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BEFORE THE

WASHINGTON UTILITIES & TRANSPORTATION COMMISSION

UG-__

GENERAL RATE APPLICATION

OF

NORTHWEST NATURAL GAS COMPANY

December 31, 2018

Direct Exhibit of Andrew C. Middleton

ENVIROMENTAL MITIGATION HISTORY

Exh. ACM-6

Oil Gas Manufacture

Oil Used at Portland Is Brought from California by Tanker to Company Docks on Willamette River

A Staff-Industry Collaborative Report . . .

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in collaboration with

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THE production of fuel gases from oils has had a long but spotty career and postdates that of coal gas by only a few years. John Taylor of England is credited with the first development in this field; his patent issued in 1815 covered "a method of making an illuminating gas from bitumens, resins, fats, vegetable oils, or animal oils" (*17*). The process involved vaporizing the oil raw material in a cast-iron retort and passing the vapor products through a clay vessel to fix the gas. It is notable that even in that early day special interest groups sometimes exerted their influence politically, for in 1824 the English Parliament passed an act prohibiting gas making by Taylor's process (*8*). Historians think this legislation was a result of pressure brought to bear by coal interests who feared competition for their own product, but whether this explanation is surmise or fact, the act did stop, for a period, all progress in oil gas manufacture. No new plants were built, and some of the operating plants were abandoned (*15*).

The next significant development in oil gas manufacture was in Germany in 1873, when Pintsch invented a process in which oil was gasified in the upper of two connected horizontal cast-iron retorts, the lower vessel serving as a fixing chamber for the gas. This was followed by a more scientific method, developed by Young and Bell, in which process the waste heat from the coal gas benches was used to crack oil in cast-iron retorts and the resulting gas, which was high in unsaturates, was used to increase the illuminating value of the coal gas (*10*).

In the United States, the abundance of coal and establishment of coal gas–producing processes resulted in the incorporation of the first coal-gas company in this country in 1816 (*12*), and the growth and security of the industry seemed assured. Little oil gas research was conducted, however, until about 1890, when L. P. Lowe, son of Thaddeus S. C. Lowe, inventor of the carbureted water-gas process, was issued patents for a method to crack oil pyrolytically in a refractory-lined shell over refractory grids. Then, because of the comparative cost of coal and oil and perhaps for other reasons, the process was not used extensively for the following 10 years.

At the turn of the twentieth century production of oil gas achieved its first substantial introduction. At that time, oil had become cheaper than coal in the Far West, and a production method, which was to become known permanently as the "Pacific

Coast Oil Gas Process," was developed. This technique, a result of modifications of the work of Lowe, consists of cracking oil to the standard B.t.u. content of manufactured gas in brick-lined shells of heated checker-brick. Large amounts of lampblack and a high percentage of hydrogen, in addition to varying percentages of carbon dioxide, illuminants, oxygen, carbon monoxide, nitrogen, methane, ethane, and traces of other gases are produced. Some of the carbon remains on the brick checker work to serve as a source of heat for the succeeding run, and that which passes through the checkers with the gas is recovered for use as fuel or other industrial applications. Extra heat required is obtained by burning oil in the shells. Generally, the gas product has a heating value ranging from 500 to 600 B.t.u. per cubic foot.

Other oil gas processes such as the Ricker-Walter, Manfield, Hakol-Zwicky, Dayton and Goldsbrough were developed, but these processes were, in general, unsuccessful because of low productive capacity, carbon trouble, or other inherent faults. None developed into the satisfactory operating techniques and by-products recovery realized with the Pacific Coast method (*13*).

Oil gas produced in the United States from 1920 to 1929 provided 7 to 8% of the total manufactured gas (*9*). These figures indicate that, from a national viewpoint, oil gas was not of major importance during this period. However, it was of great local importance, particularly in the major cities of the Pacific Coast states where for many years, because of the lack of coal supplies, oil gas was the only gaseous fuel produced on an industrial scale for public distribution.

In the late 1920's through improvements in pipe manufacture and transmission facilities and the discovery of large reserves of natural gas, natural gas transportation became possible to ever-increasing distances from the Southwest fields. Currently, the Pacific Northwest is the only region in the United States which does not have natural gas definitely scheduled. However, the large gas reserves in the province of Alberta, Can., would seem to ensure the eventual introduction of natural gas into this region.

The introduction of natural gas has created problems for gas manufacturers in all parts of the country. Of chief importance has been development of methods for meeting peak loads and providing standby capacity for emergency use or during times of curtailment of supply. Some producers of coal gas, carbureted water gas, and low B.t.u. oil gas deemed it necessary to devise methods of using their existing plants for the manufacture of a fuel having a higher heating value (about 1000 B.t.u.) to supplement natural gas. Much interest has been shown in the extensive research sponsored by the American Gas Association toward the production of a high B.t.u. oil gas which can, to a large degree be interchangeable with natural gas.

It is thus evident that during the past few years the manufacture of fuel gases from oils has taken on a new significance for gas manufacturing companies. Oil gas plants which a few years ago were limited chiefly to the Pacific Coast are now being developed in various sections of the country. Plants formerly using other fuels and processes are being converted to the oil gas process.

PORTLAND, ORE., PLANT OF THE PORTLAND GAS & COKE CO.

The Portland Gas & Coke Co. was a pioneer in the field of oil gas manufacture. The company and its predecessors have served manufactured gas in the Portland area since 1860; coal gas was introduced in the mains several weeks before news reached the city that Oregon had been admitted to the Union. In 1897 the operation was converted to water gas, and in 1906 a second conversion was made to oil gas, which has been the only type of gas manufactured by the company since that time. During the intervening years approximately 62,700,000 barrels of fuel oil have been processed into oil gas and residual products. The largest part of this operation has been carried on at the site of the present plant constructed in 1912 on the Willamette River. Currently the company serves approximately 94,000 customers. Nearly 2500 miles of main, including high pressure transmission lines extending 100 miles from the manufacturing plant with submarine crossings under the Columbia and Willamette Rivers, are used for distributing the product to 81 communities in the Willamette Valley and in the adjoining area of Washington. The company has $13,000,000 invested in manufacturing facilities and $17,000,000 in the distribution system. Installed plant capacity is approximately 54,000,000 cubic feet per day of 570-B.t.u. oil gas and 23,000,000 cubic feet per day of 570-B.t.u. equivalent butane-air gas. The company's all-time daily peak send-out of 68,500,000 cubic feet was registered in February 1950.

Table I. 1951 By-Product Sales

Light oil products, gal.	4,905,797
Tar products, gal.	8,263,470
Carbon products, tons	114,362
Gas oil, gal.	600,794

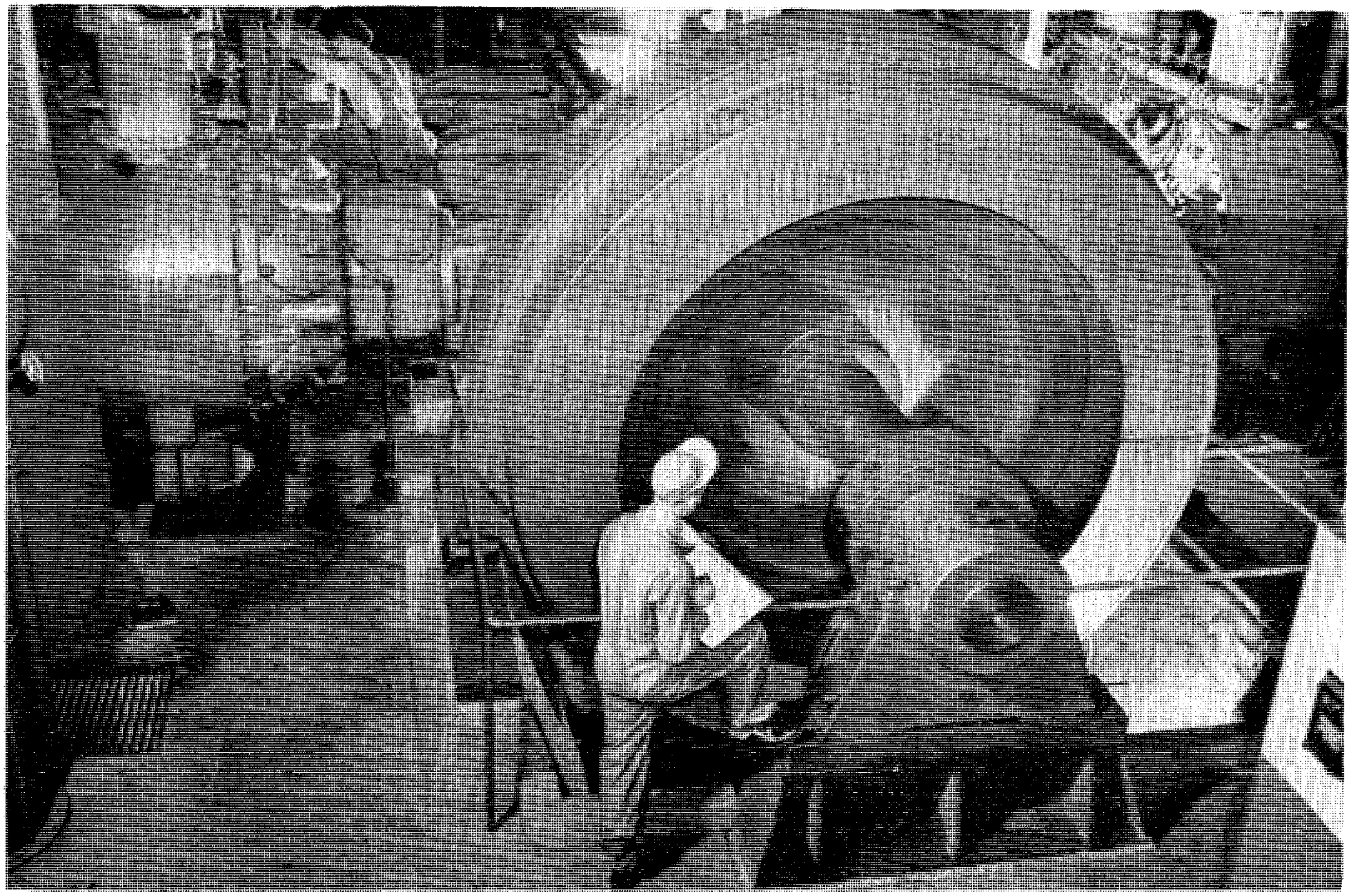
Table II. Ratio of By-Product Gross Revenues to Total Operating Revenues—1936 to 1951

	Total Revenue	By-Product Gross	By-Product Revenue, % of Total
1936	$ 3,833,202	$1,001,075	26.1
1937	3,919,391	1,012,986	25.8
1938	3,891,597	910,368	23.4
1939	3,837,798	815,319	21.2
1940	3,865,887	742,801	19.2
1941	4,182,691	937,220	22.4
1942	5,458,051	1,615,410	29.6
1943	6,254,759	1,860,123	29.7
1944	6,583,071	1,915,036	29.1
1945	7,159,845	1,960,829	27.4
1946	8,565,186	2,388,792	27.9
1947	10,002,106	2,276,093	22.8
1948	13,728,707	4,329,079	31.5
1949	12,842,133	4,011,106	31.2
1950	11,971,430	3,835,723	32.0
1951	12,909,562	4,433,516	34.3

Because of the very low cost of electric energy in the Pacific Northwest and the relatively low cost of wood waste and oil for fuel, Portland Gas & Coke Co. has energetically pursued a residual processing and by-product marketing program, and its revenues from these sources have contributed substantially to the ability of the company to compete with other low cost fuels. In 1913 lampblack was first briquetted and marketed as an ash-free domestic fuel. Ten years later a light oil recovery and refining plant was built, and motor benzene was put on the market. In 1925 the tar was first sold directly as a roadbinder, and in 1941 four oil coking ovens were installed to make 1030-B.t.u. oil gas and electrode coke and to increase the relative yields of liquid residuals.

The company has also been active in oil gas research and the development of improvements in plant operations (*3*). From 1920 to 1923 the first high B.t.u. oil gas patents were issued to Elmon L. Hall, who was chief engineer of the company at that time (*4*, *5*). This work was primarily for the purpose of obtaining increased revenue from residuals. In 1935 the single-shell oil gas generators at Portland were cross-connected in pairs to enable the company to use an inexpensive low grade, high carbon fuel oil which previously had been considered as containing too high a percentage of carbon for use by the oil gas industry. In 1947 the generator plant was converted to an automatic, fast cycle operation which substantially increased its heavy oil capacity. New high pressure light oil recovery facilities and a new electrode pitch still were also installed at that time.

The residual processing and by-products marketing program has been of tremendous importance in permitting this company to maintain rates, on a therm basis, as low as those of any other manufactured gas company in the United States and to vary rates only with the cost of fuel. In 1951 gross gas revenues were



Product Gas Is Compressed by Motor-Driven Reciprocating-Type Gas Compressors

approximately $8,500,000 from the sale of 9 billion cubic feet of gas. Gross by-product revenues were $4,400,000 from the processing and sale of the by-products (Table I). The ratio of by-product gross revenue to total operating revenues for the past 16 years is shown in Table II.

Portland Gas & Coke Co. has a vital interest in high-B.t.u. oil gas, and a portion of this report describes the company's activities in this field. In addition to lowering the net production cost of gas resulting from increased yields of liquid by-products, change-over to high B.t.u. gas would increase the capacity of a heavily loaded distribution system and would enable the processing plant to operate for standby and peak shaving after the introduction of natural gas. Such a high B.t.u. process would even enable the plant to operate profitably in conjunction with natural gas.

A great deal of work has been done in other parts of the country on high B.t.u. oil gas producers. For example, the Edwin L. Hall high B.t.u. process has been developed under American Gas Association sponsorship (*1, 16*). This process is similar to the Portland Gas & Coke Co. process but employs a lower carbon residue feedstock compared to the low priced, high carbon oil used at Portland. The first full-scale high B.t.u. tests on the West Coast for the purpose of manufacturing a gas to augment the supply of natural gas in any proportion or to replace the latter in emergencies were performed at the San Rafael, Calif., plant of Pacific Gas and Electric Co. in 1932. The results of those tests have been reported (*3, 6*).

Generator Gas Production

Raw materials used in the manufacture of oil gas are oil and steam. The conventional process is based on the gasification of oil in the presence of steam in a vessel containing heated checker-brick. The checker-brick are heated by-products of combustion of oil burned with air in chambers both below and above and from burning of carbon deposited in the brick during the gasification. The process is a cyclic one, consisting of alternate heating and gas-making periods.

All fuel oil used by the Portland plant in gas generation is obtained from California by tanker. Delivery is in 20,000- to 70,000-barrel shipments to the company's dock; from here it is pumped to one of three storage tanks, which furnish total storage capacity of 180,000 barrels. Generally, shipments are received every 4 days during the winter months and every 10 days during the rest of the year. Three classifications of fuel oil are marketed on the Pacific Coast: PS-200 (Diesel oil or cutter stock) which is approximately equivalent to No. 3 Fuel (Diesel oil) used in the East; PS-400 (heavy residuum oil) which is at the extreme heavy end of No. 6 Fuel (Bunker C); and PS-300 which is about mid-way between No. 5 and No. 6 Fuel. Portland Gas & Coke Co. is also able to receive limited amounts of straight-run residuum which is similar in gravity and carbon residue to PS-300 but higher in viscosity and lower in carbon-hydrogen ratio (higher in U.O.P. K factor). Two grades of oil are used at the present time. About 85% of the generator gas is produced from 8 to 9 °A.P.I. cracked residuum oil (PS-400), having Conradson carbon content as high as 19%, and composed of heavy, cracked, unblended residues and cracked, blending stock. The remainder is made from a straight-run residuum oil of approximately 16 °A.P.I., which is required for peaking purposes. Diesel oil is also available for emergency usage. The oils are purchased under the specifications shown in Table III.

Table III. Specifications of Oils Used in Gas Making

	PS-400 Heavy Residual Fuel Oil	Portland Gas & Coke Special Straight Run
Gravity, °A.P.I		
Min.	..	..
Max.	12.0	..
U.O.P. K Factor (Min.)	..	11.3
Flash point, Pensky-Martin, closed cup, ° F./Min.	150	150
Water and sediment (max.), %	1.5	1.5
Sulfur (max.), % by weight	1.75	1.2
Viscosity (Saybolt Furol) at 122° F., sec.		
Min.	100	..
Max.	200	200
Conradson carbon residue (max.) % by weight	19.5	10.5

PS-400 oils purchased have a Conradson carbon residue varying between 14 and 19%. High carbon residue has the effect of reducing generator capacity and for this reason oils are segregated when possible, the higher carbon residue oil being reserved for coke oven charging stock. High carbon oil (8 to 9 °A.P.I.) is used exclusively when possible, but for higher capacity during cold weather, it is blended with the lower carbon residue oil. Satisfactory mixing is accomplished by pumping the two streams into the generator supply line, a throttling V-port valve being used for the lighter grade oil for control purposes.

The gas generators used at Portland are of the straight-shot type and are dome-topped, cylindrical steel shells containing checker-brick. Twelve are 20 feet in outside diameter by 34$^1/_2$ feet high and contain 18,000 checker-brick in 30 courses spaced at 3 inches with straight-through flues (*6E*). The three top courses are silicon carbide brick. These generators are cross-connected at the bottom and operated in pairs; they have a heavy oil capacity of 2,000,000 cubic feet of gas per day per shell. Two larger generators are 27 feet in outside diameter by 45 feet high and contain 51,000 checker-brick, each in 45 courses with the same spacing (*7E*). The six top courses are silicon carbide brick. Heavy oil capacity of the larger generators, which operate individually, is 5,000,000 cubic feet of gas per day each. Steel plating used in construction of the welded shells varies from $^3/_8$ to $^5/_8$ inch in thickness. Firebrick are used in the lining, arch, and dome construction with the exception of a silicon carbide ring in the stack. Figure 1 shows design features and approximate location of flow lines.

All generator stack, steam, oil, air, and scrubber valves are controlled hydraulically. Generator control is through automatic electric timers with a system of safety interlocks or through hand-operated electrical switches (both installed in 1947) or by manual operation of levers.

Gas-making cycles of four lengths have been used by Portland Gas & Coke in recent years—30, 15, 7.5, and 12 minutes; the 15-minute cycle is currently used.

In the 570-B.t.u. gas-making process, "make" oil is first heated from 120° to 220° F. in five indirect heat exchangers rated at 100 gallons per minute, each of which currently use steam at 20 pounds per square inch gage (*4E, 10E*). The preheated oil is charged at predetermined rates to the generators through water-jacketed sprays located in the periphery of the shell above the checker level. When using 8 to 9 °A.P.I. oil (Conradson carbon content from 14 to 19%) the charging rate in the 20-foot generators is 900 gallons per hour. The oil is atomized with 350° F. steam and subsequently vaporized and cracked in passing down through the checkerwork, which has been preheated between 1800° and 2000° F. Approximately 0.9 pound of steam is required per gallon of make oil for atomization. At the end of the gas-making period, a soaking time is included to further devolatilize the remaining carbon residue. The products of the cracking process leave the base of the generator at about 1600° F. and pass through a standard water seal wash box. Steam followed by air is used to purge the shells of all oil gas before the checker-brick are reheated for the succeeding operating cycle. During the heat period, oil is sprayed into the chamber above the checker-brick and is burned with the carbon deposited during the make period. The hot products passing through the checkers return the brick temperature to between 1800° and 2000° F. In the 20-foot generators, the heating begins at the top of one shell, proceeds through the bottom connection, and up through the second shell. The direction of heating is reversed in the middle of the heating period by reversing the stack valve position and direction of air flow. The combustion products are purged from the machine by steam followed by an oil gas purge before the next make period of the cycle following (Figure 2).

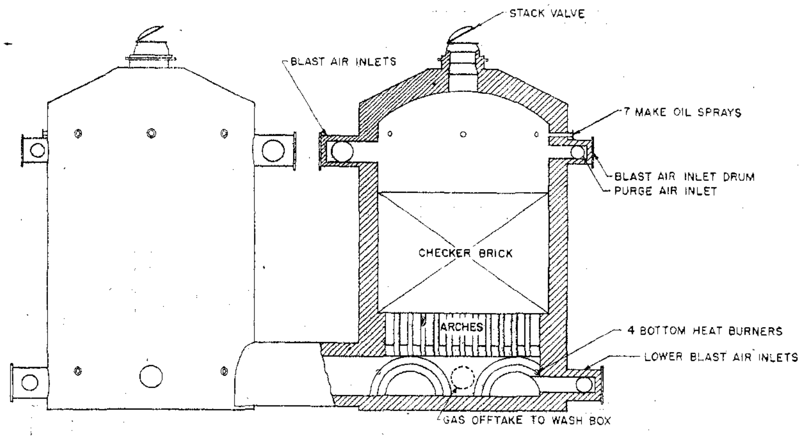


Figure 1. Elevation and Sectional Views of Cross-Connected Generators

Time distribution for the various steps in the operation of the 20-foot generators is as follows:

Cycle Time, 12–15 Minutes

Operation	% of cycle
Make time	25
Soak time	10
Steam purge time	4
Air purge time	2
Clearing before main blast	4
Heat time	50
Combustion products purge	4
Lost time for valving	1

In the gas-making period, the reactions which take place when the steam and oil are brought into contact with hot checker-brick are very complex, and many are not known. The oils used are generally of asphaltic base and the hydrocarbons present are mainly of the naphthene and olefin series. Final products of gasification include hydrogen; simple gaseous hydrocarbons, such as methane, ethane, ethylene, and propylene; recoverable quantities of benzene and other light oil hydrocarbons; heavy complex liquid hydrocarbons which chiefly form the tar; and free carbon, some deposited on the heating surface and the balance as recoverable lampblack. The carbon-hydrogen ratio of the oil is the best indication of its gas-making value. West Coast residuum oils used at Portland range from a carbon-hydrogen ratio of 9.3 to 1 for the PS-400 to 8.2 to 1 for the straight-run oil used for peaking purposes.

Steam used for make oil atomization reacts with the free carbon from the make oil to form carbon monoxide, carbon dioxide, and hydrogen. Steam also reacts directly with the hydrocarbons of the gas and oil vapors by a mechanism not definitely established to form the same products.

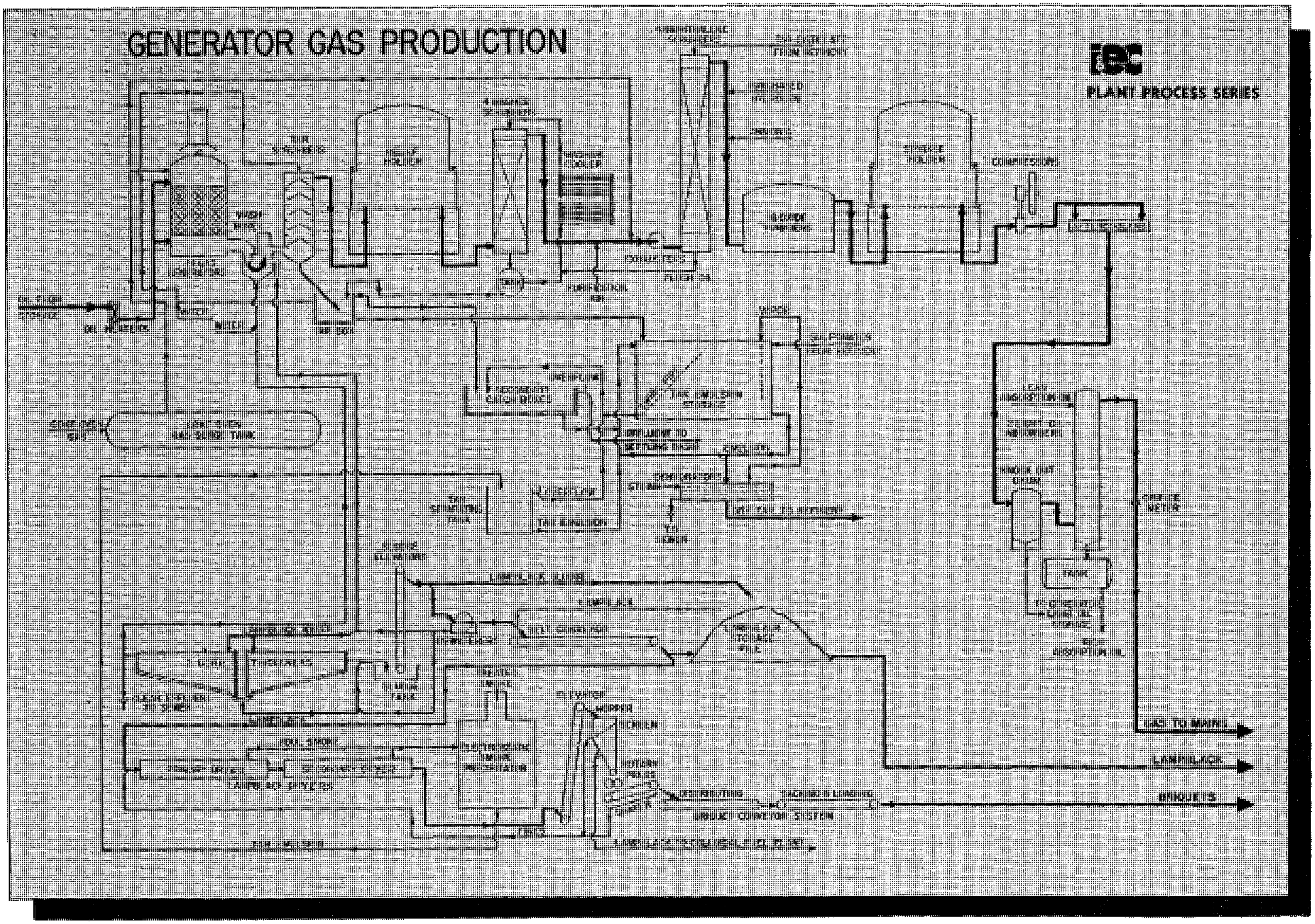


Figure 2. Flow Sheet for the Production of Generator Gas at the Portland, Ore., Plant of Portland Gas & Coke Co.

Typical gas analysis data for Portland Gas straight-run residuum and heavy residuum operations during 1950 are shown in Table IV. Of the total gas send-out 86% is produced in the oil gas generators; the balance of the gas includes coke oven gas, added purchased hydrogen, and air added for purifier operation.

Specific gravity of the street gas varies from 0.41 to 0.49 under the present operating cycle. Appliances in the area are set for a maximum gravity of 0.49. This limitation of the gas gravity and the limitation of 750 B.t.u. on the true oil gas portion (Table IV) to ensure maximum yield of high quality by-products has an important bearing on the over-all efficiency of the oil gas generating system. At least 2% air added to the raw gas for dry-box purifier revivification and 700,000 cubic feet per day of hydrogen purchased must be enriched to the required 570-B.t.u. street gas. Benzene-free generator gas must therefore be approximately 590 to 600 B.t.u. The maximum steam gas that can be tolerated to maintain the inert-free true oil gas at the optimum level of 750 B.t.u. is approximately 27%. Coke oven gas, which has a heating value of approximately 1030 B.t.u., is normally admitted to the oil gas generators for reforming to 750-B.t.u. true oil gas during the make portion of the cycle. It is occasionally added direct to the generator gas in order to raise the B.t.u. value.

Gas Treatment. The gases and by-products produced in the generators operating in parallel pass first from the base of each generator into an individual wash box equipped with a water seal. Wash boxes for the small generators are 8 feet in diameter by 7 feet high and are constructed of $^5/_{16}$-inch steel plate. The gases leaving the generator pass through a refractory-lined offtake and elbow and discharge through a dip pipe below the surface of the water. Lampblack is deposited in and removed by the water, which enters through nozzles in the bottom of the wash box and leaves with the lampblack through a U-type overflow seal and flume. The wash water is subsequently treated for recovery of lampblack. Wash boxes for the 27-foot generators are similar but larger.

The wash-box gas cooled to 150° to 175° F. passes to the bottom of the primary scrubbers for removal of tar and further cooling, a scrubber being provided for each generator. The scrubbers for the 20-foot generators (10 feet in diameter by 28 feet high) are constructed of $^5/_{16}$- and $^1/_4$-inch steel plating and equipped with conical bottoms; all are supported on structural steel columns. The scrubbers are of the umbrella type and contain five conical rings and cones which catch the wash water and convert it to a curtain through which the gas passes countercurrently. Wash water is added at the top of the scrubbers and passes out with the tar from the bottom through a 12-inch drain pipe to the primary tar boxes. The gas leaves the top of the scrubber at 100° to 150° F.

From the tar scrubbers, the gas passes directly through a 36-inch header system to the relief holder. This is a conventional water seal-type holder, 113 feet in diameter and 110 feet high, with a capacity of 680,000 cubic feet.

The gas passes from the holder to a washer cooler system; its primary purposes are to cool the gas further before it passes to the exhausters and to aid in the removal of the remaining condensable hydrocarbons. Four washers made of welded steel plate, ranging from 8 to 12 feet in diameter and 28 to 60 feet in height, are operated in parallel. The main portion of the washers is filled with wooden grids. Gas enters at the bottom and a recirculating gas liquor at the top. The circulating liquor is cooled to approximately 75° F. in a closed-coil system by water from the nearby Willamette River. The banks of coils are arranged in two decks, one above the other, each deck consisting of 31 coils made of 26 lengths of 2-inch steel pipe 18 feet long with welded headers. The vapor tension of gas and liquor are brought into substantial equilibrium, hence cooling without condensation of light oil is accomplished. Temperature of the gas drops from 130° to 80° F. in the system. Tar removed passes out the bottom of the scrubber to the tar tank.

After being subjected to the liquor cooling, the gas is drawn through an exhauster system. Two smaller units are operated in series, having a capacity of 5000 cubic feet of free gas per minute each against a normal pressure of 1.25 pounds per square inch (*8E*). These are driven by 50-hp. 3600 r.p.m. motors. Three larger units are rated at 16,000 cubic feet of free gas per minute against a normal pressure of 1.25 pounds per square inch and are operated by 160-hp., 3600 r.p.m. motors connected directly (*9E*). From the exhausters, the gas passes to four cylindrical steel, naphthalene removal scrubbers (10 × 80 feet) containing wooden grids. The scrubbers are operated in pairs, with one half of the gas flowing in series through one pair. Tar distillate is fed intermittently to the tops of the final scrubbers and circulates continuously over the initial scrubbers. Over-all rate is approximately 25 gallons per million cubic feet of gas. Recovered naphthalene is processed through the tar recovery system. Hydrogen purchased from a nearby industrial plant is added to the line from the naphthalene scrubbers at a rate of 700,000 cubic feet per day to supplement the gas supply. Ammonia is added at the rate of 4 grains per 100 cubic feet to maintain a pH of 7 to 7.5 in the purifier drips.

TABLE IV. GAS ANALYSIS DATA

	Typical Generator Gas (Light Oil–Free)	
Analysis, %	Straight-run residuum (cycle time 15 min.)	Heavy residuum (cycle time 12 min.)
CO_2	1.43	2.98
C_6H_6	. .	. .
C_4H_8	0.11	0.10
C_3H_6	0.38	0.72
C_2H_4	4.28	4.52
O_2	0.32	0.36
H_2	54.55	46.15
CO	7.29	9.46
CH_4	28.45	29.86
C_2H_6	0.00	0.60
N_2	3.19	5.25
Total	100.00	100.00
Calculated B.t.u. (dry)	570.8	586.3
Calculated B.t.u. (saturated)	561.1	576.3
Calculated sp. gr. (dry)	0.372	0.452
Composition, %		
Air	1.60	1.80
Combustion products	2.29	4.57
Steam gas	17.73	25.58
True oil gas	78.38	68.05
Total	100.00	100.00
Analysis of steam gas, %		
CO_2	5.92	8.68
CO	41.12	36.98
H_2	52.96	54.34
Total	100.00	100.00
Calculated B.t.u. (dry)	303.6	294.8
Calculated sp. gr. (dry)	0.525	0.528
Analysis of true oil gas, %		
C_6H_6	. .	. .
C_4H_8	0.14	0.15
C_3H_6	0.48	1.06
C_2H_4	5.46	6.64
H_2	57.62	47.39
CH_4	36.30	43.88
C_2H_6	0.00	0.88
Total	100.00	100.00
Calculated B.t.u. (dry)	639.4	750.8
Calculated sp. gr. (dry)	0.304	0.368

Hydrogen sulfide in the gas, which ranges from 200 to 300 grains per 100 cubic feet, is removed by passing the gas through a series of units containing a mixture of activated iron oxide and moistened wood shavings. At Portland there are 18 of these units; they are constructed of $^3/_{16}$- and $^1/_4$-inch steel plating, are 31 feet in diameter and 20 feet high, and have spherical tops. The iron oxide–shaving mixture is supported on four structural steel grids. As the gas passes upward through the purifiers, hydrogen sulfide is converted to ferric sulfide. When the oxide in the lower layers has been fouled through more or less complete conversion of the oxide to sulfide, flow through the purifier is reversed and more efficient use of oxide in upper layers is realized.

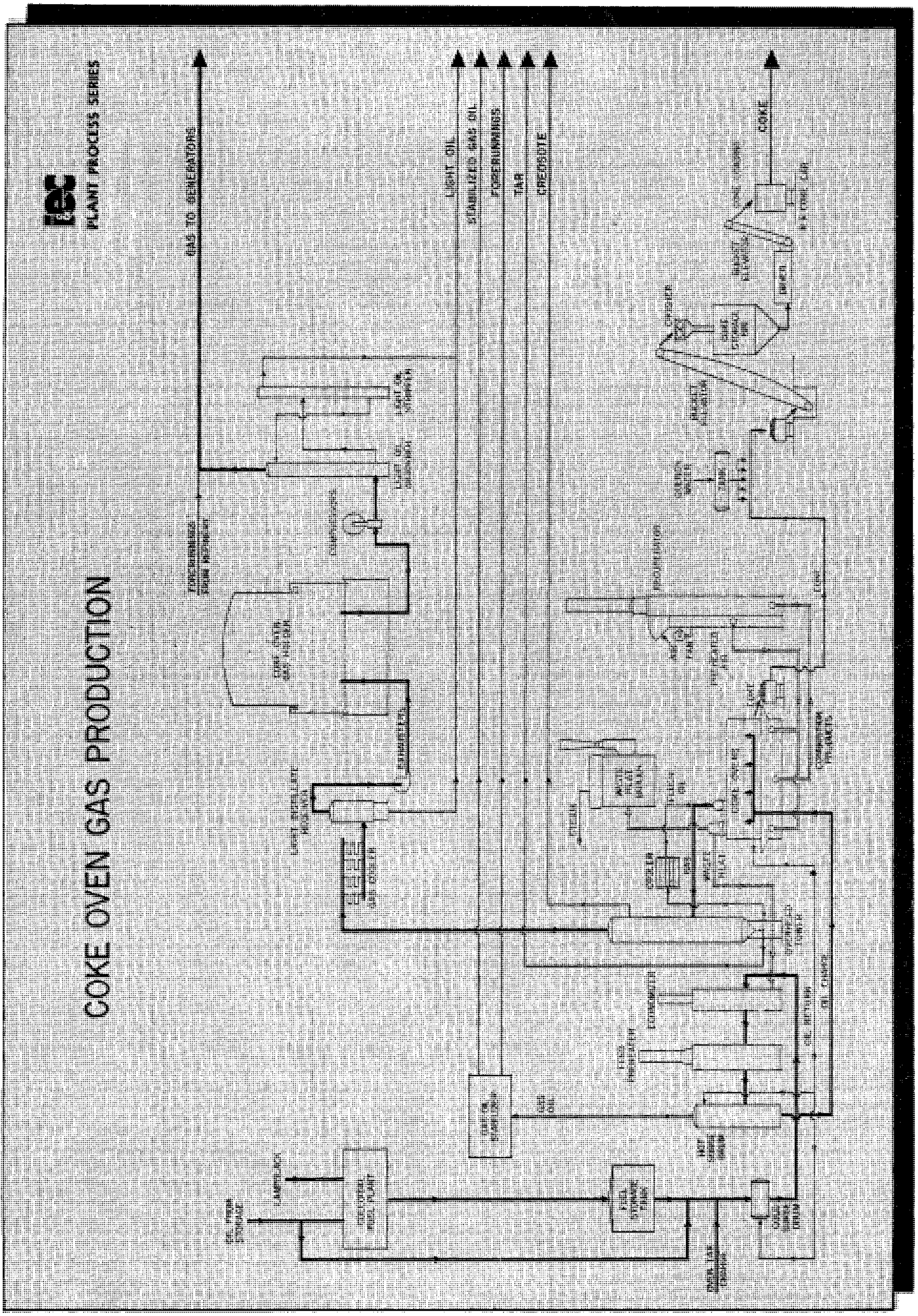
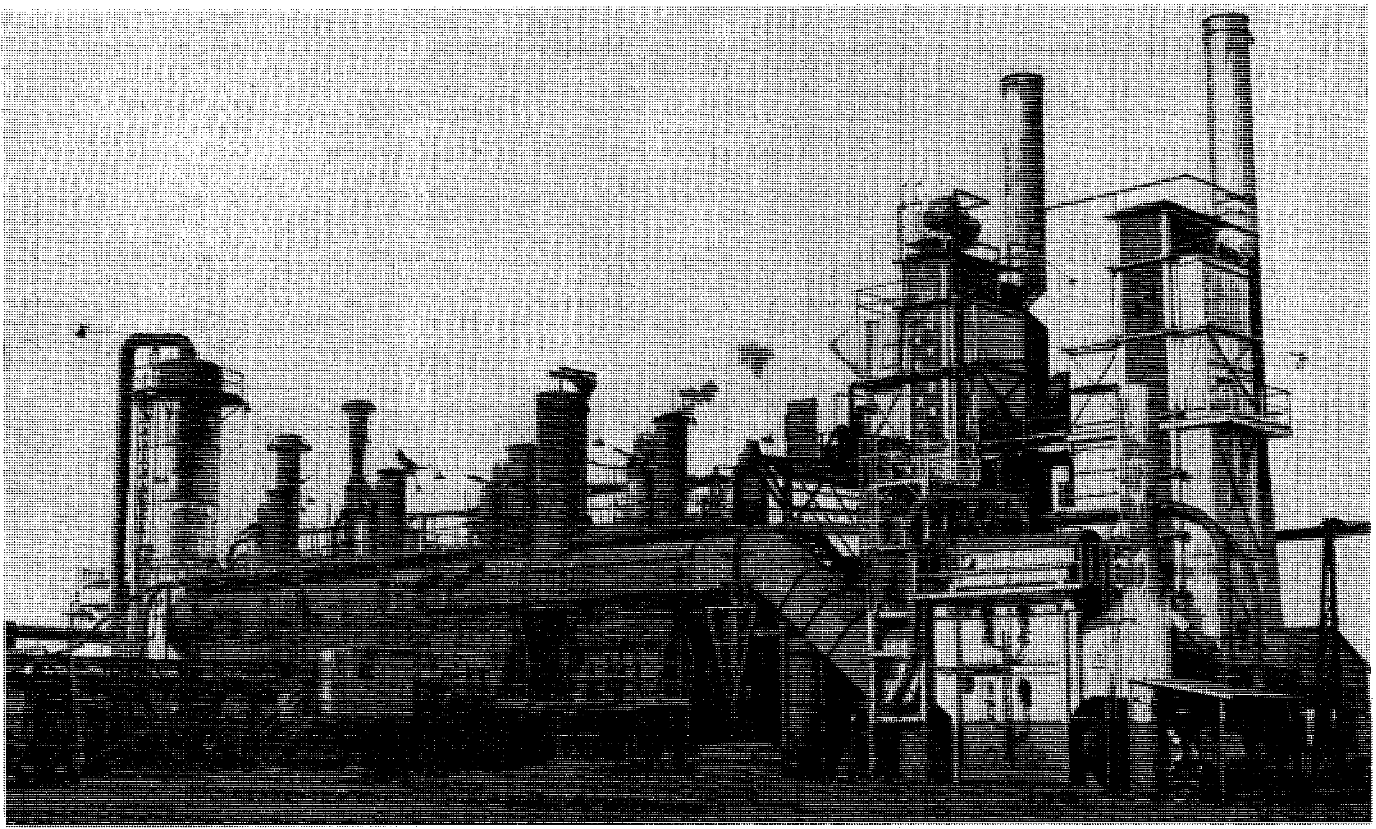


Figure 3. Flow Sheet for the Production of Coke Oven Gas at Portland Gas & Coke Co.



In Addition to 1030-B.t.u. Gas, Tar, Light Oils, and Creosote Are Produced in a Four-Oven Oil Coke Plant

Air, at a rate of 2 to 3% of gas flow, is added for restoration of the oxide. This plant is unusual in that the 18 purifiers connected in parallel make it necessary to effect complete sulfur removal in one pass through 12 feet of oxide material. No so-called catch boxes are used. More complete descriptions of iron oxide purifying systems have been published (*11*).

The gas, free of hydrogen sulfide, passes to a storage holder (similar to the one previously described), which has a capacity of 505,000 cubic feet. From the holder, the gas is compressed by reciprocating compressors to 10 to 50 pounds per square inch. One of these machines is among the world's largest reciprocating-type, electrically operated gas compressors (*3E*). It has a balanced opposed crank-shaft arrangement and is equipped with six 39 × 17 inch double-acting cast-iron cylinders, driven by a 4500-hp. 11,000-volt synchronous motor. Rated capacity of the compressor is 30,000 to 37,000 cubic feet per minute.

The compressed gas subsequently passes through three water-cooled shell-and-tube aftercoolers (each containing 3220 square feet of heat transfer area) where the temperature is reduced from 270° to 70° F. A knockout drum (10 × 14 feet) of welded steel construction, containing inclined baffle plates and louvered screen, removes oil and water fog in the gas at this point. Operating pressure varies up to 50 pounds per square inch, as required to transport the gas to the distribution center. The oils removed pass to a generator light oil storage tank.

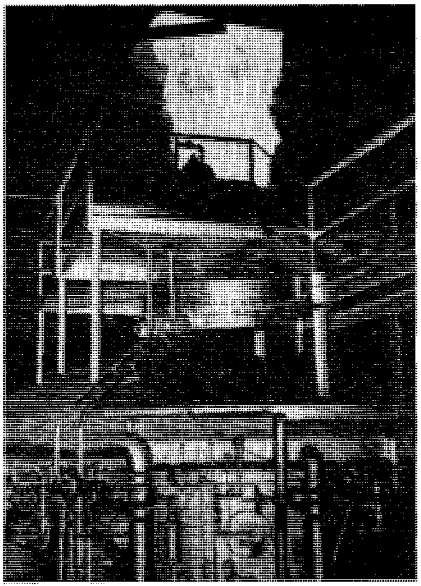
The light oil absorption system at this plant is unusual for gas plants in that it is located on the high pressure side of the compressors and thus utilizes the high transmission pressure to effect more efficient and economical light oil recovery. Formerly light oil removal was accomplished in the gas stream before purification by low pressure absorption in the currently used naphthalene scrubbers, as is sometimes practiced in manufactured-gas plants. These facilities for light oil removal, able to process only 25,000,000 cubic feet of gas per day, had been outgrown as the result of increased demand. The two high pressure absorption towers (8 feet 11 inches in diameter by 50 feet 9 inches high) are constructed of welded steel plate and contain 20 bubble-cap trays. These effectively process more than 50,000,000 cubic feet of gas per day with no increase in wash oil circulating facilities. Lean wash oil from the plant's refinery is recirculated in the towers countercurrent to the gas flow and the rich wash oil passes to a stripper where the light oils are removed for refining.

Light oil–free gas passes through two 16-inch orifice meters, which integrate for both differential and static pressure, into the company's distribution lines (*1E*).

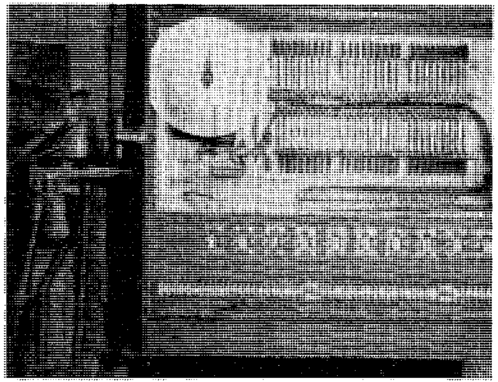
Lampblack Production. Approximately 20 to 30 pounds of residual carbon are recovered per 1000 cubic feet of gas made. This is marketed in dry bulk form or as briquets, which have a heating value of 15,000 B.t.u. per pound and may be used for domestic fuel and as process carbon in the electrochemical and electrometallurgical industries. Some carbon is also used as an additive to fuel oil for coke ovens (Figure 3).

The generator wash-box water, containing 1 to 2% solids, is concentrated to 10% solids in two 75-foot continuous, traction thickeners (*5E*). Sludge is conveyed to 6 × 6 foot press-belt type dewaterers, each with a capacity of 125 tons of cake per 24 hours of operation (*12E*). The discharge contains 60% solids and is conveyed to bulk lampblack storage or to the briquet plant. Water content of the carbon used in making briquets is reduced to approximately 10% in oil-fired, rotary dryers (6 feet 4 inches × 45 feet 6 inches) similar to cement kilns. Dryer discharge gases, containing tarry hydrocarbons, are passed through an electrical smoke precipitator before discharge to the atmosphere. Carbon discharge from the dryers is screened and formed into $1^3/_4 \times 2^1/_2$ inch pillow-shaped briquets in one of two rotary presses. The larger press, more recently installed, has 36-inch diameter rolls made of No. 32 chrome steel alloy and a capacity of 315 tons of briquets per day (*11E*). The product is shipped in 100-pound bags and in bulk.

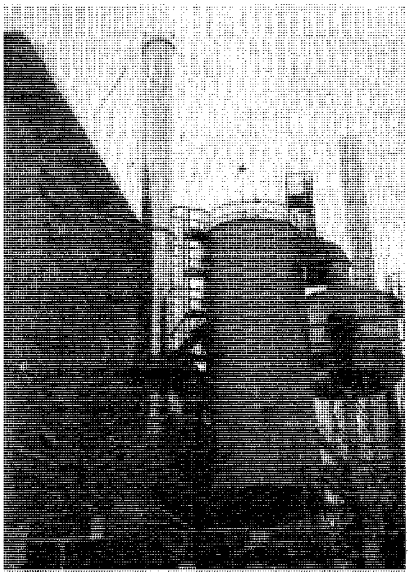
OIL GAS PRODUCTION



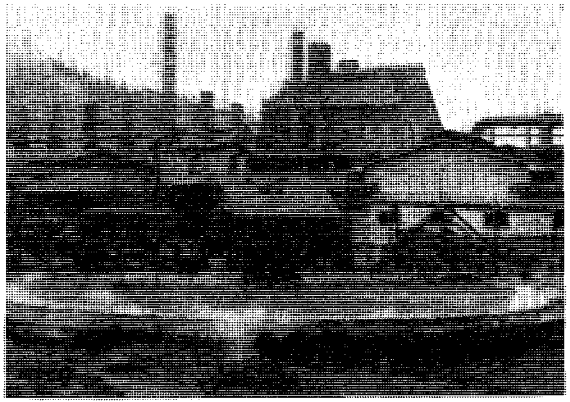
1. Generators are purged of combustion products formed during heating period before make period of next cycle



2. Generator control is through automatic electric timer and safety interlocks

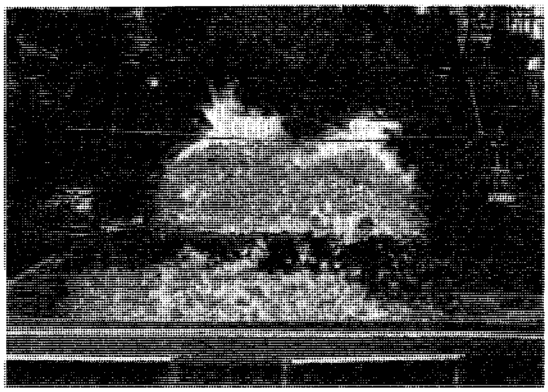


3. Carbon is removed from generator gas in wash boxes from which the gas passes to primary tar scrubbers



4. Generator wash-box water containing 1 to 2% carbon is concentrated in 75-foot diameter continuous traction thickeners

5. Carbon content of coke oven fuel is increased through addition of lampblack and oil mixture



6. At end of coking cycle coke is pushed through oven into quenching car

7. Carbon from generator gas is briquetted and marketed as low ash, high heat fuel

Generator Tar. Tar recovered from the gas scrubbers and washer cooler recirculation system is carried as a 30 to 75% water emulsion to the tar emulsion storage tank. Originally, this emulsion could be used only as a fuel. It is currently processed into electrode pitches, roadbinders, naphthalene, and wood preservatives. Several methods for reducing the water content of the tar emulsions have been tried, including centrifugal separators or other mechanical means and heat and chemical treatment.

A satisfactory method for emulsion treatment and the one currently used involves the utilization of sulfonated liquor from the plant's light oil refinery (*14*). This is added to the tar emulsion storage tank, at a ratio of 1 gallon per 100 gallons of emulsion, and heated. The emulsion breaks to yield a tar of approximately 5% water content which is then pumped to one of six pressure treating vessels; these are $5^{1}/_{2} \times 32$ foot horizontal cylindrical steel tanks made of boiler plate and equipped with steam coils. The filled, closed tanks are heated to boil off the balance of the water, and the dry tar is transferred to tar storage tanks for subsequent processing. The company now supplies 30,000 tons of electrode pitch to the aluminum industry annually, providing three of the five reduction plants in the area with their full requirements and the other two with 50% of their requirements.

Coke Oven Operation

As the aluminum industry developed in the Pacific Northwest, large amounts of petroleum coke for the manufacture of electrodes were required. Portland Gas & Coke Co. investigated the production of oil coke in a pilot coke oven in 1940 and the successful results of this operation led to a decision to install a commercial oil coke plant (*2*).

Operation of the coke plant yields an annual production of the products summarized below from a net feed of 317,000 barrels of heavy residuum plus 6000 tons of lampblack.

		Recovery by Weight, %
1030-B.t.u. lean gas, thous. cu. ft.	715,700	28.2
Coke, tons	13,000	14.5
Tar, gal.	4,800,000	39.6
Light oils, gal.	880,000	6.6
Creosote, gal.	74,000	0.6

Coke oven operation is illustrated in Figure 3. The plant includes four oil coking ovens and auxiliary equipment (*2E*). Fuel oil is a highly preheated, high carbon feedstock which is obtained by topping the same 8 °A.P.I. residuum used for gas generator stock. Carbon content of the feedstock is substantially increased through the addition of approximately 10% of a 40:60 pasty mixture of lampblack and oil, which is added to oven feed just before the cold surge drum. Topping takes place in an oil-fired, single cell, upshot type heater and appropriate surge drums which are necessary because of the cyclic nature of the feed. The topping removes about 10% of 30 °A.P.I. material which is marketed as gas oil. Residue from the topping unit is a 5 to 6 °A.P.I. material at 650° to 700° F. when fed to the ovens.

The four ovens that constitute the coking plant are each $10^{1}/_{2}$ feet wide by $42^{1}/_{2}$ feet long inside and 4 feet 7 inches high at the peak of the oven arch. The silicon carbide floor tiles are $14 \times 7 \times 3$ inches. They rest on $4^{1}/_{2}$-inch pier walls which form the flues in which oil is burned to furnish the floor heat. The flues are fired at each end of the oven with 8° A.P.I. fuel oil, employing a special locally developed steam atomizing burner. Combustion products leave by a central flue connected to each oven. A system of additional flues is provided to allow some of the products of combustion to recirculate and mix with the incoming preheated air. This makes possible a lengthening out of the oil flame and provides uniformly heated floors. The hot products leaving the flues preheat the incoming air used for combustion by means of a recuperator.

The floor vapors are cracked in twelve flues located above the oven arch as an integral part of the oven structure. They extend lengthwise with the oven and are 32 feet 8 inches long by $9^{1}/_{2}$ inches wide and $7^{1}/_{2}$ inches high. These flues are of silicon carbide construction with the exception of a fire clay covering. The floors or bottoms of the cracking flues form the tops of 8×10 inch heating flues which run parallel to the cracking flues. They are heated by combustion of 8 °A.P.I. fuel oil with separate burners in each flue. Combustion products leave the heating flues at 2000° F. and pass to a waste-heat boiler which produces about 40% of the steam used about the ovens. Silicon carbide brick is used in the construction of the cracking and heating flues to improve the rate of heat transfer from the combustion products to the hydrocarbon vapors which rise off the oven floor.

The system for handling the cracking flue vapors is as follows: All the material distilled from the floor feed enters the flues. On cracking in the flues at about 1270° F. the vapors are converted to gas, light oil, and tar. Some carbon is deposited in the flues and must be burned off before the succeeding cycle. The vapors from the flues are collected in a brick-lined breeching leading to a quench tower where they are quenched to 475° F. by tar which has been cooled to about 350° F. About 0.3-inch pressure is maintained in the oven chamber by a regulator located just after the quenching chamber. The vapors then pass through a fractionating tower containing three sets of venetian blinds or mist extractors and six bubble decks of standard construction, which effectively remove all the tar vapors and tar fog from the gas. The tar is collected in the base of this tower and is pumped through an immersion-type cooler from which it goes to storage or is returned for quenching. A small side stream of light creosote is taken from the tower and used as wash oil. The gas and light oil vapors leave the tower at 200° F. and pass through a pipe cooler where some of the light oil fractions condense and are used for refluxing the tower with the balance passing to storage. Gas is exhausted from the light oil separator to a relief holder by a steam-driven centrifugal exhauster. From the holder the gas is compressed to 35 pounds per square inch gage for light oil absorption and delivery to the 570-B.t.u. generators for reforming.

The oven cycle is 6 hours, making 16 cycles per day for the four ovens. Feed rate is controlled to prevent frothing due to the accumulation of excessive amounts of liquid oil in the oven. As the coke bed thickens, the feed rate is reduced. The present cycle was established after several years of experimentation.

At the end of the coking cycle, the doors on each end of the oven are opened and the coke is pushed through the oven by an electrically driven horizontal ram to a quenching car. After water-quenching, the coke is unloaded and passed through a rotary crusher which reduces the average particle size to 2 inches. Before loading, the coke is dried in a direct-fired rotary dryer to a moisture content of not over 0.5% using approximately 1000 cubic feet of 570-B.t.u. gas per ton of coke.

By-Products Refining

The solid products of the oil gas generators and coking ovens include solid carbon in the form of lampblack and coke. The liquid products include tar and light oil from the generators and tar, light oil, and creosote from the coke ovens. The tars are processed into creosote, soft and hard pitch, road tars, and crude naphthalene. The light oils, after being stripped from the wash oils, are refined to benzene, toluene, xylene, and solvent naphtha. Flow of the crude by-products through the plant's purification and refining facilities is shown in Figure 4.

Some of the tar is first processed to soft pitch by passing through a continuous tube still, $15^{1}/_{2} \times 21^{1}/_{2} \times 12^{1}/_{2}$ feet. Heat is furnished by both a radiant and a convection section, utilizing steam atomizing oil burners. No vaporization occurs in the vessel. The heated tar passes to a 4×23 foot stripping column containing bubble-cap trays. The overhead product, amounting

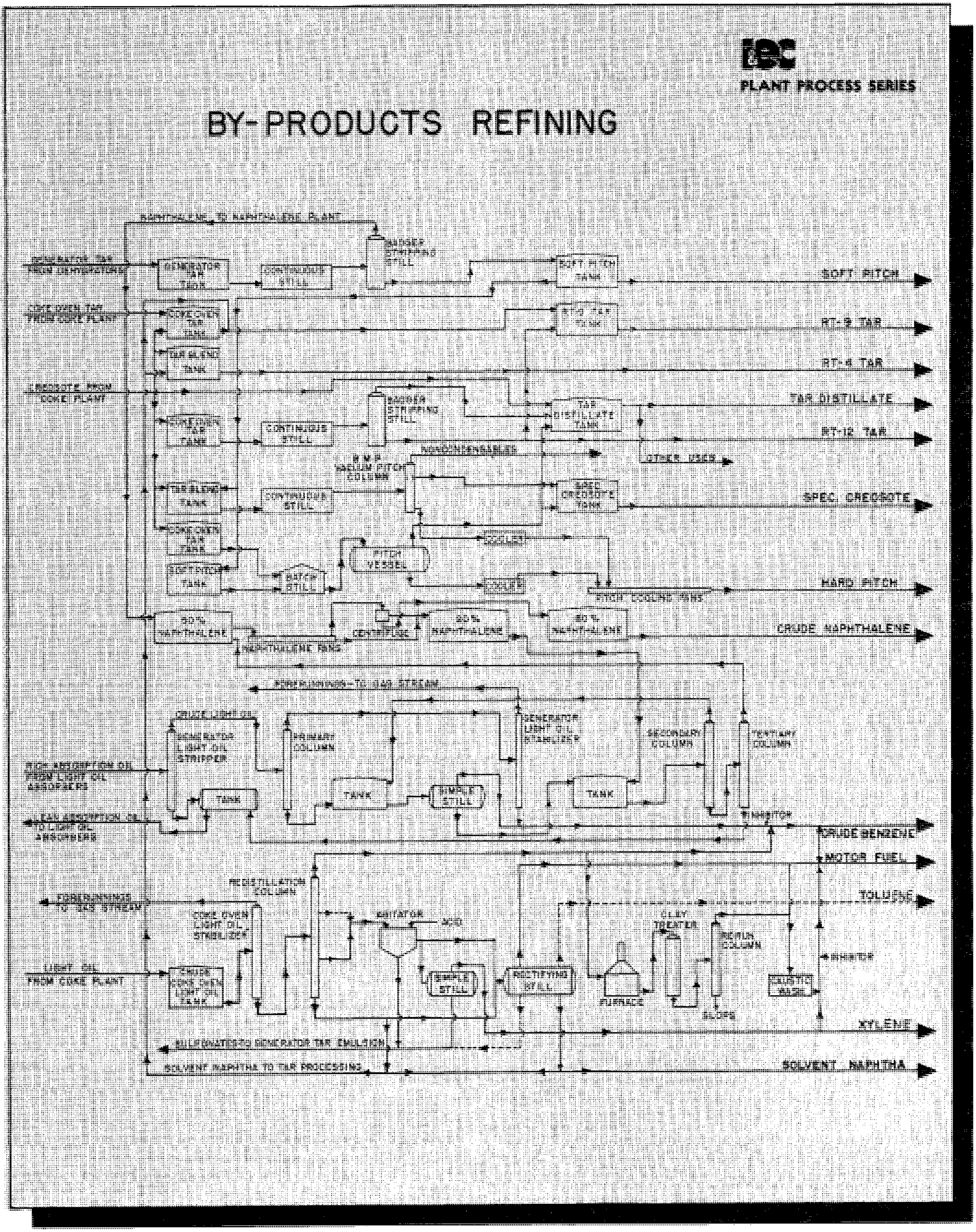
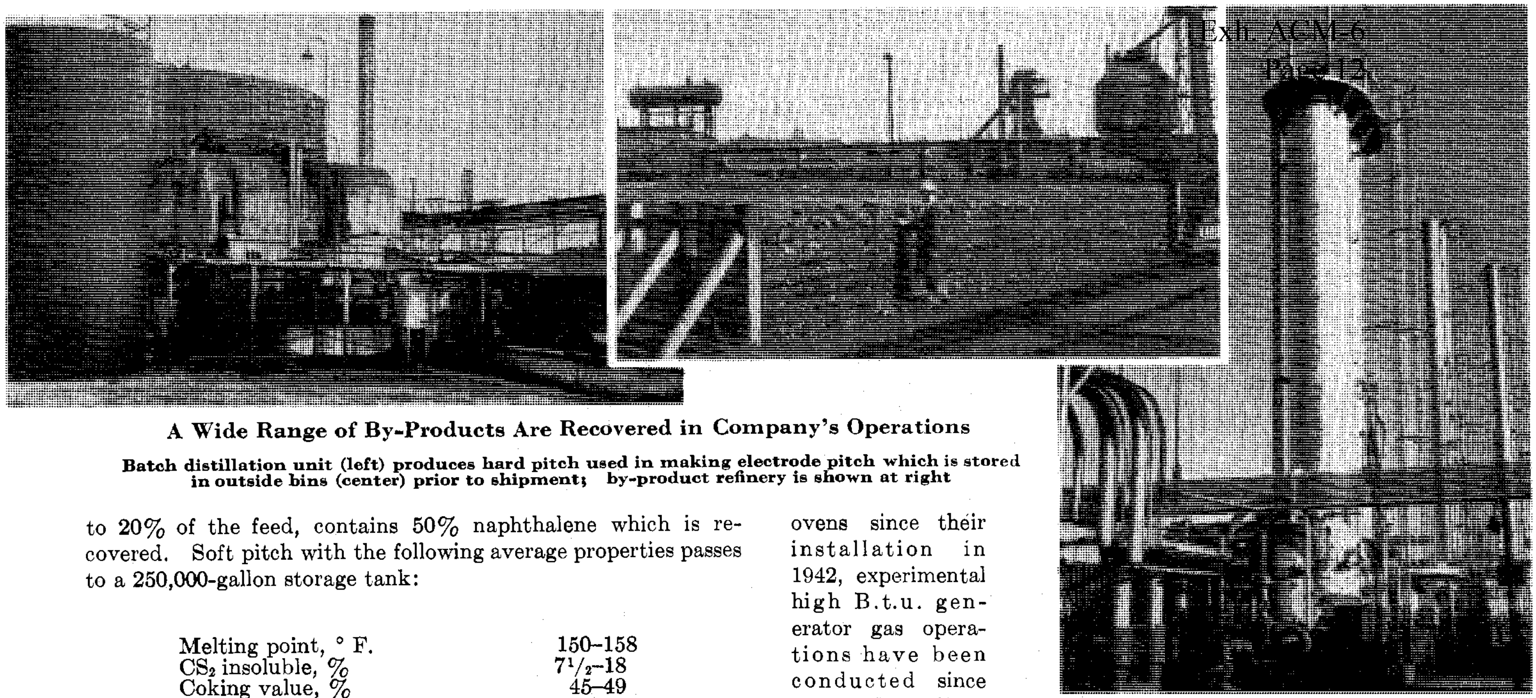


Figure 4. Flow Sheet for the Refining of By-Products at Portland Gas & Coke Co.



A Wide Range of By-Products Are Recovered in Company's Operations

Batch distillation unit (left) produces hard pitch used in making electrode pitch which is stored in outside bins (center) prior to shipment; by-product refinery is shown at right

to 20% of the feed, contains 50% naphthalene which is recovered. Soft pitch with the following average properties passes to a 250,000-gallon storage tank:

Melting point, ° F.	150–158
CS_2 insoluble, %	$7^{1}/_{2}$–18
Coking value, %	45–49
Ash, %	0.05–0.15
Distillation	
% to 272° C.	0–0.3
% to 360° C.	12–14
Moisture, %	0–0.05

Tar as made meets some roadbinder specifications. Solvent naphtha produced in the plant's light oil refinery is added in quantities up to 20% to produce cutback materials of lower viscosity. In the making of hard pitch, tar and soft pitch are mixed, batch distilled, and air-cooled to atmospheric temperature. The product has the following average characteristics:

Melting point, ° C.	108–114
Coking value, %	57–60
Benzene insoluble, %	27–33
Ash, %	0.15–0.25
C-I carbon, %	14–20
C-II carbon, %	29–34
Sulfur, %	0.80–1.25
Water, %	0.15–0.25

The distillate from soft pitch production is added to a naphthalene distillate from the light oil refining plant, and the mixture is cooled in outside cooling pans at atmospheric temperature to crystallize the naphthalene. The product is centrifuged and kept in a liquid state in a tank heated with steam coils; it is marketed as crude naphthalene—naphthalene 80 to 84 weight %, and water 3% maximum.

Distillates from tar processing produce a wide range of creosotes for use as wood preservatives, solvents, and absorption oil. Purchased pentachlorophenol, in amounts ranging from 2 to 5%, is added to some tar distillates to improve wood preserving characteristics. These are marketed under various specifications. The properties of oil gas creosotes have been published (*7*).

Generator light oil, after being stripped from the absorption oil, is distilled to remove heavy ends and stabilized for marketing as crude benzene. Heavy ends are mixed with crude coke oven light oil for fractionation into motor fuel, crude xylene, and crude solvent naphtha fractions. These are sold in crude form or are refined to specifications. Refined toluene and 2° benzene have been marketed.

HIGH B.T.U. OIL GAS RESEARCH

For reasons previously given, Portland Gas & Coke Co. has long had an interest in the production of an oil gas with a heating value of approximately 1000 B.t u. per cubic foot. In addition to the continuous production of 1030-B.t.u. gas from the coke ovens since their installation in 1942, experimental high B.t.u. generator gas operations have been conducted since 1920. The first high B.t.u. gas production was on pilot plant scale at the company's Vancouver, Wash., gas plant and led to the two patents previously mentioned (*4,5*), which were the first patents to be issued in this field. The basic difference between the two processes covered in the patents is that one involves reforming of high B.t.u. gas to street gas level, whereas the second involves simply blending high and low B.t.u. gases to obtain the standard product required for distribution.

The first successful high B.t.u. operations in large generators were conducted in November 1921 and in January of the year following, in which 18 to 19 °A.P.I. oil was used as a feedstock. Heat values of the gas made during the 3 days of test period were 870, 1062, and 890 B.t.u. A full-scale test of the process was undertaken in 1923, and the high B.t.u. gas produced was blended to standard 570-B.t.u. street gas. In order to supply sufficient tar for a growing road binder market, the high B.t.u. process, which gives a higher yield of tar and other liquid by-products, was frequently used for periods of a few days to a week on a 24-hour basis from 1923 through 1941. In 1941 the coke oven plant was installed, and its operation furnished the by-products in demand in addition to the high B.t.u. gas for reforming or blending. The combination of coke ovens and 570-B.t.u. oil gas generating equipment made it possible to produce sufficient tar to supply the market, and there was no incentive until recently to make additional tar by high B.t.u. operation on the oil gas sets. Numerous reports have been made on the production of high B.t.u. gas manufacture on the Pacific Coast (*18*).

In order to provide interchangeability in the event of introduction of natural gas as well as to meet today's expanded metallurgical pitch requirements, high B.t.u. generator operation has received additional recent study.

During the period of April 22 to May 18, 1951, a continuous series of high B.t.u. test runs was made using a heavy oil feedstock, ranging from 8.2 to 10.6 °A.P.I. with Conradson carbon residue up to 18%. Two of the 20-foot generators were operated on a 12-minute cycle producing 800- to 950-B.t.u. gas with offtake gas temperatures averaging 1000° to 1200° F. These generators and auxiliary equipment were isolated from the 570-B.t.u. and coke oven operations in order to ensure a maximum degree of reliability in the tests related to gas production, residual recovery, and by-product processing. These tests were too limited to allow development of definite and final conclusions, and additional tests are currently under way. However, certain significant trends were established and are summarized below:

1. Although the checkers in the generators had been subjected to 10,600 hours of 570-B.t.u. operation in the lower section of the generator and in excess of 5400 hours in the upper section before the high B.t.u. runs, no operating difficulties such as

plugging of checkers or stoppages in wash boxes were experienced during the several weeks' run.

2. Little or no difference in gas quality with respect to carbon dioxide and carbon monoxide content was observed when operating with steam-atomizing or mechanical-atomizing oil sprays.

3. The gas produced contained about 15% carbon dioxide and carbon monoxide in roughly equal parts above that coming from true combustion products. This dilution of the gas product did not permit production of 1000-B.t.u. oil gas for interchangeability studies, the heat content of the individual runs ranging from 800 to 956 B.t.u. per cubic foot. This led to the establishment of the oxidation gas theory, explaining the cause of the presence of the dilutents in the oil gas. This theory attributes the formation of the excessive carbon dioxide and carbon monoxide to the oxidation of carbon or hydrocarbons by the reduction of metallic oxides contained in the checker slag, rather than to the conventional steam-gas reaction. These metallic oxides, consisting of iron, vanadium, and nickel residues from the oil ash, absorb oxygen from the excess air during the heating cycle with subsequent release of this oxygen by reduction of the oxides during the making cycle.

4. During the period of the runs a substantially water-free tar was continuously produced by maintaining the recirculated water at its optimum surface tension by the addition of commercial wetting agents of the order of 0.01 to 0.05% by weight.

5. Cost data compiled indicates that on a therm basis the cost of producing the high B.t.u. gas was slightly below the 570-B.t.u. costs and therefore would justify a continuation of the high B.t.u. test series.

FUTURE PROSPECTS

Natural gas, which only a few decades ago seemed to spell doom for manufactured-gas makers, now actually suggests an encouraging future for oil gas producers for peak shaving and standby purposes. Furthermore, profitable by-product yields such as those realized by Portland Gas & Coke Co. could justify the continuous operation of high B.t.u. oil gas plants even after the introduction of natural gas.

LITERATURE CITED

(1) Hall, Edwin L., U. S. Patents 2,580,766 and 2,580,767 (Jan. 1, 1952).
(2) Hall, Elmon Lawrence, *Chem. & Met. Eng.*, **47**, 100–5 (September 1941).
(3) Hall, Elmon Lawrence, and Graf, S. H., *Proc. Pacific Coast Gas Assoc.*, **13**, 310–65 (1921).
(4) Hall, Elmon Lawrence, and Papst, Hilmar, U. S. Patent 1,409,709 (March 14, 1922).
(5) *Ibid.*, 1,466,648 (Aug. 28, 1923).
(6) Harritt, J. A., Wills, F., and Willien, L. J., *Proc. Pacific Coast Gas Assoc.*, **23**, 262–87 (1932).
(7) Martin, S. W., presented before annual meeting of American Wood-Preservers Association, St. Louis, Mo. (April 1949).
(8) Morgan, Jerome J., "A Textbook of American Gas Practice," Vol. 1, p. 451, Maplewood, N. J., Jerome J. Morgan, 1931.
(9) *Ibid.*, pp. 580–614.
(10) *Ibid.*, p. 581.
(11) *Ibid.*, pp. 804–51.
(12) Norman, O. E., "The Romance of the Gas Industry," p. 165, Chicago, A. C. McClurg & Co., 1922.
(13) Pacific Coast Gas Association, "Gas Engineers' Handbook," pp. 326–53, New York, McGraw-Hill Book Co., Inc., 1934.
(14) Ripley, R. H., and Schwarz, S. C., U. S. Patent 1,724,222 (Aug. 13, 1929).
(15) Stookey, Kenneth W., *Gas Age*, **104**, 11 (Sept. 1, 1949).
(16) *Ibid.*, **104**, 36–41 (Sept. 15, 1949).
(17) Taylor, John, Brit. Patent 3929 (June 14, 1815).
(18) Wills, S. F., *Am. Gas Assoc. Proc.*, pp. 186–96 (1933).

Processing Equipment

(1E) American Meter Co., Pittsburgh, Pa., 16-inch orifice meter, *Bull.* **EG-2.**
(2E) Brassert, H. A., & Co., New York, N. Y., four-oven modified Knowles coke plant.
(3E) Clark Brothers Co., Inc., Olean, N. Y., reciprocating gas compressor unit, Model CBA-6.
(4E) Coen Co., San Francisco, Calif., No. 40 indirect heat exchangers.
(5E) Dorr Co., Stamford, Conn., 75-foot continuous center-pier torque thickener.
(6E) Gas Machinery Co., Cleveland, Ohio, 20-foot oil gas generators.
(7E) *Ibid.*, 27-foot oil gas generators.
(8E) General Electric Co., Schenectady 5, N. Y., Type T-1 centrifugal exhausters.
(9E) *Ibid.*, Type FS 757 centrifugal exhausters.
(10E) Graham Manufacturing Co., New York, N. Y., Type 22-16 horizontal oil heaters.
(11E) Komarek-Greaves Co., Chicago 18, Ill., 36-inch briquetting press.
(12E) Oliver United Filter Co., Oakland, Calif., 6-foot continuous rotary vacuum filter.

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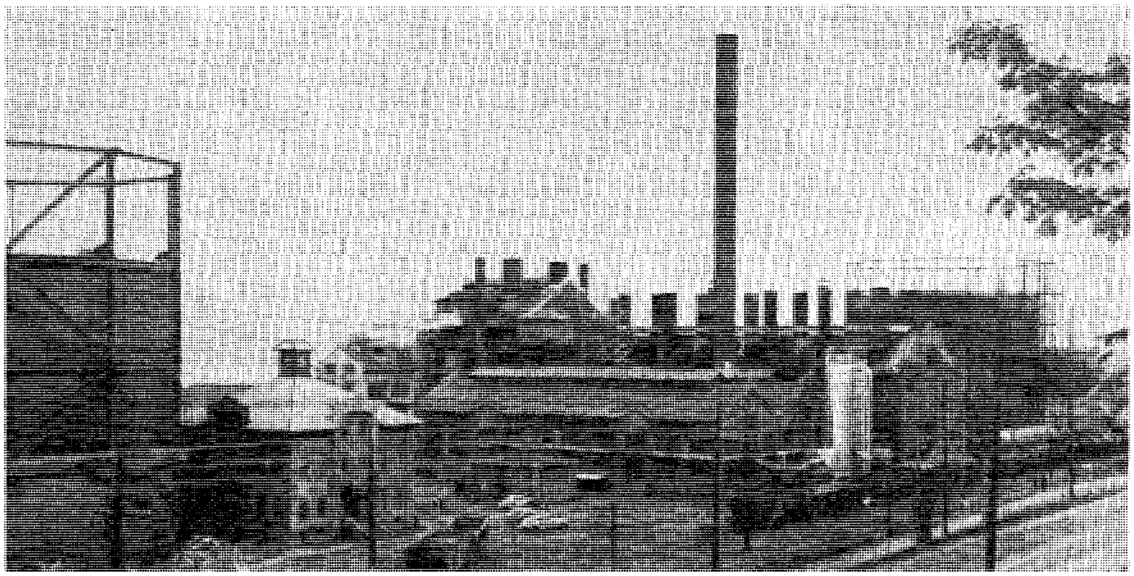

Portland Gas & Coke Co. Oil Gas Plant