CARBON BLACK

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1.0 SCOPE

This document provides loss prevention recommendations for carbon black manufacturing facilities. The predominate manufacturing method is the partial combustion of heavy oils, which is the focus of this data sheet.

1.1 Hazards

The carbon black production process involves large fuel-fired equipment, flammable gas, and combustible dust. In addition, the process generates significant waste energy, which is often used to co-generate power. The leading loss drivers in the occupancy are breakdown of rotating equipment and power generation equipment, and fires in the power generation unit. Other hazards include fire and explosion in the production units, and natural hazards.

1.2 Changes

October 2024. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Locate process reactors using natural gas or liquid fuel as a feedstock away from the control room, control equipment, and warehousing. For additional guidance see Data Sheet 7-14, *Fire Protection for Chemical Plants*.

2.2 Process Hazards/Safety

2.2.1 Process Safety

2.2.1.1 Establish a formal process safety program in accordance with Data Sheet 7-43, *Process Safety*. Place emphasis on the following:

A. Process hazard analysis for non-routine operations, including process shutdown and startup

B. Conditions to prevent coking of the preheaters and reactors, including preventive measures that inhibit coking in the feedstock system

C. Detailed operator training programs with training on all safety shutdowns, including non-routine operations

D. Management of changes process that focuses on temporary bypasses, updates to P&IDs and completion tracking

E. Incident investigative procedures that include investigations of failure of safety interlocks, devices, and combustion controls

F. Asset integrity programs focused on rotating equipment, power generation, and accelerated corrosion

2.2.2 Chemical/Material Hazards

2.2.2.1 Protect equipment handling combustible dust in accordance with Data Sheet 7-76, *Combustible Dusts.*

2.2.3 Safety Controls, Alarms, and Interlocks

The partial combustion of oil generates carbon black powder and carbon monoxide. This partial combustion process can create significant fire or explosion hazards if the process is not operated within defined operating limits.

2.2.3.1 Provide the following combustion controls for startup and operation of the reactor:

- Minimum fuel oil temperature
- Safety shutoff valves (SSOV) on pilot, auxiliary, and process burners
- Emergency stop

- Loss of pilot flame
- Main combustion air low pressure or flow
- Pilot combustion air low pressure
- Reactor purge timer
- Low and high pressure for natural gas
- Low pressure for process oil
- Loss of energy to the burner management system (BMS)
- Reactor high temperature

Additional information is provided in Data Sheet 6-10, *Process Furnaces*.

2.2.3.2 Provide combustion controls for startup and operation of the dryer in accordance with Data Sheet 6-17, *Rotary Kilns and Dryers*.

2.2.3.3 For startup and operation of downstream product collection, heat recovery, and tail gas, provide the following safety interlocks:

- Diversion stack for startup and process upset
- Interlocks for tail gas flow and stack gas fan temperature

2.2.3.4 Interlock the reactor feedstock to automatically shut down in the event of a fire.

2.2.3.5 Provide an automatic pressure interlock on the quench water spray system in the tail gas stream before entry into the bag house. Design it to shut down and vent the tail gas stream and start a secondary quench water system.

2.3 Protection

2.3.1 Provide automatic fire detection and shutoffs of the feedstock supply. Place fire detector(s) directly above the face of the reactors, pumps, and preheaters. Interlock the sensing elements with the control system of the reactors to activate an alarm and to allow for automatic shutdown of the reactors and fuel oil.

2.3.2 Automatic sprinkler protection is not required for pumps, preheaters, and reactors located outdoors if all the following conditions are met:

A. Automatic shutoffs are provided in accordance with 2.3.1.

B. Manual hose protection is provided for the burner front of the pumps, preheaters, and reactors, with a minimum 500 gpm (1900 L/min).

C. There are no factors that could increase a fire exposure, such as combustible construction elements, storage of combustible materials, lack of emergency organization, etc.

2.3.3 Provide automatic sprinkler protection in buildings containing oil-fired reactors.

2.3.4 Provide hydrant protection capable of providing 500 gpm (1900 L/min) with a minimum separation space of 300 ft (91 m) for the facility, including the burner front of the reactors, the bag house, palletized storage of carbon black, and other areas as specified in referenced data sheets.

2.3.5 Segregate carbon black storage from storage of ordinary combustibles and packing materials.

2.3.6 Provide automatic sprinkler protection for warehouses used for storage of packaging materials, or if combustible building construction exists. For protection criteria see Data Sheet 8-9, *Storage of Class 1, 2, 3, 4, and Plastic Commodities*.

2.3.7 Provide automatic sprinkler protection for lubricating oil systems over steam turbines and generators in accordance with Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*.

2.4 Equipment and Processes

2.4.1 For operations in which tail gases are used for steam production and power generation, follow the protection guidelines in Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*.

2.4.2 For guidance on startup and purging of reactors, see Data Sheet 6-10, *Process Furnaces*.

2.4.3 For guidance on rotary equipment, see Data Sheet 6-17, *Rotary Kilns and Dryers*.

2.4.4 For guidance on fans and blowers, see Data Sheet 13-24, *Fans and Blowers.*

2.4.4 Use double-braided, noncombustible hose in all feed stock supply lines. Ensure these are capable of withstanding four times the normal maximum operating pressure.

2.5 Operation and Maintenance

Significant equipment-related hazards at this occupancy include the potential for a mechanical or electrical distribution failure. The likelihood of such an event is greatly reduced by thorough and varied inspection, maintenance, and operating programs, contingency plans, and effective safeguards to prevent these types of events.

2.5.1 Establish an asset integrity monitoring program in accordance with Data Sheet 9-0, *Asset Integrity*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

Figure 3.1 provides a summary of all losses between 2004 and 2017 for this occupancy.

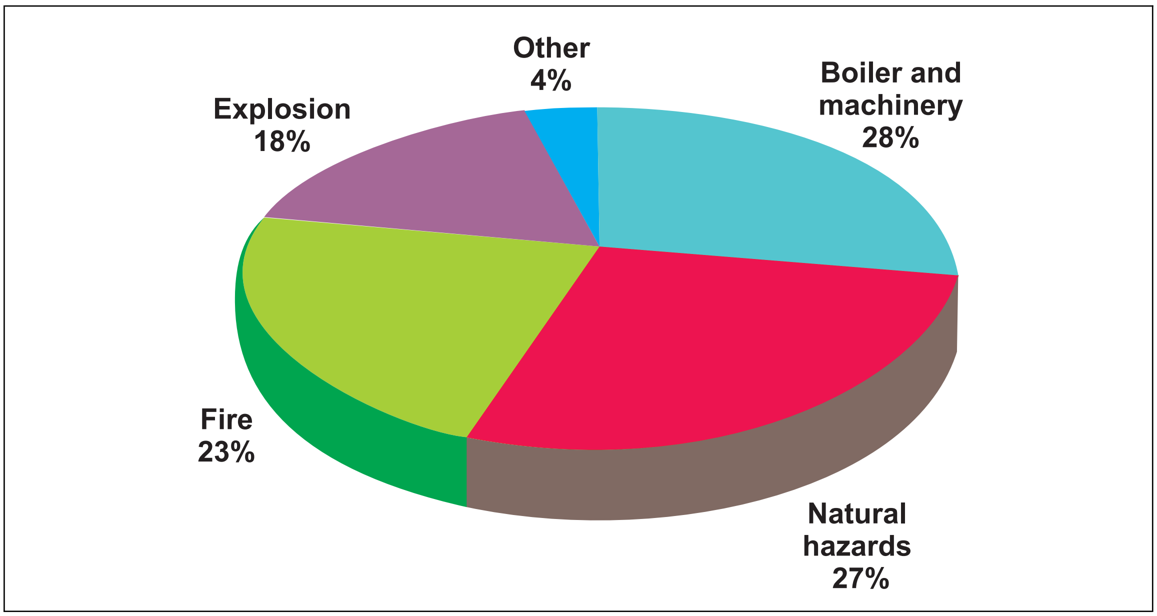

Fig. 3.1. Summary of Losses (2004-2017)

Boiler and machinery losses were driven by damage to heat exchangers in the heat recovery section of the plant, damage to turbines and generators, and electrical breakdown. The damaged heat exchangers were the result of coking tubes, loss of flow of process oil, leakage, and tube cracking. Damage to turbines and generators included loss of lubrication and other common perils described in Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*. Electrical damage was predominately related to service interruption and transformers. All the losses are typical B&M hazards for the type of equipment involved. A high degree of focus should be placed on heat exchangers, cogeneration equipment, and electrical reliability.

The fire losses were driven by fires on or around steam turbine generators. These events would have been mitigated with the fire protection recommended in Data Sheet 7-101, with the exception of one event that occurred during the installation of sprinklers. There was only one loss involving reactors, in which refractory collapsed inside the reactors, damaged a nozzle and fire extended from the reactors, damaging cabling and various equipment.

Explosion losses were predominately combustion explosions involving carbon monoxide in the filter and heat recovery sections of the plant. These sections of the plant are designed to operate with depleted oxygen (fuel rich) and poor startup procedures or other process upsets allowed oxygen into these areas of the plant, creating a flammable atmosphere. There were no reported losses in this period involving combustible dust.

Natural hazard losses were driven by hurricane events in the US gulf coast. This includes several flooding events at locations in known flood zones. There is nothing atypical in the natural hazard losses. Damage percentages are typically modest provided flood levels do not reach the height of reactors' refractory.

3.2 Process Overview

Carbon black is produced by combusting oil with a significant amount of oxygen inside a reactor. Hot air and fuel oil are introduced in a reactor to undergo complete combustion. The resulting high-temperature gas (soot near 3,000˚F [1649°C]) is atomized with water to quickly lower its temperature and inhibit the reaction. By varying the amount of oil and air, the internal temperature of the reactors can be altered, which permits manipulation of the particle size and particle connections of the carbon black being produced. Carbon black can be classified as rubber black and specialty grade. The various grades are listed in ASTM 1765-01 with a corresponding N-series number. Rubber grades primarily consist of N200-N800 series used principally for the reinforcement of rubber (approximately 90% of carbon black production). Specialty grades are used for black pigment and for its electrically conductive properties.

Exiting the reactor, carbon black is conveyed, cooled, and collected in bag filters in a continuous process. Residual gas, or tail gas, from the reactor includes a variety of gases, such as carbon monoxide and hydrogen. Most plants use a portion of this residual gas to produce heat, steam, or electric power or to send to a thermal oxidizer for pollution control. Figure 3.2 represents a simple carbon black process.

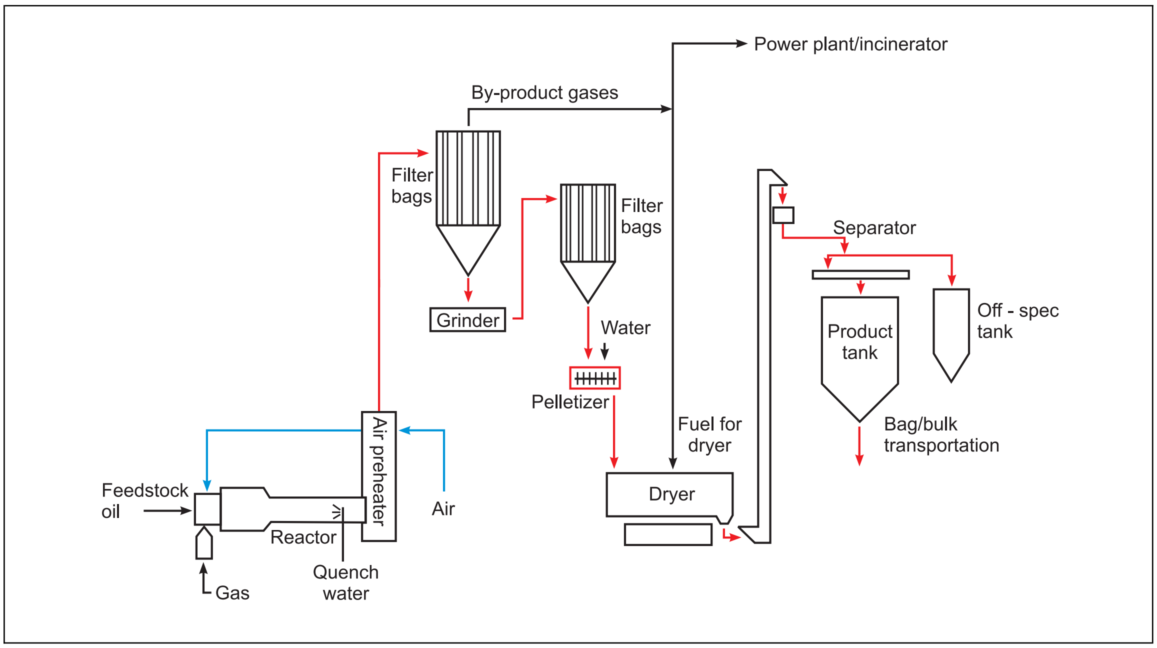

Fig. 3.2. Carbon black process diagram

Most processes are single-line process flows with various bottlenecks including utilities, reactors, blowers, dryers, filters, and cooling water.

Carbon black manufacturing plants are dusty environments. This accelerates corrosion rates throughout the plant. Mechanical and electrical equipment should be maintained against corrosion.

The reactors range in size from 4 to 6 ft (1.2 to 1.8 m) in diameter and up to 120 ft (37 m) long. Reactors are usually steel shell lined with refractory brick and can be fed axially, tangentially, or radially. The reactors' product to combustion air heat exchangers are critical for this occupancy.

The airflow is usually 5,000-6,000 cfm (8,500-10,200 m^3/hr), with many plants sized at 12,000 scfm (20,300 m^3/hr) or more. The pressure is usually up to 15 psig (1 barg). Therefore, large motors (1,000 hp and up) can be seen on air blowers, which may require extensive lead time for replacement.

Large rotary dryers, typically 8 ft (2.4 m) in diameter and up to 75 ft (23 m) long are used to dry the quenched carbon black. These dryers can be direct or indirect fired (waste heat from the process).

3.3 Equipment

3.3.1 Hoses

Braided feedstock hoses are replaced according to manufacturer's recommendations with a replacement frequency based on usage. A common problem presented by older hoses, is resistance to flex which could cause leakages at threaded connections in the fuel piping or result in hose breakage, especially if there are 90 degrees bends. Cases where hoses are bulged, stiff, or corroded need immediate attention and replacement.

Hoses in service for this occupancy are subject to both tensile and compressive stresses, internal pressure, extremes temperatures, vibration, corrosive atmospheres, physical impact and reactive forces. To reduce the impact caused by environment and operational conditions manufacture's installation and operation recommendations needs to be follow.

3.3.2 Distributed Control Systems (DCS)

Typical DCS configurations are utilized for process control. These systems typically combine to provide control features needed for plant start-up, shutdown, combustion safeguards, production optimization, emergency stops, etc. Loss of DCS in an emergency shutdown can cause fouling from coking in the feedstock system.

4.0 REFERENCES

4.1 FM

Data Sheet 6-10, *Process Furnaces*
Data Sheet 6-17, *Rotary Kilns and Dryers*
Data Sheet 7-14, *Fire Protection for Chemical Plants*
Data Sheet 7-101, *Fire Protection for Steam Turbines and Electric Generators*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-76, *Combustible Dusts*
Data Sheet 8-9, Storage of Class 1, 2, 3, 4 and Plastic Commodities
Data Sheet 9-0, *Asset Integrity*

APPENDIX A GLOSSARY OF TERMS

See also Data Sheet 7-111.

Combustible dust: Any organic material (agricultural, plastic, chemical, coal, etc.), unoxidized metal particles, or other oxidizable materials (e.g., zinc stearate) should be considered combustible. Tests involving the application of a spark, match flame, Bunsen or Meker burner flame to small layers or piles of material may help in identifying such materials but can result in false negatives.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2024. Interim revision. Minor editorial changes were made.

January 2023. Interim revision. Minor editorial changes were made.

October 2020. Interim revision. Minor editorial changes were made.

July 2019. This is the first publication of this document.