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STANDARDS SUPPORT AND ENVIRONMENTAL IMPACT STATEMENT

AN INVESTIGATION OF THE
BEST SYSTEMS OF EMISSION REDUCTION
FOR
FURNACE PROCESS CARBON BLACK PLANTS
IN
THE CARBON BLACK INDUSTRY

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(To be completed by the Standards Development Branch)

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(To be completed by the Standards Development Branch)

3.0 THE CARBON BLACK INDUSTRY

This chapter presents salient features of the carbon black industry, and a description of the carbon black furnace process and its atmospheric emissions.

3.1 GENERAL

In 1974 over 90 percent of domestic carbon black was produced by the furnace process and most of the balance was produced by the thermal process. A third process, the channel process, accounts for only 0.1 percent of carbon black industry production.[1] Since the channel and thermal processes are minor portions of the industry and since no growth is predicted for them, they are not discussed further in this report. Detailed information concerning the channel and thermal processes is available in several references.[2,3,4]

The dominance of the furnace process is partly due to its ability to produce a wide variety of carbon black products.

There are currently 29 operating furnace carbon black establishments in the United States, owned by seven companies. These plants have a total capacity of approximately 2 million tons (1.8 million metric tons) per year. Capacity is, however, a highly variable quantity that depends on desired product, available feeds, and plant operation. Most plants range from 50 to 150 million lb (25 to 70 million kg) per year. All plants contain a number of reactor trains, which may or may not be in operation at one time. Figure 3-1 shows the plant

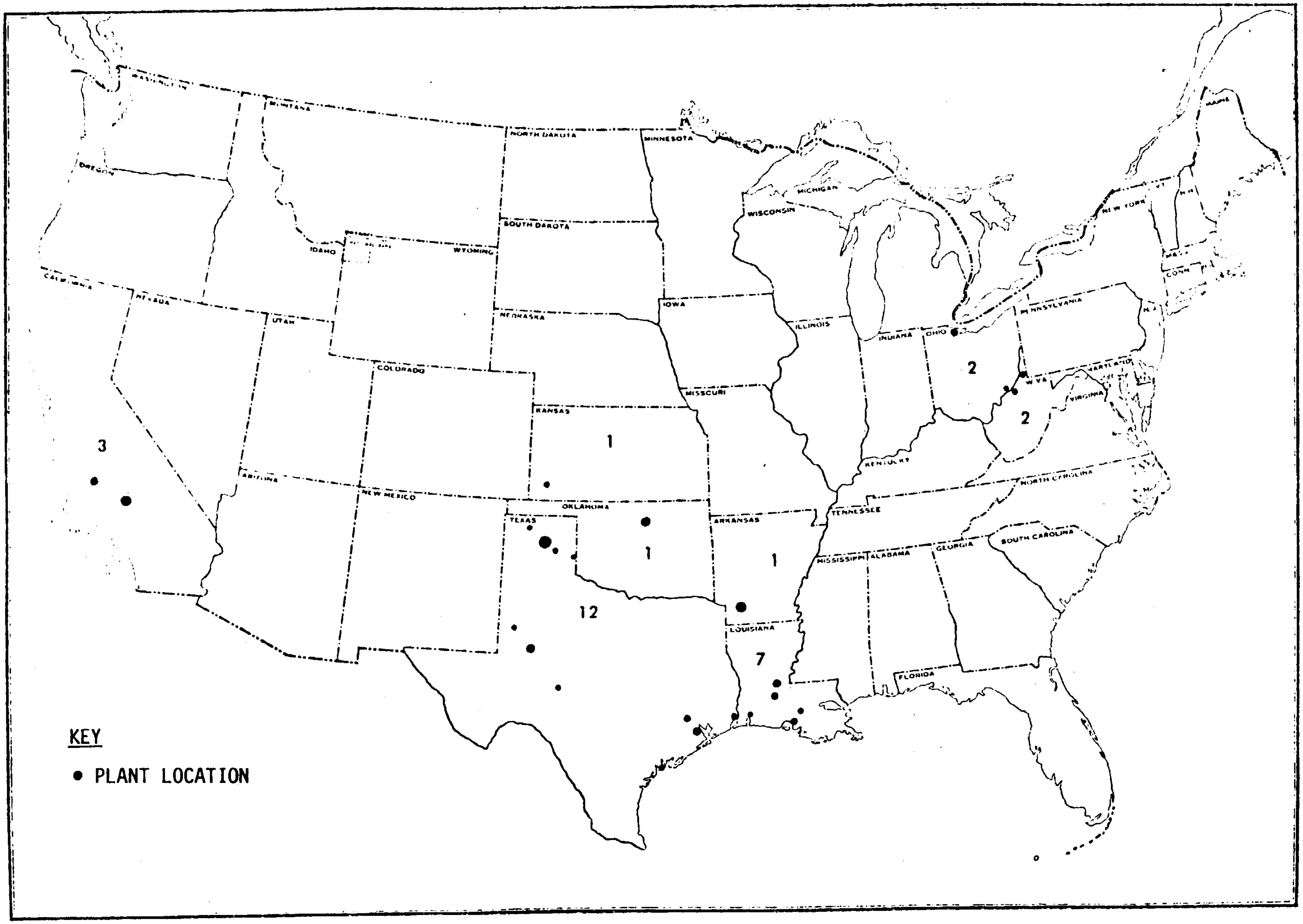

Figure 3-1. Carbon black furnace plant locations.

locations. Most of these plants, especially the larger ones, are remote from large population centers. Plant location is determined by availability of feed materials and product markets. Twelve of the plants are located in Texas, and seven in Louisiana.

The United States produces well over half of the free world's carbon black and the market is not threatened by imports from other countries. All of the carbon black plants produce a variety of furnace black grades to meet customer specifications. This is a capital-intensive industry, with relatively few employees. Total employment is too low to be tabulated regularly.[5] A new, well-controlled plant with a capacity of 120 million lb (55 million kg)/year requires only two to four operators per shift and two to three part-time maintenance men. Additional maintenance help required during major plant overhauls is usually obtained through contract labor.

Carbon black production in the United States in 1974 was 3.1 billion pounds (1.4 billion kg), of which approximately 90 percent was by the furnace process. The production rate represents about 70 percent of capacity. Although the industry traditionally operates in the 80 percent or higher capacity range, during 1975 it operated well below capacity because of decreased demand. At least one plant is shut down, and many units at other plants are shut down.

The industry growth trend is uncertain. Although a 3 percent annual increase in production is projected for the next 5 years, this growth rate is highly dependent on a number of factors. The major impacts are the current decrease in new automobile sales and the increase in percentage of small cars, resulting in reduced rubber requirements and longer tire life. Other problems facing the industry include a shortage of feedstock, particularly the desirable high aromatic, low-sulfur heavy oils, and rapidly increasing feedstock prices. At this time there are no indications that any new grass-roots plants will be built in the next 3 to 5 year period. Increases in capacity are generally accomplished by modifying existing plants through "debottlenecking" (enlarging a piece of equipment that controls the production rate).

Domestic production of various grades of black is presented in Table 3-1. High-abrasion and general purpose blacks account for over 60 percent of the total. Over 94 percent of domestic production is used in rubber production; the balance is used in printing inks and a few other minor applications. The approximate net Btu contents of the various grades is also shown in Table 3-1. This shows the average Btu content to be similar to that of the Houdry study off-gas (44 Btu/scf).[6]

Except for sulfur content, the ultimate composition of the different types of black does not vary significantly. The most important characteristic of the various furnace blacks is the particle size. Primarily because of the effect of the carbon black on the resilience of the rubber, fine-particle blacks are termed "hard" and large-particle blacks are termed "soft". A second fundamental product characteristic is the degree of particle agglomeration, termed "structure". High-structure blacks are generally of lower density and somewhat harder to handle because of poor flow characteristics.

In the past, the grades of furnace blacks have been classified according to an alphabetic code keyed partially to the physical properties. For example, a furnace black of low structure yielding a rubber of high abrasion character would be denoted HAF-LS (High Abrasion Furnace - Low Structure). This coding system has become cumbersome and is being replaced by an ASTM coding system adopted in 1968.[7] The ASTM system utilizes a four digit alphanumeric code keyed to particle size. The numeric digits are preceded by a N (normal) or S (slow), which denote the cure rate. The first of the three numeric digits signifies the particle size. The various ASTM product codes and the corresponding alphabetic codes are presented in Table 3-1.

Table 3-1. DOMESTIC CARBON BLACK PRODUCTION[8]
(Furnace Process)

Grade		ASTM Code	Typical Particle Size mμ	% of total production	BTU/SCF*
SAF	Super-abrasion furnace	N-1xx	11-19	1.0	36
ISAF	Intermediate-abrasion furnace	N-2xx	20-25	9.7	39
HAF	High-abrasion furnace	N-3xx	26-30	44.0	45
FEF	Fast-extension furnace	N-5xx	40-48	12.8	45
GPF	General-purpose furnace	N-6xx	49-60	22.0	45
SRF	Semi-reinforcing furnace	N-7xx	61-100	10.5	55
				100.0	ave. 45

*From Industry Survey

3.2 PROCESSES DESCRIPTION

Operations in the furnace black industry are highly variable because of the variety and number of products. Wide variations in product yield (kg of black per kg of oil) complicate the identification of process line capacity or plant total capacity. Obtaining subtle differences in desired particle size and structure requires complicated operating procedures, which vary from line to line and from plant to plant. Accordingly, since the industry is not amenable to a general applicable process description, the following discussion does not necessarily describe conditions at any one location. Because data covering the total industry are so highly generalized, a model plant is used in certain portions of this and later sections to assess the impact of the emission limit. This is a hypothetical plant with a total capacity of 90 MM lb (41 MM kg)/year, a typical size for a new plant and the size plant used in the Houdry Report.[6] It is assumed that there is no secondary combustion of off-gas at this plant.

3.2.1 Basic Process

The furnace process involves the incomplete combustion and thermal cracking of a hydrocarbon feedstock under controlled conditions in a reactor at a temperature of approximately 1400°C to produce a finely divided, essentially pure carbon particulate with varying degrees of agglomeration. Effluent from the reactor is quenched with water to approximately 540°C to stop the cracking reactions and to control product characteristics. Downstream the effluent gases are further cooled via heat exchange and/or water quench to about 235°C to protect the particulate (carbon black product) collection equipment. This collection equipment, which consists mainly of fabric filters, is generally considered an integral part of the process. The collected black is then pelletized and dried to facilitate subsequent handling and shipping. Figure 3-2 illustrates the process.

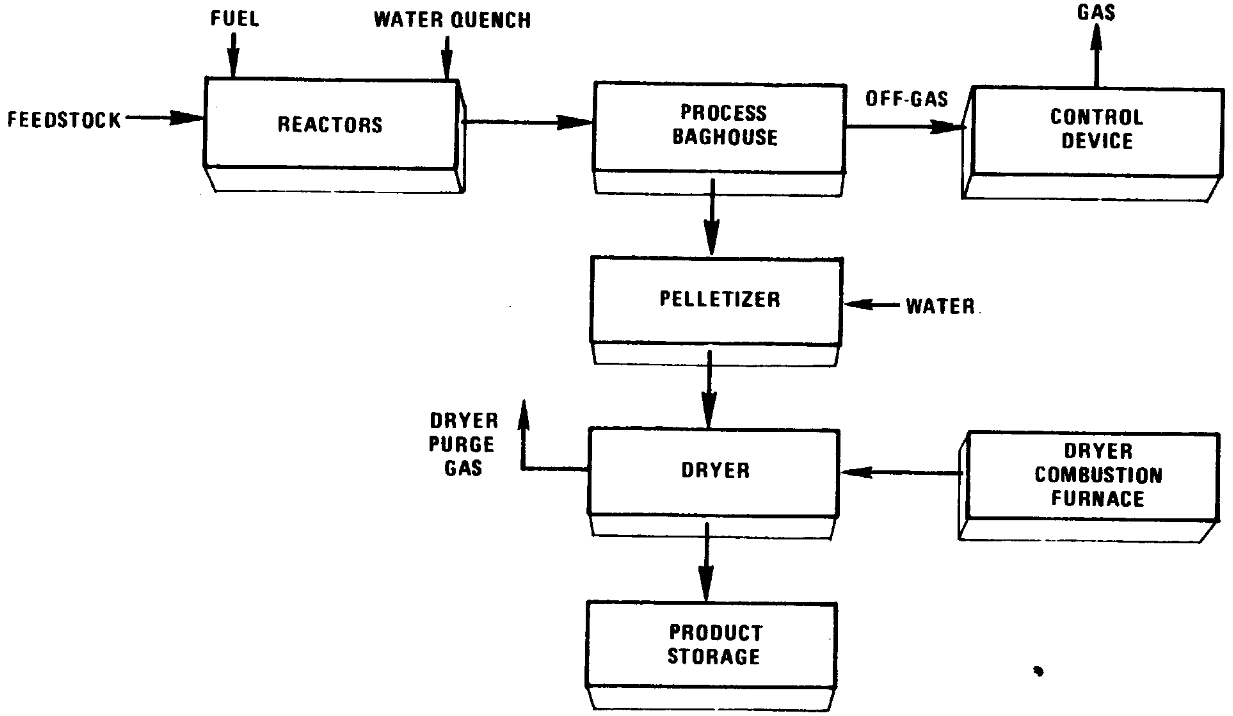

Figure 3-2. Typical Process Flow Diagram for Furnace Process for Carbon Black Manufacture

A number of reactors are normally manifolded together and served by a single collection system. Each such process line is a source of various pollutants including particulate matter, carbon monoxide, gaseous hydrocarbons, nitrogen oxides and hydrogen sulfide. Process dryers used to prepare the pellets are also sources of particulate matter. Storage bins, material handling equipment and plant vacuum cleanup systems inevitably contribute additional particulate emissions.

3.2.2 Feedstocks

Most furnace black plants in the United States use oil feedstock with natural gas for heat and for control of product quality. Highly aromatic oil is desirable feedstock because of its high product yields and low endothermic heat requirements.[4] An oil with a mid-boiling point of about 260°C is appropriate; however, any oil feed can be used. Refinery by-product residuum tars and coal tars also are desirable feeds.

Carbon black plants are being forced to utilize feedstocks with increasing amounts of sulfur, even though high sulfur content is detrimental to product yield. One plant has reported an increase in feedstock sulfur content from 0.85 percent to 1.40 percent in the last 2 years and an anticipated increase to 1.50 percent in the near future.[9] Feedstocks with 2 to 3 percent sulfur are becoming more common.

Since pollutant emissions depend partially on feedstock characteristics, the use of alternative feedstocks must be considered when applying the control options. In view of the current shortage and high cost of natural gas, it is unlikely that new gas furnace black plants will be built. Some European plants and at least one domestic plant operate entirely with oil and some use of coal tars has been reported. One domestic company has shown the feasibility of using digested waste tires as a feedstock supplement.[10] The possible impact of the use of digested waste tires on pollutant emissions is unknown.

3.2.3 Main Process Line

In the typical furnace oil process, oil feedstock is preheated by heat exchange or in a direct-fired heater to approximately 260°C before injection into the reactor.

Reactor designs are highly varied and are considered to be proprietary since they affect yield and product quality. Example reactor designs are shown in Figure 3-3. All designs incorporate a refractory-lined steel chamber. In one class of reactors, the feedstock is injected axially through an atomizing nozzle, and natural gas and combustion air (40 to 70% excess) are injected tangentially. By this means, the feedstock is heated to the cracking temperature without unnecessary combustion of the valuable oil. In addition, the oxygen-rich gases tend to scour the walls of the reactor to prevent carbon deposition.[4] The structural character of the product can be affected by the angle of approach of the tangential combustion gases.

Properties of the carbon black can be changed by a variety of techniques including recirculation of off-gases and injection of additives. Use of potassium and sodium salts (i.e. KNO_3 and $NaNO_3$) at a rate of approximately 0.1 percent by weight has been particularly effective in reducing particle size.[3,11] Aluminum and zirconium salts are also added to increase refractory life.[12]

Particle size of the product is a function of the furnace residence time, ratio of oil to air, and quench conditions. Generally, the yield of black is directly proportional to particle size.[4] Consequently, off-gas from hard black (small particle) lines produces more CO and CO_2. In addition, the heating value of off-gases from hard black lines tends to be lower because of the greater reactor air requirements and resulting higher fraction of inert materials.

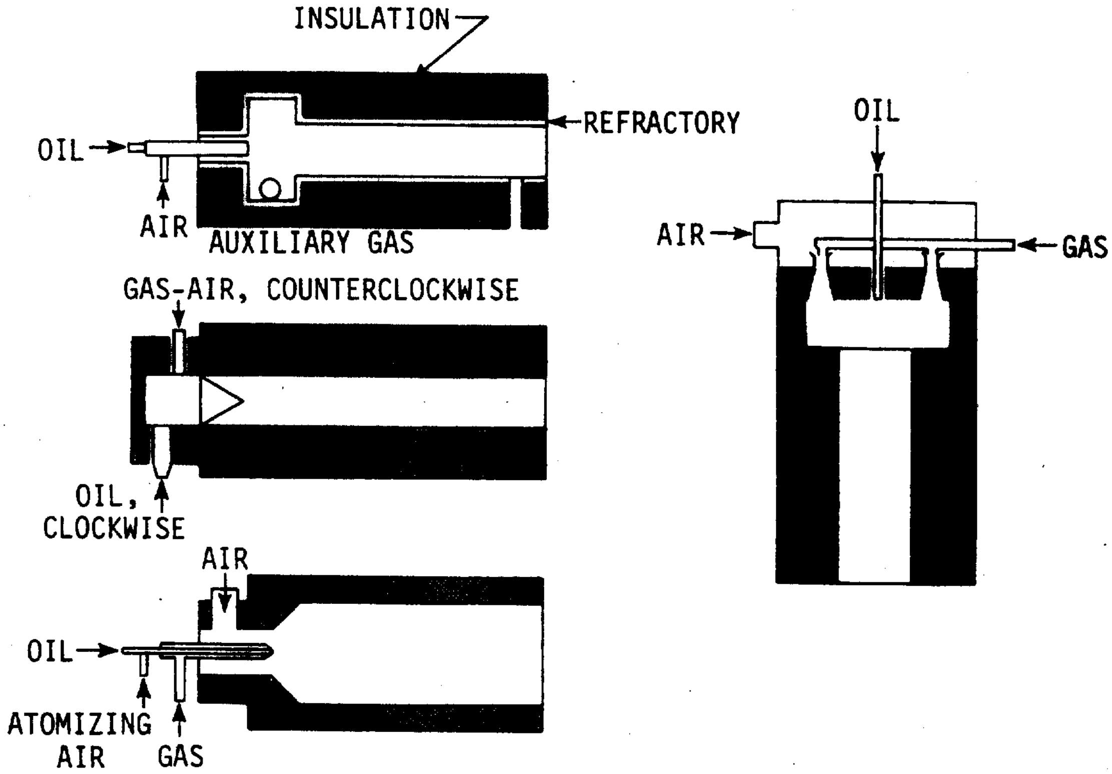

Figure 3-3. Reactor designs.[13]

For a given grade of carbon black, the feed rates and air rates are fixed and must be controlled within ± 10 percent to ensure consistent product quality.[9,14] As the particle size of the carbon black product is reduced the air-to-oil ratio increases, causing more nitrogen in the reactor effluent. This reduces the yield, varying it from 0.20 to 0.30 kg of black per kg of feed for very small-particle black to 0.50 to 0.65 for large-particle black.[2] The reduced yield for fine particle black results in relatively higher total emissions of CO and gaseous hydrocarbons.

The process off-gas is quenched to about 235°C ahead of the product collection equipment and at this point contains approximately 50 percent water. Typically, a fabric filter baghouse collects the black entrained in the off-gas. In some plants, large-diameter cyclones are used before a fabric filter for primary collection and agglomeration. All new or modified plants are expected to use fabric filters for product collection. Fabric filters are described in Section 4.1.1.

3.2.4 Pellet Production

Following discharge from the collector hoppers into a screw or pneumatic conveyor, the black is sent through a micropulverizer to remove large agglomerates. The carbon black in the fluffy state is then usually wetted and pelletized in a pin or finger-type mixer to simplify final handling. Pellets in the 40- to 60-mesh size are formed. The water is removed from the pelletized black in indirect-fired rotary drum type dryers at 175 to 260°C. Natural gas is commonly used as a fuel, supplemented in some plants with process off-gas. After the hot dryer combustion gas is used to indirectly dry the pellets, a portion (35 to 70%) of the dryer combustion gas is passed directly through the rotary drum to remove the evaporated water and the rest of the gas is directly vented. Emissions of entrained black that pass through the pellet dryers must be controlled, usually by fabric filters similar to those used on the main process stream. Scrubbers are occasionally used for this purpose, with the water recycled to the pelletizer.

3.2.5 Product Handling and Storage

The pelletized black is transferred to storage silos for subsequent shipment. Product not meeting specifications is stored in separate silos for recycling and blending.

Product transfer is accomplished mainly by air conveying, bucket elevators, and screw conveyors. Because extreme care must be exercised to prevent product loss, all conveying systems are sealed and usually subjected to negative pressure from an induced-draft fan, which is vented through a fabric filter system.

Cleanup of any spilled product and routine plant maintenance are accomplished by a vacuum system, which is also vented through fabric filters.

3.3 ATMOSPHERIC EMISSIONS

Furnace process carbon black plant reactors produce large amounts of carbon monoxide, smaller amounts of gaseous hydrocarbons, and still smaller amounts of particulate, sulfur compounds, and nitrogen oxides. The basic nature of the reaction, i.e., off-stoichiometric combustion of hydrocarbon fuels, causes formation of these compounds and little can be done to prevent it. (Chapter 4 will discuss control of CO.)

Emission data presented here were obtained in industrial surveys and are supplemented with recent EPA emission test data. The EPA data are discussed in more detail in Chapter 4 and Appendix C. All of the data presented in Chapter 3, unless otherwise specified, concern uncontrolled emissions in the off-gas after filtration for product recovery.

3.3.1 Emissions from Operating Plants

Emissions from a specific plant will vary depending on the product and the feed composition. As stated earlier, emissions of CO and hydrocarbons tend to increase and be more diluted as particle size of the product decreases.

This occurs because of the increase in combustion air and resulting decreases in product yield. Direct correlations between product characteristics and emissions are not possible, however, on the basis of the sparse available data. Sulfur emissions, mainly in the form of H_2S and CS_2, vary directly with sulfur composition of the feed. Particulate emissions depend mainly on product size and fabric filter efficiency. Trace quantities of polynuclear organic compounds are also emitted, on the order of 0.1×10^{-6} kg/kg of carbon black produced.

Typical vent gas compositions and reported ranges of emissions are shown in Table 3-2. These data, based on reported values from manufacturers, indicate the general range of emissions expected from the furnace black process. Emissions from a specific reactor train producing a specific product can be determined only by measurements.

3.3.2 Carbon Monoxide Emissions

The main atmospheric pollutant from carbon black manufacturing is carbon monoxide. This compound is formed in the reactor from the incomplete reaction of carbon and oxygen. Because the oxygen supply is insufficient, the carbon is not reacted completely to carbon dioxide. Addition of more oxygen (air) causes excessive combustion of the feed stream and reduces product yield. Production of smaller-sized product requires addition of air to the reactor, which causes an increase in emissions of CO and CO_2 and also dilutes the off-gas stream. Thus, although concentrations of CO in the off-gas are reduced, the emissions on a kilogram per kilogram of product basis actually increase because the yield decreases.

Specific data on flue gas flow and production would be required for calculation of CO concentrations and the relationship between emissions and product grade. Data reported by the carbon black industry yield an average CO concentration of 1.6 kg per kg of product, with individual values ranging

Table 3-2. RANGE OF ATMOSPHERIC EMISSIONS[6]

Component	Concentration, mole %		45,000 tons/yr example plant		
	Range	Average	lb/hr	kg/hr	kg/kg of product
Hydrogen	2.7-7.5	6.7	1,229	557	0.11
Carbon dioxide	1.6-3.3	2.5	9,978	4,526	0.91
Carbon monoxide	3-7	5.5	14,071	6,383	1.28
Hydrogen sulfide	0.005-0.1	0.1	306	139	0.03
Sulfur oxides	Trace-0.015	Trace	Trace	-	-
Methane	0.1-0.35	0.2	318	144	0.03
Acetylene	0.05-0.5	0.2	383	174	0.03
Nitrogen	32.5-40	35.5	90,686	41,135	8.23
Oxygen	0-2.5	0.3	810	367	0.07
Nitrogen oxides	8-100 ppm	44 ppm	18	8	<0.01
Particulate	0.038 gr/scf (0.100 gm/m^3)	0.048 gr/scf (0.110 gm/m^3)	24	11	<0.01
Water	42-50	49	80,223	36,389	7.28
Total		100	198,046	89,833	-

from 0.8 to 3.0. An "average" plant would emit approximately 3.5 kg of CO per second (14 tons per hour).

3.3.3 Gaseous Hydrocarbon Emissions

Gaseous hydrocarbon emissions, consisting mainly of methane and acetylene, also occur during the manufacture of carbon black. These compounds are emitted with the main process off-gas at a lower rate than emissions of carbon monoxide. Reported uncontrolled emissions average 0.1 kg per kg of carbon black 100 kg/Mg and range from approximately 0.03 to 0.26 kg/kg.[6] 20 to 260 kg/Mg Although no direct correlation between hydrocarbon emissions and product grade has been established; the hydrocarbon emissions do vary directly with CO emissions. Values obtained in EPA tests range from 0.07 to 0.1 kg of total HC per kg of product. Acetylene accounted for 50 to 75 percent of the hydrocarbons, the balance occurring mainly as methane.

3.3.4 Particulate Emissions

Particulate, consisting of carbon black, is emitted at a rate that depends on the fabric filter efficiency. Data obtained from manufacturers and from EPA tests show a wide range in emissions, from less than 0.001 to more than 0.005 kg of particulate per kg of product. The average is 0.0015 kg per kg of product. Particulate concentrations are in the range of 0.03 to 0.13 gr/dscf (0.068 to 0.295 g/DNm^3) of off-gas. The corresponding calculated fabric filter collector efficiencies range from 99.5 to 99.9 percent. The lower efficiencies generally occur when extremely fine (pigment grade) black is manufactured and when new filters are installed. Particle size distributions are not available. These high collection efficiencies are necessary in the process, since these filters collect the entire product weight. A plant producing 90 million pounds (40.8 million kg) per year (11,035 pounds or 5005 kg per hour) with a collection efficiency of 99.7 percent will emit 34 pounds (15.4 kg) per hour.

Particulate emissions from the dryer purge gas stream and the product transfer and storage processes are usually much lower than those from the main off-gas stream. Fabric filters are used in the product handling system and also on dryer purge gas streams. (A few scrubbers or cyclones are used on purge gas streams). Reported data indicate that dryer purge gas stream emissions controlled with a fabric filter system averaged approximately 0.00004 kg of particulate per kg of product.

Polynuclear organic matter (POM) is undoubtly emitted from most carbon black reactors. The high aromatic content of the feed, the high cracking temperatures, and the lack of oxygen all contribute to the formation of these compounds. Although the presence of polynuclear compounds on carbon black particles has been shown, quantitative emission data are not available in the literature.[15] The high boiling points of these compounds (340 to 600°C) would cause them to be present in a liquid or solid form in the fabric filter system, thus affecting collection somewhat. Adsorption of POM on carbon black also occurs. Ambient air sampling near large carbon black manufacturing complexes (both channel and furnace processes) showed no high concentrations of benzc(a)pyrene.[16] Limited data obtained during this study yielded an emission rate after a fabric filter of 2.6×10^{-9} kg of benzo(a)pyrene per kg of product. Total POM found in the sample amounted to 0.1×10^{-6} kg per kg of product.[17]

3.3.5 Other Gaseous Emissions

Reduced sulfur compounds, largely in the form of hydrogen sulfide (H_2S), are emitted from furnace process plants. The emission rate varies directly with the sulfur content of the feed and represents about 50 percent of the sulfur present.[6] Carbon disulfide (CS_2) and carbonyl sulfide (COS) have also been reported in the off-gas stream. The balance of the sulfur appears as elemental sulfur in the product, and in trace amounts of sulfur oxides.

~~Calculations based on~~ a 50 percent yield of carbon in the feed to carbon black product and a 50 percent conversion of sulfur to H_2S, indicate sulfide emissions of about 0.01 kg per kg of product per percent sulfur in the feed. Thus, a 2 percent sulfur content feed stream would yield approximately 0.02 kg of H_2S per kg of product or 600 to 800 ppm by volume (wet basis). EPA test data give H_2S emission values of 0.005 to 0.013 kg of H_2S per kg of product per percent sulfur.

Nitrogen oxide emissions are low at typical furnace black plants that do not burn the off-gases. Lack of excess oxygen in the reactor reduces the formation of nitrogen oxides. EPA emission tests show NO_x concentrations of approximately 7 ppm by volume, or 0.0002 kg per kg of product. (Appendix C, Test A).

3.3.6 Process Start-Up and Upsets

During start-up, the reactors and fabric filter are heated by burning only natural gas in the reactor. When a single reactor in a train is started, natural gas is burned and the products of combustion are vented directly to the atmosphere. Once the reactor is up to temperature the combustion air rate is reduced, the liquid feed is introduced and the off-gas is vented through the fabric filter system. Samples of the product are taken to determine its properties, and necessary adjustments are made in the reactor feed and/or quench rates. With these procedures, start-ups do not usually cause excessive atmospheric emissions.

Process upsets generally cause only off-specification product and not excessive atmospheric emissions. At times, some mechanical failure or operator error may lead to an explosion in the reactor that causes pressure relief valves to open or diaphragms to rupture. Such an occurrence causes excessive emissions of particulate matter for short time periods (less than a minute). When this occurs, the reactor is immediately shut down.

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4.0 EMISSION CONTROL TECHNIQUES

The effectiveness and energy utilization of various particulate and gaseous control techniques are discussed in this chapter. Emission control techniques currently in use on furnace process carbon black plants are reviewed here to define adequately demonstrated "best systems" of emission reduction. The discussion is applicable to the reactor off-gas vents, product storage and conveying systems, and the pellet dryer purge gas vents. Techniques for controlling particulate and gaseous contaminants are discussed separately.

4.1 PARTICULATE CONTROL

4.1.1 Reactor Off-Gas Stream

Multicompartment baghouses containing sets of tube-type bags are in use at all domestic plants. Particulate removal devices function both as product recovery process equipment and as emission controls. Before the general acceptance of high-temperature fabric filters, a variety of particulate control techniques were used on the reactor off-gas stream, either alone or in combination. Most predominant was a combination of electrostatic precipitators (ESP) and large-diameter cyclones. The primary purpose of the precipitator was to agglomerate the black to a size that could be easily removed in the downstream cyclones. Because of the low resistivity of carbon black, collection efficiency in the precipitator was quite low.[1,2] Overall collection efficiency of the system was approximately 90 percent.

Since 1926, over 100 precipitators have been installed in the carbon black industry; however, no new units have been built since 1958,[2] and few are now operated routinely. Among the reasons for this decline in use of ESP's, unrelated to the atmospheric emissions, are that fabric filters offer greater flexibility to accommodate various products and their operation entails fewer fire hazards.[1]

Some companies use single-stage or multistage cyclones ahead of the fabric filter, [3,4] especially for capturing small-particle grades of carbon black. The cyclones function as primary removal units and tend to agglomerate the black to improve the removal efficiency of the fabric filters.

Since the development of fabrics that can withstand continuous operating temperatures in the range of 230 to 290°C, the multicompartment fabric filter has become the standard particulate removal system.

Generally, a unit has 4 to 12 individual compartments containing 200 to 600 bags each. Tube-type glass-fiber bags with graphite, silicone, and Teflon finishes are predominant. The bags are typically 12.5 to 30 cm (5 to 12 inches) in diameter and 3.04 to 9.1 meters (10 to 30 feet) long, weighing 475 to 611 gm/m^2 (14 to 18 oz. per square yard). Filtration occurs inside the bag. Normal air-to-cloth ratios in the carbon black industry range from 1.0 to 2.0. Pressure drops range from 15 to 25 cm (6 to 10 inches) of water.

As a consequence of the low throughput limitations, the fabric filtration systems are large; they require an extensive share of the capital investment and land area, relative to reactors and other process-oriented equipment.

The gas flow resistance inherent in a baghouse represents the major energy loss of the particulate control systems.

Average lifetimes of the silicon-graphitized glass fiber bags range from 9 to 30 months. One factor affecting bag life is the load on the fabric as indicated by the air-to-cloth ratio, the longer bag life usually associated with the lower ratios.[5] Another factor apparently affecting fabric life is the use of alkali additives in the reactor to reduce product structure or to increase refractory life. The alkali materials could conceivably attack the silicon coating.[6]

Other corrosive materials can damage the surfaces of the silicon-graphitized fabric or otherwise destroy the integrity of the bags. The sulfur and organics in the feedstock can be converted to organic acids and sulfurous acid. If the temperature drops to the acid dewpoint (150 to 200°C), the acids can cause both physical and chemical damage.

Manufacturers show considerable interest in Teflon-coated glass fiber bags and pure Teflon bags.[7,8,9,10] These bags apparently offer several significant advantages over the siliconized-graphitized glass fiber fabrics. Throughput can be increased for a given filtering area, allowing an increase in capacity of the process line without additional baghouse equipment. Because of their advantages, Teflon and Teflon-impregnated fabrics may eventually be used widely in new and modified furnace black plants.

Regardless of the filter fabric, it is likely that reverse air cleaning will continue to be the primary cleaning technique. Glass fiber bags are usually cleaned on a 2- to 8- minute schedule, depending primarily on the maximum pressure drop and the dust loading in the inlet. With a multicompartment arrangement, "clean" gas from the outlet side of one compartment is repressurized and passed back through the bags in the compartment being cleaned. The repressurized off-gas is then directed back to the baghouse inlet for cleaning. Teflon fabrics, which have better cake-release properties, require less frequent cleaning.

Deterioration of filter fabric is indicated by leaks or by slowly increasing pressure drop due to penetration of small particulate into the mesh of the weave.[11] Most furnace black plants replace all bags of a compartment simultaneously. New bags are vulnerable to high-velocity blinding since their pressure drop is much lower than that of older bags in other compartments. Ideally, new bags should be "aged" or broken in slowly to build up a residual cake.

Upon release from the fabric, the black is discharged to a hopper with extremely steep side walls designed to minimize bridging. Either a pneumatic or screw conveyor is used to remove black from the hoppers to the pelletizers. Effectiveness of fabric filters is primarily a function of particle size of the product, fabric type, age of fabric and maintenance history. Although exact relationships among these factors are not established, it is generally observed that efficiency gradually improves as the fabric is aged over the 1- to 2-week period following installation. Efficiency in collection of products with small particle size is usually slightly lower than for the larger sizes.

Emission data reported by the seven domestic companies show removal efficiencies between 99.5 and 99.9 percent or greater in nearly all plants,[12] with an average of 99.85 percent. Data relating removal efficiency with the grade of carbon black produced or with the relative opacities resulting from given concentrations of different particle size blacks are not available. It appears, however, that with a well-designed unit, maintenance is the key factor affecting opacity.

Limited data are available from three EPA source testing programs in which concentrations of selected pollutants were measured before and after a combustion device (CO boiler or flare) but not before the fabric filter collection system. Reference Method 5 procedures, which included both the filterable and total particulate fractions were used in all the particulate tests. The results are summarized in Appendix C.

Because of the high moisture content of the main process off-gas stream (approximately 50 percent by volume), visible emissions are difficult to determine during cool weather. When condensation does not occur, visible emissions from well maintained baghouses are less than 15 percent opacity. Included in Appendix C are summaries of opacity data for the main process off-gas stream, obtained by trained EPA observers in accordance with Reference Method 9 procedures. Two observers made 240 independent readings at 15 second intervals over a 1-hour period at each source. Condensed water vapor was not noted during these periods, since the meteorological conditions were favorable. These data show that under normal operation, the opacity is less than 15 percent.

4.1.2 Product Storage and Conveying Systems

Fabric filter systems cleaned by reverse-air or pulsed-jet systems are common on product-conveying exhausts, storage tank vents, and plant vacuum cleanup systems. These systems operate under ambient air conditions and can thus function well with almost any type of common fabric material. Opacity data presented in Appendix C indicate that ambient temperature baghouses will have less than 15 percent opacity. Two product transfer baghouses and a plant vacuum cleanup system baghouse were tested for visible emissions for one hour each and no visible emissions were noted.

4.1.3 Dryer Purge Gas Stream

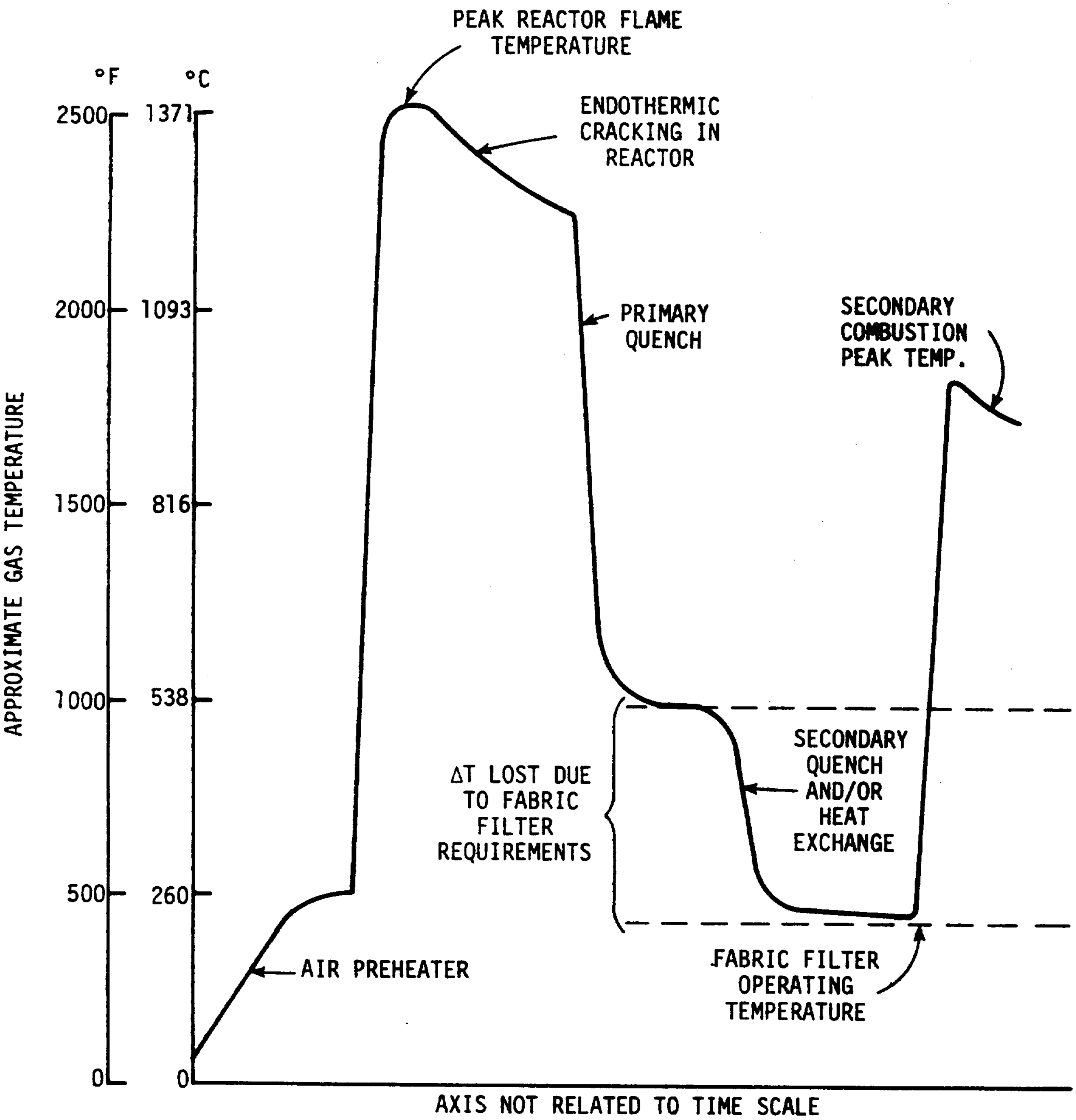
Cyclones, scrubbers, and fabric filters have been used to control carbon black emissions entrained in the dryer purge gas stream. Cyclone collectors gave low efficiency as evidenced by visible emissions. Scrubbers yielded higher efficiency, and fabric filter systems still higher. Fiber glass and Nomex fabric have been used with both reverse-air and pulsed-jet cleaning systems. Data presented in Appendix C (all tests 1 hour) shows that there were no visible emissions from three wet pelletizer dryer purge gas streams. A dry pelletizer dryer purge gas stream on a line producing ink grade black showed a maximum average opacity of 11.5 percent, so that all of the dryer purge gas streams are controlled to less than 15 percent opacity.

4.2 GASEOUS CONTAMINANT CONTROL

Gaseous pollutants from the furnace process include carbon monoxide, hydrogen sulfide, methane, and acetylene, all of which are converted to more innocuous forms by combustion. Four types of secondary combustion systems have limited use within the industry: thermal incinerators, flares, off-gas boilers (CO boilers) and product dryer combustion chambers.

The temperature limitations inherent in current fabric filter systems complicate gaseous control techniques. As shown in Figure 4-1, the off-gas temperature must be lowered to 230 to 260°C to protect the fabric. In addition to lower gas temperature, the secondary quench water decreases the heat value of the gas, which is typically difficult to burn even before quenching. Increased supplemental fuel is required to raise the off-gas heat content to reasonable combustion levels. Based on off-gas enthalpy content, raising the off-gas to combustion temperatures from 260°C requires 98 kcal/nm^3 (11 Btu/scf) more than raising it from 540°C. Elimination of secondary quench would obviously facilitate operation of secondary combustion units and would have little effect on product quality.[7]

The secondary quench can be reduced if not eliminated while using existing bag fabrics through utilization of the excess off-gas heat content. Heat transfer from the off-gas to the reactor fuel, feedstock, and combustion



NOTE: In some cases the primary quench reduces temperatures to only 816 °C (1500 °F)

Figure 4-1. Gas stream temperature profile.

air would reduce the amount of fuel needed in the reactor and would reduce the amount of secondary quench needed. The Btu loss due to the lower temperature would remain but the Btu loss due to the additional moisture would be reduced. These techniques are in use in plant A.

Another technique for raising the Btu content of the off-gas is dehydration, or removing a portion of the water from the off-gas stream. This is accomplished by spraying water into the gas stream after the baghouse to condense the moisture. The temperature of the gas stream will be lowered but the removal of the water makes the net Btu content higher. With this elevated Btu content the gas will be easier to combust. The major problem that must be taken into account when dehydrating the off-gas is that the gas is corrosive. Care must be taken in the design and operation of such a system to take this factor into account.

As stated previously, the Btu value of the off-gas is related to the product and normally ranges from 310 to 530 kcal/nm^3 (35 to 60 Btu/scf). Because of this wide range, the secondary combustion system must have a high turndown capability.

4.2.1 Off-Gas Boilers

Off-gas boilers or "CO" boilers have found application in a number of industries. For example, in the petroleum refining industry, off-gases containing 5 to 8 percent CO at a temperature of 540°C (1000°F) are burned at 980°C (1800°F) in the presence of air and supplemental fuel. This causes essentially complete destruction of the CO and most of the organic compounds in the gas stream. Combustion of the CO requires a high degree of mixing and turbulence of the off-gas, the auxiliary fuel and the air supply. CO is also burned in various boilers and stoves in the steel industry, whose streams usually contain higher amounts of CO than those in the furnace black process.

The CO boilers that are used to a limited extent in the furnace black industry are patterned after those used in the petroleum refinery industry. The main problem involved with installing CO boilers at carbon black plants is not one of technical feasibility, but rather of finding a use for the steam generated by the boiler. Thus, at a new grass roots plant designed for maximum utilization of steam via turbine pump and fan drives, only 50 to 60 percent of the steam generated by off-gas combustion can be used within the plant. The rest must be exported to a nearby plant or the off-gas must be burned in another type of control device.

Three plants in North America now operate off-gas boilers and three more operating plants are installing boilers. One of the prime reasons for retrofitting an existing plant with CO boilers is that adjacent industries can utilize the excess steam generated.[3,4,7] Boilers at Plant A are designed to consume less than 60 percent of the off-gas; boilers at Plant C consume about 52 percent of the total off-gas production. At both of these plants as much of the remaining off-gas as possible is burned in product dryers (approximately 20 percent of the total off-gas) and the rest is combusted in the direct flame incinerators.

In their original operation of off-gas boilers, Plant A had reported considerable "flame-out" problems and higher-than-expected natural gas requirements.[5] Depending on caloric value of the off-gas, the boilers had required supplemental fuel in a range of 5 to 40 percent of boiler heat requirements.[7] Since that time they have modified their process so that they can burn a 47 BTU/scf off-gas with minimal (<1 percent) supplemental fuel.[13]

Combustion efficiency and fuel requirements are affected by the method of off-gas injection. Poor mixing of off-gas and fuel is apparently one of the major causes of poor flame stability.[14]

CO boilers at Plant C normally require only about 2.5 percent supplemental heat.[15] Part of this comparatively low requirement is attributable to incomplete mixing of the off-gases from several units, resulting in a somewhat enriched feed to the boiler and correspondingly leaner feed to their incinerator.

Fuel requirements will depend largely on boiler/burner design and CO and H_2 content of the off-gas, (which in turn depends on product grade), degree of off-gas and air preheat, and firebox operating temperatures.

4.2.1.1 Combustion Efficiencies of CO Boilers -

A properly designed and operated CO boiler or incinerator will remove essentially all of the CO present in carbon black off-gas streams as well as the organic compounds and the H_2S. Proper design and operation must incorporate, 1) a high degree of mixing of the incoming off-gas and the hot combustion gases in the firebox; 2) some excess air to ensure complete oxidation (the required amount of excess air is not well defined); 3) firebox temperatures in the range of 760 to 870°C (1400 to 1600°F); and 4) residence times of about 0.4 second.

Because of the mixture of compounds in the off-gas and the complex nature of combustion reactions, the rate-controlling (slowest) step is not well established. The initial oxidation of methane to CO and then to CO_2 is probably one of the controlling steps. Other hydrocarbons present in the off-gas generally oxidize more easily than do methane and CO. Combustion of CO is usually the rate controlling step in the destruction of gaseous pollutants.[16]

EPA tests of two CO boilers in carbon black plants showed CO removal efficiencies of more than 99 percent, with resulting outlet CO emissions in the range of 0.001 to 0.005 kg per kg of product; CO concentrations ranged from 30 to 128 ppm (test durations ranged from 40 minutes to 3 hours and 5 minutes). A summary of the CO emissions is shown in Figure 4-2. Oxygen concentration in the boiler exit gas ranged from 2.5 to 5.2 percent. Gaseous hydrocarbon removal efficiencies at one unit averaged 98.5 percent, with non-methane hydrocarbon (mostly acetylene) emissions at the outlet of 0.00051 kg per kg of product (34 ppm).

Test data on the oxidation of H_2S to SO_2 in CO boilers are also very limited because of measurement difficulties. Available data indicate essentially complete conversion of H_2S to SO_2, with outlet concentrations of H_2S in the range of less than 1 to about 10 ppm.

Tests of nitrogen dioxide emissions at a single unit equipped with a CO boiler showed that the emissions of NO_2 were in the range of 70 ppm.

Particulate emissions also are reduced by passage through a CO boiler by combustion of some of the carbon black particles. EPA test data at one plant show particulate reductions in the range of 72 percent were obtained by combustion of the off-gas in a CO boiler, with an average emission of 0.0189 gr/dscf (0.04 gm/Nm^3).

4.2.2 Thermal Incinerators

Direct-fired thermal incinerators consisting of refractory-lined combustion chambers, auxiliary fuel burners, and off-gas injection ports are used at two furnace black plants in North America, one of which is in the United States. These units are set to maintain a designated combustion chamber outlet temperature, and auxiliary fuel is automatically metered to maintain a preset outlet temperature. Heat recovery could be, but is not, practiced on existing units.

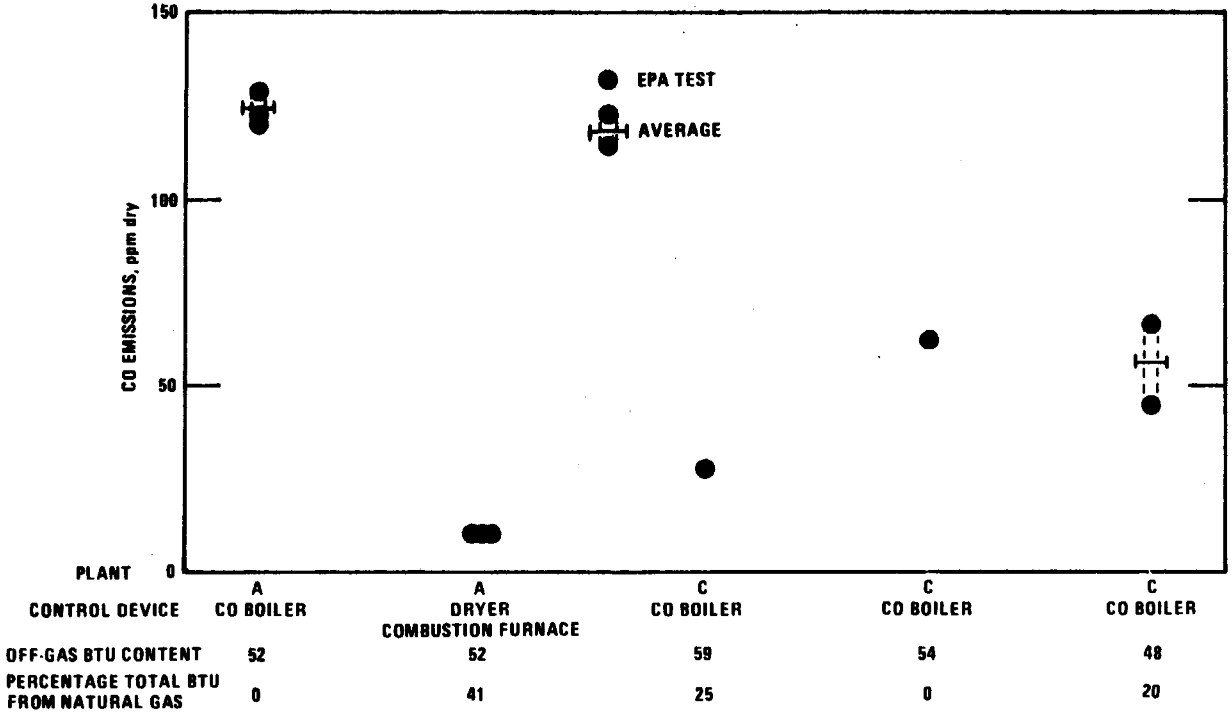


Figure 4-2. Carbon Monoxide Emissions From Off-Gas Combustion Devices

Because of limited application of direct-fired incinerators for combustion of lean CO-bearing gases, equipment manufacturers have little design information. Apparently, the incinerators are installed and the burner arrangement is then modified to achieve the desired temperature and/or efficiency.

The two operating thermal incinerators in North America are refractory-lined natural-gas-fired units operating at a peak temperature of about 982°C (1800°F) and combustion chamber outlet temperatures of about 871° (1600°F). At Plant A, two sets of natural gas burners are used, one on steady operation and the other modulated in accordance with outlet temperature sensors.[5] Operation of this unit was more satisfactory than that of their CO boilers when they were first installed (before the boilers were modified). The incinerator at Plant C is a round, vertical unit, which requires an average auxiliary fuel rate of about 6 to 10 percent of the heat input.[15]

4.2.2.1 Thermal Incineration Combustion Efficiency -

Because of sampling problems neither of the operating thermal incinerators has been tested. The Plant A unit is vented into a common stack that also serves a CO boiler, and no space is available for sampling between the incinerator outlet and the stack. The Plant C unit is vented to a short refractory-lined metal stack directly above the incinerator and is not amenable to sampling. Although no emission data are available for off-gas incinerators on furnace process carbon black plants, a pellet dryer combustion furnace is in essence an incinerator with waste heat recovery, therefore incinerator emission should be similar to the emissions from a pellet dryer combustion furnace.

4.2.3 Flares

Disposal of waste gas in flares has been widely practiced at oil refineries, petrochemical plants, and steel plants. Flares, used primarily to burn gaseous organic compounds, are also used for CO combustion. A flare is essentially an open flame, with air and auxiliary fuel supplied near the base to combust the waste-gas mixture. Steam is usually injected to provide turbulence and inspirate air, thereby reducing smoke formation.

The relatively few flares used in the carbon black industry serve mainly to reduce odorous emissions by converting sulfides to sulfur dioxide. Reductions of CO and gaseous hydrocarbons are also achieved. The flares used for carbon black off-gas combustion do not currently employ steam injection.

Two domestic carbon black plants are now using flares. Their proprietary flare design utilizes one or more natural-gas-fired pilot lights at the flare outlet. The natural gas and air rates are regulated to the pilots to produce a turbulent blow-torch-like flame. In typical operation the flares show a pale flame extending about 3.05 m (10 feet) above the stack. In production of a smaller size carbon black product on one unit, the flare would not ignite. Combustion with these units is not maintained when the heat content of the off-gas falls below 350 to 400 kcal/m^3 (40 to 45 BTU/scf).[15,17] Relighting the flare pilot has also caused some problems. Combustion air is induced by natural draft.

4.2.3.1 Flare Combustion Efficiency -

Because a flare is inherently an "open flame", measurement of emissions is difficult. Evaluation of the operating characteristics of the flare suggests that pollutant removal efficiencies are lower than those achieved by an enclosed combustion process such as a boiler or incinerator, mainly because of the short residence time at peak temperatures. Operation at a flame length of 3.05 m (10 feet) at an average gas velocity of 18.3 meters per second (60 feet per second) gives a residence time of less than 0.2 second. Thus, partial reactions may occur, and some of the hydrocarbons may be transformed to CO. Short-circuiting of some of the off-gas along the walls of the stack through cooler portions of the flame can also occur.[18]

Limited tests were made with remote optical sensing of emissions (ROSE) of a flare system (Plant B). Samples taken in the stack below the flare showed CO concentrations to be 13.3%. The ROSE showed CO concentrations of 5% with the flare off and 1000 ppm with the flare in operation.[19] Theoretical calculations reported by a vendor[20] indicate that combustion efficiencies should exceed 95 percent. This data snow the flare to be not as effective a system of emission reduction as the enclosed combustion devices.

4.2.4 Pellet Dryers

From 15 to 30 percent of the plant's off-gas can be utilized in the combustion chamber of the pellet dryer and thereby reduce the natural gas requirement in these units. This utilization of off-gases is becoming more common throughout the industry as fuel costs increase. The dryer combustion chamber must be enlarged because of the high percentage of inert gases in the off-gas. Only minor modifications to burner controls and ductwork are required to implement this change. In these units, combustion occurs in a refractory-lined vessel with 25 to 30 percent excess air, at a temperature of 980 to 1090°C (1800 to 2000°F). Combustion chamber temperature is limited by the skin temperature of the drum containing the carbon black product. Excessive temperature will affect product quality.[21]

4.2.4.1 Pellet Dryer Combustion Efficiency -

Since combustion conditions compare favorably with those of the water tube CO boilers, combustion efficiencies above 99 percent can be anticipated. Combustion is performed in a refractory-lined chamber at temperatures higher than 980°C (1800°F). The excess air maintained in the unit should ensure good combustion. In tests performed at Plant A, the dryer combustion furnace off-gas had less than 10 ppm carbon monoxide when averaged over a one hour time period. (Test summary in Appendix C.)

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5. MODIFICATION AND RECONSTRUCTION PROVISIONS

In accordance with Section 111 of the Clean Air Act, as amended in 1970 and 1974, standards of performance shall be established for new sources within a stationary source category which ". . . may contribute significantly to air pollution . . ." Standards apply to operations of apparatus (facilities) within a stationary source, selected as "affected facilities," that is facilities for which applicable standards of performance have been promulgated and the construction or modification of which commenced after proposal of the standards.[1]

On December 16, 1975, EPA promulgated amendments to the general provisions of 40 CFR Part 60 including additions and revisions to clarify the modification provision and to add a reconstruction provision.[2] Under these provisions, 40 CFR 60.14 and 60.15 respectively, an "existing facility" may become subject to standards of performance if it is deemed to have been modified or reconstructed. An "existing facility" defined in 40 CFR 60.2 (aa), is an apparatus of the type for which a standard of performance is promulgated and the construction or modification of which was commenced before the date of proposal of that standard. The following discussion examines the applicability of these provisions to furnace process carbon black plants and details conditions under which existing facilities could become subject to standards of performance. It is important to stress that, because standards of performance apply to affected facilities which, combined with existing and other facilities, comprise a stationary source, the addition of an affected facility to a stationary source through any mechanism--new construction, modification or reconstruction--does not make the entire stationary source subject to standards of performance, but rather only the added affected facility.

5.1 PROCESS MODIFICATIONS AND RECONSTRUCTION

Paragraph 60.14(a) states:[1]

> "Except as provided under paragraphs (d), (e), and (f) of this section, any physical or operational change to an existing facility which results in an increase in the emission rate to the atmosphere of any pollutant to which a standard applies shall be considered a modification within the meaning of section 111 of the Act. Upon modification, an existing facility shall become an affected facility for each pollutant to which a standard applies and for which there is an increase in emission rate to the atmosphere."

The exceptions in paragraph (d) essentially allow an existing facility to make a physical or operational change that results in an increase in the atmospheric emission rate of any pollutant to which a standard applies, as long as the total emission rate of that pollutant from all existing and affected facilities at that source is not increased.

Paragraph (e) lists other exceptions that allow certain changes in a plant without its becoming subject to the new source performance standards. These exceptions are:

(1) Routine maintenance, repair, and replacement.

(2) An increase in production rate without a capital expenditure of over 5.5 percent of the cost of the base facility.

(3) An increase in hours of operation.

(4) Use of an alternative fuel or raw material if prior to the standard the facility was designed to accommodate that fuel or raw material.

(5) Addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or is replaced by a system considered to be less environmentally beneficial.

(6) Relocation or change of ownership.

Paragraph (b) states that emissions be expressed in terms of kg/hour. Paragraph (c) states that the addition of a new affected facility (i.e. one that is subject to NSPS) to a plant does not by itself make any other facility within that plant subject to NSPS. Paragraph (f) provides for superseding any conflicting provisions.

Most of the recent increases in domestic capacity have been accomplished by enlarging the production-limiting operation in existing units (debottlenecking). This procedure normally entails adding additional dryer or pelletizer capacity. The short-term industry approach thus appears directed toward making minor process changes to meet market conditions.

Section 60.14 (c) and (d) specifies that the standard of performance applies to individual processes and pieces of equipment rather than to entire stationary sources. For a process to become an affected facility there must be an increase in actual emissions. Thus, if increased throughput can be offset by improved operation of an existing control system, there is no modification.

Section 60.14 (d) stipulates that if an existing facility undergoes a physical or operational change resulting in an increase in emissions of a regulated pollutant, this facility will not be subject to the regulations, if the <u>over-all</u> emissions of the pollutant from the entire stationary source are not increased. This stipulation allows the plant to modify one unit in a way that increases emissions and to control another unit without being subject to the standards of performance, provided the over-all plant emissions do not increase. This is potentially helpful to plants that might modify a unit producing small-particle black, which could be more difficult to control because of lean off-gas. Operators would have the option of installing combustion devices on an existing unit producing larger-sized black.

Section 60.15 regarding reconstruction states as follows:

> "An existing facility, upon reconstruction, becomes an affected facility, irrespective of any change in emission rate. "Reconstruction" means the replacement of components of an existing facility to such an extent that: (1) The fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and (2) It is technologically and economically feasible to meet the applicable standards set forth in this part."

Therefore, EPA will, on a case-by-case basis, consider technical and economic parameters in determining whether a facility is considered to be reconstructed as stated in §60.5. If it is, the facility will be subject to the standards of performance irrespective of changes in emission rates.

The following describes ways existing carbon black plants can be modified or reconstructed and whether or not an increase in emissions would likely occur.

1. A change in type and/or composition of feedstock. If the change was made to increase the yield of the feedstock, there would probably be a decrease in the CO emissions because more of the carbon would be collected as black instead of being converted to CO. If the change was due to unavailability of desirable feedstock, there could be a decrease in the yield and an increase in emissions of CO.

2. Replacement and/or addition of fabric filter systems. If the baghouse was built in order to replace a less efficient control device or to replace an old baghouse, the emissions of CO would probably remain unchanged. If the baghouse was added to increase the production of the line, the emissions of CO would increase with the increase in production.

3. Adding or restoring reactors in an existing facility. Adding reactors is a physical change that will tend to increase emissions of CO because it will add to the production capacity of the facility. Restoring a reactor should not lead to an increase in emissions.

4. Increased use of heat transfer to reduce the fuel requirements of the reactor or a CO combustion device. This should not lead to an increase in CO emissions unless the change results in an increase in the production rate.

5. Installation of off-gas combustion devices on an existing plant or rerouting off-gas to a dryer. These changes would result in a decrease of the CO emissions from the facility.

6. Conversion from natural gas to fuel oil to fire the reactors. This will not lead to an increase in emissions of CO from the facility.

7. Modification or replacement of an existing dryer or pelletizer. If the alteration was made to increase the production capacity, there would be an increase in CO emissions. There would be no increase in the emissions of CO if the production capacity is unchanged.

Any of these changes that are made to increase the production capacity of the facility will increase the emissions of CO. Addition of devices to combust the off-gas will result in a decrease in CO emissions. The emissions will remain unchanged if an alteration does not change the production capacity. The applicability of new source performance standards to facilities that undergo these changes will be discussed in section 9.7.

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6.0 EMISSION CONTROL SYSTEMS

The systems of emission reduction presented in this chapter are combinations of the three devices presented in Chapter 4; the CO boiler, direct flame incinerator, and the pellet dryer combustion furnace. All of these devices are shown in Chapter 4 to be able to achieve an emission reduction to less than 200 ppm of CO. Although some operational problems have been reported, all three secondary combustion systems have demonstrated on-line reliability so that various combinations of these devices will represent best systems of emission reduction. Since these devices control the emissions to the same level, the systems presented here do not represent different control levels, rather they are examples of typical options a new or existing plant will have for meeting the emission limit of less than 200 ppm CO. The systems are presented in order to analyze the range of environmental (Chapter 7) and economic (Chapter 8) impacts associated with combusting 100 percent of the reactor off-gas. The options selected will vary depending on the particular plant situation.

6.1 ALTERNATIVE SYSTEMS OF EMISSION REDUCTION

It is shown in Chapter 4 that portions of the reactor off-gas from furnace process carbon black plants is combusted so that the energy in the off-gas can be utilized in the plant. Fifty to sixty percent of the off-gas can be combusted in a CO boiler to produce steam for in plant use and 15 to 30 percent of the off-gas can be combusted in the pellet dryer combustion furnace. In this analysis it is assumed that for a typical plant 50 percent of the off-gas will be combusted for generating steam for in plant use and 20 percent will be combusted for drying the carbon black pellets. Figure 6-1 shows three typical off-gas distributions that are likely to occur in new or existing furnace process carbon black plants that meet the emission limit of less than 200 ppm CO. In all of the systems 20 percent of the off-gas is combusted in the pellet dryer combustion furnace in order to lower the natural gas requirements of the plant. The alternative systems of emission reduction therefore show the distribution of the remaining 80 percent of the reactor off-gas.

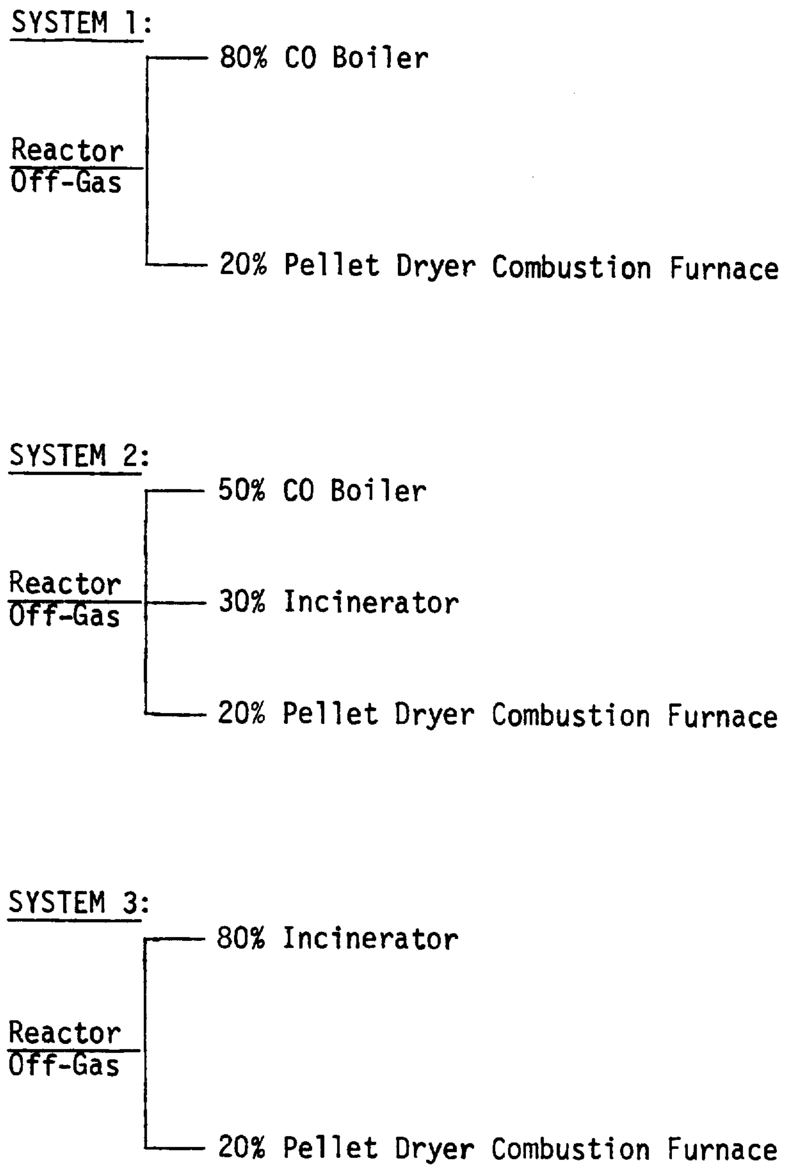
6.1.1 System 1

System 1 utilizes the heat content of 100 percent of the off-gas through combusting the remaining 80 percent of the reactor off-gas in a CO boiler. This system would be used in both new and existing facilities that have a market for excess steam. Since only 50 percent of the off-gas can be combusted for in plant steam use, the remaining steam is exported. System 1 is the best in terms of energy utilization because all of the reactor off-gas is combusted with heat recovery.

6.1.2 System 2

In system 2 fifty percent of the reactor off-gas is combusted to generate steam for in plant use and the remaining 30 percent is combusted in an incinerator with no heat recovery. This system will be used in new plants that have no market for excess steam. New plants can be designed to utilize the steam but extensive alterations may be required to retrofit existing plants with steam drives. In system 2 seventy percent of the reactor off-gas is combusted with waste heat recovery.

FIGURE 6-1. OFF-GAS DISTRIBUTION FOR
THE ALTERNATIVE SYSTEMS OF EMISSION REDUCTION



6.1.3 System 3

System 3 represents the least energy efficient emission reduction system with only the 20 percent of the reactor off-gas combusted in the pellet dryer combustion furnace utilizing the reactor off-gas heat content. Eighty percent of the reactor off-gas is combusted in an incinerator with no heat recovery. This system is the most likely system for use in existing plants that meet the emission limit of less than 200 ppm CO since few plants have markets for exported steam or would find it advantageous to retrofit the plant with steam drives.

7. ENVIRONMENTAL IMPACT

The air pollution impact and the other environmental consequences of the alternative systems of emission reduction presented in Chapter 6 are discussed in this section. These three systems represent different distributions of off-gas between the three control devices that new and existing plants may use to achieve the emission limit of 200 ppm carbon monoxide (CO). A comparison will be made between the emissions from uncontrolled plants, permitted by some State regulations and the emissions from the alternative systems prescribed in Chapter 6. Additional beneficial and adverse impacts which may be directly or indirectly attributed to the operation of these alternative systems will also be assessed.

7.1 IMPACT OF CONTROL TECHNOLOGY FOR REACTOR OFF-GAS

In Chapter 4 three different types of control devices for reactor off-gas are discussed. These are the CO boiler, incinerator and dryer combustion furnace. Each of these devices can reduce the emissions of CO from the reactor off-gas to less than 200 ppm. In order to determine the actual emission reduction that would occur as a result of applying the controls, it is necessary to estimate the reduction in air pollution it will effect beyond that which would otherwise be achieved by existing State or local regulations.

7.1.1 Air Pollution Impact

7.1.1.1 State Regulations -

Eighty-nine percent of present carbon black industry capacity is located in states with emission limitations for waste gas streams containing carbon monoxide. These waste gas disposal regulations generally specify secondary combustion of the gas in a direct flame afterburner, boiler or other device approved by the regulatory authorities. In some cases the removal efficiency or the final pollutant concentration is also included. No industry data are available to show the CO concentration of the emissions from plants conforming to these state regulations, but for the purpose of this analysis, compliance with the state regulations will be considered to be equivalent to compliance with the proposed emission limit. This seems justified in that the devices considered in Chapter 6, the CO boiler, thermal incinerator and pellet dryer are the devices that would probably be used to conform with the state regulations. The data presented in Appendix C shows that these devices will meet the proposed emission limit for CO.

Eleven percent of present carbon black capacity is located in states with no emission limitation on waste gas streams containing carbon monoxide. For this analysis it will be assumed that the industry will retain this geographical distribution. Therefore eleven percent of the 1985 affected production capacity will be considered to be the only portion of the industry that will have a change in emissions as a result of the emission limit.

7.1.1.2 Impact on Model Plant -

Both direct and indirect emission impacts are involved in the control of furnace black plants. Application of waste gas boilers, incinerators and dryer combustion furnaces significantly reduce the emissions of carbon monoxide (CO), non-methane hydrocarbons (HC), and hydrogen sulfide (H_2S).

In new plants designed to utilize steam generated in the waste heat boilers, electrical energy requirements are reduced, resulting in an indirect reduction of emissions from commercial power generation equipment. These indirect emission reductions are discussed in Section 7.1.4.3.

Gaseous pollutant emission factors for the uncontrolled and controlled plant are shown in Table 7-1. These emission factors are based on data from the literature and from stack test data obtained during this study. The effect of the proposed emission limit on the emissions from a typical 90,000,000 pounds per year carbon black plant are shown in Table 7-2. This table shows the total emissions of CO, HC, and H_2S will be reduced by over 99 percent and the particulate emissions will be reduced by 50 percent. Emissions of sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are increased, however, by applications of the control devices.

7.1.1.3 Estimated Emission Reduction in 1985 -

The values for the total 1985 carbon black production and the production subject to the proposed emission limit are developed in Chapter 8 Economic Impact. Carbon black production is estimated to increase at a rate of 3 percent per year for the next ten years so that 4250 million pounds of carbon black will be produced in 1985. Of this total it is estimated the 2520 million pounds will be produced in facilities that are new or have been modified such that they will be subject to the proposed emission limit.

The emission reduction in 1985 that would occur as a result of the proposed emission limit is shown in Table 7-3. This table is calculated using only that portion of the industry production that will be subject to the limit (11%). It is assumed that 89 percent of the new capacity will be controlled by existing state regulations to a level equal to that of the proposed emission limit. The table shows that the largest impact will be in the reduction of

TABLE 7-1. REACTOR OFF-GAS EMISSION FACTORS AND MODEL 90 MILLION POUND PER YEAR FURNACE PROCESS CARBON BLACK PLANT EMISSIONS

	Uncontrolled			Controlled*		
	Conc. (dry) mole %	kg/kg of product	kg/hr	Conc. (dry)	kg/kg of product	kg/hr
Particulate	0.20 gm/m^3	0.002	10	0.05 gm/m^3	0.001	5
CO	10.8%	1.28	6400	200 ppm	0.0049	25
Non-methane HC (as C_2H_2)	0.32%	0.035	175	17 ppm	0.0004	2
H_2S	0.2%	0.028	140	<10 ppm	<0.0003	<1.5
SO_2	trace	-	-	326 ppm	0.0183	90
NO_2	10 ppm	0.0002	1.0	72 ppm	0.003	15

From Houdry Report[1] and emission tests (Appendix C).

*CO Boiler, Incinerator or Pellet Dryer

TABLE 7-2. REACTOR OFF-GAS EMISSION REDUCTION FOR 90 MILLION POUND PER YEAR MODEL PLANT

Pollutant	Uncontrolled Emissions		Controlled** Emissions		Emission Reduction	
	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr
Particulate	10	22	5	11	5	11
Carbon Monoxide	6,400	14,100	25	55	6,375	14,045
Non-Methane Hydrocarbons	175	386	2	4	173	382
Hydrogen Sulfide	140	309	1	2	139	307
Sulfur Dioxide	-	-	90	198	-90*	-198*
Nitrogen Dioxide	1	2	15	33	-14*	-31*

*Emissions will increase.
**CO boiler, incinerator or pellet dryer.

TABLE 7-3. REACTOR OFF-GAS EMISSION REDUCTION FOR UNITED STATES FURNACE PROCESS CARBON BLACK PLANTS IN 1985 (AFFECTED PRODUCTION ONLY)

Pollutant	Emissions from plants controlled to existing state regulations[a]		Emissions from plants controlled to emission limit[b]		Emission Reduction Due to emission limit	
	metric tons/year	tons/year	metric tons/year	tons/year	metric tons/year	tons/year
Particulate	1,300	1,400	1,100	1,200	200	200
Carbon Monoxide	165,500	182,100	5,600	6,200	159,900	175,900
Non-Methane Hydrocarbons	4,800	5,300	500	600	4,300	4,700
Hydrogen Sulfide	3,800	4,200	300	300	3,500	3,900
Sulfur Dioxide	18,600	20,500	20,900	23,000	-2,300[c]	-2,500[c]
Nitrogen Dioxide	3,100	3,400	3,400	3,800	-300[c]	-400[c]

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[a] 89 percent of affected industry production controlled to emission limit, 11% of affected production uncontrolled

[b] 100 percent of affected industry production controlled to emission limit

[c] SO_2 and NO_2 emissions increase

CO, where there will be a reduction in emissions of 159,900 m tons (175,900 tons) per year. The emissions of NO_2 and SO_2 are shown to increase slightly as a result of the emission limit for CO.

7.1.2 Water Pollution Impact

The furnace black process usually operates with no liquid process waste. Wet scrubbers are used occasionally for particulate control. When this is done, the water is recycled into the pelletizer or used as part of the quench water to recover the entrained carbon black. The control strategies envisioned for new or existing plants would not contribute to any liquid discharge except for blowdown from the steam boiler. If the control strategy does not involve a steam boiler, no liquid discharge would occur.

Boiler blow down rates vary with quality of the feed water and with boiler operation. For estimating purposes, approximately 5 percent of the steam generation rate would go to blowdown. Thus, a plant producing 90 million pounds per year and burning 80 percent of its off-gas in a CO boiler (85,000 pounds of steam per hour) would have a waste stream of 32.2 liters per minute (8.4 gpm). Since some plants will use only 50 percent of the off-gas in the boiler, the resulting blowdown will be proportionately smaller. Blowdown water is alkaline (pH 8 to 10), contains little if any oxygen, and generally contains up to about 5000 mg/l of total solids. In plant A the boiler blowdown is put in settling ponds and recycled. Any runoff that would occur is put in the city sanitary sewer.

The EPA is planning water pollution control regulations applicable to carbon black plants.[2] These regulations will probably allow zero discharge of process waste from carbon black plants. The regulation will, however, permit discharge of sanitary and boiler blowdown effluent so that these regulations are compatible with the proposed emission limit.

7.1.3 Solid Waste Impact

The emission alternatives proposed will have little, if any, impact on solid waste or sludge disposal. There is no solid waste collected, so there is no disposal problem. The only potential additional solid waste would occur from scrapped equipment and refractory linings in off-gas boilers or incinerators. This material can be recycled or buried in a landfill.

7.1.4 Energy Impact

All of the control devices used for combustion of the off-gas will require supplemental fuel (natural gas or fuel oil) to combust the typical 44 Btu/scf off-gas. For this analysis it is assumed that it is necessary to enrich the "typical" 44 Btu/scf reactor off-gas stream to 50 Btu/scf even though one of the producers presently combusts 47 Btu/scf off-gas with no supplemental fuel.[3] This is done to ensure stable and complete combustion within the combustion device. The net energy impact of the proposed emission limit will be the difference between the increase in energy needed to combust the off-gas and the energy savings that result from the off-gas combustion.

7.1.4.1 Impact on 1985 U.S. Energy Use -

Table 7-4 shows the 1985 energy impact of the proposed emission limit. The impact calculations are based on the portion of the industry that will be added in areas that presently have no CO regulations. The numbers are presented in terms of total Btu per year in order that they can be readily compared against each other and so that the net energy impact can be assessed. The energy penalties are a result of increased natural gas usage in the CO boilers and/or incinerators. The energy credits are from the production of steam in the CO boiler and from the decrease in natural gas usage in the pellet dryer combustion furnace. The Btu/year from the natural gas is derived from the net 910 Btu/scf of natural gas. The Btu/year energy savings from the CO boiler is expressed as energy saved at a power plant. Steam turbines are used in place of electric drives so that there is a net decrease in electrical

TABLE 7-4. 1985 ENERGY IMPACT OF PROPOSED EMISSION LIMIT

Control System	Energy Usage 10^{11} Btu/yr		Energy Savings 10^{11} Btu/yr		Net energy Savings 10^{11} Btu/yr
	CO Boiler[a]	Incinerator[a]	CO Boiler[b]	Dryer[c]	
80% CO Boiler 20% PDCF	3.35	N.A.	7.52	5.89	10.06[e]
50% CO Boiler 30% Incinerator 20% PDCF	2.13	1.22	4.67	5.89	7.21[f]
80% Incinerator 20% PDCF	N.A.	3.48[d]	N.A.	5.89	2.41[g]

N.A. - not applicable

PDCF - Pellet dryer combustion furnace

a. Btu content of natural gas required to enrich "typical" 44 Btu/scf off-gas to 50 Btu/scf to insure stable combustion.

b. Btu required (at 10000 Btu per kw hr) to generate the electricity replaced by steam drives.

c. Btu content of off-gas combusted in dryer.

d. 0.13 x 10^{11} Btu per year is for increased electricity use

e. 17.3 x 10^4 barrels of crude oil

f. 12.4 x 10^4 barrels of crude oil

g. 4.2 x 10^4 barrels of crude oil

energy is then equated to a decrease in coal consumption at the power plant to arrive at an annual reduction in energy use of the carbon black industry.

The maximum net energy savings for 1985 is 10.06 x 10^{11} Btu. This savings would occur if all of the off-gas produced in reactors that are subject to the emission limit is combusted with heat recovery. This energy savings relates to a maximum savings of 17.3 x 10^{4} barrels of crude oil in 1985 (5.8 x 10^{6} Btu/barrel of crude oil).

7.1.4.2 Impact on Model Plant -

Table 7-5 shows the energy impact of the proposed emission limit on the model plant. All three of the control systems will decrease the net energy requirements of the carbon black plant. When 80 percent of the off-gas is combusted in a CO boiler for in plant and export steam production in a new or existing plant, there is the largest energy savings, 39.5 million Btu/hour. The least energy efficient control system is the option where 80 percent of the off-gas is incinerated with no heat recovery as would probably occur in an existing plant that had to retrofit controls. All of the control systems use the same amount of natural gas to enrich the off-gas and save the same amount of natural gas in the pellet dryer combustion furnace. The model plant decreases its need for natural gas by 10,800 scf/hour as shown in Table 7-6.

7.1.4.3 Impact on Indirect Air Pollution -

The decrease in coal consumption at the power plant will not only save energy, but it will also reduce the emissions from that power plant. The emission reduction that would result from this decrease in coal consumption at the power plant is shown in Table 7-7. For this analysis it is assumed that the power plant is burning coal and is controlled to meet the federal regulations (0.1 pounds of particulate, 1.2 pounds of sulfur dioxide, and

TABLE 7-5. ENERGY IMPACT OF PROPOSED EMISSION LIMIT ON MODEL PLANT

Control System	Energy usage-(10^6 Btu/hr)		Energy Savings-(10^6 Btu/hr)		Net Energy Savings 10^6 Btu/hr
	CO Boiler[a]	Incinerator[a]	CO Boiler[b]	Dryer Combustion Furnace[c]	
80% CO Boiler 20% PDCF	13.4	N.A.	29.7	23.2	39.5
50% CO Boiler 30% Incinerator 20% PDCF	8.4	5.0	18.5	23.2	28.3
80% Incinerator 20% PDCF	N.A.	13.9[d]	N.A.	23.2	9.3

N.A. - not applicable
PDCF - Pellet dryer combustion furnace

a. Btu content of natural gas required to enrich "typical" 44 Btu/scf off-gas to 50 Btu/scf to insure stable combustion.

b. Btu required (at 10000 Btu per kw hr) to generate the electricity replaced by steam drives.

c. Btu content of off-gas combusted in dryer.

d. 0.5 x 10^6 Btu per hour is for increased electricity use.

TABLE 7-6. TYPICAL PLANT NATURAL GAS SAVINGS

Control System	Natural Gas Usage (SCF/hr)		Natural Gas Saving (SCF/hr)	Net Natural gas savings (SCF/hr)
	CO Boiler[a]	Incinerator[a]	Dryer Combustion Furnace[b]	
80% CO Boiler 20% PDCF	14,700	N.A.	25,500	10,800
50% CO Boiler 30% Incinerator 20% PDCF	9,200	5,500	25,500	10,800
80% Incinerator 20% PDCF	N.A.	14,700	25,500	10,800

N.A. - not applicable

PDCF - Pellet dryer combustion furnace

a. Natural gas required to enrich "typical" 44 Btu/scf reactor off-gas to 50 Btu/scf to ensure stable combustion.

b. Natural gas equivalent of the reactor off-gas combusted in the pellet dryer.

TABLE 7-7. 1985 INDIRECT EMISSION REDUCTION ACHIEVED BY ELECTRICITY SAVINGS

Control System	Particulate (tons/year)	Sulfur Dioxide (tons/year)	Nitrogen Dioxide (tons/year)
80% CO Boiler 20% PDCF	38	450	260
50% CO Boiler 30% Incinerator 20% PDCF	23	280	160
80% Incinerator 20% PDCF	-1*	-8*	-5*

PDCF - Pellet dryer combustion furnace
*Emissions increase.

0.7 pounds of nitrogen dioxide per million Btu of coal consumed.) Systems 1 and 2 are shown to have a small indirect emission reduction and system 3 has virtually no effect on indirect emissions.

7.1.5 Air Quality Impact

A meteorological dispersion model has been used by the U.S. EPA Source-Receptor Analysis Branch and its associated contractor, Walden Research[4], in evaluating the control alternatives outlined in Chapter 6. This model, called the Single Source Model (JMHCRD-1), is a Gaussian-type model capable of considering multiple emission points and complex aerodynamic effects. Assumptions for application of the model include the following:

1. Emission rates are constant.
2. Pollutants are nonreactive.
3. Terrain is relatively flat.

Calculations were made for 180 receptor points located in concentric circles around a hypothetical furnace black plant. Averaging times range from 1 hour to 1 year, depending on the pollutants considered and the corresponding averaging times of the applicable National Ambient Air Quality Standards.

Emission data and plant physical characteristics used in this application of the model are based on data for a 113,000 metric ton/yr (125,000 tons/yr) furnace process plant now in operation, producing both hard and soft blacks. The plant uses fabric filters for product collection, but has no off-gas combustion. In the controlled case, all of the combusted off-gas is assumed to exit through a single stack at a height 45 meters above the ground. The results of the modeling, as shown in Table 7-8, represent the maximum impact that a large plant would typically be expected to have on air quality. Meteorological data applicable to Oklahoma City, Oklahoma, are used, since this site affords a high frequency of "worst case" condition for plants with

Table 7-8. AIR QUALITY IMPACT - 125,000 TPY PLANT

			Downwash		No downwash			
Plant	Pollutant	Averaging period	Distance to maximum, kilometers	Maximum concentration, µg/m^3	Distance to maximum, kilometers	Maximum concentration, µg/m^3	Primary NAAQS, µg/m^3	Significant Deterioration Increment
Uncontrolled	Part.	24-hour	0.3	280	0.8	30	260	30
	Part.	Annual	0.6	13	1.5	5	75	10
	CO	1-hour	0.3	220,000	0.5	45,000	40,000	
	CO	8-hour	0.3	140,000	0.8	20,000	10,000	
	NO_2	Annual	0.6	4	1.5	2	100	
	HC	3-hour	0.3	6,100	0.5	1,000	160	
	H_2S	1-hour	0.3	3,000	0.5	750	NA	
	H_2S	10-min	ND	9,750	ND	2,438	NA	
Controlled to emission limit	Part.	24-hour	NA	NA	4.0	0.1	260	30
	Part.	Annual	NA	NA	12.5	0.1	75	10
	CO	1-hour	NA	NA	2.0	8	40,000	
	CO	8-hour	NA	NA	4.0	2.8	10,000	
	NO_2	Annual	NA	NA	12.5	0.08	100	
	HC	3-hour	NA	NA	2.0	0.5	160	
	H_2S	1-hour	NA	NA	2.0	1.0	NA	
	H_2S	10-min	NA	NA	ND	3.3	NA	
	SO_2	24-hour	NA	NA	0.7	7.3	365	100
	SO_2	Annual	NA	NA	ND	0.5	80	15

NA- Not Applicable
ND- Not Determined

the physical characteristics assumed. Smaller, more typical plants would yield proportionally lower emissions and have a lesser impact if stack heights and other conditions were the same. The JMHCRD-1 Model requires the assumption of a representative building structure configuration around the emission points to account for downwash effects. Since actual configurations vary considerably, this assumption can introduce some uncertainty. For this reason, calculations for the uncontrolled plant are prepared for one case with downwash and a second case with a slightly higher stack (increase of 6 meters), in which no downwash is assumed to occur. The distance of maximum impact without downwash is 2 to 3 times farther downwind and is more representative of boundary-line conditions.

The accuracy of the concentration estimates is limited to ± 200 to 300 percent. The particulate concentration predicted for the no-downwash, uncontrolled condition corresponds well with monitoring data provided by the company whose plant was modeled. The corresponding hydrogen sulfide levels, however, are considerably higher than measured values.[5]

Considering the error range of the model, only the controlled plant satisfies all of the National Ambient Air Quality Standards, both with and without downwash. The uncontrolled case entails possible violations of the carbon monoxide, hydrocarbon, and particulate standards, especially with downwash. Hydrogen sulfide levels for the uncontrolled plant are well above the odor threshold level. The results indicate that a large uncontrolled plant will not meet Federal Air Quality Standards under all conditions.

7.2 IMPACT OF CONTROL TECHNOLOGY FOR "FUGITIVE" EMISSIONS

Currently baghouses are used to control "fugitive" emissions from furnace process carbon black plants as discussed in Chapter 4. High temperature baghouses are used on the dryer purge gas vents and ambient temperature baghouses are used on the product transfer and storage vents, on the plant vacuum cleanup system vent, and on the plant bagging and loading operations. These emission points do not normally represent a significant source of emissions because emissions represent product loss. The impact of an opacity limit on these sources will be ensurance that existing control devices are maintained.

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8. ECONOMIC IMPACT

8.1 INDUSTRY ECONOMIC PROFILE

8.1.1 Introduction

Carbon black is produced by three different processes: furnace, thermal, and channel. Speciality blacks produced by unique processes include bone black, lampblack, and acetylene black. Furnace-produced blacks accounted for 90.6 percent of the 1973 total domestic production, and of these types, high-abrasion furnace blacks continued a long-term increasing dominance, accounting for over 40 percent of total carbon black production (Table 8.1). Production of carbon black by the oldest and notably inefficient channel process began to decline in the late forties and has diminished steadily since that time, and in 1975 was produced domestically by the single remaining channel black plant operated by Cities Service Company in Gaines County, Texas (See Table 8.2).

Yields of blacks from feedstocks vary substantially depending on the desired product properties and type and method of production. For a given process, finer particle sizes are associated with lower yields. Yields of gas furnace blacks range from 10 to 30 percent and for oil furnace blacks yields range from 35 to 65 percent. Yields for thermal blacks are from 35 to 60 percent. Yields in the channel process are five percent or less and for fine particle channel sizes yields shrink to one percent.

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* *Information contained in this document is based on data in various Mineral Yearbooks, Census of Manufactures and Annual Survey of Manufactures, unless otherwise specified.

TABLE 8.1 U.S. PRODUCTION OF CARBON BLACK BY GRADE: 1973[1]

Grade (Feed)	Production Total (thousand of pounds)	Percent of Total Production, All Grades
Furnace:		
Semireinforcing furnace (gas)	326,446	9.3
General-purpose furnace*	693,858	19.8
Fast-extrusion furnace (oil)	392,316	11.2
High-abrasion furnace (oil)	1,413,599	40.4
Superabrasion furnace (oil)	34,351	1.0
Intermediate-abrasion furnace (oil)	308,630	8.8
TOTAL FURNACE	3,169,200	90.6
THERMAL	316,519	9.0
CHANNEL	14,222	0.4
TOTAL PRODUCTION	3,499,941	100.0

*Includes High-modulus furnace black which is also a gas furnace black

TABLE 8.2. U.S. CARBON BLACK PRODUCTION, BY PROCESS TYPE, 1964-73[2]
(Thousands of Pounds)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
PRODUCTION:										
Channel process	169,919	147,909	153,117	149,420	142,948	132,471	113,548	46,354	22,378	14,222
Furnace process	2,053,297	2,205,867	2,418,435	2,334,420	2,668,858	2,830,790	2,817,605	2,970,781	3,178,731	3,485,719
TOTAL	2,223,216	2,353,776	2,571,552	2,483,840	2,811,806	2,963,261	2,931,153	3,017,135	3,201,109	3,499,941

Currently there are six major grades of black produced by the furnace process. One of the six furnace grades is made with natural gas as the feedstock and the remaining five are oil furnace blacks. There have been pressures within the industry recently to limit the number and range of blacks produced and to intensify the shift to higher-yield oil furnace blacks, due primarily to sharp increases in natural gas prices and reduced supplies resulting from the energy shortage.

The most desirable feedstock in the production of carbon black is highly aromatic, low sulfur, heavy oil. The energy shortage diverted some of this supply to other competitive uses as oil producers sought to further refine these "bottom of the barrel" residuals into higher priced yields, and Mideast producers cut off low sulfur supplies.

8.1.2. Markets for Carbon Black - Domestic

To a great extent the fortunes of the carbon black industry have historically rested with the fortunes of the domestic rubber industry--most notably the manufacturers of passenger car tires. (See Table 8.3). Characteristically over 90 percent of the carbon black produced is consumed by the rubber industry and nearly 65 percent of this consumption goes into the production of tires. Similarly, somewhat in excess of 85 percent of tire production has historically been for the passenger car market.

Carbon black production totals are understandably sensitive to patterns in the rubber sector of the domestic economy. This sensitivity is best demonstrated by observing production and sales data on carbon black during the major rubber industry strike years of 1967, 1970, and to a lesser extent 1973 (See Figures 8.1 and 8.2).

TABLE 8.3. U.S. SALES OF CARBON BLACK FOR DOMESTIC CONSUMPTION, BY USE, 1968-72[2]
(millions of pounds)

	Rubber	Ink	Paint	Paper	Miscellaneous	Total[a]
1968	2445.6	67.7	13.4	4.7	56.9	2588.4
1969	2616.2	73.1	17.7	5.7	65.3	2777.9
1970	2486.1	72.8	14.6	4.5	71.5	2649.5
1971	2678.2	75.2	18.7	3.8	77.7	2853.5
1972	2953.8	82.5	21.4	4.2	84.8	3146.7
1973	3114.6	84.3	21.7	4.2	88.8	3313.6

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[a] Figures may not add to totals due to independent rounding.

Figure 8.1 Domestic Sales of Carbon Black by Volume[2]

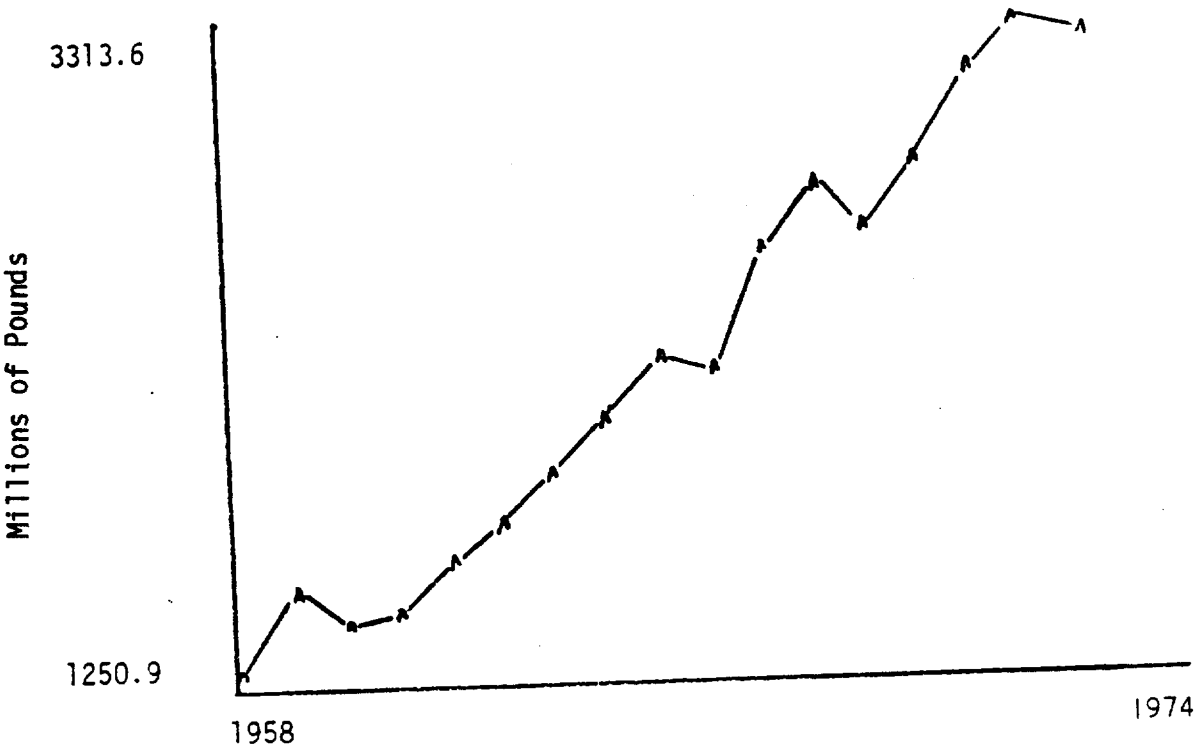
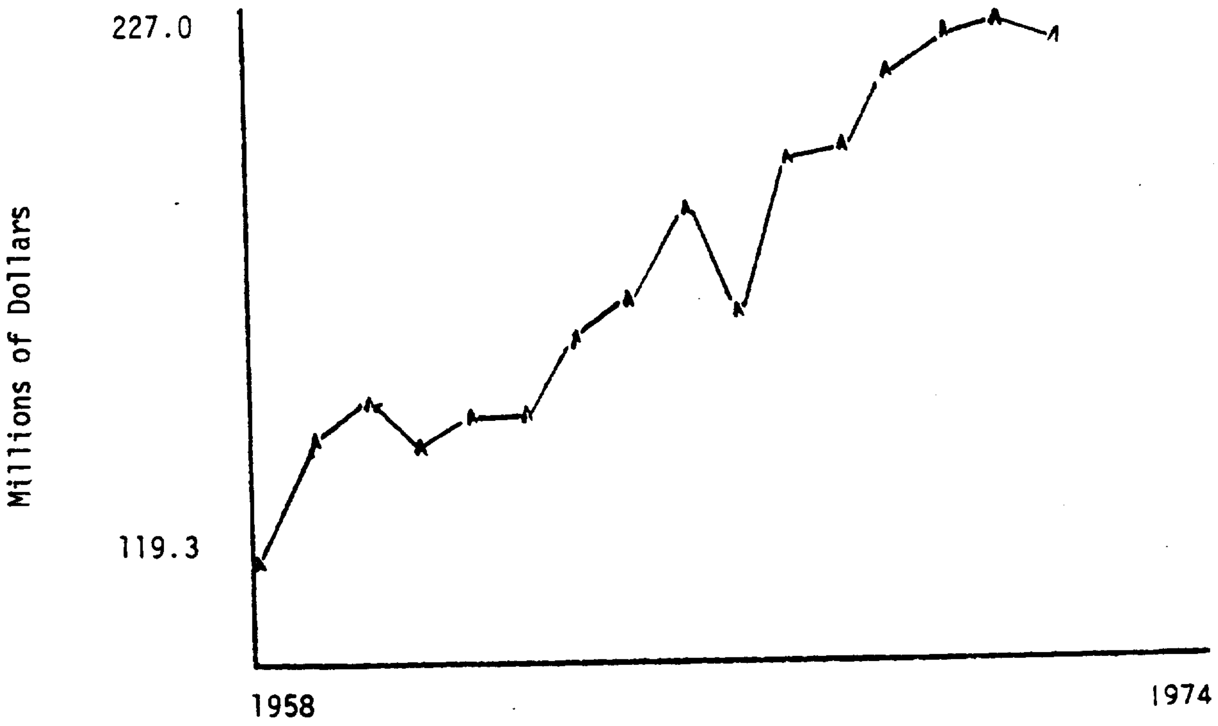


Figure 8.2. Total Value of Carbon Black Industry Shipments[2]



Production totals were significantly affected in 1974 by the economic recession. Production nationwide declined 3.1 percent and sales fell 4.8 percent. Production in Texas decreased 5.1 percent and Louisiana's production was off 1.2 percent. From the supply side carbon black is keenly affected by the energy shortage in that suppliers of feedstocks have price incentives to further refine residuals into higher-priced fuels, thus limiting total feedstock supplies to carbon black producers.

Further, the energy shortage and economic slowdown have affected the demand sector of the carbon black market in that passenger car sales have been drastically reduced and net use of passenger cars has declined. It is known that both the original equipment and replacement sectors of the tire market declined during 1974. The original equipment sector of the tire market has always been cyclical but the replacement market for tires has steadily grown. The 1974 decline in this sector was the first since the Korean War, as owners of older passenger cars delayed purchases of new tire sets. Tire imports have also increased since 1964 and in 1967 exceeded tire exports for the first time in history.

Carbon black is used in the rubber industry for other uses as well as tires, namely as hoses and belts in both the automotive and industrial sectors. These sectors are expected to continue to grow. For automotive hoses and belts there is an active replacement market which should expand as owners of autos continue to hold their cars for extended periods. Additionally, every new car produced contains approximately ten pounds of hoses and power transmission belts and carbon black represents a portion of this total. As the economy picks up and plant investment and normal replacement continues, industrial belt and hose production should expand. Mining and power plants are large users of carbon black reinforced conveyor belts.

The remaining six percent of domestic consumption of carbon black goes to the following markets: printing inks, paper, paints, plastics and foods. The printing ink sector has historically experienced growth, albeit moderate, whereas carbonblacks' use in paper products has declined rather steadily in the past decade. Some of this decline can be attributed to technological changes in the paper industry and accompanying new products reducing the use of carbon black. Consumer preferences for brighter colors is also responsible for a portion of this decline.

The use by volume of carbon black in the manufacture of paints nearly doubled in the period 1965 to 1973. The projected continued expansion of this market is dependent both upon energy developments and the overall condition of the economy. Since paint is itself a petrochemical, supplies of petroleum will affect its production. Further, consumption of paints is largely a function both of residential and nonresidential building construction and consumer expenditures on housing and home improvements. To the extent that both of these types of expenditures are deferred, so will this sector of the carbon black market experience a reduced rate of growth.

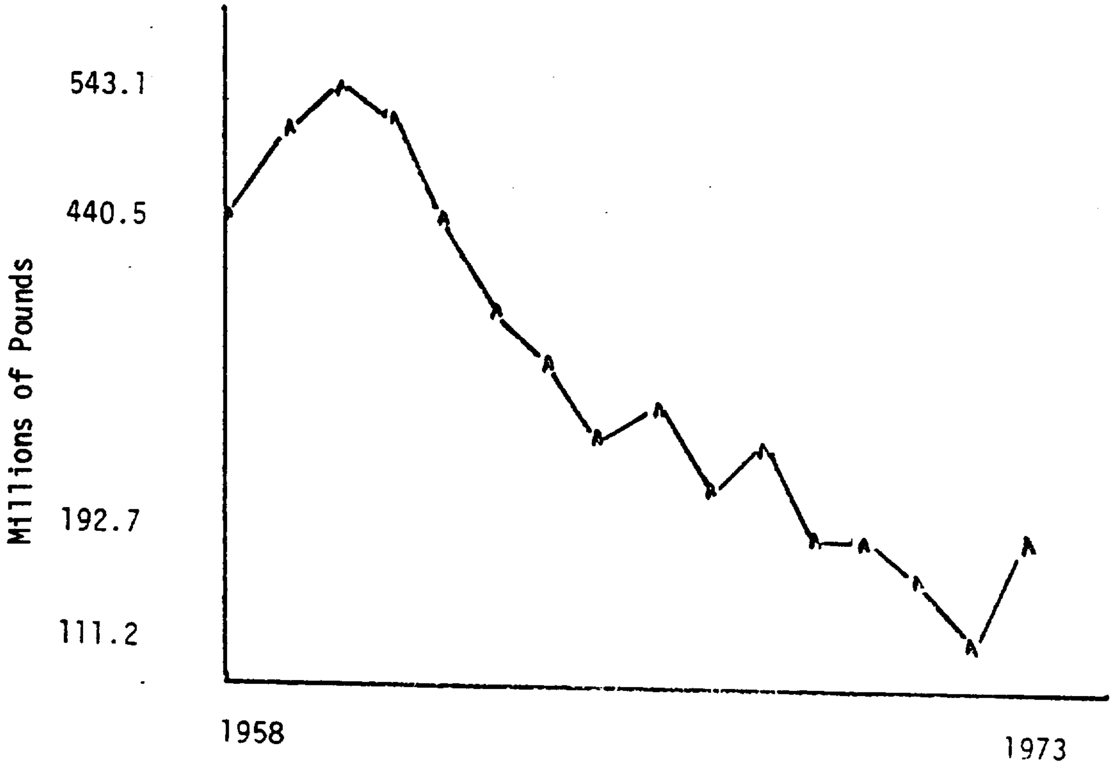
Consumption of blacks by the plastics industry has historically been lumped by the Bureau of Mines in the "miscellaneous" category, but it is known that this market is currently expanding, as uses for plastics generally have continued to multiply and uses for carbon blacks as colorants in plastics continue to be found.

8.1.3 Exports

Exports of carbon blacks currently account for approximately 5.5 percent of total shipments by volume. The export market grew steadily until 1960 when it began a fairly precipitous decline and between 1960 and 1974 has declined at an average annual rate of about seven percent (See Figure 8.3). Exports in 1974 were at a level of 192.9 million pounds, the highest they had been since 1969. Typically between 70 and 80 percent of blacks exported have been furnace blacks, the remainder higher-priced channel process grades. In 1973 furnace grades accounted for over 92 percent of the quantity exported, but only 69 percent of the total value.

In 1973 channel black exports commanded an average price of 49.9 cents per pound (46.3 cents per pound in 1972) and furnace blacks averaged 9.3 cents per pound (9.4 cents per pound, 1972). Thus, channel blacks command a price premium sufficient to compensate for lower yields in production; whether this premium will continue to be sufficient to offset rising fuel prices and emission reduction expenses is problematic at this time.

Figure 8.3. Total Exports of Carbon Black by Volume[2]



Although there has been some variation, the trend has been for European countries to be primary consumers of U.S. carbon black exports, notably West Germany, Italy, France, and the Netherlands. Generally European markets account for around 50 percent of U.S. export shipments. Japan and Canada are also large importers of U.S. blacks.

8.1.4 Imports

Imports of carbon blacks into the United States are normally limited to specialty grades and are only a small fraction of total supplies. Amounts imported vary from year to year and prices of imports are generally lower than those obtained for exports. In 1973, imported carbon black averaged 11.4 cents per pound as compared with 12.5 cents for average exports. In 1972 comparable prices were 15.3 and 13.4 cents per pound, respectively.

8.1.5 World Review

Although the United States still produces nearly half of all carbon black produced worldwide, foreign producers (particularly large manufacturers of automobiles) are beginning to seek self-sufficiency in the manufacture of this product. U.S. carbon black manufacturers and their affiliates have played an important role in the global expansion of production capabilities, both through the foreign subsidiary mechanism and through direct ownership of foreign stocks. Despite the remarkable production capacity increases in Europe and elsewhere there are no facilities outside the U.S. for the production of channel blacks; and until 1973, with the completion of facilities in Medicine Hat, Alberta, no non-U.S. company had the facilities for the production of thermal blacks. It must be noted that in the past decade production of carbon blacks in Japan has nearly quadrupled, almost tripled in West Germany and more than doubled in Italy.

Although domestic producers currently hold a wide edge over others and can expect to do so for some time, the export market might well continue to shrink in future years. This could become a critical factor in the maintenance or decline of domestic production facilities should fuel shortages and gasoline price increases continue to reduce the demand for automobiles and supplies of rubber in this country.

8.1.6. Substitutes and Competition

To date carbon black holds a unique position in the production ladder. There are no successfully marketed substitutes for carbon blacks as reinforcing agents or colorants. Attempts are being made through research to find substitute feedstocks and end products. Silica currently represents the most likely black substitute and there is a small scale operation in Texas for the production of finely crushed coal as a direct carbon black substitute in some applications. Coal is also undergoing experimentation as a feedstock source of carbon.

8.1.7. Structure of the Industry

The domestic carbon black industry consists of plants owned by eight companies including three small companies whose primary product is carbon black (Commercial Solvents, J.M. Huber and Sid Richardson) and four large, diversified companies (Ashland Oil, Phillips Petroleum, Cities Services, Cabot Corporation), for which carbon black merchant sales represent only a small portion of the total corporate product mix. One other producer, Continental Carbon, is a company solely devoted to the manufacture of carbon black but is a subsidiary of Continental Oil. For a complete plant listing, see Table 8.4. Virtually all carbon black, regardless of producer type, is made for commercial rather than captive use.

This industry appears to be oligopolistic. It is controlled domestically by eight producers, five of which are large in terms of corporate structure. Additionally, in 1975 these five producers control approximately 83 percent of total industry capacity. Capacity figures are enumerated in Table 8.4. The profit making flexibility available to corporations with other marketing capabilities such as these have allowed them substantially different competitive options vis a vis the smaller more carbon black-dependent producers in this industry. The fact that the primary manufacturers of carbon black provide their own feedstock supplies has the potential of being a critical price-determinant in this sector as well.

The industry has, in its production patterns, demonstrated a remarkable stability over time. It is currently made up of eight producer companies with 33 plants in nine states. In 1958 there were only 36 plants with the number of plants peaking at 44 in 1961 and showing minor fluctuations since that time. Parent company ownership has remained fairly stable, as has producer geographic distribution.

Given the high production dependence upon liquid hydrocarbons and natural gas as primary feedstocks, production facilities have typically located with ready access to historically low cost fuel supplies rather than close to major markets, namely tire manufacturers. It is likely that this trend will be accentuated by the ramifications of the energy shortage. Liquid hydrocarbons and natural gas supplies are critical to the output of this industry and the energy shortage has caused a disruption of normal

TABLE 8.4. 1975 CARBON BLACK PLANT INVENTORY AND CAPACITIES[5]

Parent Company	Plant Location			Approximate Annual Capacity* (million pounds)	Process**
	State	County or Parish	City		
Ashland Chemical Company				661	
	California	Kern	Mojave	64	
	Louisiana	St. Mary		235	
	Ohio	Washington	Belpre	100	
	Texas	Aransas		150	
	Texas	Wheeler	Shamrock	112	
Cabot Corporation				950	
	Louisiana	Evangeline	Ville Platte	195	
	Louisiana	St. Mary	Franklin	385	
	Texas	Gray	Pampa	60	
	Texas	Howard	Big Spring	200	
	West Virginia	Pleasants	Waverly	110	
Cities Service Company				1,037	
	Arkansas	Union	El Dorado	97	
	California	Kern	Mojave	60	
	Kansas	Grant	Ulysses	60	
	Louisiana	Avoyelles	Echo	66	
	Louisiana	Ouachita	North Bend	238	Thermal
	Louisiana	St. Mary	Franklin	120	
	Texas	Gaines		34	Channel
	Texas	Montgomery	Conroe	117	
	Texas	Terry	Seagraves	95	
	West Virginia	Marshall	Moundsville	150	
Commercial Solvents				145	
	Louisiana	Ouachita	Sterlington	145	Thermal
Continental Carbon Company				450	
	Alabama	Russell	Phenix City	50	
	California	Kern	Bakersfield	70	
	Louisiana	Calcasieu	Westlake	109	
	Oklahoma	Kay	Ponca City	122	
	Texas	Moore	Sunray	99	
J. M. Huber Corporation				404	
	Texas	Harris	Baytown	234	
	Texas	Hutchinson	Borger	170	Thermal
Phillips Petroleum Company				473	
	Ohio	Lucas	Toledo	60	
	Texas	Hutchinson	Borger	318	
	Texas	Orange	Orange	95	
Sid Richardson Carbon & Gasoline Company				200	
	Louisiana	W. Baton Rouge	Addis	75	
	Texas	Howard	Big Spring	125	
Total Approximate Domestic Annual Capacity				4,320	

*Plant capacities are all approximate production capacity figures but may vary substantially with feedstock and product mix.

**Process not specified if basic "furnace".

interstate flows of these vital fuels. If the energy shortage continues, regardless of price increases, it is feasible that supplies may conceivably be available only to producers located in southern states. This curtailment of feedstock supplies would cause further incentive for producers of carbon black to expand capacity by enlarging or converting existing production facilities in southern states.

Plants in Louisiana and Texas have typically manufactured nearly 80 percent of all blacks produced domestically (see Table 8.5) although those states' relative shares of production have experienced some minor fluctuations from year to year. Although the actual number of plants has remained fairly stable from year to year, production quantities, dollar values and capacities have steadily increased. The newest production facility was constructed by Ashland Oil in Washington County, Belpre, Ohio in 1969 and additional industry-wide production requirements have been met by extensions of existing facilities, and this trend toward large old facilities is expected to continue as there are no known plans currently for any new plant construction.

An examination of the number of plants operating in this industry does not fully reflect the dynamics of industry growth. The most striking feature of change in the industry has been the virtual elimination of carbon blacks produced by the channel process. Although channel blacks command high prices in the export market and continue to meet specific needs sufficient to keep one plant in operation, the process is chemically inefficient and, thus, increasingly costly. In 1960 there were 15 channel black plants in the United States and today but one remains. Some of these plants have been shut down, while others have converted to furnace black production units.

TABLE 8.5. 1975 CARBON BLACK PLANT CAPACITY*, BY STATE[3-7]

State	Total State Annual Capacity (million pounds)	Percent of Total Capacity	Number of Plants
Alabama	50	1.2	1
Arkansas	97	2.2	1
California	194	4.5	3
Kansas	60	1.4	1
Louisiana	1,568	36.3	9
Ohio	160	3.7	2
Oklahoma	122	2.8	1
Texas	1,809	41.9	13
West Virginia	260	6.0	2
Grand Total	4,320 *	100.0	33
Bureau of Mines 1973 Total Capacity	4,224		34

*Approximate total capacity in the Bureau of Mines 1973 Minerals Yearbook preprint equals 4,224. This figure is overstated in relation to the 1975 capacity total estimated by RTI in that it includes the capacity of two channel black plants, only one of which remains operative in 1975, and understated to the extent that expansion of facilities between 1973 and 1975 is not, of course, included.

In addition, plant numbers seem in many instances to be misleading in that the reduction of the number of plants does not always represent the real dismantling of production facilities. In some cases, plants are shut down until increased market demand makes production profitable. Characteristically capacity has increased at existing facilities.

Plant sizes vary substantially, ranging from about 30 to nearly 300 million pounds annual production capacity, with the majority of plants having production capabilities around or between 60 to 150 million pounds per year (See Table 8.6).

8.1.8. Patterns of Production

Since 1958 the domestic carbon black industry has experienced fairly consistent rates of growth in production and sales, with the exception of years (notably 1967 and 1970) in which widespread strikes in the rubber industry were fairly serious and lengthy and 1974 when the recession caused both production and sales to decline markedly. Production by volume during the period 1958 to 1973 expanded at an average annual rate of 4.8 percent while value of production increased nearly six percent. Sales for domestic consumption by volume increased steadily at an average annual rate somewhat in excess of six percent. All of these indicators followed closely the growth patterns in the domestic shipments of pneumatic casings (tires), this sector averaging an annual growth of about 5.7 percent (See Figure 8.4).

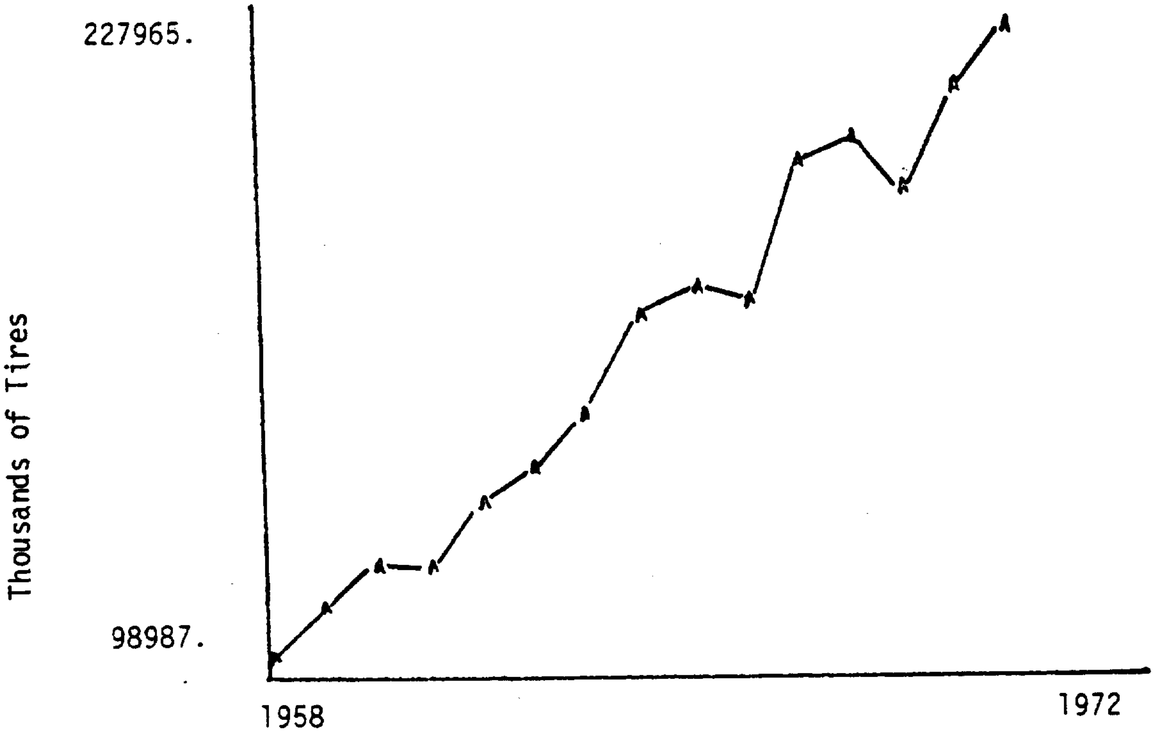
8.1.9 Production Costs

The industry is capital intensive. In 1967, 21 of 34 operating plants registered between 20 to 99 employees. Labor costs as a percent of total shipments have remained constant since the late 1950's and

TABLE 8.6. 1975 PLANT SUMMARY, BY CAPACITY RANGE [3-7]

Annual Capacity (million pounds)	Number of Plants in Range
0 - 49	1
50 - 99	13
100 - 199	13
200 - 299	4
300 and above	2

Figure 8.4. Total Shipments of Pneumatic Casings[8]



account for only 14 percent of total costs (see Table 8.7), and the actual number of all employees and production workers dropped in the period 1958 to 1972 (see Table 8.8). Payroll per employee increased during the same period nearly four percent annually, as did value added to manufacture per employee. During the same period the value added in manufacture per production worker man hour more than doubled. In the same period the average value of carbon black production (calculated as cents per pound) increased from 7.0 cents to 8.12, or nearly one percent annually (See Figure 8.5). In 1974 the average value of carbon black production rose to 10.98 cents per pound, up drastically from the 1973 level. This average value was a reflection primarily of increased feedstock prices.

The prices of feedstocks have been the major element of change in production costs in recent years. In 1963, 44 percent of total nonlabor, noncapital costs were accounted for by fuel oil expenditures and 28 percent by natural gas (See Table 8.9). In 1972 natural gas costs had diminished to 13 percent of this total and fuel oil had climbed to 54 percent, gaining almost the entire share relinquished by natural gas expenditures. This shift is explained primarily by the drastic and continuing reduction in channel black production which is produced exclusively with natural gas as the feedstock. A portion of this reduction may be attributable to increases in the interstate prices of natural gas which began in the interim period. Since 1958 the average cost of natural gas used by the carbon black industry has increased steadily whereas the average value of liquid hydrocarbons experienced some fluctuation prior to increasing steadily commencing in 1963. In 1974 the average cost of natural gas

TABLE 8.7. CARBON BLACK PRODUCTION COSTS AS A PERCENT OF VALUE OF SHIPMENTS[9] (values @ millions of dollars)

Year	1972		1967		1963	
	%	Value	%	Value	%	Value
Labor	14.0	31.9	14.0	22.8	14.0	20.7
Production Workers	11.0	24.1	11.0	18.0	10.0	14.9
Administrative Personnel	3.0	7.8	3.0	4.8	4.0	5.8
Materials, Energy, etc.	39.0	88.9	40.0	67.4	37.0	55.0
Materials and Parts*	34.0	78.3	36.0	60.9	33.0	49.3
Fuels for Space Heating	5.0	10.6	2.0	2.8	4.0	6.2
Electricity			2.0	3.3		
Resales			neg.	0.4		
Contracts			0.0	**		
Capital and Fixed Costs[a] and Profit	47.0	107.1	46.0	77.2	49.0	73.4
Total Value of Shipments		227.8		167.8		149.1

*Includes fuel oil used as feedstocks

**Less than $50,000.

[a] Computed as total value of shipments less labor and material costs.

TABLE 8.8. CARBON BLACK INDUSTRY DATA [9]

Year	Total Employment (Number)	Production Workers (Number)	Payroll Per Employee ($)	Value Added by Manufacture (Millions $)	Value Added in Manufacture per Employee ($)	Value Added in Manufacture per Production Worker Man-Hour ($)
1958	3162	2600	$ 5884	72.6	$22973	12.86
1959	3102	2600	6355	81.0	26114	14.07
1960	3165	2700	6522	84.7	26772	14.16
1961	3101	2600	6682	88.2	28432	15.64
1962	3005	2400	6836	92.5	30788	17.64
1963	3010	2300	6867	91.8	30482	18.68
1964	2833	2200	7411	101.0	35657	20.73
1965	2837	2300	7462	105.5	37177	20.91
1966	2883	2300	8145	113.1	39231	22.48
1967	2800	2300	8202	100.8	36770	19.45
1968	2800	2300	8500	125.9	44964	25.18
1969	2900	2300	9140	125.5	43276	24.13
1970	3300	2500	9390	128.8	39030	23.85
1971	3200	2600	9940	137.9	43094	26.52
1972	2900	2300	11000	137.6	47448	26.98

Figure 8.5

Average Value of Carbon Black Production[2]
(Value at the Plant)

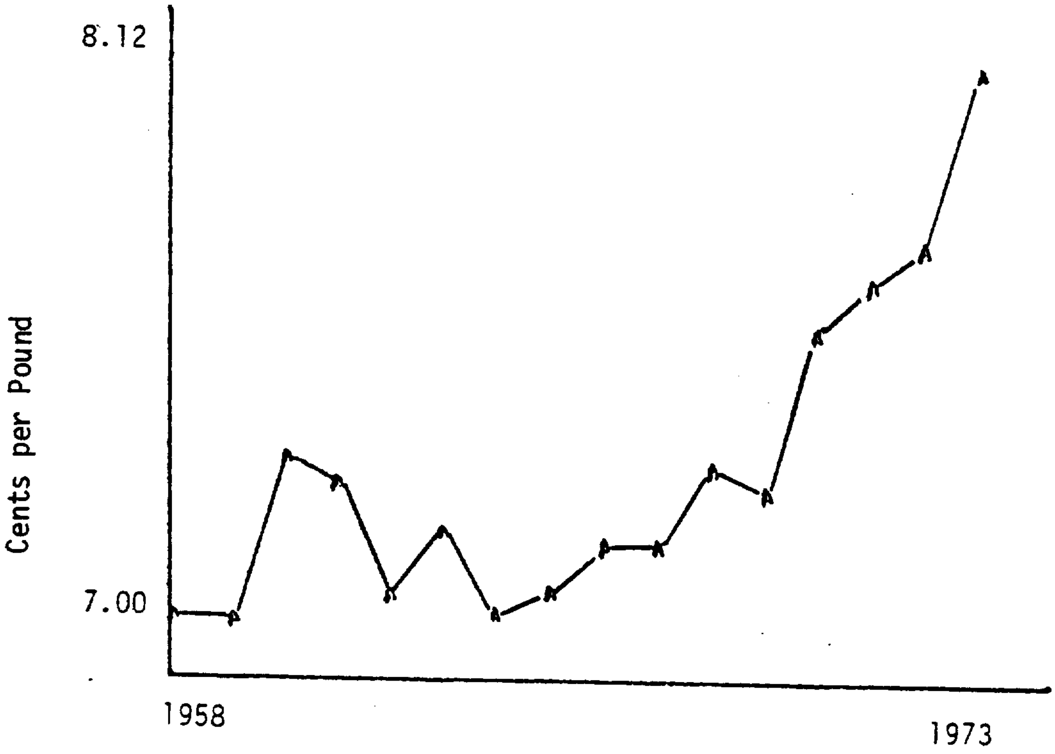


TABLE 8.9. MATERIAL PRODUCTION COST BREAKDOWN BY VALUE[9]
(values @ millions of dollars)

Year	1972		1967		1963	
	Value	%	Value	%	Value	%
Total Cost of Materials Fuels, Energy, etc.	$88.9	100.0	$67.4	100.0	$55.5	100.0
Cost of Fuel Oils Used as Raw Materials	48.1	54.	29.5	44.	24.3	44.
Cost of Natural Gas Used as Raw Materials	11.7	13.	14.5	22.	15.4	28.
Total Cost of Fuel Oil and Natural Gas	59.8	67.	44.0	65.	39.7	71.
Cost of Other Materials and Parts	18.5	21.	16.9	25.	9.6	17.
Cost of Fuels Consumed as Energy and Electricity and Resales and Contracts	10.6	12.	6.5	10.	6.2	11.

Note: Figures may not strictly add due to rounding.

used was 40.87 cents per thousand cubic feet compared with 24.19 cents per thousand cubic feet in 1973, an increase of 69 percent. The average cost of liquid hydrocarbon feedstocks increased from 9.03 cents per gallon in 1973 to 23.87 cents per gallon in 1974.

Accompanying the price increases partially reflected in the average cost figures, total usage of feedstocks registered reactions to these price increases. Natural gas usage had declined consistently over the period partially due to higher price increases relative to liquid hydrocarbon price increases and due as well to continued phase-outs of channel black production units. Use of liquid hydrocarbons has increased to partially make up for the decline in natural gas used.

Although there is some question as to the reliability of average yield figures for specific feedstocks, trends in yields are useful and are probably accurate within a range derived from Minerals Yearbook data. Average yields since the late fifties for liquid hydrocarbons have steadily increased and natural gas yield increases peaked in 1964 and have since declined (See Figures 8.6 and 8.7). Yields reflect both shifts in process types and shifts in carbon black production grades. The yields given here confirm known facts regarding increased production of higher yield oil furnace blacks and diminished production of exceedingly low yield channel blacks.

8.1.10 Industry Capacity

Capacity numbers and utilization calculations for the carbon blacks industry are, at best, approximations since the numbers are rather closely held by individual producers and vary greatly as a function of feedstock variations and product mix.

Figure 8.6. Average Yield of Liquid Hydrocarbons used in the Production of Carbon Black[2]

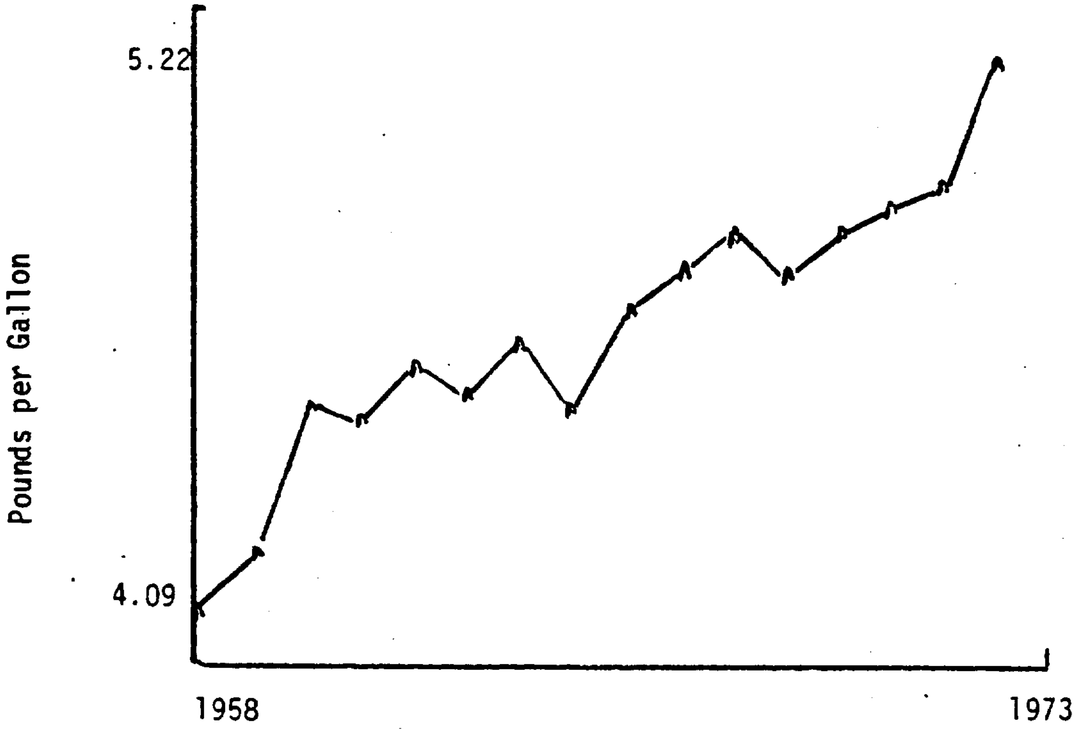
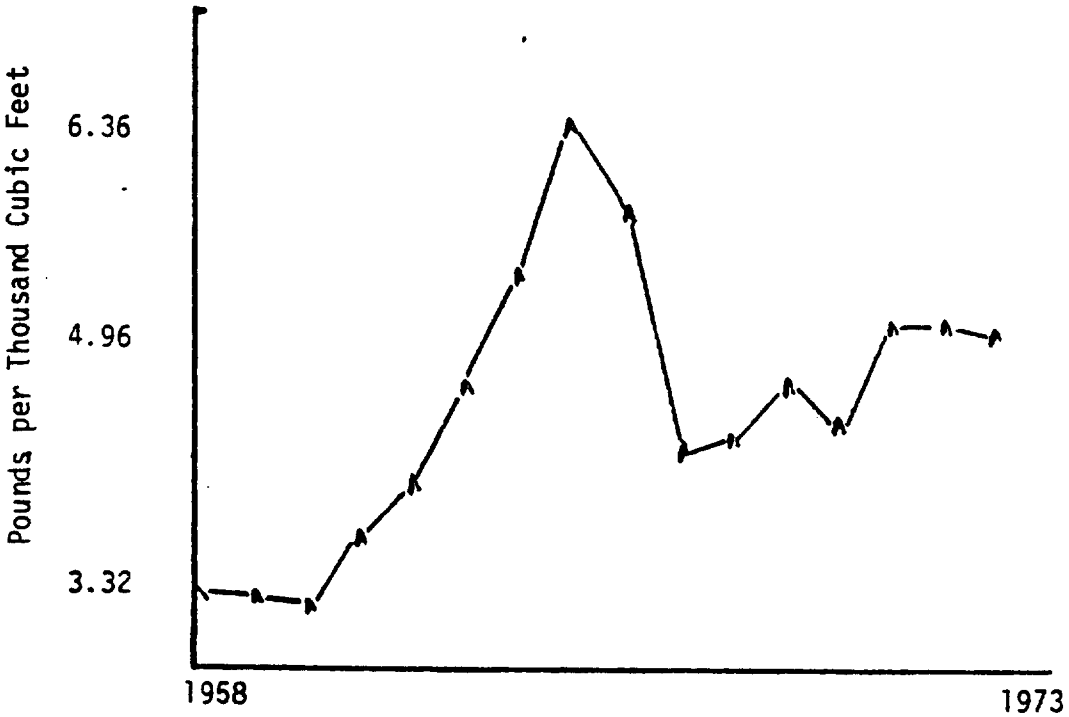


Figure 8.7. Average Yield of Natural Gas Used in the Production of Carbon Black[2]



Engineering sources indicate that production capacities can vary as much as 30 percent depending upon product and feedstock mix. Trends, however, can be discerned. Overall, during the period 1958 to 1973 total daily capacity has increased at an approximate average annual rate of 4.6 percent (See Table 8.10). Year to year, however, there have been variations in growth generally characterized as moderate expansion of facilities in the early to mid-sixties, followed by fairly rapid growth in the late sixties, tapering to a modest rate of increase in the early 70's. Since 1970 annual capacity growth has been about three percent. Between 1973 and 1974 capacity, even in the face of general industry slowdown, continued to expand by 1.6 percent.

Capacity utilization has tended to vary in the 10 years from 1964 to 1973 over the range of approximately 76 to 84 percent, as shown in Table 8.10. The relatively steady growth in demand has apparently permitted the firms in the industry to plan the construction of new plants and the closing of old plants efficiently so that supply was balanced with the market. In 1974 and the first half of 1975 firms in the industry have been reported operating at as little as 60 percent of capacity and as much as 105 percent of capacity. The decline of industry generally and decreased demand for carbon black for use in the rubber industry at the same time that new capacity was coming into operation indicate that the operating ratio probably is substantially below the normal level. In 1974 the industry apparently operated at approximately 78 percent of capacity and this has declined in 1975 to an estimated 74 percent.

TABLE 8.10. CARBON BLACK PLANT CAPACITY UTILIZATION[2]

Year	Number of Plants	Total Annual Capacity (million pounds)	Production As Percent of Total Industry Capacity[1]
1958	36	2056	80.0
1959	41	2102	93.6
1960	42	2354	87.2
1961	44	2568	77.1
1962	41	2573	79.9
1963	33	2564	80.3
1964	37	2660	83.6
1965	34	2935	80.2
1966	34	2928	87.8
1967	35	3102	80.1
1968	34	3346	84.0
1969	38	3664	81.0
1970	37	3753	78.0
1971	37	3886	76.0
1972	34	4177	76.6
1973	34	4224	82.9
1974	34	4292	79.0
1975	33	4320*	

[1] Calculated by taking production (lbs.) as a percent of daily capacity x 365 (x 366 in leap years).

8.1.11. Industry Growth

Production grew at an annual rate of 4.8 percent between 1958 and 1973, increasing from 1644.6 million pounds to 3499.9 million pounds. At the same time annual capacity increased from approximately 2056 to approximately 4224 million pounds. In those years domestic sales increased from 1250.9 to 3313.6 million pounds and exports declined from 440.5 to 192.7 million pounds.

In 1974, productive capacity increased to approximately 4293 million pounds, but production and sales declined. Exports were down only slightly, but total sales declined by approximately five percent, with domestic shipments totaling 3148 million pounds out of production of 3390 million pounds. This decline in domestic sales was apparently due in part to the decline in demand for original equipment tires on cars, trucks, and busses as the automotive industry contracted, accounting for an estimated three percent of the carbon black decline. Another one percentage point is estimated to be the effect of declining demand for replacement tires, due in turn to the gasoline shortage, higher prices, and lower speed limits. The remaining percentage point of total sales decline is attributed to small decreases in the rest of the domestic carbon black market and in exports.

The first half of 1975 showed continued downward pressures on the tire market as the automotive industry has contracted further (down 19 percent for the first five months compared to the same period in 1974) and gasoline prices increased again, indicating further reduction in consumption of gasoline, less driving, and less demand for replacement tires. As a result of this trend, it is estimated that 1975 sales of carbon black were approximately 3150 million pounds. Capacity continued to expand in 1975 despite the closing of one plant, reflecting construction already underway or committed for at year-end. If production was held close to total sales of 3150 million pounds, this would indicate an operating ratio of approximately 73 percent of the estimated capacity of 4320 million pounds in 1975.

It is unlikely that the industry will return to the pre-1974 growth trend. Rather, the industry growth pattern will reflect the effect of continued higher prices for gasoline which will reduce the number of miles driven which, in turn, will lower the demand for replacement tires. In addition, the trend in the automobile industry to smaller cars will result in reduced rubber requirements and longer tire life. Other problems facing the carbon black industry that will affect growth include a shortage of feedstock, particularly the desirable high aromatic, low-sulfur heavy oils, and rapidly increasing feedstock prices.

Taking into account these factors and using published estimates of the impact of higher prices on gasoline demand over time,[10] carbon black demand is estimated to grow at a rate of three percent per year for the next 10 years. This would put 1985 production to meet demand at close to 4250 million pounds. Assuming the industry operates at 80 percent of capacity, 5300 million pounds of capacity would be required by 1985, representing an increase of 1000 million pounds over 1975 capacity. At this time there are no indications that any new grass-roots plants will be built in the next five years. Because of under-utilization of present capacity, only an additional 250 million pounds of capacity will be needed to meet increased demand by 1980. Increases in capacity will generally be accomplished by expanding existing plants or by "debottlenecking" existing plants by enlarging a piece of equipment that controls the production rate.

8.2 COST ANALYSIS OF ALTERNATIVE CONTROL EQUIPMENT

In this section, data are presented on the costs incurred for installing and operating carbon monoxide (CO) and sulfur dioxide (SO_2) emission control systems at carbon black model plants. Costs for visible emission control have not been developed since all plants utilize efficient fabric filter systems as part of their process equipment. Following the discussion of the capital and operating costs associated with each control system, analyses of the model plant costs are given for three different control systems for new plants and three systems for retrofitted plants.

Data for estimating off-gas composition, heat content and volume have been based on previous studies.[11] All costs are general since a specific site has not been selected for the study; such cost estimates are considered accurate to within ± 30 percent.

8.2.1 Carbon Monoxide Control Costs

As previously discussed in Chapter 4 of this report, carbon monoxide (CO) boilers and thermal incinerators, when properly designed and operated, can effectively control CO emissions. Control costs for both devices have been developed. Where applicable, costs for combinations of control devices have been estimated by adding individual costs for each system.

8.2.1.1 Installed Cost Estimates - Costs for control equipment have been obtained from equipment manufacturers[12-20] based on verbal descriptions of the off-gas stream quantity and composition. These equipment costs have been obtained for a model carbon black plant producing 11,000 lbs/hr (90 million lb/yr) of carbon black with an off-gas rate of 198,000 lbs/hr (57,400 scfm on a wet basis) at 450 to 500°F. The CO content of this gas may vary from 6 to 14 volume percent, and heat value from 35 to 65 Btu/scf depending on the grade of carbon black being produced. Depending primarily on the heat content, the off-gas rate per unit of carbon black may range from 200 to 315 Scf per lb of black produced. For purposes of installed cost estimating, the latter off-gas rate has been used. This flowrate corresponds to a plant producing relatively low heat content off-gas (about 39 Btu/scf). Further, it is assumed here that 20 percent of the vent gas will go to the product dryer furnace, and the remaining 80 percent to the control equipment.

The method used in estimating the installed cost is described separately for each CO control device, but consists basically of obtaining the major equipment costs and then estimating costs of installation. Indirect costs related to installation have also been included. Since these are model plant installed cost estimates they do not account for site-specific conditions.

The installed cost data presented here are based on 4th quarter 1975 material prices and labor costs. The installed cost for each CO control device is described by the equation:

$$C = a P^{n}$$

Where:

C = installed cost (dollars) of specified device

P = production rate of carbon black (lbs/hr)

a = a constant

n = an exponent

The thermal incinerator considered here consists of a refractory lined combustion chamber complete with burners, stack, fan and motor.[14-17] Because inlet gas is already hot (approximately 450°F) a pre-heater is not required and a relatively small amount of natural gas is required to operate the unit. The installed cost for the model incinerator has been estimated by combining costs for equipment, foundations, ductwork, insulation, piping, electrical, instrumentation, and indirect costs as shown in Tables 8-11 and 8-12.

The total installed cost for an incinerator burning 80 percent of the off-gas from the 11,000 pounds per hour carbon black model plant is estimated to be $397,000. Ductwork costs are a major part of the installed costs and may increase significantly if extremely long duct runs are required. The installed cost equations for incinerators of different sizes are:

Installed Cost = $3,719 $P^{0.5}$ for $P \leq 11{,}000$ lbs/hr

Installed Cost = $ 578 $P^{0.7}$ for $P > 11{,}000$ lbs/hr.

Regarding CO boilers, manufacturers have indicated that a boiler for this application would be a field erected unit.[12,13] Consequently, the cost for a CO boiler is much higher than the cost for a package unit of equal steam generating capacity using conventional fuels.

The equipment cost for a CO boiler serving the model sized carbon black plant, with a theoretical capacity of 140,000 pounds of steam per hour at 450 psig and 750°F,[a] is approximately $1,500,000. The installation cost for a field erected CO boiler is estimated to be

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[a] However, in normal operation, the amount of steam generated is less than this amount, due to variance in the heat content of the off-gas, gas volumetric flowrate, and thermal losses.

Table 8-11. DIRECT COSTS, THERMAL INCINERATOR[a]

Cost item	M (equip. and material, $)	% of equip. cost	L (labor, $)	% of equip. cost
Equipment - incinerator, fan, motor	166,000	-	-	-
Foundations including setting	1,500	0.9	3,200	1.9
Ductwork including valves	38,700	23.3	13,300	8.0
Duct insulation	2,200	1.3	5,000	3.0
Piping including insulation	10,000	6.0	14,900	9.0
Electrical	8,300	5.0	11,600	7.0
Instrumentation	7,100	4.3	1,500	0.9
Paint	200	-	800	0.5
Total	234,000	40.8	50,300	30.3

Total direct costs = M + L

= $284,300

[a] Based on an inlet volumetric flowrate of 104,000 Acfm at 500°F.

(Source: PEDCo - Environmental)

Table 8-12. INDIRECT COSTS, THERMAL INCINERATOR[28,a]

Cost item	Cost $	% of (M) cost	% of (M + L) cost
Interest during construction	2,600		0.9
Contractor's fee and expenses	25,500		9.0
Engineering	28,400		10.0
Freight	5,800	2.5	
Taxes	7,000	3.0	
Allowance for shakedown	5,700		2.0
Spares	2,300	1.0	
Total, I	77,400	6.5	21.9

Total of Direct and Indirect costs: $361,700
Contingency (10% of Direct and Indirect costs) = $36,200
Grand total = $397,000

[a] Based on an inlet volumetric flowrate of 104,000 Acfm at 500°F.

(Source: PEDCo - Environmental)

equal to the equipment cost.[28] Thus, the installed cost is twice the erected boiler cost. The installed cost equations are:

$$\text{Installed Cost} = \$28{,}600\ P^{0.5} \quad \text{for } P \leq 11{,}000$$

$$\text{Installed Cost} = \$\ 4{,}450\ P^{0.7} \quad \text{for } P > 11{,}000$$

Note that these four equations have been based on combustion of eighty percent of the off-gas. If some smaller (or larger) fraction of the off-gas is burned, a different value for P must be substituted in the formulas. For instance, if 50 percent of the gas is combusted, then 5/8 P is used instead of P.

In addition to costs for these two devices, an estimate has been projected for the incremental cost for installing steam turbine power drives (vs. electric drives) in a carbon black plant used in conjunction with steam boilers. Steam drives would be installed so that the steam produced by the boilers could be utilized for in-plant power generation. For the model plant size, a steam drive incremental installed cost of $610,000 has been estimated, which is approximately five times the cost of an electric drive system of comparable size.

The last installed cost computed is that for enlarging the product dryer to accomodate 20 percent of the reactor off-gas. This cost, of course, varies considerably, depending on the specific dryer being enlarged, the plant process equipment layout, and other variables. In this section, a modification cost of $12,000 (equal to 4 percent of the installed cost of the unmodified dryer) has been used.

Finally, the subject of retrofit control costs must be considered. When CO control devices are installed in existing, rather than new, carbon black plants, the costs are usually higher, due to increased installation expenditures (extra ductwork, building enlargement, etc.). The value of this additional installation cost (or "retrofit penalty") varies from plant to plant, depending on the situation peculiar to each. In this section, the existing plant installed costs for CO boilers and incinerators have been computed at 1.33 times the respective new plant installed costs. For steam drives, the retrofit penalty has been estimated at 30 percent of the new plant incremental installed cost, cr $180,000.

8.2.1.2 Annual Operating Costs - The cost of operating a control device depends on the size and type of equipment, amount and cost of utilities (especially fuel), operating labor, maintenance charges, credits from by-products, and capital charges.

Combustion devices used for carbon black off-gas control generally require some supplemental fuel for stable operation. The exact amount of fuel required depends on the off-gas heat value and temperature, desired combustion temperature, and the amount and temperature of combustion air.

Utility unit costs used herein are:[22]

Natural gas	$1.75/million Btu
Boiler feed water	$0.40/thousand gal
Power	3¢/kwh

A thermal incinerator, once started, does not require operator attention, so the labor cost for this device is zero. However, a full-time operator is required with a CO boiler, so a labor cost ($10 per manhour) has been computed for it.[13]

The maintenance cost for incinerators has been estimated at 2 percent of the total installed cost per year. The CO boilers' maintenance costs have been estimated at 3.5 percent per year of the installed cost.[13]

For purposes of computing operating costs, the plant has been assumed to operate 8200 hours per year and to burn 44 Btu/scf off-gas (corresponding to a flowrate of 44,000 scfm).

Operating costs based on EPA figures have been computed with the following equations:

For thermal incinerators:

Direct Operating cost ($/yr) = 0.02C + 20.41P

For CO boilers:

Direct Operating Cost ($/yr) = 82,000 + 0.035C + 24.28P

where: P = carbon black production rate (lbs/hr)

C = total installed cost of control device ($)

Since the combustion of 20 percent of the off-gas in the product dryers yields energy that would otherwise need to be supplied by natural gas, a credit has been computed for this fuel savings. For both devices, the following formula has been used:

Natural Gas Credit ($/yr) = 33.25 P

In the case of the CO boilers, two credits have been computed for the generated steam: one for in-plant consumption and the other for steam consumed (exported) outside the plant. These are:

Steam Credit (In-House) ($/yr) = 39.51 P

Steam Credit (Export) ($/yr) = 47.41 P

Unit prices of \$1.00 and \$2.00 per 1,000 lbs. of steam based on EPA figures have been used in computing the in-house and export credits, respectively.

The annualized capital charges take into account the depreciation and interest on the installed cost investment, as well as charges for taxes, insurance, and administrative overhead. A capital recovery factor (11.75 percent) based on the equipment life (20 years) and the annual interest rate (10 percent), has been used to compute the depreciation and interest charges. The administrative charges have been calculated at 4 percent of the installed cost per year. Adding the two has resulted in the following:

Annualized Capital Charges (\$/yr) = 0.1575 C.

The total annualized cost has been computed by adding the direct operating cost to the annualized capital charges, and subtracting from this sum credits for natural gas and (where applicable) generated steam.

8.2.1.3 Control Options - CO boilers and incinerators, when properly designed and operated, remove more than 99 percent of CO present in the carbon black tail gas stream. Each of the three different control options (systems) for the new and retrofitted model plants is designed to achieve 99 percent control. However, as Table 8-13 indicates, because the installed and annualized control costs depend on the combination of control devices used and the fraction of off-gas ducted to each, the costs vary among the systems.

For both the new and retrofitted plants, System 1 and 2 each includes two CO boilers for steam generation, a steam drive system, and an

Table 8-13. MODEL PLANT CARBON MONOXIDE CONTROL COSTS (90,000,000 Lb/Yr Production)

Control Option	Installed Cost	Direct Operating Cost	Steam Credit	Natural Gas Credit	Annualized Capital Charges	Total Annualized Cost (Credit)
I. New Plant:						
System 1	$5,359,000	$514,800/yr	$956,100/yr	$365,800/yr	$844,100/yr	($37,000/yr) or (0.04¢/lb)
System 2	$4,611,000	$468,400"	$434,600"	$365,800"	$726,200"	$394,000" or 0.44"
System 3	$ 409,000	$232,800"	NONE	$365,800"	$ 64,400"	($69,000") or (0.08")
II. Existing Plant:						
System 1	$7,105,000	$569,500/yr	$956,100/yr	$365,800/yr	$1,119,000/yr	$367,000/yr or 0.41¢/lb
System 2	$6,110,000	$509,900"	$434,600"	$365,800"	$962,300"	$672,000" or 0.75"
System 3	$541,000	$235,200"	NONE	$365,800"	$85,200"	($45,000") or (0.05")

enlarged pellet dryer. Each of the two boilers is, in turn, sized to handle sixty percent of the combined gas volume ducted to them. It is assumed with both Systems 1 that 80 percent of the offgas is ducted to the boilers and 20 percent is burned in the pellet dryer, producing a natural gas credit of $365,800/year. Five eighths (5/8) of the steam generated is used to power equipment in the plant. The remaining 3/8 is sold to other users outside the plant, thus providing the firm added revenue. The steam credit listed in Table 8-13 ($956,100/year) represents the sum of these two amounts. As shown in Table 8-13, the installed cost for Systems 1 are $5,359,000 and $7,105,000, for new and existing plants, respectively - the highest among the three systems. The total annualized figures for this system in the new and retrofitted plants are, in turn, a credit of $37,000/year (.04 ¢/lb) and a cost of $367,000/year (0.41 ¢/lb).

System 2 is similar to System 1, except that here it is assumed that the plant is located where there is no export market for steam. Consequently, only 50 percent of the offgas is burned in a CO boiler to generate steam for in-plant use, and the credit ($434,600/year) is, therefore, 45 percent as much as with System 1. 30 percent of the offgas is burned in an incinerator, and the remainder is routed to the pellet dryer as in System 1. Because the combination of a CO boiler and an incinerator is less expensive than two CO boilers, the System 2 capital costs are lower, but without the revenue from the sale of exported steam, the total annualized costs are $394,000 (0.44 ¢/lb) for a new plant, and $672,000 (0.75 ¢/lb) for a retrofitted plant.

System 3 evaluates the option using an incinerator only for combustion of eighty percent of the off-gas, without employing the option of steam generation and use. The only credit attributable to this case is that from the natural gas savings in the pellet dryer. Although there is no steam credit for this case, the much lower installed costs (for the incinerator and dryer modification, only) - $409,000 and $541,000 - effect total annualized credits of $69,000/year (0.08 ¢/lb) and $45,000/year (0.05 ¢/lb) for new and retrofitted plants, respectively.

Since the total CO emission reduction is the same for all cases, System 3 is clearly the most cost-effective control option both for the new and retrofitted model plants.

Costs for achieving state regulations for CO (SIP's) have not been included in Table 8-13. This is because the emission reduction considered here (greater than 99 percent) is assumed to be equivalent to the SIP's in those states in which carbon black plants operate. If a carbon black plant is located in one of these states (89 percent of the industry capacity is), the additional cost impact for achieving the EPA emission reduction, versus meeting the SIP regulation, would be zero. However, if a plant were situated in a state having no CO regulation, the impact would be exactly equal to that of the system in Table 8-13 having the least cost, namely System 3.

8.2.2 Sulfur Dioxide Control Costs[30]

In addition to estimating the costs for controlling carbon monoxide at the model plant, sulfur dioxide (SO_2) control costs have been computed. Although no carbon black plants currently control SO_2 with add-on equipment, there is no technological reason to assume that certain SO_2 removal systems, proven with demonstration-scale power plants, cannot be applied to this process.

Based on this premise, cost estimates have been made for controlling carbon black SO_2 by using the limestone slurry scrubbing system, described in reference 3.

8.2.2.1 Installed Cost Estimates - As with the carbon monoxide control systems, the limestone slurry scrubbing system has been sized for each option, based on the 11,000 lb/hr (90,000,000 lb/yr) model plant production rate, burning a low-Btu gas.

The SO_2 content of the off-gas remains essentially constant at 326 ppm (by volume), corresponding to an uncontrolled mass rate of approximately 200 lb/hr. The system has been designed for a removal efficiency of 90 percent, which is the control level considered here. Although the model plant production rate remains the same throughout, the volumetric flowrate from the combustion device to the limestone slurry system varies among the respective carbon monoxide control systems discussed previously. The flowrates used in computing the installed costs are:

System 1: 194,000 acfm
System 2: 232,000 acfm
System 3: 296,000 acfm

The scrubbing system costs include various components, such as: limestone receiving and storage equipment, feed preparation facilities, SO_2 scrubbers and ductwork, stack gas reheaters, fans, calcium solid disposal equipment (off-site), utilities, and service and construction facilities.

The method used in estimating the various installed costs is detailed in reference 30. Essentially, installed costs for the various components of the scrubbing system have been computed individually and combined to obtain the direct cost. To obtain the total installed cost, to this have been added indirect costs for engineering design and supervision, construction field expense, contractor fees, contingency, allowance for startup and modification, and interest during construction. Lastly, the costs have been computed to reflect 4th quarter 1975 prices for equipment and installation labor and materials.

It must be emphasized that these, like the CO, costs are generalized to a model plant, and do not consider conditions specific to an actual carbon black installation. However, if installed cost estimates need to be made for a plant having process parameters different from those for which model plant costs have been developed, the following formulas may be used:

For a new plant:

Installed cost (\$) = $23{,}413\ V^{0.84} + 3{,}535\ S^{0.70}$ (for $V \leq 1{,}550$ Macfm)

Installed cost (\$) = $\$94{,}888\ V^{0.65} + 3{,}535\ S^{0.70}$ (for $V > 1{,}550$ Macfm)

Where: V = volumetric flowrate to slurry system (Macfm)

$S = SO_2$ mass rate to slurry system (lb/hr)

For a retrofitted plant:

Installed cost (\$) = $33,102\ V^{0.82} + 3,926\ S^{0.70}$ (for $V \leq 1,550$ Macfm)

Installed cost (\$) = $115,440\ V^{0.65} + 3,926\ S^{0.70}$ (for $V > 1,550$ Macfm)

Two sets of formulas have been provided, because the cost of installing a slurry system in an existing carbon black plant would normally be higher, due to special design considerations, ducting requirements, etc.

8.2.2.2 Annual Operating Costs - Unlike the installed costs, the operating costs have been computed for a model plant burning 44 Btu/scf off-gas, a value which is typical for the industry.

The direct operating cost items to consider for the limestone slurry system are: operating labor, power, maintenance, steam, process water and off-site waste disposal. The unit prices for labor and power are the same as used in section 8.2.1. Maintenance is computed at 6 percent per year of the total installed cost. Steam and process water unit costs are \$2.00/Mlbs and \$0.25/M gal, respectively. The cost for off-site disposal of gypsum and other solid waste generated by the system has been estimated at \$4.00/ton.

To estimate the direct operating cost at plants whose parameters differ from those of the model, the following expression may be used:

Direct Operating Cost (\$) = $0.06\ C + 260.7\ S + 2,509\ V + 11,006\ V^{0.45}$

Where: C = total installed cost (\$)

As with the CO control systems, the annualized capital charges are comprised of depreciation of the capital investment, annual interest on the capital, and administrative charges for insurance, taxes, and overhead. The depreciation and interest are computed by means of a capital recovery factor (0.1061), which, in turn, considers the 30-year system operating life and the same ten percent annual interest rate. Adding in the 4 percent for administrative charges, we have:

Annualized Capital Charges = 0.1461 C.

The sum of the annualized capital charges and the direct operating cost is the total annualized cost. (Unlike the CO control systems, there are no credits here for steam, fuel, etc.)

8.2.2.3 Control Options - As Table 8-14 illustrates, the cost of the limestone slurry scrubbing system varies for each of the respective CO control systems to which it is applied. First, the installed cost runs from \$2.1 to nearly \$3.7 million, mainly due to the different combustion gas flowrates associated with the various systems. (This has been discussed in detail in section 8.2.2.1.) However, some of the variability is also attributable to the condition of the plant (i.e., new or existing) in which the scrubbing system is installed. For example, the capital costs for System 3 in the new and existing plants are \$2,932,000 and \$3,678,000, respectively - a difference of nearly \$750,000.

However, the variability in the direct operating cost among the systems is solely due to the change in the inlet gas flowrate. As the table shows, this is a rather significant difference - \$300,000.

Table 8-14. MODEL PLANT SULFUR DIOXIDE CONTROL COSTS
(90,000,000 Lb/Yr Production)

Control Option	Installed Cost	Direct Operating Cost	Annualized Capital Charges	Total Annualized Cost
I. New Plant:				
System 1	$2,100,000	$646,900/yr	$306,800/yr	$954,000/yr or 1.06¢/lb
System 2	$2,416,000	$745,900"	$353,000"	$1,099,000" or 1.22"
System 3	$2,932,000	$910,200"	$461,800"	$1,372,000" or 1.52"
II. Existing Plant:				
System 1	$2,649,000	$679,800/yr	$387,000/yr	$1,067,000/yr or 1.19¢/lb
System 2	$3,041,000	$783,400"	$444,300"	$1,228,000" or 1.36"
System 3	$3,678,000	$955,000"	$537,400"	$1,492,000" or 1.66"

When the total annualized costs for the systems are divided by the annual carbon black production rate (90,000,000 lbs), the unit costs per pound are obtained. On this basis, the least expensive option is System 1 - New Plant (1.06 ¢/lb); the most expensive at 1.66 ¢/lb is System 3 - Existing Plant. (For purposes of comparison, the current average selling price of carbon black is 12 ¢/ lb.)

Finally, because it is assumed that carbon black plants are not currently regulated with respect to SO_2, the cost for meeting state SIP's would be zero. Therefore, the cost impact for achieving the EPA emission reduction (90 percent), relative to the SIP's, would be exactly equal to meeting the EPA regulation.

8.2.3 Combined Costs for Controlling Carbon Monoxide and Sulfur Dioxide

To provide cost estimates for controlling both CO and SO_2 in the model plant, the data in Tables 8-13 and 8-14 have been added, to yield the figures in Table 8-15. In so doing, the assumption has been made that the costs of the CO and SO_2 control system components are algebraically additive. That is, no cost advantages due to elimination of duplicate auxiliaries and/or other equipment have been taken into account. Because of this, the combined costs here may be somewhat higher than in an actual plant where installation of both kinds of control systems may afford certain economies.

Regarding installed costs, note that the highest are associated with System 1 - New and Existing Plants. With System 1 as well as System 2 the biggest part of these costs is attributable to the SO_2 control system. This is also the situation with System 3, where the

Table 8-15. COMBINED CARBON MONOXIDE AND SULFUR DIOXIDE CONTROL COSTS FOR MODEL PLANT
(90,000,000 Lb/Yr Production)

Control Option	Installed Cost	Direct Operating Cost	Steam Credit	Natural Gas Credit	Annualized Capital Charges	Total Annualized Cost
I. New Plant:						
System 1	$7,459,000	$1,161,700/yr	$1,086,500/yr	$365,800/yr	$1,150,900/yr	$917,000/yr or 1.02¢/lb
System 2	$7,027,000	$1,214,300"	$ 434,600"	$365,800"	$1,079,200"	$1,493,000" or 1.66"
System 3	$3,341,000	$1,143,000"	NONE	$365,800"	$ 526,200"	$1,303,000" or 1.45"
II. Existing Plant:						
System 1	$9,754,000	$1,249,300/yr	$1,086,500/yr	$365,800/yr	$1,506,000/yr	$1,434,000/yr or 1.59¢/lb
System 2	$9,151,000	$1,293,300"	$434,600"	$365,800"	$1,406,600"	$1,900,000" or 2.11"
System 3	$4,219,000	$1,190,200"	NONE	$365,800"	$622,600"	$1,447,000" or 1.61"

SO_2 control system costs are the highest (see Table 8-14). However, because the System 3 CO control option specifies the use of a relatively inexpensive incinerator (only) to combust the off-gas, the combined installed costs are the lowest of the three: $3.3 and 4.2 million.

To contrast, the direct operating cost among the systems varies from $1,161,700 to $1,293,300/yr, a difference of only 11 percent. For all options, the SO_2 control costs constitute the major portion of direct operating expenses. This fraction ranges from 55 to 80 percent.

Note further that the steam and natural gas credits for the combined costs are the same as those appearing in Table 8-13. This is because the limestone slurry process has no operating credits associated with it.

Finally, the total annualized costs show that System 1 - New Plant and System 2 - Existing Plant are, respectively, the least and most expensive control options. Their incremental annualized costs are 1.02 and 2.11 ¢/lb. This contrasts significantly with their CO control costs of (0.04 ¢/lb) and 0.75 ¢/lb, for these systems, which indicates that SO_2 is the more expensive pollutant to control in the model plant.

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9. TECHNICAL STUDIES TO DEFINE PERFORMANCE OF BEST SYSTEMS OF EMISSION REDUCTION

9.1 SELECTION OF SOURCE FOR CONTROL

Section 111 of the Clean Air Act of 1970 and 1974 extends authority to EPA to regulate emissions by developing standards of performance for new stationary sources based on the degree of emission limitation achievable through application of the best systems of emission reduction. Section 111(b), which allows EPA to limit emissions of pollutants for which air quality criteria have been prescribed, is appropriate for the furnace process carbon black industry, a major source of carbon monoxide (CO) emissions.

Emissions from furnace carbon black plants include carbon monoxide (CO), particulate, sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrocarbons (HC) and hydrogen sulfide (H_2S). The emissions of CO and hydrocarbons are significant. A typical uncontrolled plant will emit 52,300 m tons (57,600 tons) per year of CO and 1430 m tons (1580 tons) per year of HC from the process baghouse based on the emission factors shown in Chapter 7, Table 7-1.

In a study performed by The Research Corporation of New England for EPA on October 24, 1975, the furnace process carbon black industry ranked 3rd highest out of 42 in a list of all stationary CO source categories, 9th highest out of 82 in a list of all stationary HC sources, and 77th highest out of 108 in a list of all stationary particulate sources.[1]

Carbon black plants have been identified as a source that can contribute to significant deterioration of the air. It has been proposed that construction of new carbon black plant capacity can be denied unless the State determines the plant operation will not cause the quality of the air to be significantly reduced.[2]

The meteorological dispersion model presented in section 7.1.4 shows that a large (125,000 ton per year) plant could exceed the National Ambient Air Quality Standards (NAAQS) for particulate, CO, and non-methane hydrocarbons (HC). A more typical 45,000 ton per year (90 million pound per year) plant could still exceed the NAAQS for CO and HC if downwash is allowed to occur.

9.2 SELECTION OF POLLUTANTS AND AFFECTED FACILITIES

The control systems are presented in Chapter 6 for the major source of emissions in the carbon black industry. This "affected facility" is a reactor line and the equipment used to separate the product from the off-gas stream (the process baghouse). The pollutant controlled from this affected facility is CO. Controlling CO emissions also results in effective control of hydrocarbons and particulate matter. There can also be significant emissions of particulate from other facilities at a carbon black plant. These facilities include the pellet dryer, transfer and storage operations, bagging and loading operations and plant vacuum cleanup systems. These "fugitive" emissions can cause the ambient concentrations of particulate near the plant to be high.

9.2.1 Pollutants

Carbon monoxide and opacity restrictions are recommended for control in the carbon black industry. Carbon monoxide emissions are significant and technology has been developed to reduce these emissions. Even though a high degree of particulate emissions control is a matter of process economics, an opacity limit on these emissions will ensure proper maintenance of the control devices.

It has been shown (in Chapter 4) that demonstrated control technology exists which can reduce the emissions of CO from carbon black plants by over 99 percent. The combustion devices used to control the CO emissions also reduce other gaseous emissions to a similar extent. The emissions of non-methane hydrocarbons (HC) and hydrogen sulfide (H_2S) are also almost completely eliminated. Efficient combustion of the product gas will also reduce the particulate emissions by over 50 percent.

Emissions of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) from uncontrolled carbon black plants are small. The application of the best demonstrated control devices for CO increases the emissions of these pollutants. The atmospheric dispersion model (section 7.1.5) shows that these emissions will still be below the NAAQS. As the percent sulfur in the fuel and feedstock increases, however, the proposed significant deterioration increments for SO_2 may become threatened, if downwash is allowed to occur.

Data from the test at plant A indicate the emissions from a model plant would be 90 kg/hr (200 lb/hr) of SO_2 and 14 kg/hr (31 lb/hr) of NO_2. The emissions of NO_2 are too small to be concerned with at this time. The emissions of SO_2 are fairly high and there does exist technology for removal of the pollutant. The cost of removing the SO_2 from the gas stream was considered, but the cost would be from 9 to 14 percent of the selling price of carbon black. For these reasons limits on the emission of NO_2 and SO_2 are not considered.

Particulate emissions from the main product gas and from other "fugitive" emission sources will be regulated through opacity restrictions. No mass emission limits for particulate are recommended.

9.2.2 Affected Facilities

The facilities to which the emission limits will be applicable in a furnace process carbon black plant are (1) the reactor line and the associated equipment for collection of the carbon black product from the reactor line off-gas stream (main process baghouse), (2) the product pelletizer and dryer system, (3) the product transfer and storage equipment, (4) the loading and bagging operations and (5) the plant vacuum cleanup system. These are all of the emission points in a carbon black plant. The emissions from these points can be significant and demonstrated control technology exists to reduce the emissions.

As discussed in section 9.1 furnace process carbon black plants are major sources of CO emissions. Furnace process carbon black plants are the only type of carbon black plants chosen for control because they account for over 90 percent of the present industry production and because there is little or no growth predicted in the channel and thermal process, the only other processes in the carbon black industry. The process and emissions of the channel and thermal process plants are different from those at a furnace process plant, so that in order to consider all processes extensive additional study would have to be performed for little or no environmental benefit.

9.3 SELECTION OF BEST TYPE OF CONTROL DEVICE

9.3.1 Reactor Line and Main Process Baghouse

The emissions of CO from furnace process carbon black plants can be controlled to less than 200 ppm by a CO boiler, an incinerator, or a dryer combustion furnace. These devices have the same supplemental fuel requirements but differ in maintenance requirements, capital and operating costs, and other secondary environmental impacts, so that none of these devices can be described as the best. In most plants a combination of the devices will be best. Every plant will burn some of the off-gas in the pellet dryer in order to lower their natural gas requirements. Approximately 20 percent of the off-gas produced in the process can be combusted in the dryer combustion furnace. The plant must therefore decide which device(s) it will use to combust the remainder of the off-gas. A CO boiler would likely be selected if the plant can use steam drives or can find a market for exported steam. An additional 50 percent of the off-gas can be utilized for in plant steam use, so when the off-gas is combusted in the dryer combustion furnace and in the CO boiler for in plant steam use, the plant will only be able to use 70 percent of the product gas. Therefore gas in excess of what can be used in the plant or exported would have to be incinerated. The quantity that will likely be incinerated (no heat recovery) will range from 30 percent if the steam is used in plant only to 80 percent if there is no steam use. If the plant has a market for excess steam, 80 percent of the off-gas will be combusted in a CO boiler and there will be no need for an incinerator.

The costs of using these combinations of control devices are considered in Chapter 8, Economic Impact. These costs are developed using a typical 44 Btu/scf off-gas that is enriched to 50 Btu/scf to ensure stable combustion, and the off-gas distributions explained above. (System 1 - 80% used for producing steam for use in plant and for export, and 20% used in the pellet dryer combustion furnace; System 2 - 50% used for producing steam for use in plant, 30% incinerated and 20% used in the pellet dryer combustion furnace; and System 3 - 80% incinerated and 20% used in the pellet dryer combustion furnace.) The reactor off-gas distributions used in developing the costs are approximate but they help give a feeling for how the costs of control will relate to the price of the carbon black. From the cost analysis it appears as though existing plants may not retrofit CO boilers for in plant steam use (System 2) because the cost of control is 6.2 percent of the price of carbon black. (Assuming the average furnace process carbon black sells for 12 cents per pound.) The rest of the control systems cost a maximum of 3.7 percent of the average price of carbon black.

In summary, the two main factors which will affect the choice of best control systems are whether a use can be found for steam (in plant or exported) and whether the controls are being applied to a new or existing plant.

9.3.2 Pellet Dryer and "Fugitive" Emissions

Furnace process carbon black plants presently control pellet dryer purge gas emissions with high temperature baghouses similar to those used in the main process baghouse. "Fugitive" emissions are controlled by ambient temperature baghouses - that is the emissions from the product transfer and storage equipment, the bagging and loading operation, and the plant vacuum cleanup system. These controls are employed as a matter of process economics to recover product, and as a control device to comply with state particulate regulations.

9.4 SELECTION OF FORMAT

Concentration units are recommended for the CO limit for the emissions from the reactor line and main process baghouse. A concentration limit is recommended because of the ease with which it can be used for compliance testing. The off-gas will normally be split between a number of control devices, thus making a total mass flowrate and a mass emission rate difficult to determine. A process weight regulation would also be very difficult to determine because the production rate is not continuously monitored. A concentration limit is corrected to zero percent moisture so that the amount of quench water will not be a factor in measuring the emissions. It is recommended that the limit not be corrected to any certain percent oxygen because it is unlikely that there will be dilution of the reactor off-gas. With the typically low heat content of the reactor off-gas, combustion would be adversely effected if an operator attempted to add excess air. Therefore it is in the best interest of the operator to add no more air than is necessary for complete combustion, and thus an oxygen correction is unnecessary.

9.7 MODIFICATION/RECONSTRUCTION CONSIDERATIONS

"Existing facilities" [those sources existing before a new source performance standard (NSPS) is proposed] may become subject to standards of performance if they are modified in a way that will result in an increase in mass emissions or if they are reconstructed irrespective of any change in emission rate. The modification/reconstruction regulations are discussed in Chapter 5. An important consideration in determining the extent to which existing facilities must comply with the emission limit is the definition of the affected facility to which the standard of performance is applicable. Normally the intent is to define the affected facility in such a way that the following objectives will be met:

1. To accurately define the affected facility so that application of the modification/reconstruction provisions will be straightforward.
2. To ensure that no significant detrimental effects (i.e. cost or energy) will result from the NSPS when there is little environmental benefit to be derived.
3. To ensure that existing facilities that are modified in a way that would result in a significant increase in emissions would be required to comply with the NSPS.

4. To prevent the operator from circumventing the NSPS by gradually replacing (reconstructing) existing facilities.

In the case of the proposed CO emission limit for furnace process carbon black plants, the affected facility is defined to be reactor line and process baghouse, as opposed to a single reactor or the whole plant. This choice is the most consistent with the intent of the modification/reconstruction regulations.

In a furnace process carbon black plant the reactor line and process baghouse act as a single unit. All of the reactors in a line produce the same grade of black, the off-gases are ducted together and the black is removed from the off-gas stream in a single baghouse. The off-gas from each reactor is indistinguishable and the off-gas from one reactor line is in no way related to the off-gas from any other line in the same plant. Therefore the choice of the reactor line and process baghouse as the affected facility appears to be the most straightforward one.

There are changes that can take place in a carbon black plant that are a result of the energy situation. Existing plants may have to convert to different feedstocks due to availability problems. They may also have to convert from natural gas to fuel oil firing due to the shortage of natural gas. Existing plants are also increasing the use of heat transfer from the reactor off-gas to the feedstock, fuel, and combustion air. None of these changes will significantly increase emissions so it is recommended that none of these be considered modifications.

Based on discussions with the industry, a substantial portion of the growth in the furnace process carbon black production capacity over the next few years will occur as a result of enlarging the piece of equipment in the facility that is limiting the production of the line (debottlenecking). Such modifications can occur on the baghouse, dryer or pelletizer. It is reported that many plants can increase their capacity by 10 to 30 percent in this manner. Such changes will result in a corresponding increase in emissions. In choosing the reactor line as the affected facility these plants will probably either have to control the increase in emissions or they will have to comply with the NSPS. This is consistent with the intention of the modification/reconstruction regulation in that modifications that could significantly increase emissions are addressed.

Installation of a CO combustion device or rerouting off-gas to an existing dryer will result in a decrease in the emissions of CO. For this reason existing facilities that retrofit combustion of off-gas would not be subject to the NSPS for this modification.

Based on discussions with industry, it appears doubtful that any facilities will be reconstructed. If a facility is nearing the end of its useful life, the facility would be shut down and replaced by a similar facility. This facility would be a new source and thus subject to the NSPS.

9.8 SELECTION OF MONITORING REQUIREMENTS

Under § 114(a) of the Clean Air Act as amended in 1974, the EPA has the authority to require the owner or operator of any emission source to install, use, and maintain such monitoring equipment as reasonably required. The present recommendation is that no continuous CO or opacity monitors need to be installed. Application of continuous monitors would not significantly reduce the CO emissions from a furnace process carbon black plant. In order to combust the lean reactor off-gas the plant must employ good combustion techniques. If a facility demonstrates compliance with the emission limit shortly after startup it should continue to meet the limit because good combustion techniques are required to keep the control device in operation. Another reason for not requiring continuous CO monitors and the reason for not requiring continuous opacity monitors is the fact that there are many emissions points. Only if every emission point is monitored will there be assurance that all emissions are within acceptable limits, and this does not seem reasonable and it would probably not result in a significant decrease in emissions.

9.9 SELECTION OF PERFORMANCE TEST METHODS

The reference test method selected for determining compliance with the proposed emission limit for carbon monoxide (CO) is EPA Method 10. This method was used in the second test at plant A. The other CO testing was done at plant C. The test method used at this plant is similar to, but not as accurate as EPA Method 10. For this reason EPA Method 10 is recommended for CO compliance testing.

The reference test method selected for determining compliance with the proposed visible emission limit is EPA Method 9. The visible emission testing conducted at plants D, E, and F was done in accordance with EPA Method 9. Visible emissions testing was performed during the first test at plant A but it was not done in accordance with Method 9, as most of the readings were taken at 30 second intervals instead of 15 second intervals. Since all of the plant A readings were consistently low it appears that deviation from standard methods would not detract from the results. Instead of six minute averages, the plant A data is expressed as 24 reading averages to be consistent with the intent of the averaging. In all future visible emission testing, however, it is recommended that EPA Method 9 be used exclusively.

REFERENCES

1. "Impact of New Source Performance Standards on 1985 National Emissions from Stationary Sources," prepared for the U. S. Environmental Protection Agency by The Research Corporation of New England, Contract 68-02-1382, Task No. 3, October 24, 1975.
2. "Prevention of Significant Air Quality Deterioration," Federal Register 39 FR 42510 (December 5, 1974).

APPENDIX A

HISTORY OF EVENTS LEADING TO SELECTION OF BEST SYSTEM OF EMISSION REDUCTION

Date	Activity
April 1973	Tests conducted at the Phillips Petroleum Co. plant in Toledo, Ohio, by TRW, Inc. as part of petrochemical industries study. The tests were conducted at the inlet and outlet of the CO boiler and resulted in EPA Air Pollution Emission Report No. 73-CBK-1.
June 1973-June 1974	Background data on carbon black industry gathered by Houdry Co. This study resulted in Report No. EPA-450/3-73-006a.
June 1974	Contract 68-02-1321, Task No. 9, initiated with PEDCo-Environmental Specialists, Inc. to provide background information for determining best emission reduction systems for furnace carbon black plants.
June 30, 1974	Summary of draft summary report on location of carbon black plants and best controlled plants submitted to EPA by PEDCo.
July-August, 1974	PEDCo updates emission data obtained from carbon black manufacturers originally contained in the Houdry report and arranges for visits to best controlled plants.
Aug. 7, 1974	PEDCo and EPA project officer visit Cabot Corp. plant in Waverly, W. Va. to observe and discuss operation for flares and related control problems.
Aug. 8, 1974	PEDCo and EPA project officer visit Phillips Petroleum Co. plant in Toledo, Ohio to observe and discuss operation of CO boilers and incinerator.
Aug. 15, 1974	Final summary report issued to EPA (See June 30, 1974).
Aug. 21, 1974	PEDCo staff visits Cabot Corp. plant in Sarnia, Canada to observe and discuss operation of CO boiler and incinerator.

Date	Activity
Sept. 20, 1974	Draft of Chapter 3 of the Background Information document submitted to EPA for review.
Sept. 1974	Plans initiated for source testing at Cabot Corp. plant in Waverly, W. Va. Information from equipment vendors is obtained on control equipment.
Sept. 23, 1974	PEDCo visits corporate office of Continental Carbon Co. in Houston, Texas. Information was obtained on off-gas heat value and some of the problems involved in measuring and controlling off-gases.
Sept. 24, 1974	PEDCo visits J. M. Huber Corp. Baytown, Texas. General information on process operation in pollution control systems was obtained.
October 1974	Work proceeded on drafting various chapters of this report document and contacts were made with a number of European plants to obtain information on their emissions and control systems. Little quantitative data was obtained from these plants by telephone. Chapters 1 and 2 submitted to EPA.
Dec. 9-13, 1974	Emission tests conducted at Cabot Corp. plant in Waverly, W. Va. by Battelle Columbus Laboratories. Tests were conducted before the flare system for polycyclic organic matter, H_2S, SO_2, CO and selected hydrocarbons.
Dec. 4, 1974	Revised format for preparation of emission of standard support documents received from EPA and revised schedule prepared.
Dec. 6, 1974	Presurvey conducted at Cabot Corporation plant in Sarnia, Canada by Clayton and Associates personnel. Chapters 9 and 10 submitted to EPA in December.
Jan 14-16, 1975	Emission tests conducted at Cabot Corp. plant in Sarnia, Canada by Clayton Associates and Battelle Columbus Laboratory personnel. Particulate emissions were measured after a CO boiler, and gaseous emissions were measured before and after the boiler.
Jan 17, 1975	Review meeting held with EPA to discuss progress todate and present status of the SSEIS document. Discussion centered around selection of pollutants, selection of facilities, the best systems of control and the actual emission limits. Emphasis on the need for both economic data and dispersion modeling was presented by PEDCo.
Jan. 27, 1975	Draft of Chapter 8 was submitted to EPA. Information on model plants and emissions was presented to EPA by PEDCo for use in their dispersion modeling work.

Date	Activity
Feb. 10, 1974	Revised scope of work received from EPA. This revision incorporates those changes required by the revised format and the environmental impact sections for these documents.
Feb. 20, 1975	Chapters 6 and 10.1.2 submitted to EPA. Draft report on Waverly, W. Va. tests conducted by Battelle received by PEDCo.
February 1975	Revised drafts of Chapters 3, 4, and 5 in line with new format submitted to EPA.
March 1975	Contacts made with carbon black manufacturers to arrange for visible emissions observations by EPA personnel.
March 17, 1975	Emission test report at the Cabot Corp. plant in Sarnia, Canada was received. Data summary and insertion of data into Chapter 3 started.
April 8, 9, 10, 1975	Visible opacity observations made by EPA personnel at the Ashland, Cabot and Continental plants in the Pampa, Texas area. PEDCo obtained process operating data during these observations.
May 9, 1975	Visible opacity data received from EPA for the tests conducted in early April. Also on this date, PEDCo received the final report on the source tests at the Cabot, Waverly, W. Va. plant and the Sarnia, Canada plants.
May 1975	Rough draft of the modeling analysis of the ambient air impact of carbon black plants received from EPA. This section had been prepared by Walden Research Div. of Abcor, Inc.
June 1975	Environmental impact analysis completed and remaining sections of the report assigned to PEDCo were completed.
July 1975	Project Officer's comments were incorporated in revised drafts, and complete draft report submitted to EPA. Economic data still not available. L. Evans replaced J. Dale as Project Officer.
Aug. 1975	K. C. Hustvedt to work with Project Officer L. Evans.
Nov.-Dec. 1975	EPA comments on completed report will be incorporated. Major revisions on form of standard, and for the analysis of energy recovery were made.
Nov. 1975	EPA Project Officers visit Phillips Petroleum Co. plant in Toledo, Ohio to discuss improvements in off-gas combustion.

Date	Activity
Dec. 1975	EPA tests Phillips Petroleum Co., Toledo, Ohio plant for CO emissions after the CO boiler and the pellet dryer combustion furnace.
January 1976	Final report submitted by PEDCo.
March 1976	K. C. Hustvedt replaced L. Evans as Project Officer.

Plant C in Canada

APPENDIX C. EMISSION SOURCE TEST DATA

INTRODUCTION

Three plants utilizing off-gas combustion systems were tested to obtain emission data. These plants were the only ones in North America with off-gas combustion systems during the time when the testing was performed. A summary of the carbon monoxide (CO) emission data obtained at two of these plants is shown in Table C-1. Three additional plants which utilized fabric filter control systems were selected for visible emission testing. A summary of the six minute averages of these visible emission readings is shown in Table C-2.

C.1 PARTICULATE AND GASEOUS EMISSION TESTS

C.1.1 Plant A - Test 1

Testing was conducted on the No. 1 off-gas boiler during the period April 9-12, 1973, by TRW Environmental personnel. The No. 1 boiler is one of five units that combust the off-gas from two carbon black production lines at plant A (2 CO boilers, 2 dryers and 1 incinerator). During testing, the boiler was operated such that a maximum amount of off-gas from Line 2 and a minimum amount of auxiliary natural gas were used.

Samples were collected simultaneously before and after the boiler to determine filterable and total particulates, sulfur dioxide, hydrogen sulfide, nitrogen oxides, carbon monoxide, and total non-methane hydrocarbons.

Plant Description and Operation -

Plant A has two independent process lines. The heat content of the off-gas is utilized when off-gases are combusted in the two parallel CO boilers and two indirect-heated product dryers. If the total heat available in the off-gas stream were used for these purposes, more steam would be generated than could be used in the plant. The excess off-gas is therefore combusted in an incinerator and no unburned gases are vented except in an emergency.

The equipment tested was the No. 1 CO boiler. The boiler was a standard Babcock and Wilcox small-tube, twin drum, water-tube boiler with a water-cooled combustion chamber. The boiler is designed to produce 45,000 lb/hr of 400 psig, 650°F steam. An auxiliary support fuel (natural gas) must be burned with the off-gas to prevent flame-outs. The boiler is normally operated with about 20 percent of the total heating value of the mixed fuel from natural gas. During testing 16 percent of the total heating value was from natural gas.

During testing, the off-gas from Line 2 was burned in the two boilers and the off-gas from Line 1 was burned in the process dryers and the incinerator. Boiler No. 1 was operated with minimum natural gas and maximum off-gas. The remainder of the Line 2 off-gas was burned in Boiler No. 2. Boiler No. 1 was producing 72 percent of its rated steam capacity during testing.

Line 2 was producing carbon black Grade N330 (a tire grade black with average 53 Btu/scf) during the test. The production rate during the test was measured by collecting the material produced each day in a separate storage bin. At the end of a timed collection period the collected black was bagged and weighed.

The proportional product rate to Boiler No. 1 was calculated by multiplying the total product rate from Line 2 by the ratio of off-gas to Boiler No. 1 to total off-gas from Line 2. As can be seen from Table C-3, the average product rate that can be associated with the off-gas to Boiler No. 1 is 2640 lb/hr.

The age of the bags in each of the eight compartments at the time of testing was:

2 compartments at 2 months

3 sets of 1 compartment each at 3,5, and 15 months, respectively

3 compartments at 4 months

Test Results -

Table C-3 summarizes the emission data collected at the first test of this plant.

Particulate - Total filterable particulate (Reference Method 5; probe, cyclone and filter catch) averaged 0.1363 grains per dry standard cubic foot (gr/dscf) or 0.00327 pounds per pound of product. Outlet concentration from the CO boilers was 0.0189 gr/dscf. Total particulate removal (combustion) efficiency on a pounds per hour basis was greater than 70%. The CO boiler inlet particulate data indicated a fabric filter collection efficiency of 99.44 percent. Total catch in the sampling train was approximately 70% greater than the filterable catch values presented.

Testing for particulate matter was conducted under extremely difficult conditions, especially at the inlet location, but the conditions were not felt to have significantly affected the results.

Hydrogen Sulfide - The average emission rate for H_2S was 520 ppm (20.9 lb/hr) at the inlet testing location. No results were obtained for the testing at the boiler outlet because all samples that were collected exhibited irregular behavior during collection and analysis. During outlet sample collection, the reagent used in the impingers was expended, while none of the characteristic yellow precipitate was formed. During analysis, an excessive amount of iodine was required to react with the collected sample. Because of these difficulties the H_2S concentration at the boiler outlet could not be determined. One test was attempted with an isopropanol prescrubber, but the same results occurred.

Sulfur Dioxide - The average emission value for SO_2 was 326 ppm or 46.4 lb/hr at the outlet location. No sulfur dioxide was detected at the inlet since the concentration was below the minimum detectable limit of 45 ppm.

Nitrogen Oxides - The average emission rate at the inlet was 10 ppm or 0.57 lb/hr, and at the outlet the values were 72 ppm or 7.4 lb/hr.

Hydrocarbons - The average emission rate at the CO-boiler inlet was 10,000 ppm or 185.7 lb/hr total hydrocarbons. The outlet hydrocarbon emissions were 72 ppm or 2.6 lb/hr; the non-methane hydrocarbons were 34.2 ppm or 1.23 lb/hr. These analyses were completed utilizing a gas chromatograph.

Particle Sizing - The summary results for particle sizing show a low mass median diameter of 0.09 microns to a high of 0.86.

Visible Emission Results - Visible emissions observations were made on a stack which exhausted two identical boilers, therefore, the readings are on the combined plume of the two boilers. The maximum 24 reading average opacity observed was 2.5 percent. The averages are shown in Tables C-4 to C-6. Although these are not six minute averages they still show that there is a low level of visible emissions from the CO boiler.

Carbon Monoxide - Measurement of carbon monoxide at the boiler outlet by nondispersive infrared technique was attempted, but levels appeared to be in excess of the limit of the instrument (500 ppm). The readings were less than the minimum detectable on the Orsat (2000 ppm). Quantitative outlet data were thus not obtained.

The inlet data showed CO concentrations in the range of 5.3 to 13.4 percent (0.85 to 1.5 lb/lb of product) when analyzed by Orsat. Gas chromatographic analysis during Run 1 yielded a value of 13 percent.

C.1.2 Plant A - Test 2

Plant A was tested for a second time on December 10, 1975. Many changes were made at plant A since the first test in order to improve the fuel efficiency of the plant. Two of the changes are greater use of the heat content of the reactor off-gas to preheat the reactor feed and a higher off-gas temperature at the baghouse inlet, both of which decrease the amount of water needed in the secondary quench. The decrease in amount of water quenching and the increase in the gas temperature to the baghouse both increase the net Btu content of the off-gas. The plant has also developed better methods of off-gas combustion so that they can combust the off-gas with less supplemental natural gas.

The facilities tested were the CO boiler number 1 and the dryer combustion furnace number 1. Line number 1 was producing 4890 lb/hr of N-375 grade carbon black during the test period. Plant personnel reported this grade black to have a net heat content of 52.5 BTU/scf. The CO boiler was operated with no supplemental fuel during the test, but the dryer combustion furnace had 39 percent of its total BTU content from natural gas. The natural gas was added to the pellet dryer combustion furnace because there was not enough off-gas available to operate both units without supplemental natural gas. The plant operated normally throughout the testing.

The results shown in Table C-7 show both the CO boiler and the dryer combustion furnace removed essentially all of the carbon monoxide from the gas stream. Since there was no supplemental fuel added to the CO boiler, its average CO level of 124 ppm is probably more representative of the performance of a typical off-gas combustion device.

C.1.3 Plant B

During the period December 9-13, 1974, field sampling was conducted at plant B by Battelle Columbus Laboratories (BCL) personnel. This plant utilizes flares to burn off-gases. Battelle Columbus Laboratories measured gas compositions in the stack 10 feet below the flares for polycyclic organic matter (POM), H_2S, SO_2, CO, and selected hydrocarbons. In addition, BCL measured CO_2, O_2 and moisture content of the gas and visible emissions. These measurements were obtained in order to determine the uncontrolled emissions from the plant. Concurrent with the BCL measurements, EPA used an infrared telespectrometer system to attempt to obtain emission spectra of flare species over the spectral range of 2 to 14 microns from a remote location.

Plant Description and Operation -

Plant B has 3 process units which produce carbon black from residuum tar. Each process train is equipped with a separate baghouse for collecting the carbon black product and an atmospheric flare for combustion of off-gases. The plant has a vertically oriented design with the reactor effluent going to the baghouses at the top of the structure and the carbon black passing to successively lower levels for each processing step. A portion of the flue gas (about 13 to 15%) from one train is used as auxiliary fuel for the direct-fired dryer ovens.

During the field-sampling period process operations at plant B were maintained at normal operating levels on Units 2 and 3, while Unit 1 was out of service. No major upset or change in operating conditions were encountered during the sampling periods. During the last day of sampling the flares on Unit 2 were turned off and could not be reignited because of high winds. This should have no significant effect on the samples collected before the flares.

Remote Sensing Tests - A remote optical sensing of emissions (ROSE) system was employed to measure CO after the flare at this plant. These tests were made with the flare on and then off to determine differences in CO concentrations at the point of observation which was just above the flare exit. The CO concentration before the flare was measured to be 13 percent. The ROSE measurements showed a concentration of 5 percent CO by volume with the flare off, and 0.1 percent (1000 ppm) with the flare in operation. The CO concentration with the flare off has a lower value than that within the stack due mixing with ambient air as the off-gas leaves the stack. These numbers are reported to be accurate at least within a factor of 2. Some acetylene was also detected when the flare was off.

C.1.4 Plant C

An emission test program was conducted during January 14-16, 1975, at plant C to determine particulate and gaseous concentrations before and after a CO boiler.

A direct-fired incinerator was also located at this plant but adverse sampling conditions at the outlet of this device made it not amenable to emission testing.

Process Description and Operation -

The No. 1 CO boiler was built with the original plant (in 1953) at a design capacity of 30,000 lb/hr of 250 psig steam. The No. 2 boiler was installed about 1960 with a design capacity of 60,000 lb/hr of steam. Finally, a thermal oxidizer installed in 1972 has no heat recovery capacity. The feedstock is residuum tar.

Separation of carbon black from furnace gases is accomplished by fabric filter systems. Each of the process lines has its own baghouse. Three process lines use a Wheelabrator reverse-air system with fiber glass bags; three use

Test Results -

Table C-8 summarizes the emission data obtained during this test series. Tests 1 and 2 were conducted on Unit 3 which produced product grade N351 (~ 44 Btu/sc
Test 4 was conducted on Unit 2 which produced grade N375.

Polynuclear Organic Hydrocarbons -

A sample collected especially for polynuclear organic matter (POM) yielded an emission rate of 6.6 x 10^{-4} lb/hr or 1.8 x 10^{-4} lb/ton of product while making product grade N351. Of the total POM, 5.2 x 10^{-6} lb/ton of product or 1.9 x 10^{-6} lb/hr was made up of benzo(a)pyrene.

Carbon Monoxide -

CO emissions were fairly consistent from day to day and averaged 13.3 percent by Orsat analysis. Analysis by gas chromatograph showed slightly lower values in the range of 10.4 to 11.8 percent. The GC samples were, however, taken over very short time increments (5 minutes), and the Orsat samples were taken over longer (1 to 2 hours) time periods. The Orsat data yielded an average emission rate of 1.007 lb/lb of product.

Hydrocarbons - Total gaseous hydrocarbons ranged from 1.7 to 1.9 percent of the off-gas volume with methane accounting for about 25 to 30 percent of the total and acetylene the bulk of the remainder. The total hydrocarbon emission rate averaged 0.11 lbs/lb of product.

Hydrogen Sulfide and Sulfur Dioxide - H_2S was measured by both EPA Method 11 and a gas chromatograph. Method 11 generally yielded higher results, but sampling times were not equivalent. Average H_2S emissions were 0.06 lbs/lb of product.

Sulfur Dioxide emissions were in the range of 1 to 10 lbs/hr (0.00014 to 0.0014 lb/lb of product). The feed contained 2.2 percent sulfur (0.044 lb S per lb of product at 50 percent yield).

Particulate - Only CO boiler outlet particulate data were obtained even though efforts were made to also obtain inlet data but adverse side conditions prevented collection of usable data.

Total filterable particulate (Reference Method 5; probe, cyclone, and filter catch) after the CO boiler averaged 0.030 grains per dry standard cubic foot (gr/dscf). The impinger catch adds approximately 50% more material to the total particulate emission levels.

Carbon Monoxide - Inlet CO concentrations were 12.3-12.4 percent. Limited inlet flow data prevented calculation of the emission rates except during Test 2 when 15,800 lb/hr entered the two CO boilers (2900 lb/ton or 1.45 lb/lb of product). Outlet concentrations averaged 45 ppm (7.2 lb/hr of 1.75 lb/ton).

Hydrocarbons - Limited data at the CO boiler inlet showed a concentration of 1.1 to 1.2 percent of total gaseous hydrocarbons. Outlet data were not obtained.

Hydrogen Sulfide - H_2S concentrations were reduced by 98 to 99 percent by passage through the CO boiler. Outlet emissions ranged from 0.008 to 2.2 lb/hr (0.003 to 0.49 lb/ton of product).

Visible Emissions - Opacity readings were attempted but no results were obtained. Due to the high moisture content of the off-gas stream and the cold atmospheric temperatures, there was a large steam plume in which no carbon black could be detected.

C.2 OPACITY READING SUMMARIES

In addition to the emission tests, visible emission readings were made using EPA Method 9 at three plants by two EPA observers from the Emission Measurement Branch during the period April 9-11, 1975. All of the readings were done over a one hour period. Results of these observations are summarized in Table C-2 and

Micropulsair bag filters with Nomex bags and reverse-jet steam cleaning. The Micropulsair bag filters can run with a high air-to-cloth ratio at about 375°F and the Wheelabrator runs at about a 1- to 1.5-to-1 ratio.

Off-gas from one process line was vented to the atmosphere because of its low Btu value during the test periods. Three process lines were introducing off-gas into the header. This gas was consumed as fuel by both Boilers 1 and 2 and the dryers. The need for the thermal oxidizer was eliminated by the venting of the low Btu off-gas.

The plant operations were in good working order. All process lines maintained steady-state conditions while feeding off-gas to the header. When any operational problem occurred, that process line's off-gas was removed from the header and vented. For this reason, no tests were performed during upset conditions.

Two process lines had new fiber glass bags installed on July 10, 1974, and August 12, 1974, respectively. Another had new Nomex bags installed on November 27, 1974. All process lines were representative of a well-controlled carbon black process. The average production of carbon black was calculated by plant personnel based on feed data. The carbon black production during testing was about 5500 lb/hr from one process line, 2100 lb/hr from another line and 3400 lb/hr from a third process line.

Boiler No. 2 was operated at 50,000 pounds of steam per hour at a pressure of 260 psig during all tests (over 80 percent of capacity). The second test on Boiler No. 2 was performed during the combustion of off-gas only. Natural gas provided 20 to 25 percent of the heat input in Tests 1 and 3.

Test Results -

Table C-9 summarizes the data collected during the test series. Emission data have been prorated to represent total plant emissions since there were 2 CO boilers.

TABLE C-1. SUMMARY - CO DATA

	Combustion Device	Off-Gas BTU Content	% of BTU From Natural Gas	Average Inlet CO Concentration (%)	Average Outlet CO Concentration (ppm)
Plant A (test 1) 4-73	CO Boiler	66	16	11.2	N.D.
		51	17	6.5	N.D.
		49	16	13.4	N.D.
		49	16	13.4	N.D.
Plant A (test 2) 12-75	CO Boiler	52	0	~13	124
	Dryer Combustion Furnace	52	39	~13	<10
Plant C 1-75	CO Boiler	59*	20*	12.4	28
		54*	0	12.3	62
		48*	20*	12.3	106

*Approximate

N.D. - Not determined

the complete results are shown in Tables C-10 through C-23. The results show that the maximum 6 minute average opacity is 11.5 for ink black and 5.0 for the rest of the blacks.

TABLE C-2. OPACITY SUMMARY - 6 MINUTE AVERAGES

	Type of Baghouse	Product Size (mμ)	No. of Averages	% Zero Averages	Max. 6 Minute Ave.
Plant D					
Unit # 2	High Temp.	78	20	0	5.0
Unit # 3 South end	High Temp.	62	20	95	0.2
Unit # 3 North end	High Temp.	62	20	50	1.7
Plant E					
Unit # 2 Main Process Filter	High Temp.	29	20	20	4.4
Unit # 2 Process Filter	Ambient Temp.	29	20	100	0
Unit # 2 Drum Dryer	High Temp.	29	20	100	0
Unit # 3 Main Process Filter	High Temp.	29*	20	0	10.2
Unit # 3 Process Filter	Ambient Temp.	29*	20	100	0
Unit # 3 Dryer Purge Filter	High Temp.	29*	20	0	11.5
Plant F					
Unit # 1 Process Filter	High Temp.	80	20	100	0
Unit # 1 Drum Exhaust Filter	High Temp.	80	20	100	0
Unit # 2 Process Filter	High Temp.	80	20	100	0
Unit # 2 Drum Exhaust Filter	High Temp.	80	20	100	0
Clean Up Filter	Ambient Temp.	80	20	100	0

* Ink Black

TABLE C-3. EMISSION DATA SUMMARY FOR CO BOILER NO. 1 AT
PLANT A - TEST 1

Test No.(date)	1 (4-10-73)			2 (4-11-73)			3 (4-12-73)			4 (4-12-73)		
Production rate, lb/hr	2420			2620			2780			2750		
Emissions	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton
Particulate[a]												
Inlet												
Filterable		No data		0.104	7.1	5.4	0.0678	4.2	3.2	0.237	15.1	11.0
Total				0.200	13.7	10.4	0.165	10.2	7.5	0.342	21.8	15.8
Outlet												
Filterable	0.015	1.9	1.57	0.0186	2.2	1.68		No data		0.023	3.1	2.26
Total	0.032	4.0	3.3	0.0287	3.4	2.60				0.0375	5.0	3.64
CO												
Inlet	11.2%	-	-	5.3,7.7%	2271	1734	13.4%	4,220	3,036		No data	
Outlet	N.D.	-	-				N.D.	-	-			
HC												
Inlet		No data		1.0%	199	152	1.0%	179	129		No data	
Outlet	125 ppm	4.5	3.7	45 ppm	1.5	1.1	50 ppm	1.8	1.3			
							70 ppm	2.5	1.8			
H_2S												
Inlet	754 ppm	30.0	25	362 ppm	15	11.5	334 ppm	13	9.3		No data	
				546 ppm	23	17.6	800 ppm	30	22			
SO_2												
Outlet	356 ppm	52.2	43	284 ppm	39	30	290 ppm	45	30		No data	
				344 ppm	47	36	356 ppm	52	37			
NO_x												
Inlet	6.7 ppm	0.36	0.3	9.2 ppm	0.53	0.4	10.0 ppm	0.52	0.37		No data	
				13.5	0.77	0.59	12.6 ppm	0.65	0.47			
Outlet	75 ppm	7.9	6.5	73 ppm	7.2	5.5	63 ppm	6.6	4.7			
				75 ppm	7.3	5.6	75 ppm	7.8	5.6			

[a] Particulate concentration in grains/dscf.
N.D. - not determined

TABLE C-4

FACILITY A

Summary of Visible Emissions

Date: 4-10-73

Type of Plant: Carbon Black CO Boiler

Type of Discharge: Stack (two boilers)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 80'

Height of Observation Point:

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Clear

Wind Direction: SE

Wind Velocity: 20 MPH

Color of Plume:

Detached Plume:

Duration of Observation: One observation per 5 minutes for 1:25 hours

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1525	1650	30	1.9

TABLE C-5

FACILITY A

Summary of Visible Emissions

Date: 4-11-73

Type of Plant: Carbon Black CO Boiler

Type of Discharge: Stack (two boilers)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 200-300'

Height of Observation Point:

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: South

Wind Velocity: fast

Color of Plume:

Detached Plume:

Duration of Observation: One reading every 30 seconds for 1/2 hour

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1430	1442	20	0.8
2	1442	1454	15	0.6
3	1454	1500	0	0

TABLE C-6

FACILITY A

Summary of Visible Emissions

Date: 4-12-73

Type of Plant: Carbon Black CO Boiler

Type of Discharge: Stack (two boilers)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 200-300'

Height of Observation Point:

Direction of Observer from Discharge Point:

Description of Background: Sky

Description of Sky: Overcast

Wind Direction: West

Wind Velocity: 10 MPH

Color of Plume:

Detached Plume:

Duration of Observation: One reading every thirty seconds for 1/2 hour

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1	1600	1612	60	2.5
2	1612	1624	25	1.0
3	1624	1630	15	1.2

TABLE C-7. EMISSION DATA SUMMARY FOR PLANT A TEST 2

Facility	CO Boiler No. 1				Dryer Combustion Incinerator Furnace No. 1			
Run No.	B-1	B-2	B-3	Avg.	D-1	D-2	D-3	Avg.
Date	12/10	12/10	12/10		12/10	12/10	12/10	
ppm CO	128	123	120	124	N.D.	N.D.	N.D.	<10 ppm
% CO_2 by NDIR	12.0	12.0	11.4		11.7	10.0	8.1	
% CO_2 by gas chromatog.	11.1	11.4	10.7		10.6	11.5	9.8	
% O_2 by GC	5.4	5.2	10.5		7.3	8.1	10.1	

N.D. = <10 ppm

TABLE C-8. EMISSION DATA SUMMARY FOR PLANT B
(UNCONTROLLED EMISSIONS BEFORE A FLARE)

Test No. (date)	1 (12-10-74)			2 (12-11-74)			4 (12-12-74)		
Production rate, lb/hr & grade	7250 N351			7250 N351			7385 N375		
Emissions	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton
POM[a]		0.00066	0.00018						
CO	(11.8 GC)[c]	5934	1637	13.3% (10.4-11.5 GC)	5380-6879	1484-1898	13.3% (11.7 GC)	6806-7737	1876-2133
HC (total)[b]	~1.8%	766	211	1.9%	806	222	1.7%	850	234
H_2S	700[c] ppm	40.1 (42.7 GC)[c]	11.8	800[c] ppm	84.5 (50.4 GC)	13.9	~600[c] ppm	83.8 (40.1 GC)	11.1

[a] Polynuclear organic matter.

[b] About 70% present as acetylene.

[c] Gas chromatographic data.

TABLE C-9. EMISSION DATA SUMMARY FOR PLANT C-CO BOILER

Test No.	1 1-14-75			2 1-15-75			3 1-16-75		
Production rate, lb/hr	8900			11,000			5500		
Emissions	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton	Conc.	lb/hr	lb/ton
Particulate[a]									
Filterable	0.029	8.0	1.8	0.028	10.0	1.82	0.032	9.2	3.34
Total	0.045	12.0	2.7	0.048	16.8	3.06	0.042	12.4	4.56
CO									
Inlet	12.4%	No data		12.3%	15,800	2900	No data		
Outlet	28 ppm	3.8	0.86	62 ppm	11	2.0	45	6.7	2.4
HC									
Inlet	1.2%	No data		1.1%	1036	188		No data	
Outlet		No data			No data			No data	
H_2S									
Inlet	719 ppm 629 ppm	No data		592 ppm 668 ppm	92 104	16.7 18.9	799 ppm 1011 ppm	No data	
Outlet	8.7 ppm 13.5 ppm	1.4 2.2	0.31 0.49	1.6 ppm	0.34	0.06	0.04 ppm	0.008	0.003

[a] After CO boiler; concentration expressed in grains/dscf.

For tests 1 and 3, 20 to 25 percent of the heat content was from natural gas.

For test 2 no natural gas used.

TABLE C-10

FACILITY D

Summary of Visible Emissions

Date: April 8, 1975

Type of Plant: Carbon Black, Unit # 2 Main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 89'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Blue Sky

Description of Sky: Clear

Wind Direction: WSW

Wind Velocity: ~15 MPH

Color of Plume: White (steam)

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	11:30	11:36	120	5.0	90	3.8
2	11:36	11:42	95	4.0	95	4.0
3	11:42	11:48	80	3.3	95	4.0
4	11:48	11:54	100	4.2	80	3.3
5	11:54	12:00	70	2.9	50	2.1
6	12:00	12:06	15	0.6	80	3.3
7	12:06	12:12	80	3.3	95	4.0
8	12:12	12:18	40	1.7	95	4.0
9	12:18	12:24	30	1.3	35	1.5
10	12:24	12:30	45	1.9	80	3.3

TABLE C-11

FACILITY D

Summary of Visible Emissions

Date: April 8, 1975

Type of Plant: Carbon Black, Unit # 3 South end, main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 79'

Distance from Observer to Discharge Point: 700'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: SE

Description of Background: Hazy Blue sky

Description of Sky: Partly cloudy

Wind Direction: SW

Wind Velocity: 15 MPH

Color of Plume: Black

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	2:00	2:06	0	0.0	0	0.0
2	2:06	2:12	0	0.0	5	0.2
3-10	2:12	3:00	0	0.0	0	0.0

TABLE C-12

FACILITY D

Summary of Visible Emissions

Date: April 8, 1975

Type of Plant: Carbon Black, Unit # 3 North end, main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 70'

Distance from Observer to Discharge Point: 700'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: SE

Description of Background: Blue haze

Description of Sky: Partly cloudy

Wind Direction: SW

Wind Velocity: 15 MPH

Color of Plume: Black

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	12:45	12:51	0	0.0	20	0.8
2	12:51	12:57	40	1.7	35	1.5
3	12:57	1:03	5	0.2	25	1.0
4	1:03	1:09	0	0.0	0	0.0
5	1:09	1:15	0	0.0	0	0.0
6	1:15	1:21	5	0.2	0	0.0
7	1:21	1:27	0	0.0	15	0.6
8	1:27	1:33	0	0.0	5	0.2
9	1:33	1:39	0	0.0	5	0.2
10	1:39	1:45	0	0.0	5	0.2

TABLE C-13

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon black, # 2 Main Process Baghouse

Type of Discharge: Stack

Height of Point of Discharge: 83'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0

Direction of Observer from Discharge Point: NW

Description of Background: Blue Sky

Description of Sky: Clear

Wind Direction: SW

Wind Velocity: 15 MPH

Color of Plume: Black

Detached Plume: NO

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No.1		Observer No.2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	12:00	12:06	0	0.0	0	0.0
2	12:06	12:12	0	0.0	0	0.0
3	12:12	12:18	25	1.0	30	1.3
4	12:18	12:24	60	2.9	40	1.7
5	12:24	12:30	105	4.4	25	1.0
6	12:30	12:36	75	3.1	10	0.4
7	12:36	12:42	85	3.5	5	0.2
8	12:42	12:48	95	4.0	10	0.4
9	12:48	12:54	65	2.7	20	0.8
10	12:54	1:00	10	0.4	5	0.2

TABLE C-14

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon Black # 2 product transfer baghouse

Type of Discharge: Stack

Height of Point of Discharge: 65'

Distance from Observer to Discharge Point: 750'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: S

Description of Background: Blue sky with some clouds

Description of Sky: Partly cloudy

Wind Direction: West

Wind Velocity: 15 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	5:15	6:15	0	0	0	0

TABLE C-15

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon Black, Unit # 2 Wet process drum dryer purge gas baghouse

Type of Discharge: Stack

Height of Point of Discharge: 53'

Distance from Observer to Discharge Point: 400'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: West

Description of Background: Blue sky

Description of Sky: Clear

Wind Direction: 15

Wind Velocity: SW

Color of Plume: Black

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	10:50	11:50	0	0	0	0

TABLE C-16

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon black, # 3 Main Process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 83'

Distance from Observer to Discharge Point: 350'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: W

Description of Background: Blue sky

Description of Sky: Clear

Wind Direction: SW

Wind Velocity: 15 MPH

Color of Plume: Black

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	1:10	1:16	245	10.2	190	7.9
2	1:16	1:22	210	8.8	200	8.3
3	1:22	1:28	220	9.2	210	8.8
4	1:28	1:34	225	9.4	225	9.4
5	1:34	1:40	230	9.6	240	10.0
6	1:40	1:46	185	7.7	215	9.0
7	1:46	1:52	170	7.1	235	9.8
8	1:52	1:58	210	8.8	215	9.0
9	1:58	2:04	190	7.9	195	8.1
10	2:04	2:12	240	10.0	230	9.6

TABLE C-17

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon Black, #3 Product transfer baghouse

Type of Discharge: Stack

Height of Point of Discharge: 65'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: SW

Description of Background: Cloudy

Description of Sky: Clouds

Wind Direction: NW

Wind Velocity: 10 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	4:02	5:02	0	0	0	0

TABLE C-18

FACILITY E

Summary of Visible Emissions

Date: April 9, 1975

Type of Plant: Carbon Black, Wet process dryer purge gas baghouse

Type of Discharge: Stack

Height of Point of Discharge: 0'

Distance from Observer to Discharge Point: 350'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: SW

Description of Background: Blue sky

Description of Sky: Clear

Wind Direction: NW

Wind Velocity: 10 MPH

Color of Plume: Black

Detached Plume: No

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No.1		Observer No. 2	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1	2:35	2:41	230	9.5	265	11.0
2	2:41	2:47	225	9.4	235	9.8
3	2:47	2:53	240	10.0	220	9.2
4	2:53	2:59	235	9.8	240	10.0
5	2:59	3:05	250	10.4	240	10.0
6	3:05	3:11	255	10.6	235	9.8
7	3:11	3:17	245	10.2	145	6.0
8	3:17	3:23	270	11.3	140	5.8
9	3:23	3:29	250	10.4	135	5.6
10	3:29	3:35	275	11.5	150	6.3

TABLE C-19

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon black, # 1 Main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 70'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy blue sky

Description of Sky: Partly cloudy

Wind Direction: S

Wind Velocity: 5-10 MPH

Color of Plume: Not Visible

Detached Plume: Not Visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	10:40	11:40	0	0	0	0

TABLE C-20

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon Black, # 1 Wet process drum dryer purge gas baghouse

Type of Discharge: Stack

Height of Point of Discharge: 70'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy Blue sky

Description of Sky: Partly cloudy

Wind Direction: South

Wind Velocity: 10-15 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No.3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	11:45	12:45	0	0	0	0

TABLE C-21

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon Black, # 2 Main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 61'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy blue

Description of Sky: Partly cloudy

Wind Direction: South

Wind Velocity: 15-20 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	1:00	2:00	0	0	0	0

TABLE C-20

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant:Carbon Black, # 1 Wet process drum dryer purge gas baghouse

Type of Discharge:Stack

Height of Point of Discharge: 70'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy Blue sky

Description of Sky: Partly cloudy

Wind Direction: South

Wind Velocity: 10-15 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No.3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	11:45	12:45	0	0	0	0

TABLE C-21

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon Black, # 2 Main process baghouse

Type of Discharge: Stack

Height of Point of Discharge: 61'

Distance from Observer to Discharge Point: 500'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy blue

Description of Sky: Partly cloudy

Wind Direction: South

Wind Velocity: 15-20 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No. 1		Observer No. 3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	1:00	2:00	0	0	0	0

TABLE C-22

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon Black, # 2 Wet process drum dryer purge gas baghouse

Type of Discharge: Stack

Height of Point of Discharge: 44'

Distance from Observer to Discharge Point: 250'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Hazy blue

Description of Sky: Partly cloudy

Wind Direction: South

Wind Velocity: 15-20 MPH

Color of Plume: Not Visible

Detached Plume: Not Visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No.1		Observer No. 3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	2:00	3:00	0	0	0	0

TABLE C-23

FACILITY F

Summary of Visible Emissions

Date: May 1, 1975

Type of Plant: Carbon Black, Plant vacuum cleanup baghouse

Type of Discharge: Stack

Height of Point of Discharge: 20'

Distance from Observer to Discharge Point: 100'

Height of Observation Point: 0'

Direction of Observer from Discharge Point: East

Description of Background: Blue

Description of Sky: Clear

Wind Direction: South

Wind Velocity: 5-10 MPH

Color of Plume: Not visible

Detached Plume: Not visible

Duration of Observation: 1 hour

SUMMARY OF AVERAGE OPACITY

			Observer No.1		Observer No.3	
	Time		Opacity		Opacity	
Set Number	Start	End	Sum	Average	Sum	Average
1-10	9:30	10:30	0	0	0	0

APPENDIX D. EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 Emission Measurement Methods

For visible emission and carbon monoxide measurements from stacks, EPA relies primarily upon Methods 9 and 10, respectively, which have been established as reference methods.

Although the combustion process of carbon black manufacturing produces large quantities of water (approximately 40% by volume in some cases), determination of opacity was possible during the NSPS testing. The relatively high stack gas temperatures (approximately 350°F) coupled with the warm ambient temperatures of the south where many of the carbon black plants are located, were sufficient to prevent condensed vapor plumes from forming at the point of stack gas discharge. In only one plant was the plume of the detached type, but visible emission readings were feasible. However, in this one plant, gusty wind conditions prevailed such that readings were not taken every 15 seconds according to Method 9. Instead, readings were taken only when conditions permitted them.

Method 10 was followed using the procedures in the <u>Federal Register</u> of June 11, 1975. Method 3 (gas composition - Orsat) and Method 4 (moisture) determinations were made in conjunction with Method 10 so that corrections to the gas volume could be made. Additionally, measurements using Methods 1 and 2 (sampling location and gas velocity) were obtained so that emission rates could be calculated. Methods 1 - 4, as prescribed in the <u>Federal Register</u> (December 23, 1971), were conducted without difficulty.

Based on prior application of Method 10 in the refinery CO recovery boilers, where the effluent gas stream consisted of high CO_2 and water vapor quite similar to the carbon black industry, Method 10 was considered suitable for application in the carbon black industry. The Environmental Monitoring and Support Laboratory (EMSL) of EPA has conducted collaborative tests using Method 10 and identified problem areas in the method that could lead to an error of as much as ± 87 ppm at the 500 ppm level. The collaborative tests showed that in several instances the calibration gas mixtures deviated significantly from the values reported by the gas vendor. In addition, because the response of some instruments were not linear, the calibration curve could not accurately be determined by the single span point.

In one test conducted prior to the EMSL quality assurance guidelines that yielded results which were to be used for NSPS, the tester used calibration gases which were certified against known gas concentrations prepared gravimetrically. Although this procedure is similar to that used by the National Bureau of Standards (NBS), the collaborative tests showed that this still does not totally ensure accuracy of the calibration gases. In the second area, a calibration response curve was constructed in the laboratory and used in the field; the linearity of the instrument was not assumed. The exact magnitude of improvement, however, cannot be determined; it can only be said that the results of this test can be expected to have an error somewhat less than the 87 ppm at the 500 ppm level. The EPA tested another plant using Method 10. The calibration gases used in this study were traceable to NBS and the response curve of the analyzer was checked in the field with two levels of calibration gases in the range of the measurements. These data were considered accurate to 10 ppm on the low analyzer range of 0 - 500 ppm.

D.2 Monitoring Systems and Devices

The visible emission monitoring instruments found adequate for power plants, as covered by EPA performance standards contained in Appendix B of 40 CFR Part 60 (Federal Register, September 11, 1974), should also be applicable to the carbon black industry. The high moisture contents of the effluent stream from the carbon black industry sources should not be a problem since the high temperature of the gas within the ductwork keeps the water in a gaseous state. Carbon black industry personnel have reported that fine carbon black particles deposited on the optical surfaces of their transmissometer, thereby causing more frequent maintenance or even causing the transmissometer to be inoperative. These problems were encountered using older transmissometer designs. Current transmissometers protect the optics with air curtains and should not be subject to the same fouling problems. The EPA, however, has not investigated this.

Carbon monoxide monitoring equipment is also available for combustion sources similar to carbon black plants. However, EPA has not completed a comprehensive evaluation needed to identify critical operating parameters and minimum performance specifications for these CO monitoring equipment, when operated at carbon black plants.

Equipment and installation costs, for opacity monitoring, are estimated to be $18,000 to $20,000 per site and annual operating costs, including data recording and reduction, are estimated at $8,000 to $9,000. Some economies in operating costs can be made if multiple units are installed at a facility.

The cost of a carbon monoxide monitoring system equipment and installation is estimated to be $7,000 to $10,000 and annual operating costs including data recording and reduction are estimated at $2,000 to $3,000. Since most sampling systems are extractive, there is a possibility of time sharing the instrumentation between several stacks and minimizing the cost of monitoring for the plant.

D.3 Performance Test Methods

Method 9 for visible emissions is recommended as the performance test method. If possible, the tests should be scheduled on warm days when the water condensation does not create a white plume that remains attached to the stack. The fine black particulates are easily seen under these conditions and no problems should be encountered with this method.

Method 10 for carbon monoxide and Methods 1 to 4 (required for mass flow determination) are recommended as the performance test methods. Due to the low concentrations normally encountered, in a well-designed carbon monoxide recovery boiler, the calibration of the NDIR with accurate calibration gases is necessary. To minimize problems associated with obtaining an accurate calibration as described in a prior section, the use of two ranges of calibration gas certified traceable to concentrations prepared by the National Bureau of Standards is recommended. Nominal concentrations of 90% and 50% of scale are recommended with full scale set at approximately 1.5 times the standard. In this manner, the gases bracket the standard, and the two points can be used to check the linearity of the instrument response.

Sampling costs for a test consisting of 3 one-hour integrated runs, the number normally specified by performance test regulations, is estimated to be about $3,000 to $4,000. This estimate is based on the sampling site modifications such as ports, scaffolding, ladders, and platforms being less than $2,000 and testing being conducted by contractors. If in-plant personnel is used to conduct the test, the costs will be somewhat less.

Since the outlet gas stream from the control devices used in this industry are generally well-contained, no special sampling problems are anticipated.

APPENDIX E. ENFORCEMENT ASPECTS

E.1 GENERAL

The control systems will limit the emission of particulate matter and carbon monoxide (CO) from furnace process carbon black plants. These limits include concentration limitations for CO from the reactor off-gas and visible emission limitations for particulate from the reactor off-gas, the dryer purge gas, and vents on the product transfer and storage operations, the bagging and loading operations, and the plant vacuum cleanup systems. The control systems which are installed to comply with the CO emission limit are enclosed combustion devices and normally baghouses are installed to comply with the particulate visible emission limit.

Operating changes, which are within the design limits of the reactors are required to meet changing product demands. Consequently, when a new affected facility is constructed or an existing facility modified, it is important that a record be made of (1) the intended purpose for which it was installed, (2) any anticipated variations in the characteristics of the materials to be handled and the products to be produced, and (3) its maximum design capacity and anticipated normal operating capacity. The control system should be designed to assure that standards of performance are achievable for any and all anticipated process variations.

E.2 DETERMINATION OF COMPLIANCE WITH THE CONCENTRATION EMISSION LIMIT

The control systems installed to comply with the proposed emission limit may have any of several configurations. One control device may serve several affected facilities, or several control devices may serve one affected facility. Where several control devices are involved, the use of a flow-weighted average concentration to determine compliance is being considered. In a case where a CO boiler, an incinerator, and a pellet dryer combustion furnace are all used to control one reactor line this would be applicable. For the other case, a common compliance test of the single control device is sufficient to show compliance for all the affected facilities, such as when one incinerator is used to control several reactor lines. These provisions allow the proposed standards to be reasonably enforced without restricting options for the design of control system.

The methods specified in 40 CFR 60 (Methods 3, 4, 10) provide specific guidelines for the measurement of carbon monoxide emissions from a stack. New and affected existing sources should be designed in such a way that will ensure optimum accuracy of sampling.

E.3 DETERMINATION OF COMPLIANCE WITH VISIBLE EMISSION LIMITS

Considering the time and expense required to perform quantitative emission measurements, they are not a means of ensuring that emissions are within acceptable limits over the long term. On the other hand, visible emission readings require only trained observers and can usually be performed with minimal preparation and no prior notice to the owner. Visible emission limitations are recommended for the affected facilities of furnace process carbon black plants (1. reactor line and main process baghouse, 2. product pelletizer and dryer, 3. product transfer and storage, 4. bagging and loading and 5. plant vacuum cleanup system) to help assure that the existing emission control devices are properly maintained and operated. All visible emission observations should be made in accordance with the procedures established in EPA Method 9.

E.4 INSTALLATION AND OPERATION OF CONTINUOUS MONITORS

No visible emission or CO continuous emission monitors are recommended for the control devices in a furnace process carbon black plant. There are too many independant emission points within a plant to have monitors on all of them, or even on a representative number of them. Therefore, even though the technology is available (but unproven in furnace process carbon black plants) for continuous monitoring of CO and opacity, it is the present recommendation that their installation not be required.

E.5. STARTING, SHUTDOWN AND MALFUNCTIONS

When a reactor or a reactor line is started up it is heated with natural gas and vented through the baghouse. After the reactor is sufficiently heated, the feedstock is introduced and samples are taken to determine the characteristics of the black being produced so that the process can be adjusted to make the proper grade. During this process the off-gas should be combusted in one of the available devices so that there are no excessive emissions. A process malfunction usually results in off specification product and does not increase emissions. Mechanical failure or operator error may lead to excessive emissions but when this occurs the reactor is usually immediately shut down. When a line is shutdown it should also not result in excessive emissions.