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.

I. THE POWER PLANT. (Cont'd.)

(c) The power plant contains the following units:

(1) Boiler house with coal conveyors and preparation;
(2) Turbo-generators, low pressure steam generator, water purification and pump unit;
(3) Electric control station.

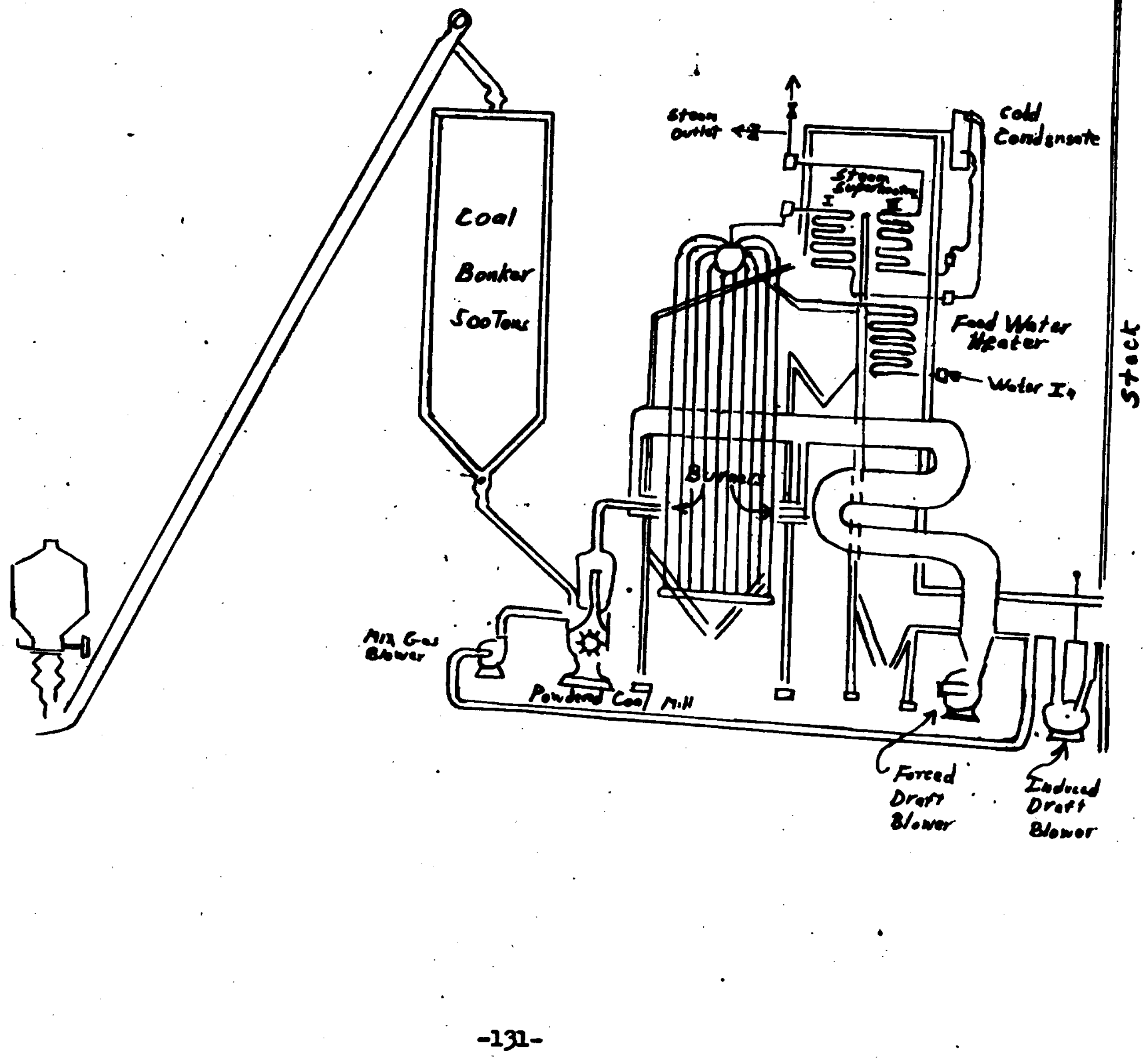
(d) In the boiler house high pressure steam at seventy (70) atmospheres pressure is produced. This is run through turbines, producing electric energy in three (3) stages: at eighteen (18), 3.5, and 0.4 atmospheres. The largest quantity is expanded to 3.5 atmospheres whence it goes to an exchanger-generator. By indirect exchange the 3.5 atmosphere steam in contact with 2.5 atmosphere soft water converts the latter into the steam. In this way the total condensate from the turbines is saved for boiler use and is not contaminated with other water streams. The loss and make up of other steam takes place in distillation unit.

(e) The 2.5 atmosphere steam is made from soft water which is made from treated plant water. This is done by decarbonization through milk of lime, Permutit softener, and a heating of above one hundred ten (110) degrees centigrade in order to remove the dissolved oxygen.

(f) In order to care for variations in electric load the turbines were equipped with condensers which allow for increasing the power from the turbines with the same boiler capacity.

(g) The boiler house (Fig. 28) is equipped with five (5) boilers, each capable of producing sixty-four (64) to eighty (80) tons of steam per hour at eighty (80) atmospheres and five hundred (500) degrees centigrade. Four (4) more boilers were almost completed. The boilers are of the flash type (one drum) with integral feed water heater and steam superheater. They also have air preheaters and pulverized coal burners. The temperatures are controlled by Askania regulators, which inject condensate into the superheated steam flow to maintain five hundred (500) degrees centigrade. Boiler feed water is fed through two (2) types of pumps, electric or steam turbine driven. In order to remove scale forming components, a constant blow down of two (2) percent is maintained.

FIG. 28
Boiler House



I. THE POWER PLANT. (Cont'd.)

(h) The fuel is dried lignite having fifteen (15) percent water content. Also, provision is on hand to use briquette fines and semi-coke dust from the gas plant, as well as excess tail gas from the hydrogenation unit. The coal is transported in special railway cars, in an atmosphere of CO_2. Each boiler is equipped with five (5) pulverizing mills. The combustion gases are removed from the boilers at one hundred eighty (180) to two hundred (200) degrees centigrade through a smoke stack one hundred (100) meters high whose natural draft is augmented by an induced draft fan. The expansion of the boiler house called for a second stack. The ashes are removed from the combustion chamber by a water slurry and pumped into a catch basin.

(i) The original plan called for four (4) steam turbines with condensats. Later two (2) back pressure machines were installed. The turbines discharged ninety-five (95) tons per hour of exhaust, of which thirty-two (32) tons per hour passes through the condensers. In straight condensing operation, a maximum of eight thousand (8,000) kilowatts can be produced. A maximum load requires ninety-five (95) tons per hour of steam which amounts to eighty (80) tons per hour of exhaust at 3.5 atmospheres. Under such operations thirteen thousand (13,000) kilowatts can be produced. For generating one thousand (1,000) kilowatts, twenty (20) tons of steam at eighteen (18) atmospheres or seventeen (17) tons of steam at 3.5 atmospheres or four (4) tons of condensate are required. The generators are so built that when loaded to thirteen thousand (13,000) kilowatts, the resulting power factor is 0.8. The voltage of the generators is six thousand (6,000) volts.

(j) Each turbine has three (3) stages. The first expands from forty (40) to eighteen (18) atmospheres and as such produces the eighteen (18) atmospheres plant steam and the superheated steam for the 2.5 atmosphere steam operation. The temperature of the eighteen (18) atmosphere exhaust is held constant at three hundred (300) degrees centigrade by injecting condensate. The second expansion stage produces 3.5 atmosphere steam which also indirectly produces the 2.5 atmosphere steam for the generator. To cool the condensate the compressor cooler water from the gas plant is used. Its temperature is approximately seventy (70) degrees higher than the temperature of the plant water system.

I. THE POWER PLANT. (Cont'd.)

(k) All turbines are equipped with over speed trips which automatically operate above three thousand (3,000) revolutions per minute.

(l) The boiler house can continue to supply plant steam even if the turbines are not in operation by means of the throttle stations which reduce the boiler pressure to the various plant requirements.

(m) In order to convert the 3.5 atmosphere extraction steam from the turbine to 2.5 atmosphere plant steam, six (6) exchanger-type steam generators are used. Each can produce forty (40) tons per hour of 2.5 atmosphere steam, and by raising the pressure from 2.5 to 4.5 on the high pressure side, the out-put can be raised from forty (40) to fifty-five (55) tons per hour.

(n) The generator is fed with soft water. In order to remove scale formation, approximately three (3) percent of the soft water is blown down constantly. The soft water is stripped of its oxygen before entering its generator by heating to one hundred five (105) degrees centigrade and then further warmed to one hundred thirty (130) degrees. This heating is done by 2.5 atmosphere steam.

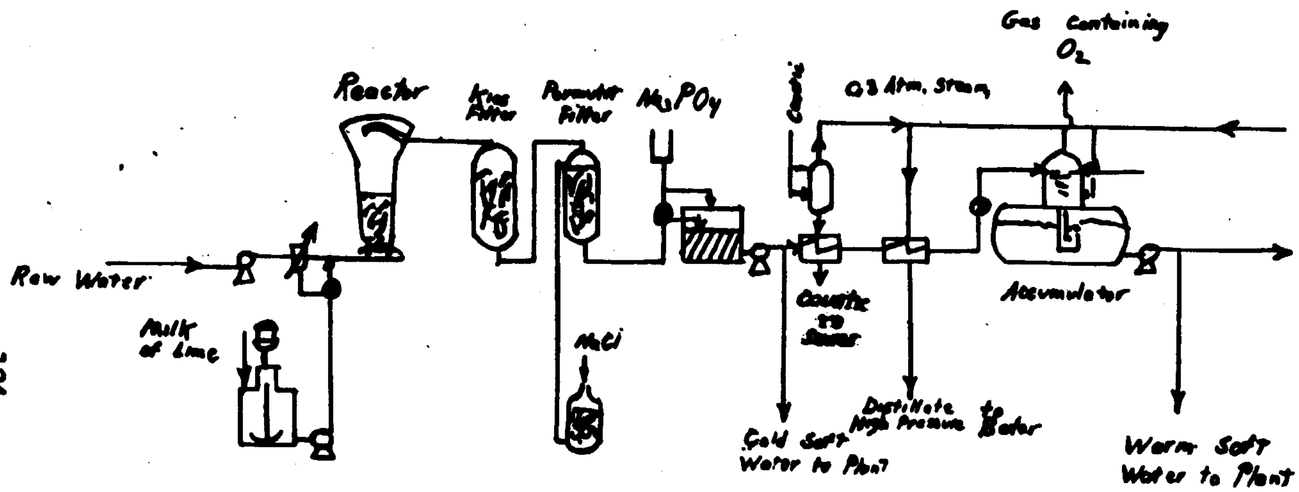
(o) The soft water used in making the 2.5 atmosphere steam is made from plant water which passes through the calcium softener, Permutit unit and de-aerator (Fig. 29).

(p) The softening is done by adding milk of lime in the so-called agitation reactor which is filled with small particles of marble. The plant water is quickly mixed with calcium hydroxide which combines with the total CO_2 content and converts the calcium bicarbonate to calcium carbonate. The result calcium carbonate settles out on the marble balls in solid form. When the marble particles become too large they are renewed.

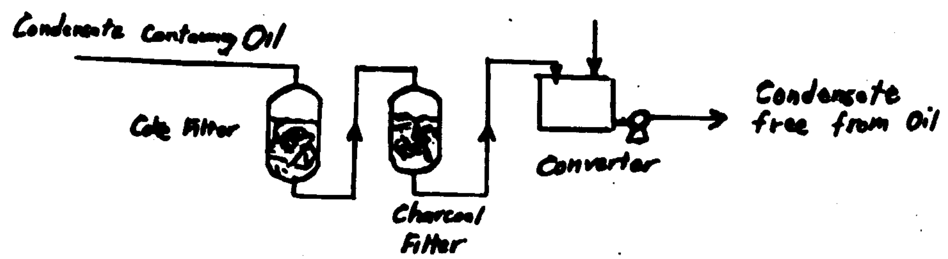
(q) After leaving the agitation reactor the water passes through a Kies filter in which the large particles are removed, and enters the Permutit filter. This is filled with a zeolite which works by a standard well known process. Finally to remove traces of calcium carbonate, Na_3PO_4 is added. The water is then

FIG. 29

Flow Sheet of Water Softener



Flow Sheet of Plant Water Unit



I. THE POWER PLANT. (q)(Cont'd.)

freed of oxygen by heating. The degassed soft water is now taken to the generator and vaporized. In order to prevent scale formation on the tubes, two (2) to three (3) percent of distilled water is constantly added while the same quantity is blown down.

OPERATING DATA 1943

Avg. No. of boilers on stream	4.02
Avg. load boilers	60.5 tons/hr
Avg. No. of turbines on line	3.05
Avg. Load each turbine	11,542 kw.

FUEL DEMAND

Boiler coal	38.45 tons/hr
H_2O content of coal	15.07 %
H_u - Kg. cal/kg	4,692

PRODUCTION
70 Atm. Steam

Production	244.11 tons
Used - boiler feed pumps	1.10
Used - turbines	235.39
Used - reduction - throttle	1.92

TURBINE EXHAUST

Condensate	40.58 tons
3.5 atmosphere steam	170.11 tons
18 atmosphere steam	24.70 tons
Loss	— —
Total exhaust	235.39 tons

STEAM TO FACTORY

18 atm. steam	14.66 tons
3.5 atm. steam	17.99 tons
2.5 atm. steam	110.88 tons
Condensate - de-oiled	33.46 cu.met.

I. THE POWER PLANT. (Cont'd.)

STEAM TO FACTORY (Cont'd.)

Turbine condensate	6.24 cu.met.
Soft water - worm	90.61 cu.met.
Soft water - cold	26.10 cu.met.

ELECTRIC ENERGY

Produced in plant	34,862	kwh
Outside power	26,615	kwh
Total required	61,477	kwh
Used in power house	3,015	kwh
Used in plant	54,904	kwh

OTHER FACTS

Steam/coal (ton/ton) (cool 4,500 W.E./kg)	5.78	
70 atm. steam demand/kwh	6.752	
Total coal required/kwh	1.217	
Condenser steam energy	10,144	kw
Total power capacity	34,862	kw

II. TREATMENT OF DISCHARGE WATER.

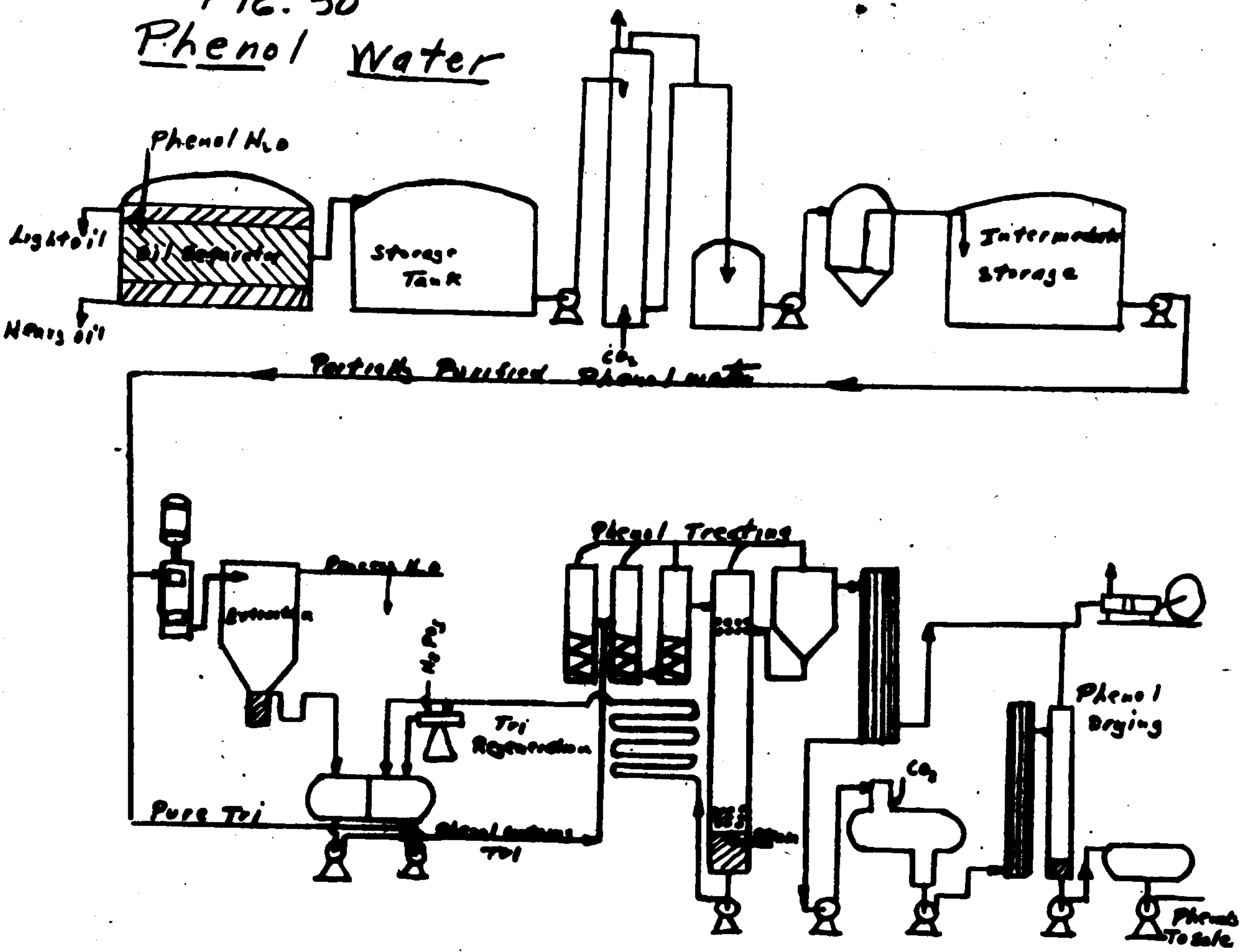
(a) The discharge water treatment removed the largest part of the impurities in the process water, and thereby prevented the pollution of the Rhine. The discharge water streams are:

(1) Water separated from the coal and gasoline stall effluent chamber products in the discharge water tanks;
(2) Water in coal and gasoline effluent which is obtained in the overhead cuts from distillation;
(3) The condensate from the coking residue;
(4) The wash water from the rich gas washer;
(5) The rinse water from all of the oil treating units.

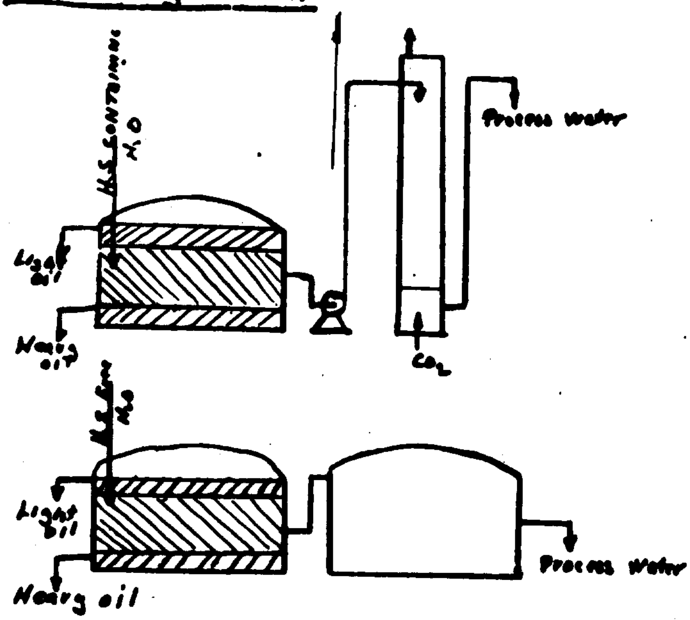
The impurities are: oil, H_2S, and phenols. The discharge waters were divided into two groups for separate treatments. These are the phenol water and dirty water containing oil (Fig. 30).

FIG. 30

Phenol Water



Oil-Containing Water



II. TREATMENT OF DISCHARGE WATER. (Cont'd.)

(b) In the first group belong all waters containing more than one (1) gram/liter of phenol. These are effluent waters of the coal and prehydrogenation chambers, the condensate from the coal effluent and prehydrogenation distillation, and the water produced at the gas plant and the coking kilns.

(c) The second group contains the effluent and distillation water of the gasoline chambers, the wash water from the rich gas washer, and all of the oil-containing rinse waters.

(d) The purification treatment for the oil-containing dirty water is simple. For H_2S-free water it consists in allowing the oil to settle out. For water containing H_2S the oil is first separated and then it is treated with CO_2 to remove most of the dissolved H_2S.

(e) The water containing phenol is given a somewhat extensive purification which consists of extraction with tricresyl phosphate in addition to the oil separation and the CO_2 treatment. The tricresyl phosphate, called "Tri" for short, is a mixture of triphenyl, tricresyl, and trixylenyl phosphates, whose, absorption power depends on the triphenyl phosphate content.

(f) A special characteristic of the Tri process is that the extraction medium boils higher than the dissolved phenols, hence these latter must be distilled out of the absorption medium. This operates so that the phenols produced are very pure, while the impurities remain behind as still residue with the Tri. The Tri must next be purified.

(g) In general the operation of the dephenolating unit is: The phenol-containing water was treated at forty (40) degrees centigrade in three (3) mixing chambers and separators located one behind another. Fresh extraction medium was added periodically. The mixing chambers were constructed with slow moving agitators because the Tri tended to emulsify with water when violently agitated. All together the concentration of Tri was about ten (10) percent of the water. The phenol-containing Tri was vacuum distilled to remove the phenols. The Tri remained as still bottoms. The phenols were condensed, the water separated, and

II. TREATMENT OF DISCHARGE WATER. (g)(Cont'd.)

then vacuum distilled a second time. They were then sold.

(h) The Tri was cooled to about forty (40) degrees centigrade and used for further extraction of phenolic containing water. A fraction of about six (6) percent of the product was centrifuged out to remove impurities, and a second smaller fraction was treated with 0.5 percent phosphoric acid by stirring several hours followed by centrifuging. The dephenolated water was led by a special pipe to the discharge water collection at the Rhine.

(i) Many operating difficulties occurred in the purification of the phenol-containing water from the coal stall effluent, especially when the sludge from the coal chambers overflowed into the effluent. The coal stall effluent could become as dense as the water through the cooling of the latter and then either passed on through the separator or the gravel filter. These disturbances usually led to increased quantity of impurities in the Rhine, since the only remedy was to discharge the water into the Rhine. Once, oil passed through the gravel filter to the extractive vessel and contaminated the tricresylphosphate.

(j) The remedy consisted in preventing the occurrence of the disturbances, for example, as described in the sump phase and coal effluent distillation, the addition of diluent oil to coal effluent produces a deposit. Other points are: the improvement of the apparatus and increased supervision of the high pressure operation, avoiding the addition of emulsion promoting oils, such as heavy oil from the coking residue and unsuitable outside oils to the coal effluent product.

(k) On account of the special properties of the Tri, most higher boiling substances are removed from the water besides the phenols. These materials raised the viscosity of the Tri tenfold inside of three (3) months from the original of three and one-half ($3\frac{1}{2}$) E°. This was in spite of the mechanical and chemical purification of a small bleed. The concentrationof the impurities then were from forty (40) to fifty (50) percent. At the same time the solubility of the phenolics in the Tri, especially phenol itself dropped sharply, so that the phenolic content of the washed water rose from seven hundred (700) milligrams/liter to nearly three (3) grams/liter.

II. TREATMENT OF DISCHARGE WATER. (Cont'd).

(l) Furthermore, the impurities in the Tri tended to cake on the walls of the apparatus. The crust deposits are difficult to remove. It was tried to remove these cakes by circulating hot concentrated NaOH solution, but usually it was necessary to take the apparatus apart.

(m) These difficulties demanded that the Tri be renewed at least every three (3) months. The change was made at suitable intervals to keep the formation of tightly-adhering cokes in check. The product which is drawn off can be regenerated by a high vacuum distillation, which must be used for want of another suitable distillation apparatus. The purified water in the discharge water treatment contained NH_3. This led to the formation of thicker crusts, in particular $CaCO_3$, in the discharge water sewer through its mixing with process water. On this account a pipe line for the impure water was laid to the Rhine in the process water drain.

(n) The disadvantages of the Tri process led to its removal in favor of the "Phenosolven" dephenolation process of Lurgi. Phenosolven is chiefly isobutyl acetate in a mixture of esters that boils lower than the extracted phenols. It is distilled out of the extraction mixture and therefore remains clean. The impurities remained in the phenolic extract and were sold with them. This change in the process produced a far better phenol yield. The phenol content of the treated water was one hundred (100) to two hundred (200) milligrams/liter.

IMPORTANT OPERATING RESULTS

Quantities

Dirty oil from dirty water	8,900	annual tons
Dirty oil from phenol water	2,600	annual tons
Oil containing dirty water	47	M^3/hr
Phenol water	32	M^3/hr
CO_2 used for injection in the water	600	M^3/hr

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II. TREATMENT OF DISCHARGE WATER. (Cont'd.)

H_2S Content

Of the un-gassed phenol water	1.2	g/liter
Of the gassed phenol water	0.2	g/liter
The outlet gases	4	Vol %
Production of phenol oil	950	annual tons

Analysis of Phenol Oils

H_2O	1.2
Mentul oil	2.0
Phenol	31.3
Cresols	43.0
Xylenols	11.5
Rest	11.0

Phenol Content

Of the phenol water	5.2 g/liter
Of the dephenolated water	1.9 g/liter
Phenol production	63.0 %

Tri Content

Of the outlet water	0.086 g/liter
Of the phenol oils	9.5 g/liter