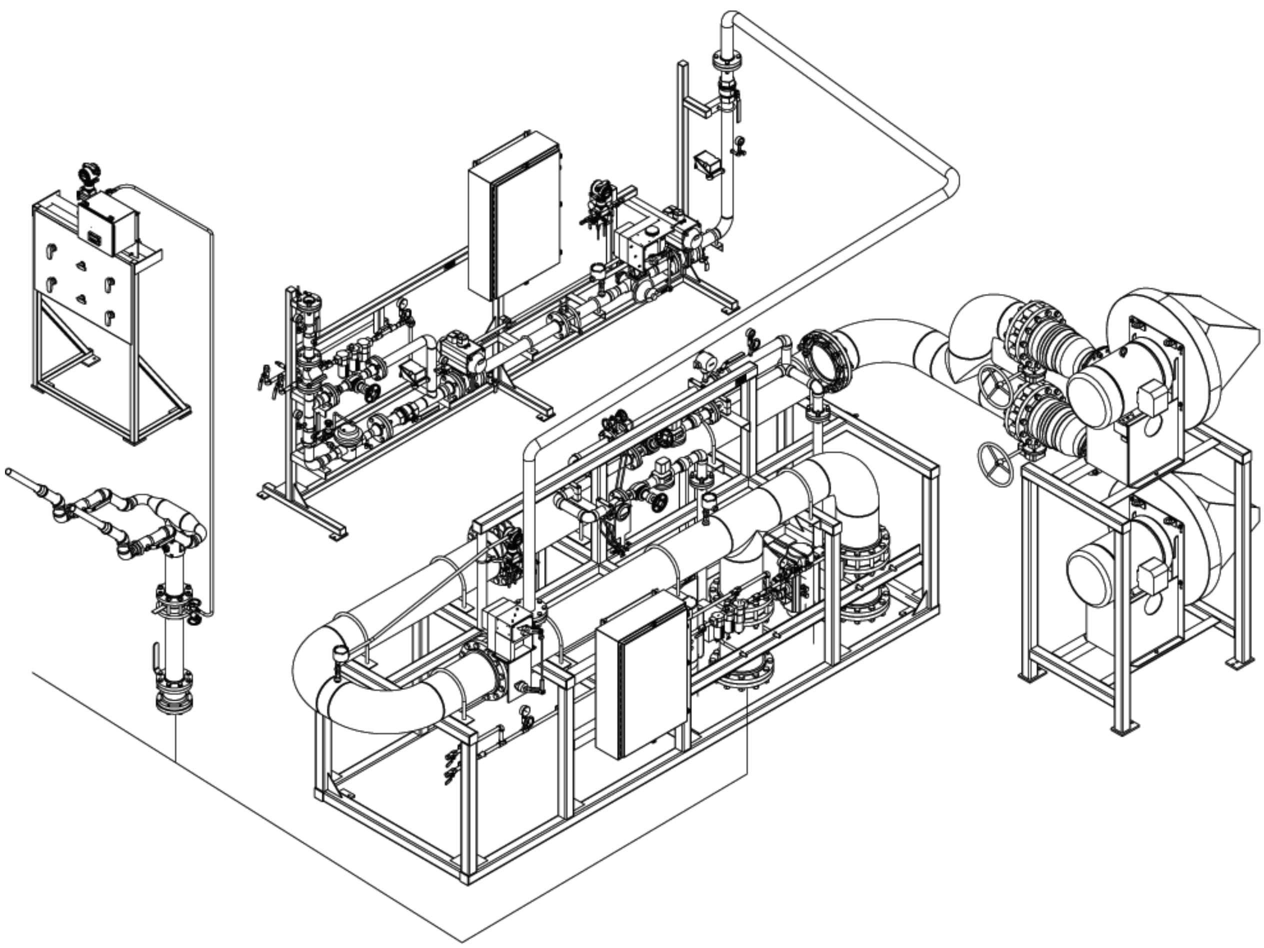
Installation Guide 1170
8/9/2013

Eclipse Oxygen Enriched Air Staging

OEAS Series



ECLIPSE®
Innovative Thermal Solutions

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The material in this manual is believed adequate for the intended use of the product. If the product is used for purposes other than those specified herein, confirmation of validity and suitability must be obtained. Eclipse warrants that the product itself does not infringe upon any United States patents. No further warranty is expressed or implied.

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Any operation expressly prohibited in this manual, any adjustment, or assembly procedures not recommended or authorized in these instructions shall void the warranty.

Document Conventions

There are several special symbols in this document. You must know their meaning and importance.

The explanation of these symbols follows below. Please read it thoroughly.

How To Get Help

If you need help, contact your local Eclipse representative. You can also contact Eclipse at:

1665 Elmwood Rd.
Rockford, Illinois 61103 U.S.A.
Phone: 815-877-3031
Fax: 815-877-3336
http://www.eclipsenet.com

Please have the information on the product label available when contacting the factory so we may better serve you.

ECLIPSE® Innovative Thermal Solutions www.eclipsenet.com
Product Name
Item #
S/N
DD MMM YYYY

⚠	This is the safety alert symbol. It is used to alert you to potential personal injurt hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.
⚠ DANGER	Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
⚠ WARNING	Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
⚠ CAUTION	Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
NOTICE	Is used to address practices not related to personal injury.
NOTE	Indicates an important part of text. Read thoroughly.

Table of Contents

Introduction 1

Product Description

Eclipse OEAS/BAS systems are used for NOx emissions control on regenerative air-gas fired glass furnaces.

OEAS/BAS technology utilizes a unique method of combustion air/oxygen or air only staging to control NOx formation by reducing the oxygen available in the burner flame's high temperature zone and improving flame temperature uniformity. The amount of primary combustion air entering through the port(s) is reduced to decrease NOx formation in the flame, and oxygen enriched air is injected into the furnace near the exhaust port(s) to complete the combustion in a second stage within the furnace. The bulk of the combustion is, therefore, relatively oxygen deficient (or fuel rich) to inhibit NOx formation.

Effective CO burnout in the exhaust port can be achieved when a secondary oxidant is properly mixed with the primary zone combustion products utilizing OEAS/BAS technology.

If OEAS is chosen, the user selects the level of oxygen enrichment desired between 21 and 40%. The control system maintains the overall air/fuel ratio in the furnace even if the furnace operator makes fuel or combustion air changes.

Staging can be performed in two modes:

1. Oxygen Enriched Air Staging (OEAS).

2. Blower Air Staging (BAS).

Through the use of a PLC system (Compact Logix control system with a Panelview Plus 1000) the furnace operator is able to choose the second stage oxidant's flow rate and oxygen content. This allows optimization of the staging system for operating costs, furnace efficiency and NOx control level.

OEAS/BAS systems may be configured for side-port or end-port furnaces.

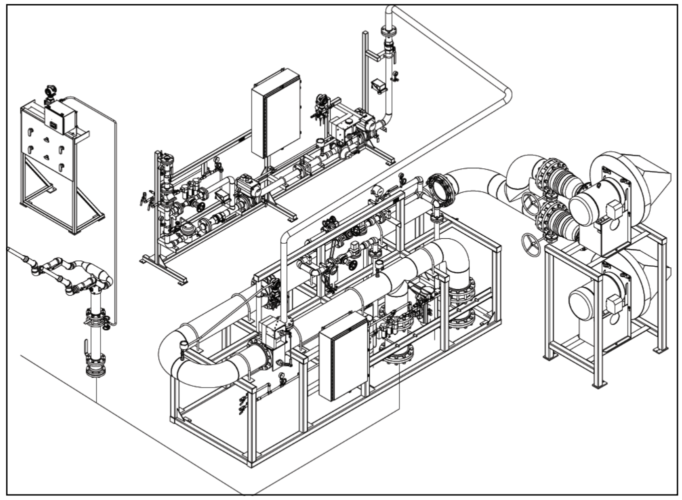

Figure 1.1. Oxygen Enriched Air System

Audience

This manual has been written for people who are already familiar with all aspects of OEAS and BAS and its add-on components. These aspects are installation, use and maintenance.

The audience is expected to have previous experience with this type of equipment.

OEAS Documents

Installation Guide No. 1170

- This document

Spare Parts List No. 1170

- Used to complete installation

System Checklist Series 1170

- Used to complete installation

Related Documents

- EFE 825 (Combustion Engineering Guide)
- Eclipse Bulletins and Info Guides: 610, 710, 720, 730, 744, 760, 930, I-354

Purpose

The purpose of this manual is to ensure that you carry out the installation of a safe, effective, and trouble free OEAS/BAS system.

Safety 2

Important notices which help provide safe system operation will be found in this section. To avoid personal injury and damage to the property or facility, the following warnings must be observed. All involved personnel should read this entire manual carefully before attempting to start or operate this system. If any part of the information in this manual is not understood, contact Eclipse before continuing.

Safety Warnings

⚠ WARNING

- **Injectors, hoses and couplers are likely to have HOT surfaces. Always wear the appropriate protective equipment when approaching the injectors.**
- **Exposure to liquid oxygen or cold oxygen gas can cause severe burn-like injuries.**

The temperature of liquid oxygen in the typical storage vessel is -279 °F. Contact with liquid or cold gaseous oxygen will freeze living tissue within seconds. Typically the hazard exist only within the boundaries of the storage area, specifically between the storage vessel and the vaporizers. The oxygen pipeline downstream of the storage area contains oxygen gas at ambient temperatures. Interlocks at the storage area prevent liquid or cold gas from entering the oxygen pipeline.

When working near cryogenic liquids or cold gas pipelines, wear loose fitting gloves, eg. Leather and safety glasses or goggles.

The oxygen pipelines may contain pressures up to 200 psig. Exercise care when working on or around these pressurized lines. Ensure the pressures have been vented before breaking any connection. Tag out a line before performing any work on it. Wear a face shield when working on pressurized lines.

- **High concentrations of oxygen readily accelerates the combustion of most materials and could damage equipment and injure personnel.**

Oxygen concentrations in excess of 23.5% significantly increase the fire hazard exposure to personnel and equipment. Those materials which burn in air will burn more violently and sometimes explosively in oxygen.

Reducing the hazard requires meeting stringent oxygen guidelines for specifying equipment, materials of construction and system cleanliness. Only those personnel familiar with the hazards of oxygen and safe practices for oxygen systems should be permitted to operate and maintain the system. Material Safety Data Sheets (MSDS) for oxygen, Safetygrams for both liquid and gaseous oxygen and Compressed Gas Association (CGA) standards for oxygen pipelines and piping systems are readily available from CGA and online.

- **Electric chock can cause severe personal injury or death.**

The control circuits for the OEAS/BAS system may use 120 volts AC. Do not attempt to work on the system without first turning the power off and tagging out the system in accordance with plant tag out procedures.

- **Open All Valves Slowly.**

Since many materials will burn in the presence of oxygen, the temperature rise caused by adiabatic compression of the oxygen gas could result in igniting pipeline materials. Rapid filling of an oxygen line from one pressure level to another will result in a temperature increase of the gas within the line due to adiabatic compression. Lines should thus be pressurized slowly to minimize this temperature rise. To avoid adiabatic compression, slowly open all valves until pressure has equalized across the valve, then open the valve fully.

- **Use only equipment specifically designed for oxygen service.**

The equipment installed in the oxygen distribution system has been carefully selected to meet strict oxygen compatibility and velocity requirements. Inappropriate materials of construction increase the danger of ignition of pipelines and controls. Sizing is just as important to ensure all velocity restrictions for oxygen are met.

- **Maintain oxygen cleanliness at all times.**

All equipment and piping in contact with oxygen must be cleaned to conform to specifications outlined in CGA codes. Failure to clean components and piping increases the danger of ignition and fire. Note that even the cleaning solvent must be removed completely before the equipment can be placed into service. Maintain cleanliness during assembly, installation and repair.

- **No open flames, smoking or sparks are permitted near oxygen equipment.**

Since many materials will burn in oxygen, the best method in preventing fires is to eliminate sources of ignition. Where oxygen control equipment is being used or where concentrations of oxygen are greater than 23.5%, avoid open flames, sparks or sources of heat. Never weld on a pressurized oxygen line. Make sure signs are posted warning personnel that oxygen is in use.

- **Do not substitute oxygen for compressed air.**

Substituting oxygen for compressed air is dangerous. Generally the instrument air equipment is neither compatible with oxygen nor cleaned for oxygen service. Oxygen used to clean off equipment or clothing could come in contact with a source of ignition (spark, flames or other) and ignite. In some cases, the elevated oxygen levels could linger even after the source has been shut off.

- **Oxygen General Information.**

In the USA for guidance in oxygen piping systems design, cleaning and best practices, reference the specifications outlined in the latest edition of CGA codes.

For Europe the equivalent oxygen code is the latest edition of European Industrial Gases Association (EIGC) codes.

NOTICE

- **This manual provides information regarding the use of OEAS/BAS systems for their specific design purpose. Do not deviate from any instructions or application limits described herein without written approval from Eclipse.**

Causes of Oxygen Fires

In an oxygen system the fire triangle is inseperable, the fuel contains the oxygen and the oxygen contains the source of ignition energy.

Three elements are needed to create a fire: an oxidizer (air), fuel and ignition. In ordinary situations separating these three elements will prevent a fire. Oxygen systems are unique because the three elements are inseparable. The fuel, fittings, valves and regulators contains the oxygen and cannot be separated from it.

Oxygen fires need a source of ignition energy which can come from the compressed oxygen itself due to adiabatic compression.

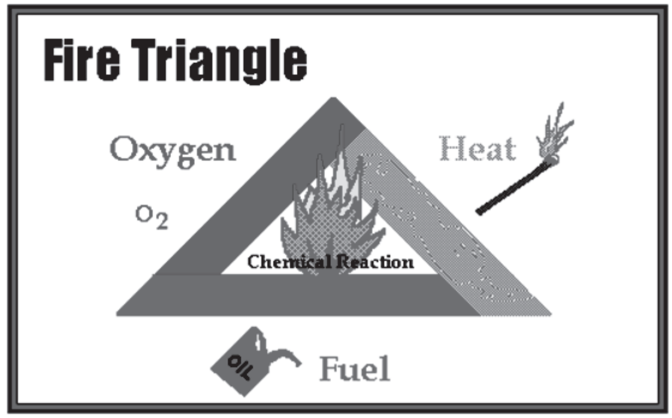

Figure 2.1 Oxygen Fire Triangle

Capabilities

Only qualified personnel, with sufficient mechanical aptitude and experience with combustion equipment, should adjust, maintain or troubleshoot any mechanical or electrical part of this system. Do not operate or repair this system without first reading and understanding this operations manual, oxygen safety literature and the hazards associated with oxygen.

Operator Training

The best safety precaution is an alert and trained operator. Train new operators thoroughly and have them demonstrate an adequate understanding of the equipment and its operation. A regular retraining schedule should be administered to ensure operators maintain a high degree of proficiency.

Replacement Parts

Order replacement parts from Eclipse only. All Eclipse approved valves or switches should carry UL, FM, CSA, CGA and/or CE approval where applicable.

Installation 3

Introduction

In this section you will find the information and instructions that you need to install the OEAS/BAS system. Four types of OEAS/BAS installations are described in this manual:

1. OEAS system for sideport furnaces
2. BAS system for sideport furnaces
3. OEAS system for endport furnaces
4. BAS system for endport furnaces

All four types of installation include the following major sub-systems:

- Blowers. There are two in parallel, one for normal service and one in standby mode.
- Air flow control train.
- PLC cabinet. The PLC cabinet is an OEM (Allen-Bradley) processor with Panelview touch screen monitor, supplied by Eclipse.
- P&ID's for typical OEAS and BAS systems for sideport furnaces and endport furnaces are shown on pages 8-13.

The OEAS and BAS for sideport furnaces include the following major sub-systems:

- Air metering panel(s).
- Metering spools (legs/upcomers). There can be any number of metering spools, normally there will be one for each furnace port.
- Injectors, connecting hoses, and hardware. These interconnecting components serve to transport the oxy/air mix to the furnace. The hoses are flexible braided stainless steel. The injectors are mounted in holes bored in the tuck stones at angles specified in the injector layout drawings (provided by Eclipse). Hardware may include various types of brackets, T-bolts, and gaskets that hold the injectors in place and ensure a tight seal. See typical detail on page 19.

  Injector blocks/sleeves are also required for mounting the injectors. Injector blocks/sleeves are usually provided only for new systems. For existing systems, the customer usually bores existing tuckstone or blocks.

The OEAS and BAS for endport furnaces include the following major sub-systems:

- Supply Headers – One per Furnace side.
- Injectors, connecting hoses, and hardware. These interconnecting components serve to transport the staging air mix to the furnace. The hoses are flexible braided stainless steel. The injectors are mounted on the furnace sidewalls generally 2 or 3 stacked injectors per side as specified in the Injector layout drawings (provided by Eclipse). Hardware may include, T-bolts, and gaskets that hold the injectors in place and ensure a tight seal. See typical detail on page 20.

  Blocks are also required for mounting the injectors to the furnace sidewall. Blocks are usually provided for either hot work or new furnace installation.

The OEAS for both sideport and endport furnaces include the combustion oxygen train sub-system.

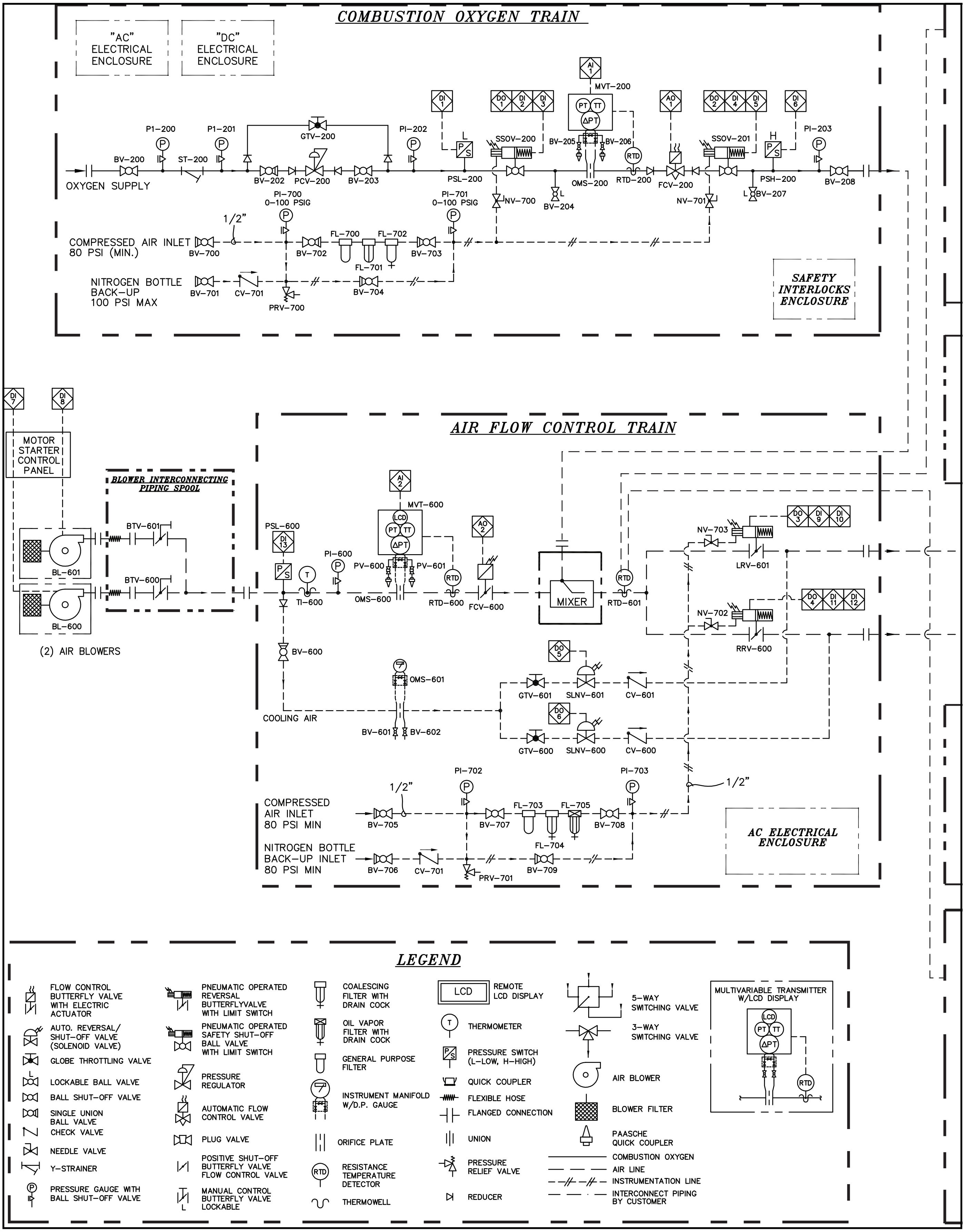

Figure 3.1. OEAS Sideport Part 1

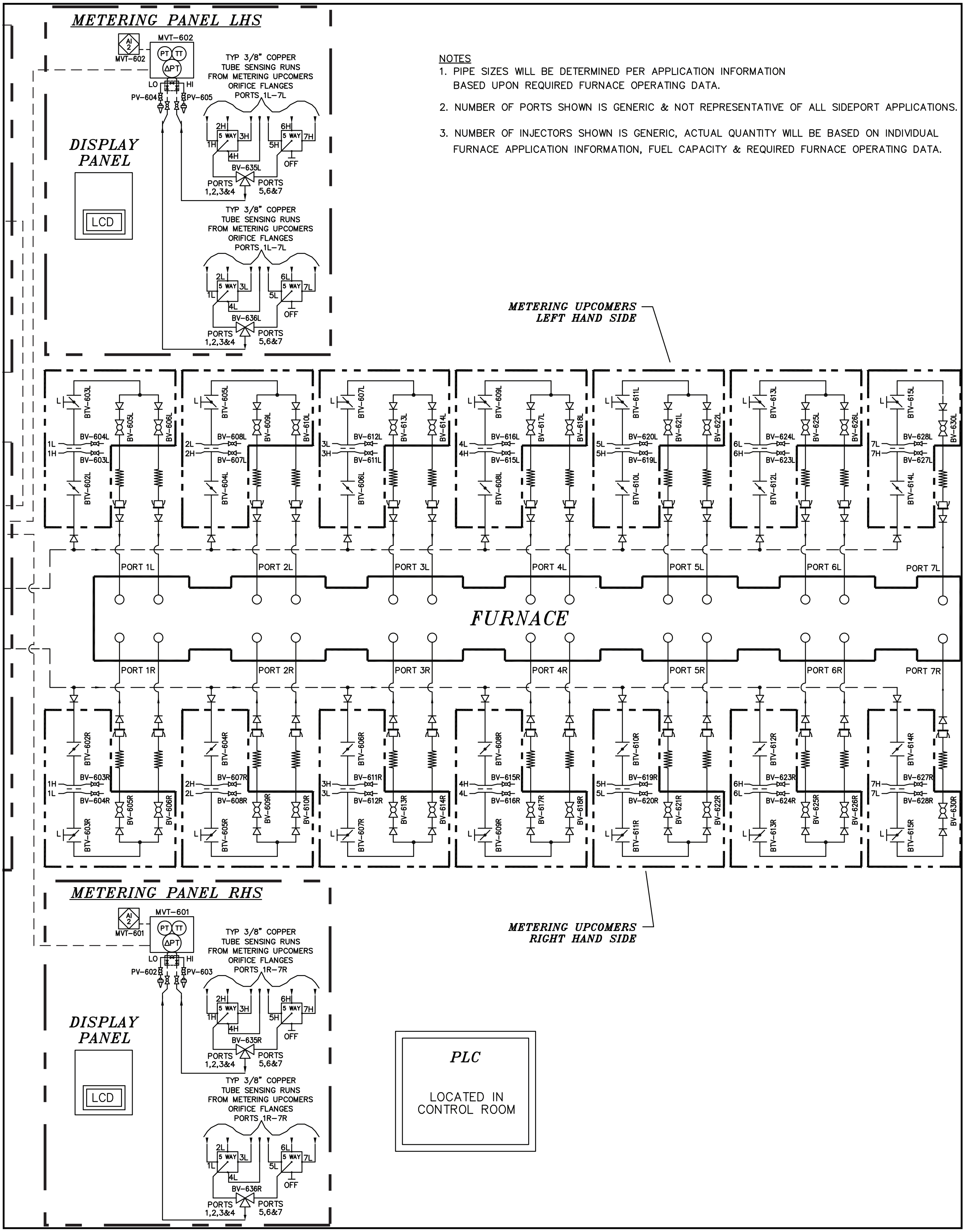

Figure 3.2. OEAS Sideport Part 2

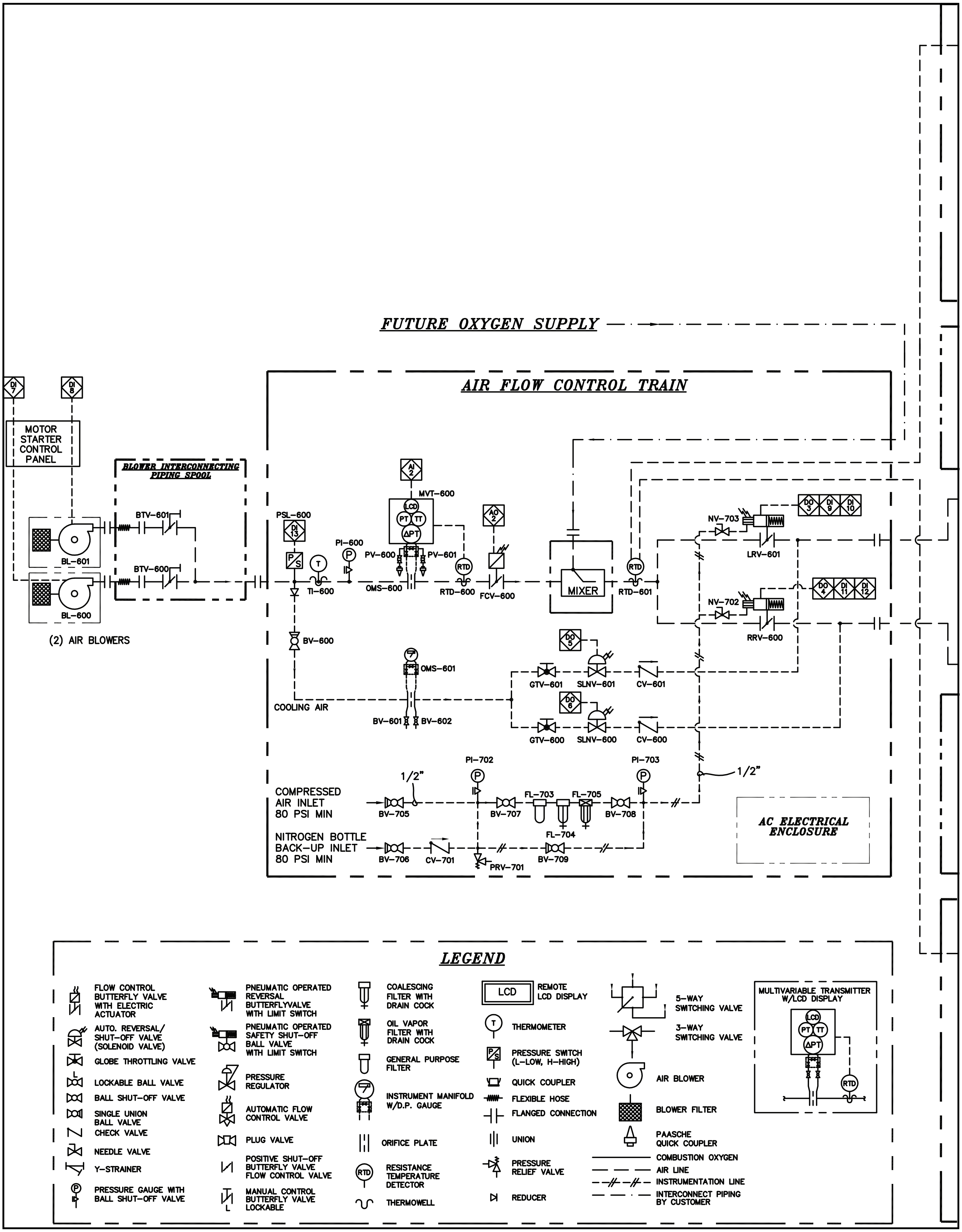

Figure 3.3. BAS Sideport Part 1

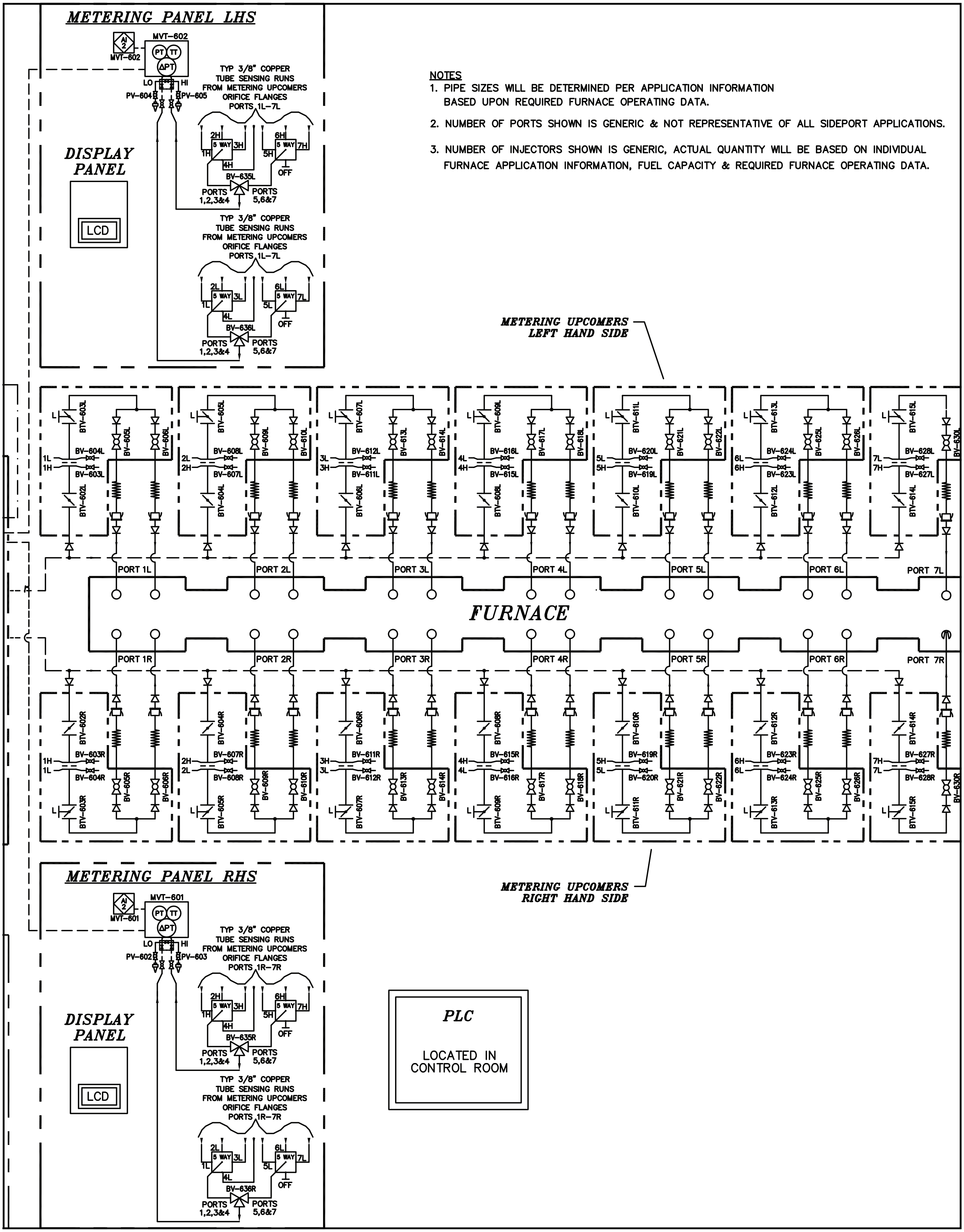

Figure 3.4. BAS Sideport Part 2

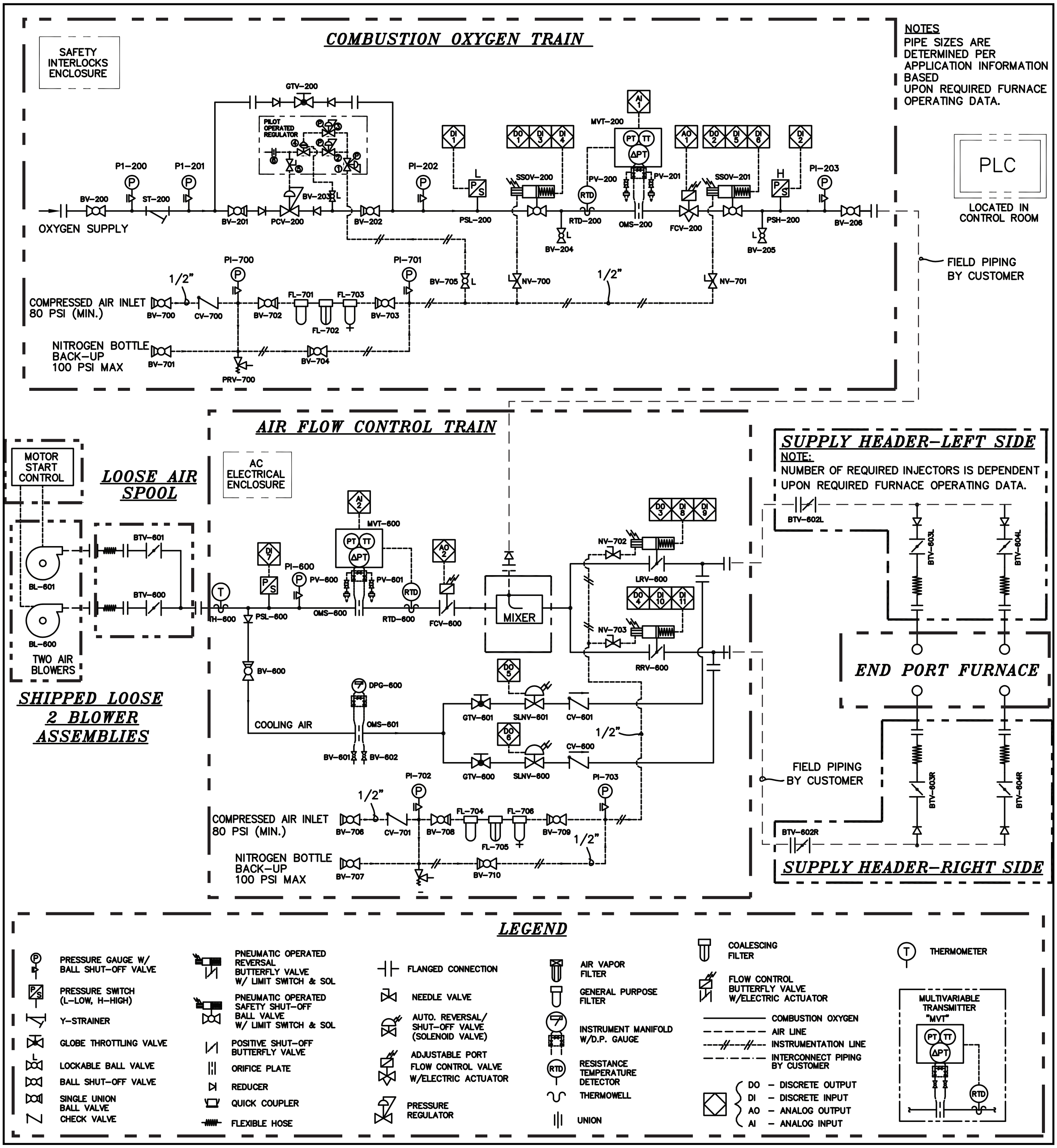

Figure 3.5. OEAS Endport

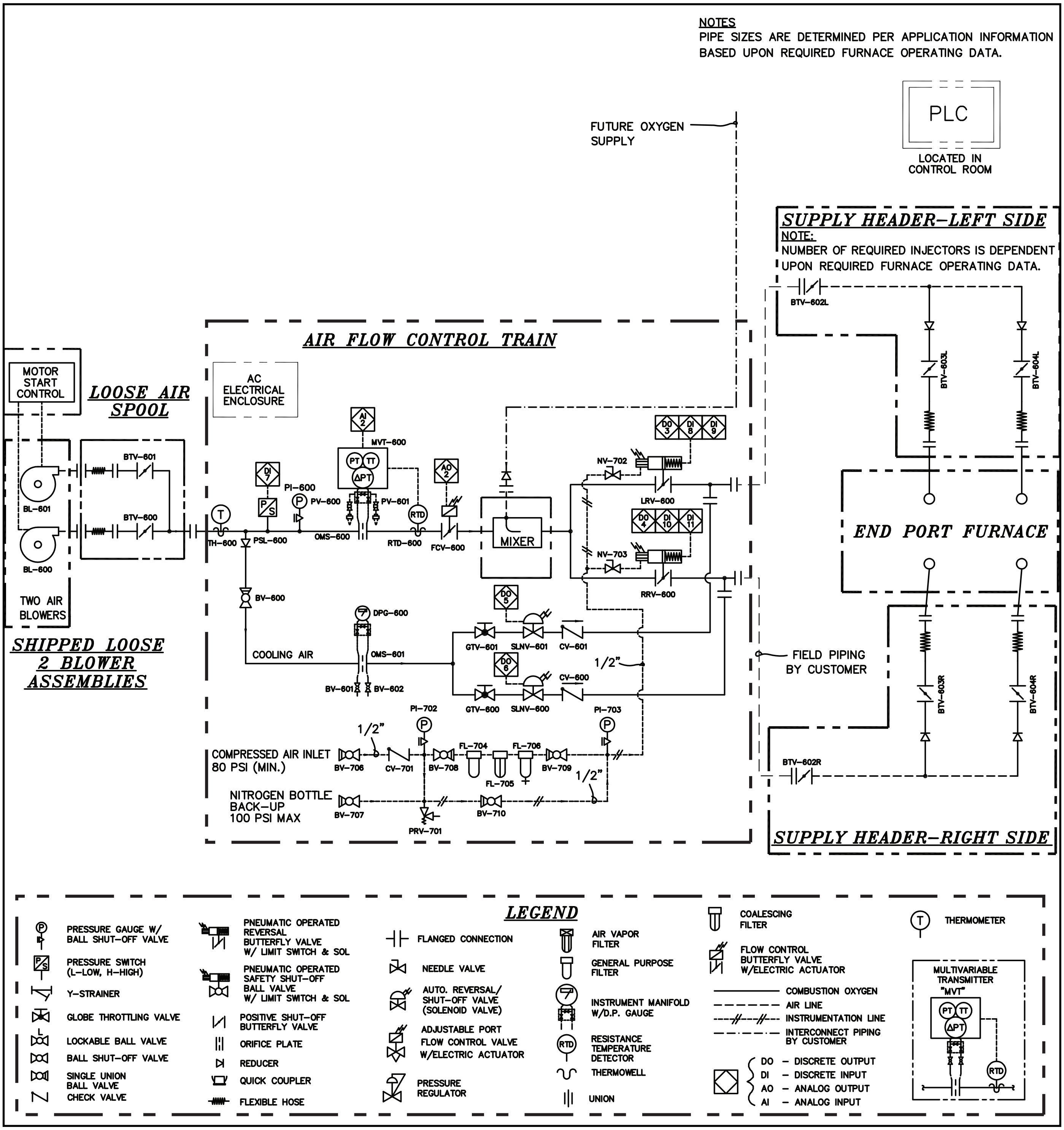

Figure 3.6. BAS Endport

Installation

- Make sure that the area is clean.
- Protect the components from the weather, damage, dirt and moisture.
- Protect the components from excessive temperatures and humidity.
- Take care not to drop or damage components.

A general understanding of factory operations and best practices is assumed. Each installation will be different depending on field conditions and the specifications of the system being installed. The customer and/or contractor is responsible for determining and supervising the details of each installation, and contacting their Eclipse representative with any questions regarding specific installation questions.

Storage

- Make sure that the components are clean and free of damage.
- Store the components in a cool, clean, dry room.
- After you have made sure that everything is present and in good condition, keep the components in the original package as long as possible.

NOTICE

- **When the refractory block or sleeve is supplied with the system, it is critical that the instructions for handling and storage are followed. The refractory should be considered fragile; improper handling and storage will cause premature failure.**

Approval of Components

Limit Controls and Safety Equipment

All limit controls and safety equipment must comply with all applicable local codes and/or standards and must be listed for combustion safety by an independent testing agency. Typical application examples include:

- American: NFPA 86 with listing marks from UL, FM, CSA
- European: EN 746-2 with CE mark from TuV, Gastec, Advantica

Electrical Wiring

All the electrical wiring must comply with all applicable local codes and/or standards such as:

- NFPA Standard 70
- IEC60364
- CSA C22
- BS7671

Piping

All the oxygen and air piping must comply with all applicable local codes and/or standards such as:

- CGA G - 4.4
- NFPA Standard 54 and 86
- ANSI Z223
- EN 746-2

Where to Get the Standards:

The NFPA Standards are available from:
National Fire Protection Agency
Batterymarch Park
Quincy, MA 02269
www.nfpa.org

The ANSI Standards are available from:
American National Standard Institute
1430 Broadway
New York, NY 10018
www.ansi.org

The UL Standards are available from:
333 Pfingsten Road
Northbrook, IL 60062
www.ul.com

The FM Standards are available from:
1151 Boston-Providence Turnpike
PO Box 9102
Norwood, MA 02062
www.fmglobal.com/approvals

Information on the EN standards and where to get them is available from:
Comité Européen de Normalisation
Stassartstraat 36
B-1050 Brussels
Phone: +32-25196811
Fax: +32-25196819
www.cen.eu

Comité Européen de Normalisation Electronique
Stassartstraat 36
B-1050 Brussels
Phone: +32-25196871
Fax: +32-25196919
www.cenelec.org

Checklist Before Installation

The customer must obtain the services of a licensed contractor to install the system according to local regulations. The customer and/or contractor must determine locations of all the sub-systems and components prior to beginning installation.

Weights and dimensions for the OEAS/BAS equipment supplied by Eclipse can be found on equipment drawings in the specific project CD manual.

⚠ CAUTION

- **Failure to determine the exact location of each subsystem and component prior to beginning installation can result in costly delays and damage to equipment.**

Access

Make sure you install the OEAS/BAS system in such a way that you can get easy access for inspection and maintenance.

Environment

Make sure the local environment matches the original operating specifications. Check the following items:

- Voltage, frequency and stability of the electrical power
- Supply pressure of the oxygen and compressed air
- Presence of damaging corrosive gases in the air

System Installation

Several components must be installed on a OEAS/BAS system before it can operate. Installation instructions follow.

Blower(s)

Blowers are provided by Eclipse. The blowers must be securely bolted to the factory floor using the appropriate size and type of fasteners. The size and type of fasteners must be determined based on the specific system and local regulations. The installing contractor is responsible for determining and providing the correct size and type of fasteners.

Blowers should be installed in an accessible location for inspection and maintenance with adequate free area available at the filter inlet. Blowers should be located on a level floor or mounting platform to avoid unnecessary wear on the motor bearings.

Vibration Pads

If the blowers are provided with a flexible connector (typically neoprene) between the blower outlet butterfly valve & interconnecting field piping & are mounted on a level floor then vibration mounting pads for the blowers are not necessary. Otherwise Vibration pads are provided by the customer/contractor. Vibration can shorten motor bearing and rotor life. To prevent blower vibration, the blower should be mounted on compressed rubber mounting/vibration pads between the blower base and floor. The appropriate size and type of vibration pad must be determined by the customer and/or contractor. The customer or contractor must provide the vibration pads.

Butterfly Valves

Two butterfly valves (blower isolation valves) are provided by Eclipse as part of the system. These valves are either supplied loose or attached to interconnecting piping depending on what is quoted with the system. The customer or contractor must determine the location in which to install the valves and perform the installation. The specific type of butterfly valve supplied with each system is detailed in the equipment manual supplied with the system.

Field Piping/Ductwork

The customer or contractor must provide and install the interconnecting piping/ductwork between the butterfly valves on the blowers and the air flow control train inlet if not contained in the quoted equipment scope and also the field piping between the air flow control reversal outlets to the port metering spools/upcomers.

Blower Disconnect Switch Enclosure

The start disconnect switch/motor starter control panel for the air blowers is usually provided loose by Eclipse if included in the Eclipse scope of work.

The customer contractor must install the enclosure in a safe location and use the appropriate size gauge cable for connections. This sizing is based upon the motor size and local electrical codes (NEC).

Instrument Air Supply

The air staging train and oxygen train (if supplied) usually contains an instrument air line, which includes filters, valves and pressure gauges. This instrument air line is piped to the two staging air train pneumatic reversal valves and the two oxygen train safety shut off valves (if supplied). If available oxygen pressure to the main oxygen safety train is less than 15 psig, the main oxygen pressure regulator dome loader may also be required to be loaded with compressed air. See specific project P&IDs for details. The plant compressed air supply to the 1/2” connection on the trains should be a minimum supply pressure of 80 psig.

Oxygen Supply (If Oxygen Train Supplied).

The oxygen supply pressure should be given to the Eclipse representative before system engineering is completed as the available oxygen pressure affects how the main oxygen regulator diaphragm is loaded. Minimum pressure is typically approx 10 psig and max 60 psig.

Metering Spool/Upcomer

One metering spool/leg is required for each port. The metering spools are usually installed on the regenerator wall. The customer and/or contractor must determine the location for the metering spools. In general, each metering spool must be centralized in the port it serves. Each metering spool will service one, two or three injectors, depending on the specific system requirements.

3/8" copper or stainless steel tube sensing runs must be installed by the customer between the orifice plate dp metering connections on the metering spool to the appropriate connections on the back of the metering panel.

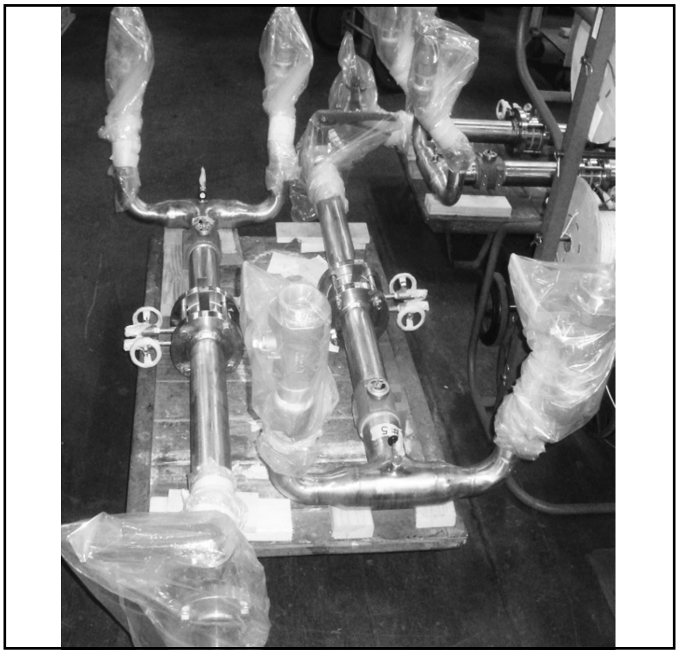

Figure 3.1. Metering Spool / Upcomers
(Note: Two injector metering spools shown)

Injectors

The injectors are mounted in holes drilled into the tuckstone. These holes are drilled at angles specified by Eclipse for each specific system and are shown in the injector layout drawing for the particular project. (Figure 3.8)

The injectors are held in place by a bracket and sleeve. The bracket and sleeve must be assembled so that they are able to move independently to allow for thermal expansion. The injector brackets are welded to the local buckstay/port steel.

The injector holes, buckstays and brackets should all be prepared prior to heatup. After the holes are bored in each tuckstone and the injectors are trial fitted into the holes, remove the injector and plug the hole with Kao-Wool or the equivalent.

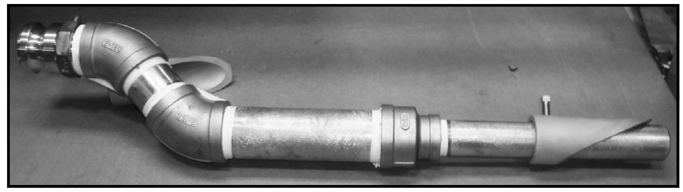

Figure 3.2. Injector for Sideport Furnace
(Note: Locking collar not always provided)

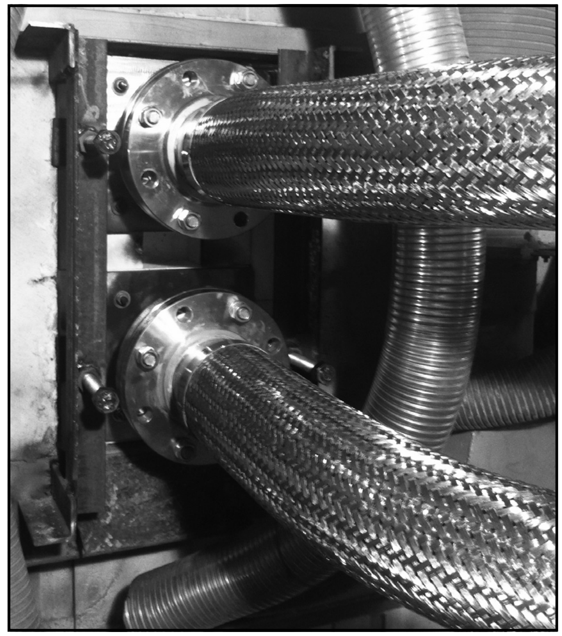

Figure 3.3. Injector for Endport Furnace
(Note: Two injectors shown stacked)

Metering Panel(s)

The metering panel(s) must be secured to the floor in a location to be determined by the customer and/or contractor. The metering panel must be securely bolted to the factory floor using the appropriate size and type of fasteners. The size and type of fasteners must be determined based on the specific system and local regulations. The installing contractor is responsible for determining and providing the correct size and type of fasteners.

The metering panel interconnections should be made using four-conductor shielded cable. The signal cable must be installed between the RTD (Resistance Temperature Detector) in the air flow control train and the MVT. Electrical connections must be made according to local regulations and electrical codes. The wiring should be subjected to all appropriate safety tests, including continuity tests and ground fault tests.

3/8” copper or stainless steel tube sensing runs must be installed between the appropriate connections on the back of the metering panel and the orifice sensing ports on the metering spool. These sensing runs should be made with single continuous tubing with no interconnections. The runs should be located or provided with protection to prevent damage.

Note: Metering panels are only provided on sideport regenerative furnaces. For endport regenerative furnaces there is no metering required as there is only one single OEAS/BAS supply to each side of the furnace. In this case two basic supply pipes/headers are supplied with isolation valves and hoses to each breastwall injector (Figure 3.3 and 3.6).

On sidefired furnaces there is the option where there may be one metering panel to serve both left and right furnace port metering with switching valves and MVT transmitter or optionally two metering panels, one dedicated to left side ports and one to the right side ports.

Figure 3.4. Metering Panel Front

Figure 3.5. Metering Panel Back

Oxygen Train

The oxygen train must be secured to the floor in a location to be determined by the customer and/or contractor. The oxygen train must be securely bolted to the factory floor using the appropriate size and type of fasteners. The size and type of fasteners must be determined based on the specific system and local regulations. The installing contractor is responsible for determining and providing the correct size and type of fasteners.

Oxygen cleanliness is critical to the operation of an OEAS system. The piping for oxygen must be stainless steel or copper. The customer and/or contractor must supply and install the stainless steel or copper piping for oxygen that connects the oxygen train to the mixer on the staging air flow control train. The interconnecting pipe size is shown on the Eclipse P&ID for the system (reference CD manual). Oxygen stainless steel field piping supplied by the customer to the oxygen train must be sized so that maximum piping velocities do not exceed 30 m/s (98 ft/s) in areas of flow impingement. For copper field piping system design higher piping velocities are allowed but reference the latest version of CGA G-4.4 for guidance. The oxygen piping must be installed according to industry best practices and local regulations.

Staging Air Header

The staging air header distributes air to the various metering spools. The air header usually runs under the ports. The air header for OEAS systems should be fabricated from stainless steel. For BAS only systems (no future OEAS) the air header can be carbon steel. The customer and/or contractor is responsible for installing the connecting piping between the air flow control train and the metering spools/upcomers. The customer and/or contractor must determine the correct elevation for installing the header.

The supply header installation for side port and end port furnaces is different. (See specific project P&IDs for details).

The piping must be installed between the exit on the staging air flow control train and the inlet on the staged air header and sized according to the system Eclipse P&ID. Piping runs should be as short as possible and elbows should be kept to a minimum. Long radius elbows should be used to minimize pressure drop and for low velocity impingement in the case of OEAS (field piping should be cleaned for oxygen service and designed in accordance with the latest version of CGA G-4.4 The oxygen piping must be installed according to industry best practices and local regulations).

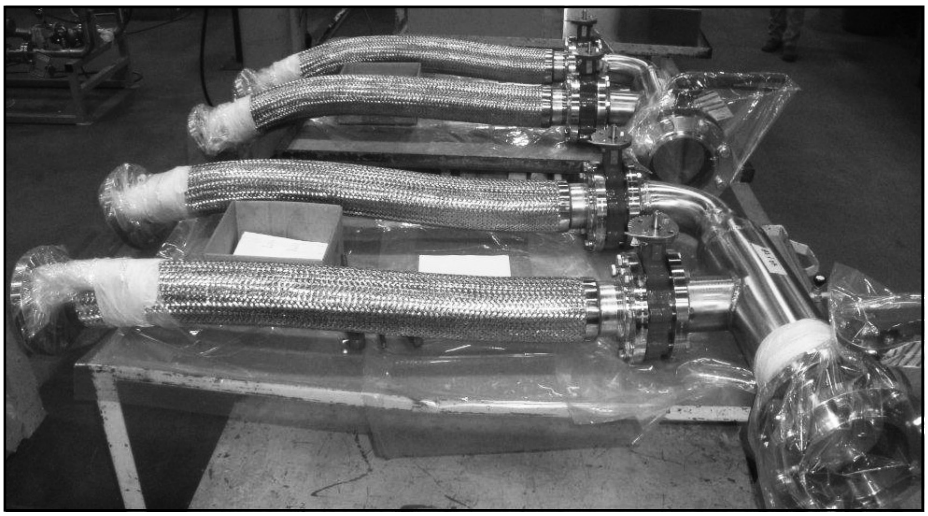

Figure 3.6. Supply Header with Hoses for Endport Furnace (Note: Two injector supply headers shown)

PLC Panel

The PLC panel should be mounted in an air conditioned room on a wall. The customer and/or contractor must determine the desirable location for the PLC panel. The field wiring for the PLC panel must be provided by the customer and/or contractor. All wiring must be installed in accordance with industry best practices and applicable local codes.

The customer's existing furnace control system can be connected to the Eclipse system if required by customer.

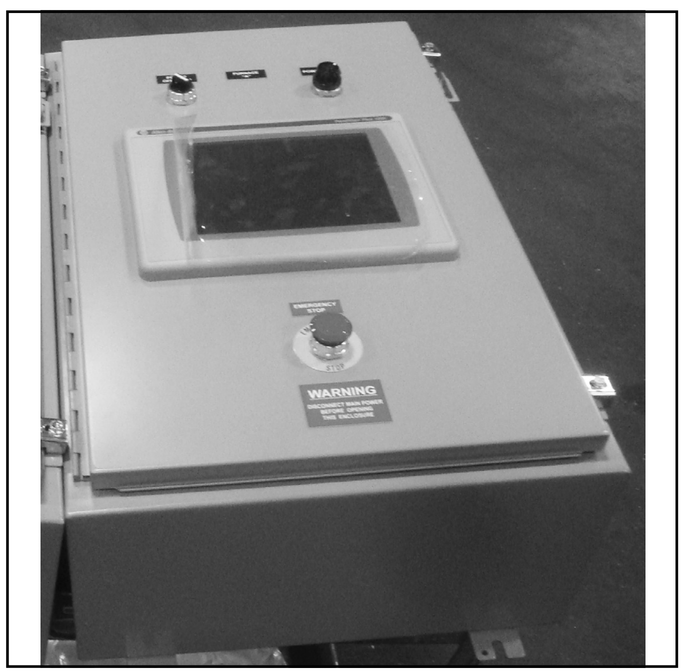

Figure 3.7. PLC Panelview

Miscellaneous:

Gaskets for customer supplied field piping:

Flange gaskets supplied by the customer for OEAS and Oxygen field piping installations should be compatible with oxygen and cleaned for oxygen service. The recommended gasket type is the 1/16” thick Garlock, Gylon, style 3503 PTFE composition, (off white style 3510 cleaned for oxygen service).

Typical Injector Layouts

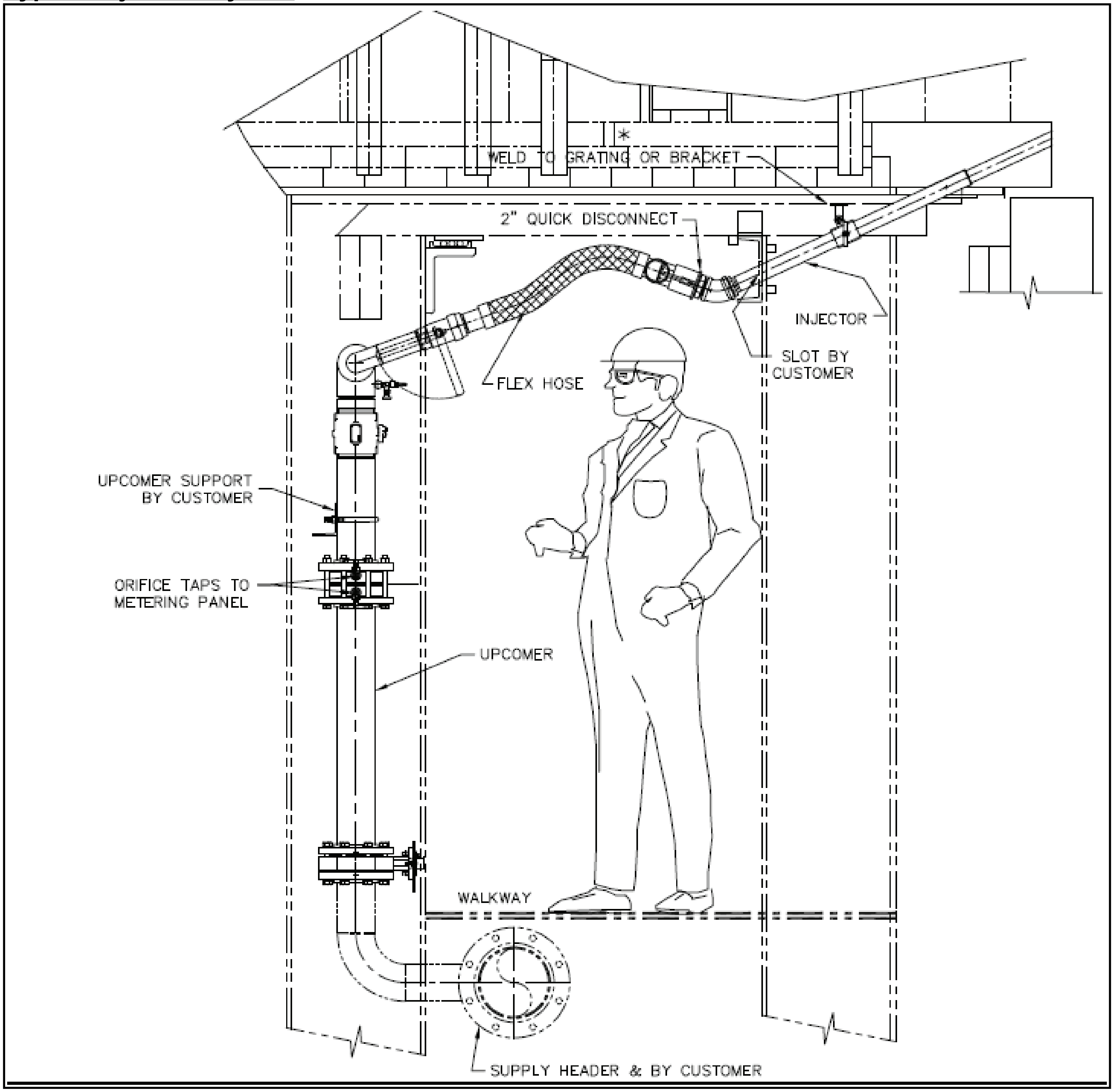

Figure 3.8. SideFired Injector Layout
(Section through port alley between furnace and regenerator)

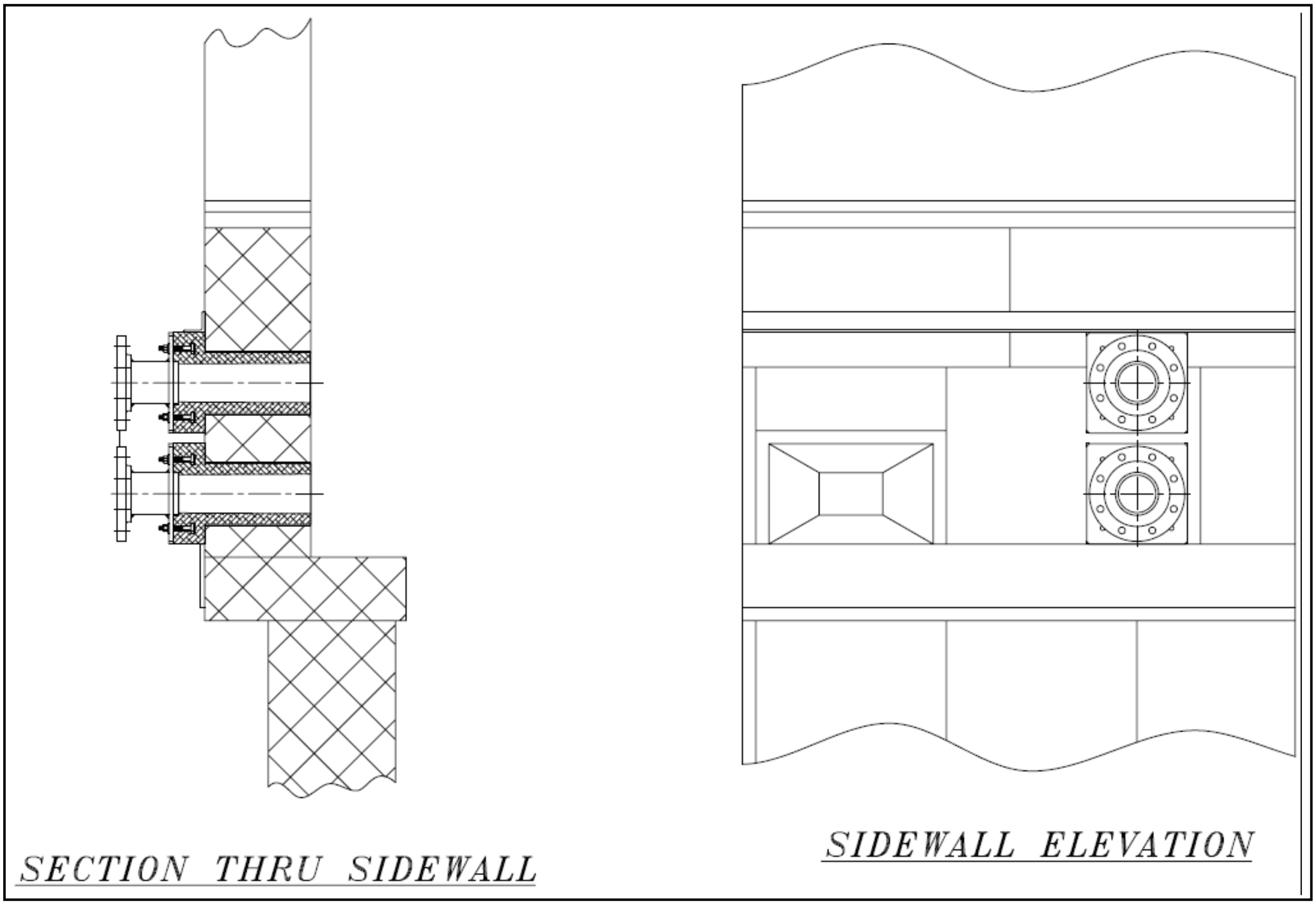

Figure 3.9. SideWall Injector Layout - Endport Furnace

Final Preparations

CAUTION

- **Be sure that OEAS/BAS system operators and personnel have read and understood all the sections of this installation guide before operating the system.**
- **Operators and personnel should also be familiar with the location and functionality of all equipment within the project scope at the site installation.**

Operational Readiness Inspection

Use this inspection as a final preparation for system startup:

1. Be sure the operations manual and equipment CD manual supplied by Eclipse is available for reference.
2. Review the hazards regarding the use of combustion oxygen.
3. Check that all components are installed in accordance with the system drawings.
4. Check that all piping connections have been made correctly and are secure.
5. Review the location of the oxygen system equipment isolation valves.
6. Check the system electrical connections have been made correctly and that the correct power is available.
7. Check the adequacy and proper location of all warning signs. These signs must be clearly visible to anyone in the area of the hazard or potential hazard.
8. Explain to everyone the consequences of improper procedures.
9. Verify that all field piping is clearly labeled. The direction of flow must be conspicuous.
10. Verify that all system piping has been leak tested.

Preparing OEAS/BAS System for startup:

1. Verify power is available at air blowers, air flow control train, main oxygen safety train, metering panels (if applicable) and PLC control system.

2. Close all shut-off valves.

3. Ensure correct supply pressure of combustion oxygen is available.

4. Ensure correct supply pressure of instrument air is available.

5. Notify all personnel in the area that the system is being started.

CAUTION

- **The customer is required to diligently observe the system and respond to any alarms by investigating the cause and correcting deviations or faults prior to proceeding to the next step during the system startup.**

The system is now ready to start.

Adjustment, Start and Stop

4

In this chapter you will find instructions on how to adjust a system, and how to start and stop a system.

⚠ DANGER

- **Do not bypass any safety feature. You can cause fires and explosions.**

Normal Operation of Air Blowers

Introduction

Two Eclipse air blowers with premium efficiency motors are provided for supplying ambient staging air to the air flow control train.

Under normal OEAS/BAS operation one primary blower is running continuously with one secondary blower as standby.

Description

Each blower is provided with the following equipment.

- Inlet filter
- Motor control panel with disconnect switch (panel provided loose for installation by customer).

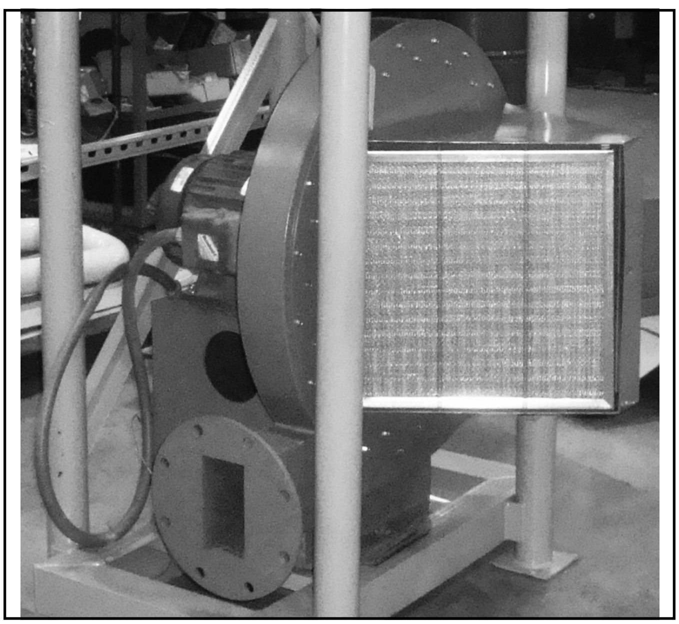

Figure 4.1. Air Blowers

Startup

1. Turn disconnect switch to "ON" position.
2. Ensure E-Stop is "ON" (in pulled position).
3. To select primary blower A, push "BLOWER A START" button; green "ON" light illuminates.
4. Verify blower A is mechanically running and direction of fan blade/rotor rotation is correct. If rotation is incorrect, reverse wiring.
5. To select primary blower B, push "BLOWER B START" button; green "ON" light illuminates.
6. Verify blower B is mechanically running and direction of fan blade/rotor rotation is correct. If rotation is incorrect, reverse wiring.

⚠ WARNING

- **When starting blower B immediately turn off blower A as both blowers should not be run simultaneously for an extended period.**

Shutdown

1. Shutdown of the BLOWER(S) can be achieved by:
   a. Panel blower 'A' or 'B' E-stop button.
   b. Panel main disconnect switch

Normal Operation of Air Flow Control Train

Introduction

The Eclipse air flow control train provides for total flow monitoring and flow control of staging air, injector cooling air, staging air reversal and the option of adding oxygen piped from the main oxygen train via a mixing pipe to enrich the staging air. The air flow control train is located between the blowers and field piping run headers to the upcomers (sideport furnace) or supply headers (endport furnace).

Description

The air flow control train is divided into three main systems: air staging, cooling air and compressed air (may optionally be only provided on the main oxygen train), and electrical. The main components are as follows:

- Air flow control train consists of the following major components, starting at the inlet:
  - Thermometer
  - Low blower air pressure switch
  - Pressure gauge with isolation valve
  - Orifice plate metering system including pressure and temperature compensation
  - Flow control valve with electric actuator
  - Oxygen mixing pipe (optional)
  - Right and left side furnace reversal valves

- Cooling air train consists of the following major components, starting at the inlet:
  - Isolation ball valve
  - Orifice plate metering system with DP magnehelic gauge
  - Isolation globe valves – left and right
  - Solenoid reversal valves – left and right
  - Check valves – left and right
- Compressed air system (optional - may be piped from staging air control train)
  - One set of air filters, including general purpose, coalescing, and adsorbing filters
- Miscellaneous valves
  - Various pressure gauges and isolation valves
  - Pressure relief valve
- Electrical System:
  - Includes complete wiring from each component (except flow control actuator, which is wired directly) to the numbered terminal strips located in JIC box. See the electrical schematic on the technical documentation CD.

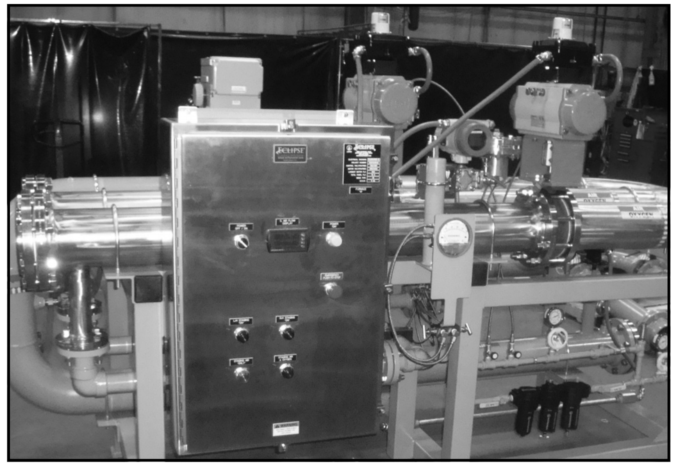

Figure 4.2. Air Flow Control Train

Startup

1. Ensure one blower is running per "Normal Operation of Air Blowers" section, page 22.

2. Turn the off/on selector switch on the control panel to "ON". The white power "ON" light will illuminate.

3. Ensure E-Stop is “ON” (in pulled position).

4. *Air staging left reversal valve opens. The green panel light illuminates.

*Based upon signal received from customer control signal sequence. Left reversal valve opens, right reversal valve closes.

5. Check cooling air solenoid is open. (opposite to staging air reversal side position)

6. Verify panel staging air flow digital display is illuminated and showing flow.

7. Verify flow control valve electric actuator is powered.

8. *Inside panel verify that Flex I/O is illuminated with green light.

***Only a qualified technician is to open the control panel.**

Shutdown

1. Shutdown of the air flow control train can be achieved by:

   a. Pushing "Emergency Push to Stop" button.

   b. Set the panel power on-off switch to "off".

Normal Operation of Main Oxygen Train

Introduction

The Eclipse main oxygen train provides for filtering, safety shutoff, pressure regulation, total flow monitoring and flow control of combustion oxygen. The main oxygen train is located between the plant oxygen generation facility and the mixing pipe on the staging air flow control train.

Description

The main oxygen train is divided into three main systems: combustion oxygen, compressed air (may optionally be only provided on the air flow control train), and electrical. The main components are as follows:

- Combustion oxygen train consists of the following major components, starting at the inlet:
    - Manual shut-off ball valve
    - Y-Strainer
    - One pressure regulator with globe valve bypass valve and isolation valves
    - Two safety shutoff valves
    - One set of high and low pressure switches
    - Orifice plate metering system including pressure and temperature compensation
    - Flow control valve with electric actuator
    - Various pressure gauges and isolation valves
- Compressed air system (optional - may be piped from staging air control train)
    - One set of air filters, including general purpose, coalescing, and adsorbing filters
- Miscellaneous valves
    - Various pressure gauges and isolation valves
    - Pressure relief valve
- Electrical system:
    - Includes complete wiring from each component (except flow control actuator, which is wired directly) to the numbered terminal strips located in JIC box. See the electrical schematic on the technical documentation CD.

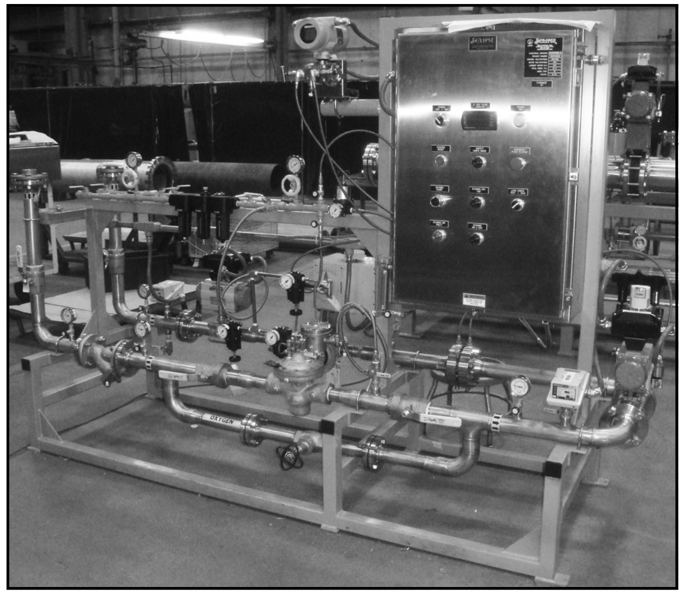

Figure 4.3. Main Oxygen Train

Startup

1. Ensure isolation ball valves are closed.
2. Open oxygen train manual inlet ball valve.
3. Open ball valve to permit compressed air to the selected safety shut off valve pneumatic actuator.
4. Open the outlet valve for the combustion oxygen pressure regulator, then **slowly** open the inlet side valve. Once oxygen starts to flow, adjust the pressure on the dome loaded regulator to hold the desired oxygen pressure.
5. Turn the power off/on selector switch on the safety interlock control panel to "ON". The white power "ON" light will illuminate.
6. Ensure E-Stop is “ON” (in pulled position) and "leak check” selector switch is in the “RUN” position.
7. Push “SYSTEM RESET” button (green). If pressure switches are satisfied the “SAFETY LIMITS MADE” green light will illuminate.
8. Push “OXYGEN START” button. “STAGING OXYGEN ON” green light will illuminate. Primary safety shut off valve will open, secondary safety shut off valve will open with staging air reversal valve signal.
9. Verify panel oxygen flow digital display is illuminated and showing flow.

10. Verify flow control valve electric actuator is powered. Set the flow control valve to manual and open to about 20%. Slowly open the ball valve located downstream of the flow control valve. Oxygen will now flow to the mixer on the air flow control train.

11. *Inside panel verify that Flex I/O is illuminated with green light.

***Only a qualified Technician is to open Control Panel.**

12. Panelview control system instructions on page 26. For staging selection for air or air/oxygen verify SIC panel light is illuminated

Shutdown

1. Shutdown of the main oxygen train can be achieved by:
   a. Manual intervention at the train by closing inlet ball valve.
   b. Pushing “E- Stop” button.
   c. Set the power on-off switch to "Off" on the main oxygen train.
2. Automatic interlock shutdown will occur in the event of the following:
   - Electrical power interruption.
   - Low or high combustion oxygen pressure
   - Blower shut shutdown (low pressure or open contact on motor starter

Oxygen Train Safety Interlock and Control Panel

Introduction

The Eclipse safety interlocks control panel will monitor the status of pressure switches mounted in the main oxygen train. In the event of unacceptable conditions, the system will immediately close the safety shut-off valves.

Description

The safety interlocks control panel consists of one system mounted in an electrical JIC box. Terminal strips wired to system components are provided for ease of installation and troubleshooting.

Safety Interlock Summary

To start the oxy-fuel system, all safety interlocks must be met. Listed below is a summary of all safety switches:

a. Combustion oxygen low - Typ set point 2.0 psig
b. Combustion oxygen high - Set point dependent upon incoming oxygen pressure.
c. Blower air low presssure switch - Typ set point 5" w.c.
d. Blower auxiliary contacts made.
e. E-Stops satisfied.
f. Customer gas safety signal satisfied.

Once these values are within acceptable limits and the appropriate switches are energized, the green safety limits made light on the safety interlock control panel will be lit and the system is ready to be opened.

If combustion oxygen limits are exceeded, combustion oxygen will shut down

Normal Conditions: Operation and Maintenance

1. When removing any component in the oxygen system:
   - Follow plant lockout and safety procedures.
   - Ensure isolation valves are closed.
   - When component is removed, immediately protect exposed ends of pipe left in place to ensure oxygen clean system integrity. The exposed ends should be covered with clean plastic bags secured with rubber bands and sealed with adhesive tape.
   - Ensure component is oxygen cleaned/compatible after servicing/repair/calibration and prior to reinstallation.
   - Always store oxygen service components in clean, sealed, plastic bags. **Use only oxygen compatible materials for service.**

2. If the main inlet strainer becomes plugged, the downstream pressure gauge will show a drop-off in pressure.

3. Pressure regulation is achieved via a Kaye McDonald pressure regulator. If the regulator malfunctions:
   - Open the bypass globe valve.
   - Close the ball valves located before and after the regulator to be isolated.
   - Shutoff compressed air supply to the regulator (if dome is loaded via compressed air.
   - Adjust bypass globe valve to obtain desired downstream oxygen pressure.

Note: Once the regulator is isolated, it can be repaired as needed.

4. Total flow of combustion oxygen is controlled via an adjustable port valve with Honeywell 10260 CAT electric actuator.
   - If the Honeywell Actuator selector switch is set to "Auto," control is via the Furnace PLC Control Instrumentation.

- If the Honeywell Actuator selector switch is set to "Manual," the valve can be controlled via the "increase and decrease" switches at the Actuator.
- If the Honeywell Actuator selector switch is set to "Off," the valve can be controlled at the Actuator by manually operating the hand wheel

Additionally there are several parameters which should be monitored during normal operation:

1. Regularly check the compressed air pressure at pressure gauge. At least 80 psig is required for proper functioning of the two oxygen safety valve actuators and the two air reversal valve actuators.

2. Regularly check static pressures and differential pressures at each of the air and oxygen upcomer orifice plates to verify flow to the injectors.

3. Regularly check cooling air flow meter (magnehelic) to verify cooling air flow to the Injectors.

4. Regularly clean blowers air filters (check daily). If the pressure gauge on the air train is indicating below 50 iwc clean filters.

System Shutdown Procedure

At any undesirable high or low pressure or temperature condition the system will either shut down automatically or for manual intervention the emergency stop button on the control cabinet in the control room or on the electrical panel on the oxygen train can be pushed to stop staging.

Doing so will cause the air reversal valves to shut and the oxygen safety valves to close. On re-start after an Emergency stop, the E-STOP buttons must be pulled out and the flashing RESET E-STOP on the train control screen must be pressed.

Air blowers will remain on to provide cooling air to the injectors. Any shut down of the blowers would be required to be done manually via the disconnect switch.

OEAS Control System Panelview Instructions

The OEAS system consists of a Compact Logix control system with a Panelview Plus 1000 Screen for operator interface, staging blower air control train with an oxygen mixer, oxygen control train, injector headers and Injectors. The Compact Logix controls the system, while the Panelview is used as an interface to change control mode and/or set points of the system.

The touch screen Panelview is provided as the standard operator interface. Touching the area of the screen where changes are needed operates it. By touching the areas of concern, the system changes selector switch position, toggles between different modes of operation, and number keypads come up when different numerical information is needed.

In operation, the staging injectors are injecting staging requirements on the opposite side of the furnace as the flames are firing. If the main flame is on the left side, the injectors are running on the right side, if the main flame is on the right side, the injectors are running on the left side. When the injectors are not running, there is cooling air flowing through them.

Starting Point for Staging Requirement

Before starting the AS/OEAS system, fine tune the combustion system (burner angle, flame length and coverage, etc), make sure the O_2 contents in flue gas is about 0.5 - 2%, take the furnace's flame ratio as the staging system's overall ratio. Set the furnace overall ratio in the staging control system to the ratio the main flames are firing at with no staging. From the furnace control system, lower the main flame ratio by 0.4 - 0.6 (i.e. if the ratio was 10.0, lower it to 9.4 - 9.6). In automatic control the staging control system will automatically put back the correct requirements of air and oxygen to finish the combustion. If lower NOx is required, lower the main flame ratio. If NOx is lower than required, raise the main flame ratio. Adjust the overall furnace ratio parameter in the staging control system to get the desired O_2 (0.5 - 2%) and CO readings. Lowering the overall ratio will increase CO and lower O_2. Increasing the overall ratio will lower CO and raise O_2. In OEAS mode, the oxygen content of the staging mixture can be adjusted between 21 and 40%. Note, 21% is used as a base reference with air only. For the staging system to lower the NOx emissions, the main flame ratio must go below the stoichiometric ratio (the flame needs to be fuel rich). The staging control system will calculate and control the amount of air and oxygen needed to finish the combustion between the main flame ratio and the overall furnace ratio. The overall ratio must be higher than the main flame ratio. See section 4, "Staging Control," page 28, for more detail.

*Initial setup: Before starting the staging system, go to "Configuration," section 6, page 31 and set up the input ranges, flow units, reversal time delay and which mode (1, 2 or 3) of operation that will be used as described in section 4 on page 28.

Main Screens on the Panelview:

Section:

1. Overview Screen
2. Staging Control (start/stop) Screen
3. Manual Staging Control Screen
4. Staging Control (Mode 1, 2 or 3 Run Control)
5. Alarm History Screen
6. Configuration
7. Oxygen Totals

1. Overview Screen

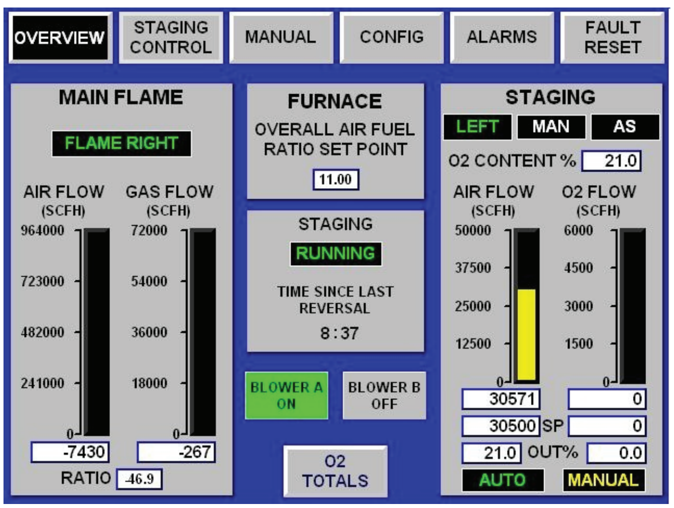

Figure 4.4. Overview Screen

This screen is used to monitor what the staging system is doing. No changes can be made from this screen. In the main flame box, furnace gas and air flow is shown as well as the calculated air fuel (flame) ratio from the furnace, and what side the furnace is firing on. (left, right or off) The furnace box shows the overall ratio set point that the staging system is set to. The staging box shows, actual staging air and oxygen flow, the calculated set point flows for the staging air and oxygen flow, valve position, whether the system is in OEAS or AS (air staging) mode, what side is staging (left, right or off), and if the system is in Mode (1, 2 or 3) or manual operation. The O_2 totals button will display the oxygen totals screen.

2. Staging Control

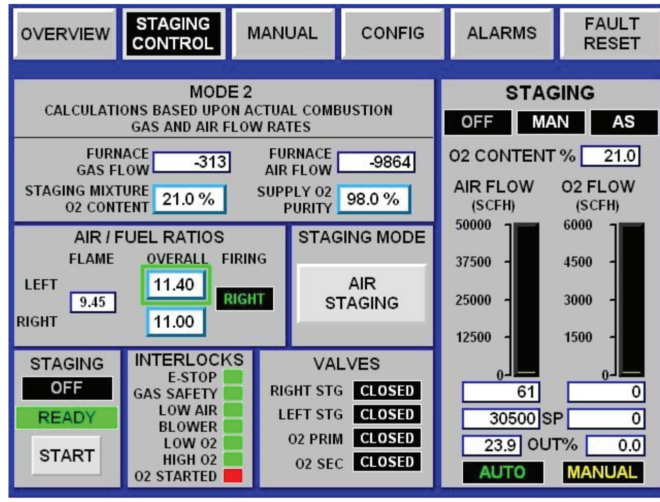

Figure 4.5. Staging Control

From this screen, the staging can be started or stopped, OEAS or AS can be selected. Staging mode OEAS or AS, pressure interlocks (high, low oxygen and air pressure), left and right staging reversal valves open or closed and primary and secondary oxygen valves open or closed can be monitored.

Starting the Staging System

To start the staging system, select AS or OEAS as the staging mode, go to the manual screen (section 3, pg 28) and put the staging air control in manual control and set the air valve to 15 - 20% open and the oxygen valve (if required) to 0 - 5% open.

Note: the oxygen valve can only be adjusted if in the OEAS mode. Make sure the interlocks are satisfied. When the interlocks are satisfied READY will be displayed above the start button.

AS Mode Interlocks: Select AS for staging mode

- All E-stop buttons are satisfied
- Customer gas safety signal is satisfied
- Blower is turned on, motor contactor is closed and contact switch is satisfied
- Low air pressure switch is satisfied
- No Alarm conditions exist.

OEAS Mode Interlocks: Select OEAS for staging mode

- All E-stop buttons are satisfied
- Customer gas safety signal is satisfied
- Blower is turned on, contactor is closed and contact switch is satisfied
- Low air pressure switch is satisfied
- Manual oxygen valves has been opened on the Oxygen train
- Low/high oxygen pressure switches are satisfied

Push fault reset button to reset system, if all is OK, the button will not be blinking red.

For OEAS mode, go to the oxygen train and push the oxygen start button, the primary oxygen valve should open. Make sure the test/run switch is in run position. In test position the secondary oxygen valve will not open. The secondary oxygen valve will open when either the left or right staging air valves are open in the OEAS mode.

Push the staging start button and it will move from a start button to the stop button and staging is now running.

To manually control staging air flow, see section 3 below. For automatic control, see section 4.

3. Manual Staging Control Screen

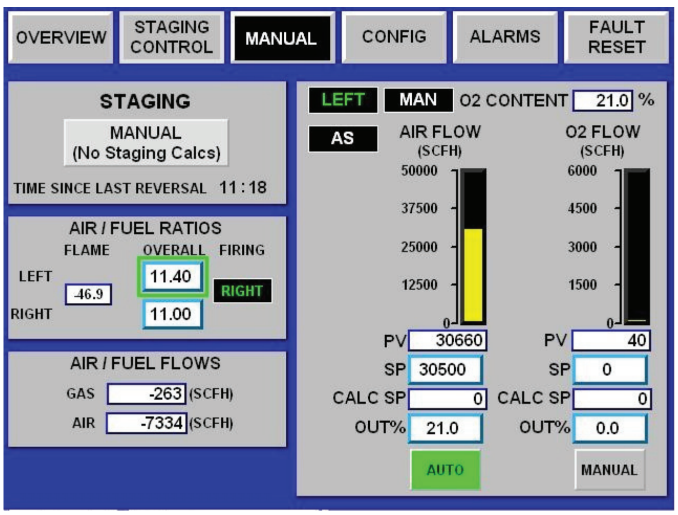

Figure 4.6. Manual Staging Control Screen

The Manual Control Screen allows the operator to switch from manual to automatic control, manually control what valve percentage for the staging air and oxygen valve, put in an air set point, select either manual by valve position control or manual flow rate. This screen monitors, (Left, Right or off) staging, manual or mode (1, 2 or 3) operation, air flow, calculated air flow set point, manual air set points, and valve position.

***Manual or automatic control can only be changed from the Manual Staging Control Screen.**

Manual Mode:

To put the system in manual control, push the staging and flow auto/manual buttons on the screen to manual mode. In the right upper part of the staging box, the small box should read MAN.

There is two ways to control this system in manual mode, valve position control or flow rate control. In the manual mode control box, select which mode of manual control is required. Pushing the selector switch changes this mode.

- Valve Position Control

  In this manual mode, the air and oxygen valves are driven to what percent open that the operator puts in. The percentage can be changed by pushing the OUT% value box on the staging air or oxygen flow controls and typing in what percent is needed. The actual flow can be monitored below the bar graphs in the staging box on this screen.

- Flow Rate Control

  In this manual mode, the operator can set the air and oxygen flow rates. Push the auto/manual button on the air or oxygen flow control to place it in manual, verify/set the staging control to manual. The flow rates can be entered in by pushing the SP value box on the staging air flow. When pushed, type in the flow rate parameter needed. The system will automatically hold the parameters put in for air in this mode. The actual and manual set point flow is also displayed in the staging box on this screen.

Automatic Mode:

To put the system in automatic control, push the staging and flow auto/manual buttons to auto. In the center upper part of the staging box, the center small box should read MODE (1, 2 or 3) depending on what automatic mode the system is in.

Note: before putting the system in automatic mode, manually adjust the flows to be close to the calculated set point shown in the staging box so there will be smooth transition to automatic control.

4. Staging Control (Mode 1, 2 or 3 Run Control)

Only one of these staging control screens (Mode 1, 2 or 3) will be used at one time. The mode is determined by the customer inputs and is chosen in section 6, page 32, "Selecting the Auto Stage Mode." Look at the information below for what mode (1, 2 or 3) the system is operating in for automatic control. The Mode (1, 2 or 3) screen comes up when the Staging Control button is pushed from any screen having this button.

*** For the staging system to lower the NOx emissions, the main flame ratio must go below the stoichiometric ratio (the flame needs to be fuel rich). The staging control system will control the amount of staging mixture to complete proper combustion. The amount of staging mixture is determined by the difference between the overall air fuel ratio and the main flame ratio. When higher amounts of staging are required, higher staging mixture oxygen content is needed to make the system work more efficient to complete the combustion process.

Mode 1 Run Control:

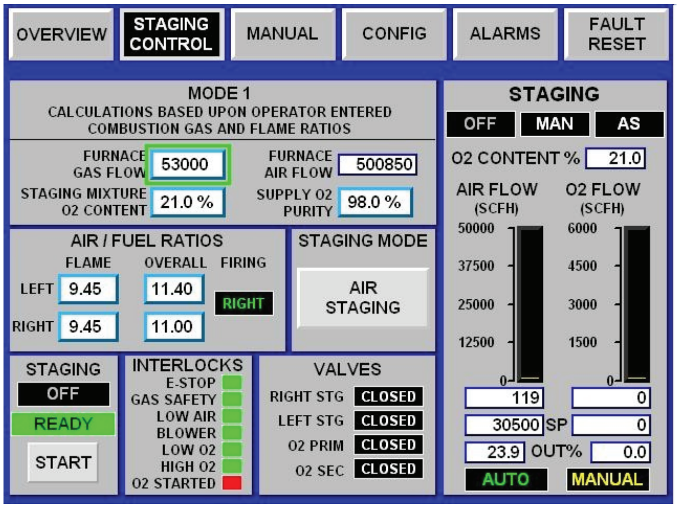

Figure 4.7. Mode 1 Run Control

Mode 1 is used when there are no 4-20ma signals coming into the staging system representing the furnace gas and combustion air flow. Gas flow and main flame ratio are manually put in and the combustion air flow is automatically calculated from this. Changes to parameters on this screen are done by pushing the box that the change is to be made and typing in the new data.

From this screen the operator can put in staging furnace gas flow, left and right main flame ratios, and left and right overall ratios. This screen monitors the calculated furnace air flow, (left, right or off) staging, manual or Mode 1 control, OEAS or AS Mode, actual oxygen % of staging mixture, actual staging air and oxygen flow rates, staging air and oxygen set points and valve positions.

Furnace Gas Flow: The melter gas flow must be manually entered into this box. The staging system will control to what value is put in. If the furnace gas flow changes, the operator must make a change in this box.

Flame Air Fuel Ratio: A left and right side melter flame ratio must be manually entered into these boxes. The staging system will look at what side is firing and use these values for the staging calculations on that side. Note: the flame ratio must be lower than the overall ratio and the main flame needs to be fuel rich for staging to lower NOx. If the furnace flame ratio changes, the operator must make a change in this box. Changes to the furnace main air fuel ratio need to be done in the furnace control system.

Furnace Air Flow: The furnace air flow is automatically calculated from the operator inputted furnace gas flow and left or right flame air fuel ratio depending on what side is firing. The box labeled Firing shows what side the furnace is currently firing on.

Overall, Air Fuel Ratio: A left and right side furnace overall ratio must be manually entered into these boxes. The staging system will look at what side is firing and use these values for the staging calculations on that side. The staging air and oxygen flows are calculated by the difference between the overall air fuel ratio and the flame air fuel ratio. Note: the overall air fuel ratio must be higher than the flame air fuel ratio.

Supply Oxygen Purity Box: In this box, put in the purity of the oxygen being used, between 80 and 100%. Liquid oxygen is typically 99.9%. See oxygen supplier for the purity of their oxygen.

Staging Mixture Oxygen Content Box: In this box, put in the percent oxygen that the staging mixture is to be, between 21 and 40%. 21% is used for air only, no extra oxygen is required. For 27% staging mixture oxygen content, the system will add the amount of oxygen to the air to make the staging mixture have 27% oxygen. Note: in AS Mode, it will be fixed at 21%. The higher the oxygen content reduces the total amount of staging air required. When higher amounts of staging is required, higher oxygen content is needed to make the system work more efficient to complete the combustion process.

Mode 2 Run Control:

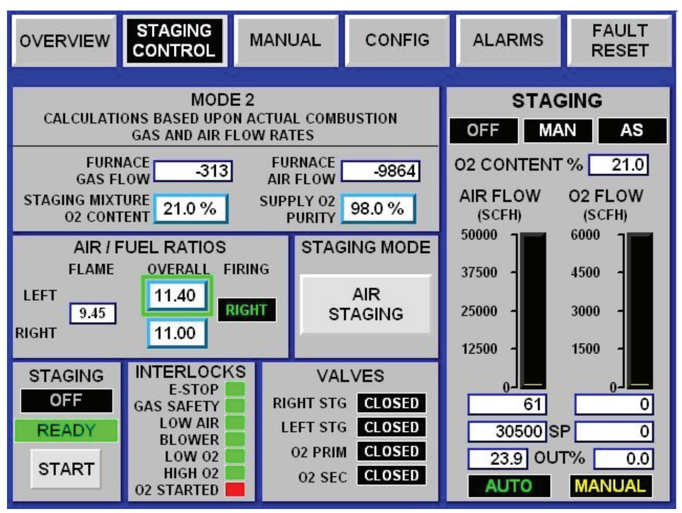

Figure 4.8. Mode 2 Run Control

Mode 2 is used when there are 4-20ma signals coming into the staging system representing the furnace gas and combustion air flow. The staging control system will automatically update staging requirements as the actual furnace air and gas flow change. The main flame air fuel ratio is automatically calculated from the incoming gas and combustion air signals. Changes to parameters on this screen are done by pushing the box that the change is to be made and typing in the new data.

From this screen the operator can put in staging left and right overall ratios. This screen monitors the furnace gas and combustion air flow rates, calculated furnace main flame air fuel ratio, (left, right or off) staging, manual or Mode 2 control, OEAS or AS Mode, actual oxygen % of staging mixture, actual staging air and oxygen flow rates, staging air and oxygen set points and valve positions.

Furnace Gas Flow: The furnace gas flow will be automatically displayed this box. The staging system will control staging outputs according to the actual gas flow used in the furnace. If the furnace gas flow changes the system will automatically see the change and make the necessary adjustments to the outputs.

Flame, Air Fuel Ratio: The furnace flame air fuel ratio will be automatically calculated from the incoming gas and combustion air signals from the furnace control system. Note: the flame ratio must be lower than the overall ratio and the main flame needs to be fuel rich for staging to lower NOx. Changes to the furnace main air fuel ratio needs to be done in the furnace control system.

Furnace Air Flow: The furnace combustion air flow will be automatically displayed this box. The staging system will control staging outputs according to the actual combustion air flow used in the furnace. If the furnace combustion air flow changes the system will automatically see the change and make the necessary adjustments to the outputs.

Overall, Air Fuel Ratio: A left and right side furnace overall ratio must be manually entered into these boxes. The staging system will look at what side is firing and use these values for the staging calculations on that side. The staging air and oxygen flows are calculated by the difference between the overall air fuel ratio and the flame air fuel ratio. Note: the overall air fuel ratio must be higher than the flame air fuel ratio. The box labeled Firing shows what side the furnace is currently firing on.

Supply Oxygen Purity Box: In this box, put in the purity of the oxygen being used, between 80 and 100%. Liquid oxygen is typically 99.9%. See oxygen supplier for the purity of their oxygen.

Staging Mixture Oxygen Content box: In this box, put in the percent oxygen that the staging mixture is to be, between 21 and 40%. 21% is used for air only, no extra oxygen is required. For 27% staging mixture oxygen content, the system will add the amount of oxygen to the air to make the staging mixture have 27% oxygen. Note: in AS Mode, it will be fixed at 21%. The higher the oxygen content reduces the total amount of staging air required. When higher amounts of staging is required, higher oxygen content is needed to make the system work more efficient to complete the combustion process

Mode 3 Run Control:

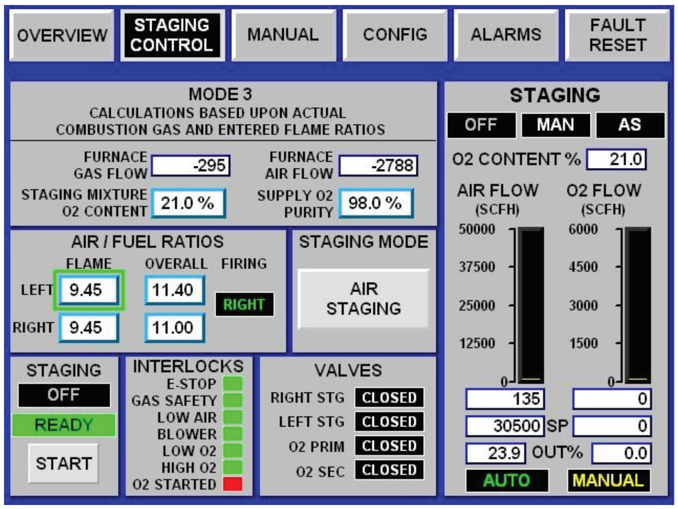

Figure 4.9. Mode 3 Run Control

Mode 3 is used when there is a 4-20ma signal coming into the staging system representing the furnace gas flow and no signal for the furnace combustion air flow. The staging control system will automatically up date staging requirements as the actual furnace gas flow changes. Main flame left and right air fuel ratio is manually put in, and the air flow is automatically calculated from this. Changes to parameters on this screen are done by pushing the box that the change is to be made and typing in the new data.

From this screen the operator can put in staging mixture oxygen content, supply oxygen purity, left and right main flame ratios, and left and right overall ratios. This screen monitors furnace gas flow rate, the calculated furnace air flow, (left, right or off) staging, manual or Mode 3 control, OEAS or AS Mode, actual oxygen % of staging mixture, actual staging air and oxygen flow rates, staging air and oxygen set points and valve positions.

Furnace Gas Flow: The furnace gas flow will be automatically displayed this box. The staging system will control staging outputs according to the actual gas flow used in the furnace. If the furnace gas flow changes the system will automatically see the change and make the necessary adjustments to the outputs.

Flame, Air Fuel Ratio: A left and right side furnace flame ratio must be manually entered into these boxes. The staging system will look at what side is firing and use these values for the staging calculations on that side. Note: the flame ratio must be lower than the overall ratio and the main flame needs to be fuel rich for staging to lower NOx. If the furnace flame ratio changes, the operator must make a change in this box. Changes to the furnace main air fuel ratio needs to be done in the furnace control system.

Furnace Air Flow: The furnace air flow is automatically calculated from the incoming furnace gas flow rate and the operator inputted furnace left or right flame air fuel ratio depending on what side is firing. The box labeled Firing shows what side the furnace is currently firing on.

Overall, Air Fuel Ratio: A left and right side furnace overall ratio must be manually entered into these boxes. The staging system will look at what side is firing and use these values for the staging calculations on that side. The staging air and oxygen flows are calculated by the difference between the overall air fuel ratio and the flame air fuel ratio. Note: the overall air fuel ratio must be higher than the flame air fuel ratio. The box labeled Firing shows what side the furnace is currently firing on.

Supply Oxygen Purity Box: In this box, put in the purity of the oxygen being used, between 80 and 100%. Liquid oxygen is typically 99.9%. See oxygen supplier for the purity of their oxygen.

Staging Mixture Oxygen Content Box: In this box, put in the percent oxygen that the staging mixture is to be, between 21 and 40%. 21% is used for air only, no extra oxygen is required. For 27% staging mixture oxygen content, the system will add the amount of oxygen to the air to make the staging mixture have 27% oxygen. Note: in AS Mode, it will be fixed at 21%. The higher the oxygen content reduces the total amount of staging air required. When higher amounts of staging is required, higher oxygen content is needed to make the system work more efficient to complete the combustion process

5. Alarm History Screen

Figure 4.10. Alarm History Screen

From this screen system alarms can be viewed, acknowledged and cleared.

When an alarm occurs, it will be recorded on this screen with a time and date. The alarm will also show as a pop-up on any screen when it happens, the alarm at this point can be accepted or acknowledged to get it off that screen. The alarm will be on this page in alarm history. The alarm history can be cleared by touching the clear history box. To get out of the alarm history screen, touch the go to over view box or Auto Stage Screen box depending on what screen is wanted

6. Configuration

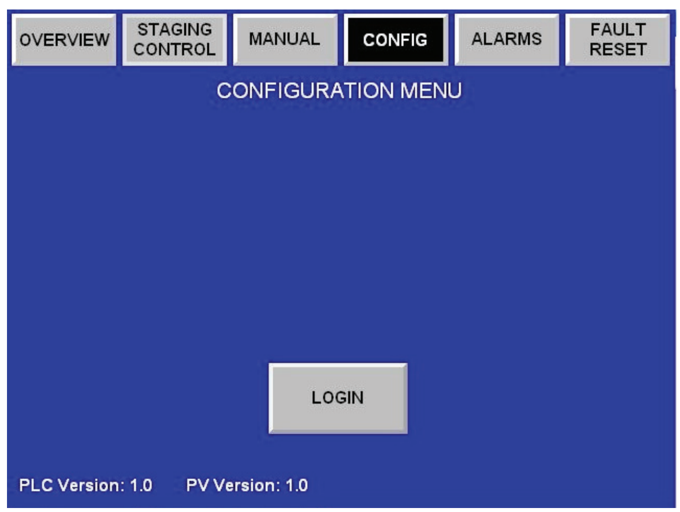

Figure 4.11.

To access the configuration menu, a password is required. Push the login button and a window will pop-up requesting user name and password. User name is op. Default password is 1234. When successfully logged in the configuration menu will be displayed as shown below.

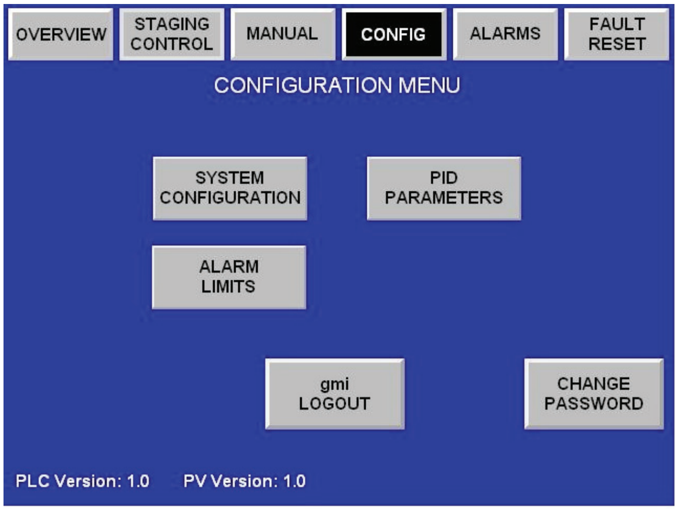

Figure 4.12.

The login button will change to a logout button with the user name displayed. To change the password of the current logged in user push the change password button.

System Configuration

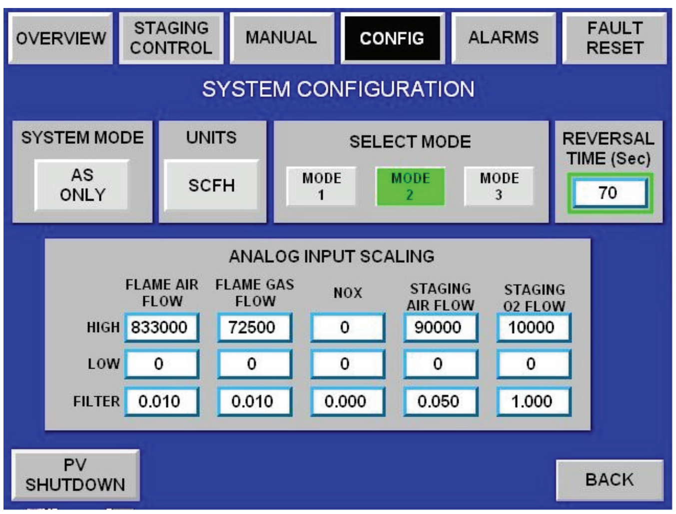

Figure 4.13. System Configuration

Changes to this screen should be done when staging is off.

This screen is used to set up the input ranges for the staging air and oxygen flow, input ranges for the furnace air and gas flow, select the mode of operation, Mode (1, 2 or 3), select the units of flow SCFH or NM3/HR), put in the reversal time delay, and select system mode.

Setting up input ranges and flow units:

In the box labeled "units," select the units by pushing the box with the units, it will change between SCFH and NM3/HR

In the Analog Input scaling boxe, push the button corresponding to the parameter being put in.

High and Low Flow: In these parameters, put the minimum flow rate in the out min flow box and the maximum flow rate in the out max flow box that corresponds to the 4-20ma signal or flow rate being represented.

Filtering: Enter a number for the amount of filtering. A value of 1.0 is no filtering, lower the number less than 1.0 the more filtering is applied.

Selecting the Auto Stage Mode (1, 2 or 3) Run Control:

In the box labeled "select mode," push the mode number box that is to be used for your systems staging control and operation. There are three different modes that can be used; only one will be used at a time. The mode chosen will be the screen that comes up for the Staging Control. See the description below to determine which mode to use.

Mode 1: Calculations are based upon operator entered gas and air flow rates. This is used when there are no 4-20ma signals coming into the staging system representing the melter gas and combustion air flow. The operator must manually type in the melter gas flow and the flame air/gas ratio, which calculates the air flow. The staging system will automatically control staging outputs and will only change staging outputs when the operator makes a change to the inputs.

Mode 2: Calculations are based upon actual gas and air flow rates. This is used when there are 4-20ma signals coming into the staging system representing the furnace gas and combustion air flow. The Staging system will automatically read the air and gas flow from the furnace control system and adjust staging outputs as the gas and air flow changes. Flame ratio is automatically calculated based on the incoming gas and air flow rates.

Mode 3: Calculations are based upon actual gas flow, but entered air flow rates. This is used when there is a 4-20ma signal coming into the staging system representing melter gas flow rate, but there is no 4-20ma signal representing combustion air flow. The operator will type in the melter flame air/gas ratio. The system will automatically calculate the air flow based on the incoming melter gas flow signal and the manually entered air/gas ratio. The staging system will automatically read the gas flow signal from the melter control system and adjust staging outputs as the gas flow changes based upon the operator entered air/gas ratio.

Required inputs: There must be a signal from the furnace control system for when the furnace is firing left and right, emergency stop input, and a signal that the main gas safety valve is open.

Flow inputs: Linear 4-20ma signals for gas and combustion air flow when used.

Setting the reversal delay time:

The reversal delay time is used to hold the system in manual for a period of time after the furnace has completed the reversal and started firing again. The staging system will manually hold the last position of the valves when the furnace is in a reversal cycle, when the furnace has started firing again, it will go back into automatic control when the reversal delay time has timed out. The amount of time is determined by how long it takes the incoming combustion air and gas signal to stabilize. The time can be set between 0-300 seconds (0-5 minutes). A starting point can be 120 seconds.

PV Shutdown:

This button allows the operator to shutdown normal Panelview operations and go to the Panalview setup screen and set the correct time in the Panalview. This allows for the proper time to be recorded for the alarms. To get out of config mode, push the run mode button

PID Adjusting Screen

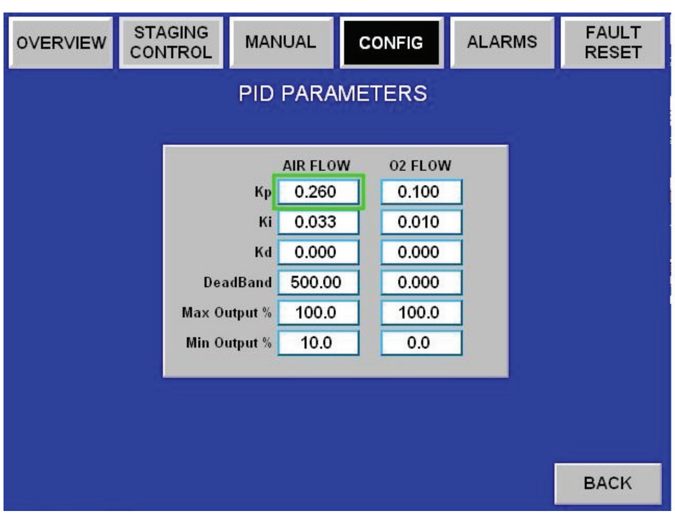

Figure 4.14.

From this screen an operator can put in the loop tuning constants; gain, integral, derivative, dead band and min/max output %. The tuning constants need to be adjusted so the loop control is stable, see below table for reference on starting points.

The Min PID output % allows the operator to put in a percentage that the automatic valve will not go below in automatic control. Typically would set the air valve at 15 - 20% for the min so the air will not shut off to the injectors, which may cause overheating. This does not affect manual operation in Valve Position Control.

The Max PID output % allows the operator to put in a percentage that the automatic valve will not go above in automatic control. This does not affect manual operation in Valve Position Control.

Typical Starting Points for Tuning Constants

Parameters	**Air Flow Actual**
Gain (Kp)	0.260
Integral (Ki)	0.033
Derivation (Kd)	0
Deadband	500
Minimum Out	15
Maximum Out	90

Alarm Limits

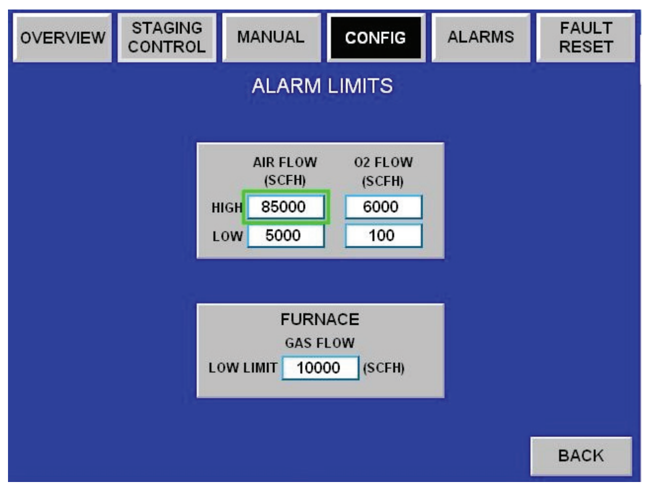

Figure 4.15.

This screen allows the operator to put in high and low flow limit alarms for the staging air and oxygen. If the flow goes out of these limits, the system will send out an alarm.

This screen is used to monitor how much oxygen is used in a day and what was used on the previous day. Set PLC time to the current date and time. Set the counter rollover time to the time the counter is to start and stop counting for the day. At that time it sends the information to the previous 24 hours and starts counting the oxygen consumption for the current time.

7. Oxygen Totals

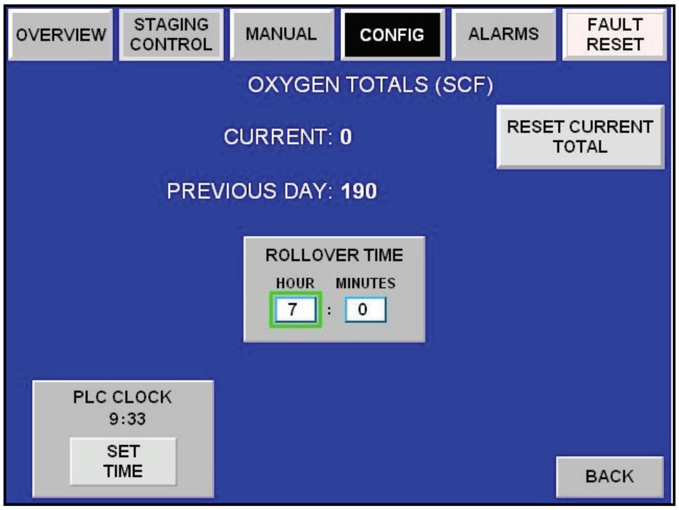

Figure 4.16.

The PLC will totalize the oxygen flows on a daily basis. The oxygen totals are displayed as current day and previous day. When the rollover time is reached the current day value is moved to the previous day and the current day total is reset to zero. The rollover time can be set by entering in the hour an minutes of the desired rollover. The current day total can be reset at any time by pressing the reset current total. The PLC clock is used to determine the rollover it can be set by selecting the set time button.

Panelview Alarms

There are several alarms that can occur during staging operation. Most alarms, if prolonged, will result in an automatic emergency stop of the system. If an emergency stop occurs, staging will stop (reversal valves close), the oxygen safety valves will close, and the blowers will turn off. Below is a description of each alarm, probable causes, and the staging controller's response.

1. Furnace Gas Safety Valve Closed: If the furnace's gas safety valve closes the staging system will go to an immediate emergency stop. The furnace alarm system will sound, an alarm banner will appear on the Panelview screens, and the alarm will be recorded in the alarm history.

2. Staging Set Point Too Low: If either the staging air requirements dip below 10,000 scfh or the staging oxygen requirements dip below 500 scfh for more than five seconds an alarm will be triggered. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, and a 300 second countdown clock will be started. If the setpoint flows are not raised within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents unnecessary operation of the staging system.

3. Low Oxygen Pressure: Oxygen supply pressure below 2 psig for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screen, the furnace alarm system will sound, the alarm will be recorded, and a 300 second countdown clock will be started. If the supply pressure is not raised within 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with inadequate supply pressures.

4. High Oxygen Pressure: Oxygen supply pressure above 15 psig for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm be recorded, and a 300 second countdown clock will be started. If the supply pressure is not lowered within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with excessive supply pressures.

5. Low Air Pressure: Blower air pressure less than 15" w.c. for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm be recorded, and a 300 second countdown clock will be started. If the supply pressure is not raised within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with inadequate supply pressures. The most probable causes are a failed motor or clogged air filter.

6. Low Oxygen Flow: Oxygen flow below the values set in the flow limit screen for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm be recorded, and a 300 second countdown clock will be started. If the flow is not raised within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with low flow conditions.

7. High Oxygen Flow: Oxygen flow above the value set in the flow limit screen for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm will be recorded, and a

300 second countdown clock will be started. If the flow is not lowered within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with high flow conditions.

8. Low Air Flow: Air flow below the value set in the flow limit screen for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm will be recorded, and a 300 second countdown clock will be started. If the flow is not raised within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with low flow conditions.

9. High Air Flow: Air flow above the value set in the flow limit screen for more than 5 seconds will trigger an alarm. This will result in an alarm banner being displayed on the Panelview screens, the furnace alarm system will sound, the alarm will be recorded, and a 300 second countdown clock will be started. If the flow is not lowered within the 300 second period the staging system will go to an automatic emergency stop. This alarm prevents prolonged operation of the staging system with high flow conditions.

10. Overall Air Fuel Ratio < (less than) Flame Air Fuel Ratio: In local staging control mode if the operator enters an overall furnace air fuel ratio less than the primary flame's air fuel ratio an alarm will be triggered. An alarm banner will appear on the Panelview screens and the alarm will be recorded, however the furnace alarms will not sound since the operator will be present. The controller will continue to use the previous set point until the error is corrected. This alarm prevents faulting the processor do to a math error.

Likewise, in remote staging control mode, if the operator enters an overall furnace air fuel ratio less than the flame's actual air fuel ratio (based on combustion air and gas flow) an alarm will be triggered.

System Checklists

OEAS and BAS - Air Train			
	Blower A	rotation	motor starter contacts air panel ch. 4
	Blower B	rotation	motor starter contacts air panel ch. 5
	low prs switch setting		confirm setting, function, SLC indication
	multi variable transmitter		confirm programming, zero, SLC indication
	flow control valve	function	smooth operation, proper response to control signal
	reversal valves left/right	function	confirm piping to proper side of furnace
	flow display		confirm configuration
	cooling air solenoid	function	
	cooling air DP		total scfh, 500 scfh/injector sideport. 1000 scfh/injector endport
	instrument air	80 psi	confirm adequate pressure, throttling to actuators
	electrical panel	wiring	confirm field wiring, connections secure

OEAS only - Oxygen Train			
	Regulated pressure		confirm regulator function, proper outlet pressure
	LPS setting		confirm switch function, setting, PLC indication
	HPS setting		confirm switch function, setting, PLC indication
	SSOVs	function	confirm PLC indication
	FCV	function	smooth operation, response to control signal
	MVT		confirm programming, zero, PLC indication
	Display		confirm configuration
	Electrical panel purge flow	5-6 scfh	panel vent open (purge not required on intrinsically safe units)
	Electrical panel purge pressure	minimum	minimum required to achieve proper flow
	Electrical panel	wiring	confirm field wiring, connections secure
	Instrument air	80 psi	confirm adequate pressure

OEAS and BAS - Metering Panel (Side Port Furnace)			
	RTD tied back to air train		
	multi variable transmitter		confirm programming, zero
	flow display	wiring	confirm configuration
	multi port valves	function	confirm function, sensing lines to proper location, DP readings correct

OEAS and BAS - Login Screen			
	enter username	op	
	enter password	1234	customer can change as required

OEAS and BAS - System Configuration Screen (password login required)			
	staging mode		
	air flow display units		
	staging minimum flow air	0	
	staging maximum flow air		

OEAS and BAS - System Configuration Screen (password login required)			
	staging minimum flow oxygen (OEAS only)	0	
	staging maximum flow oxygen (OEAS only)		
	furnace out minimum flow air	0	from customer
	furnace out maximum flow air (OEAS only)		from customer
	furnace out minimum flow gas (OEAS only)	0	from customer
	furnace out maximum flow gas		from customer
	reversal delay time	as required	

OEAS and BAS - Input Signal Filtering (1.0 = 0 filtering, values below 1.0 add filtering)			
	primary combustion air	as required	0.010
	gas	as required	0.010
	staging air	as required	0.050
	staging oxygen (OEAS only)	as required	

OEAS and BAS - PID Adjusting Screen (access from configuration screen)			
		Typical Setting	**Final Setting**
	KP gain air	0.26	
	KI integral air	0.33	
	KD derivative air	0	
	dead band air	500	
	minimum PID output air %	15	
	maximum PID output air %	90	
	KP gain oxygen (OEAS only)	?	
	KI integral oxygen (OEAS only)	?	
	KD derivative oxygen (OEAS only)	?	
	dead band oxygen (OEAS only)	?	
	minimum PID output oxygen % (OEAS only)	0	
	maximum PID output oxygen % (OEAS only)	90	
	PLC internal time - PV (panelview) Shutdown - System configuration - Terminal Settings - Run Application to Exit		

OEAS and BAS - Flow Alarm Limits Screen (access from configuration screen)			
	low air flow	5000	
	high air flow		maximum flow - 1000
	low oxygen flow (OEAS only)	500	
	high oxygen flow (OEAS only)		maximum flow - 500
	furnace gas low limit	10,000	

OEAS and BAS - Overview Screen
System monitoring only

OEAS and BAS - Staging Control Screen			
	staging start/stop selection		check operation
	staging mode selection	AS/OEAS	check operation
	fault reset		check operation
	monitor pressure interlocks		check operation
	monitor reversal valves	open/close left/right	check operation
	mode	2	
	furnace gas flow		automatically displayed
	furnace air flow		automatically displayed
	flame ratio left/right		automatically displayed
	overall ratio left		enter prior to staging
	overall ratio right		enter prior to staging
	oxygen content % (OEAS only)		enter prior to staging

OEAS and BAS - Manual Control Screen			
	manual/auto mode selection		check operation
	manual flow control	air	confirm control via "flow control" or "valve position"
	manual flow control (OEAS only)	oxygen	confirm control via "flow control" or "valve position"

OEAS and BAS - Alarm History Screen
Records alarm occurrences, clears alarms
Alarms may appear on any screen, acknowledging an alarm will remove it from the screen and store it in the alarms history

OEAS and BAS - Final Ratio Information				
Firing Left			Firing Right	
Baseline Ratio			Baseline Ratio	
Final Ratio Reduction			Final Ratio Reduction	
Flame Ratio			Flame Ratio	
Overall Ratio			Overall Ratio	

Port Balancing For Lower Emissions

Pre OEAS/BAS glass furnace port balancing for lowered emissions (BrightFire or similar burner)

Balancing port gas flows is an important part of maintaining the operation of the combustion system as well as aiding in the control of emissions.

On a typical side port furnace there will be two burners per port. (one on each side) Both burners on any given port should have equal gas flow and be adjusted as a pair. Some provision should be in place for balancing gas flow to individual burners (pressure reading would be the minimum requirement). An imbalance here can lead to over or under firing of a burner, difficulty in achieving good flame geometry and upset the process of controlling emissions.

Port to port balancing should be performed to maintain equal proper air/fuel ratios across the ports. Again, improper balancing here can lead to problems with controlling emissions. One port with improper ratio can become an “emissions generator” and throw the entire furnace out of compliance.

After reversal allow the gas and air flow to stabilize.

Place gas flow control to manual. (In some case the air may also need to be in manual)

Adjust gas flow balance to individual burners of each port and establish good flame geometry.

Flame length should be as long as possible (at least 2/3 of the furnace width) short of entering the far side port or lofting to the point of contacting the furnace crown. Attempts should be made to separate the flames of each port as much as possible without impinging on refractory surfaces to help lower emissions. Flames should be adjusted to get the lowest possible NOx levels.

Record flue gas analysis in the regenerator for each port.

Adjust gas flow to each port as required to achieve 0.5 to 1.0% excess Oxygen in the exhaust stream. (high CO levels may be reduced by adjusting burner angles/velocity to improve mixing) Excess O_2 levels and CO should be kept similar per port.

The technique for this may vary depending on conditions. Typically you can add fuel to a port with high excess Oxygen readings. This will redistribute the gas flow from the manifold and take fuel away from ports with lower excess Oxygen readings. In some cases it may be necessary to do the opposite and lower fuel flow to a port with low excess Oxygen readings in order to redistribute the flow. In this case you will need to be careful not to “choke” one port to the point that any required fuel flow cannot be achieved.

If a good excess Oxygen balance is achieved across the ports but is outside of the 0.5 to 1.0% window adjust the air/fuel ratio to bring the levels in line. (a side to side ratio bias may be required depending on conditions)

This can be a time consuming process. The furnace will typically fire on one side for twenty to thirty minutes. In some cases it may be possible for the operator to delay the reversal, but you will still have limited firing time per side for adjustments and flue gas analysis.

*Remember that the furnace is the “boss” when attempting to lower emissions. A temperature profile in the furnace may be desirable, but combustion air flow through a given port will dictate the fuel flow for that port based on the flue gas analysis.

OEAS/BAS Balancing (BrightFire or similar burner)

Balancing port gas flows is an important part of maintaining the operation of the combustion system as well as aiding in the control of emissions.

After balancing the furnace, record the NOx, O_2, and CO. CO should be little to none at this point. Determine the % of NOx level reduction required, if % reduction is less than 25 - 30%, little to no oxygen needs to be added, if between 30 - 50% reduction is required, 8 - 15% added oxygen should be used to give 29 - 36% oxygen content of the staging media. Can be up to 40% if required. Set the Staging PLC Oxygen content to estimated % level.

Tuning the furnace with BAS or OEAS (staging) applied will be similar to what is stated above. However to establish a baseline with staging injectors installed and cooling air flowing (Staging off) the excess Oxygen target should be 0.5 to 1.5%

NOTE: keep an eye on furnace operations while adjusting, don’t allow furnace temps and/or operations to get out of control during this procedure.

During this tuning process, the staging PLC and furnace gas need to be in manual control.

Before starting staging, with the furnace tuned per above procedure and then adjusted to have 0.5 to 1% excess oxygen, go to staging PLC and set the overall ratio equal to the flame ratio.

Go to the individual Staging port flow controls and open the flow valve to 100%.

Start the Staging system.

1. Keeping furnace gas the same, slightly lower the air gas ratio until excess O_2 in the ports are 0 - 0.5%, adjust gas per port so the excess O_2 and CO are close to the same in each port.

2. Manually adjust the staging flows at the staging PLC to the calculated numbers from the staging PLC. Measure the O_2 and CO at the ports. Adjust the individual staging port control valves to get the O_2 and CO close the same in each port.

Repeat 1 and 2 until NOx is in the desired range, if needed, adjust the overall ratio in the staging PLC so the excess oxygen is in the 0.5 to 1% range.

Return furnace Gas and Air, and the staging PLC to auto control.

**With good balance and emission levels achieved the staging system should track changes to furnace conditions and maintain the original percentage of NOx reduction from baseline.

Maintenance and Troubleshooting

5

This chapter is divided into two sections:

- Maintenance procedures
- Troubleshooting guide

Maintenance

Preventive maintenance is the key to a reliable, safe and efficient system. The core of any preventive maintenance system is a list of periodic tasks. The following are suggestions for a daily list, monthly list and a yearly list.

Note: The daily, monthly and yearly lists are an average interval. If your environment is dirty, the intervals may be shorter.

Daily Checklist

1. Check excess oxygen in each port of the melter. Confirm that there has been no sudden shift in the reading as this could indicate a failure in metering of oxygen or air, or a blower issue.
2. Check the outlet pressure of the regulator of the oxygen to confirm it is holding at set point.
3. Check the inlet pressure and outlet pressure of the oxygen strainer to confirm there is no pluggage. There should be no change in differential pressure.
4. Check the blower to make sure it sounds normal and there is no bearing failure.
5. Check oxygen actuator for the flow control valve, this should not be significantly different unless a set point change has been made.
6. Check the air actuator for the flow control valve; this should not be significantly different unless a set point change has been made.
7. Check filters on blowers, and clean if needed.

Monthly Checklist

1. Switch blowers by turning on the spare, opening the isolation valve, shutting the other isolation valve, and turning off the blower. This is very important to confirm blower is functional.

WARNING

- **When starting Blower ‘B’ immediately turn off Blower ‘A’ as both blowers should not be run simultaneously for an extended period.**

2. Check injector condition by pulling injector out of sleeve and see if it is in good condition. Change out if damaged.

WARNING

- **Cooling air to the injectors (on the non injection side) should be on at all times. If cooling air is stopped, melted batch may tend to be forced into the nozzles and plug up the injectors. Cooling air stoppage should therefore be limited to as short a period as possible, one hour max. If cooling air is turned off, the injector isolation ball valves (on sideports) or butterfly valves (on endports) should be closed to prevent positive furnace pressure and heat from backflowing into the staging system. If injectors or injector hoses are removed temporarily, adequate insulation should be used to plug the injector hole to prevent heat escape from the furnace.**

Yearly Checklist

- Have transmitters and actuators calibrated by a qualified technician. For instructions, see the technical documentation CD.

Recommended Spare Parts

Quantity	Description
2	Lances / Injectors
2	Ceramic Inserts (if used)
1	Multivariable Transmitter for Metering Panel
1	Pressure Switch for Staging Air Flow Control Train
1	Multivariable Transmitter for Staging Air Flow Control Train
1	RTD Sensor for Staging Air Flow Control Train
1	RTD Sensor for Oxygen Train
1	Blower with Motor
1	Electric Actuator for Staging Air Flow Control Valve
1	Pneumatic Actuator for Oxy Safety Shut Off Valve
1	Pneumatic Actuator for Staging Air Reversal Valves
1	Pressure Regulator for Oxygen Train
1	Pressure Switch Low for Oxygen Train
1	Pressure Switch High for Oxygen Train
1	Safety Shut Off Valve for Oxygen Train
1	Multivariable Transmitter for Oxygen Train
1	Pressure Gauge for Oxygen Train
1	Pressure Gauge for Staging Air Flow Control Train
1	Solenoid for Oxy Safety Shut Off Valve and Air Reversal Valve

Appendix

Conversion Factors

Metric to English

From	To	Multiply By
actual cubic meter/h (am³/h)	actual cubic foot/h (acfh)	35.31
normal cubic meter/h (Nm³/h)	standard cubic foot /h (scfh)	38.04
degrees Celsius (°C)	degrees Fahrenheit (°F)	(°C x 9/5) + 32
kilogram (kg)	pound (lb)	2.205
kilowatt (kW)	Btu/h	3415
meter (m)	foot (ft)	3.281
millibar (mbar)	inches water column (“w.c.)	0.402
millibar (mbar)	pounds/sq in (psi)	14.5×10^{-3}
millimeter (mm)	inch (in)	3.94×10^{-2}
MJ/Nm³	Btu/ft³ (standard)	26.86

Metric to Metric

From	To	Multiply By
kiloPascals (kPa)	millibar (mbar)	10
meter (m)	millimeter (mm)	1000
millibar (mbar)	kiloPascals (kPa)	0.1
millimeter (mm)	meter (m)	0.001

English to Metric

From	To	Multiply By
actual cubic foot/h (acfh)	actual cubic meter/h (am³/h)	2.832×10^{-2}
standard cubic foot /h (scfh)	normal cubic meter/h (Nm³/h)	2.629×10^{-2}
degrees Fahrenheit (°F)	degrees Celsius (°C)	(°F - 32) x 5/9
pound (lb)	kilogram (kg)	0.454
Btu/h	kilowatt (kW)	0.293×10^{-3}
foot (ft)	meter (m)	0.3048
inches water column (“w.c.)	millibar (mbar)	2.489
pounds/sq in (psi)	millibar (mbar)	68.95
inch (in)	millimeter (mm)	25.4
Btu/ft³ (standard)	MJ/Nm³	37.2×10^{-3}

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