XI. RAW AND FINISHED PRODUCTS.

(a) The raw materials used in making the final product are pure lignite, outside oil (tar oils, etc.) and petroleum. Seventy-eight (78) percent of the finished product comes from lignite and the rest from oil. The outside oil is partly used as diluent oil, and partly as feed to the cool stall effluent distillation unit, the boiling range, specific gravity, water and solid content, are fixed. All oils containing either water and more than twenty (20) percent middle oil are passed through the A-distillation unit. The remainder is mixed with diluent oil.

(b) Variations in quality of final product can be made in operational changes: reactor throughput, reactor temperature, coal paste injection, amount of catalyst and boiling range of middle and heavy oil.

(c) Properties of Pure Lignite Charge Stock.

The pure Rheinish lignite is easily decomposed chemically. However, the resulting oils are difficult to hydrogenate, requiring the high pressure seven hundred (700) atmosphere operation in the sump phase. This is apparently due to the high car-

XI. RAW AND FINISHED PRODUCTS.(c)(Cont'd.)

bon content in the lignite. The lignite seems to be mixed with decayed stumps and plants. The latter did not seriously affect operation after properly sifting the raw coal.

ANALYSIS OF THE LIGNITE

Water content	7.5 %
Ash content	6.0 %
Tar content (Fischer Test)	8.0 %

ULTIMATE ANALYSIS

C	67.76 %
H_2	5.10 %
O_2	25.30 %
N_2	1.10 %
S	0.75 %

ASH ANALYSIS

SiO_2	2.9 %
Fe_2O_3	22.5 %
Al_2O_3	4.1 %
CaO	45.1 %
MgO	4.9 %
SO_3	20.1 %

The underlined values play an important part in the process.

(d) CaO Content.

This is converted into $CaCO_3$ by the chemical decomposition of the lignite. This results in salt crust or "caviar" formation leading to serious operating difficulties.

(e) O_2 Content.

Due to its high value, twenty-five (25) percent, it uses up large amounts of hydrogen, two-thirds of it being converted into water in the process.

(f) Sulfur content.

It amounts to only 0.75 percent which is relatively low compared to lignites from middle Germany. Extra sulfur has to be injected to meet the sulfur content requirements of the catalysts.

XI. RAW AND FINISHED PRODUCTS. (Cont'd.)

(g) Outside Oil.

This consisted of shale oil, petroleum residue, hard coal tars, and lignite tars of aliphatic, naphthenic and aromatic character. Variations in the same produced different products. However, these variations were hardly felt in the final product due to the large part of hydrogenated lignite effluent used and the proper operation of the gas phase catalyst. By using too much road asphalt (over five (5) percent) as diluent oil, a highly asphaltic product resulted. Best results from hard coal tar occurred when the resulting middle oil end point was reduced from three hundred fifty (350) degrees to three hundred thirty (330) degrees centigrade.

(h) The final products were:

(1) Ordinary Diesel oil;
(2) Marine Diesel oil;
(3) Cold service Diesel oil for winter campaigns in Russia;
(4) Crude gasoline for the DHD plant of I. G. at Ludwigshaven - prehydrogenation only;
(5) Ordinary aviation gasoline;
(6) Ordinary $C_3 - C_4$ gas for automobiles;
(7) Special aviation $C_3 - C_4$ gas for use in aviation engines.

INSPECTIONS OF PRODUCTS

(1) Ordinary Diesel oil

Sp.gr. @ 15° C	0.8 - 0.885
Viscosity - Engler @ 20° C	1.1 - 2.6
Pour point	
Summer not over	- 10° C
Winter not over	- 20° C
Flash point over	21° C
Cetane No. - not under	35

INSPECTIONS OF PRODUCTS (Cont'd.)

(2)	Marine diesel oil	
	Sp. gr. @ 15° C	0.840 - 0.870
	Viscosity - Engler @ 20° C	1.2 - 2.6
	Cloud point	± 0° C
	Flash point not under	± 55° C
	Cetane No. - not under	35
(3)	Diesel oil (Russian quality)	
	Viscosity, Engler @ 20° C - not under	1.1
	Cloud point, under	- 30° C
	Pour point, under	- 35° C
	Flash point, over	21° C
(4)	Gasoline for D.H.D. unit	
	F.B.P.	165° C
(5)	Ordinary aviation gasoline	
	Sp. gr. @ 15° C	0.725 - 0.750
	I.B.P. not under	40° C
	10 % min. vol. 10	70° C
	50 % " " 10	100° C
	90 %	145° C
	F.B.P.	165° C
	Max. R.V.P.	0.5 @ 37.8° C
	API max.	52° C
	Octane No.	
	Motor method - clear	- 70
	+ 0.09 vol. T.E.L.	87
(6)	Normal C_3 - C_4 gas for automobiles	
	Vapor pressure	
	1.4 - 31.8 - minimum	0.7 atm. @ 0 °C
	- maximum	16.7 atm. @ 40°C
	1.9 - 31.3 - minimum	1.5 atm. @ -15°C
	- maximum	16.7 atm. @ +40°C
	H_2S - not over	0.2 mg/cu.met.
	Organic sulfur - not over	250
	Elemental sulfur	negative
	Mercaptan (Doctor test)	"
	NH_3	"

1-6

XI. RAW AND FINISHED PRODUCTS. (Cont'd.)

(7) Aviation C_3 - C_4 gas for aviation motors

C_4	70 - 80 %
C_5	20 - 30 %
Max. H_2 content	5 %

Vapor pressure not over 2 atm @ 0° C
Other specs. as per normal power gas requirements

All the above specs. were met. only the winter quality Russian Diesel oil failed to meet its cloud point test.

XII. STEELS IN THE HYDROGENATION UNIT.

(a) The great technical development of the high pressure hydrogenation process would be impossible without the existence of suitable steels for the high pressure apparatus. The steels must be safe in regards to the high pressure requirements, but in addition the apparatus must not be too heavy and unmanageable. It must in addition be resistant against H_2 and the corrosive influx of the products of hydrogenation, especially of the contained H_2S. In zones of high temperatures, they must be able to meet the special properties.

(b) These requirements are met only by alloy steels, which have been given a special treatment. Especially suitable are the V_2A steels, which are mixtures containing over twenty-five (25) percent Ni and Cr. The faults of these aloy steels forced the development of other steels with lower impurities. It is to the credit of the I. G. Farbenindustrie that they produced such special steels, having strength meeting the requirements of the high pressure hydrogenation with a metal of lower alloy content. Through a specific heat treatment, the steels are given a structure, which gives them great mechanical strength and high resistance against chemical attack. The treatment consists in prolonging the heating in the austenitic region, quenching and short tempering. The heating and the quenching make the steels hard, but brittle. Through the tempering the hardness and brittleness again will be partially raised. The steels receive by this means a sufficient toughness for working safety.

(c) The added tabular groupings give an insight into the hitherto developed steels and their distribution for individual

HIGH PRESSURE 325 Atm

Applications of the Working Materials

Temp. Stage	Operating Temp. C	Nominal Range	Applicable Material for: Tubes	Formed Pieces	Blind Flanges	Screw Flanges	Bolts	Nuts	Lenses
I	0-200	6-16 16-160 200	St.45.29 St.35.29	S2	S2	S1	S3 K4Ms K1,K1MS	S3	S2
II Now 200 - 400°C	200-400	6-200	N8A	N8A	N8A	K4MS,K1, K1MS	K4MS,K1, K1V,K1CV K1MS	S3	N5A
II Previously 200-480°C	200-480	6-200	N8	N8	N8	K3,K3CV	K3,K3CV	S3	N5
III Now 400-510°C	400-510	6-200	N9	N9	N9	K3CV K3	K3CV K3	S3	N6A N5
III Previously 480-510°C	480-510	6-45 58-200	N8 N8V,N10	N8 N8V,N10	N8 N8V,N10	K3,K3CV K3,K3CV, K5,K5V	K3,K3CV K5,K5V	S3 K1MS,K3 K1V,K1CV	N8 N8A

HIGH PRESSURE 700 Atm

Applications of the Working Materials

Temp. Stage	Operating Temp.°C	Nominal Range	Applicable Working Materials for: Tubes	Formed Pieces	Blind Flanges	Screw Flanges	Bolts	Nuts	Lenses
I	0-200	6-16 24-160 except 135 135	K2N K2	S3 S3	S3 K4MS K1 K1MS	S1 K1 K1MS	S3 K4MS K4MS K6	S3 S3,K1, K1V,K1CV	S2 S3
II Now 200-400°C	200-400	6-45 58-160 except 135 135	N8A	N8A	N8A	K4MS,K1 K1MS K4MS,K1 K1,K3 K3CV	K4MS,K1 K1V,K1MS K4MS,K1,K1V K4MS K6	S3 S3,K1,K1V K1CV	N5A N6 N8A
II Previously 200-420°C	200-420	6-160	N8	N8	N8	K3,K3CV	K3,K3CV	S3	
III Now 400-510°C	400-510	6-16 24-45 58-160	N9 N10,N8V N9	N9,N8V N8V	N9,N8V N8V	K3CV K5,K5V K7	K3CV K5,K5V K7	S3 K3,K1V K1CV K1MS	N5A N8
III Previously 420-510°C	420-510	6-160	N10W	N10	N10	K7 K5,K5V	K7 K5,K5V	K1MS K3,K1CV	N8A

XII. STEELS IN THE HYDROGENATION UNIT. (c)(Cont'd.)

working purposes. An attached formulation shows the timely development of the steels, their composition, strength properties, the methods of their testing, as well as the art of the heat treatment. First named are the steels, which could be employed for the cold parts of the apparatus of the original two hundred (200) atmosphere working pressure apparatus. These are ordinary carbon steels, in part with a low Cr addition. For the hot parts of the apparatus were developed (see in part) the N1 to N8 steels. N1 is the standard steel for the high pressure vessels. For all other purposes, N8 will be employed especially for piping at high temperatures. The principal characteristics of these steels is their Cr content which usually amounted to three (3) percent. The remaining elements are Mo and V, which are used in the amount of 0.5 percent. These steels have the advantage of needing only a local tempering after welding, while the later developed steels must be heated in a furnace.

(d) After the introduction of the higher pressures of seven-hundred atmospheres, the strength qualities of S-steels no longer sufficed for cold piping, one bought steels, which had a Brinell hardness of seventy (70) to eighty (80) instead of the hitherte fifty (50) and sixty (60). Such steels would be made under the designation K-steels. They differed from the S-steels through a Cr content of about one (1) percent and a lower Mo composition.

(e) For the hot seven hundred (700) atmosphere apparatus the N8A to N10 and some K-steels were used. Of these K5 and K7 are outstanding. All of these steels contain V. Another characteristic is the somewhat higher C content of the K-steels.

(f) The best developed steel for high temperatures is the N10 steel with a creep strength of sixteen (16) at five hundred fifty (550) degrees centigrade. It is employed for the most stressed tube piping and bends of the seven hundred (700) atmosphere apparatus, expecially for the hot preheater tubes.

(g) The lack of tungsten and molybdenum forced the preparation of substitute steels, such as the N8A, N8V, N9, K1CV, K3CV steels. In these, the contents of V and Mn was increased.

XII. STEELS IN THE HYDROGENATION UNIT. (Cont'd.)

(h) When chrome also became scarce, Si was added. Thus originated the seven hundred (700) atmosphere steels K1MS and K4MS. Al of the last named steels could not be used under normal conditions. The added summary about the availability of the material for the separate apparatus of high pressures are presented to help installation men. The adjacent table "Material summary for high pressure 325 and 700 atmospheres" gives the classification indicating the steels, that would be available for the duration of the war.

THE CONSTRUCTION STEELS IN THE WESSELING HIGH PRESSURE WORKS

For 325 atmospheres	
High pressure hollow vessels	N1
Cold tubes	S2
Hot tubes	N8, N8A, N10
Gas preheater	N8, N8V
Electric preheater	N8, N10
Formed pieces	S2, N8, N8A, N9, N10
Lenses	S2, N5, N5A, N8
Flanges	S1, K1, K3, K3CS, K4MS
Bolts	S3, K1, K3, K3MS, K5
For 700 atmospheres	
High pressure hollow vessels	N1
Cold tubes	K2
Hot tubes	N8, N8A, N10
Gas preheaters	N8, N8V, N9, N10
Formed pieces	N8, N8A, N9, N10
Lenses	S3, N5, N5A, N5C, N8
Flanges	K1, K3, K3CV, K5, K4MS
Bolts	S3, K1, K3, K3CV, K4MS, K5, K6, K7

(i) The preceding expose of the correct application of the steels is a reliable control for average strength values. The minutest detail must be watched, since the improper application of the smallest parts of the apparatus such as bolts and lens packings can cause trouble.

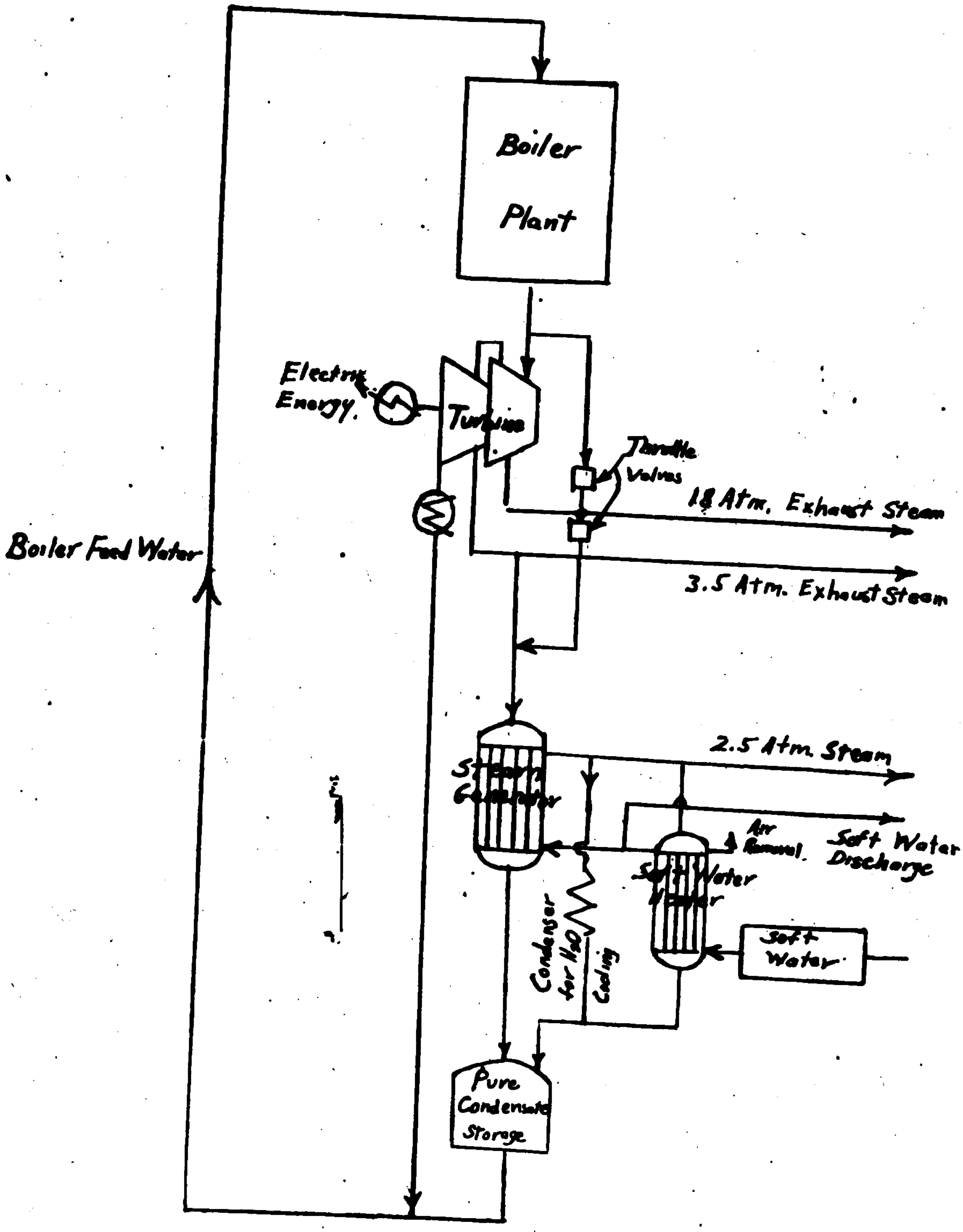
(j) The supervision starts with the analyses. There are two methods available: the quantitative complete analysis; and the rapid, or so-called spot method. The latter consists in a

STEELS FOR HYDROGENATION [illegible] QUALITY

[illegible]

Treatment Conditions	C	Mn	Si	Cr	W	Mo	V	Strength Kg/mm²	Min yield point Kg/mm² @ °C. 20	200	300	400	Min Elongation %	Notch Toughness mkg/cm²	Min [illegible]	Creep 450	Strength [illegible]	Kg/mm² 550	@ °C.	Heat Treatment Forging °C	Annealing °C	Hardening °C	Cooling Medium	Tempering °C
Normal	0.20-0.24	0.60-0.80	0.20-0.35					50-60	27				20	6						1050 - 850	700	870	Air	
"	0.15-0.20	0.40-0.60	0.20-0.35					40-48	-				26	10						1100 - 850	680	880	"	600 - 680
"	0.31-0.35	0.50-0.90Max	0.20	0.30-0.50				50-60	30				26	6						1100 - 850	680	850	"	"
"	0.18-0.25	1.10-1.30	0.20-0.40					50-60	30				24	6						"	650 - 700	"	"	500 - 580
"	0.22-0.29	0.55-0.90Max	0.30	0.30-0.50				50-60	30				26	6						1150 - 880	650 - 700	"	"	600 - 680
"		"						50-60	30				24	6						1050 - 800	"	"	"	500 - 580
Oil Temper	0.22-0.30	0.40-0.60	0.20-0.35	2.50-3.00		0.20-0.35		65-77	45	35			15	6						1100 - 850	700 - 750	900 - 950	"	650 - 700
Air	0.17 Max	0.30-0.50	0.20-0.40	"		0.20-0.30		50-60	30				20 lg	maximum						1050 - 850	750	"	"	700 - 750
"		0.40-0.80	0.25-0.35	"			0.10-0.20	50-60	35				22 lg	10						1100 - 850	"	900 - 1000	"/oil	"
"		0.30-0.50		"				50-60	-				22 lg	maximum						1050 - 850	"	950 - 980	"	"
"	0.1-0.2		"	"			0.10-0.20	50-60/55-65	30-35		20-27		20-17-18	6 6						1100 - 880	"	900 - 1000	"	"
"			"	8.5 Min.		0.35-0.45	0.10-0.20	60-75	35				18	maximum						"	"	950 - 970	Air	650 - 750
Oil		0.30-0.40	"	2.50-3.00	0.40-0.60	0.40-0.60	0.05-0.15	65-80	45			35	18	6	35	20	10			1100 - 900	700 - 750	950 - 970	oil	650 - 750
"	0.25-0.35	0.50-0.80	"				0.25-0.35	70-85	50			35	16	0.1/5 qu	35					"	"	950 - 980	"	650 - 700
Air	0.18-0.23	0.40-0.60	"	"		0.40-0.60	0.40-0.50	80-95	55-60				16	10.6 - 8.5			17	12	7.5	1050 - 850	"	1000 - 1050	"	650 - 680
"	0.19-0.24	"		3.00-3.50		0.30-0.30	0.45-0.55	80-95 75-90	55-60				16	10.6 - 8.5			17			"	"	1000 - 1050	Oil or Air	650 - 680
"		0.30-0.40	"	2.50-3.00	0.35-0.45	0.35-0.45	0.70-0.85	80-95 70-85	55-60				14	10.6 - 8.5		25	30	16	11	1100 - 900	700 - 740	1050 - 1080	"	650 - 750
"					0.30-0.30	0.25-0.35	0.80-0.90	80-95 70-85	55-50				14	10.6 - 8.5		25	30	16	11	"	"	"	"	650 - 750
Water	0.28-0.33	1.00-1.30	0.50-0.80	1.00-1.30				70-80	50				16 lg 12qu	7 lg 6 qu						1050 - 850	700 - 750	880 - 880	Water	620 - 680
"	0.2			1.8			0.2	70-85	50	38	34	30	17	6	38	15	8			"	700 - 750	950	Oil	600 - 680
"	0.28	1.2	1					70-85	50				16	6						"	"	"	"	"
Oil-Air	0.23-0.28	0.60-0.90Max	0.40	0.90-1.10		0.20-0.35		60-70	38				15	maximum						1100 - 850	"	220	Oil or Air	"
"		0.60-0.80	0.20-0.30	0.90-1.10				60-70	38				15	maximum						"	700 - 750	"	"	"
"		1.2 -1.5	0.4					55-60	40				18	maximum						"	"	"	Oil	600 - 660
Water	0.28-0.30	0.50-0.70	0.20-0.30	1.0 -1.2		0.14-0.30		70-80	50				16	6						"	"	950 - 980	Water	640 - 680
"	0.2	0.7		1.2			0.25	70-80	50				17	8	30	30	10			1050 - 850	700 - 730	860	Oil	600 - 680
"	0.33-0.40	1.1 -1.4	1.1 -1.6					80-90	60	45		40	14	6	15	10	5			1100 - 850	680 - 720	880	"	680
Oil	0.20-0.28	0.60-0.80	0.25-0.40	1.3 -1.6		0.50-0.60	0.30-0.40	80-95	65	60	56	50	16	8	45	36	26	8		1100 - 900	700 - 750	960 - 1000	" or Wat.	650 - 680
"	0.4 -0.5			1			0.2	90	60	45			14	6						1050 - 850	700 - 730	850	Oil	600 - 680
"	0.3	1.0		1.8			1.2	80-95	60				16	6 - 6	40	30	30	10		"	700 - 720	1000-1050	" or Air	640 - 680

FIG. 27


Boiler Plant
Electric Energy
Turbine
Throttle Valves
18 Atm. Exhaust Steam
3.5 Atm. Exhaust Steam
Boiler Feed Water
Steam Generator
2.5 Atm. Steam
Air Removal
Soft Water Discharge
Soft Water Heater
Condenser for H2O Cooling
Soft Water
Pure Condensate Storage

XII. STEELS IN THE HYDROGENATION UNIT. (Cont'd.)

moistening of the piece under observation with H_2SO_4, HNO_3, or HCl, and observing the formation of colored spots. In conclusion, all installed apparatus was tested first by the quantitive method and second by the spot method.

(k) Another point of interest is the characteristic of the materials. All larger pieces of apparatus, formed and tube pieces, are marked with stamps, showing the type, the current application, and tests used to show the correct application and testing. With smaller parts, as lense packing, bolts, etc., the material is recognized through grain or similar ways.

(l) The supervision of the correct installation of single pieces of working apparatus is followed closely by outlines and sketches, on which the technical material data of each construction part is recorded. The lists would be changed after each repair.

(m) It should be stressed that the nearly four (4) years of plant operation not a single working stoppage occurred through material failure or incorrect material application.

C. UTILITY PROCESSES.

I. THE POWER PLANT.

(a) The power plant supplies the factory with steam, power, soft water, and condensate (Fig. 27). The maximum demands of each of the above quantities is as follows:

(1) Electric energy - 80,000 kilowatt;
(2) Demand of 18 atmospheres steam - 25 tons per hour;
(3) Demand of 3.5 atmospheres steam - 30 tons per hour;
(4) Demand of 2.5 atmospheres steam - 180 tons per hour;
(5) Feed water at 185° C - 50 tons per hour;
(6) Pure condensate 50 - 80° C - 25 tons per hour.

(b) From the above steam quantities, one hundred (100) tons per hour of condensate are returned to the power plant.