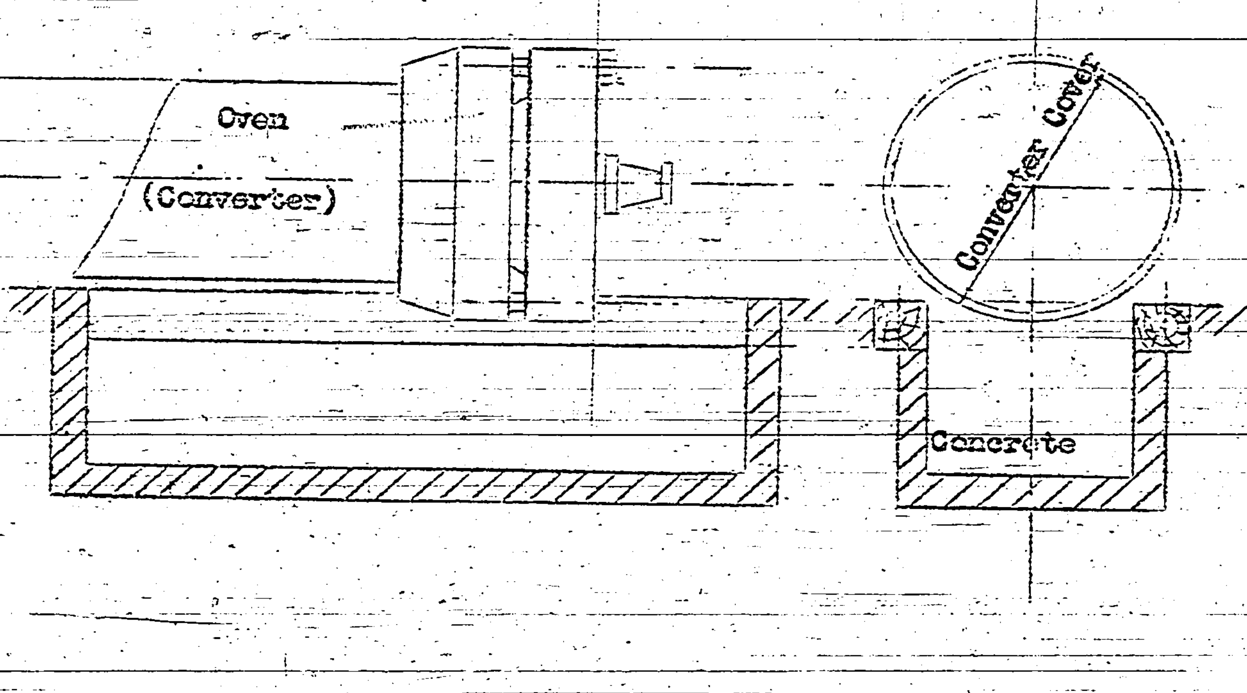

Oven
(Converter)
Converter Cover
Concrete

Fig. 7

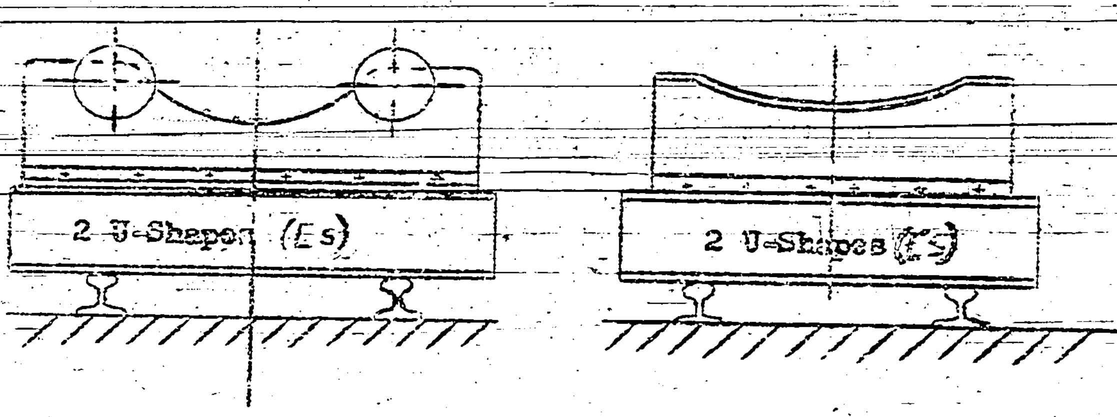

2 U-Shapes (Es)
2 U-Shapes (Es)

Fig. 8

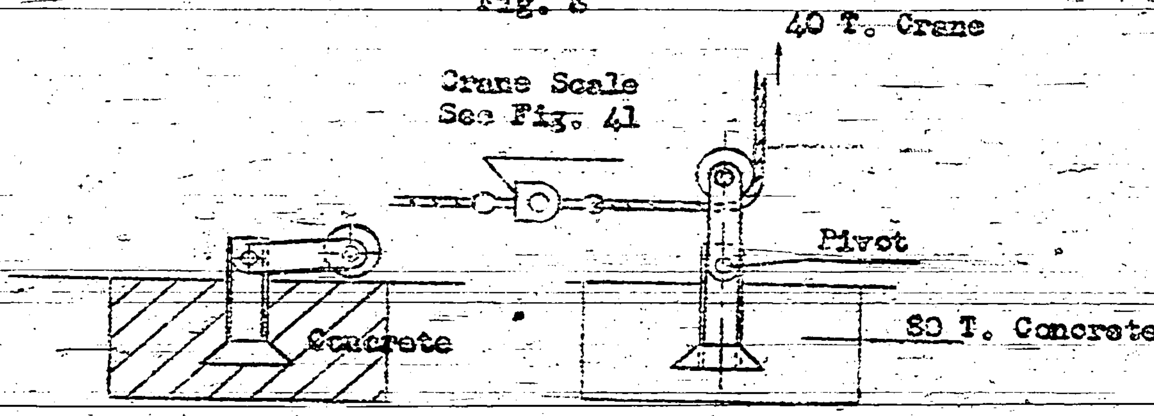

40 T. Crane
Crane Scale
See Fig. 41
Pivot
Concrete
80 T. Concrete

Fig. 9

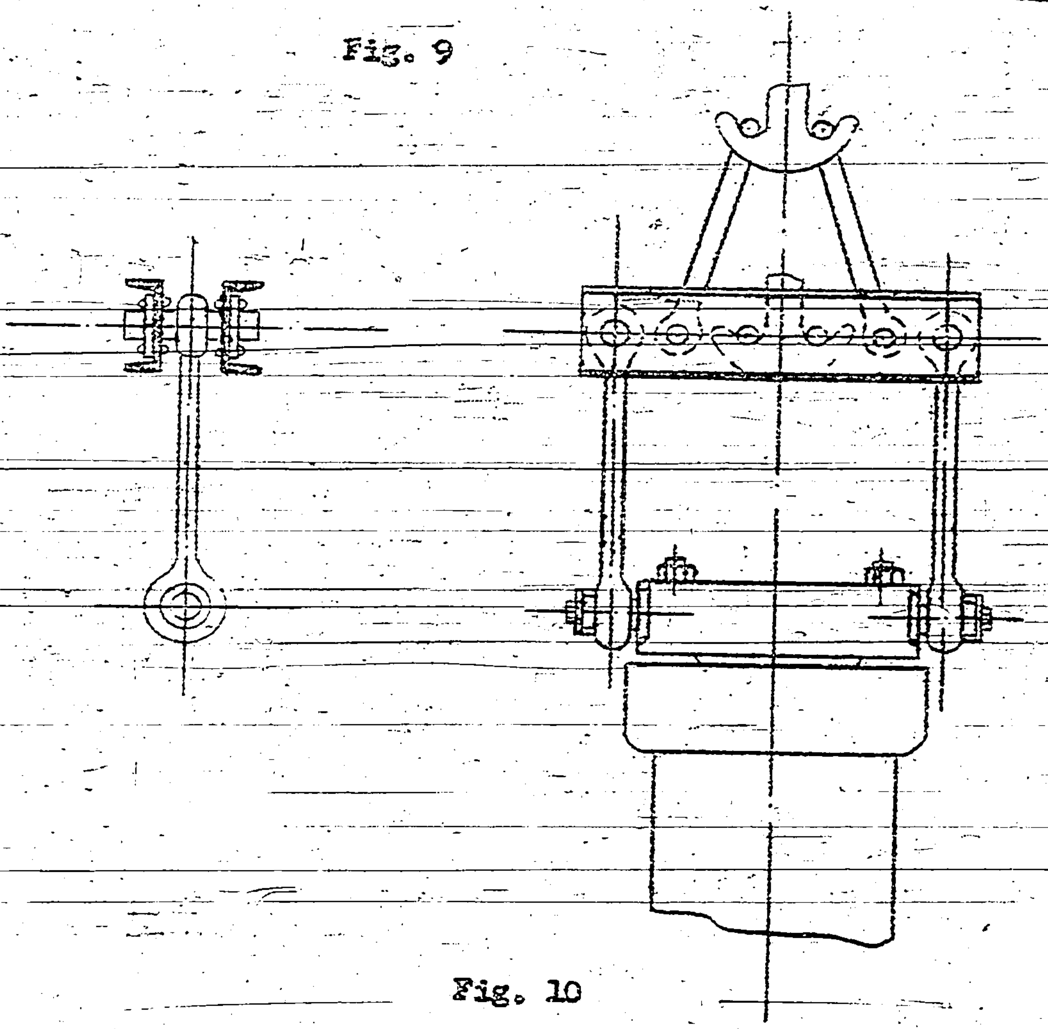
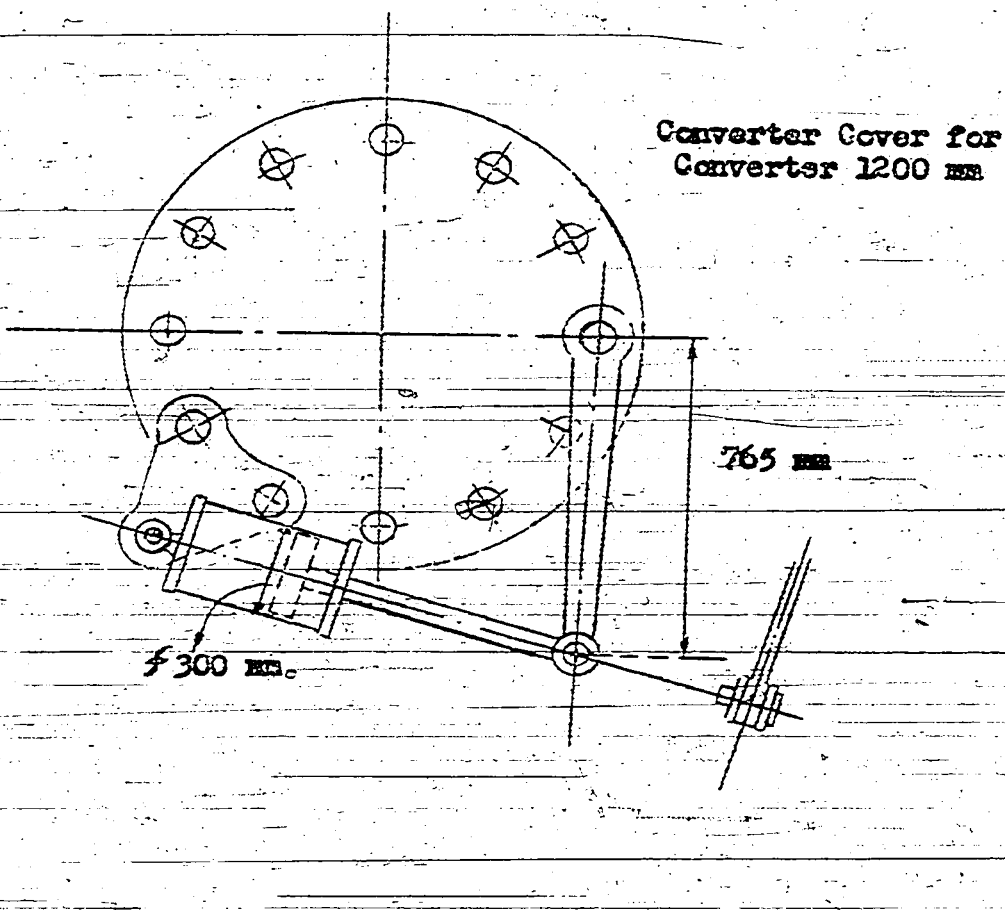


Fig. 10



Ag-1
SECTION "A-B"

B. INSULATING AND FIRE PROOF MATERIALS (Dipl. Ing. Hermann)

To determine the kind and thickness of insulating materials for pipe lines and vessels their inside temperature and service for which the pipe lines or vessels are to be used must be known.

I. G. chooses such materials so that the insulation may be completed without heating the pipes during the insulating operation or without having to wait until after they have first been placed in operation. The use of shells (molded lengths) for the rigid insulating materials is general.

I. G. uses:

1) For Temperatures from -100°C to 0°C

Corkstone shells (molded shredded cork), a cork insulation with asphalt or bituminous binder and with the smallest possible porosity. This latter property is necessary because otherwise water vapor would condense in the pores, freeze and burst the shell.

2) For Temperatures from 0°C to + 100°C

Corkstone shell, a cork insulation with clay binder. The cork in some brands is expanded, that is, it is sharply elongated at 120 to 130°C. The density is decreased considerably by this operation. This material is used for general purposes, but it is not used on lines containing inflammable substances. I. G. has developed a foam insulation material for replacing this cork material, which is suitable for temperatures from -80°C to +80°C. This foam insulating material absorbs no water. The composition is not known, it is some form of synthetic resin foam substance. Distributor; Lüneburger Isoliermittel und Chem. Fabrik A.G., Lüneburg.

3) For Temperatures from 100°C to 230°C

Diamag shell. This shell is made of $MgCO_3$ + Kieselguhr + asbestos fibers (white). The proportion of these materials is approximately 60 : 25 : 15 parts by weight. $MgCO_3$ disintegrates at 180°C and gives off CO_2 in the process. Therefore $MgCO_3$ is to be used only to this temperature. By the admixture of Kieselguhr the maximum use-temperature is raised, but when this insulating material is used for higher temperatures it disintegrates and its resistance is very much reduced. (?)

4) For Temperatures to 400-450°C.

Glass-or cinder wool. These materials are applied by the stuffing method. For larger lines flat iron rings which

(over)

a diameter equal to the outer diameter of the glass or cinder wool layer are laid around the lines (see figure 12). These rings are spaced at intervals of about 50 cm. The rings are connected with each other by light, 6 mm. diameter, round iron rods. About this basket a fine-mesh wire screen is drawn. A slit is left open at the top, through which the insulating material may be inserted into the space around the pipe. The open slit is closed with wire screen after the filling. Then the cinder or glass wool layer is covered with a 10 - 20 mm thick layer of a mixture consisting approximately of 9 parts Kieselguhr and 1 part cement, which is applied in a moist or plastic condition and then hardens.

Another insulating cement is composed of Al_2O_3 - Kieselguhr - asbestos (white) and a binder material. Composition: approximately 6 : 90 : 4 parts by weight. After the application of the paste the insulation is covered with tar-free pasteboard. The pasteboard is fastened with galvanised wire. This cover of pasteboard is used only for those pipe lines where there is no danger of fire. In case the lines are subject to the danger of fire, they are covered with 3/4 to 1 mm thick hot-galvanised sheet iron. The sheets are fastened by means of metal bands.

In answer to a pertinent question by the Anic gentlemen: Flintkote (Shell product) might be used instead of insulating cement and pasteboard; in the opinion of I.G., Flintkote, however, is expensive compared with bituminous pasteboard.

<u>Cinder Wool</u> is cheaper than glass wool.

<u>Glass Wool</u> however has higher insulating properties.

Common qualities of cinder wool are used up to 450°C.
The cinder wool should contain not more than 10% by weight of melting slugs. Common qualities of glass wool are used up to 400°C; fiber thickness, if possible, below 0.025 mm diameter. However better qualities of glass wool can be manufactured, which may be used up to 500°C.

Cinder wool and glass wool start to soften and become sticky at the maximum temperatures given herein and are therefore unsuited for higher temperatures.

The entrance of water into the insulating layer should be prevented because glass and cinder wool decompose in water at 100°C. In the aforementioned stuffing method the density after the stuffing of the cinder or glass wool should be carefully watched. Good insulating properties will be maintained if the following densities are adhered to:

Glass Wool: 180 kg/m³: coefficient of thermal conductivity (Theoretical)
(at 100°C = 0.044
(at 200°C = 0.063

Cinder Wool: 220-260 kg/m³ : coefficient of thermal conductivity (theoretical)

(at 100°C = 0.043
(at 200°C = 0.056
(at 300°C = 0.074

All coefficients of thermal conductivity - kcal/m/h/°C

5) For Temperatures over 450°C to 800°C, DIATOMITE

(For special purposes to 600°C Asbestos Cement)

a) Diatomite - common, soft burned Kieselguhr (that is, made at a low temperature).

Strength: 6-8 kg/cm², coefficient of thermal conductivity = 0.08 at 100°C and 1 atm., density 450 kg/m³.

Application: Apparatuses and lines.

b) Diatomite - hard, hard burnt Kieselguhr (that is, made at a high temperature).

Strength: 25 kg/cm², coefficient of thermal conductivity = 0.12 at 100°C and 1 atm., density 650 kg/m³.

Application: Heat exchanger tube bundle insulation.

The coefficient of thermal conductivity of Diatomites a) and b) at 200-300 atm. and 300°C (oil drenched) = 0.4 - 0.8 kcal/m/h/°C

c) Asbestos Cement is used for special purposes, converter insulations, etc.

The coefficient of thermal expansion = 0.4 - 0.8 (these values are based on asbestos cement samples which were taken from a converter after it had been in operation for a lengthy period).

It is recommended that blue asbestos be used for this purpose because the mechanical resistance of this fiber at 600°C is approximately twice as great as the white asbestos.

Common White Asbestos is to be used only for temperatures up to 300°C (water of crystallisation is given off at higher temperatures).

6) For Temperatures from 800°C to 1100°C

Insulating brick of porous clay.

At 100°C, coefficient of thermal conductivity = 0.26

Strength: 40 kg/cm², density 700 kg/m³, 25-30% Al_2O_3; the rest Si_2O_3.

(over)

7) For Temperatures to 1200°C

Medium quality fire brick, 30 to 40% Al_2O_3.

8) For Temperatures to 1250°C

Better quality fire brick, 40 to 44% Al_2O_3.

9) For Temperatures to 1600°C

Sillimanite, burnt from Indian cyanite: 66% Al_2O_3
33% Si_2O_3

10) Mats or Mattresses: Of blue asbestos material.

a) Filled with cinder wool or glass wool for temperatures to 450°C. For thick mattresses only glass wool filling should be used because of its lower weight.

No water: If necessary, should be protected against rain.

Application: Fittings, circulating-gas fans (glass wool 60 mm thick), preheater, etc.

b) With blue asbestos filling, suitable for temperatures up to 600°C. Blue asbestos is acid proof, but should not be used for lye (in that case "Serpentin" white asbestos (to 500°C) should be used. I. G. has set up a table for the economically correct insulation layer thickness which is based on steam costs at Leuna, 5 or 10 years amortisation of the insulation, and the installation wages, etc. (see sketch II and figure 13). (Sketch II not available). I. G. has worked out this table (sketch II) for the insulation layer thicknesses of lines for various purposes (oil, steam, gas, etc.)

According to the inside temperature of the lines, the diameter of the lines and the local conditions, the outer temperature of the insulation is assumed to be from 3 to 20°C above the surrounding temperature.

Flanges of steam lines from 100 to 350°C are insulated. (high pressure steam lines at Leuna 16 atm).

Flanges of steam condensate lines are not protected.

In winter simple mattresses of cinder wool may be applied to avoid too great losses on unprotected flanges of oil and steam lines.

Flanges of high pressure lines at high temperatures in the stalls are not insulated. Bolts must always remain cold so that at temperature fluctuations no loosening of the flange faces may occur.)

The steel beam supports of vessels in the stalls in Leuna are insulated to diminish the danger of buckling in a fire. As shown in sketch (figure 14) the steel shapes are covered with common brick and a single close-mesh wire screen. These bricks are covered with a layer of alumina cement with gravel and sand of an approximate thickness of 15 to 20 mm.

The supports of high pressure vessels are covered with a layer of Diatomite of about 65 mm and cement of 15 to 20 mm (see figure 15).

These insulations for beams and supports are a satisfactory protection against fire in the stalls of about one-half hour's duration. (The emergency purge of a stall lasts about 20 minutes).

Literature:

1) "Wärme & Kälteverluste isolierter Rohrleitungen und Wände" (Heat and cold losses thru insulated pipe lines and walls).
Verlag Springer 1928 (many tables).
Published by insulation firm in Ludwigshafen. (Grünzweig und Hartmann G.m.b.H.)

2) "Richtlinien zur Bemessung von Wärme and Kälteveschutzanlagen." (Standards for measuring of heat and cold protection equipment).
V.D.I. Verlag 1931.

3) "Regeln für die Prüfung von Wärme und Kälteveschutzanlagen" (Rules for the testing of heat and cold protection equipment).
V.D.I. Verlag 1930.

Composition and Supplying Firms:

a) Insulating cement is supplied by "Asbest & Kieselguhrwerke", Uelzen.

Per cent by weight:
- 4% asbestos
- 90% Kieselguhr
- 6% alumina

} + binder material

b) Diamag shells supplied by "Lüneburger Isoliermittel und Chemische Fabrik A. G.", Lüneburg.

Per cent by weight:
- 15% asbestos
- 60% $MgCO_3$
- 25% Kieselguhr

Asbestos cement inner insulation for high pressure converter jackets (see also TD Memo 1151 or T-44). (TD Memo 1151 not available).

Mixing of asbestos and cement with a rake (see figure 16).

The sections of the perforated cover sheets of "St.oc" have a length of about 80 cm. Each section has 3 provisional or temporary stiffener rings (see figure 17).

The non-rigid sheet is guided by the wooden wedges so that it may be accurately centered during the tamping. The stiffener rings (see figure 18) are used to support the scaffolding for the worker who guides the tamper.

In winter the space below the converters is heated. The converter proper here acts as a chimney (the temperature of the insulation must not drop below 0°C as long as it is not fully dry.)

Fig. 16

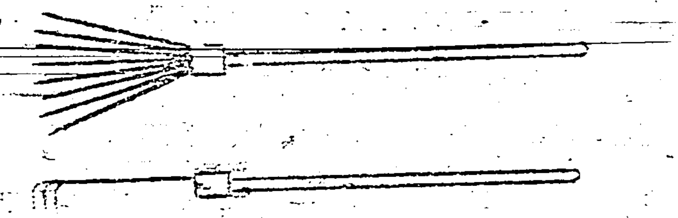


Fig. 17

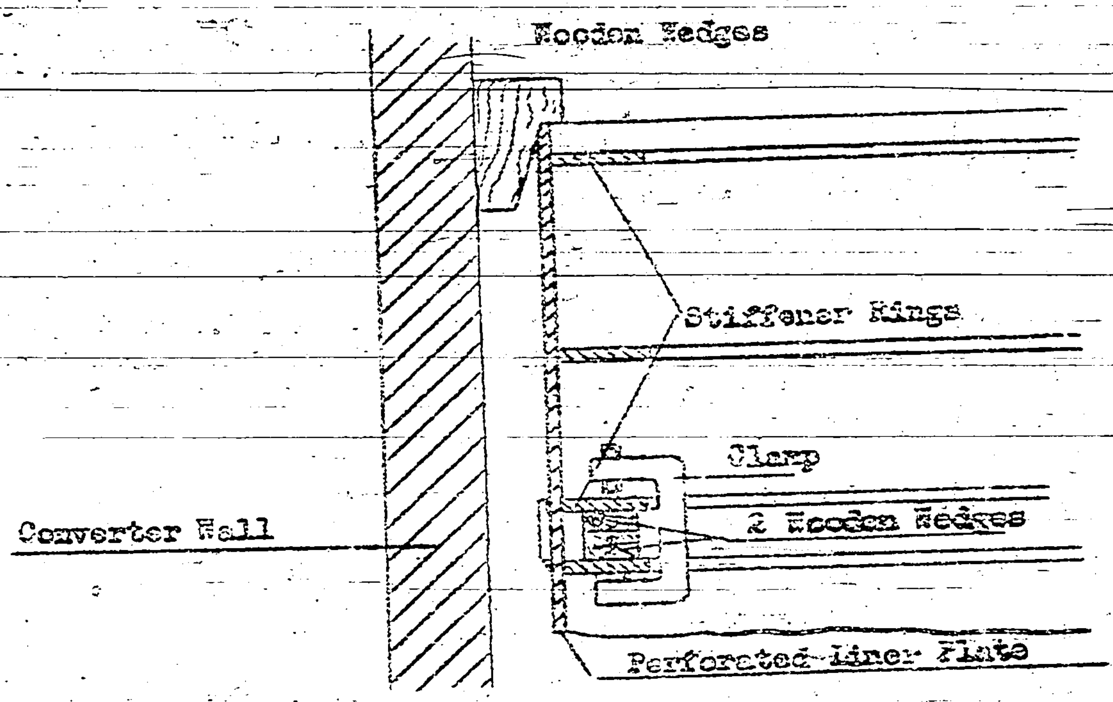
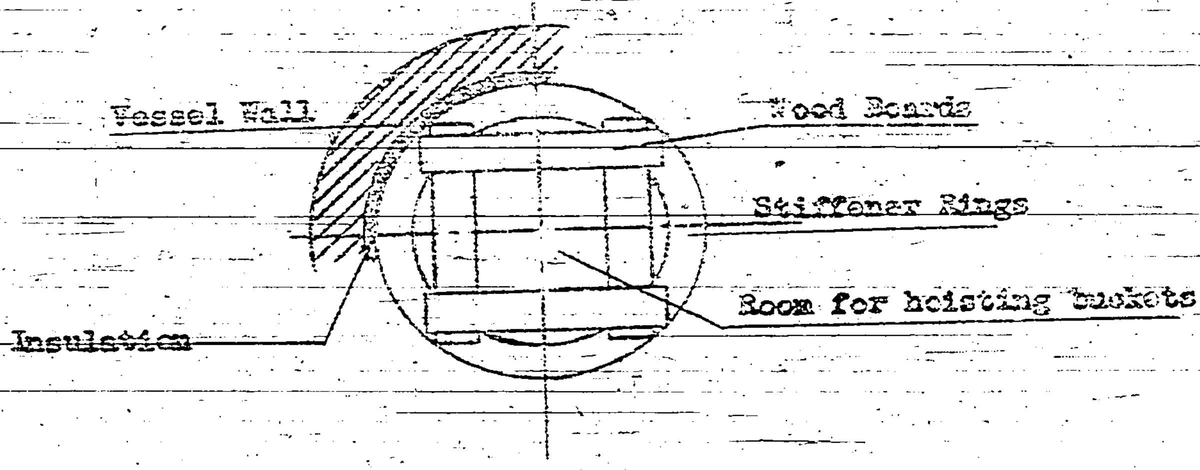


Fig. 18



Ba

FIG. 11.

Arrangement of ✓

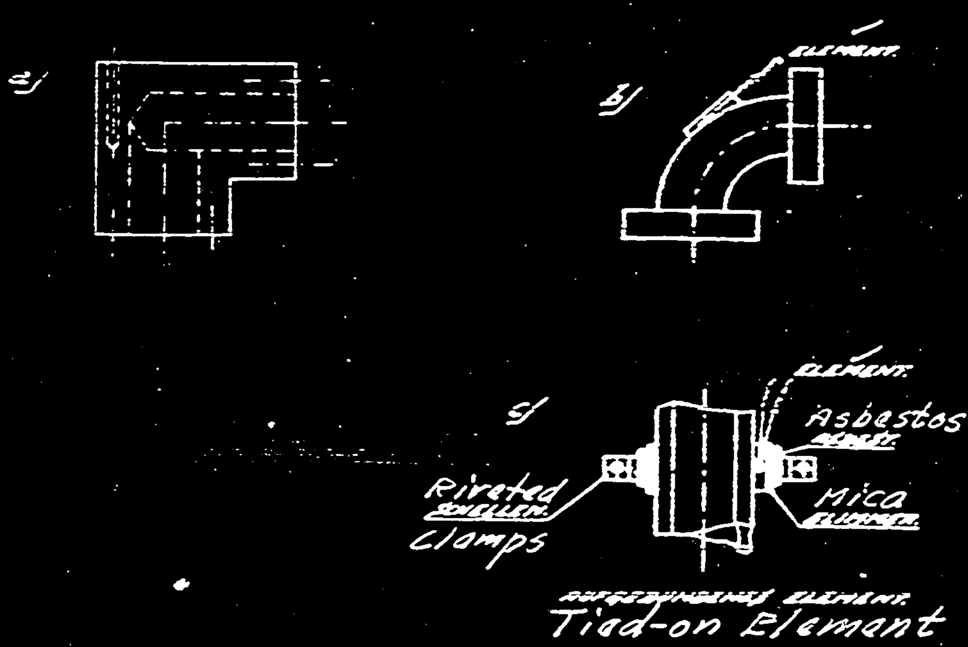
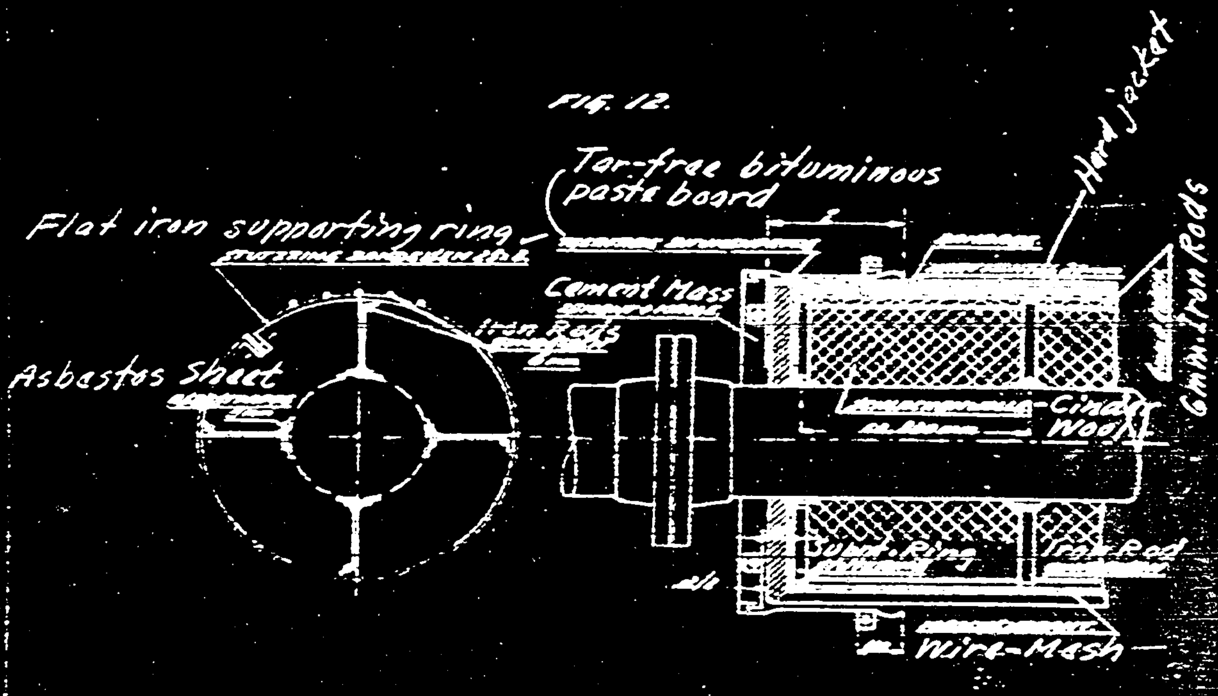


FIG. 12.



C. OPERATIONS CONTROL AND NON ELECTRICAL MEASURING INSTRUMENTS

(Dipl. Ing. Schwab and Dr. Hörold)

All liquid quantities necessary for the calculation of operations balances are measured by means of "Eckardt" displacement meters.

For the measuring of gas quantities pressure gauges (orifice disks) are exclusively used (see figure 19).

For orifice disk measurements the following must be known:

1) The pressure difference between the 2 sides of the orifice disk (recording)

2) The absolute pressure head ahead of the orifice disk (recording)

3) The density of the gases.

4) The temperature of the gases (recording)

The measuring disk must be located a distance of at least 10 x the diameter of the pipe line behind a change in direction of the line.

For measuring of the mean density a suction vessel may be connected with which a mean sample of the gas may be obtained over a lengthy period of time.

The vessel is filled with water (expelling all air). Then the water outlet cock is opened far enough so that the vessel may be emptied in about one week.

The gas outlet cock is opened somewhat so that fresh gas may be sucked in at all times.

The gas sample is weighed, giving the mean density of the gas. (See also "Der - Chemie - Ingenieur" Eucken & Jakob. Volume II, Part 2 - Orifice Disk Measurements. Leipzig. Akademische Verlagsgesellschaft.

Density Indicating Recorder

Measuring the density of the circulating gas at the inlet and outlet, based on air.

A detailed description of this instrument is given in "Der Chemie - Ingenieur", Volume II (Physical control of operations), Part 4.

The measurement in per cent H_2 is relative.

The difference in density of the inlet and outlet gases should not exceed a certain limit. The inlet gas is contaminated in the stall by CH-substances, CO_2, etc., which changes the density of the gases. When the difference becomes too great the operating procedure of the stall must be changed (corrected or adjusted).

(over)

Manometers in Leuna are provided with 2 shutoff valves behind each other and also with an orifice disc with an opening of 0.5 mm dia. When the manometer spring becomes loose only a little gas or liquid can leak out before the valves are closed. Quick closing valves for manometer connections are not available at Leuna.

Test of Heat Exchangers

Before putting into service the heat exchangers are put under pressure and tested for strength.

a) Tightness of the tube bundles.

All connecting flanges of the completed heat exchangers are provided with blind flanges and the space around the tubes subjected to a pressure of 10 to 15 and if necessary up to 25 atms. (maximum permissible pressure difference) air or nitrogen).

If the tube bundle is not tight the gas will enter the tubes and the cover spaces and this gas is caught in a water bottle (gas bubbles). This test is very sensitive. If one blows into the tube space and then attaches a water bottle air bubbles will immediately appear.

b) Tightness of the stuffing box.

The stuffing box is tested in a vertical position. For this purpose the tube is closed with a rubber stopper and the stuffing box chamber filled with water. At 10 to 15 atms. (air or N_2) air bubbles will appear if the box is not tight.

c) Covers

The conical seals are tested for tightness at 200 atm. N_2 pressure. For this purpose the vessels are immersed in water in a horizontal position. It is particularly important that even during the loading to the foregoing pressure the pressure difference between the inside and outside of the tubes shall not exceed 15 atms. Therefore, 2 lines with 2 manometers must be attached, of which one is connected to the space around the tube and the other to the space within the tubes.

d) Resistance of Heat Exchangers

In this test 150 m^3/h compressed air or N_2 is blown through. The resistance in the spaces outside and inside of the tubes should not exceed 50 mm W. G.

Normally the resistance in both cases, with a heat exchanger of 300 tubes, is about 20 to 30 mm W. G. The heat exchanger in this test is open at the upper end. The connection is made according to figure 21.

To obtain a comparable measurement the same measuring distances and the same connecting pieces must be used. If the resistance exceeds the 50 mm the heat exchanger must be flushed out with oil to remove all dirt or foreign material. If necessary the circulating oil should be heated somewhat. If this does not reduce the resistance the heat exchanger must be dismantled in the shop.

In a suitable place manometer connections are provided (for example, the cooler platform), for measuring the resistance in the various apparatuses. These resistance measurements give information on the condition of converters and heat exchangers (see also chapter P, figure 81).

The first resistance measurement is made when a stall is heated up and H_2 is circulated. The second measurement is made when the stall is in operation. This measurement is made once every 14 days by means of a precision manometer with mirror reading.

In all measurements the sum of the measured resistance of all apparatuses must equal the total resistance of the stall (measured in the circulating gas lines).

In important apparatuses (liquid phase preheater and heat exchanger) differential pressure indicating recorders could be used so that the resistance could be read off at all times.

(over)

D. ELECTRICAL MEASURING INSTRUMENTS (DR. HÖROLD)

Thermo Element Connections to Converters. A pressure tube 16/28 mm diameter containing 4 thermo-elements (8 wires) is extended through the cover of the converter. On top of the cover a T is connected. At the top of this T is an asbestos plate with wire clamps (Figure 23). The thermo-elements are here inclosed and are connected in the liquid phase stalls with the connecting wires to the pressure-tight head (Figure 24).

The pressure tight head forms the shutoff of the high pressure protecting tube. In case this high pressure tube is ground or worn through, a manometer connected to the flange ring of the T indicates the pressure (figure 23).

The pressure tight heads are fastened to the stall wall. From here all thermo-element connections lead to switch boxes at varying heights in the stalls. The connections of iron and Constentan are made of Fe-wire of 1 mm thickness and Con. wire of 0.7 mm (flexible connections).

From the switch boxes 1.0 mm Fe and 2.0 mm Constantan wires lead to the main distribution boxes. In the older installations these boxes also contain the equalising resistances.

Primary Scheme

The milli-volt (mv) meter (see figure 25) must have a resistance of about 1,000 to 1,500 ohms. If, for example, the instrument originally has a resistance of 1100 ohms and we take out 80 ohms for the outside lines, the meter must then have a total resistance of 1,020 ohms. If the lines together have a resistance of 45 ohms, then the equalising or added resistance should be about 35 ohms.

The mv meters are very sensitive against heating, change of resistances and mechanical restraints (point bearings, etc.) The simple scheme (Figure 25), changes to Figure 26 in case copper connections to the central panel are chosen.

Rudimentary Scheme

The 2 Con-Fe elements and the 2 Cu-Con elements must have the same temperature and are therefore arranged in the same box (figure 26). The switching is so chosen (through keys) that the number of cold-solder points (thermostats) equals the number of mv meters.

The wiring diagram for measuring installations without compensation is shown in figure 27.

The Cold Solder Point (thermostat) (figure 28) must always have a constant temperature in order to be able to measure the temperatures of the stalls in an absolute sense.

Formerly the boxes with the cold solder points were held at constant temperature with hot water (by means of steam). A thermograph was arranged for

Fig. 19

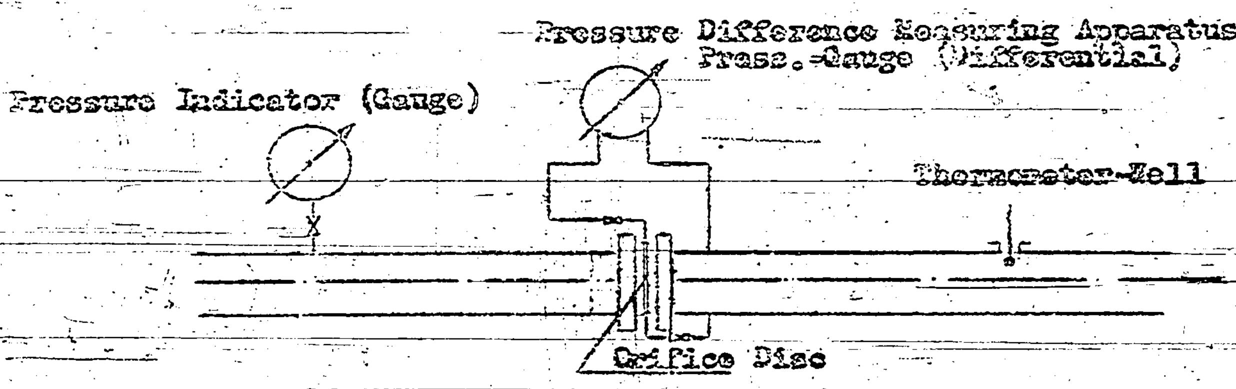

Pressure Difference Measuring Apparatus
Press.-Gauge (Differential)
Pressure Indicator (Gauge)
Thermometer-Well
Orifice Disc

Fig. 20

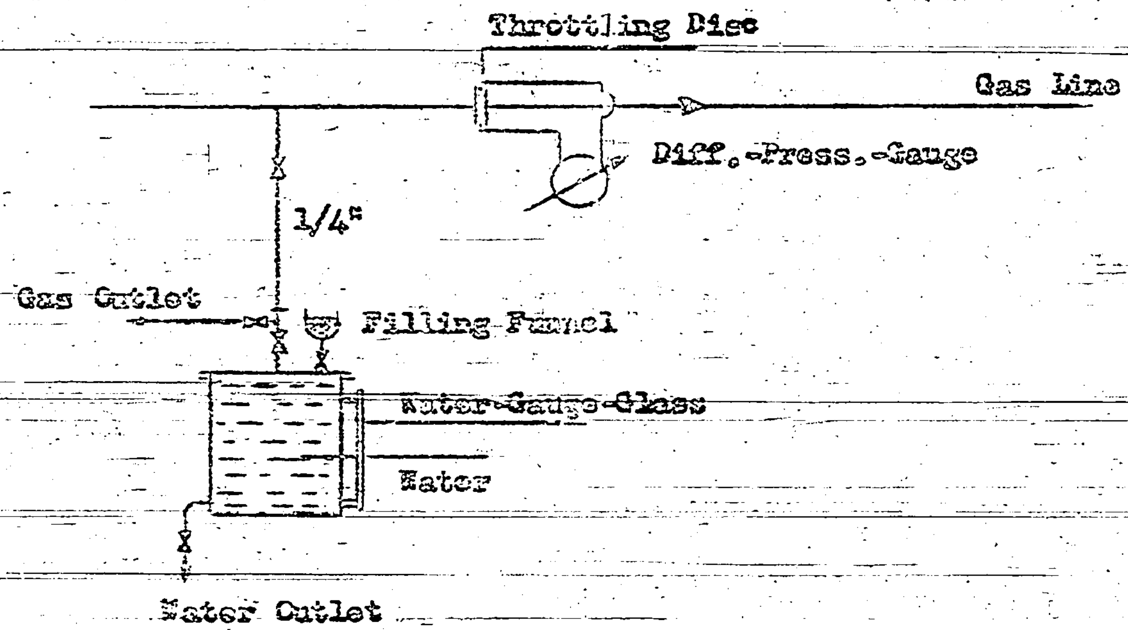

Throttling Disc
Gas Line
Diff.-Press.-Gauge
1/4"
Gas Outlet
Filling-Funnel
Water-Gauge-Glass
Water
Water Outlet

Fig. 21

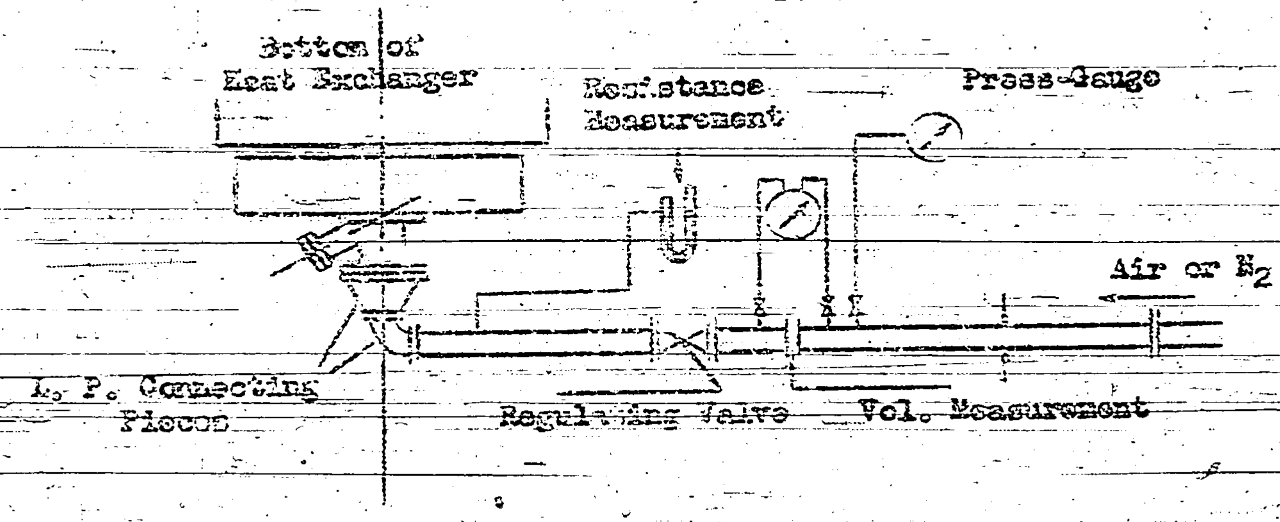
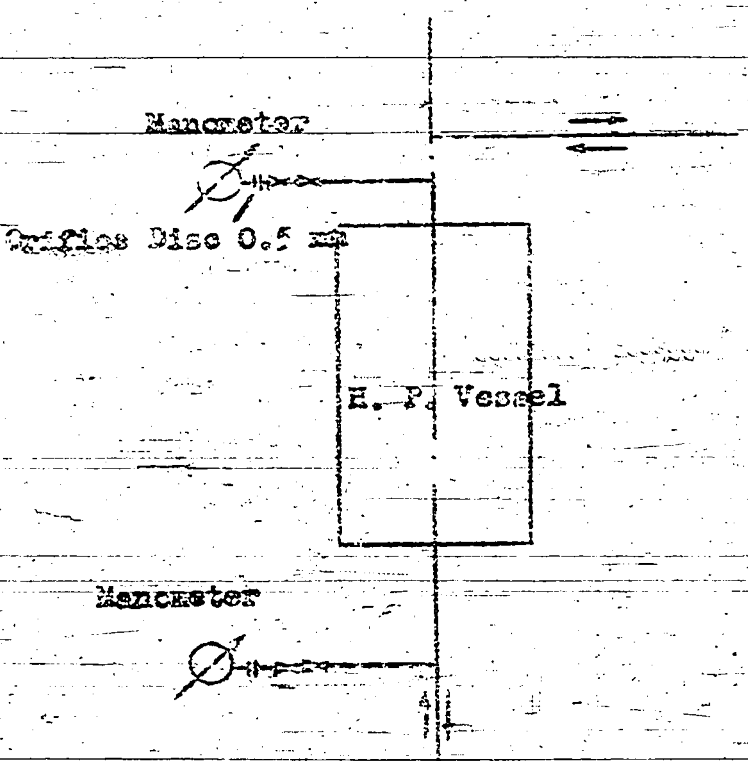

Bottom of
Heat Exchanger
Resistance
Measurement
Press-Gauge
Air or N_2
L. P. Connecting
Pieces
Regulating Valve
Vol. Measurement

Fig. 22


Manometer
Orifice Disc 0.5 mm
H. P. Vessel
Manometer

temperature control. The newest installations have an electrically heated copper block in which the thermo-elements are enclosed. This block is insulated against loss of heat.

The temperature of the block is measured and recorded by means of a resistance thermometer. The resistance is a platinum wire which is wound on a spool. The value of the resistance (basis for temperature) is measured by means of a Wheatstone bridge.

The mercury thermometer, which is provided with 2 contacts, automatically switches the heating current on or off and holds the solder points at 30 to 40°C (see figure 29).

Scheme With Compensation (Compensating Wire Connections)

I. G. has eliminated the sensitivity and possible wrong reading of the mv meters by a connection which eliminates the effect of the mv meters and in which the tension of the thermo-elements is measured by means of stable instruments in a foreign circuit (compensation). The wiring diagram is shown in figure 30.

Classification of Thermo-Element Materials According to Temperature Range.

Fe and Con. for temperatures to 600°C.

Fe at 700°C undergoes a change of structure and the measurement at this temperature is no longer accurate. The thermo-elements for this temperature range are soldered with silver.

Cr-Ni-B and Thermominus from 600°C to 1,100 - 1,200°C.

Thermominus is a nickel alloy.

The materials are welded together at the solder point.

Platinum and Rhodium to a Temperature of 1,400°C.

For identification of these materials, I. G. uses the following insulation colors.

Fe	-	red
Con	-	blue
Cr-Ni	-	green
Thermominus	-	yellow

Thermo Elements, Gas Heated Preheater: Platinum and Rhodium elements are little used. These elements are used only for the combustion chamber temperature of the gas preheaters. They are built in according to figure 31. For other preheater elements (first pass of the preheater) Cr-Ni-B or Thermominus elements are used (figure 32).

Other preheater passes (lower temperature) have Fe-Con. elements. All materials for the thermo-elements must be tested for resistance (see resistance table below).

Thermo elements are gauged in an electrical oven (figure 33).

Table of Specific Resistances of Thermo-Element Wires:

Material	Thickness in mm	Resistance in ohms/m
Constantan	1.0	0.64
Constantan	2.0	0.16
Iron	1.0	0.21
Cr-Ni-E	1.0	1.40
Cr-Ni-E	2.0	0.35
Thermominus	1.0	0.25

Fig. 23

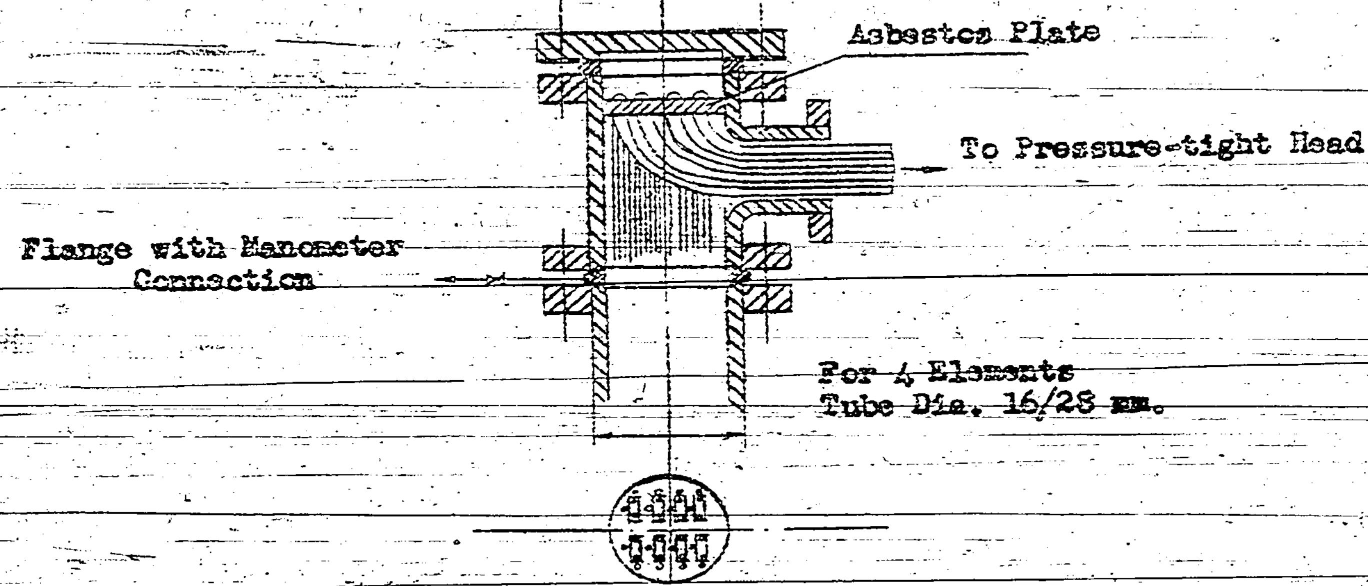
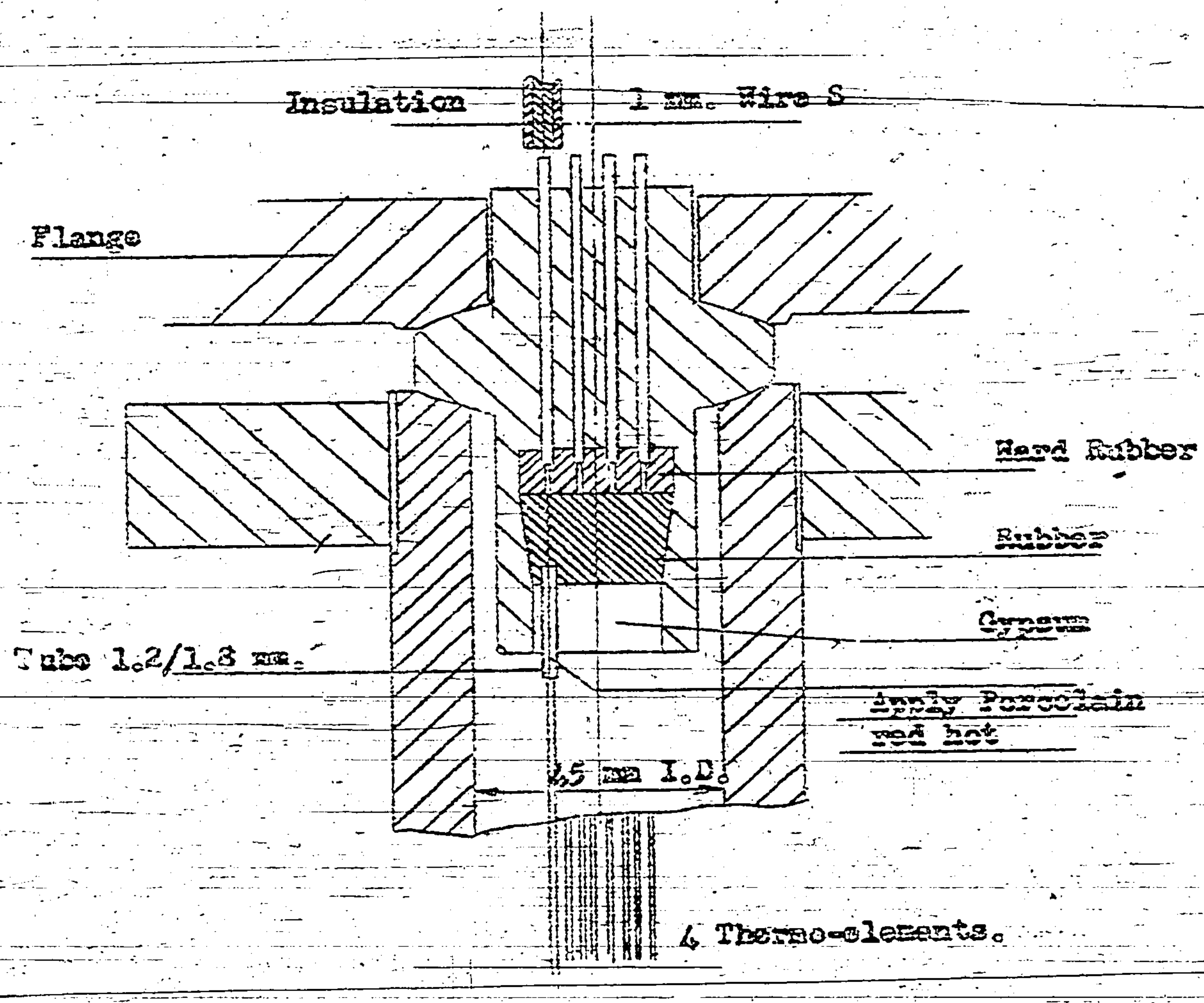

Asbestos Plate
To Pressure-tight Head
Flange with Manometer Connection
For 4 Elements
Tube Dia. 16/28 mm.

Fig. 24


Insulation
1 mm. Wire S
Flange
Hard Rubber
Rubber
Gypsum
Tube 1.2/1.8 mm.
Apply Porcelain red hot
4.5 mm I.D.
4 Thermo-elements.

Db

Fig. 25

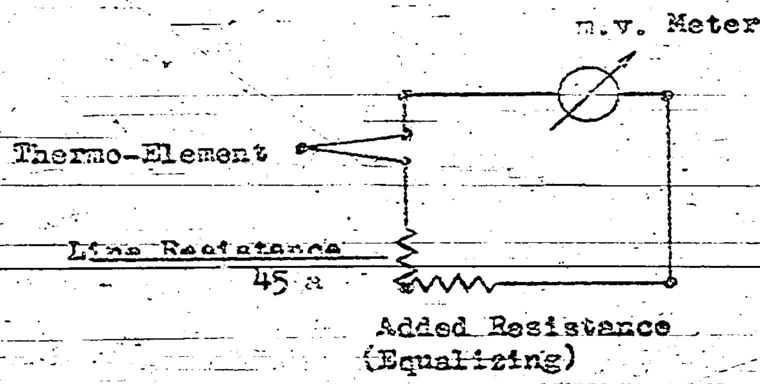


Fig. 26

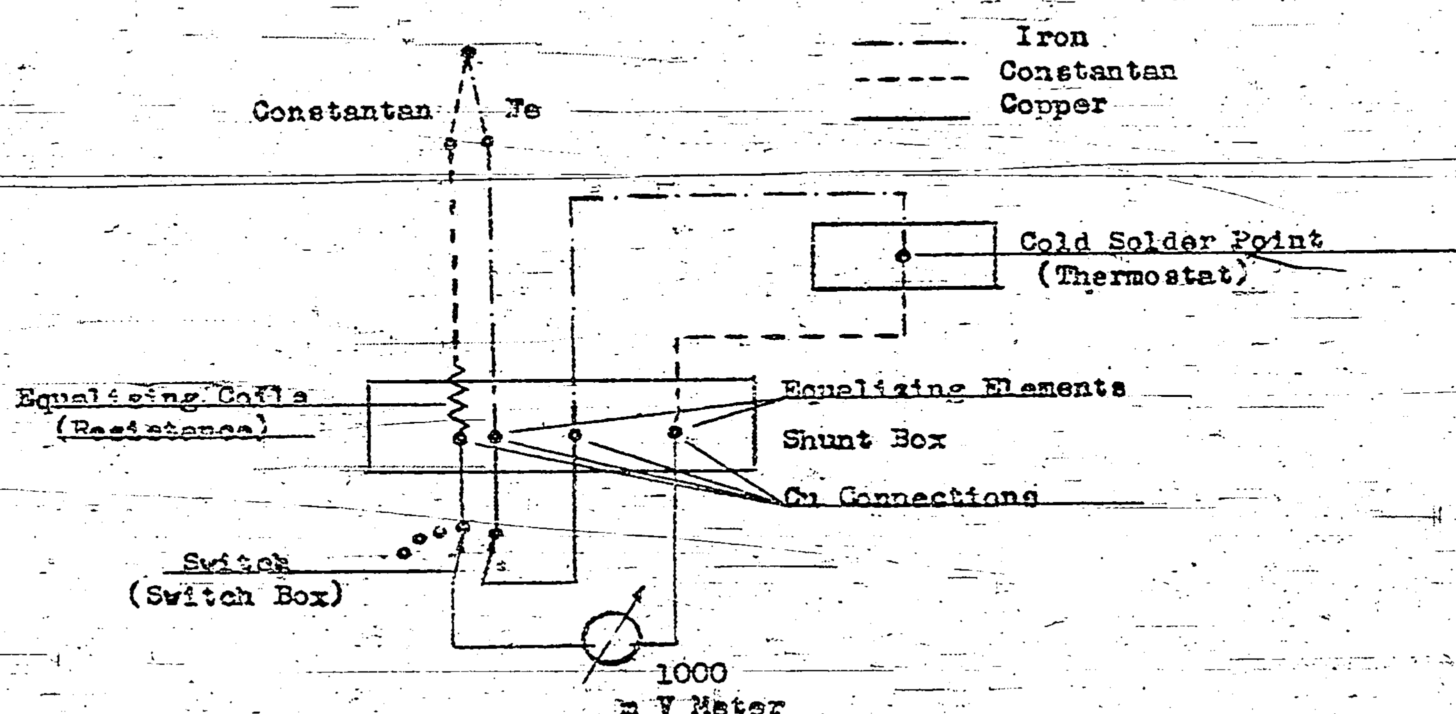


Fig. 21

Wiring Diagram

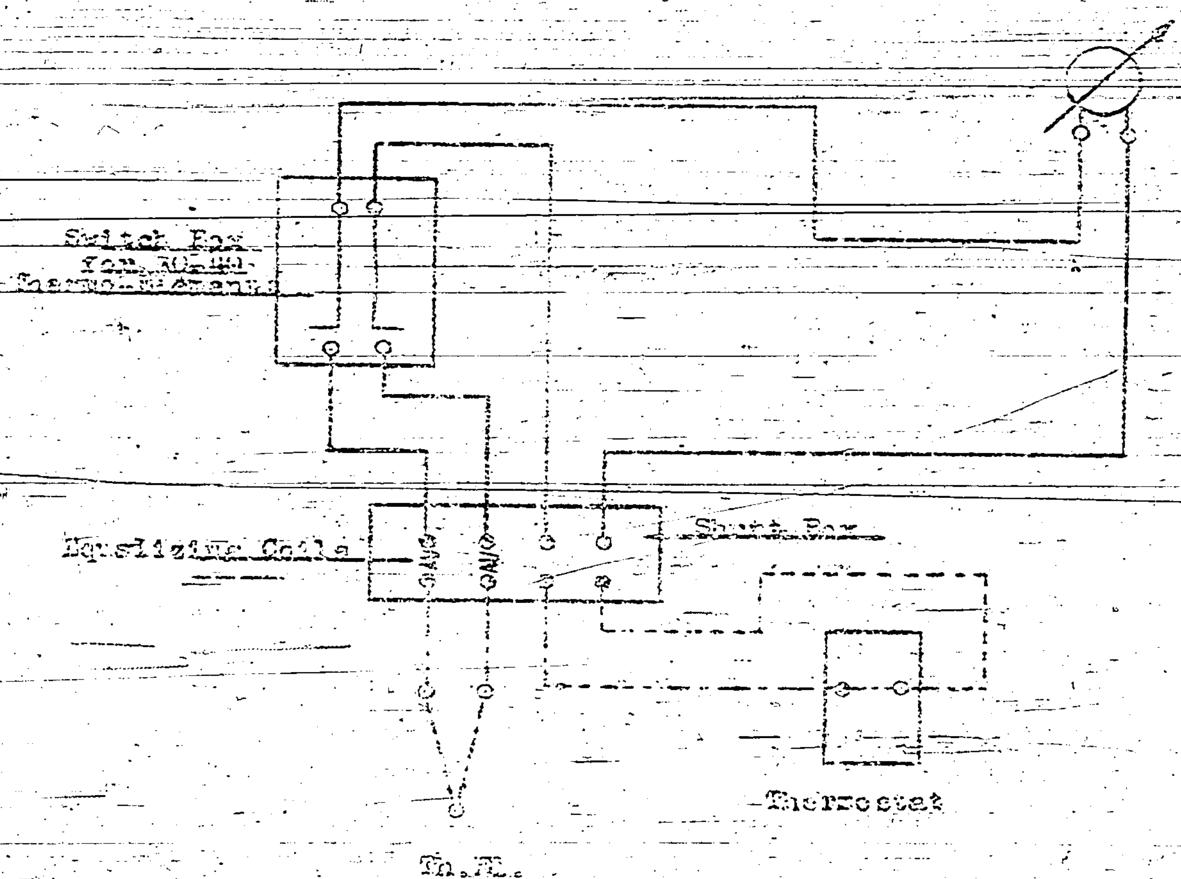


Fig. 28

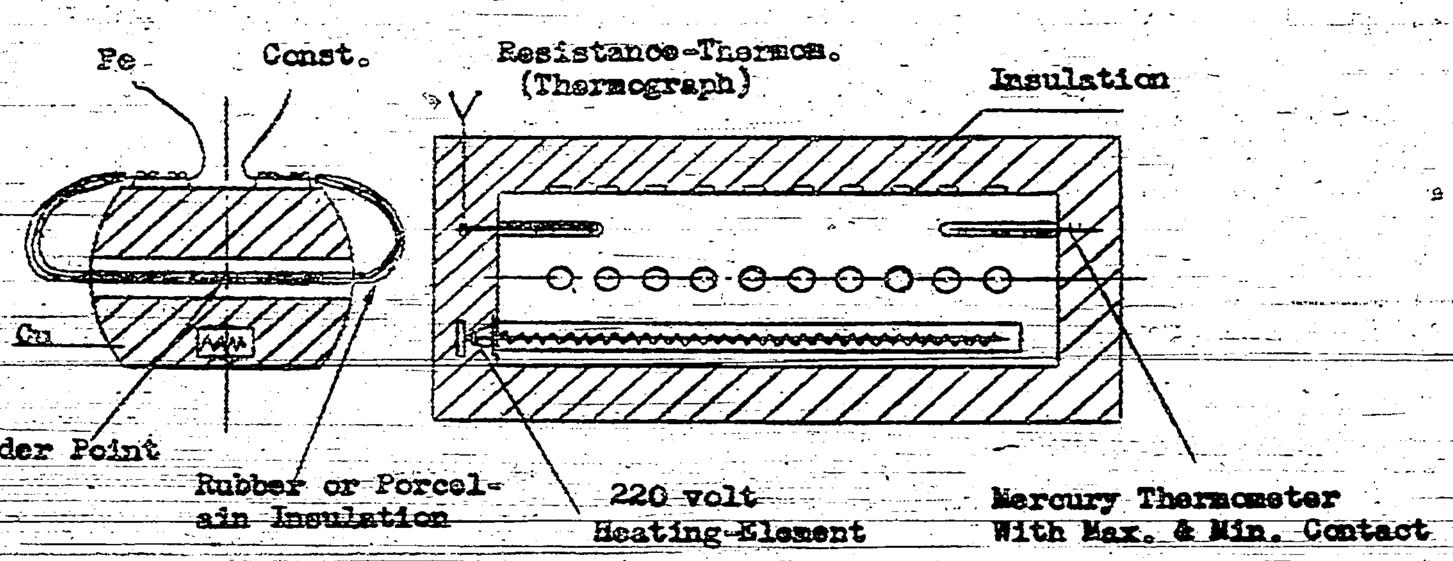


Fig. 29

Wiring Diagram for Heating-Current, Cold-Solder Point

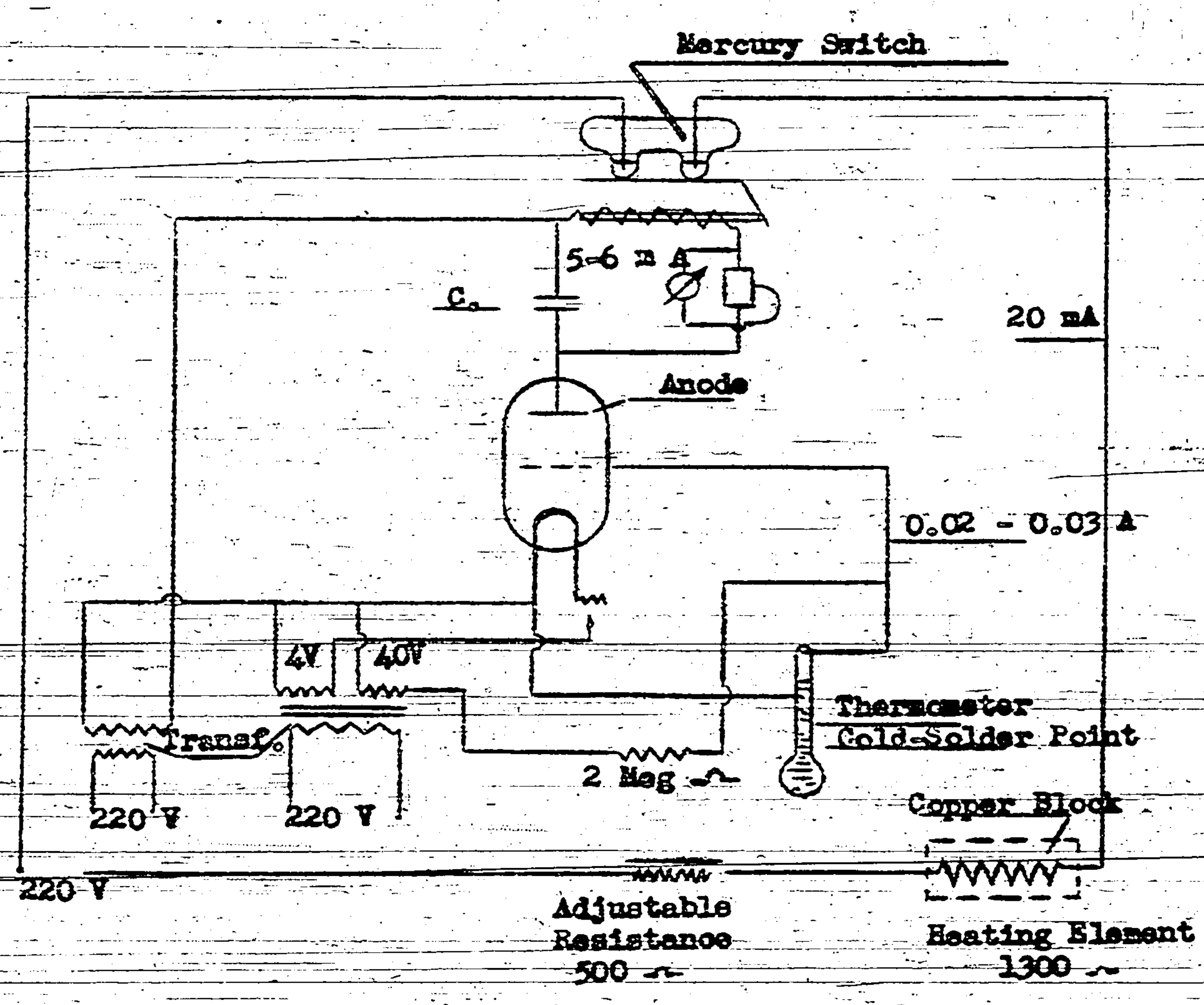


Fig. 30

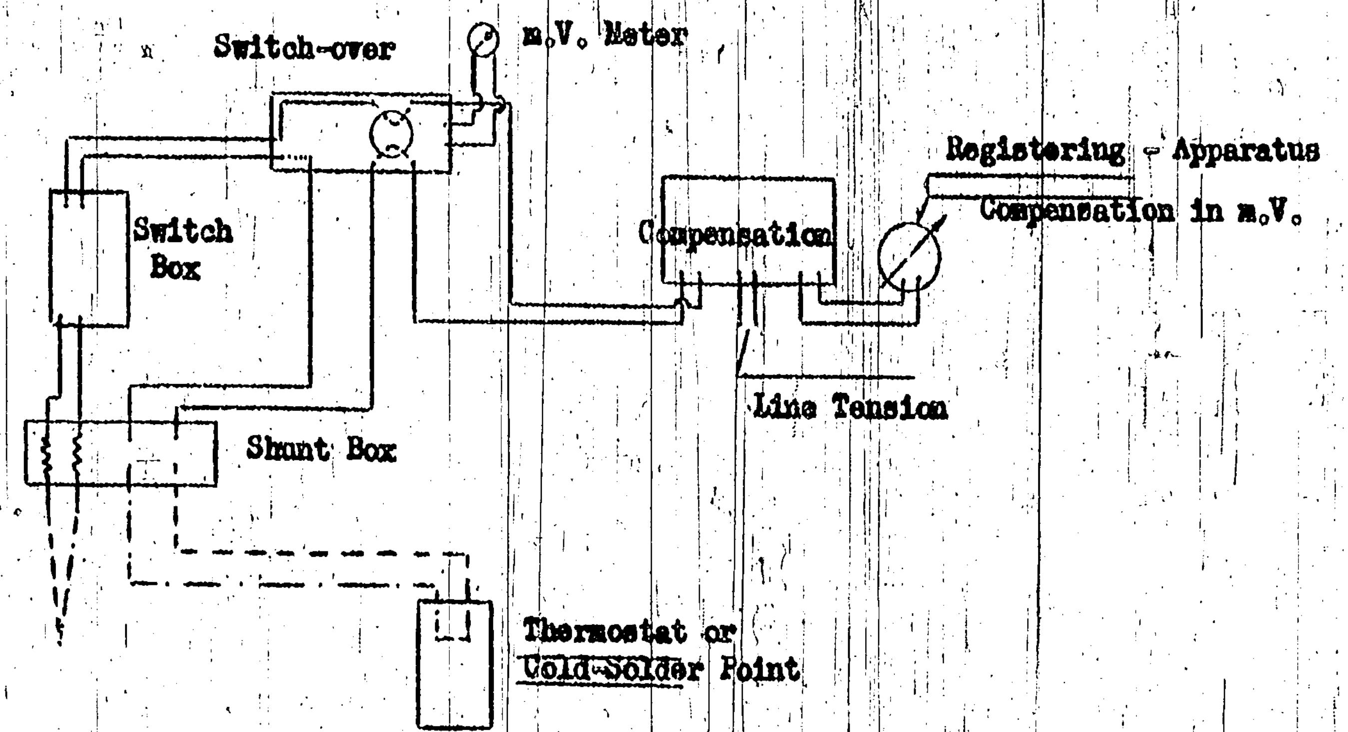

Switch-over
m.V. Meter
Switch Box
Shunt Box
Compensation
Registering - Apparatus
Compensation in m.V.
Line Tension
Thermostat or Cold-Solder Point

Fig. 31

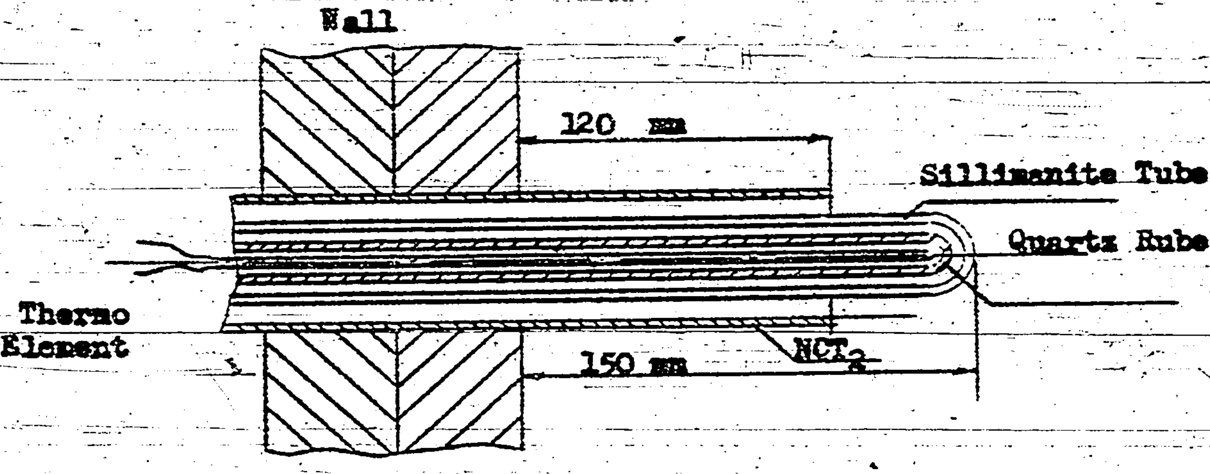


Fig. 32

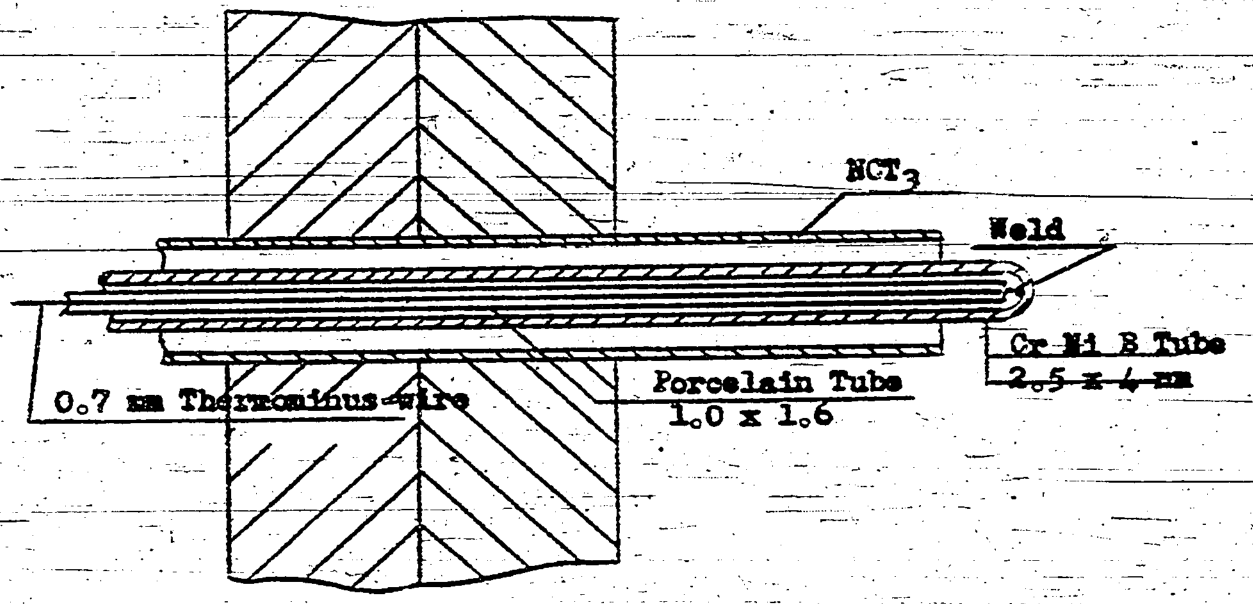
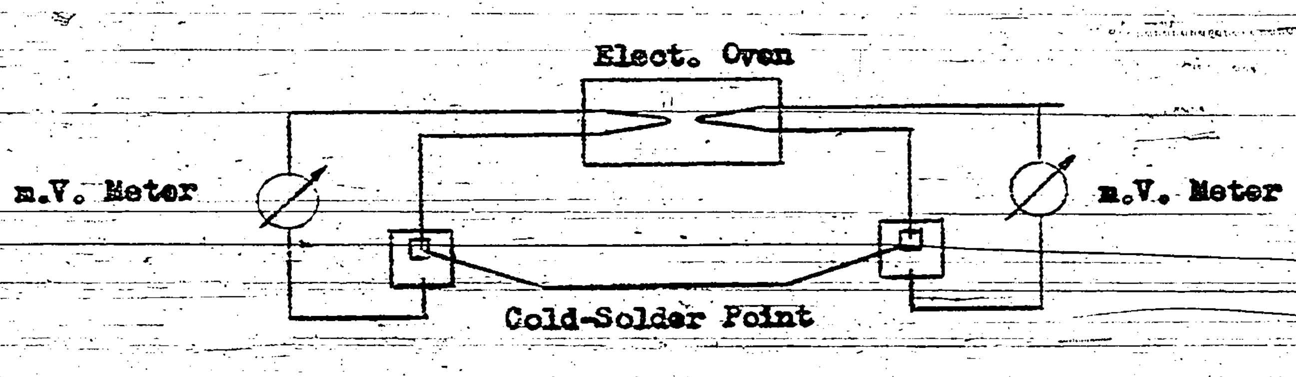


Fig. 33



E. WORK SHOPS

Machine Tools, etc. The machine tools were reviewed and particular attention paid to the horizontal boring and milling machines, of which several sizes and forms were available. Most of these machines are provided with a leading spindle for thread cutting on tubes, hairpin bends, special fittings, etc. A number of these machines were also at hand with horizontal bench adjustments, rotary tables and rotary columns. The most practical construction of these machines seems to be if the main spindle rotated in a vertical plane. These machines were generally less stable than machines with non-adjustable spindle.

The thread cutting on high pressure tubes is done on a long, common lathe with collar plates. Threads and conical flange surfaces are cut in 1 setup. In these operations the tube is held between the center points. The sealing surfaces of the flanges are not ground.

V2A is worked on a lathe with Co, Va or W steels (no hard metal).

Balancing Machine. All high velocity rotating runners are tested by I. G. on a "Lawacek" machine. Such runners are rotors on electric motors and circulating gas fans.

Buttwelding Machine. The large electrical buttwelding machine (resistance welding) has a capacity of 25,000 mm^2 surface. The machine works fully automatic and for welding of a high pressure tube of 120 mm inside diameter about 4 minutes is required. The tubes of N5 and N8 are heat treated after welding. Because N8 is an air hardening material it must be inserted into heated sand or ash immediately after welding. The sand must always be dry. In this way a slow cooling is effected and hardening is avoided. Afterwards the weld is locally annealed in a short electrical oven.

After annealing for 3 to 6 hours at 750°C and slow cooling the material is suitable for transportation and further working. (large tubes must be annealed for 6 hours). The preheater tubes, which must be provided with fins, are first turned after welding and then the fins are welded on to about 50 cm from the upper end (the side where a fixed arch is attached). Then the double arches and the additional fins (in two pieces) are welded on. When all welding is completed the entire hairpin coils are annealed for 6 hours at 750°C. All welds on high pressure tubes must be examined for tears and slag enclosures. The 4 methods are:

1. Welds are polished and etched with Fry's solution for N8 (nitric acid)
2. The welds are ground with a plain file and examined with a microscope.
3. Magnetic examination by means of colored oil in which magnetic ferrocarbonyl is suspended in colloidal form. With tears the color changes.
4. X-ray method.

(over)

The arc-welding of fins on preheater tubes is done with a covered "Griesheim" electrode of 3 mm diameter, brand Ke-Mo. The welding of these fins to the tubes is done on a simple machine where the tube rotates at the welding speed. A 120 mm inside diameter tube rotates with a speed of 0.5 rpm. The welding itself is done by hand (see figure 34). After the welding the tubes are annealed. In general N5 and N8 materials are welded with an ECT$_3$ electrode.

Vapor Phase Converter. The inner lining of N5 catalyst tubes of the vapor phase converters consists of V_2A plates. A plate of 0.5 - 2 mm is bent and welded together to a diameter slightly smaller than the tube diameter. The length of the plates is such that their diameter is about 5 mm smaller than the inner diameter of the N5 tube. The welding is properly done autogenously with V_2A or electrically.

The tube plate is now pushed into the N5 cylinder.

The second liner of V_2A plate is now welded and inserted, etc. To obtain a neat fitting of the plate it is peened at the ends.

The plate should have a thickness of 1.5 to 2 mm. Plates of 0.5 mm can also be used, but are often weak and the peening is not satisfactory.

The welding seams of a plate must be tight so that no oil can seep behind the liner. Because of different coefficients of thermal expansion of N5 and V_2A, Leuna at present galvanises (spray) the converter liners of N5 with fairly good results. Figure 36 shows 2 possibilities for fastening this liner plate to the supporting rings of the diaphragms.

Cold Gas Tubes for Vapor Phase Converters. The elliptical part of the tubes is made by "Mannesmann", (seamless). The cylindrical tubes are connected by means of transformation pieces (see figure 37). The latter are conically turned and forged to the correct form and then welded on autogenously.

Remarks on the Building of Heat Exchangers (see also Memo 1151)(not available)

In demounting the upper exchanger covers special methods must be used. After the stuffing box of the tube extending through the cover has been removed, the cover is pulled off. For this purpose the work shop crane is used. One crane rope serves for holding the cover so that the tube fastened to the bundle cone (funnel neck) will not be damaged, the second serves for pulling off the cover (see figure 38). The other cover is pulled off together with the tube bundle. It is recommended not to pull the tube bundle out of the exchanger in the work shop in a too cold condition. If it is not possible to pull out the bundle immediately after the demounting of the heat exchanger out of the stall the heat exchanger must be heated up in the work shop (see figure 39).

The normal life duration of a bundle is 1 to 2 years. The pulling out is done in a horizontal position. The power required for this is up to 30 - 50 tons. Usually less power is required. A crane is necessary for this pulling out with a spring or hydraulic crane scale attached to the pulling rope (figure 41). Manufacturers of these crane scales are: (1st: Schäffer & Budenberg, Madgeburg; 2nd: Grefe, Düsseldorf).

If greater power is required for the pulling out of the tube bundle other means must be used; for example, a traverse and small screw winches.

Inserting the tube bundle into the shell is done by a crane (see figures 42 and 43). The necessary power required for this operation is approximately 3 to 4 tons. The tube bundle is always transported either in the testing tube or on a channel iron cradle. (see figure 47). For the first lifting out of the "Dornbank" (apparently tubes assembly bench) 4 ropes are required (figure 46). For transportation with a crane, a special hoisting fixture is used (see figure 44).

Insulation.

The difference in diameter between the inner diameter of the heat exchanger jacket and the outer diameter of the Diatomite insulation is about 5 mm. The insulation below the N5 pull rod is cinder wool (figure 45). In the insulation of the tube bundle with Diatomite bricks (about 35 cm long) a mortar is used consisting of ground Diatomite, some alumina (Al_2O_3) and water. The Diatomite bricks are held together by means of galvanised iron wire.

Testing Tube. A testing tube for the pressure test of the heat exchanger tube bundles has a wall thickness of 15 mm and is illustrated in figures 49 and 50. For the cutting of the threads (for the funnel) in the tube bottoms special centering rings are used as illustrated in figure 50. In this operation the testing tube turns in 2 or 3 collar plates.

Tube Bundle. The "Dornen" of the exchanger tubes is described in TD Memo 1161. (This memo does not seem to be available but "Dornen" seems to imply the assembly of the tubes into the manifold, in which the tube end is expanded in the cone-shaped manifold by means of a "Dorn", or plug, as used in expanding seamless tubes.) The elongation of the tube due to this operation is about 1.5 to 2 mm on both ends. The depth of the square threads in the tube holes of the bottoms is approximately 0.5 mm.

After the assembly("Dornen") the tube ends are milled even with the tube bottom or face of the manifold. A groove is turned to facilitate the welding, which is done in a vertical position. (figure 40) (welding with NCT_3.)

For pressing the covers on to the jackets of high pressure vessels in the shop, I. G. uses a hydraulic press of a maximum capacity of 1,500 tons. For a converter of 800 mm diameter an oil pressure of 80 to 100 atm. is applied to the press piston, which exerts a pressure of 400 to 500 tons on the cover.

The press is furnished by the "Kalker Maschinenfabrik" (figure 48). After the pressing the nuts are slightly drawn on the bolts. A pneumatic machine for tightening the bolts is used in the stalls. (see figure 10 preceding).

General Remarks. I. G. studies the possibility to replace the resistance welding method by a reliable autogenous or electric welding method for the high pressure pipe lines of alloy steel. No data is as yet available on these experiments.

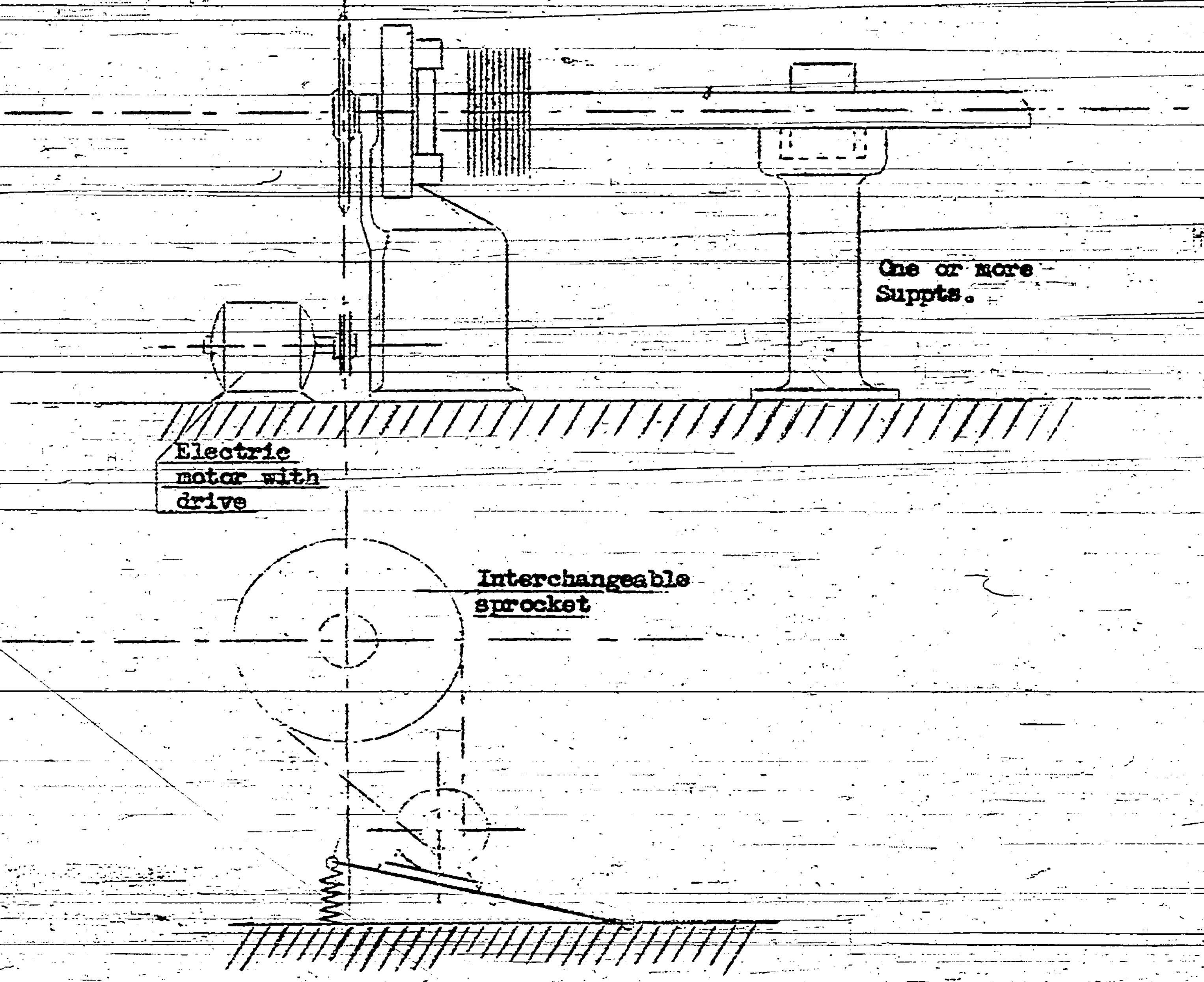
The galvanising of preheater tubes of N8 has as yet not been done in Leuna.

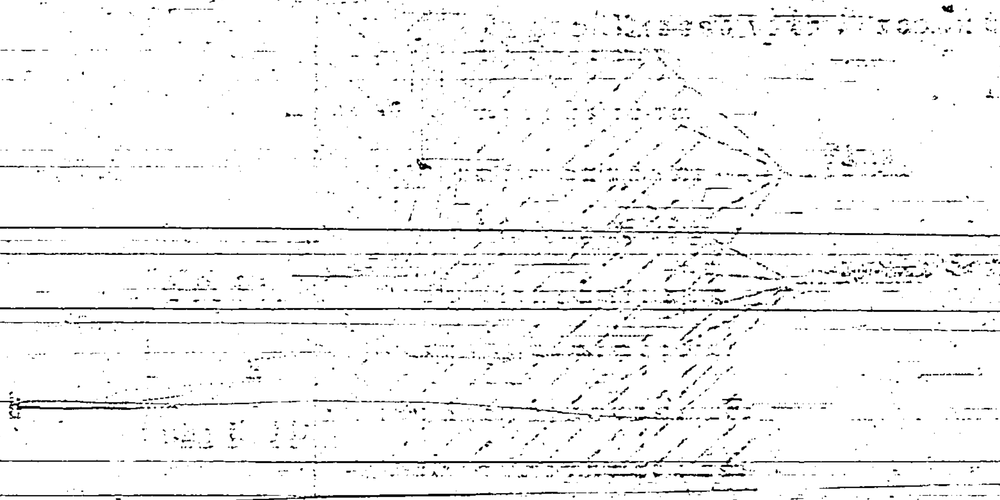
(over)

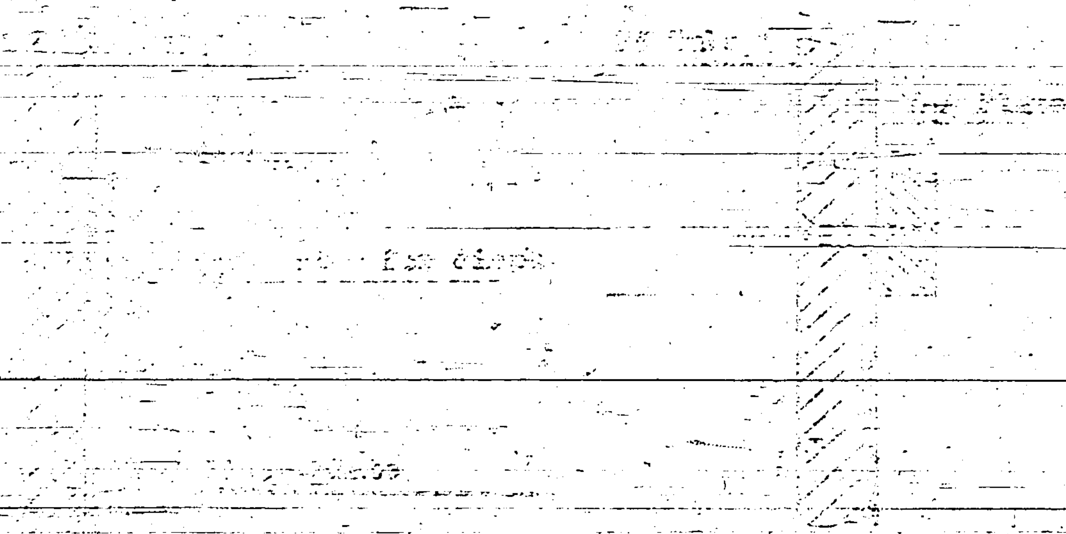
I. G. however is now making experiments along this line.

Thermometer connections for measuring the wall temperature on preheater tubes (figure 35) are made after the hairpin bends are completed. The bending of double tube coils (H_2 preheating) is done by the corresponding tube works which have ovens large enough for the annealing of the coils.

FIG. 34.


One or more
Suppts.
Electric
motor with
drive
Interchangeable
sprocket





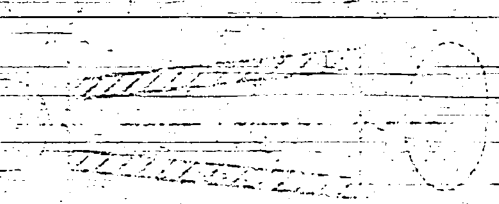


Fig. 38

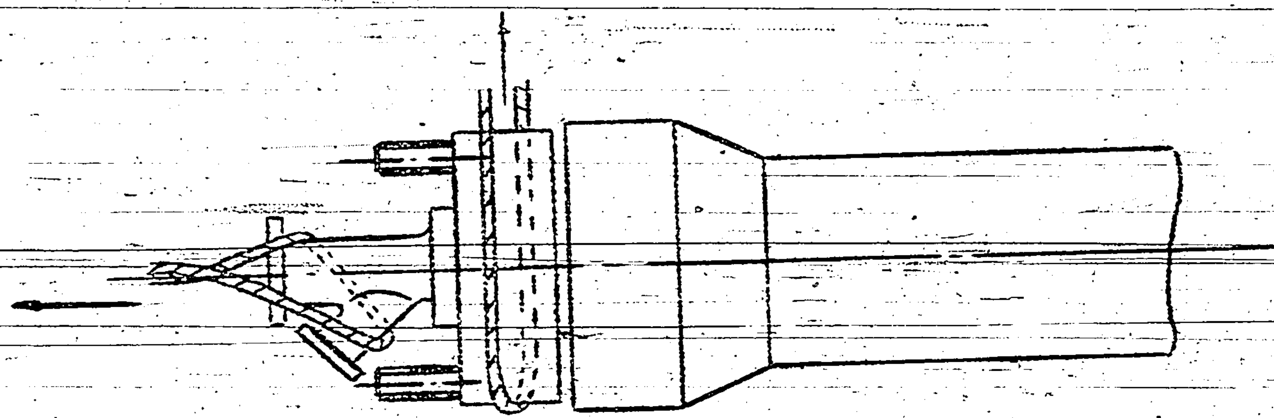


Fig. 39

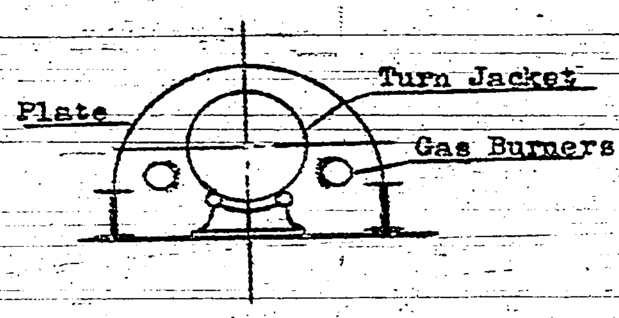


Fig. 40

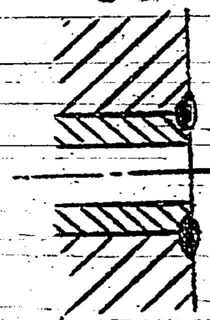


Fig. 41

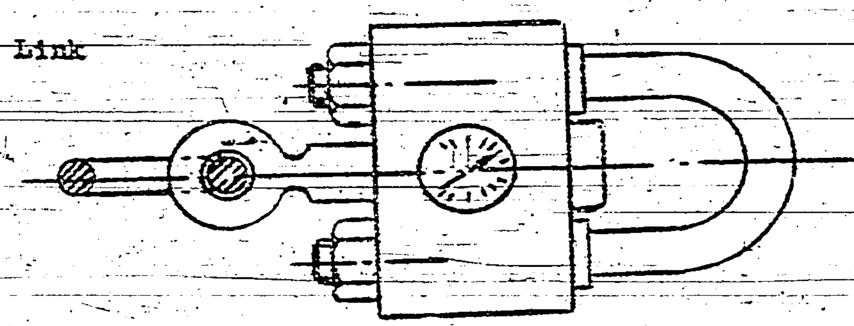


FIG. 42.

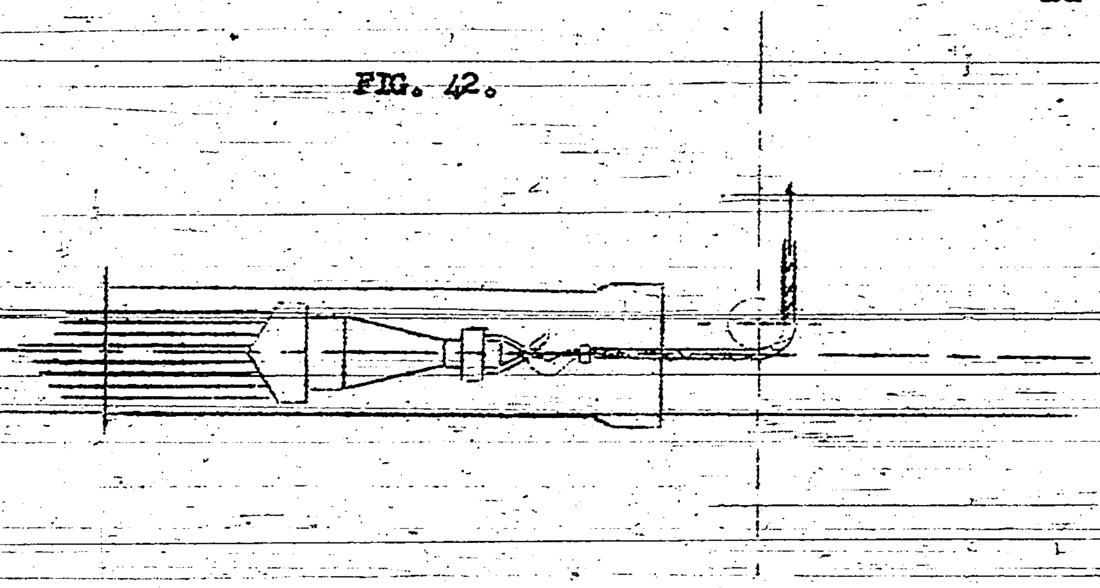
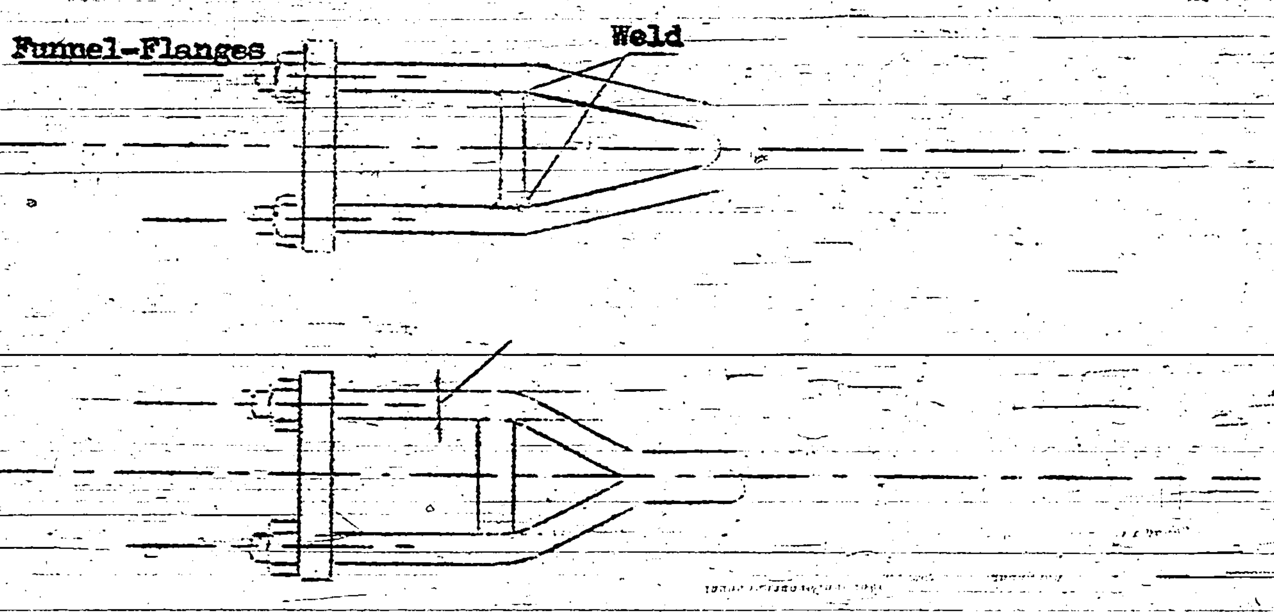
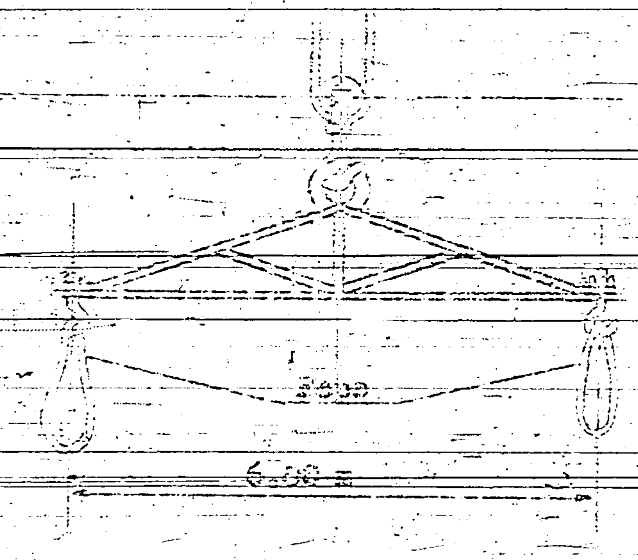


FIG. 43.





Section thru tube-bundle insulation

FIG. 45

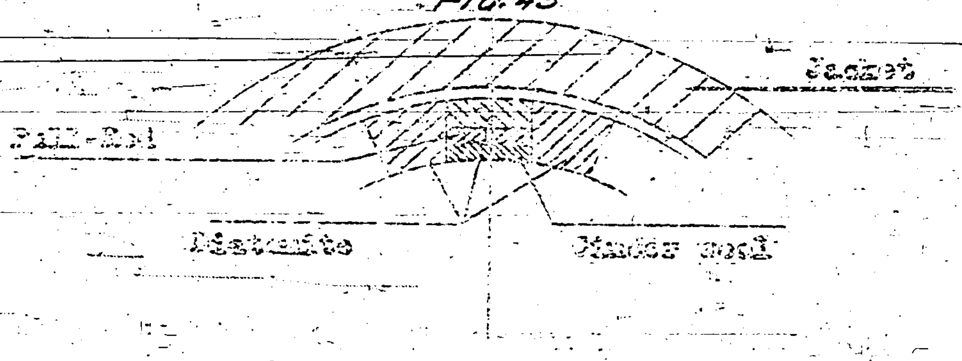


Fig. 46

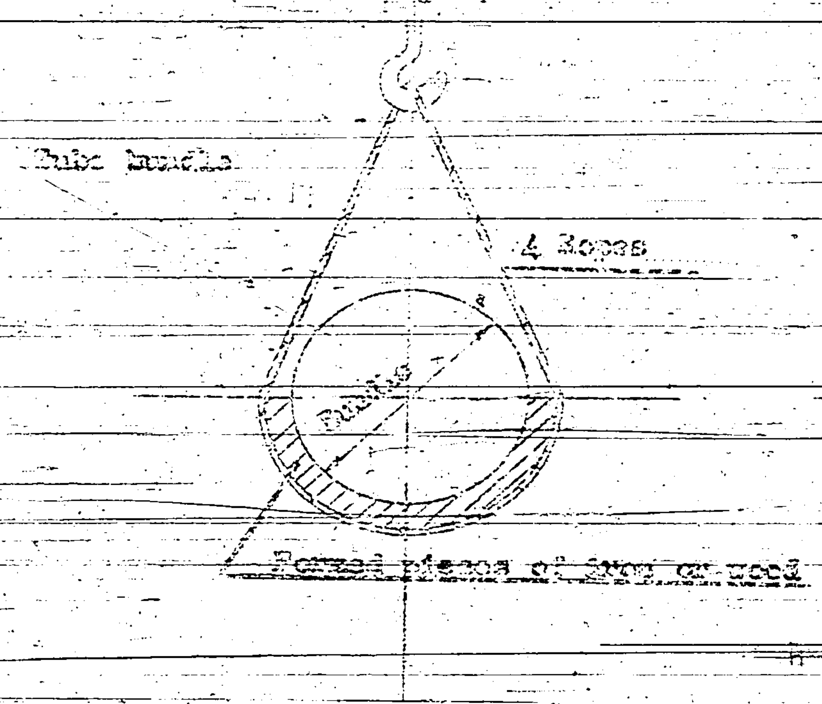


Fig. 47
Bundle on Cradle

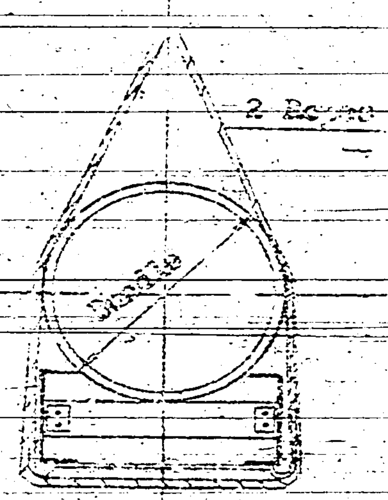
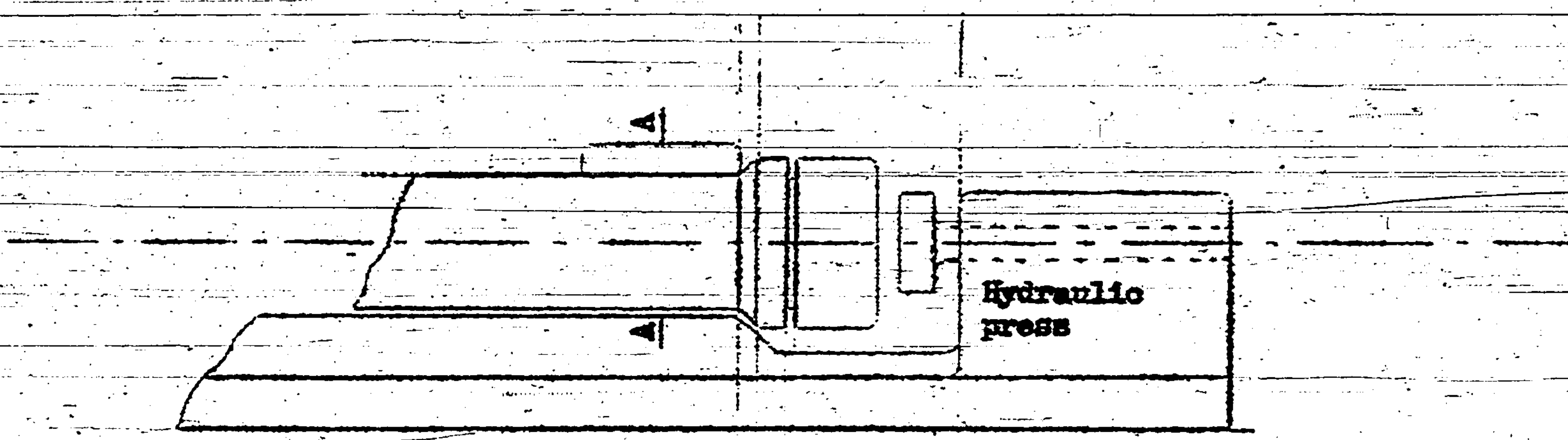


FIG. 48.



After pressing on the cover, the nuts are lightly drawn on the bolts.

Section "A-A"

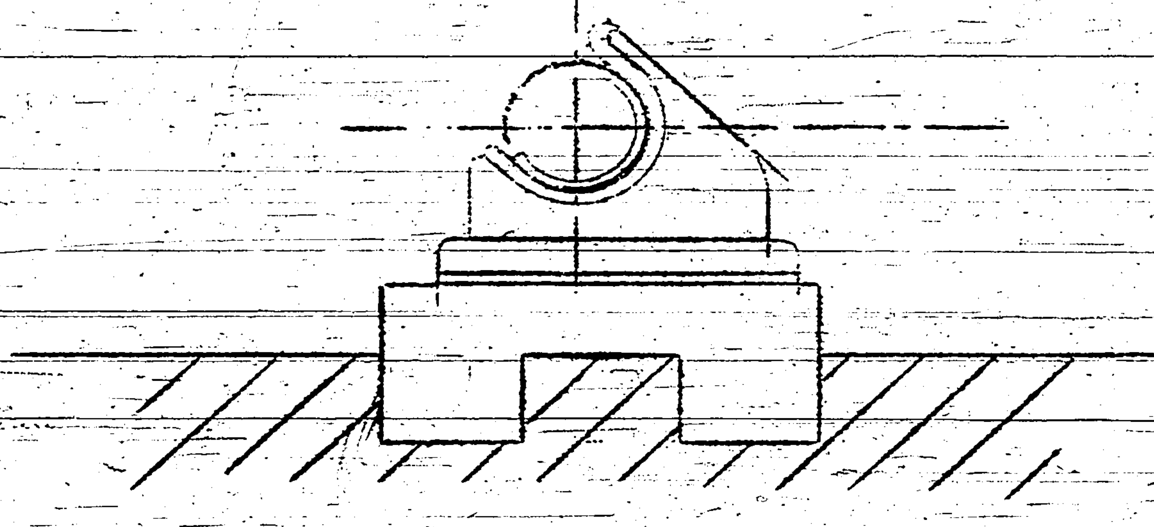


Fig. 49

Testing Tube for Bundle Pressure Test

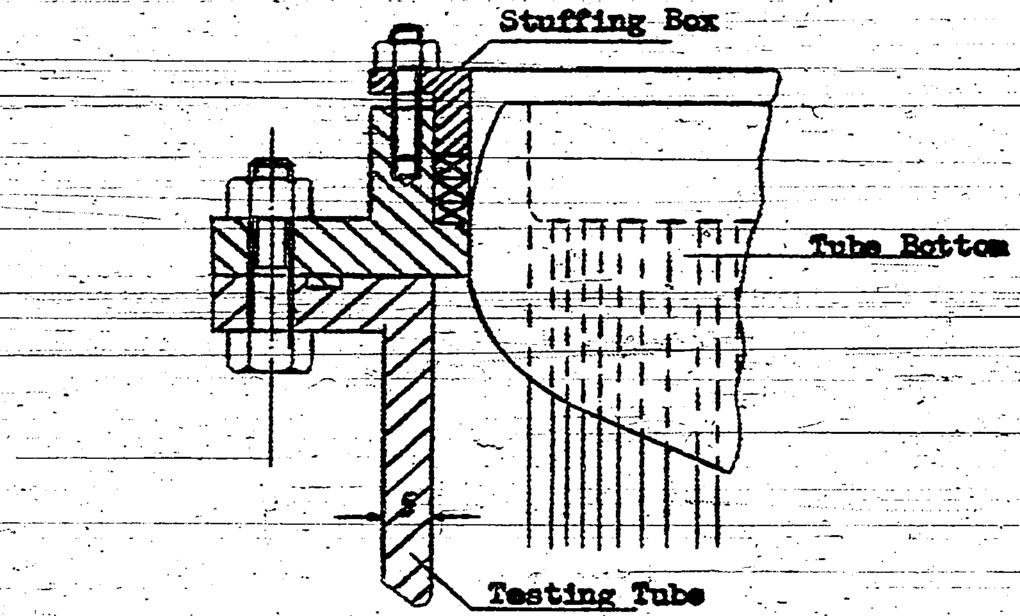
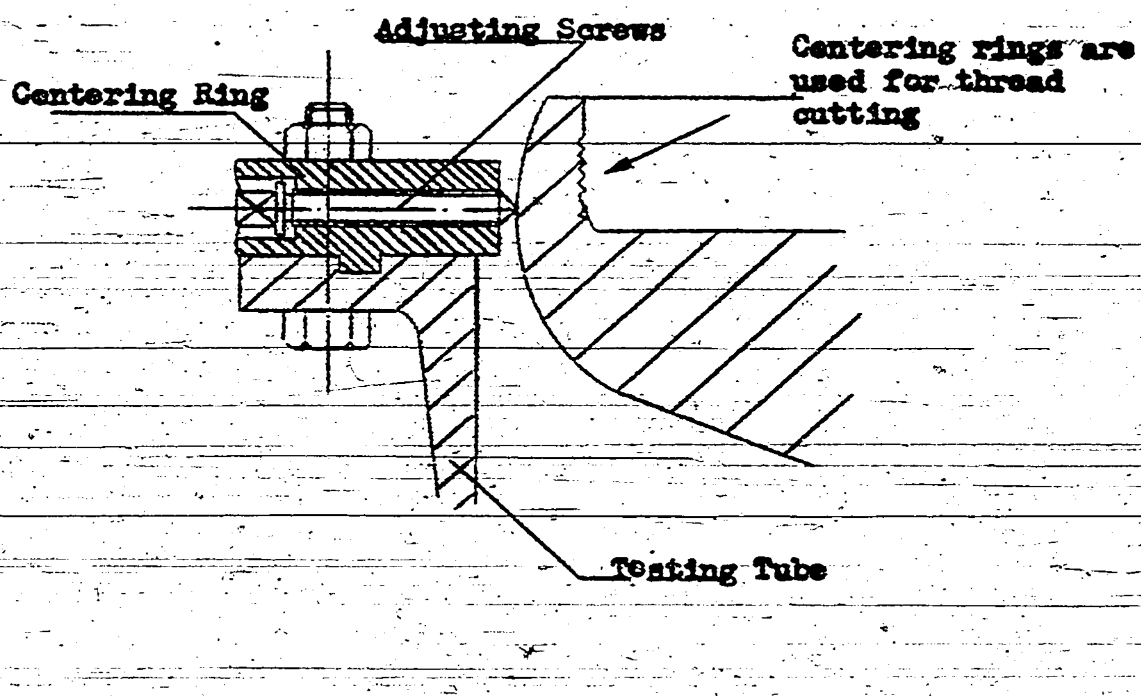


Fig. 50



F. HOT OIL LET-DOWN (HOLD)

In the newest stalls the regulation of the level in the hot catchpot is located in the HOLD building; that is, the high pressure line runs from the hot catchpot (via double coil and water cooler) to this building, where the regulating valves (needle-valve type) are located.

The pressure difference scale (weighted lever ?) of the level indicator for the hot catchpot is provided with a relay which electrically transmits the position of the scale to the regulating valves where it may be read off on a measuring instrument. The foregoing water cooler is located immediately ahead of the valve group. Following this cooler 2 HOLD lines are provided for each stall (figure 51) and each line has 2 pressure relief (purge) groups. Each of these groups consist of 3 shutoff valves and 2 regulatin valves. (Figure 51 shows only 1 regulating valve for each of the 2 groups). Of the 2 regulating valves only the first has a stem with valve seat and disk. The second valve has no disk and offers only a little throttling in the purging. In consideration of the wear special T's and bends are provided after the cooler (bends with a larger mean radius than in normal construction).

Two of these groups connected to one high pressure line again have two lines each, which carry the purged HOLD to the pressure relief vessel (purge tank). High pressure material is used for these lines up to the purge tank.

When one group must be changed over the liquid is switched on to the second line. The purge tanks have no check valves.

The purge tank may be open or closed. In an open tank a liquid shutoff is necessary at the tank. The HOLD is pumped for further processing. If the vessel is closed, a fixed level must be held in it. The principle of the leveling is given in figure 53.

Equal masses of nitrogen are blown into the tank through the stand pipes (risers). A U-tube with two shanks of unequal cross section is connected to the two nitrogen lines. When the level in the suction vessel rises the water column in the smaller shank of the U-tube rises. The vessel attached to the weighted lever is filled and the valve in the air line will open, the air controlled valve in the steam line opens, duplex pump starts, etc.

If for some reason the level in the vessel should continue to rise; for example, if the pump should not work, an alarm is set off, which is shown schematically in figure 53A.

A U-tube filled with mercury, and provided with 2 platinum contacts (in the same shank) is arranged parallel with the U-tube in figure 53. When the level rises abnormally a battery circuit is closed, which in turn lifts the lever of an air valve and the alarm whistle is set off.

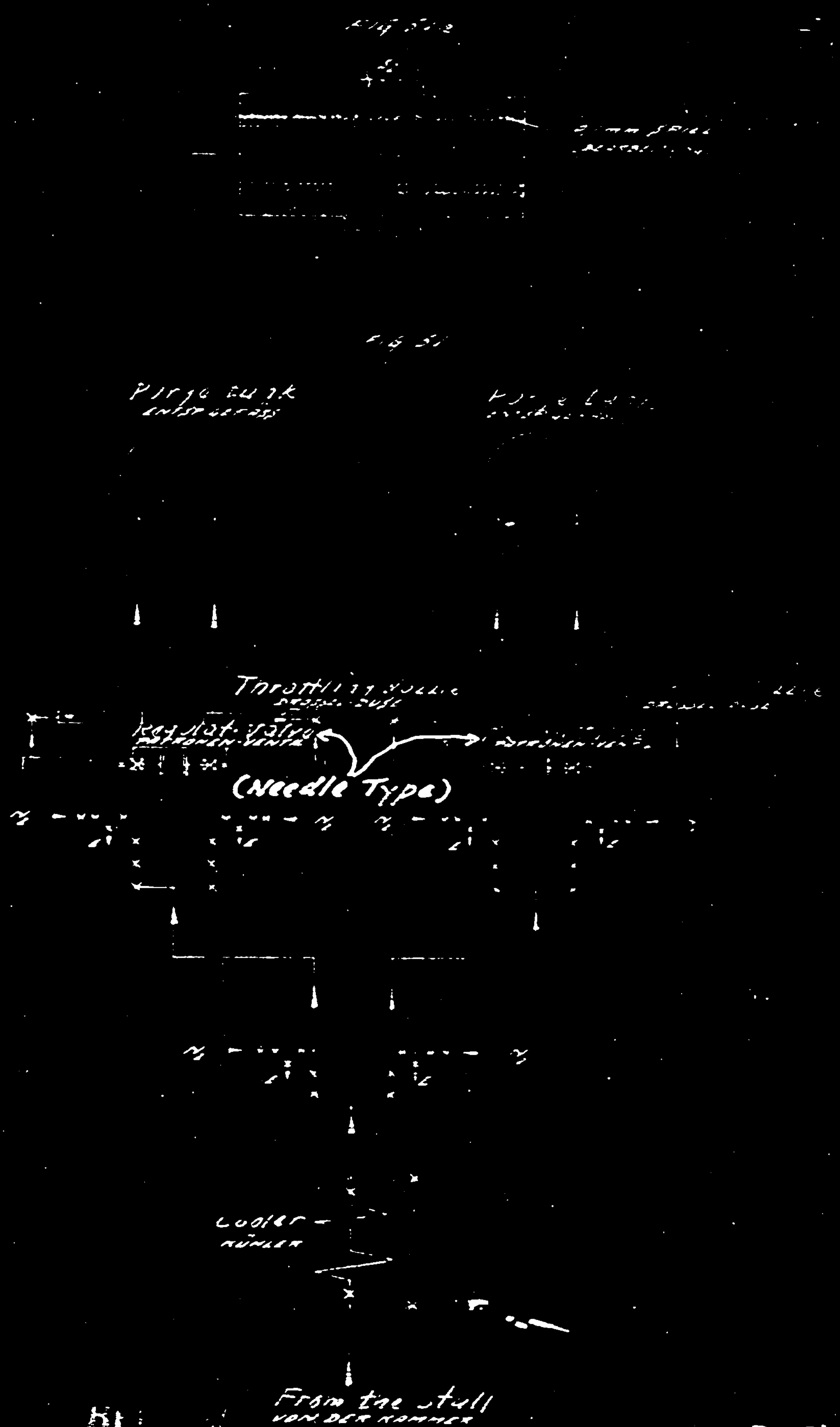
The regulating valves are built if WIDIA, DURA or WALIRAMIT. Both of the latter materials are supplied by Rhein-Ruhr Maschinen Vertrieb - Essen and have a considerably longer life duration than WIDIA.

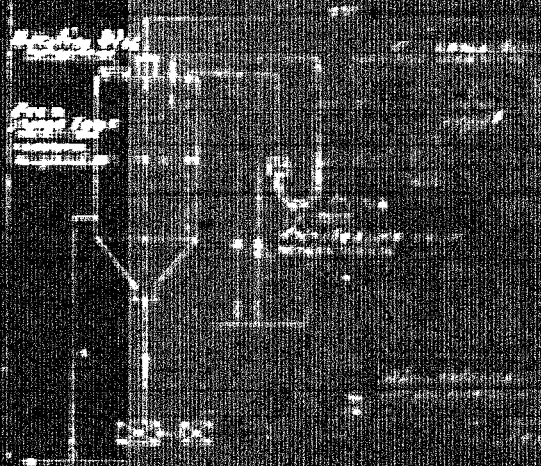
(over)

Formerly all the valve seats were made of WIDIA or some other metal. At the present time these parts are lined only with wear-resisting materials (figure 51A).

The hard metal lining is soldered with brass into the S2-holder (hard soldering). For this purpose the steel body is uniformly heated to a cherry red. In unequal heating the hard metal bursts because of heating stresses. A special welding powder by Griesogen is used for soldering (borax is unsuited).

The hard metal conical valve seats are not ground when built into the valve. These are removed and ground after wear. As received from the supplier the surface of these cones is fairly rough.


(Needle Type)
Cooler



G. MACHINE HOUSE WITH PASTE PRESSES, CATALYST PUMPS, AND MIDDLE OIL INJECTION PUMPS.

The valves are arranged either on the inside or outside depending upon the available space.

The injection pumps of the vapor phase have a safety valve installed in the pressure line outside of the machine house (see also figure 80). The safety valves are connected to a reservoir set into the floor. This reservoir has CO_2 or N_2 connections. A surge vessel (hydraulic shock absorber) of 600 to 700 li. capacity, which can take up shocks in the pressure line, is installed in the pump by-pass line. Leuna recommends the use of these vessels which makes the operation of the injection pumps more flexible. The vessel is partly filled with N_2. A sight glass is not built into the vessel. If the pressure fluctuates radically nitrogen is added to the vessel (no gas cushion). This N_2 addition is therefore not steady. In order to prevent a gas formation in the suction line, the suction valve box of the middle oil injection pumps is provided with a vent.

Gas Circulating Pumps.

The capacity of these pumps is 120,000 m^3/h at 90 rpm.

The maximum capacity of the steam engine is 1,200 hp. In normal operation at 25 atm. pressure difference about 850 hp is used. The pumps are double acting and have a stuffing box at the top which permits low height and easy control of the stuffing box. The pumps have 2 pull rods (arranged top and bottom) which are constantly in tension. The spring loaded relief valve of the pump opens at 35 atm. pressure difference.

Holding the Pressure Difference. About 10 to 15 per cent of the total gas passes through the by-pass. This quantity is necessary to permit a flexible gas supply to the stalls. The regulating is done by means of one large valve (70 mm) and one small valve of 16 mm. The gas passing through the by-pass and again entering the suction line of the pumps is cooled by a tube cooler.

The separators in the gas circulating lines and the valves are insulated and heated so that the ammonium carbonate cannot crystallise out (below 30 to 40°C).

The valves are all arranged outside of the building. The valve stems go through the wall. The heated valves have a steam jacket.

Product Pressure Relief Vessels (Purge Vessels).

All cold catchpots and purge vessels of the liquid phase are partly or entirely heated and insulated. (Viscosity of the products is very high in winter).

Control Board. No valves are installed in the control room, only the valve stems go through the wall of the control room. The valve stem extension rods are spring loaded to prevent their being lifted off the valves.

(over)

Accumulator for Oil Control.

Figure 54 shows an accumulator scheme for oil control of the valves. The operating pressure is about 170 atm.

When the accumulator is full, the electric motor is shut off. When the electrical cutout fails the weight will continue to rise. In its highest position a valve opens mechanically by means of a pull rod, permitting the oil to flow back into the tank.

X. ELECTRICAL PREHEATER (BY MESSRS. DIPL. ING. HOFFMANN & RIEGER)

The vapor phase preheaters in Leuna have 4 to 6 hairpin tubes of 90 mm inside diameter. Each such tube has a transformer of a capacity up to 300 kw. The power factor varies from 0.70 to 0.76. All transformers are of the stepless regulating type. This construction is preferable because closer temperature regulation is possible. The total radiation losses of an electrical preheater are about 50,000 heat units/h (HE/h). From this loss and the electrical power the efficiency may be determined.

Each transformer has a kw-Amp-, and a voltmeter on the secondary side. It is recommended that transformers be built with a $CaCl_2$ absorption vessel to prevent the absorption of water vapor (contained in the air) at the cooling of the transformer oil. The regulation of the transformers is done from the control board. The pulling in and out of the regulating coils is done mechanically by means of an electric motor worm gear and rack. In case the electrical control from the control board fails, the transformer may be regulated by hand on the transformer platform.

The stepless transformers have the advantage of dependability and low upkeep. These transformers are often in operation for a period of 10 years without repairs. This is a great advantage compared to the step transformers. If much regulating has to be done the contacts wear off rapidly and repairs are necessary.

The primary current has a potential of 6,000 volts. The secondary current of a transformer is 6,600 Amps at 70 volts. The power factor is 0.7 to 0.76. The arrangement of a 4-hairpin preheater with 4 transformers of a maximum capacity of 4 x 300 kw is shown in figure 55.

In laying the secondary lines the following is to be observed: The individual bars from the poles must be staggered, that is, the bars must alternately be plus and minus alongside of each other (see figure 56), in order to decrease the phase displacement and the unit load on the bars.

The permissible current density in the bars is about 1.5 to 2 Amps/mm^2 for copper. The total drop in potential in the lines should not be more than 2 to 3 volts. Joints in the bars must always have as large as possible contact surfaces to assure good conductivity with this low voltage current (see figure 57).

The spacing of the wood packing (insulation according to figure 56) between the bars should not be more than 1 meter, considering the possible buckling of the bars by heat expansion. The wood for the insulation of the copper or aluminum bars may be beech, oak or pine, impregnated with I. G. lacquer. This assures a good insulation.

Flexible cables must be used on the connections of the bars to the transformers and pre-heaters.

Electrical Preheater

In the insulation of the preheater hairpin tubes consideration must be given the fact that each tube is in potential with the ground and the other tubes.

(over)

The suspension of the tubes must be considered separately. It has been found that the preheater tubes are lifted if the entrance and outlet tubes are arranged vertically (see figure 59). This lifting can be partly avoided by means of joints as already indicated for the stalls in figure 4. Another form of suspension is shown in figure 60. The latest construction for tube suspension is shown in figure 61.

The temperature of the porcelain insulators does not exceed 70°C, if properly arranged.

Installation of Electrical Preheaters:

1) Erection of jackets.

2) Inserting the tubes.

3) Building the fire brick arches.

4) Tamping in the cinder wool insulation.

5) Putting in the bottom.

The preheater tubes must always be so connected to the electrical current that the passing of the current through the flanges and bends is prevented (see figure 62), because it has been shown that the densest current occurs on the inside of the bends, which may cause local heating. Measurements have shown that the temperature difference on a normal bend may reach 100°C. (Nitrogen should be passed through the bends during the test).

For the control of the wall temperature of the preheater tubes, I. G. specifies thermo-elements, which are attached to the top or bottom of each tube (see figure 63). The measurement of temperature is not absolute but relative and to be used only for comparison. With N8 at 225 kg/cm² pressure a temperature of 580° (at 325 atm. temp is less than 560°C) must not be exceeded. The absolute temperature will be about 1-2 mv higher than the measured temperature. The wall temperature in this type of preheater will be about 40° higher than the product temperature.

In the measurement of the tube wall temperature a mica sheet is placed between tube wall and the thermo-element to avoid false readings (electrical heating currents) (see figure 63).

The wiring of 3 transformers for 3 hairpin tubes is shown in figure 64.

Electric Motors and Equipment:

Transformer Switch Gear. The potential of the conductor bars is 6,000 volts. The oil switches are 2 phase and can be operated from the control board. For this purpose a white signal lamp is installed on the control board. When the lamp burns, the switch is closed. For safety reasons, 2 power stations with 3 different conductor bar systems are desirable. The second station may be connected to the main bars of the switch gear as a reserve. However, this reserve is not always considered necessary for the transformers because, in a pinch, operations may proceed without a preheater (depending on the heat exchange). The temperature in the tubes, however, may drop very rapidly on the cutout of the transformer, which may lead to loosening of the flanges. The transformer oil switches have only maximum current protection.

Induction Motors (Kurzschlussmotoren) for Preheaters, Circulating Gas Fittings, Etc.

In general it may be said that for important motors, which must be kept running and which have no reserve, 2 oil switches (Stations A and B) and 2 cable connections on the motor should be provided. The oil switches are mechanically locked. When 2 motors are provided, of which one serves as a reserve, one of them is connected to Station A and the other to Station B.

Motors are connected as follows:

1) Above 100 kw to a 6,000 volt line

2) Under 100 kw to a 380 to 500 volt line

Lately 500 volts is frequently used by I. G. because the copper measurements are decreased thereby.(?)

Circulating Gas Fans.

When 2 motors are required for one preheater, one switch and one motor is connected to Station A and one switch and one motor to Station B. When one motor is available, it has two connections and two oil switches, one for connecting to Station A, the other for connecting to Station B.

Linde Works would specify this type of connection for electrically driven injection pumps or gas circulating pumps. The reserve units for these pumps may also be connected to the second station.

The stopping of circulating gas fans should be avoided, because it causes too high tube temperatures. In any case, an alarm is to be provided for these fans. A U-tube with mercury filling is connected to the suction pipe when the fan stops, the mercury rises in one shank of the U-tube, a platinum contact is closed and an electrical alarm signal is operated.

The connection should not be made on the pressure side of the fan because this will cause the U-tube to be fouled by dust.

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I. GENERAL REMARKS.

Cleaning of Tubes.

For tubes 30 mm inside diameter and larger, are cleaned by rotating milling cutters made by Bader & Halbög, Halle (Devoorde Apparatus) similar to those used on water tube steam boilers, but with flexible shaft drive. The electric motor drive for this apparatus has 3 different speeds, 700, 1,400 and 2,800 rpm. In cleaning, water is flushed through the tube in a direction opposite to the movement of the cleaner. Tubes below 30 mm inside diameter, for example: heat exchanger tubes, are cleaned by means of a long spiral boring tool (figure 66). The drive is by means of a pneumatic boring machine. This method is also recommended for tubes with reduced neck diameter because with sufficient flexibility of the shaft the walls are also cleaned. This cleaning should be done from both ends of the tubes.

Mounting of Manometer Lines.

The connecting lines have an inside diameter of 6 mm. These lines are made of S2. They must be supported at all points where flanges occur, because otherwise vibration may strip the threads in the flanges.

Valves. Normally high pressure valves are so arranged that the stall pressure is on the conical disk. Only in exceptional cases, and dependent upon space conditions, should the valves be so arranged that the pressure is on the stuffing box (when closed).

Example: Two 90 mm valves in the branches of the main circulating gas lines to the stalls. The first valve, taken from the main gas line, has the gas line pressure. The second valve has the stall pressure against the valve seat.

Pressure Release or Purge Lines, which discharge into the atmosphere, must be well supported and fastened. These lines should be bent to large radii. Figure 68 shows a method of fastening several gas purge lines ending alongside of each other.

Condensation Traps in Steam Lines are by Klein, Schanzlin & Becker.

High Pressure Sight Glasses on catchpots and expansion vessels have no quick-closing valves. Neither do the manometers have such a valve (see also C2)

Expansion joints in circulating gas lines are made according to figure 67. Recently corrugated expansion joints have been used, which require less space. These are furnished by Franz Wagner & Co., G.m.b.H., Grimmitschau/Sa.

FIG. 66. Ia

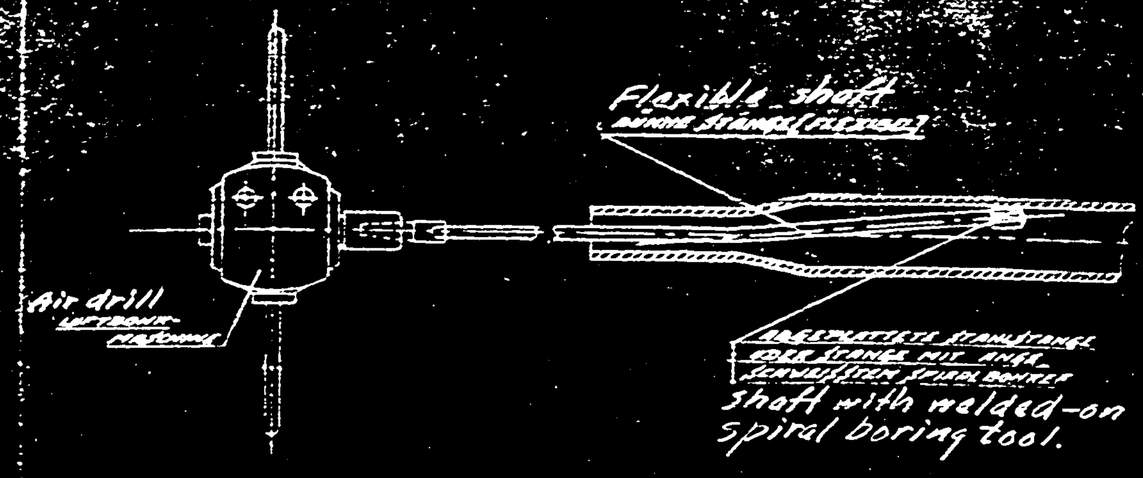


FIG. 67

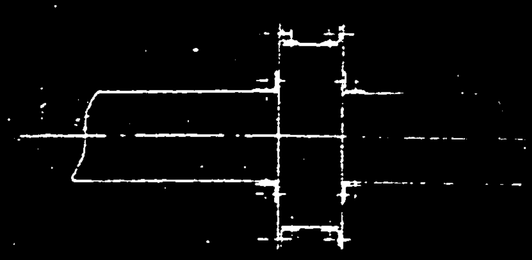


FIG. [illegible]

K. MATERIAL CONTROL.

The steels used in the hydrogenation plants may be divided into 2 groups, namely: hydrogen-proof and non-hydrogen-proof steels (at higher temperatures). By suitable galvanising they can be converted into H_2S proof steels.

Difference in Materials

H_2 Proof	Not H_2 Proof
H_2S Proof by Galvanizing	Not H_2S Proof by Galvanizing
Alloy Steels, for example N8	Steels like S2

Application:

(For hot lines (for temperatures over 200°C	(For cold lines (and cold gas valve groups for (temperatures to 200°C and 325 (atm., beginning at 220°C de- (carbonisation takes place in an (H_2 atmosphere.
To be H_2S proof, N8 must be galvanized. If not galvanized, N8 will eventually be attacked by sulfur (formation of Fe.S). A layer of 1 mm N8 corresponds to a layer thickness of 3 to 4 mm Fe.S.	If S2 is well annealed and very homogenous, decarbonization begins at 280°C.

When an attack is present or expected, the materials must be remeasured or investigated from time to time. For example; tube wall thicknesses, by boring or by remeasuring the diameter of a tube originally turned to a known diameter. These diameters are entered on a file card.

For the administrative control of materials used in a stall, all pipes and fittings, etc. are marked and numbered. All pipes, parts of pipes and forgings have their own card in the file (see diagram K3 and card K4). Sketches are also made of each stall on which all existing alloyed steels are carefully indicated with the corresponding numbers of the parts.

In addition, all materials are tested when received (see diagram K5 and K6).

Alloyed Steels	Non-Alloyed Steels
Wall thickness of tubes Physical properties Flattening test (figure 65) Control and composition of the delivered order	The same tests as for alloyed steels

(over)

Each tube or forging to be tested by means of a drop of spot test (
Chemical analysis of file samples)

After the tests have been made, the corresponding piece is stamped and the material may be used for its given purpose.

As already mentioned above, each piece of tube or forging is numbered on a sketch of the stall and recorded in the file.

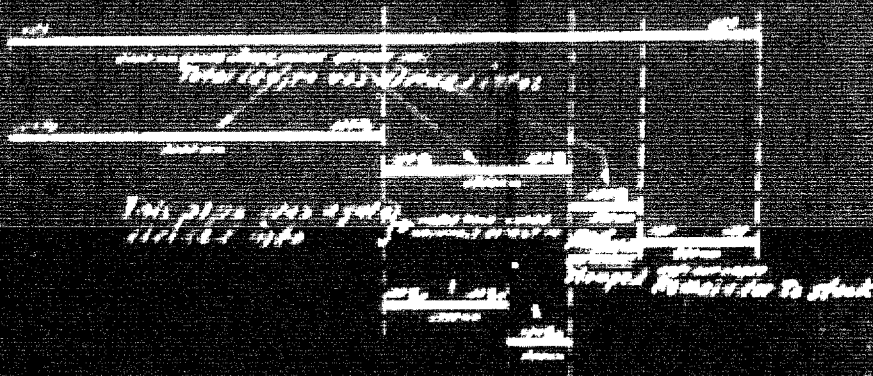
In this manner it is possible to follow the history of each piece of alloyed steel. To be absolutely certain, each piece of tube or forging is again tested by a technician by means of the spot test at the completion of the stall installation and before putting it into operation.

For the sake of a good control, it is recommended that the supervision of the entire installation and dismantling of a stall be given one supervisor, who will be responsible for the work.

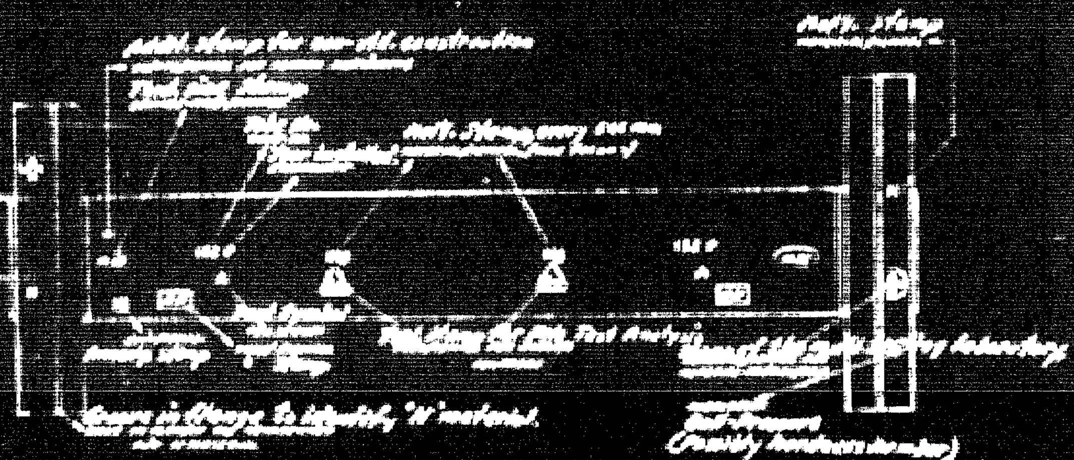
KCBraun/mc/pkl

K3

Classification [illegible] for Parts of [illegible]



K5



Remarks:- Letters m, n, i &c are followed by a number designating the instal. supervisor or inspector.

K6

Installation located at

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (phone, etc.)	Remarks
[illegible]	[illegible]			[illegible]			

OPERATION OF HYDROGENATION PLANT

I. Starting of the Coal Stall.

When first starting a coal stall particular attention must be paid to the preheater. The refractory brick work must be dried for about 2 days. This drying is begun when N_2 is pumped into the installation.

About 8 hours are required to start the pressure gauges, testing for the levels and purging the nitrogen. Should the preheater then fail to be dry, purging with nitrogen must be continued. The purging with nitrogen is complete when the excess pressure is equal to about 1 m. water column.

Order of Manipulations:

1. Flushing with N_2 (see also vapor phase and Figure 69).
2. Compression with 300 atm. N_2. (Should the installation have been in operation for some time previously the compression is done to a lower pressure).
3. Purging of N_2 to 50 atm. (The nitrogen released will be used for compression in other parts of the high pressure equipment.)
4. Starting the circulation gas pumps.
5. Dry firing of the preheater.
6. Starting on the pressure gauges.
7. Testing of all the level indicators.
8. N_2 completely purged.
9. Filling with circulation gas to 300 atm.
10. Starting the gas circulation pumps.
11. Starting the pressure gauges and the level indicators.
12. Beginning of heating with 12,000 m^3/h gas intake. From this amount, some 2,000 m^3/h are passed over the heat exchanger double coil (Figure 69A)
13. Raising the temperature 0.8 - 1 mv/h (this temperature is measured at the intake of the first converter).
14. At 15 mv the catalyst is being introduced (catalyst paste) at the rate of about 1,000 li/h to the preheater (30% concentration). The amount is increased to 3,000 li. in the course of half an hour.
15. The oil is introduced simulatenously with the catalyst by injection of around 1,000 li/h into the heat exchangers.
16. Starting of the hot circulation with the hot circulation pump (figure 70). Filling the flushing oil line with oil (flushing oil).
    - (a) First filling of one line until no more air is left. The expansion valve of this line is closed.
    - (b) Filling of the other line through the pump body with an open bypass in the pump.
    - (c) Starting simultaneously the pump at low rpm.
    - (d) When all air is expelled from the relief piping the purge valve of this line is closed.

(over)

(e) The pressure in the flushing line is kept at 300 atm.
(f) Opening the shut-off valve at the inlet and outlet at the valve box.
(g) Closing the by-pass around the pump.
(h) Raising the pump delivery (2,000 li/h to 6,000 - 7,000 li.) inside of 30 minutes.
(i) The valve box is put in operation as soon as the HOLD separator shows the stand of the liquid.

17. The HOLD is simultaneously started through the group of throttling valves. The level in the catchpot is kept at a height of 30 to 40 mm on the chart. If too much gas is carried over with the HOLD the level must be raised.
18. The consumption of fresh oil rises with the rising temperature.
19. When the consumption amounts to 6,000 - 7,000 li/h the catalyst is begun to be supplied through the heat exchanger.
20. The cooling water is started through the feed cooler (with an oil of a low flow point, the amount of water at first must be restricted).
21. The temperature at the outlet from the exchanger coil is recorded. Should it be necessary the amount of gas through the coil is increased.
22. At 23 mv the temperature is increased hourly by 0.5 mv.
23. The upper cold gas valve is opened.
24. When the temperature reaches 24 mv (460° - pencil notation) it is raised still slower until the full thru-put has been reached.
25. Replacing the catalyst (addition of fresh catalyst) depends upon the stall yield (see 28). The amount carried over by the HOLD must be replaced.
26. The concentration of solids in the HOLD must be watched during the whole operation. In Leuna the amount of solids in the HOLD is 28 - 30% (figure 71).

STOPPING A TAR STALL AND COLD OPERATIONS.

1. Reduction of the temperature 0.8 - 1 mv/h by throttling of the fuel gas. The fresh tar consumption is correspondingly reduced. The gas thru-put and the hot circuit remains at first unaltered.
2. Stopping the introduction of catalyst at 22 mv. The drop in temperature causes the formation of more HOLD and the supply of fresh tar is correspondingly reduced.
3. The temperature in the cold catch pot is kept constant since otherwise the product will plug it up.
4. At 12 - 10 mv. the converter temperature is slowly lowered. The strongly throttled fuel gas may by now be entirely turned off.

5. Turning off of the fuel gas (see Figure 71a). The blowers are turned off. The suction valves, check valves and the purge valves are closed to eliminate unnecessary suction in the preheater. The air valves in the burner are closed and N_2 is introduced into the firing box. For longer shutdown of the preheater, it is recommended to push the blind gate into the fuel gas piping as soon as no more N_2 is being introduced into the firing chamber.
6. The hot circulation is stopped at 8 - 7 mv, also the fresh tar addition. There should still remain enough heat in the converters to permit the proper HOLD operations behind the stall without any plugging up. Stopping the hot circuit: the hot circulation pumps are turned off, the valves closed at the inlet and outlet of the valve box, the flushing oil line is purged and drenched with oil, and finally blown out with N_2.
7. After 10 minutes the gas is entirely turned off.
8. HOLD separation until gases go through:

   the HOLD catch pot
   converters 4 - 1
   heat exchanger 2

9. Ten minutes later the gas is again fully turned on and turned off finally after 2 hours.
10. The stall is purged. The by-pass around the stall remains closed, the oil valves are closed on the pressure and the suction sides, the purge valves are open. HOLD again used during purging. The manometer is observed at the intake and outlet of the stall to see that the pressure difference in the stall does not exceed 15 atm. Should this happen the purging is slowed down or else the by-pass is carefully opened. Manometers frequently give erroneous readings of pressure differences because they are apt to stick!
11. The "Ratsch" valves in the circuit (on the pressure and the suction sides) are closed, the purging made between the "Ratsch" valves and the oil valves.
12. The stall is rinsed with N_2. The by-pass around the stall must be closed! The flushing continued for some 15 minutes. During flushing the cold gas piping, the double coils, etc., must also be flushed out with nitrogen.
13. The outlet gases should contain not over 5% of combustibles.
14. Should repairs be required in the high pressure line, blind gates should be inserted between the pressure and the suction lines.

Computation of the Level in the HOLD.

It is assumed:

1. That the reading of the level indicator is 200 mm of Hg = 200 mm x 13.6 = 2,720 mm.
2. That the specific gravity of the HOLD is 0.9

$\frac{2,720}{0.9}$ = 3,020 mm, the level of the oil measured from the lower end of the long measuring tube.

(over)

to follow L

FIG. 69

N_2 rinsing of one stall

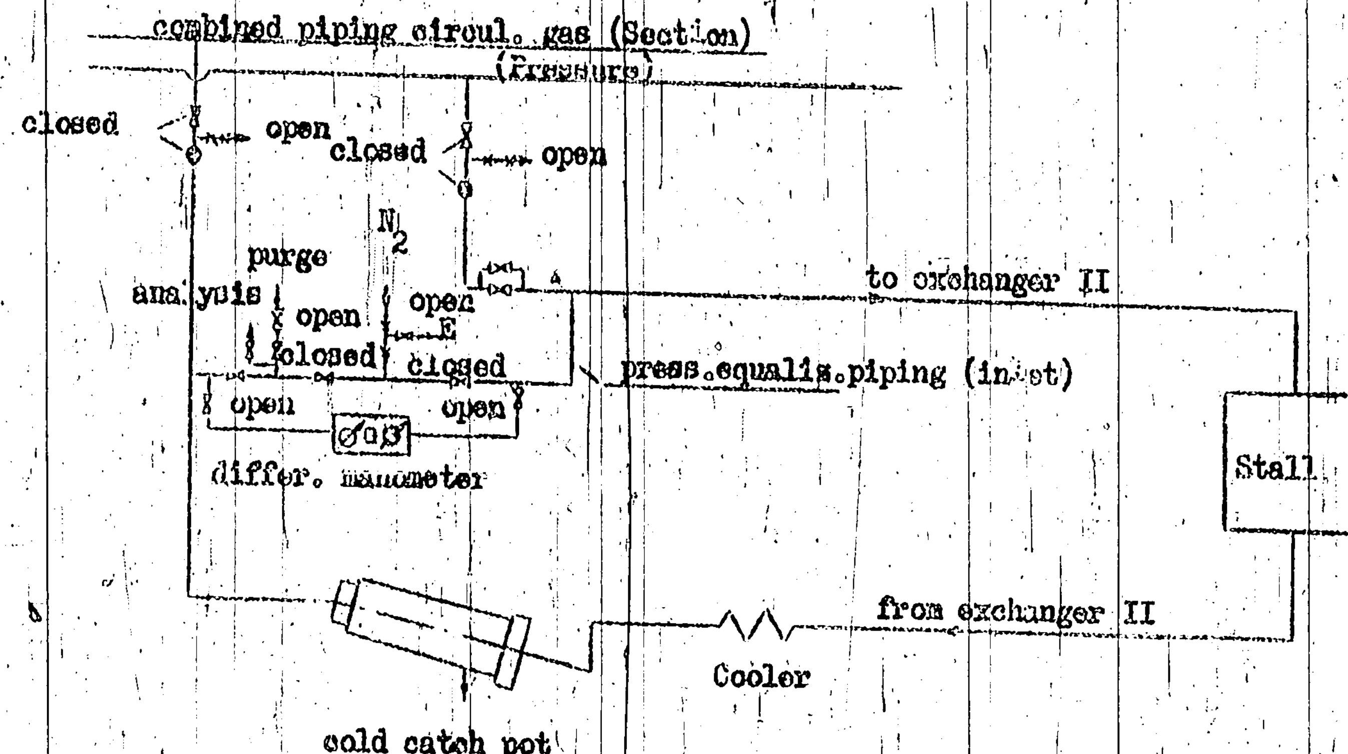
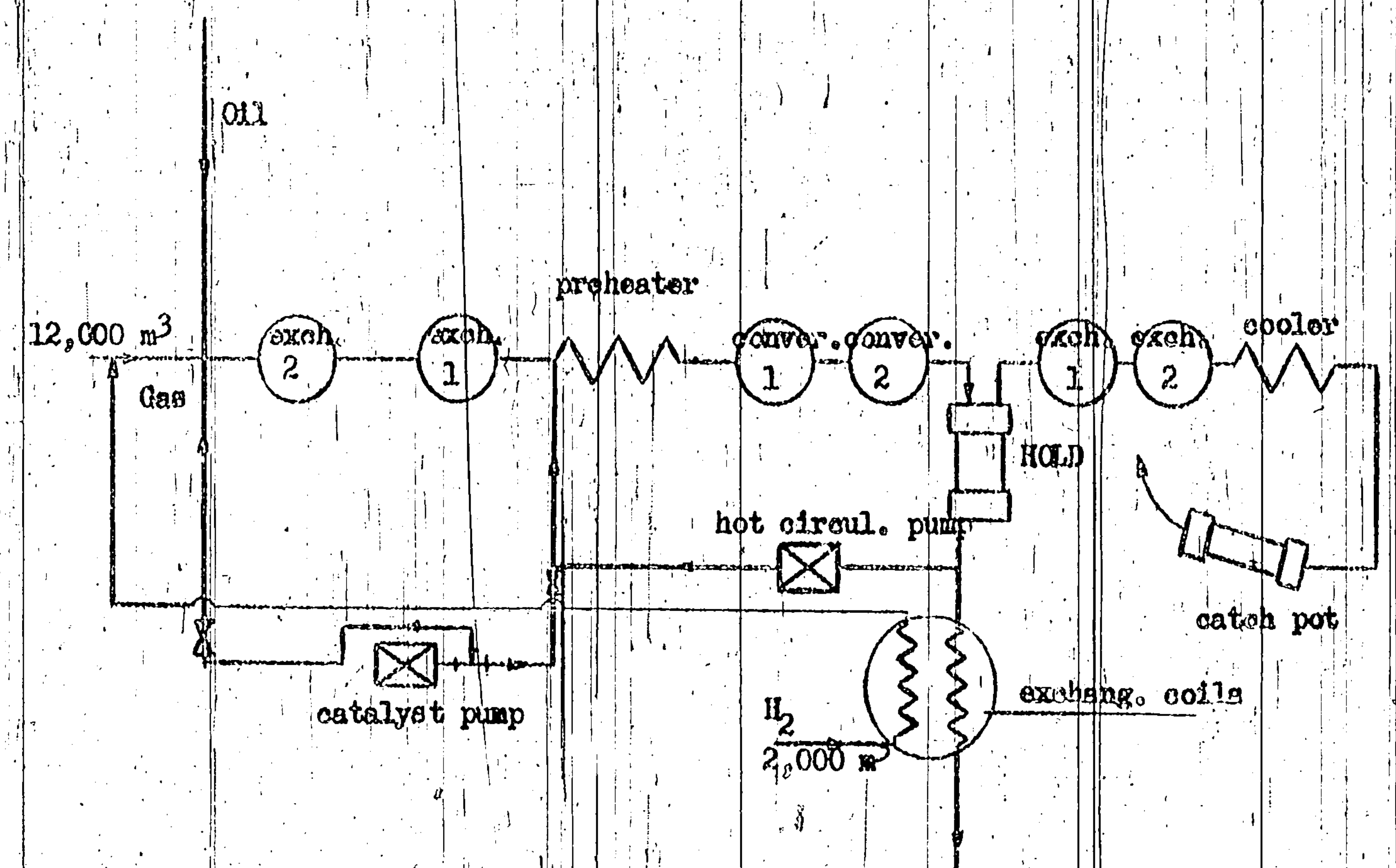


FIG. 69a


Oil
12,000 m³
Gas
exch. 2
exch. 1
preheater
conver. 1
conver. 2
exch. 1
exch. 2
cooler
HOLD
hot circul. pump
catch pot
catalyst pump
exchang. coils
H₂
2,000 m

to follow L

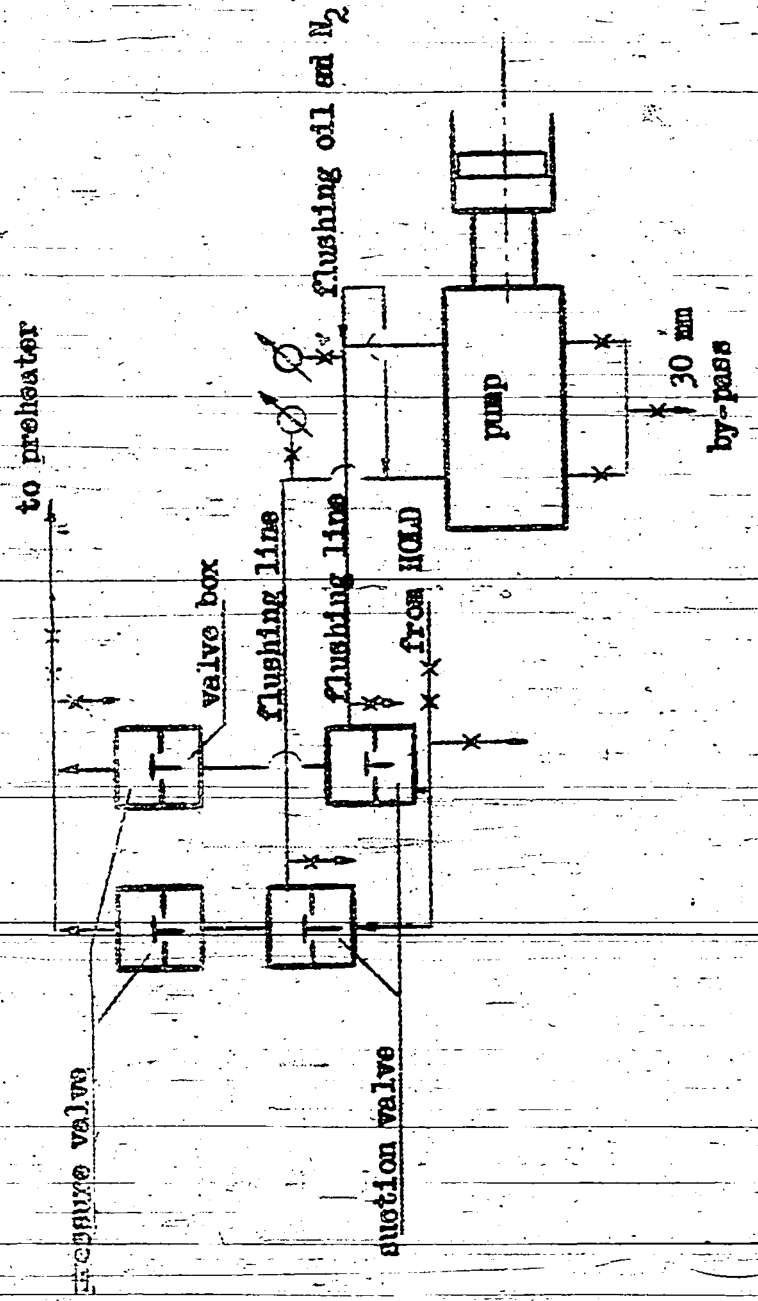
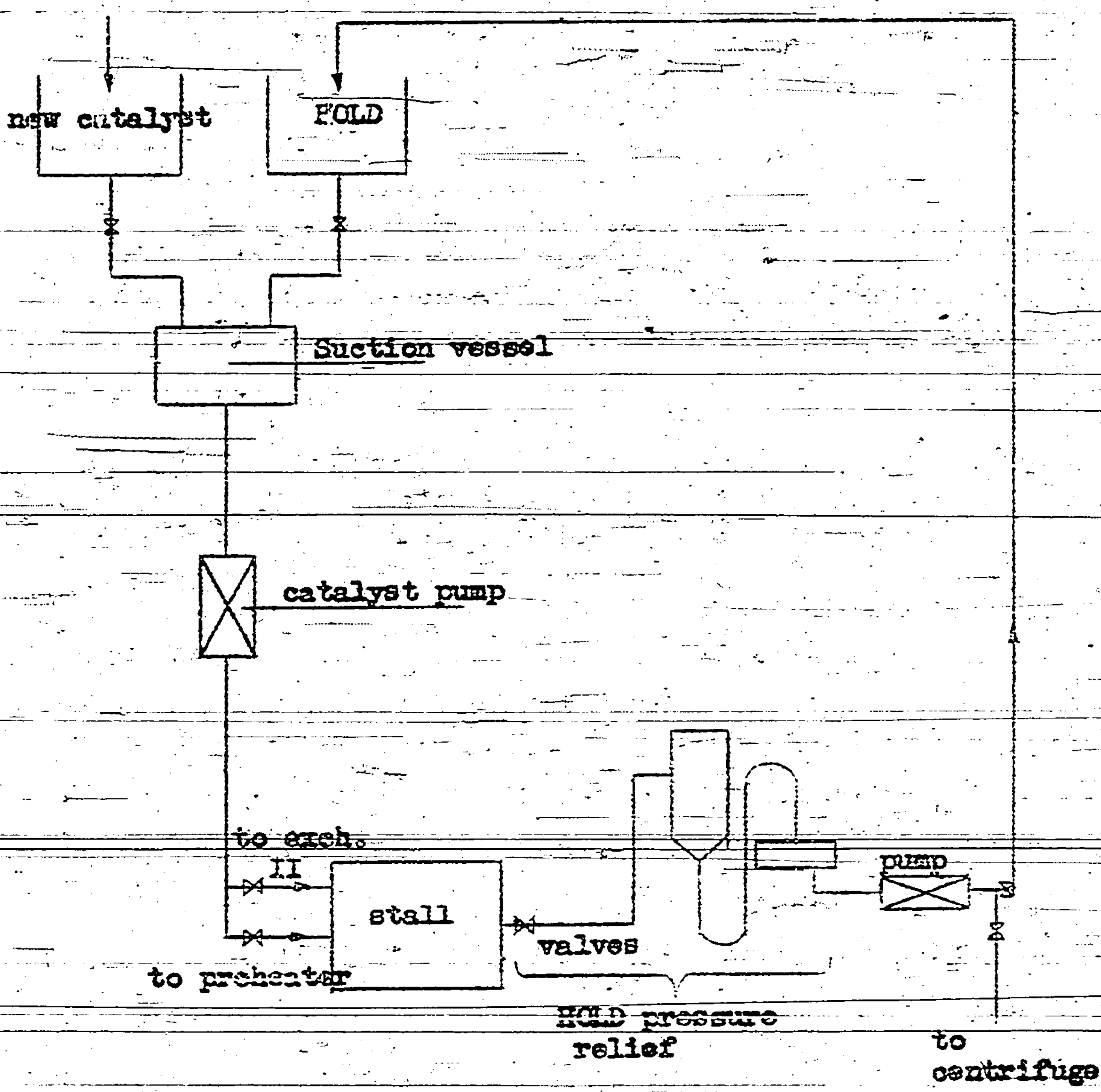


FIG. 70

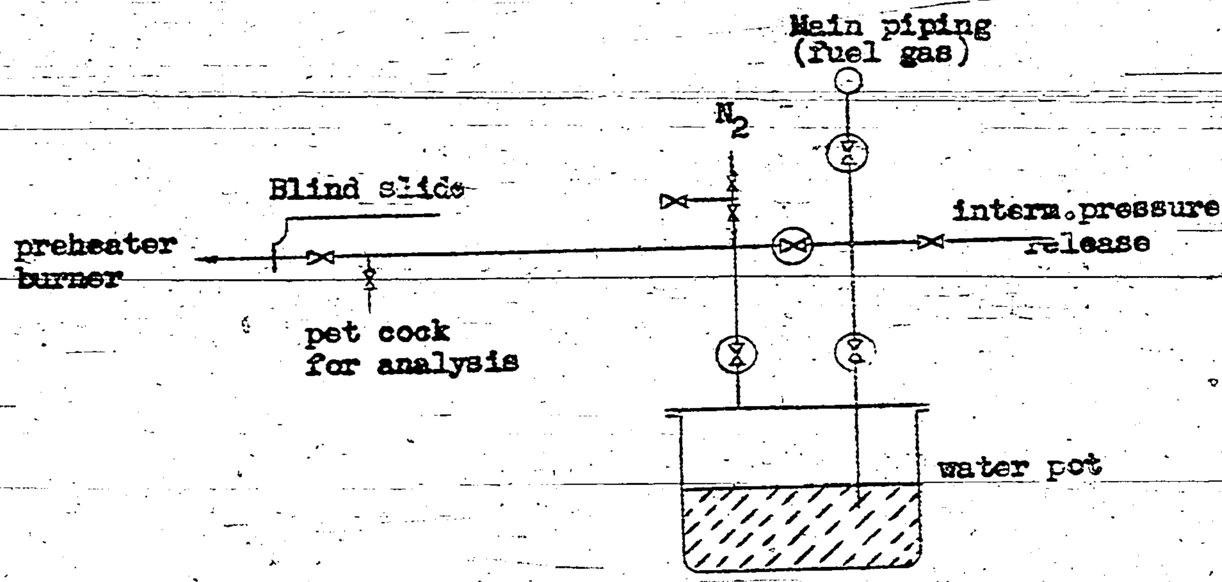
to follow L

FIG. 71



to follow L

FIG. 71a



during heating (valve symbol) closed and

the intermediate purge valve open the blind disk sticks!

M. STARTING OF THE VAPOR PHASE STALL AND COMPRESSION WITH N_2

(New Stall)

The electric preheater is tested with N_2 before compression. The transformer is set down to about 20 volts and the current is briefly turned on. The voltage and the amperage are then taken. It is recommended to watch the electrical resistance (volt/ampere) during the operation. Before the heating current is turned on, the connections must be examined in order to see that loose bolts, etc., produce no short circuit.

1. Rinsing with N_2. The O_2 content should not exceed 0.5% (figure 69). The N_2 must be first tested for the H_2 content.
2. The pressure of N_2 is increased, by increasing the pressure from 1 to 20 atm. in the course of one and one-half hours and from 20 to 300 atm. in the next two hours. This rate is necessary for protection of the catalyst 5058 and 6434.
3. The pipe line is tested for tightness when under pressure.
4. Installations which had been previously used are tested in Leuna at a pressure of 30 atm. (with N_2).
5. The gas circulation pumps are not started with a high N_2 pressure. N_2 has too high specific gravity, 1.147 kg/m^3 against H_2 = 0.086 kg/m^3 and circulating gas of about 0.19 kg/m^3. (The oil breakers would regularly break the circuit with electric pumps). (The valve resistance became too high.)
6. The pressure in the stall is reduced to 50 atm. and the circulating pumps started.
7. The pressure gauges can now be tested (correctly connected?). About 5,000 m^3/h of nitrogen are pumped over.
8. Testing whether N_2 at 300 atm. could be used elsewhere before purging.
9. (Immediately) after purging of nitrogen the piping and the stall are filled with circulating gas.
10. The temperature control is necessary during filling with H_2. (When H_2 is added to the catalyst, especially 5058, heat is liberated).

    The filling with H_2 must be done carefully:

    1 to 20 atm. in about 1-1/2 hours
    20 to 300 atm. in about 2 hours.
11. The temperature rise is 3 - 4 mv. Should the temperature rise too rapidly the gas intake should be somewhat throttled (regulation valve).
12. When the pressure in the system (apparatus and pipe line) becomes equal to the principal suction pipe line of the circulating gases, the hydraulically operated valves on the suction side may be opened.
13. The re-pumped circulating gas is brought to 10,000 m^3/h. The amount may be read off at the pressure gauges at the inlet and outlet.

14. Heating up at 0.5 mv/h. The temperature is read at the thermo-couple near the inlet into the first converter (below).
15. When the temperature has risen to 10 mv, the cold gas supply is tested by observing the effect upon the temperature (thermo-couple in the catalyst space of the converter, see section P).
16. When the oil injection is begun the cold gas pipe line must be connected. This is invariably done by first opening fully the first valve in the line (in the direction of the passage of the stream); the regulation is done with the second valve and the by-pass.
17. The oil injection is now begun. The middle oil pumps should at first require very little, since the amount depends on the converter capacity. We recommend injecting one-half m^3/h in a stall with a single converter.
18. The movement of the oil through the stall can be observed on the thermo-couples of the heat exchangers. At the beginning of the oil flow they are reduced by about 0.5 mv as soon as the oil reaches the corresponding couple. When the oil reaches the catalyst in the first converter, the initial heat of reaction will be indicated by the temperature rise. The inlet temperature in the first converter is now kept constant. Should it rise rapidly, the heating current in the cold gas inlet should be reduced.
19. Should the temperature rise too rapidly the electric power is turned off.
20. 500 li more is injected per hour until the total injection would reach 7 m^3/h.
21. Water is turned on at the cooler when injection is begun.
22. If for any reason whatsoever the temperature in the vapor phase converters drops off strongly with large oil thru-puts, it is best first to retard the oil thru-put by one-half and then only increase the heat. Otherwise the heat of the reaction may be liberated suddenly in the stall causing carrying over of the oil.
23. Whenever possible the temperature in the converters is kept constant by means of addition of cold gas.
24. It is recommended to take hourly samples of the injection at the pump and of the catch pot for the determination of specific weights. Should the specific weight of the middle oil in the vapor phase rise suddenly without apparent reasons, the injection must be completely reduced or entirely interrupted until the cause has been found. Heavy oil permanently damages the catalysts, and so does water.

<u>Closing down the Vapor Phase Stall.</u>

The injection is reduced hourly by 2 - 3 m^3. The catalyst temperature must remain unchanged until injection has been interrupted. The converter temperature is next measured at the intake of the converter I and reduced by 0.5 - 0.7 mv. Should the last converter temperature drop off too rapidly, it can be raised by circulation gas.

....

(over)

When the vapor phase stall is shut off, the gas pressures are reduced at the same rate as shown under 10.

The shutting off of the circulation gas should proceed slowly (during 10 minutes), with reference to the circulation gas pump operations (compare the shutting off of the coal stall). During emergency purge of the liquid or vapor phase stalls the procedure is the same as described above.

FIG. 72

to follow M

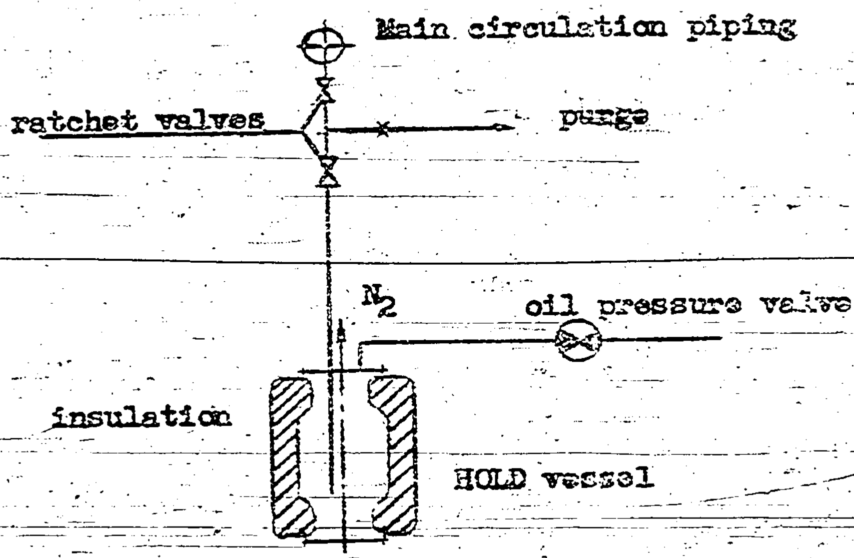
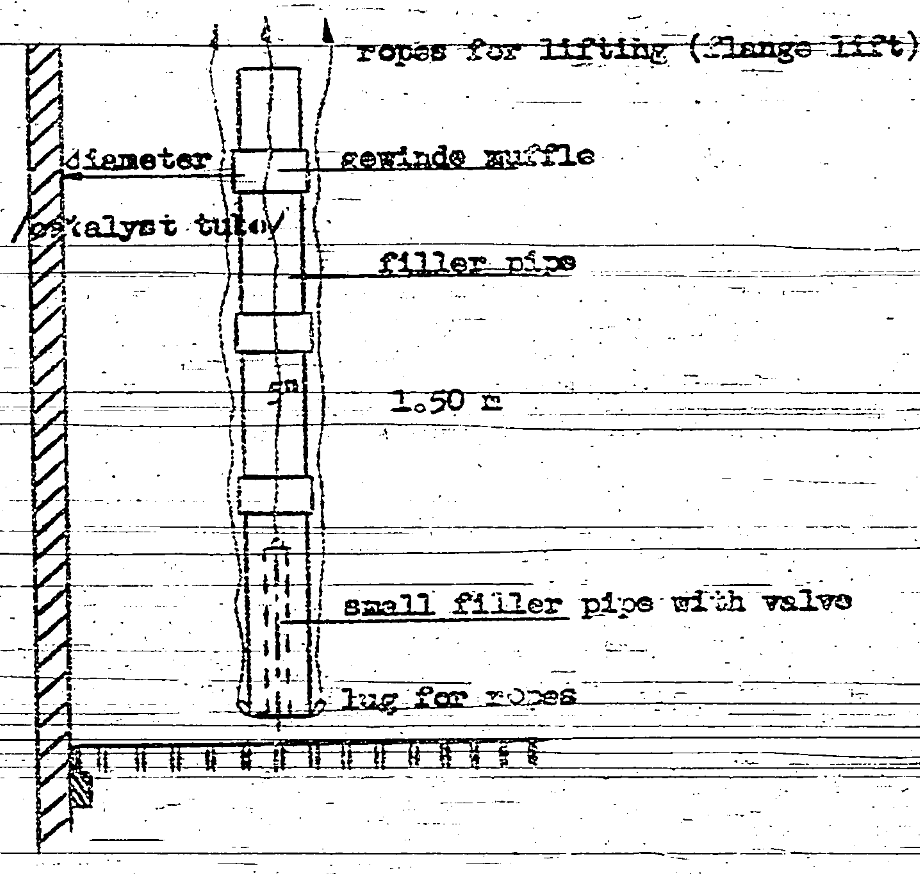


FIG. 73



N. FILLING UP VAPOR PHASE CONVERTERS WITH CATALYST

The charging of the vapor phase converters with catalyst is done on the reserve mounting structure near the stall(cf. A). The catalyst tube is inserted into the cold gas pipe line in the shops. A provisional structure is placed above the converter to charge with the catalyst. The catalysts (cylindrical pills 10 mm diameter and 10 mm long) are shipped in air-tight containers. The pills must be sifted before charging into the converter which is done as follows (see figure 73).

The large filling tube (5") is permitted to dip into the converter. The large filling tube is filled by means of a small filling tube with a valve. The large actual filling tube is now slowly lifted and refilled by means of a funnel. This is done to avoid breaking of the catalyst pills.

oooooooooooooooooooo

A new grate must be mounted after one layer of catalyst has been introduced. The grate is guided through the thermo-couple protection tube collars. The tubes are inserted for that purpose by means of heavy iron rods to prevent any bending during the lowering of the grate and the cover. The grates are tightened with asbestos cord in contact with the walls. The air concentration is very low in the converters during the filling (addition of N_2). The smith must go down into the converter with a compressed air mask. Provisions must be made for bringing the smith up.

oooooooooooooooooooo

When the grate is introduced, the loading with catalyst may be continued. When the actual filling tube has been raised sufficiently, a tube length of 1.50 m is unscrewed. Filling of blending converter with catalyst (1,000 x 18,000 mm) requires about 10 shifts with 10 men.

As soon as possible the filling must be covered up. No water may come in contact with the catalyst. The loading is done in a neutral atmosphere (to prevent oxidation) and for that reason a nitrogen pipe line is introduced underneath into the converter. Nitrogen is made to stream through all the while.

oooooooooooooooooooo

When the vapor phase converter is emptied (in an inclined position) some N_2 must be continuously passed through (possibly with cooling by means of dry ice). The catalyst is transferred into containers and sent over for regeneration. The catalyst of the vapor phase converters is frequently used for 2 years.

Dampers are introduced into the converter in order to get a good distribution of the gases as shown in figure 75.

The level of the temperature measuring spots in the converter is shown in figure 74. The construction of the inlets of the cold gas tubes into the catalyst tube is shown in figure 76.

Before the start of operations in the vapor phase converters, they must be blown out from top to bottom with N_2. The catalyst dust will in that way be for the most part removed. One can advantageously introduce N_2 through one of the available cold gas leads into the converter (figure 86). During the flushing the converter is opened from below.

FIG. 74

to follow N

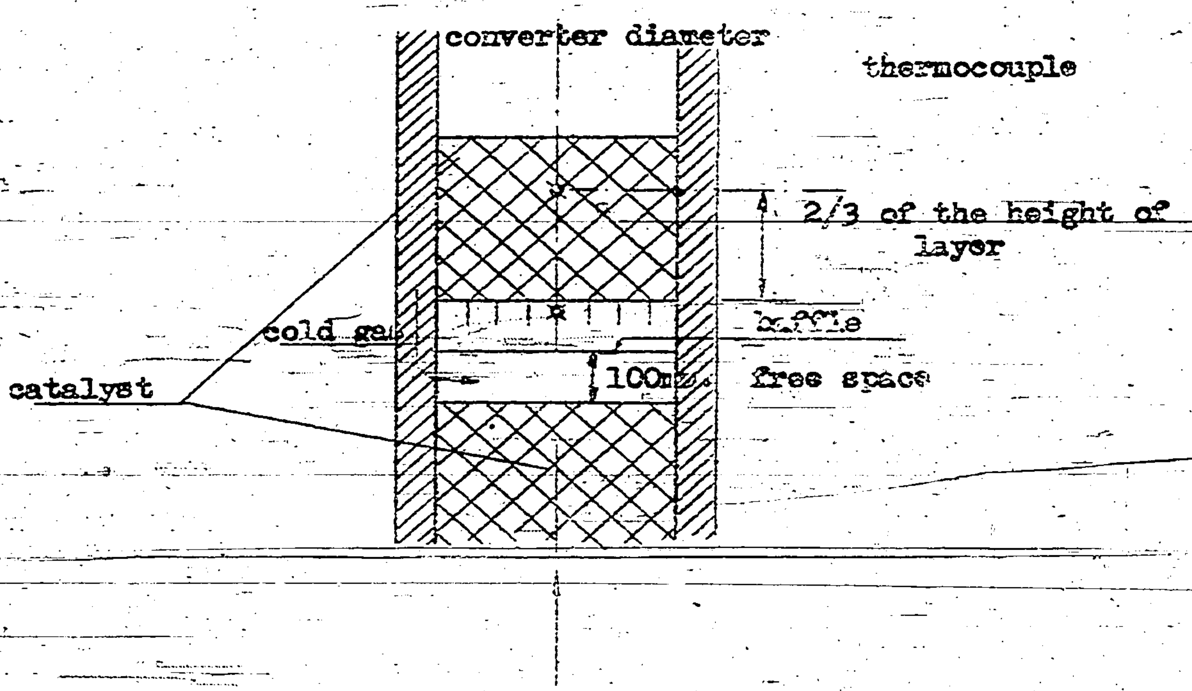


FIG. 75

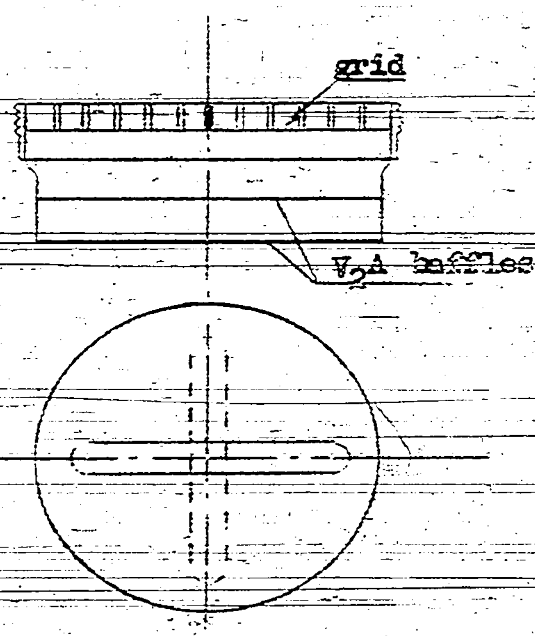
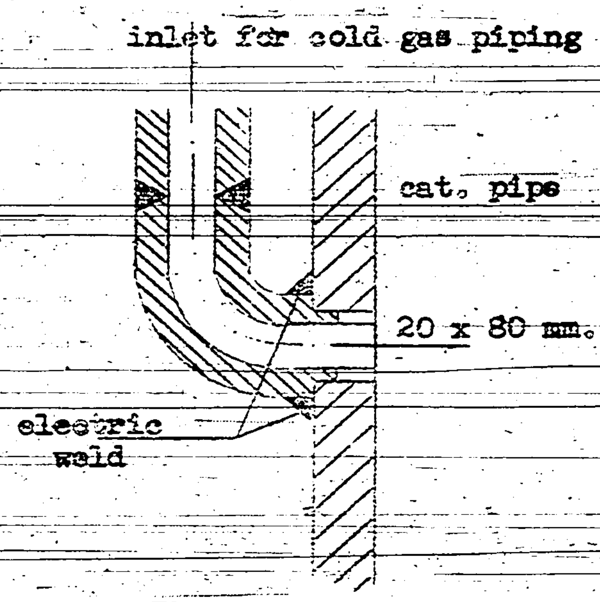


FIG. 76



C. STARTING OF GAS CIRCULATION AND INJECTION PUMPS.

These pumps are started as follows (figure 77):

1. Rinsing with H_2 (the by-pass around the pump must be closed !). Testing for O_2. The reserve pumps are kept under 10 - 20 atm. of H_2 to flush the stuffing boxes.
2. The suction and pressure emergency valves (hand operated) in the H_2 pipe line are opened. The oil valves remain closed.
3. The by-pass valves around the pumps are opened.
4. The pumps are washed with hand pressed oil in high pressure stuffing boxes. The regulating valve in the suction pipe line is opened (a by-pass for the oil valves).
5. When the pressure in the two pipe systems reached about 50 atm., machines are started.
6. The pressure in the pumps is permitted to rise until it becomes equal to the pressure of the main suction line. The regulating valve is closed.
7. The oil valve on the suction side is opened.
8. The pressure difference is regulated with a by-pass valve until the pressure in the pump becomes equal to the pressure on the pressure side (differential manometer).
9. The oil operated valve on the pressure side is now open.
10. By-pass closed.

INJECTION PUMPS (Figure 78)

New pumps must be run for 1 to 2 days without any pressure in order to work-in the pistons, the stuffing boxes and the drive, and the suction box and pump body must be filled with middle oil to prevent the pistons from running dry. The suction valves are raised; when this is impossible the oil must be returned through a high pressure pipe line into the tank without the use of any pressure. During purge directly into the suction piping the oil may become too warm, especially if the pressure is subsequently raised during the trial run.

The figure 78 shows schematically the piping. If geared drive is introduced between the motor and the pump, the driving oil must be changed as follows; after the first 400 to 500 hours of operation, then after 1,500 hours of operation, and finally after 4,000 additional hours of operation.

TRIAL RUN OF AN ELECTRICALLY DRIVEN 3 PISTON-PUMP

The following high pressure valves remain closed: 4, 6, 7, 9, 10 and 11.

To open:

The gate (1) in the suction line, high pressure valve 8 in the return; the purge low pressure valve 2 for taking

(over)

samples) must be closed. The auxiliary pump is to be started. The proper pressure for the suction box should be set with the gate 1.

The lubricating oil is to be pressed into the bearings with a hand pump and the oiler set for the plunger.

The suction valves are raised in the high pressure pump; the motor of the high pressure pump started, and immediately upon that the oiling of the bearings and of the drive is tested.

The pump is turned off after 2 hours and the oil screen of the drive lubrication is cleaned. The same is repeated after 4 further hours of operation until the screen remains clean. It is optional with the operator whether to close the suction valves or not. During this test-run the plunger may also be brushed with a brush by a man.

RAISING THE PRESSURE

After completion of the 1 to 2 days low pressure test-run, the pressure may be raised in the course of one day to the later required operating pressure. The setting of the valves is such as given above, and by a careful throttling of the valve 8 the pressure is developed in the pump with open suction valves. Only very dependable men must be permitted to operate this valve. The pressure is at first slowly raised to 50 atm. and kept at this pressure for several hours. The pressure then is very gradually raised to 100 atm., etc. Leaky stuffing boxes must be carefully tightened.

STARTING THE BUFFER TANK

Valve 10 is closed. The buffer vessel is filled with N_2 to the required operating pressure. N_2 is turned off.

The setting of the valves:

Valves 5, 7, 9, 10 and 11 are closed.

Valve 1 is opened, and only after that valves 4, 6 and 8.

The high pressure pump is started as described above and the pressure slowly raised by throttling the valve 8.

After the pump had reached the same pressure as the equalising vessel, valve 10 is opened.

Valve 8 is then to be completely closed and the pressure regulated by careful opening of valve 9. It only remains to open valve to start injections.

Valve 9 is used for continuous regulation of the pressure in the injection piping. Should there be too much nitrogen in the buffer, some nitrogen must be purged until the oil level may be seen in the level glass below.

POSITION OF THE VALVES OF THE AUXILIARY INJECTION PUMP

The following valves are closed:

1, (2), 4, 5, 7 and 8.

Valve 6 is opened and the suction valves are slightly opened.

SHUTTING OFF OF THE INJECTION PUMP AND STARTING THE AUXILIARY PUMP

Auxiliary Pump:

The slide 1 is opened.

The valve 4 is slowly opened and the pressure becomes established up to the return valve 3. Should it not be entirely tight the manometer at the outlet of the high pressure pump will rise. This in itself is not harmful because the pump valves will take up the pressure. Should these valves not be tight either, some oil will enter the suction line. For this reason the slide 1 must be first opened, as it may otherwise be pushed in.

The motor of the high pressure pump is started.

The suction valves on the auxiliary pump are opened individually and the suction valves of the other pump are simultaneously closed. The operator handling valve 9 must be previously instructed and supervised!

The Injection Pump: (to be shut down)

The motor is turned off.

Valve 4 is closed.

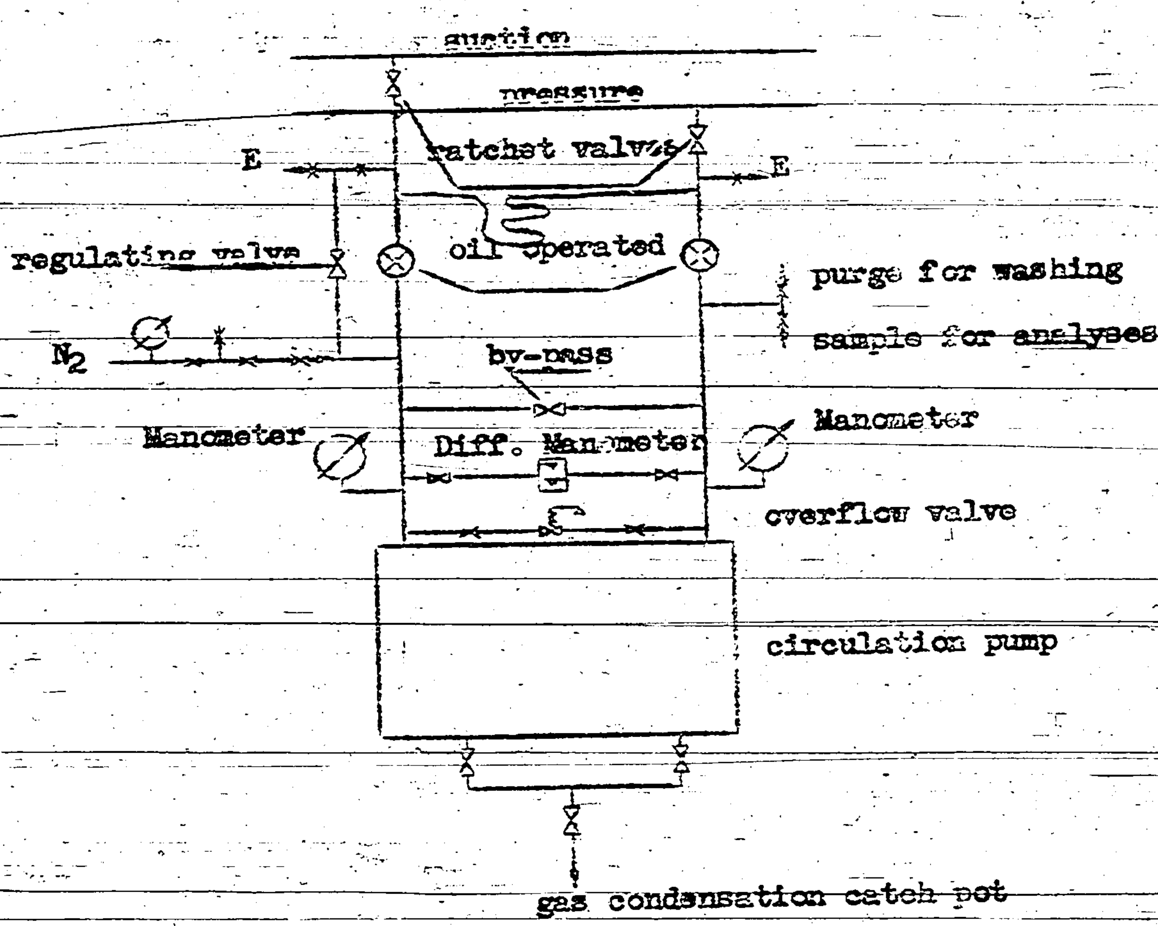
The pressure released in the pump by the opening of valve 7 (valve 8 is closed). If the pressure is not entirely relieved at the pump, the return valve and valve 4 are not tight. Valve 6 must in that case also be closed and the intermediate purge valve 5 must be opened. Only now may the slide 1 be closed. The manometer at the outlet of the high pressure pump occasionally still indicates pressure, while the pump pressure has actually already been relieved. Gentle tapping of the manometer will indicate the manometer indicator had stuck.

(over)

The safety valves on the pressure side are connected to a vessel filled from the bottom and kept continuously under CO_2. It is recommended to watch that the safety valves be not operated under normal circumstances, because it has been found from experience that after such a valve had once been opened it can in most cases not be completely shut down. It always leaks somewhat. It is preferable to have in this case two safety valves in parallel with the closing valves which can be used alternately. One of these valves may then be closed whenever the other is opened as is shown in figures 79 and 80.

to follow 0

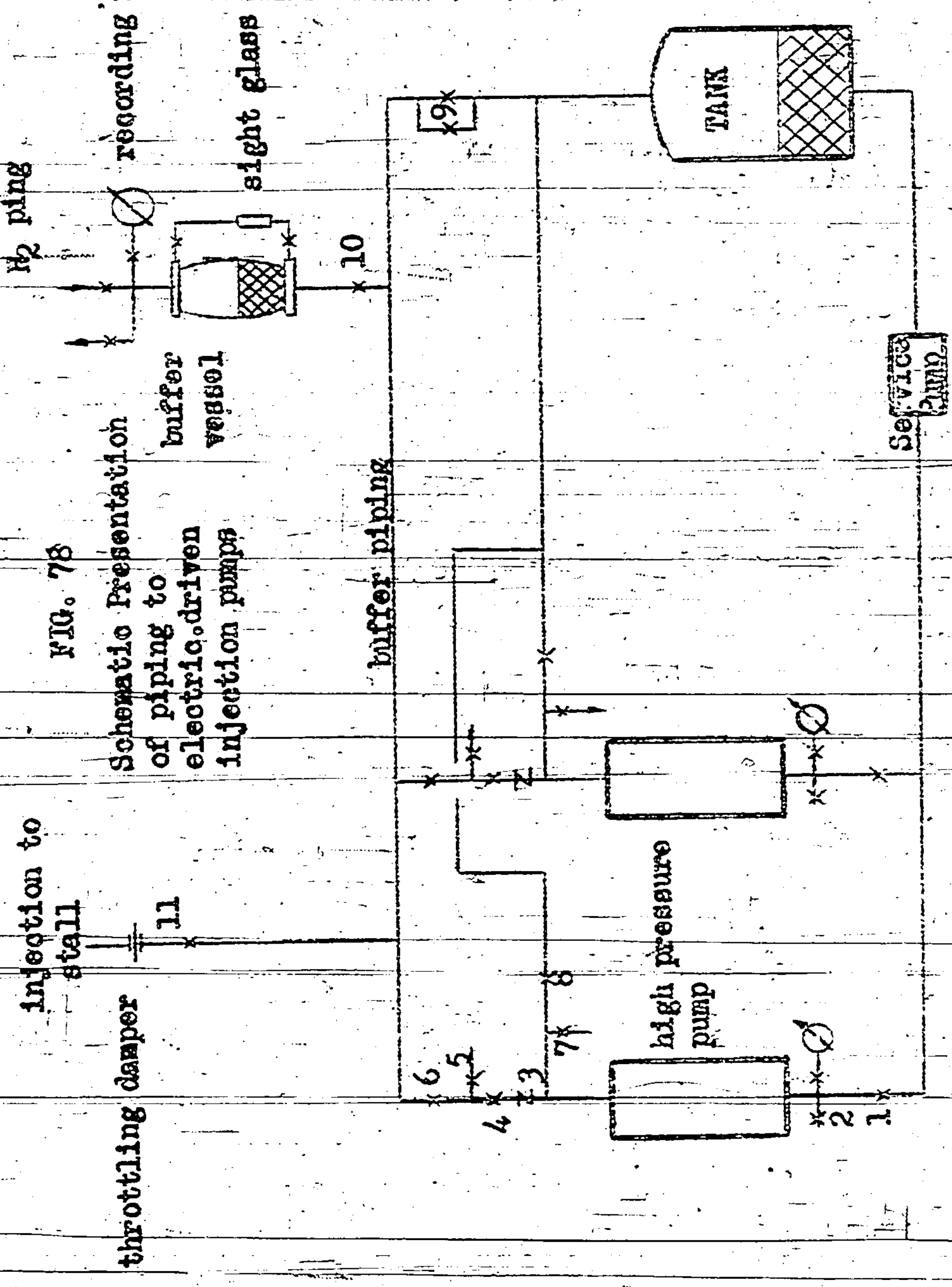
FIG. 77



to follow 0

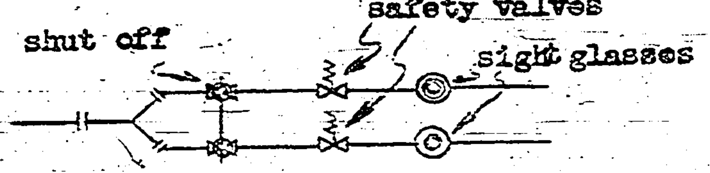
FIG. 78

Schematic Presentation of piping to electric-driven injection pumps



The safety valve and the manometer at the outlet of the high pressure pump have not been shown.

FIG. 79



shutting off, after fig. 80

FIG. 80

Safety valves middle oil injection

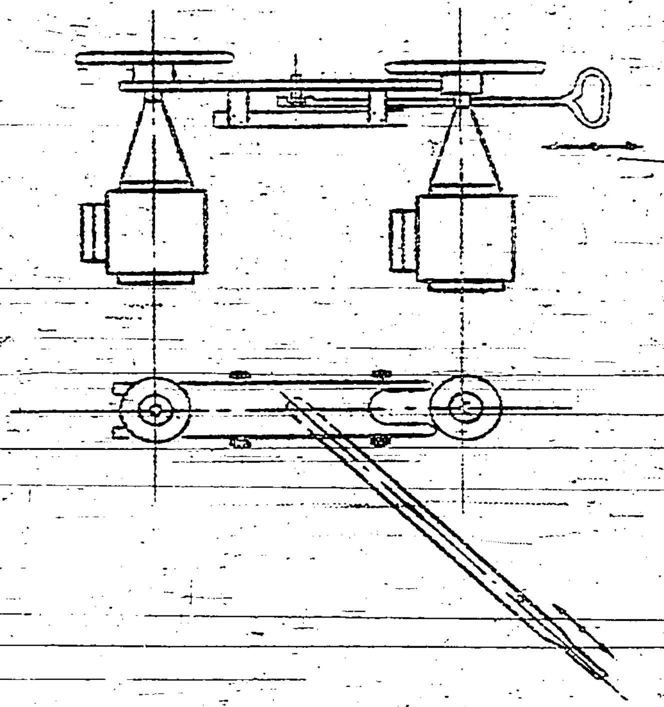
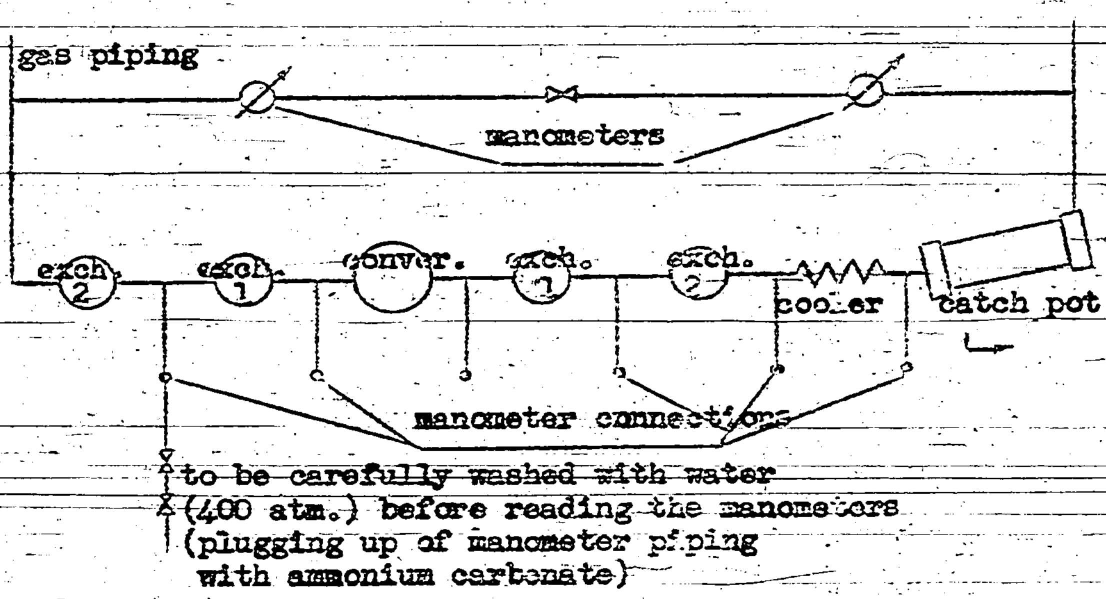


FIG. 81
resistance measurement



F. GENERAL REMARKS ABOUT SUPERVISION OF OPERATIONS AND INTERRUPTIONS

(a) Temperature control of the converter.

(b) Controls of the cold gas line and the thermo-couples belonging to it.

(c) Heat computations.

(d) Catchpots.

(e) Measurements of resistance in the stall.

(f) Catchpots and valves for pressure measurements.

Temperature controls of the converters.

(a) Should some temperature measured with thermo-couples be incorrectly indicated, if for instance the readings are too high, this does not always mean that operations do not proceed normally. Should one feel uncertain about temperature readings, the density recorder of the circulating gas should first be read off, and the density of the gas must be found to change rapidly with rising temperature. When the density remains normal the abnormal rise in temperature indicates an error in the measurement of the converter temperature and may prove the existance of a short circuit in the thermo-couple connections.

We may say in general that abnormal measurements must be interpreted in the light of the other instrument readings.

oooooooooooooooooooooo

The vapor phase stall and the converters must be continuously under observation (especially those with 5058 and for tar middle oil). When the temperature in one converter is too much out of line the following measures must be taken:

1. Power must be turned off.

2. Oil injection must be completely stopped (no fresh oil into the converters).

3. When the temperature in the line does not drop with a maximum cold gas addition but continues, to rise the gas must be purged.

One converter of the vapor phase stall gave successive readings of 21 - 29 - 30 mv while the amount of injection was 28,000 li/h, the injection gas 24,000 m^3/h, the outlet gas + 50,000 m^3/h. This amount of gas is not sufficient to lower the temperature and the operations of the stall should be handled as above (under 1 and 2). In a few hours the stall could again be operated normally.

(b) The cold gas line and the thermo-couples in the converters belonging to it were tested during the heating up of the converter. When the temperature of the stall had increased to 10 mv the cold gas is introduced through the different cold gas lines and a temperature drop must be indicated on the corresponding thermo-couples. These tests must be made in all the converters, from top to bottom and from the last converter to the first one.

(c) Heat computations. Below are the heat computations which must be carried out by the operating shift using some simplified methods and numbers.

We may use as an example a vapor phase stall (figure 82) which is operating with middle oil of a specific gravity 0.830 at 15°C. The injection is 25,000 li/h.

Amount of gas 30,000 m^3/h

	Heat Exchanger II (bottom)	Heat Exchanger II (above)	Heat Exchanger I (above)
Pressure side outlet	35°	180°	360°
Suction side	80°	210°	380°
Temperature =	45°	30°	20°

Water equivalent of oil: 25,000 x 0.830 x 0.6 = 12,220 heat units

" " " gas: 30,000 x 0.3 = 9,000 " "

Total 21,200 heat units

Specific heat:

Middle oil	0.6
Tar	0.5
Gas (H_2)	0.3

Radiation:

Heat Exchanger I	70,000 heat units)	for a heat exchanger of 500 mm
Heat Exchanger II	50,000 " ")	dia., 18,000 mm long

Heat Exchanger II $180^\circ - 35^\circ = 145^\circ$ (heating)

$145 \times 21{,}200 = 3{,}120{,}000$ heat units

+ Radiation 50,000 heat units

Given up by the oil vapors on the return pass: 3,170,000 heat units

Heat transfer: $K = \frac{3{,}170{,}000}{0 \times \Delta t}$, where 0 is the heating surface of the bundle of tubs = 150 m^2

$\Delta t = \frac{45 + 30}{2}$ = about 38

and K = 555 $kcal/m^2/^\circ C/h$

This K value is very high and is not reached under normal conditions. The temperatures were only estimated in this example.

We may assume an average heat transfer number with the thru-puts above and new heat exchangers as being 400.

One may normally calculate with K = 200 - 250.

As a maximum value K = 500.

This K value is recalculated for all heat exchangers every 3 days and entered in a diagram. The course of the curve for heat exchangers I and II is shown in figure 83.

Similar K values are found for the liquid phase heat exchangers (for tar and brown coal).

(d) The HOLD level must also be controlled (cold catchpot)!!

When the level in the HOLD drops too much, gas will enter from the oil line. The pressure in the suction line of the circulating pump will correspondingly drop very rapidly and this drop in pressure level will be immediately indicated on the double recording manometer (figure 84).

(over)

(a) Resistance measurements (figure 81).

Manometers are suitably located in order to give at all times a clear idea about the behavior of the different equipment parts and their resistance. Pressures are measured every 14 days and compared with previous readings. The sum of all the resistances is equal to the total resistance of the stall (double recording manometer). The readings are made with 2 precision manometers with mirror indicators (see C).

(2) Hot Catch Pot Flasks for pressure Measurements.

Pressure balances on the service side and their flasks are numbered to permit an immediate closing of the proper valves should any spiral capillary of these instruments burst.

The separation of the liquid during gas pressure measurements must be made by first closing two valves of the balance. The flasks are next emptied. The measurements of the liquid by means of the pressure scale require no catchpot flasks (unlike gas measurements). The instrument lines go directly from the valve to the scale.

FIG. 82

to follow P

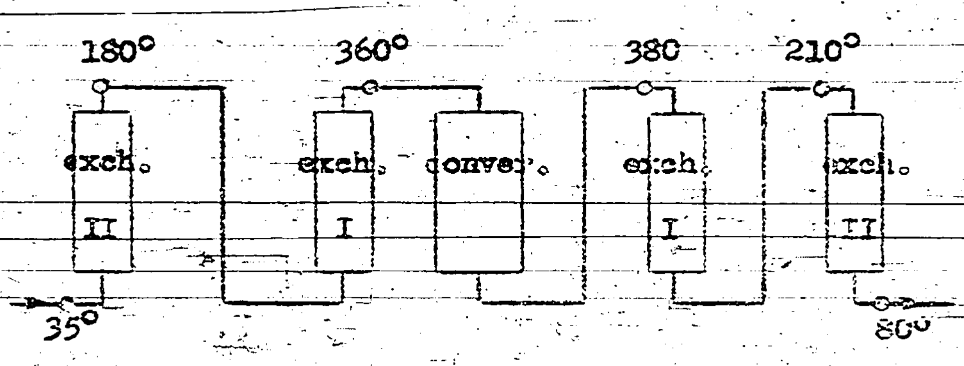


FIG. 83

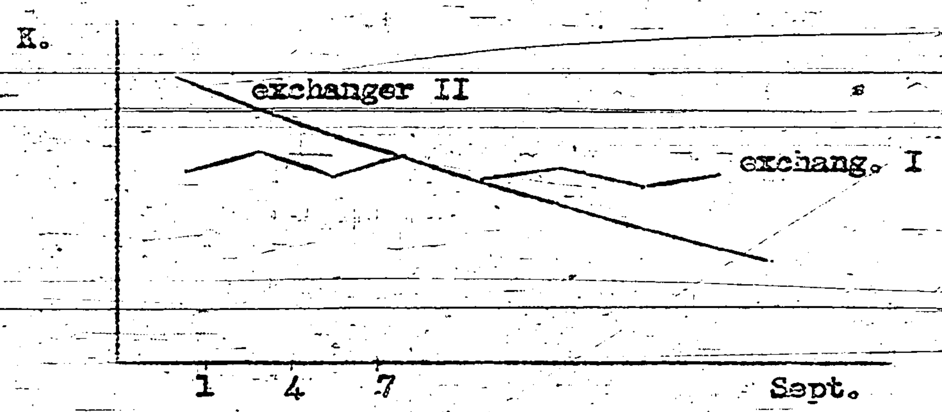
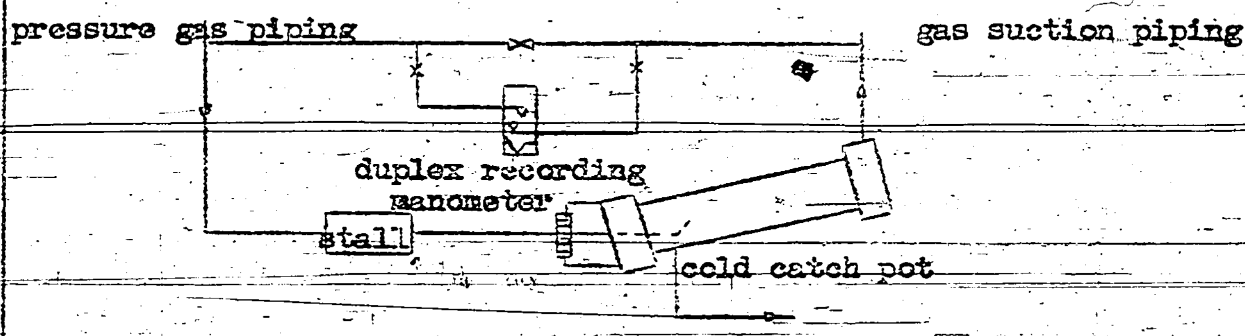


FIG. 84



Q. CENTRIFUGE OPERATIONS

The system Heybold with a horizontal well (periodically operated).

Capacity: ≅ 400 kg volume

n ≅ 1,200 rpm

Diameter of the basket - 500 mm

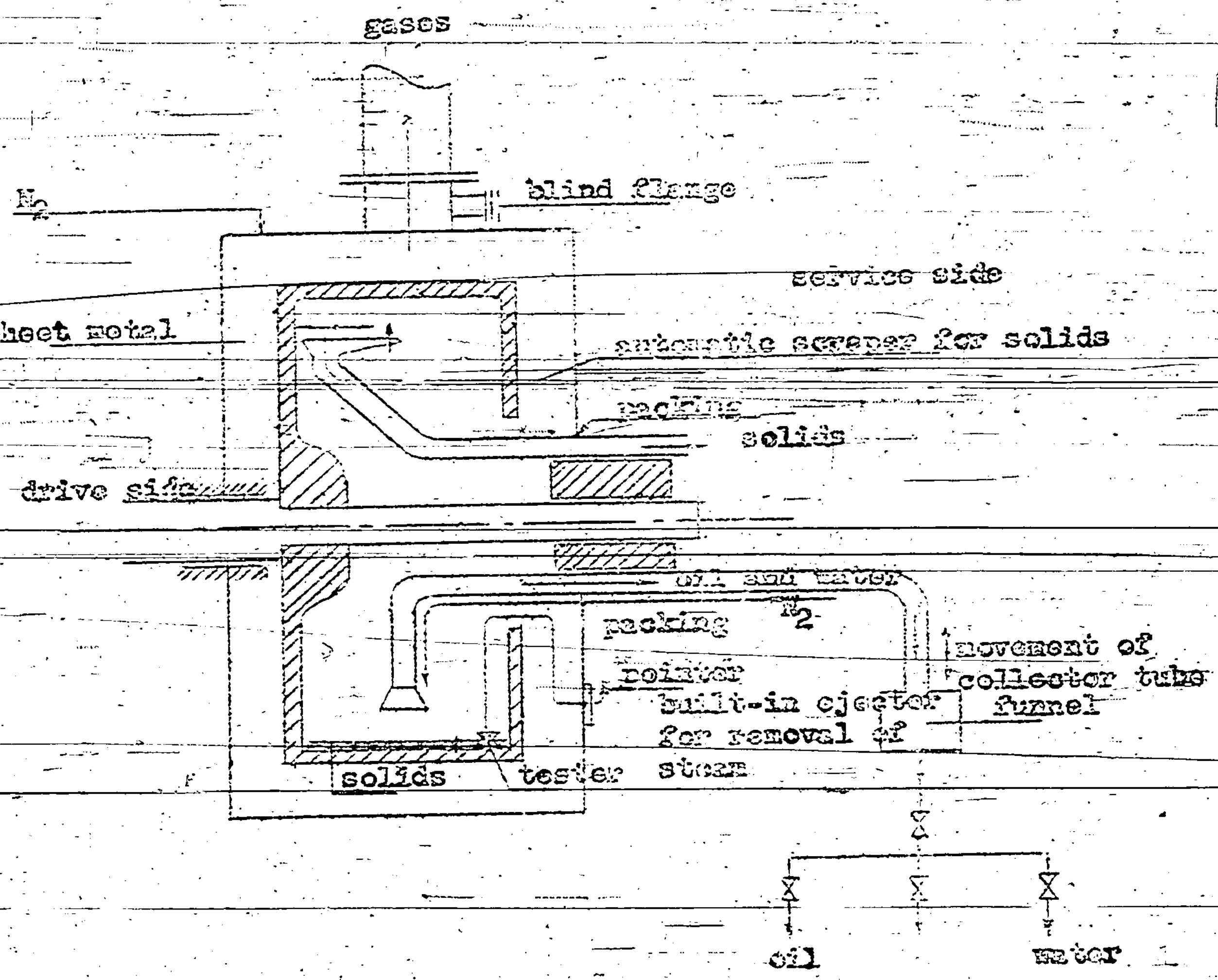
The oil to be fuged was supposed to contain 30% H_2O, 2% solids and the balance oil. The flash point was 32°C.

It takes about 4 minutes to centrifuge 400 kg of such oil. When the emulsion does not break a little acid is added. The receiving pipe can be radially moved from the inside out and removes oil first (figure 85), next comes water while the solid parts remain in the paste. When the solid layer becomes 30 to 50 mm thick, the solids are removed with a spoon. The spoon is made to move automatically forward and backward. The thickness of the layer is measured by means of a tester and indicated in the front of the machine. N_2 or CO_2 are continuously introduced during operations (no air admitted). A gas sampling tube and a blind gate are also connected to the gas outlet. Oil and water drain off into a funnel. The ejector sucks off the vapors and the entrained droplets.

The so-called scraping of the layer of the solid material is carried out at about 900 rpm (the drive is with reversible pole electric motors). The scraping requires about 10 minutes.

FIG. 85 to follow Q

Schemat. horizontal centrifuge



R. GENERAL REMARKS:

Flushing of pumps, pressure scales, etc.

Preheater for the liquid and vapor phases.

Packing valves.

Thermographs.

Fuel oil.

Catalyst pumps.

Groups of compressing valves.

FLUSHING OIL (Heavy Oil)

Catalyst Pumps:

Flushing oil connections on the packing boxes are provided in Leuna. The oil lubricates the stuffing boxes and the cylinder walls. The amount used up by these pumps amounts to about 120 li/h. The capacity of the pumps is at most 6 m^3/h. The normal thruput is 3 - 4 m^3/h. In the tar stalls, tar is used as the flushing oil for the catalyst pumps. In the opinion of the I. G., the oil used for this purpose should not be too light.

Hot Circulation Pumps:

These pumps must be connected to stuffing box flushing oil connections. Pressure scales for measurement of amounts of oil with flow point of over 30° are marked in such a way that the connecting lines of the throttling disk could be flushed continuously. With a pressure drop from 30 to 50 atm. the capillary tubes transmit some 20 li/h (figure 88). Attention must be paid to have the 2 capillary tubes transmit the same amounts. The initial pressure of the flushing oil is at about 300 atm. with a stall pressure of 200 - 220 atm. The flushing oil should be a middle oil fraction or washing oil.

Manometer.

The manometer piping connected to the heavy oil line must be flushed when the flow point of the oil is inconveniently high (see F under pressure scales). A capillary tube is introduced between the flushing oil piping and the manometer line and determines the amount of flushing oil (figure 88A)

PREHEATER OF THE COAL STALL # 8

A mixture of 2/3 of gases and of the paste is made to pass 2 sections of hairpins of the preheater, while 1/3 of the gases is heated up in the third section (figure 87). It is possible by a suitable distribution of gases to regulate the velocity of the paste through the preheater tubes not to exceed 8 m/sec. This maximum velocity is also admissable for a tar preheater. The gas velocity is limited by the resistance of the tubes.

(over)

Blowers.

The circulating gas blowers are driven by squirrel cage (Kurzschluss) motors. When starting, the valves on the suction side and in the stack are closed. The blower motor has a capacity of 72 KW (in the original a pencil mark: 3 200 KW). The high pressure motors are built for 6,000 volts. These blowers use normally about 7 amperes at 50 cycle frequencies. Number of revolutions 1,470 rpm.

Capacity: 30,000 N m^3/h of gas at 450°C of the flue gas temperature.

Pressure: 250 mm water column.

Preheater Vapor Phase:

Velocities of 15 m/sec. are permitted in the preheaters of the vapor phase, with the oil assumed to enter as a liquid while velocity computations are made.

PACKING OF HIGH PRESSURE VALVES

When a stall is closed down all the stuffing boxes of the high pressure valves are tested for permissible play, to permit additional tightening up during operations; should this prove insufficient the valves are replaced. Woven asbestos rope with rubber and graphite (Burgmann special) is used for packing. Burgmann sola without rubber is preferable. It is woven asbestos with graphite. No rubber packing should be used for hot valves or for oil valves.

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Steam Line Valves:

Schäfer and Budenberg use flocculated graphite for these valves (stamped in). The steel stems must be hardened and polished. There must be very little play room between the stuffing boxes, the pipe base and the stuffing boxes, the pipe base and the stem used. For several months in Leuna experimentally in H_2 lines (200 mm diameter slides).

Temperature Records.

There are 2 recording thermometers for each vapor phase in Leuna. Each indicates 6 temperatures (I and II):

I [illegible] + cold junction temperatures.

II For converter temperatures.

Driving Oil:

Refrigeration machine oil has been used for driving oil of the hot circulating pumps, paste pumps and catalyst pumps.

CATALYST PUMPS:

The catalyst pumps selected should not be too small. In this case the velocity will not be too great at normal operations. The suction and pressure valves of these pumps are ordered in Leuna to permit interchanging (great wear) instead of using valve boxes. These pumps are of the same type as the paste pumps.

COMPRESSION VALVE GROUPS:

All groups of gas valves and piping in the circulation gas system are to be compressed with N_2 at 220 - 250 atm. The blind slides then close the cold gas pipe line, gas line to the exchanger and the circulating gas line.

In this way many flanges, valves and stuffing boxes are tested and compression of the stall proper may take place at low pressures (saving in time).

Sternberg/mc/phl
7-10-1946

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FIG. 86

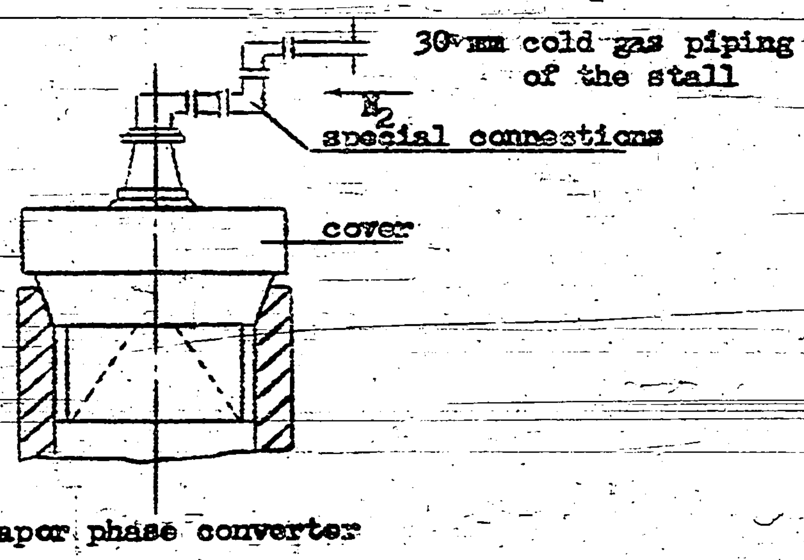

FIG. 87