Water Requirements of the Carbon-Black Industry

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1330-B

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By HOWARD L. CONKLIN

WATER REQUIREMENTS OF SELECTED INDUSTRIES

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A study of manufacturing processes with emphasis on present water uses and future water requirements

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PREFACE

This report is one of a series describing the water requirements of selected industries that are of national importance. It was prepared at the request of and in consultation with the Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, Department of Commerce. The report is designed to serve the dual purpose of providing basic information for national defense planning and at the same time rendering a valuable service to business and industry in their development of water resources for present and future use.

Background material for this report was obtained from a search of the literature on the subject. Statistics and technology relating to the industry were obtained principally from various issues of Minerals Yearbook, U. S. Bureau of Mines. Technical information regarding the methods of production was obtained in large measure from the publications of Dr. I. Drogin, director of research, United Carbon Co., Inc., Charleston, W. Va.

In dealing with details of the manufacturing processes, the simplest procedure is to use the terminology of the trade, the explanation or definition of which is beyond the scope of this report.

Appreciation is expressed to the officials of all producing companies of the carbon-black industry for granting the author and a colleague the privilege of visiting their plants and to the management of each plant visited for their courtesy and cooperation. Sincere thanks are due Dr. Drogin for furnishing copies of his books that are cited and for permission to draw upon them for technical information. Thanks are due R. W. Byram & Co., Austin, Tex., for production reports they provided. The author is greatly indebted to his colleague, O. D. Mussey, who made the survey of the carbon-black plants in the gulf area of Texas and of all plants in Louisiana and Arkansas.

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ABSTRACT

Carbon blacks include an important group of industrial carbons used chiefly as a reinforcing agent in rubber tires. In 1953 more than 1,610 million pounds of carbon black was produced, of which approximately 1,134 million pounds was consumed by the rubber industry. The carbon-black industry uses small quantities of water as compared to some industries; however, the water requirements of the industry are important because of the dependence of the rubber-tire industry on carbon black.

Two methods are used in the manufacture of carbon black—contact and furnace. The only process use of water in the contact method is that used in pelleting. Water is used also in the plant washhouse and for cleaning, and sometimes the company camp may be supplied by the plant. A survey made during the last quarter of 1953 showed that the average values of unit water use at contact plants for process use, all plant uses, and all uses including company camps are 0.08, 0.14, and 0.98 gallon of water per pound of carbon black respectively.

In addition to use in wet pelleting, large quantities of water are required in continuous and cyclic furnace methods to reduce the temperature of the gases of decomposition in order to separate and collect the entrained carbon black. The 22 furnace plants in operation in 1953 used a total of 12.4 million gallons per day for process use. Four furnace plants generate electric power for plant use; condenser-cooling water for one such plant may nearly equal the requirements of the entire industry for process use. The average values of unit water use at furnace plants for process use, all plant uses and all uses including company camps but excluding power generation are 3.26, 3.34, and 3.45 gallons of water per pound of carbon black respectively.

Carbon-black plants in remote, sparsely settled areas often must maintain company camps for employees. Twenty-one of twenty-seven contact plants surveyed in 1953 had company camps. These camps used large quantities of water: 0.84 gallon per pound of carbon black as compared to 0.14 gallon per pound used in the plants.

Furnace plants can generally be located near a labor supply and, therefore, do not require company camps. Ten of the twenty-two furnace plants surveyed in 1953 had company camps.

Because water used for pelleting and gas quenching is evaporated, leaving the dissolved minerals in the product as objectionable impurities, particular attention was paid to the quality of water available for use at the plants visited during the 1953 survey. Reports of chemical analyses of water samples were obtained at 23 plants. A study of these reports does not develop a pattern of the limits of tolerance of dissolved solids in water used in process or of the need for water treatment based on geographical location of the plant. However these analyses show that water used for quenching contains less dissolved solids than water used by the industry for any other purpose.

Based on trends in the industry it is expected that the quantity of water used by the carbon-black industry will increase more rapidly than will the quantity of carbon black produced because of the increasing percentage produced in furnace plants, and that selection of sites for modern furnace plants will be influenced more by quantity and quality of the available water supply than was the case in selecting sites for contact plants for which low-cost natural gas was the primary consideration.

INTRODUCTION

PURPOSE AND SCOPE

This report, one of a series of investigations on the water requirements of important industries, presents a summary of basic data on water use in the production of carbon black by all current processes in the United States. This kind of information is needed to plan more intelligently the overall development of specific areas and the most effective use of our water resources. The average water requirements shown in this report will help to establish a reasonable conception of the water needs of the carbon-black industry. If defense mobilization should be necessary, the results of this survey would be especially helpful in determining locations of new plants so that they will be assured adequate water supplies of suitable quality and at the same time not interfere with the requirements of other industries with which they must share the water.

The scope of this report goes beyond tabulating the overall water requirements of the industry. The quantity and quality of water required in each step in the manufacture of carbon black by different processes are given. Information is given in sufficient detail so that the effects of reuse and changes in plant location and manufacturing procedure can be evaluated. The manufacturing processes are described briefly to show how water is used in the industry, and information is given on consumptive use and the effects of water quality on quantity of water used and quality of the product. Trends in water requirements as well as present needs of the industry are given.

The investigation consisted of a review of the literature and a field survey. The literature was reviewed to obtain published information on the water requirements and to obtain an understanding of how water is used in the industry and the water-supply problems.

Field investigations, which were carried out during the last quarter of 1953, consisted of a visit to each of the 49 plants in the United States that was producing carbon black at any time during that year by any commercial process. Detailed studies were made in order to determine the quantity of water required for each process and plant use, for steam generation of electric power, and for other uses not directly chargeable to process or plant, such as the quantity of water furnished by the plant to the company camps. Equally important was the determination of how much of the total water intake was used consumptively, where it was used in plant operation, and to what extent water was reused.

Information was sought concerning the source of water, the adequacy of the supply, the quality of the water, the need for water treatment, the manner of disposal of waste water, and any changes in process or plant practice that would indicate a trend in water use.

DEFINITION OF CARBON BLACK

The term "carbon black" identifies an important group of industrial carbons used chiefly as reinforcing agents in the rubber-tire industry and as coloring pigments in the ink and paint industries. Chemically they are nearly pure elementary carbon with varying amounts of hydrogen and oxygen and have ash contents generally less than 1 percent. Physically they are composed of essentially spherical particles, similar to graphite in structure, that have colloidal dimensions. The properties for which carbon black is valued in industry are associated primarily with its fine state of subdivision, which ranges from particle diameters of 500–50,000 micromicrons (Encyclopedia of Chemical Technology, 1939, p. 34). The variation in properties displayed by different types of carbon black is due in large part to differences in average particle size.

Present knowledge indicates that lampblack is properly classified as carbon black. It has been the custom, however, for purely historical reasons, to consider lampblack in a separate category. This distinction has been observed in this report, and the production figures given for carbon black do not include those for lampblack, which constitutes approximately 3 percent of the gross production.

MANUFACTURING PROCESSES

Carbon black is manufactured by either partial combustion or thermal decomposition of gaseous or liquid hydrocarbons. The partial-combustion processes are known as contact methods from the cold metal in contact with the burning hydrocarbon and on which the carbon black collects. Contact plants are either channel, roller, or disc plants depending on the shape of the cold metal in contact with the burning hydrocarbon. The thermal-decomposition processes are known as furnace methods from the furnaces or retorts in which the decomposition takes place. Furnace plants are either continuous or cyclic. Carbon black produced by the contact method is often called contact black and that produced by the furnace method is called furnace black.

IMPORTANCE OF THE INDUSTRY

The carbon-black industry is of great importance to the economy of the country, either in time of peace or in time of war. This importance, however, is not due to the magnitude of production nor the dollar value of the product. The Bureau of Mines (1954b) reported that 1,610.4 million pounds of carbon black was produced in 1953. The value of the total production was approximately 105 million dollars; the average value of carbon black at producing plants was 6.51 cents per pound. Total domestic sales amounted to 1,200.9 million pounds. The importance of the carbon-black industry lies in the fact that it furnishes to the rubber industry, which takes about 95 percent of the total quantity used domestically, an agent that greatly improves the usefulness of rubber, both natural and synthetic. It is highly unlikely that the rubber-tire and automobile industries would have reached their present gigantic proportions without rubber having the properties of long tread wear at high speeds, resiliency, and freedom from flex cracks. All of these properties are due to the blending of the correct grade and amount of carbon black with natural or synthetic rubber.

The carbon-black industry uses a relatively small quantity of water compared to such industries as steel, petroleum refining, and some basic chemical manufacture. The combined water requirements of all 49 plants in operation in 1953 averaged about 28.8 mgd (million gallons per day), a large part of which was used at one plant as cooling water for power generation, gas compressors, and other plant uses.

The water requirements of this strategic segment of our economy are important, not because of the quantity of water required, but because of the location of existing plants and possible future expansion. Many older plants were of necessity located at natural-gas fields in areas where surface- and ground-water supplies are deficient and, in some areas where water was of unsatisfactory chemical quality. Furnace plants, designed to use gaseous or liquid hydrocarbons from refineries, may be located near an ample supply of water of suitable quality.

HISTORY AND GROWTH OF THE INDUSTRY

The first carbon-black plant utilizing natural gas as a raw material was erected by Howarth and Lamb at New Cumberland, W. Va., in 1872. West Virginia remained the chief producing State until about 1920 when pipelines to cities in Pennsylvania and Ohio increased the price of gas above its economic value for use in carbon-black plants (Mantell, 1946).

Soon after the turn of the century the industry migrated to the enormous gas fields in western Louisiana in order to utilize natural gas that was then being flared or otherwise wasted. The Caddo oilfield, Caddo Parish, La., furnishes an example of the magnitude of the waste of this natural resource. During the early history of the field (1906–8), when there was no market outlet for gas, the waste of natural gas attending the production of oil from this field alone was as much as 70 million cubic feet per day (Grandone and McHarg, 1952).

However, pipelines and local fuel uses once again introduced competition, and by 1929 the industry had located to a large extent in the gas fields of the Texas Panhandle. Since 1929, Texas has been the leading producing State and Louisiana is second. The remainder of the United States production in 1953 was confined to Arkansas, California, Kansas, and New Mexico.

The early carbon-black plants were predominately contact plants. As late as 1941, just before the entry of the United States into World War II, production from furnace plants was only 101.2 million pounds or approximately 17 percent of the total production of 594.0 million pounds.

When imports of natural rubber were greatly reduced during the war, synthetic rubber was substituted as rapidly as possible for natural rubber. The fine-particle contact blacks formerly required for natural rubber, which constituted by far the largest percent of the total contact-black production, proved to be less suited to synthetic rubber than grades of larger particle size (Drogin, 1945).

Synthetic rubber is harder to process and necessitates the use of types of carbon black not required for natural rubber (Jeffers, 1943). The program for the making of furnace blacks, which had not been used extensively with crude rubber in prewar tires, was a large one (Dewey, 1944). The greatly increased use of synthetic rubber during the war and its continued use in subsequent years gave impetus to the development of new grades of furnace blacks.

As a consequence of the abnormal wartime demand which spurred intensive research and experimentation, grades from furnace plants have gained equal acceptance with those from contact plants for many applications in the rubber and printing industries. By 1953, the annual production of furnace blacks had increased to 1,157.1 million pounds, about 72 percent of the total production (table 1).

Table 1.—*Carbon-black production, in thousands of pounds, 1925–53*

[Data for 1925–43 compiled by Drogin, 1945, and for 1944–53 by U. S. Bureau of Mines, 1946, 1951, 1952, 1953, and 1954]

Year	Contact processes[1]	Other processes[2]	Furnace processes	Total
1925	143,701	33,716		177,417
1930	350,254	29,688		379,942
1935	316,284	36,465		352,749
1940	491,765	77,027		568,792
1941	492,857		101,208	594,065
1942	428,665		145,341	574,006
1943	379,923		213,498	593,421
1944	414,676		387,184	801,860
1945	538,539		514,259	1,052,798
1946	619,109		625,312	1,244,421
1947	653,966		664,999	1,318,965
1948	677,133		620,596	1,297,729
1949	627,650		595,986	1,223,636
1950	616,765		765,225	1,381,990
1951	645,881		1,031,482	1,677,363
1952	563,597		1,040,505	1,604,102
1953	453,345		1,157,092	1,610,437

[1]Channel plants only through 1940; channel, disc, roller plants, 1941–52.
[2]Disc, roller, and furnace plants.

LOCATION OF CARBON-BLACK PLANTS

The requirement of a large volume of gas available at a low price has been responsible for the migratory nature of the industry. Plants formerly were located in regions where there was little or no demand for gas as a domestic or industrial fuel. However, with the extension of pipeline systems to all important natural-gas fields, the migratory phase of the industry seems to be drawing to a close (Mantell, 1946).

The increased cost of natural gas resulting from competition between pipeline companies for the use of the gas has been reflected in a corresponding increase in the price of carbon black. Indeed, some contact plants operated by producers of natural gas when the gas was a waste product have been shut down because the gas has become more valuable for sale to a gas-transmission company than for the production of carbon black. Other plants, both contact and furnace, using natural gas have been shut down or moved when the low-price gas contract terminated. Two plants were shut down for this reason during 1952, and 7 during 1953 (Bureau of Mines, 1954a, 1954b).

Much of the gas used today for carbon-black production is unsuited for supplying to pipelines. The principal sources of the basic raw material, or feedstock as it is generally called, of carbon black are natural gases stripped of their propane, butane, and pentane fractions; waste refinery gases; and gases of high sulfur content for which there is no domestic market or pipeline demand (Drogin, 1945).

Some furnace plants still use natural gas as feedstock. Furnace plants built in the past several years, however, are designed to use waste refinery gases or liquid hydrocarbons that are obtained from gasoline refineries after the more valuable fractions have been removed. The most recent furnace plants, therefore, have been built near the refinery from which the feedstock is obtained. Refineries require large quantities of water for their operation; the amount used by the carbon-black plant is insignificant in comparison. At one plant visited, waste water from the adjacent refinery supplied all process needs at the carbon-black plant.

The trend of a gradually decreasing number of contact plants and an increasing number of furnace plants has considerable effect upon the water use of the industry.

METHODS OF WATER USE

To determine the water balance of each carbon-black plant water uses are classified in this report as process, nonprocess, and company camp.

PROCESS

Pelleting.—Pelleting is a packaging process and as such is a part of production. Approximately 95 percent of all carbon black consumed in the United States during 1953 was used by the rubber industry, principally in tire manufacture. The fluffy rubber-grade carbon blacks are difficult to handle in mill-room processing at tire factories, and they create an unfavorable environment for the workers. In recent years it has been customary to ship much of the rubber-grade carbon blacks in pellet form. Shipment in this form is more economical and results in less carbon-black dust at the tire factories.

The exceedingly fine particles of carbon black are formed into tiny pellets, or beads as one producer calls them, by various patented methods. Carbon black is pelleted dry at some plants, at others water is first mixed with the carbon black to form a slurry.

The proportions of carbon black and water in the slurry differ between plants. It was found during the field study of the industry that the quantity of water used ranges from 40 to 60 pounds per 100 pounds of slurry. The ratio of water to carbon black, both measured by weight, therefore ranges from $66\frac{2}{3}$ to 150 percent.

In contact plants water used to form the slurry for the pelleting machines is the only process use of water. Contact plants that ship carbon blacks compacted in paper bags or pelleted by a dry method use no water in the process.

The quantity of water required for pelleting by a wet process differs not only between plants because of the different percentage of water used by different wet processes, but also at a given plant because the percent of the carbon black that is wet pelleted differs from time to time. The quantity of water amounts to as much as 0.033 mgd at contact plants and 0.029 mgd at furnace plants.

The total quantity of water used for pelleting at all contact and furnace plants is approximately 0.105 mgd and 0.141 mgd, respectively. Twenty carbon-black plants, both contact and furnace, which constitute about 40 percent of all those in production in 1953, used no water for pelleting. Carbon blacks produced from those plants were shipped either compacted in bags or in bulk, having been pelleted by a dry process usually because of high mineral content of the water available. Carbon blacks produced by the roller and thermatomic processes are not pelleted because pelleting would adversely affect the physical properties of these grades.

The average use of process water over the entire industry for pelleting is 0.05 gallon per pound of carbon black.

Gas quenching.—In the continuous furnace process, carbon black is produced by incomplete combustion at temperatures that range between 2,200° and 3,000°F. The hot gases from the combustion of the hydrocarbons carry the carbon black in suspension to gas-quenching towers and separation and collection equipment. Process water ranging in amount from 0.1 to 5.3 mgd is used for quenching or cooling these gases. Practically all water used for gas quenching is used consumptively.

Equipment for collecting and separating carbon black consists of a Cottrell electrostatic precipitator and one or more cyclone collectors from which the gases of combustion pass out the stack. The gases of combustion are cooled to approximately 500°F before they enter the electrostatic precipitator by the interposition of a gas-quenching tower between the flue and the precipitator. The action in the quenching towers generally is downflowing water sprays of sufficient volume to cool the upflowing gases by the heat of evaporation of the quenching water. The quantity of water used in gas-quenching towers is controlled to provide sufficient cooling effect without an excess of water draining off. About 30 percent of the carbon black in suspension in the gases of combustion and water vapor is agglomerated and shaken off into the collecting hoppers attached to the bottom of the precipitator.

The gases and entrained carbon not collected in the precipitator are withdrawn in continuous flow from the precipitator and led into the cyclone collectors usually arranged as a battery of two in series. Although the collectors recover, to a large extent, the carbon black agglomerated in the precipitator but not retained in its collecting hopper, nevertheless some fine-grained carbon black escapes from the cyclone collectors and passes from the stack as black smoke.

In order to improve plant efficiency, some furnace plants pass the gases from the cyclone collectors through bag filters. This equipment consists of a large number of cylindrical bags, 6 inches in diameter and 10 feet long, enclosed in a sheet-metal housing. The gases enter the top of the bags and pass through them, the carbon black remaining in the bags much as dust is collected in a household vacuum cleaner. The bags are made of closely woven orlon, which chars at approximately 260°F, requiring further reduction of the gas temperature when bag filters are used. This is accomplished by passing the gases through water sprays in a quenching tower between the cyclone collectors and the bag filter.

When a quenching tower is used in conjunction with a bag filter more water is commonly used in the quench-tower sprays than is evaporated by the upflowing gases. The effluent water, with carbon black carried in suspension, may be recycled by reintroducing the mixture into the water-supply lines leading to the spray heads in the gas-cooling tower, in order to reuse the water and reclaim the carbon black, or it may be wasted by draining to an evaporation pit.

Figure 13 is a flowsheet for a continuous furnace plant that employs one stage of water cooling and separation by electric precipitator and cyclone collectors. This arrangement is quite common in older plants.

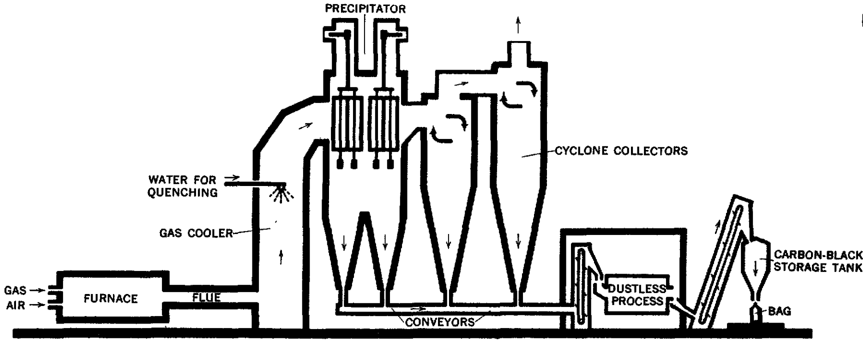

Figure 13. —Flowsheet of continuous furnace process. (Reproduced with the permission of United Carbon Co., Inc.)

The advantage of the use of secondary quenching and bag filters is the recovery, as reported by plant management, of as much as 10 percent of plant production which otherwise would be lost as smoke. By this arrangement practically complete recovery of carbon black is assured and the gases of combustion are almost invisible as they leave the stacks except for the white plumes of condensed water vapor.

The disadvantage of the use of orlon bag filters lies in the low temperature to which the gases must be cooled in order to prevent charring of the fabric. Condensation of water vapor takes place on the surface of the filter enclosure and, because the feedstock, whether it is gas, oil, or a combination of both, has a high sulfur content, corrosion of the metal structure that houses the bag filter is a serious and costly maintenance problem. The flowsheet of a continuous furnace plant using three stages of gas quenching is shown in figure 14.

The cyclic furnace plant, of which there are only two in the United States, produces carbon black by thermal decomposition of the feedstock. This requires a slightly different method of cooling. At one plant, at which carbon black is the sole item manufactured, the products resulting from cracking are cooled with sprays of water, and the carbon black is removed from the gaseous stream by a bag filter. Figure 15 shows a flowsheet of the process employed at this plant. At the other plant the stream of gases and entrained carbon is passed through a wash box somewhat similar to a gas scrubber, where the carbon black is washed out and subsequently filtered, dried, and bolted.

Wide variation in the amount of water used for cooling in the different plants is accounted for by such variables as size of

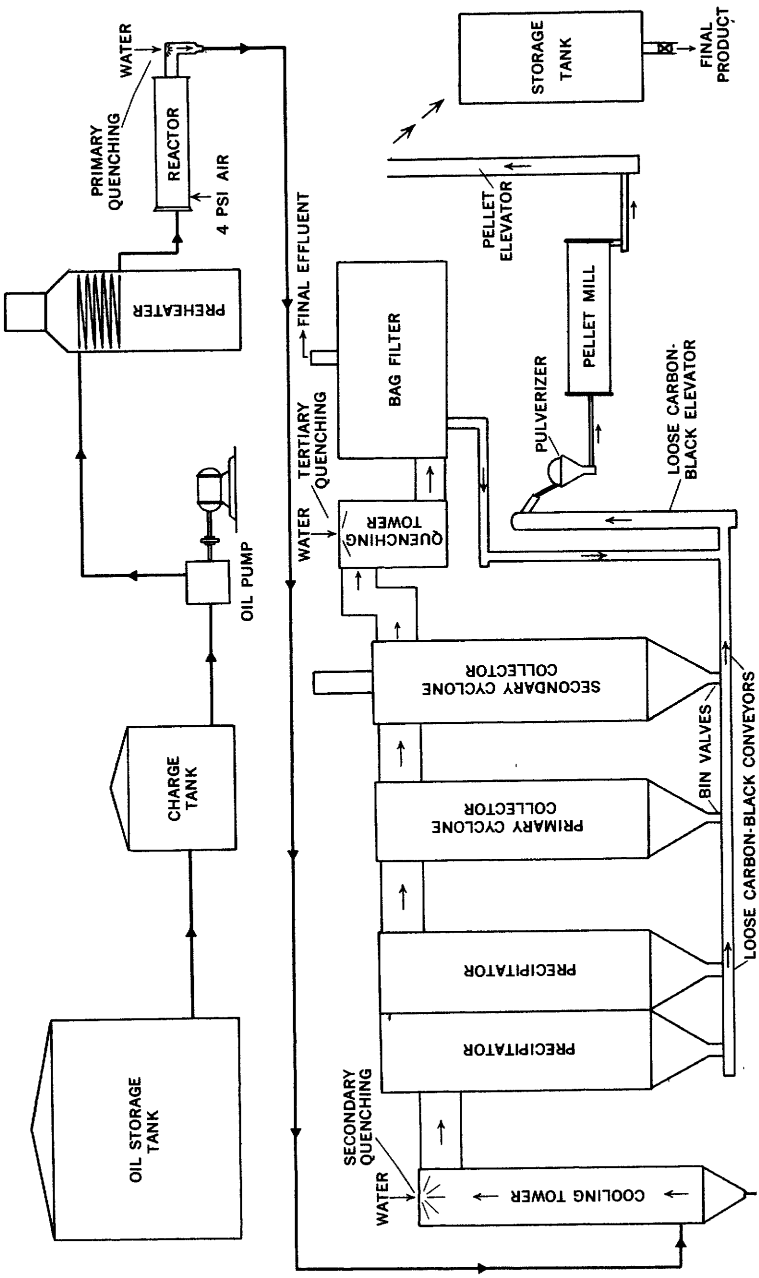

Figure 14. —Flowsheet for furnace plant using three stages of gas quenching.

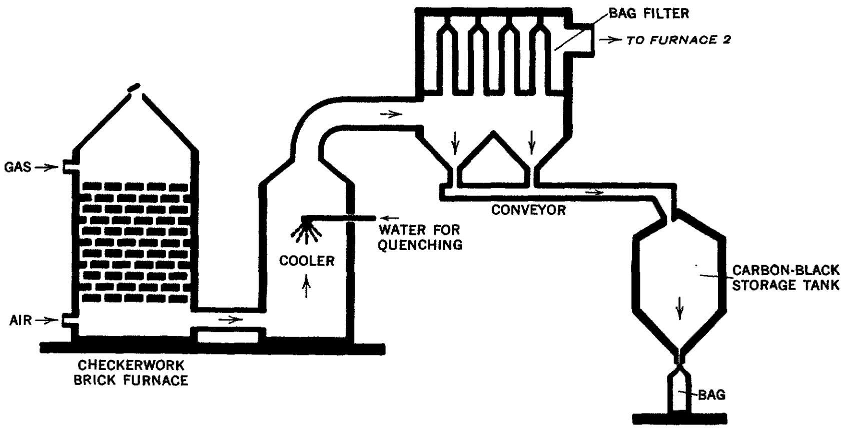

Figure 15.—Flowsheet for cyclic furnace process. (Reproduced with the permission of United Carbon Co., Inc.)

plant, method of collection, reuse of cooling water, availability of adequate supply, cost of water, and quality of water. This last is especially important because water used for cooling is evaporated and dissolved solids in the quenching water adhere to the particles of carbon black and reduce the purity and value of the product.

The total quantity of water used by all furnace plants to reduce gas temperatures and to scrub the gases averaged approximately 12.3 mgd during 1953. The average of water consumed over the entire industry for process uses at furnace plants was 3.26 gallons per pound of product. Nearly all of this process water was required for gas cooling since the other process use of water—pelleting—accounts for only 0.04 gallon per pound.

NONPROCESS

All water used at the plant other than for process use has been considered nonprocess plant use. Some nonprocess uses are common to all carbon-black plants. Other uses are peculiar to a few furnace plants that have steam-boiler installations for the generation of electric power for plant needs. Some of these powerplants are operated without condensers; others use large quantities of water for condenser cooling. The cooling water is such a large proportion of the total water requirements of the entire industry that for some uses of this report it may be desirable not to include it. For this reason boiler-feed and condenser-cooling water are listed separately in the tabulations that follow.

Plant services.—In this category falls all the water used for "domestic" services, such as drinking water, washhouses, and sanitary facilities. Nonprocess use of water for such plant services is common to all plants in the industry.

Boiler-feed water.—Electric power is generated at four carbon-black plants by steam powerplants. One steam plant is operated without condensers; at this plant the quantity of boiler-feed water used is more than the total water used for pelleting at all 49 carbon-black plants.

Cooling water.—Three furnace plants generate the electric power needed for their operation with steam powerplants using condensers. Two of the steam plants recirculate the condenser-cooling water, and one does not. Other cooling water uses are for gas dehumidification and air- and gas-compressor jackets.

COMPANY CAMP

Owing to the location of many carbon-black plants at natural-gas fields, often in sparsely settled areas, employees and their families are sometimes housed in company camps. This condition applies especially to contact plants; of 27 such plants all but 6 maintain company camps. At some contact plants there are only 2 or 3 houses for key personnel; at others there may be as many as 80.

Furnace plants burning natural gas and located at the gas field have the same housing problem, but others located near refineries in towns or cities do not require company camps. Of the 22 furnace plants in operation in 1953, 10 maintained company camps.

Stress is laid on the practice of providing company camps for several reasons; the water used at the camp has nothing to do directly with the production of carbon black, and the quantity of water used at company camps for domestic use, air conditioners, and lawn sprinkling is substantial. For example in 1953 the total water intake for all contact plants for all purposes was approximately 1.3 mgd; of this quantity 1.1 mgd was used at company camps.

Although it is recognized that water supplied to a company camp, frequently located a mile or more from the plant, is open to question as properly chargeable to plant operation, it is included as a water use necessary to attract workers and to maintain favorable employee morale. Generally water used at the camp is furnished by the plant water-supply system.

YIELD OF CARBON BLACKS

The yield is the quantity of carbon black recovered per thousand cubic feet of gas or per gallon of liquid hydrocarbon burned as fuel or feedstock. It determines to some degree the quantity of water used in process and the unit water use for process and total plant use, expressed in gallons of water per pound of product. The recovery of carbon black is governed by the process of manufacture, composition of the hydrocarbons in the feedstock, and quality of carbon black desired. The better the reinforcement characteristics of the product, the lower the yield per unit of feedstock. The greater the percentage of hydrocarbons of high molecular weight, the higher the yield (Drogin, 1945). A better understanding of yield may be had by examining the percentage of recovery by different processes. Natural gas contains about 35 pounds of carbon per thousand cubic feet, varying slightly with the composition of the gas. The recovery of carbon black by the contact method varies according to the composition of the gas and the quality of the carbon black produced. The yield of all contact plants averages about 1.6 pounds per thousand cubic feet of gas. This yield represents a recovery of about 5 percent of the total carbon contained in the feedstock.

In comparison the average yield of furnace plants of 8 pounds per thousand cubic feet of gas represents a recovery of 22.8 percent of the carbon content of the fuel. The yield of furnace plants varies more than that of contact plants because furnace blacks cover a wider range of grades. The yield of medium thermal furnace (MTF) black is approximately 16 pounds per thousand cubic feet of gas, a recovery of almost 50 percent of the total carbon in the feedstock; of semireinforcing furnace (SRF) black, about 9 to 12 pounds; of high modulus furnace (HMF) black, about 6 pounds when produced from unenriched gas, and approximately 4 pounds per gallon of fuel when produced from liquid hydrocarbons; of fine furnace (FF) black, approximately 4 pounds per thousand cubic feet; and reinforcing furnace (RF) black, about 3 pounds (Drogin, 1945, p. 21, 24).

This not only indicates the higher efficiency of furnace plants as compared to contact plants, but also shows the wide variation of the yield depending on the grade of carbon black produced.

The yield has a direct bearing on the quantity of water used in the production of carbon black. If a furnace plant that had been producing SRF black is adjusted to produce HMF black, the gases of combustion and entrained carbon black will leave the furnace at a higher temperature than when SRF black was being produced; consequently, a greater quantity of water is required to reduce the temperature of the gases to approximately 500°F before they enter the electrical separator. Furthermore, the yield when producing HMF black is only about half of what it was when the same furnace, burning the same quantity of feedstock, was producing the SRF grade. The unit water use for gas cooling expressed in gallons per pound of HMF carbon black is, therefore, more than twice the unit use when SRF carbon black was being produced.

QUANTITY AND QUALITY OF WATER USED

SOURCES OF WATER SUPPLY

The carbon-black industry uses both ground water and surface water. Of 49 plants in production during 1953, 48 use ground water, either wholly or in part, for plant water requirements. With a single exception, all 33 plants in Texas depend entirely on ground water pumped from company-owned wells or purchased. The plant that uses no ground water in its operation purchases all the required water from a municipal waterworks, the source of supply for which is a river.

All plants in the Texas panhandle and the southern High Plains use only ground water. Although the quality of ground water at a large number of the plants in this area is not of satisfactory quality for use in process and washhouses, mainly because of its hardness, dependable sources of surface water are not available. The same applies to the three plants in Kansas and to the three plants in New Mexico; the plants in New Mexico are only a few miles west of the New Mexico-Texas State line.

Climatic conditions throughout Louisiana are quite different from those in the semiarid High Plains, and this difference is reflected in water use. All carbon-black plants in Louisiana use ground water to some extent but draw so heavily on lakes and rivers that about 75 percent of all the water used by the carbon-black industry in the United States is from surface-water sources.

UNIT WATER USE

Unit water use at each plant, expressed in gallons of water per pound of product, for each process and nonprocess plant use, including company camps, is shown in tables 2 and 3. The data given in these tables are the values reported by plant managements at the time the survey was made.

Table 2.—*Unit water requirements of contact plants, in gallons per pound of carbon black*.

Order of requirement	Process use (pelleting)	Nonprocess plant use	Total plant use	Company camps	Total
1	0	0.18	0.18	5.06	5.24
2	.19	.71	.90	2.38	3.28
3	.08	.02	.10	3.08	3.18
4	0	.08	.08	2.16	2.24
5	0	.67	.67	1.55	2.22
6	.04	.06	.10	2.12	2.22
7	.08	.02	.10	1.86	1.96
8	0	.15	.15	1.73	1.88
9	.09	.04	.13	1.51	1.64
10	.17	.04	.21	1.20	1.41
11	.18	.06	.24	1.17	1.41
12	.18	.05	.23	.76	.99
13	.19	.19	.38	.57	.95
14	0	.03	.03	.72	.75
15	.11	.08	.19	.22	.41
16	.10	.04	.14	.17	.31
17	.17	.04	.21	.07	.28
18	0	.04	.04	.22	.26
19	.14	.07	.21	0	.21
20	0	.11	.11	0	.11
21	0	.11	.11	0	.11
22	.04	.02	.06	.04	.10
23	0	.03	.03	.05	.08
24	.04	.04	.08	0	.08
25	0	.02	.02	.06	.08
26	0	.04	.04	0	.04
27	0	.04	.04	0	.04
Weighted average	.08	.06	.14	.84	.98

Table 3.—*Unit water requirements of furnace plants, exclusive of power generation, in gallons per pound of carbon black*

Order of requirement	Process (pelleting and quenching)	Nonprocess plant use	Total plant use	Company camps	Total[1]
1	20.46	0.06	20.52	0.08	20.60
2	5.01	.16	5.17	1.03	6.20
3	3.07	.26	3.33	1.60	4.93
4	4.80	.02	4.82	.09	4.91
5	4.15	.09	4.24	0	4.24
6	3.05	.76	3.81	.30	4.11
7	3.74	.05	3.79	0	3.79
8	3.51	.06	3.57	0	3.57
9	3.40	.03	3.43	0	3.43
10	3.15	.23	3.38	.04	3.42
11	2.52	.04	2.56	.69	3.25
12	2.73	.04	2.77	0	2.77
13	2.53	.10	2.63	.03	2.66
14	1.65	.04	1.69	0	1.69
15	1.51	.02	1.53	0	1.53
16	1.28	.09	1.37	.07	1.44
17	1.37	.06	1.43	0	1.43
18	1.27	.04	1.31	0	1.31
19	1.16	.04	1.20	0	1.20
20	1.00	.03	1.03	0	1.03
21	.79	.04	.83	.03	.86
22	.82	.03	.85	0	.85
Weighted average	3.26	.08	3.34	.11	3.45

[1]In addition, one plant uses 6.70 gallons of water per pound of carbon black for gas dehumidifying.

The assignment to survey the carbon-black industry goes beyond the factual reporting of the quantity of water used by the industry. The necessity for determining the minimum quantity of water required as distinguished from the water used is inherent in order to plan for future expansion of the industry. Not all the water reported as plant intake is absolutely essential for the production of carbon black.

The water balance of the individual plants shows the amounts of total plant intake charged to process uses, nonprocess plant uses, and company camps. Total water intake at contact plants ranges from 250 to 223,000 gallons per day. This wide range is due in part to the different amounts of water used in pelleting; 12 of the 27 contact plants use no water for this process because they either do not pellet the product or do so by a dry method. Part of the variation is accounted for by differences in production which ranges from 1,800 to 175,000 pounds per day. The quantity of water used for plant services, such as washhouses and sanitary facilities, is a function of size of plant and varies directly with the number of employees. The most significant variable in the water balance of contact plants is the quantity of water used at company camps. Water used for this purpose was as much as 0.216 mgd. At the plant using the largest amount, water is available at low pumping cost, and 97 percent of the total water intake was furnished to the camp for domestic use, air conditioning, and lawn sprinkling. As a result the shade trees and lawns of the company camp form an oasis in a semiarid region which doubtless adds to the morale of the employees. The large quantity of water furnished by the plant should be included in an inventory of the total water used by the plant, but it is questionable if this water is a requirement for production of carbon black.

Water-use data show a greater variation at furnace plants than at contact plants. Process use of water, for pelleting and gas quenching, ranged from 0.10 to 5.32 mgd. The total quantity of water used by all furnace plants for pelleting is relatively small—0.141 mgd. Gas quenching, essential to the furnace method of production of carbon blacks by processes now in use, consumed 12.3 mgd. Plant services accounted for 0.302 mgd. The total, 12.7 mgd, is approximately the minimum quantity of water needed to produce 3.808 million pounds of carbon black per day by the furnace processes.

The total quantity of water used at furnace plants, as reported by the managements, was 27.5 mgd. The large difference between 12.7 and 27.5 mgd—14.8 mgd—is mostly accounted for by the water used to produce electric power at four plants; however, some of this water was used to dehumidify reformed gas.

Although part of the 14.8 mgd is used consumptively for boiler-feed water makeup and for cooling-tower operation at steam powerplants, most of it is used once as cooling water for steam powerplant condensers and for dehumidification of reformed gas. Most of the process use of water in the carbon-black industry is consumptive, but cooling water that is used only once is returned to its original source substantially unchanged except for a rise in temperature.

For planning industrial expansion it may be justifiable to assume that future plants will be so located that company camps will not be required and that the generation of electric power for future plants usually will not be necessary or profitable. If it is found that conditions peculiar to a proposed plant will require a company camp or that the generation of electric power for plant needs is desirable, the additional water requirements for these services can be added readily to the basic water requirements. Therefore, the data from plant water balances were compiled, omitting the amount of water used in company camps and electric-power generation and plotted in figures 16—18. As a result of these omissions, there is considerably more uniformity in unit water requirements between plants producing carbon black by the same process than would be apparent from an analysis of figures of gross use. These graphs emphasize conformities and anomalies in water use in various phases of the production of carbon black.

Figure 16 shows that 18 of the 27 contact plants use less than 0.1 gallon of water per pound of product for process use, and the remaining 9 plants use from 0.1 to 0.2 gallon per pound. In contrast to this uniformity is the wide variation shown for furnace plants, ranging from 0.7 to 20.5 gallons of water per pound of product. As previously discussed, the sole process use of water at contact plants is for pelleting when done by a wet process. At furnace plants there is the additional process use of water required for gas quenching. The manner in which reduction of gas temperature is accomplished, the final temperature required, and, in some plants, the use of gas scrubbers explain the wide variation in water requirements for process uses at furnace plants.

Unit water requirements for nonprocess plant uses, such as washhouses, sanitary lines, and plant washdown (fig. 17), indicate that 20 contact plants use less than 0.1 gallon of water per pound of product and all but 2 plants use less than 0.2 gallon per pound. The unit water use of each of these 2 other plants is approximately 0.7 gallon per pound; both of these are roller plants. The yield by the roller method is approximately one-fifth that of a channel plant similar in size, producing rubber grades of carbon

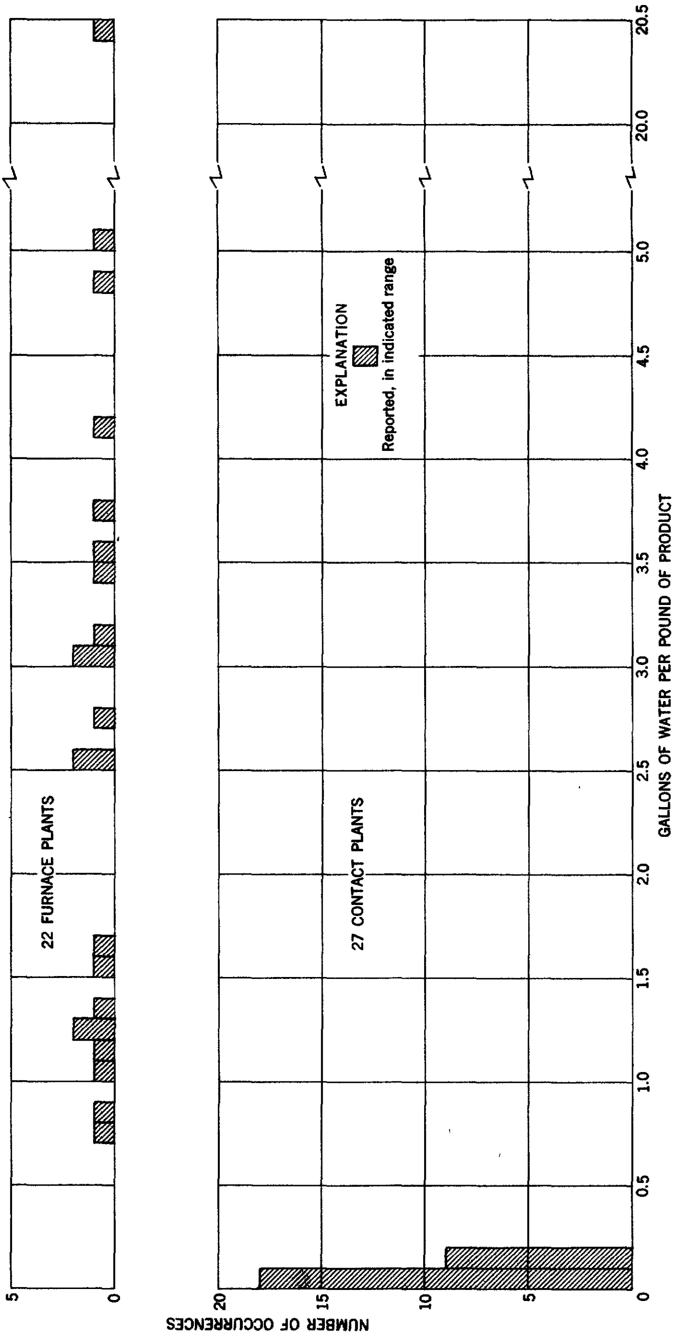

Figure 16. —Frequency graph of unit water requirements for process use.

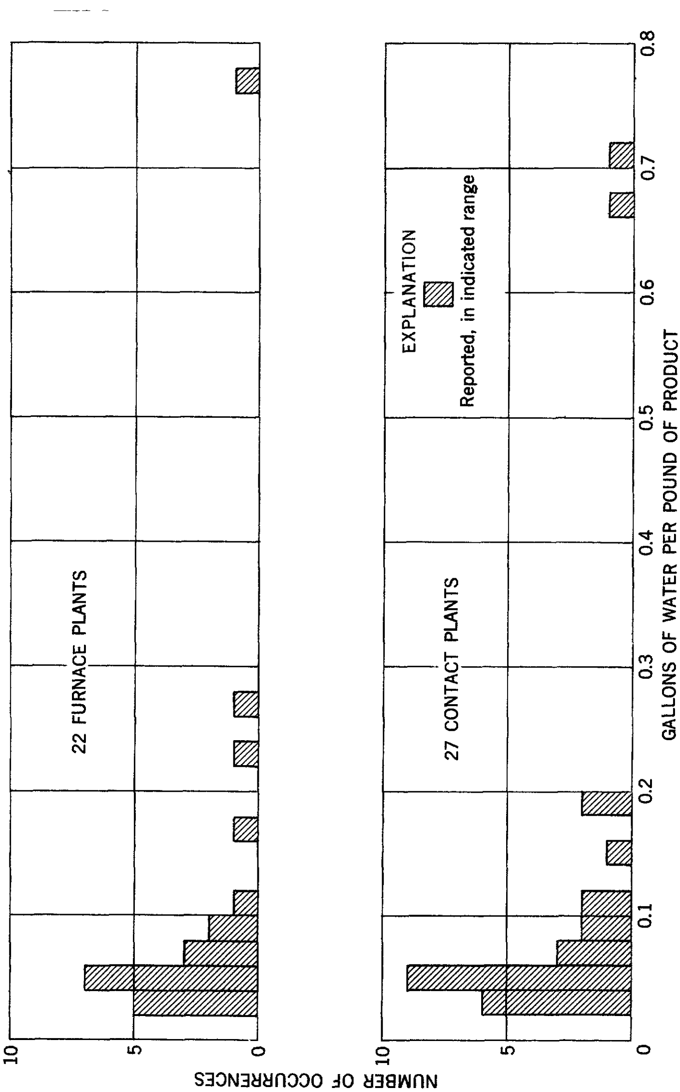

Figure 17.—Frequency graph of unit water requirements for nonprocess plant uses, power generation and gas dehumidification not included.

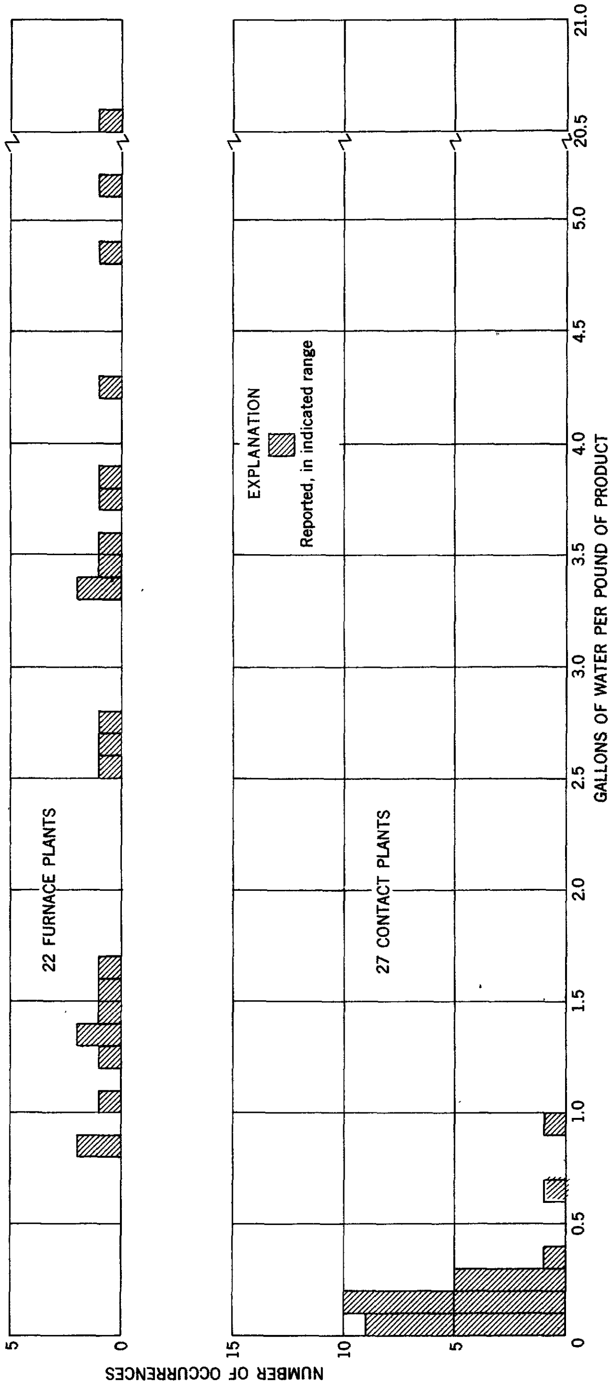

Figure 18.—Frequency graph of total water requirements, company camps, power generation, and gas dehumidification not included.

black, and about the same number of employees are needed for the plant's operation. Unit water requirements for furnace plants are reasonably uniform because the quantity of water required is generally proportional to the number of employees—or about proportional to plant capacity.

Unit water requirements per pound of product for all purposes, exclusive of company camps, gas dehumidification, and the generation of electric power for plant use show little variation for contact plants (fig. 18). There is a wider spread in this requirement at 21 furnace plants, ranging from 0.8 to 5.17 gallons per pound. The remaining plant used 20.52 gallons per pound.

CONSUMPTIVE USE

Some water uses are consumptive, a term that denotes the water so used ceases to exist as a liquid by being converted into water vapor that passes into the atmosphere. Other uses are nonconsumptive; for example, cooling water leaves the plant unchanged except for a rise in temperature. Nearly all process water used in the production of carbon black by any method of manufacture is used consumptively.

For all practical purposes, water for nonprocess plant uses for a large majority of all carbon-black plants is used consumptively. The exception is condenser-cooling water utilized at three plants at which electric power is generated. Water supplied for plant services such as washhouses and sanitary facilities is drained to septic tanks from which the effluent is dispersed by tile fields or evaporation ditches. Water furnished by plants to company camps is disposed of in a similar manner. Since 84 percent of the carbon-black plants are in areas where normal annual precipitation is approximately 20 inches, and the normal annual potential evaporation is approximately 80 inches (Linsley, Kohler, and Paulhus, 1949), it is doubtful if any of the water thus disposed of from plants in this area reaches the water table.

The remaining 8 plants are in a region where the average annual rainfall is 50 inches, the average annual potential evaporation is 60 inches, and the water table is near the land surface. Waste water at these plants is returned in large measure to surface- and ground-water supplies.

Another consumptive nonprocess plant use is boiler-feed water at the one steam-generating plant operated without condensers.

It seems to be a reasonable assumption, therefore, that a very large part of the water charged to plant uses is used consumptively, passing into the atmosphere as water vapor through evaporation or transpiration. Thus nearly all of the plant water intake of the industry is used consumptively with the exception of condenser-cooling water. The quantity of condenser-cooling water is large, amounting to almost half of the total water requirements of the industry, but it is a water use that is neither essential to the manufacture of carbon black nor is it general practice.

REUSE OF WATER

The production of carbon black by contact methods does not afford any opportunity for the reuse of water; plant water intake for all process needs is used consumptively.

Furnace plants require water for another process use in addition to pelleting the product—gas quenching. When the method of collection is such that more water is fed to the sprays in the various stages of quenching than is required for the desired reduction in temperature, the excess water is drained off and sometimes reused in the gas-cooling cycle. This reuse of the slurry consisting of water and entrained carbon black, however, is not a universal practice because at some plants the cost of maintenance, due to corrosion, exceeds the value of the water saved and carbon black recovered.

QUALITY OF WATER

The quality of water used in the manufacture of carbon black is important. Because water used for pelleting and gas quenching is used consumptively, the dissolved minerals in the water remain in the product as an impurity.

Dr. I. Drogin (Drogin and Bishop, 1948, p. 38), director of research, United Carbon Co., Inc., states:

> The ash in furnace black may test as high as 1.5 per cent in comparison with 0.05 in channel black. The high ash content is due to salts in the water used for cooling the carbon black and gaseous products before they enter the electrical precipitator and to the water used in the wet-pelleting of the black. High modulus (HMF) blacks, which are made at higher furnace temperatures, contain more ash than semi-reinforcing (SRF) blacks because more water is used for their cooling.
>
> Furnace black is alkaline, and its pH runs as high as 10; channel black is acid, with a pH ranging from 4 to 5. The alkalinity of furnace black is due, to a great extent, to the hydrolysis of salts in the cooling water. The black is but very slightly alkaline before it reaches the cooling tower.

Particular attention was paid to the quality of water available at the plants visited during the course of this survey. Chemical analyses of water samples were obtained from 23 plants; included are analyses from all 16 plants at which water treatment of any kind is given. At some plants the samples analyzed were taken individually from more than one well; at others a composite sample was made. Only a few of the reports provided by plant managements gave complete chemical analyses.

The results of chemical analysis most commonly available were hardness, dissolved solids, and pH. Maximum, minimum, and median values of each of these results for different categories of use are shown in table 4. Wherever the water was treated, an analysis of the treated water was used in preparing table 4.

It is apparent that the water used for gas quenching has the lowest content of dissolved solids and that water for the company camps is the softest.

From a review of the analyses it is seen that no definite pattern develops, either of limits of tolerance of dissolved solids in water used in process, or as an orderly progression from water of fairly good quality to poor quality based on geographical location. Wide variations in the quality of water may exist within a relatively small area, as is illustrated at one carbon-black plant in Texas. Because the water from each of four wells drilled at the plant site is unsatisfactory, water for process use is purchased from a water company whose well field is about 2 miles away. Water from the wells at the plant is used for sanitary purposes, slab washing, plant cleanup, and, after being softened by the zeolite process, for the washhouses. A comparison of some of the values from the results of chemical analyses of these waters of widely varying quality is shown below.

	Dissolved solids (ppm)	Alkalinity (ppm)	Hardness (ppm)
Composite sample (four wells at plant)	1,620	269	1,048
Composite sample (purchased water)	895	223	417

The number of plants treating water arranged by kind of treatment is given in table 5. The principal treatment of water for use at carbon-black plants is softening, generally by ion exchange (zeolite). Of the 12 plants at which water is softened, all but 3 use the softened water only for washhouse use; at one plant the capacity of the softener in excess of washhouse requirements is used in the gas-cooling tower.

Table 4.—*Hardness, dissolved solids, and pH of water used in carbon-black plants*

[Results except pH in parts per million]

Use	Hardness as $CaCO_3$				Dissolved solids				pH			
	No. of samples	Maximum	Minimum	Median	No. of samples	Maximum	Minimum	Median	No. of samples	Maximum	Minimum	Median
Process:												
Pelleting........	13	581	10	190	9	1,267	22	540	11	8.0	6.2	7.5
Gas quenching..	18	581	10	160	12	1,267	22	420	15	8.1	6.1	7.5
Nonprocess:												
Washhouse.......	21	581	16	180	17	1,970	60	600	19	10.4	6.1	7.6
Other.............	22	1,048	16	160	15	1,970	180	530	19	9.2	6.1	7.6
Company camps...	10	422	16	120	8	1,970	181	440	10	8.1	6.2	7.6

Table 5.—*Number of carbon-black plants treating water*

Treatment	Any use	Process		Nonprocess					Company camps
		Pelleting	Gas quenching	Washhouse	Boiler feed	Cooling	Drinking	Other	
Chlorination..........	5	2	1	2	0	1	4	2	1
Softening.............	12	0	1	12	0	0	4	3	1
Adjustment of pH...	6	0	1	4	1	1	3	3	0
Filtration..............	4	2	1	3	1	0	4	3	1
Addition of boiler compounds.........	2	0	0	0	2	0	0	0	0

The water supply at five plants is chlorinated. Probably the low number is attributable to the use of ground water as the principal source of supply. Boiler-feed water is treated to adjust the pH at one of the four plants that operate steam powerplants. One plant adjusts the pH of water for gas quenching and in washhouses, but does not adjust the pH of boiler-feed water.

EFFECT OF TRENDS IN THE INDUSTRY ON USE OF WATER

The steady increase in the number of furnace plants and the declining number of contact plants in operation indicates that the total water requirements of the carbon-black industry is increasing at a rate greater than the proportional increase due solely to increased plant capacity.

Changes in the furnace method of production may have significant effects on the water requirements of a given plant. Mention has been made of the use of bag filters at some furnace plants to achieve greater recovery and to eliminate air pollution from smoke. At present, gas temperature must be reduced to approximately 260°F to prevent charring of the woven orlon bags now used in bag filters. If, however, present experiments in the use of woven glass fibers prove successful, it is reasonable to assume that the use of orlon bags will be discontinued. As the gases of combustion need not be lowered below 500°F when fiber-glass bag filters are used, less quenching water may be consumed. Other advantages, such as reduction of corrosion to the sheet-metal housing and clean exhaust gases, may induce more widespread use of bag filters and elimination of gas scrubbers if the experimental use of fiber-glass bags proves successful.

Chemical & Engineering News (1954) in an item referred to a new furnace process that, if successful, would reduce the process use of water. The item is as follows:

More carbon black may be in the making if Consolidated Carbon goes through with its plans for 10 new plants. Company recently signed an agreement with Lynn Carbon Black for use of the Lynn Furmatic process, claimed to have 50% higher yield than conventional furnace plants. Process makes use of either natural gas or oil—doesn't produce smoke—they say. Consolidated has recently finished satisfactory test runs in an experimental plant in Texas. Process is air cooled which is something new.

Another trend is the increasing use of oil as feedstock at furnace plants and the decreasing use of gas. During 1951 and 1952 liquid hydrocarbon yielded approximately 53 percent of the total production of furnace blacks. In 1953 these blacks had increased to nearly 60 percent (Chemical Week, 1955). A given furnace plant has the same water requirements for gas quenching and pelleting the product whether gaseous or liquid hydrocarbon feedstock is used. The significance of the trend toward greater use of oil lies in the wider choice of sites for oil-consuming furnace plants which permits the use of a site with an ample supply of water of satisfactory quality (Chemical Week, 1955).

CONCLUSIONS

Water requirements of the carbon-black industry assume importance principally because of the dependence of industry and national defense on rubber. The rubber industry is dependent on carbon black as the most satisfactory agent to impart long wear and other desirable properties to its products, whether made from natural or synthetic rubber.

Unit water requirements of contact plants, including company camps, averaged 0.98 gallon of water per pound of carbon black produced in 1953. The average use of water for furnace plants in 1953, excluding company camps, dehumidifying reformed gas, and the extremely large use of water for steam-power generation at several plants, is 3.34 gallons per pound of product. Furnace plants, however, used 7.22 gallons of water per pound of product when all uses were considered. The trend toward a larger percent of total production by the furnace method portends a greater use of water per pound of product in future years.

The quantity of water used by the carbon-black industry probably will increase more rapidly than the rate of increase of production because of the decreasing number of contact plants. The output of furnace plants constitutes a progressively greater percentage of total industry production. Carbon black produced at furnace plants by present methods requires considerably more water per pound of product than that manufactured at contact plants.

The quality of water used in the production of carbon black was relatively unimportant when the contact method was the principal method of production—this was changed as a result of World War II. For example, in 1941 approximately 75 percent of the total output of carbon black was made by the contact method. At that time, of necessity, plants were situated at the gas field; if the quality of water available was unsatisfactory for use in wet pelleting, a dry pelleting method was used, and no water was used in process. In 1953 the output of contact plants had declined to approximately 28 percent of the total.

This change within the industry has significant effects not only on the greater quantity of water required by the furnace method of production of carbon black but also on the quality of water that can be tolerated in its manufacture by that method. The product may be pelleted by a dry process at furnace plants as readily as at contact plants, but the far larger use of water at furnace plants for gas quenching is necessary with methods in use at the present time. The dissolved salts in the water used in the various stages of gas quenching remain in the product as an impurity; therefore, the quality and quantity of water available become more important considerations in choosing the location for a furnace plant than for a contact plant. Sites for contact plants were chosen primarily for their proximity to low-priced natural gas.

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