BOILER FURNACE AND DRAFT SYSTEM IMPLOSIONS

Table of Contents

Page

1.0 SCOPE....2
1.1 Hazards....2
1.2 Changes....2
2.0 LOSS PREVENTION RECOMMENDATIONS....2
2.1 Introduction....2
2.2 Equipment and Processes....2
2.2.1 Design and Construction....2
2.2.2 Control System Design....2
2.3 Operation and Maintenance....3
2.4 Training....3
3.0 SUPPORT FOR RECOMMENDATIONS....3
3.1 Loss History....3
3.2 Illustrative Losses....4
3.2.1 Control Air Failure Shuts Dampers....4
3.2.2 Lack of Backup Power System Contributes to Implosion....4
3.2.3 Damaged Instrument Plug-in Connector Leads to Implosion....4
3.2.4 Thermal Overload Trip on FD Fan Leads to Ductwork Implosion....4
3.2.5 Misoperation of ID Fan Damper and Material Degradation Leads to Spray Dryer Absorber Implosion....5
4.0 REFERENCES....5
4.1 FM....5
4.2 NFPA Standards....5
APPENDIX A GLOSSARY OF TERMS....5
APPENDIX B DOCUMENT REVISION HISTORY....5
APPENDIX C SUPPLEMENTAL INFORMATION....5
C.1 Background Information....5
C.1.1 Factors Leading to Implosions....5
C.1.1.1 Master Fuel Trip....5
C.1.1.2 Equipment Malfunction or Misoperation....6
C.1.1.3 System Degradation....6
C.1.2 Controls, Interlocks and Operational Safeguards....6
C.1.2.1 Interlocks and Alarms....6
C.1.2.2 Operational Procedures and Sequencing....7
C.2 Other Standards....7

List of Figures

Fig. 3.1. Typical Boiler Furnace and Draft System....4
Fig. C.1.2.1. Furnace draft system interlocks....7

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1.0 SCOPE

This data sheet provides guidance for preventing implosions of boiler furnaces and associated draft system components located between the furnace and induced draft (ID) fan(s). It addresses structural design, inspection, testing, maintenance, control systems, interlocks and operating practices intended to minimize implosion hazards. This data sheet applies only to boiler systems equipped with one or more induced draft fan(s) downstream of the furnace.

1.1 Hazards

A boiler furnace or draft system implosion is a violent inward contraction caused by a rapid decrease in pressure, resulting in boiler damage due to forces in excess of yield strength. Implosions can occur in boiler furnaces and at any location between the furnace and the induced draft fan(s). These implosions typically result from one or more of the following three causes. See Appendix C.1.1 for additional detail.

1. Master fuel trip or loss of power, causing rapid cooling and pressure drop in the furnace
2. Fan, damper, or control system malfunction or misoperation
3. Degradation of equipment, resulting in failure below design pressures

1.2 Changes

October 2026. Full revision. Title updated to include "Draft System".

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

The primary safeguards that address the risk of furnace and draft system implosions include proper structural design, a robust control system with alarms and interlocks, an asset integrity program, and effective operator training.

2.2 Equipment and Processes

2.2.1 Design and Construction

2.2.1.1 Design and construct the furnace and downstream draft systems to withstand normal and transient pressures (e.g., full load master fuel trip) without permanent deformation.

2.2.1.2 Design and construct the furnace to be capable of holding an internal pressure of ±35 in. of water (±8.7 kPa, 87 mbar), or to withstand the test block capability of the Induced Draft (ID) or Forced Draft (FD) fans, whichever is more negative.

2.2.1.3 Design fan dampers to fail to their safe operating position during a loss of power event to minimize pressure excursions during fan coast down.

2.2.1.4 When adding or upgrading equipment such as induced draft fans or environmental control systems, conduct a site-specific engineering draft study to ensure proper design ratings, instrumentation requirements, control setpoints and interlocks. Ensure that plant retrofits and equipment upgrades meet the management of change (MOC) recommendations in Data Sheet 7-43, *Process Safety.*

2.2.1.5 When designing draft system equipment such as ductwork, spray dryer adsorbers and baghouses, take into account operating environment (e.g., corrosive or abraisive flue gas streams).

2.2.2 Control System Design

2.2.2.1 Ensure the boiler and draft system controls meet the recommendations in Data Sheet 7-110, *Industrial Control Systems*.

2.2.2.2 Make provision for backup power sources to be connected to critical control systems and transmitters.

2.2.2.3 Provide three furnace pressure transmitters, each connected to the furnace on its own tap, as a cross-reference for the control equipment to avoid problems caused by faulty measurements from malfunctioning equipment.

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2.2.2.4 Provide a boiler air flow demand signal other than the measured air flow signal, initiated from an interrelated system (fuel flow, boiler master or other index of demand).

2.2.2.5 Provide a furnace pressure control subsystem to maintain the furnace at the pressure setpoint.

2.2.2.6 Provide a furnace pressure control protection subsystem to minimize furnace pressure excursions under both auto and manual operating modes.

2.2.2.7 Implement controlling equipment settings, such as furnace pressure setpoints, alarm points, trip points, trip sequencing, time delays, etc. in accordance with NFPA 85 guidance and OEM or consultant recommendations. See Figure C.1.2.1 for basic draft system interlocks that should initiate a master fuel trip (MFT).

2.3 Operation and Maintenance

2.3.1 Maintain the furnace and draft system pressures between the limits suggested by the manufacturers, using furnace pressure control equipment.

2.3.2 Operate system in automatic mode whenever possible.

2.3.3 Make and record regular maintenance checks on all draft controlling equipment such as fans, dampers, damper drives, etc, to ensure that all equipment is functioning properly and with unrestricted movement. See Data Sheet 13-24, *Fans and Blowers,* for additional detail on fan and damper inspection, testing and maintenance.

2.3.4 Test furnace draft system interlocks annually or at major outages. This testing includes furnace high and low pressure, loss of all forced-draft fans (FD) and loss of all induced-draft (ID) fan interlocks. See Figure C.1.2.1 for basic draft system interlocks that should initiate a master fuel trip (MFT).

2.3.5 Establish and implement a boiler draft system inspection, testing and maintenance program, considering the operating environment, to ensure continued ability to withstand design pressures without failure. Degradation that could reduce component strength below design limits shall be identified and corrected. See Data Sheet 9-0, *Asset Integrity*, for guidance on developing an asset integrity program.

2.4 Training

2.4.1 Establish and implement an operator program. See Data Sheet 10-8, *Operators*, for guidance on developing an operator program, including operator training on standard and emergency operating procedures (SOPs and EOPs). Ensure that operators are knowledgable of implosion hazards and prevention methods. See Section C.1.2.2, Operational Procedures and Sequencing, for additional detail.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Loss History

Loss experience indicates that boiler implosions have occured in boiler furnaces and at various locations throughout the draft system, upstream of the induced draft fans, including ductwork and emissions control equipment. Implosions have occurred in boilers fired with oil, coal, waste and black liquor. These implosions have led to property damage and extensive business interruptions. No incidents have been reported on natural gas-fired units because few gas-fired boilers are balanced draft. Figure 3.1 shows a general representation of a boiler and draft system, and shows the areas of the system where implosions can and have occured. Note that many different equipment configurations of boiler draft systems exist, including situations where multiple boilers tie into a common air pollution control system. This figure is illustrative only.

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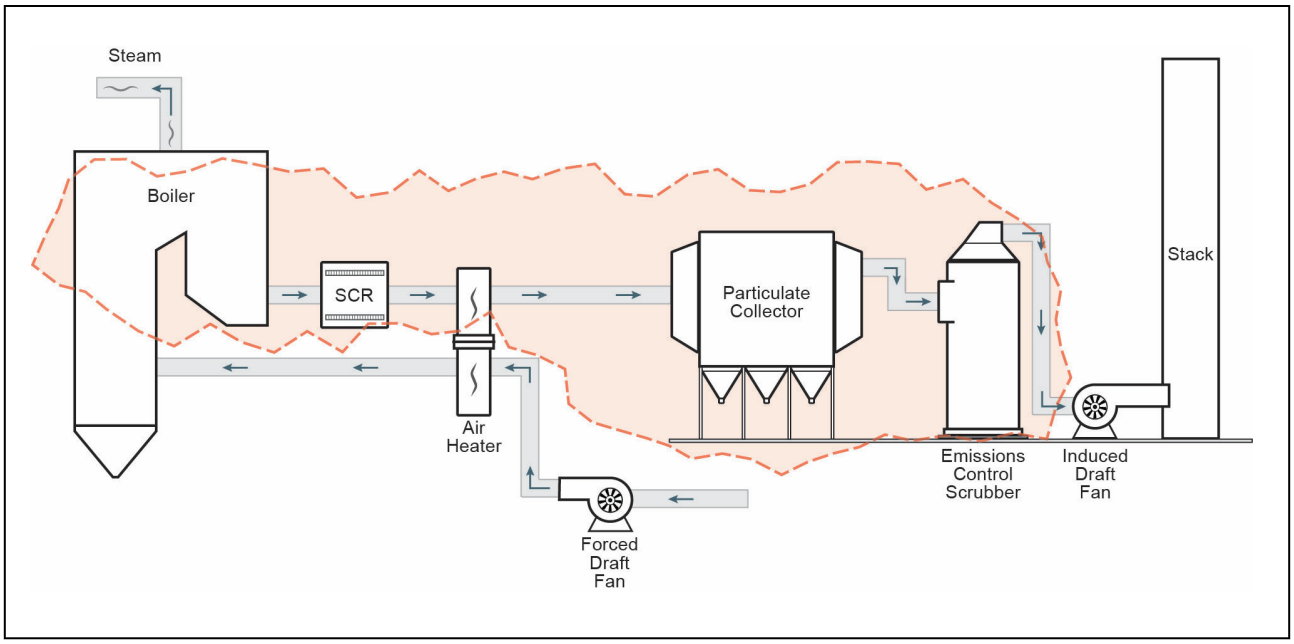


Fig. 3.1. Typical Boiler Furnace and Draft System

3.2 Illustrative Losses

3.2.1 Control Air Failure Shuts Dampers

An arcing fault in the switchgear caused a 100% shutdown of the coal mills. Following restoration of power, damage to the boiler structure (14 buckstays) was found. Maximum inward deflection was measured at 2 in. (50 mm). Repairs reset boiler walls to a maximum deflection of 1 / 2 in. (13 mm) corner to corner. Damage was directly attributable to loss of control air upon electrical power loss. Primary, secondary and forced air dampers closed upon loss of control air. Before ID fans could be tripped, draft gauges pegged at –10 in. water (2.49 kPa, 24.9 mbar). Under test conditions, the ID fans are capable of producing vacuum of –26 in. water (1.49 kPa, 15 mbar).

3.2.2 Lack of Backup Power System Contributes to Implosion

A large utility boiler rated at 5,841,000 lb stm / hr, 2600 psig (18 mPa, 179.2 bar) and 1005°F (540°C) superheat and reheat suffered an implosion. Damage consisted of approximately 30 tubes split or ruptured. Three furnace walls were drawn in a maximum of 30 in. (760 mm). Roof tube refractory had to be replaced. Penthouse buckstays fell to the floor. Several buckstays had to be replaced. Left and right front corners were opened. Oil gun assemblies were damaged. Skin casing on three walls, along with insulation, had to be replaced. The cause of the implosion was determined to be loss of primary power to the control system, which kept the ID fan from tripping upon high furnace vacuum trip. Backup system wiring (battery power) was never completed. When this unit went back into service, the furnace walls were designed to withstand a furnace pressure of –20 in. (4.98 kPa, 49 mbar). Original design called for –12 in. water (2.99 kPa, 29 mbar).

3.2.3 Damaged Instrument Plug-in Connector Leads to Implosion

A 1000 ton / day black liquor recovery unit has a working steam pressure of 900 psig (6.2 mPa, 62.0 bar) at the superheater outlet with a steam temperature of 850°F (454°C). An electrical panel that contains wiring for the furnace draft system is located on the second mezzanine floor level in a high wash area. The plug-in connector for this panel was bent prior to this incident, damaging the rubber grommet seal. Several minutes after the area was water washed, a high, negative draft was recorded. When the draft condition had stabilized, the unit was inspected. Several buckstays were found to be deflected inward, some up to 2 ft (0.6 m). The tubes on the south wall were bent inward at least 9 in. (230 mm). The bent plug-in connection allowed water into the cabinet, which short circuited the signals, causing the FD fan control damper to close and the ID fan to speed up, resulting in the implosion.

3.2.4 Thermal Overload Trip on FD Fan Leads to Ductwork Implosion

This incident affected three generating units capable of 250 MW each, operating on a common exhaust duct. While operating near full load, a forced draft fan tripped due to a thermal overload. The induced draft fan controls were in manual mode at the time, contributing to inadequate control response. During the resulting transient pressure event, the measured pressure upstream of the induced draft fan was -17.3 in (-440 mm) H_2O to -20.5 in (-520 mm) H_2O, compared

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to a trip point of -26.4 in (-670 mm) H_2O. A section of ductwork, approximately 164 ft (50 m) long and 16.4 ft (5 m) x 16.4 ft (5 m) in cross section upstream of the induced draft fans and common to all three units, was damaged by implosion.

3.2.5 Misoperation of ID Fan Damper and Material Degradation Leads to Spray Dryer Absorber Implosion

During startup of a coal-fired boiler, an operator was troubleshooting an ID fan inlet control damper problem and inadvertently opened the damper, creating a high negative draft of -33 in. (-838 mm) H_2O that imploded the cone section of the spray dryer absorber. The spray dryer absorber was designed to withstand -40 in. (-1016 mm) H_20; however, during inspection, the carbon steel cone showed some loss of metal thickness. Non-destructive examination was conducted, and the damaged cone was temporarily stiffened to allow for continued operation while a replacement cone was ordered.

4.0 REFERENCES

4.1 FM

Data Sheet 6-2, *Pulverized Coal-Fired Boilers*
Data Sheet 6-5, *Oil- and Gas-Fired Multiple Burner Boilers*
Data Sheet 7-43, *Process Safety*
Data Sheet 7-110, *Industrial Control Systems*
Data Sheet 9-0, *Asset Integrity*
Data Sheet 10-8, *Operators*
Data Sheet 13-24, *Fans and Blowers*

4.2 NFPA Standards

NFPA 85, *Boiler and Combustion Systems Hazards Code*.

APPENDIX A GLOSSARY OF TERMS

Explosion: a violent outward expansion caused by a rapid increase in pressure, resulting in boiler damage due to forces in excess of yield strength.

Implosion: a violent inward contraction caused by a rapid decrease in pressure, resulting in boiler damage due to forces in excess of yield strength.

APPENDIX B DOCUMENT REVISION HISTORY

October 2026. Full revision. Title has been updated to include "Draft System".

APPENDIX C SUPPLEMENTAL INFORMATION

C.1 Background Information

C.1.1 Factors Leading to Implosions

This section provides additional detail on the reasons that implosions occur in boilers and draft systems, including:

1. Master fuel trip or loss of power, causing rapid cooling and pressure drop in the furnace
2. Fan, damper or control system malfunction or misoperation
3. Degradation of equipment, resulting in failure below design pressures

C.1.1.1 Master Fuel Trip

A master fuel trip (MFT) can be initiated by either a trip or loss of the fuel supply system, or by a separate system interlock. Understanding the relationship of the furnace pressure and volume to the furnace temperature is important. This relationship can be expressed by the perfect gas law,

$PV = nRT$

Where:
P = absolute furnace pressure
V = volume of furnace

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n = number of moles of gas in furnace
R = fixed gas constant
T = absolute furnace temperature

When an MFT occurs, a rapid decrease in the furnace temperature results as the combustion ceases and the furnace begins to cool. According to the perfect gas law, since the volume of the furance is constant, the rapid drop in temperature results in a rapid drop in pressure.

In some cases, the system designer will program a slower withdrawal of fuel after the MFT occurs. This design can allow for a more controlled decrease of the furnace temperature, but it is system-specific and not universal.

Note that the furnace, draft system and control system should be designed to handle the transient pressures of a MFT without system deformation. However, in the case of improper design or when accompanied by equipment malfunction or system degradation, a MFT can result in implosion.

C.1.1.2 Equipment Malfunction or Misoperation

In balanced draft systems, the forced draft (FD) and induced draft (ID) fan(s) work together to control combustion air and furnace pressure. Fans are controlled by inlet dampers / guide vanes or variable frequency drives (VFDs) and managed by a control system. In a typical arrangement, the FD fan(s) adjust airflow into the furnace based upon fuel input; and the ID fan(s) adjust to maintain the furnace pressure setpoint.

Implosion can occur when FD fan(s) trip or otherwise reduce the airflow into the furnace, and the corresponding ID fan(s) fail to promptly modulate or trip. Another scenario involves an unintended increase in ID fan variable frequency drive (VFD) speed or damper position while FD fan(s) remain constant. Both scenarios result in a high vacuum inside the furnace and draft system.

Problems can include damper / guide vane or actuator trouble, control system issues or loss of power, or system interlocks not properly set or malfunctioning. Improper operator action can cause or compound these issues.

These problems can arise during both the firing or non-firing cycle of a unit, such as a purge cycle. Fan or control system problems can worsen the transient pressure effects of a MFT.

C.1.1.3 System Degradation

In some cases, even properly designed and constructed draft systems may degrade from erosion and / or corrosion over the course of their service. This degradation can result in draft systems imploding below their design pressures and even below the interlock setpoints.

Therefore, the inspection, testing and maintenance of gas path equipment should be included in a site's asset integrity program. This program is of particular importance in systems with abraisive or corrosive flue gas streams such as in spray dryer absorbers (SDAs).

C.1.2 Controls, Interlocks and Operational Safeguards

This section deals primarily with implosion-related controls and interlocks, and discusses general operational procedures intended to mitigate against boiler and draft system implosions.

C.1.2.1 Interlocks and Alarms

Boilers equipped with induced draft systems should incorporate combustion safeguard interlocks that prevent excessive negative furnace pressure. At a minimum, protection should include a high furnace pressure trip, a high furnace draft trip, forced draft and induced draft fan failure interlocks, furnace pressure monitoring and alarms that provide operators warning of deteriorating draft conditions. Interlock setpoints and control responses should be established in accordance with NFPA 85, OEM recommendations, and supporting engineering analyses to prevent furnace and draft system implosions.

Figure C.1.2.1 shows the interlocks associated with high and low furnace pressure protection. See NFPA 85 for a full list of minimum required interlocks for multiple-burner boiler protection.

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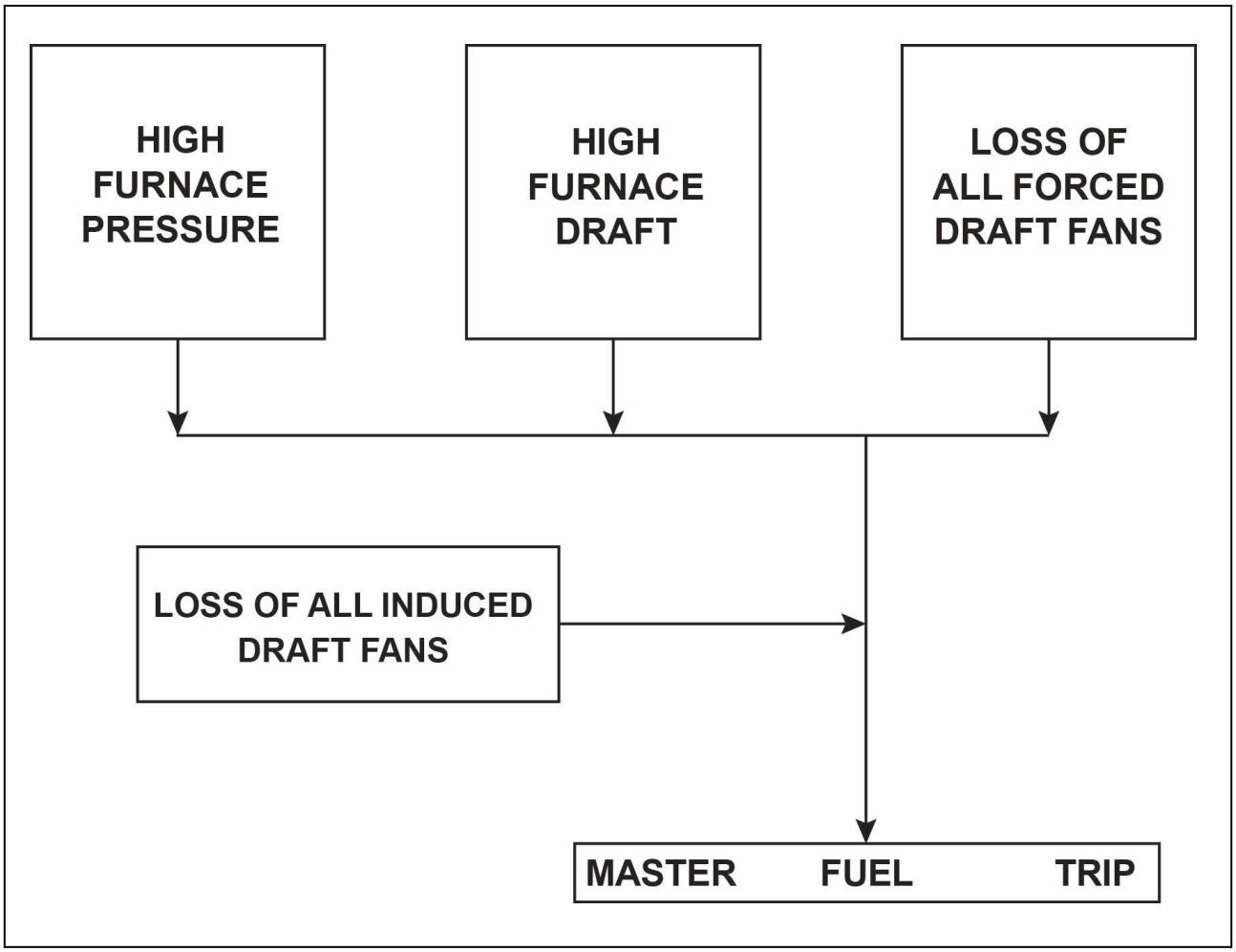


Fig. C.1.2.1. Furnace draft system interlocks

C.1.2.2 Operational Procedures and Sequencing

To minimize the risk of boiler and draft-system implosions, operating procedures and controls should establish and maintain proper sequencing of fuel systems, burners, fans, dampers and combustion controls during startup, normal operation, shutdown and emergency conditions. Operators should follow documented procedures that maintain control of furnace pressure, particularly during fuel trips, fan transfers and equipment failures. Sequencing logic, operating practices and operator training should be consistent with NFPA 85 requirements, OEM recommendations and engineering evaluations of the draft system.

(Detailed startup and shutdown procedures for ID and FD fans are covered in Data Sheet 6-2, *Pulverized Coal-Fired Boilers* and Data Sheet 6-5, *Oil- and Gas-Fired Multiple Burner Boilers*.)

C.2 Other Standards

Prevention of furnace implosions in multiple burner boiler-furnaces is also covered in NFPA 85, *Boiler and Combustion Systems Hazards Code*. There are no known conflicts with this standard.

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