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**System Description for the  
K-25/K-27 D&D Project  
Polyurethane Foam  
Delivery System,  
East Tennessee Technology Park,  
Oak Ridge, Tennessee**

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Peter Kortman

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3/05/08

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**Date Issued—February 2008** |

**Prepared for the  
U.S. Department of Energy  
Office of Environmental Management**


**BECHTEL JACOBS COMPANY LLC  
managing the  
Environmental Management Activities at the  
East Tennessee Technology Park  
Y-12 National Security Complex Oak Ridge National Laboratory  
under contract DE-AC05-98OR22700  
for the  
U.S. DEPARTMENT OF ENERGY**

## APPROVALS

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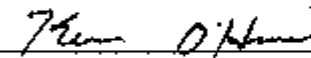
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## ACRONYMS

BJC	Bechtel Jacobs Company LLC
D&D	Decontamination and Decommissioning
DSA	Documented Safety Analysis
HMI	Human-machine interface
gpm	Gallons Per Minute
LASS	List of Active Safety Systems
LDFs	List of Design Features
PGE/P	Process gas and non-process equipment/piping
PLC	Programmable Logic Controller
PMDI	Polymeric Methylene Diphenyl Diisocyanate
QAP	Quality Assurance Program
SMPs	Safety Management Programs
SS	Safety Significant
SSC	Structures, Systems and Components
TSR	Technical Safety Requirements
TSU	Temperature sensing unit
WCP	Work Control Program

## 1. BACKGROUND INFORMATION

The Foam Delivery System used in the decontamination and decommissioning (D&D) project for the K-25/K-27 Buildings at the East Tennessee Technology Park (ETTP) is comprised of a trailer-mounted Gusmer® H20/35 Pro-TEC Proportioning Unit and the associated equipment to convey electrical power, air, and foam component material to the unit. This high-pressure, plural-component polyurethane foam pouring system will be used to fill process gas and non-process equipment/piping (PGE/P) within the K-25/K-27 Buildings with polyurethane foam to immobilize contaminants prior to removal. The system creates foam by mixing isocyanate and polyol resin (Resin) component materials. Currently, the project plans to utilize up to six foaming units simultaneously during peak foaming activities. Also included in this system description are the foam component material storage containers that will be used for storage of the component material drums in a staging area outside of the K-25/K-27 Buildings. The Foam Delivery System and foam component material storage enclosures (i.e., Foaming Component Protective Enclosures) used to store polymeric methylene diphenyl diisocyanate (PMDI) component material are identified as Safety Significant (SS) Structures, Systems and Components (SSC) in the Documented Safety Analysis (DSA) for the project, *Documented Safety Analysis for the K-25 and K-27 Facilities at the East Tennessee Technology Park, Oak Ridge, Tennessee*, DSA-ET-K-25/K-27-0001.



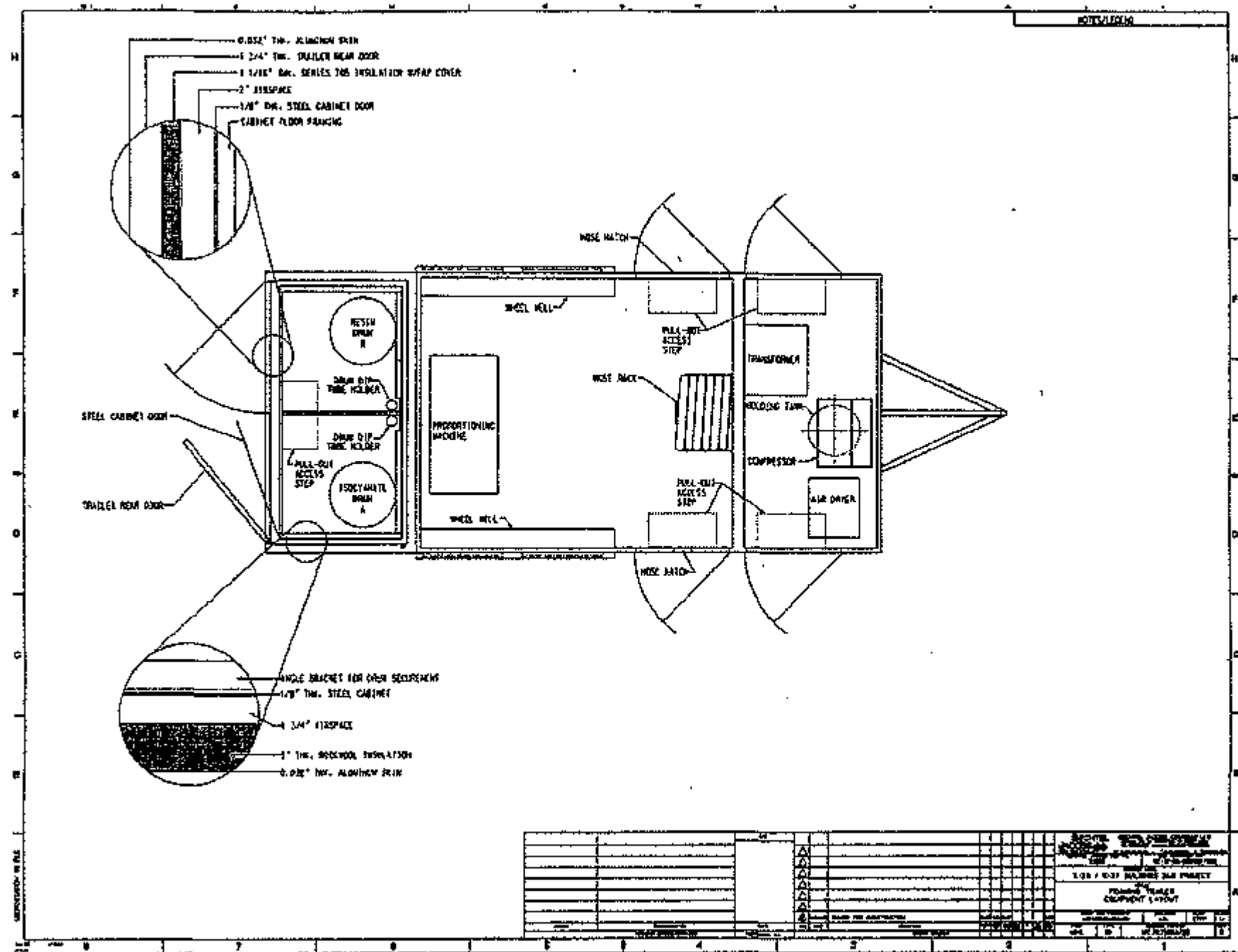
## **2. CONFIGURATION INFORMATION**

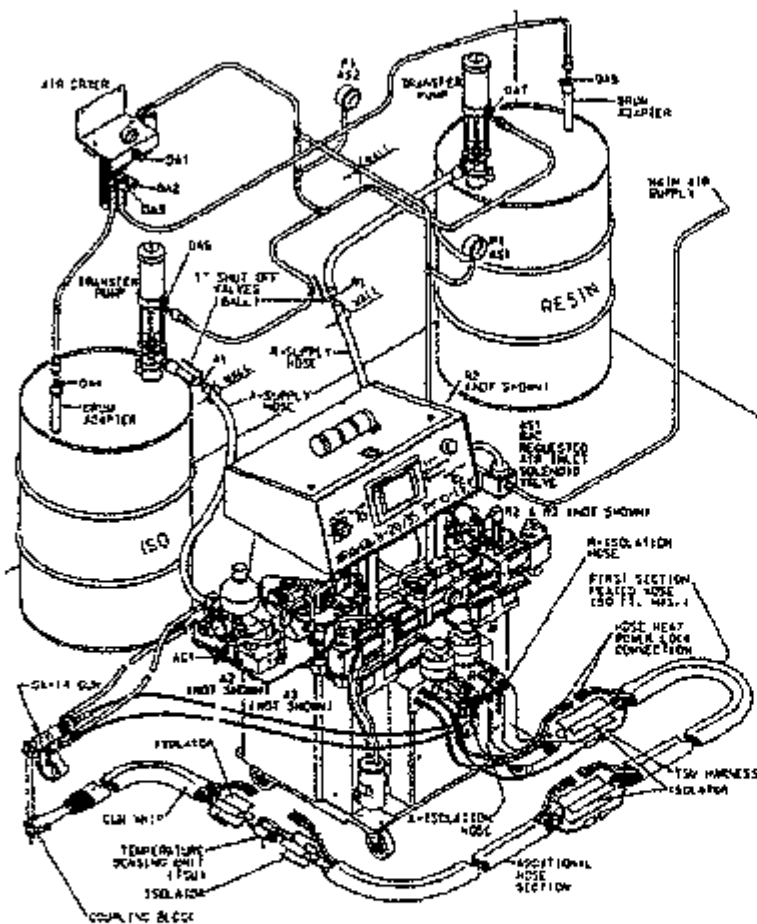
### **2.1 DESCRIPTION OF SYSTEM, SUBSYSTEMS, AND MAJOR COMPONENTS**

The Foam Delivery System consists of the following major components or subsystems:

- Foam Delivery System trailers;
- trailer-mounted Foaming Component Protective Enclosures;
- foam component feed drums and associated feed equipment;
- foam proportioning machine;
- foam delivery hoses and dispensing gun;
- Foam Delivery System support equipment consisting of the electrical power feed, air compressor, and air dryer equipment; and
- Staging area Foaming Component Protective Enclosures.

The major systems/subsystems of the Foam Delivery System trailers are shown in drawings M1E702500A720, Foaming Trailer Equipment Layout; M1E702500A721, Foaming System Installation Isometric; J1E702500A001, Foaming System Process Flow Diagram; and E1E702500A125, Foaming System Single Line Diagram (Figs. 1–4). The layout and dimensions of the external Foaming Component Protective Enclosures are shown in drawing C1E702500A114, Foaming Storage Building (Fig. 5).



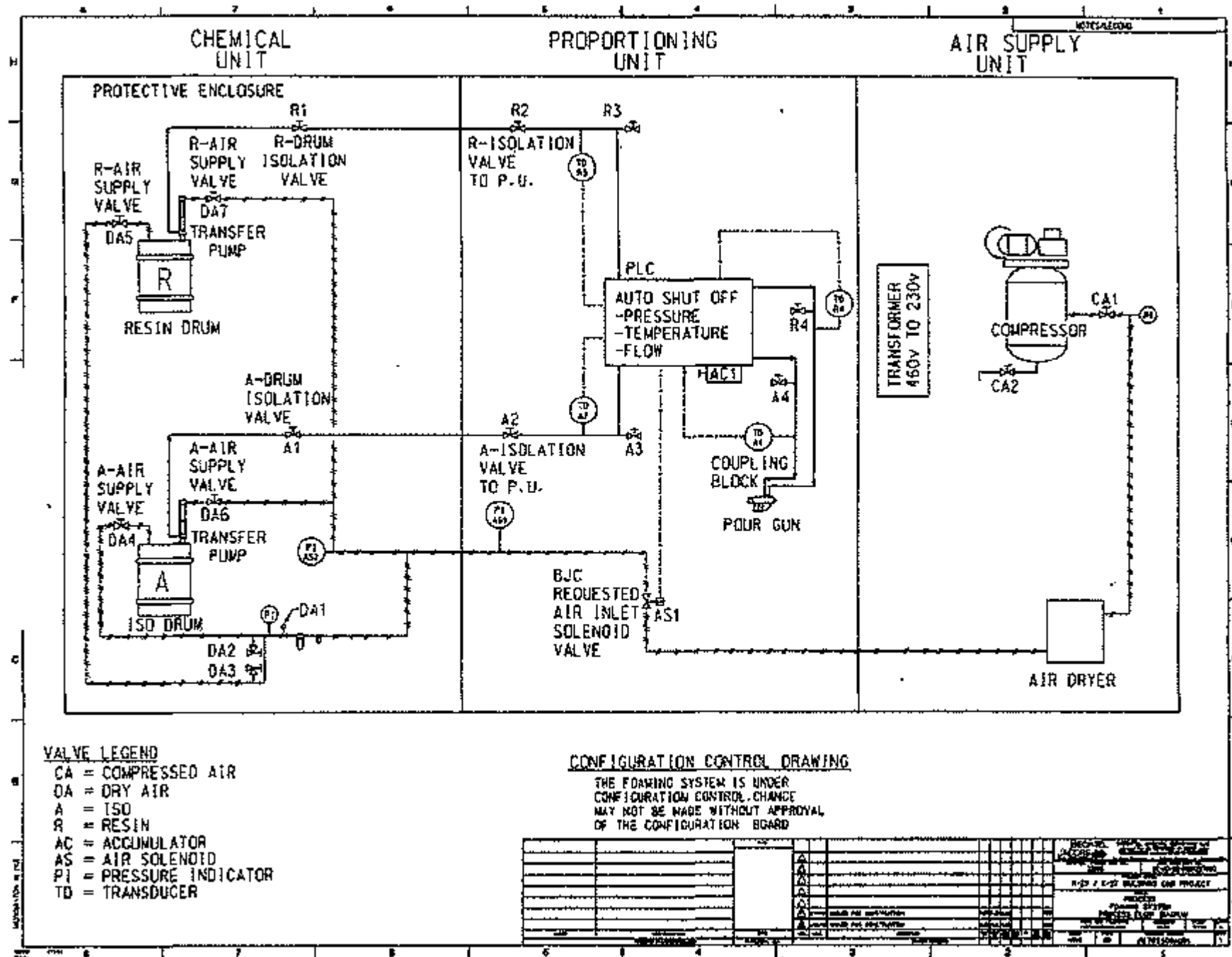


• GDS IS  
SAFETY SIGNIFICANT

VALVE LEGEND  
CA = COMPRESSED AIR  
DA = DRY AIR  
A = ISO  
R = RESIN  
AC = ACCUMULATION  
AST = AIR SOLENOID

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Fig. 2. Foaming system installation isometric.







### 2.1.1 Foam Delivery System Trailers

The Foam Delivery System trailers contain all of the equipment used for storage and delivery of the component materials, mixing of the materials, and delivery of the materials to the equipment being foamed. This system, and all the components that make up the system, were purchased as commercial grade items. The Foam Delivery System trailers are self-contained units, with the exception of electrical power. The outside dimensions of the Foam Delivery System trailers are 21 ft 10 in. long (including the 2-in. ball hitch), 8 ft 4 in. wide, and 9 ft 1 in. high with a tandem axle configuration. The trailers have been physically configured to optimize the space within the trailer and to fulfill one of the Safety Basis requirements for PMDI foam component isolation in a protective enclosure. The trailer and major Foam Delivery System/subsystems are shown on drawing M1E702500A720, Foaming Trailer Equipment Layout. This drawing illustrates the three compartments on the trailer. The front section houses the air compressor, air dryer, and the 480-VAC to 230-VAC/120-VAC transformer with power disconnects. In this compartment, the electrical power enters via cable through the compartment floor. The mid-section contains the Proportioning Unit and product delivery hose connected to the Proportioning Unit. The rear section contains the Foaming Component Protective Enclosure for the drums of foam component material, along with two pneumatic drum pumps and a step-down air regulator/dryer for drum dry air blanketing.

All three compartments are lighted using incandescent fixtures, and each contains a fire extinguisher. 120-VAC electrical space heaters are installed in the middle and rear compartments to support operation during cold weather. Drawing M1E702500A721, Foaming System Installation Isometric, depicts typical equipment installation and routing of the air and component hoses in relationship to the proportioning machine. Drawing J1E702500A001, Foaming System Process Flow Diagram, is a process flow diagram for the system. Drawing E1E702500A125, Foaming System Single Line Diagram, is an electrical single-line, block diagram for the trailer electrical system. The Foam Delivery System is powered by 480-VAC construction feed to the Foam Delivery System trailer on-board transformer, where it is stepped down to 230-VAC and 120-VAC for the system components. Components that require 230-VAC are the Proportioning Unit and the air compressor, both of which are hard-wired. There is 120-VAC service to the air dryer, overhead lights in each compartment, space heaters, and several service outlets within the trailer.

Other than specifically credited aspects of the trailer design (e.g., trailer insulation credited as part of the Foaming Component Protective Enclosure) described in the following sections, the Foam Delivery System trailers do not require configuration management as safety significant items. Although some of the equipment contained within the Foam Delivery System trailers is credited with fulfilling a safety significant function in DSA-ET-K-25/K-27-0001 (e.g., portions of the foam proportioning machine), the trailers, in general, do not fulfill any specific safety function and are not considered to be within the boundary of the credited safety features. The components credited as safety significant items, if replaced, are commercial-grade items but must be purchased and dedicated under BJC-DE-1018, *Procurement, Control, Evaluation, and Use of Commercial Grade Items in Safety Significant Applications*.

### 2.1.2 Trailer-Mounted Foaming Component Protective Enclosure

The protective enclosures on the Foam Delivery System trailers are built into one of the compartments of the trailer and are designed to house one drum each of the PMDI and Resin components. To protect the foaming component materials, the protective enclosures are constructed of fire-resistant insulating materials and include drum overpressure protection to prevent the release of PMDI outside of the enclosure, which could result if the enclosure were exposed to a fire leading to rupture of the drum.

The Foaming Component Protective Enclosure is designed to provide a protective barrier capable of maintaining the internal air temperature below 270°F for 1 hour during a fire involving combustible or flammable material in quantities within the Fire Protection Program limitations separated by at least 40 ft. The 270°F design temperature limit is based on a limiting flash point temperature of 300°F for the Resin foam component material. The limiting temperature of 270°F also ensures that the flash point and boiling point of the PMDI material (390°F and 625°F, respectively) will not be exceeded. The ability of the protective enclosure to meet the functional requirements necessary to fulfill the safety function is validated through documented, Fire Protection Engineer-approved engineering evaluations CAF-7K2527-A013 and CAF-7K2527-A497. The enclosure walls and roof are constructed of plates of rolled, continuous-welded steel to form the enclosure interior walls. The enclosure is insulated with fire-rated insulation between the steel interior walls and the trailer walls. The enclosure is accessed for drum loading through floor-to-ceiling doors that overlap at the rear-center of the trailer. The doors and all penetrations (including hose penetrations) are designed to provide fire-resistance capability equivalent to the roof and wall design. The enclosure design includes a feature to allow the doors of the enclosure to remain closed during foam application operations. The materials of construction, arrangement, and dimensions of the enclosure are shown in Bechtel Jacobs Company LLC (BJC) Drawing M1E702500A720. The inner and outer walls, floor, ceiling, and doors of the enclosure (i.e., both inner steel components and trailer materials, and associated penetrations) are credited with meeting the design safety feature. Other aspects of the enclosure design (e.g., lighting, space heaters and drum stands) are not considered to be within the boundary of the credited safety feature and do not require configuration management as safety significant items.

### **2.1.3 Foam Component Feed Drums and Associated Feed Equipment**

The isocyanate (PMDI) and polyol resin (Resin) component materials are delivered from the vendor in Department of Transportation-rated drums (UN/1A1/X1.8/300 rating). Both drums, as provided by the vendor, have a design test pressure of 43 psig. The drums are filled with approximately 49 gal of material. Drum-mounted, pneumatically driven feed pumps are used to transfer the foam component materials from the drums to the proportioning machine. The fluid side of the pumps is of a cylinder and piston, positive displacement design. The pumps are designed for a 2:1 pressure ratio (i.e., fluid side pressure two times air side pressure) with a maximum design output capacity of 11 gal per minute (gpm) intermittent duty and 5.5 gpm continuous duty. Maximum design operating air pressure to the pumps is 180 psig. The pump operating speed is controlled through operation of a needle valve installed in the air line at the air supply inlet to the pumps (identified as valves DA6 and DA7 on Drawings M1E702500A721, Foaming System Installation Isometric, and J1E702500A001, Foaming System Process Flow Diagram). Details of the design of the transfer pumps and associated equipment are contained in the manufacturer's manuals (*Gusmer Corporation 2:1 Ratio Transfer Pump, Operating Manual with Parts Identification*, OP232-INST).

The feed hose running from the feed pump to the proportioning machine is a ¾-in.-ID hose. The hose connects to the feed pump discharge and runs through the wall of the protective enclosure and connects to the proportioning machine inlet y-strainer.

Operating air for the feed pumps is supplied from the system air compressor via a solenoid operated air control valve mounted on the proportioning machine (identified as AS1 on M1E702500A721, Foaming System Installation Isometric, and J1E702500A001, Foaming System Process Flow Diagram). The control valve is a two-position solenoid operated valve. The valve is solenoid operated to open, with spring pressure to shut, and fails closed on a loss of power. The valve design includes a manual override feature to allow manually latching the valve open. This manual override capability is permanently disabled on the installed valves. The control power for the valve is provided by the Foam Delivery System Programmable Logic Controller (PLC). Dry blanketing air for the drum headspace is supplied



from the system air compressor via the same solenoid operated air control valve for the feed pumps and after passing through a filter/regulator assembly mounted inside the protective enclosure. The air filter/regulator assembly consists of an air regulator (identified as valves DA1 on Drawings M1E702500A721, Foaming System Installation Isometric, and J1E702500A001, Foaming System Process Flow Diagram), air filter, and pressure relief valves in the air line going to each drum (identified as valves DA2 and DA3 on Drawings M1E702500A721, Foaming System Installation Isometric, and J1E702500A001, Foaming System Process Flow Diagram). Details of the design of the air filter/regulator assembly are contained in the manufacturer's manual (*Gusmer Corporation Model OP 1 55 Air Dryer, Operating Instruction and Parts Identification Manual, OP155-INST*).

The pressure relief valve installed in the dry air supply line connected to the PMDI and Resin component material drums (DA2 and DA3) protects the drums from rupture due to regulator failure and will relieve pressure buildup resulting from the temperature rise in the enclosure during a fire event. The installed valves have a design lift pressure of  $5 \pm 1$  psig. This overpressure device is of a simple, direct-acting mechanical design. The setpoint is established by design and is non-adjustable. When the pressure within the supply drum reaches a pressure of  $5 \pm 1$  psig, a plunger in the relief device is tripped, opening the valve chamber to the pressure in the drum. At this point, the cap pops off the relief device, venting the drum to atmosphere and exposing a red warning band. The relief valve and hose connecting the valve to the drum are the only portions of the air system credited with meeting the design safety feature.

In summary, DSA-ET-K-25/K-27-0001 identifies the Foam Delivery System as performing a safety significant function of mitigating a release of the PMDI foam component material in a fire by containing the material within the Foaming Component Protective Enclosure and limiting the volume of PMDI foam component material contained in the Foam Delivery System components outside of the Foaming Component Protective Enclosure. The feed transfer pump design operating flow, feed hose, and associated valving internal volumes, drum design pressures, drum dry air relief valve design and setpoint (DA2 and DA3), and the solenoid operated air control valve (AS1) design are the only aspects of the feed equipment identified in DSA-ET-K-25/K-27-0001 as being associated with this safety significant function. Other portions of the feed equipment are not considered to be within the boundary of the credited safety feature and do not require configuration management as safety significant items.

#### **2.1.4 Foam Proportioning Machine**

The foam proportioning machine is a self-monitored system that operates with constant feedback program logic and a touch-screen human-machine interface (HMI). The system is designed to monitor and control components related to feed input/output pressure and temperature, hydraulic pressure, component levels, and hose heat trace functions. The foam proportioning machine has the following three major functions: (1) boosting the foam component line pressure to approximately 1500 psig using a reciprocating pump, (2) heating the foam material to approximately 100°F, and (3) containing and controlling the hydraulic power plant that powers the gun trigger mechanism and reciprocating pump. The two sides of the foam component material portions of the machine (i.e., PMDI and Resin side) are essentially identical. Details of the design of the proportioning machine equipment are contained in the manufacturer's manuals (*Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Operating Manual, 61942-H-1, and Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Parts Identification Manual, 61942-H-ID*).

The system utilizes a PLC to control system operation with constant feedback program logic and a touch-screen HMI. The system is designed to monitor and control components related to feed input/output pressure and temperature, component flow rate, and delivery hose heat trace temperature. The HMI enables an operator to observe or change equipment operation and provides access through a password protected administrative feature (referred to as the "setup mode") to adjust selected values and conditions

of data and parameters in the PLC. The PLC is programmed for industrial applications and reads both discrete inputs, such as proximity switch signals indicating the spray gun trigger is open or closed, and analog inputs, such as voltage, current, or temperature. The PLC software reads sensor inputs, processes program logic, and writes outputs to control devices. The PLC turns discrete outputs ON or OFF to actuate various relays and indicators. The PLC also directs output voltages and currents to various control devices and indicators. The system PLC provides control signals for the component material heaters, hose heaters, hydraulic system, and solenoid operated control valve in the air supply line to the component feed pumps. The PLC programming provides for monitoring and control of Foam Delivery System parameters for normal system operation, warning alarm, and shutdown purposes. Errors in the PLC function or associated inputs will be indicated by fault or error messages on the HMI or abnormal system readings (e.g., flashing lights for pressure readings).

The PLC is programmed using system development software to read inputs, process the logic of the program, and write to the outputs. Reliability of the design of the PLC software is assured by Quality Assurance Program (QAP) software control requirements applied to the initial development, acceptance, and changes to the software. The password protected administrative feature (i.e., setup mode) allows access to adjustable system operating and safety shutdown features (including dwell time settings) controlled by the PLC, but does not allow access to the control logic or PLC software programming. Modification of the control logic or software programming requires access using system development software and can only be performed by the equipment vendor. Any changes to the credited PLC equipment (including controlled system operating or shutdown setpoints or dwell times, or vendor modifications to the software) are required to be controlled through the Configuration Management and Software QA Programs and will require validation through functional testing. The software QA requirements associated with the PLC are contained in the *Software Quality Assurance Plan for the Gusmer H20/35 Pro-TEC Foam Delivery System at the East Tennessee Technology Park, Oak Ridge, Tennessee* (BJC/OR-2210).

Shutdowns and warnings associated with system flows, pressures, and temperatures are included in the PLC design to protect the equipment, ensure the appropriate ratio of component materials are being delivered to the dispensing gun, and ensure proper final foam properties (e.g., high-pressure alarm and shutdown, component flow differential alarm and shutdown, and component high or differential temperature alarm and shutdown). In addition, a bimetallic thermal cutoff for the Primary heater controls and a high-pressure shutdown on the hydraulic power plant are provided independent of the PLC controls. The PLC automatic shut-off controls that detect a low-pressure condition in either the PMDI feed or the delivery hose line indicating a catastrophic hose failure (i.e., rupture) and that close the solenoid operated control valve in the PMDI feed pump air supply (AS 1) within 8 seconds of loss of pressure in either line are the only PLC control functions that are specifically identified in DSA-ET-K-25/K-27-0001 as a safety significant feature. The other PLC control, alarm, and shutdown features are provided for normal process control and personnel or equipment safety, but they are not considered to be within the boundary of the credited safety feature and do not require configuration management as safety significant items.

The hydraulic power plant for the proportioning machine operates between 1000 and 2000 psig and supplies operating fluid to the foam component material proportioning pump via a reversing valve controlled by the system PLC. The hydraulic power plant also provides hydraulic operating power to the dispensing gun at the end of the delivery hose. Starting and stopping of the hydraulic pump is controlled by the PLC through the HMI. An automatic unloading valve controls operating pressure of the hydraulic power plant. The hydraulic pump control circuitry includes an overpressure safety switch to protect against failure of the automatic unloading valve and a motor overload sensor that provides a signal to the PLC to generate a system shutdown in the event of a motor overload. A small, nitrogen-loaded accumulator provides a pre-load pressure for the system and a surge volume to maintain stable pressure in the hydraulic system during operation.

The proportioning machine contains two component material proportioning pumps (one for each component). The pumps are hydraulically operated piston- and cylinder-type positive displacement pumps with a maximum design output capacity of ~ 4 gpm. The flow of the hydraulic operating fluid to the proportioning pump drive side is directed through a reversing valve controlled by the system PLC to provide the operating force for the pumps. The drive side of the two pumps is interconnected through a single hydraulic drive piston such that the pumps stroke in a diametrically opposed fashion.

The proportioning machine contains two sets of electric heaters (one set for each component material) on the outlet of the proportioning pumps that heat the materials to approximately 100°F. Each set of heaters is rated for 9000 watts and is powered from a heater control unit controlled by the system PLC. On the outlet of the component material heaters is a flowmeter, which provides a signal to the system PLC for use in monitoring and control of system operation. The delivery hoses are connected to the proportioning machine at a test valve assembly (A4 and R4 on Drawings M1E702500A721, Foaming System Installation Isometric, and J1E702500A001, Foaming System Process Flow Diagram) downstream of the flowmeters.

The proportioning machine includes the following sensors that provide input signals to the system PLC for use in system monitoring and control:

- pressure transducers downstream of the inlet strainers for sensing component material pressure in the feed lines (both PMDI and Resin sides),
- pressure transducers at the outlet of the proportioning pump for sensing component material pressure in the delivery lines (both PMDI and Resin sides),
- thermocouples downstream of the inlet strainers for sensing component material temperature in the feed lines (both PMDI and Resin sides),
- thermocouples in the primary heater bundle for sensing component material temperature at the heater outlet (both PMDI and Resin sides),
- a thermocouple in the temperature sensing unit (TSU) for sensing PMDI component material temperature at the hose end,
- flowmeters at the outlet of the primary heaters for sensing component material flow in the delivery lines (both PMDI and Resin sides),
- a proximity switch on the dispensing gun for sensing the dispensing gun trigger position, and
- a hydraulic motor overload signal from the hydraulic motor circuit breaker.

The pressure transducers located in the feed inlet provide a signal to the PLC proportional to the associated hose pressure and are relied on to provide indication of a potential rupture of the feed hose. The specified pressure transducers have an operating range of 0–250 psig and an accuracy of  $< \pm 1\%$  of full scale. The pressure transducers located in the proportioning pump outlet provide a signal to the PLC proportional to the associated hose pressure and are relied on to provide indication of a potential rupture of the delivery hose. The specified pressure transducers have an operating range of 0–3000 psig and an accuracy of  $< \pm 1\%$  of full scale. The high-pressure transducer also includes a switching circuit that is used to provide a high-pressure shutdown indication to the PLC. A loss of the pressure signal from the feed or delivery hose line pressure sensors will be seen by the PLC as a low-pressure indication.

The proportioning pump design operating flow, the proportioning machine internal volumes, and the components associated with the automatic low-pressure shut-off feature described above (i.e., the PLC programming logic and input/output circuitry associated with the pressure transducers and air solenoid valve, the proportioning machine inlet and outlet pressure transducers, and the solenoid operated control

valve in the feed pump air supply line) are the only aspects of the proportioning equipment identified in DSA-ET-K-25/K-27-0001 as performing a safety significant function. Other portions of the proportioning machine (e.g., the hydraulic power plant and associated control circuitry) are not considered to be within the boundary of the credited safety feature and do not require configuration management as safety significant items.

### **2.1.5 Foam Delivery Hose and Dispensing Gun Equipment**

The component materials are delivered to the dispensing gun through flexible hoses (referred to as delivery hoses) supplied with hose heaters to keep the components at approximately 100°F and protected with two layers of protective material. The hose assembly consists of the two component material hose lines, two hydraulic lines for operation of the dispensing gun, two hose heat cables, two signal cables for the dispensing gun proximity switch, and 1 signal cable for the hose TSU. The delivery hose is provided in 50-ft sections connected with threaded mechanical fittings and quick disconnect-style electrical connections. A TSU is connected in the delivery hose line between the last 50-ft section of delivery hose and a 10-ft whip section of hose. The dispensing gun is connected to the whip hose. The equipment is normally configured with a total of 160 ft of hose (three 50-ft sections and the whip section), but the system is designed to operate with up to 400 ft of delivery hose with a 10-ft whip section on the end for a total length of 410 ft. The TSU contains thermocouples that monitor the component material temperature and provide a signal to the system PLC for hose heater and system monitoring and control purposes.

The dispensing gun contains the mixing chamber where the two component materials are combined and are dispensed into the desired location. The dispensing gun mixing valve is activated under hydraulic pressure due to close tolerances on the metal components of the ports in the gun. Actuation of the mixing valve is controlled by a signal from the PLC based on a signal from a proximity switch on the dispensing gun trigger assembly. The high pressure on the foam component lines creates impingement mixing of the components within the dispensing gun mixing chamber when the trigger is activated. Details of the design of the dispensing gun are contained in the manufacturer's manuals (*Gusmer Corporation Model GX-14 Pour Head, Operating Manual*, 33943-1, and *Gusmer Corporation Model GX-14 Pour Head, Parts Identification Manual*, 33943-ID).

The delivery hose and dispensing gun internal volumes are the only aspects of the delivery hose and dispensing gun equipment identified in DSA-ET-K-25/K-27-0001 as performing a safety significant function. Other portions of the equipment (e.g., hose heaters and associated control circuitry) are not considered to be within the boundary of the credited safety feature and do not require configuration management as safety significant items.

### **2.1.6 Foam Delivery System Support Equipment**

The front compartment of the Foam Delivery System trailer houses the air compressor and air dryer for the feed pump operating air and component material drum dry air blanket and a step-down transformer and electrical panel for supplying power to the trailer-mounted equipment. The Foam Delivery System is powered through a 480-VAC construction feed plug connection on the Foam Delivery System trailer, where it is stepped down by the on-board transformer to 230-VAC and 120-VAC for the system components. The support equipment is not considered to be within the boundary of the credited safety features.

### 2.1.7 Staging Area Foaming Component Protective Enclosures

The enclosures used for outdoor storage are designed to hold as many as 16 drums in each enclosure (Drawing C1E702500A114, Foam Storage Building). Up to six (6) enclosures will be used to facilitate replenishing of material for the Foam Delivery System trailers. The external enclosures will be staged in various locations external to the K-25/K-27 Buildings. To protect the foaming component materials, the protective enclosures are constructed of fire-resistant insulating materials and include drum spill containment features to prevent the release of PMDI outside of the enclosure that could result if the enclosure were exposed to a fire leading to rupture of the drum. The units are pre-engineered hazardous material storage units with a 2-hour fire rating as approved by Factory Mutual. The protective enclosures also are designed with environmental controls (i.e., heating and air-conditioning units) to maintain the components in compliance with the manufacturer's recommendations for storage. Power is provided to the enclosures from a 120-VAC construction feed connection.

The Foaming Component Protective Enclosure is required to be designed to provide a protective barrier capable of maintaining the internal air temperature below 270°F for 1 hour during a fire involving combustible or flammable material in quantities within the Fire Protection Program limitations separated by at least 40 ft. The 270°F design temperature limit is based on a limiting flash point temperature of 300°F for the Resin foam component material. The limiting temperature of 270°F also ensures that the flash point and boiling point of the PMDI material (390°F and 625°F, respectively) will not be exceeded. The ability of the protective enclosure to meet the functional requirements necessary to fulfill the safety function is validated by the Factory Mutual 2-hour fire rating certification for the containers, as documented in BJC Fire Protection Calculation CAF-7K2527-A497. The 2-hour fire rating design and testing requirements ensure that with an initial internal air temperature of 105°F the internal air temperature will stay below 134°F for a 1-hour period when exposed to an external fire involving combustible or flammable material in quantities within the Fire Protection Program limitations separated by a distance of at least 40 ft. The enclosure structure (i.e., walls, floor, ceiling, penetrations, and doors of the enclosure) is credited with meeting the design safety feature. Other aspects of the enclosure design (e.g., lighting, heating, and air-conditioning equipment) are not considered to be within the boundary of the credited safety feature.

The design of the protective enclosures includes a built-in spill containment sump with sufficient capacity to contain a liquid volume equal to the combined volume of the maximum number of standard design 55-gal drums the enclosure is designed to store (minimum 880 gal).

## 2.2 PHYSICAL LAYOUT AND LOCATION

The physical layout of the Foam Delivery System (trailers) is shown in Drawing M1E702500A720. Currently, the project plans to utilize up to six foaming units simultaneously during peak foaming activities. The trailers will be moved to the required locations within the K-25/K-27 Buildings using appropriate towing vehicles (e.g., fork trucks). The system is currently configured with 160-ft-long hoses to minimize the number of trailer movements required to access the objects to be foamed. The system can operate with up to 165 ft of 3/8-in. ID delivery hose and still be within the chemical volume limitations set by the Project's Technical Safety Requirements (TSR), *Technical Safety Requirements for the East Tennessee Technology Park K-25 and K-27 Facilities* (TSR-ET-K25/K27-0002).

As many as six staging area Foaming Component Protective Enclosures will be used to facilitate replenishing of material for the Foam Delivery System trailers. The external enclosures will be staged in a designated external staging area in the vicinity of the K-25/K-27 Buildings.

## **2.3 BOUNDARIES AND INTERFACES**

The Foam Delivery System consists of self-contained units, with the exception of electrical power and foam component material feedstock. Power must be provided using appropriately sized wire for the 480-VAC or 120-VAC feed from the construction power grid. Foam component material will be replenished as necessary and is containerized in 55-gal drums. Interface of the Foam Delivery System with the equipment being foamed is controlled through a work package prepared specifically for the foaming action to be performed. The work package provides specific requirements for identification of the location to be foamed, work instructions and safety controls specific to the work location, and documentation and record keeping requirements for each foamed location. There are no other physical or support system interfaces between the Foam Delivery System trailer unit, staging area Foaming Component Protective Enclosures, and other operations.

## **2.4 PRINCIPLES OF OPERATION**

The Foam Delivery System equipment is designed to produce polyurethane foam normally used for injection molding applications, void filling, or spraying of foam for wall/roof insulation applications. BJC has selected this system for the purpose of contaminant immobilization within the PGE/P.

The system creates foam by mixing isocyanate (PMDI) and a polyol resin (Poly). This is achieved by the transfer of the component material contained in 55-gal drums located in the rear of the trailer to the proportioning machine located in the center section of the trailer. Drum pumps powered by the air compressor/air dryer system, located in the front of the trailer, create this transfer pressure.

The proportioning machine has three major functions: (1) boosting the foam component line pressure to approximately 1500 psi using a reciprocating pump, (2) heating the foam material to approximately 100°F, and (3) containing the hydraulic pump system that powers the gun trigger mechanism. The high pressure on the foam component lines creates impingement mixing of the components within the dispensing gun mixing chamber when the trigger is activated. The trigger is activated under hydraulic pressure due to the close tolerances on the metal components of the ports in the gun. The heated components are kept at approximately 100°F in the delivery hoses. The resulting mixture is dispensed into the object to be foamed where, by exothermic reaction, the mixture expands to approximately 10–25 times its original volume. Different PMDI and resin mixtures are used to obtain varying densities as required by the application work packages for various equipment to be foamed.

The equipment is to be operated by trained personnel. Once the equipment startup is completed, the foaming operation encompasses identification of the item(s) to be foamed and calculation of the amount of foam to be dispensed for that item. Openings (punched holes) in the piping or equipment are made at locations required to facilitate foam insertion, but this activity and the objects to be foamed are not part of the Foam Delivery System. The foam is dispensed through the gun, with or without additional tubing attached to the gun head, into the opening. The trigger is depressed for the pre-determined time period (typically less than 1 minute) to fill the object with the appropriate amount of foam material. This activity is repeated for all sections of pipe and individual pieces of equipment to be foamed.

## **2.5 SYSTEM SAFETY FEATURES**

The Foam Delivery System controls include the following protective safety features (i.e., "Faults"):

- an overpressure safety switch set at 2800 psig in the hydraulic pump control circuitry (i.e., independent of the PLC control system) to protect against over-pressurization of hydraulic power plant components;
- component material primary heater outlet high-temperature bimetallic thermocouple shutdown set at 200°F in the Primary heater control circuitry (i.e., independent of the PLC control system);
- PMDI and Resin proportioning pump inlet low-pressure shutdowns by the PLC control system to protect against proportioning machine damage or detect a rupture of the feed hose;
- PMDI and Resin proportioning pump outlet low-pressure shutdowns by the PLC control system to detect a rupture of the delivery hose;
- PMDI and Resin proportioning pump outlet high-pressure shutdown by the PLC control system set at 2200 psig to protect against over-pressurization of delivery hoses; and
- hydraulic pump motor overload system shutdown by the PLC control system to protect against equipment damage.

If the established setpoint is exceeded for any of these parameters, the unit will shut down and the HMI will default to the Alarm Status Screen to inform the operator of the "Fault" condition. A message text will prompt the operator with suggestions to analyze and clear the fault condition. The machine cannot be put back to normal operation until the fault is cleared and reset. The Alarm History Screen will track historical alarm data for future reference.

Other parameters also are monitored and controlled by the PLC for normal system monitoring, operation, and warning alarm purposes (e.g., monitoring and/or control of system flows, temperatures or pressures, and associated alarms and shutdowns when one of these parameters exceeds a preset control band). These other parameters and associated alarms and shutdowns are provided for normal process control and are not considered safety features. The vendor design also includes an emergency shutdown of the Foam Delivery System, which can be actuated manually from a push button located on the face of the proportioning machine control panel, independent of the PLC automatic shut-off functions. Although included in the original vendor design, the safety shutdowns described above have obviated the need for the emergency shutdown as a safety feature. However, it does provide a means of rapidly securing the process in an upset condition.

The PLC logic also includes programmable dwell time settings that must be exceeded before the PLC will initiate a system shutdown following detection of a parameter outside the established setpoint. These dwell times are utilized to preclude spurious system shutdowns from normal system pressure transients while still providing initiation of an automatic shut-off in a period of time that ensures safe operation. The PLC programming includes the capability to adjust the setting of these shutdowns and dwell times through a setup mode. Access to the PLC setup mode is controlled through a password protected administrative function accessible through the HMI.

The accident analyses in DSA-ET-K-25/K-27-0001 have determined that the unmixed polyurethane foam components (specifically the PMDI constituent) may result in significant chemical consequences if exposed to a fire. To address this issue, the Foam Delivery System has been credited in the safety analysis with the following controls to minimize such exposure. These include:

- housing the unmixed foam components in a protective enclosure;
- limiting the amount of PMDI contained within the system outside the protective enclosure to less than 1.6 gal; and
- providing automatic shut-off controls that detect a low-pressure condition in either the PMDI feed

or delivery hose line indicating a catastrophic hose failure (i.e., rupture) and close the solenoid operated control valve in the PMDI feed pump air supply within 8 seconds of loss of pressure in either line

The Foam Delivery System's basic functional requirement is to limit the volume of PMDI that could potentially be exposed to a fire outside of the Foaming Component Protective Enclosure to < 4.3 gal. The Foam Delivery System helps to protect the unmixed PMDI foam component inside the system equipment that is located outside the Foaming Component Protective Enclosure from direct exposure to fire. However, the system will not withstand direct flame impingement. Therefore, the system controls also are designed to limit the amount of material that could be released from the system in the event of a fire. To meet this functional requirement, the system design includes the following features:

- The Foam Delivery System design limits the volume of PMDI contained in the Foam Delivery System components outside of the Foaming Component Protective Enclosure to less than 1.6 gal.
- The Foam Delivery System design includes automatic shut-off controls that detect a low-pressure condition in either the PMDI feed or delivery hose indicating a catastrophic hose failure (i.e., rupture) and close the solenoid operated control valve in the PMDI feed pump air supply within 8 seconds of the rupture.

These features are required to work in conjunction with each other such that the amount of PMDI material from a single foaming unit potentially exposed in a fire event would not equal or exceed 4.3 gal (i.e., combined volume of the system outside of the Foaming Component Protective Enclosure and PMDI released in the event of a hose rupture is < 4.3 gal).

The total volume of 4.3 was selected based on the accident analysis, which indicated that this quantity of PMDI released in a fire would result in *High* off-site consequences. This value also was determined to be achievable with the expected system response time to a hose rupture and the maximum design system volume (i.e., considering the maximum hose length of 410 ft). This quantity of material could be exceeded if two Foam Delivery System units are allowed to be collocated and therefore potentially involved in a single localized fire. Therefore, to allow the operational flexibility of having two units collocated while still minimizing the quantity of material that could be involved, the volume of PMDI contained in the Foam Delivery System components outside of the Foaming Component Protective Enclosure is limited to 1.6 gal maximum by operationally limiting the PMDI component delivery hose length to 165 ft. The accident analysis acknowledges that, with this system volume, a localized fire involving two Foam Delivery System units could result in a release of up to 6.2 gal of PMDI.

The system volume limitation of 1.6 gal was based on providing maximum operational flexibility in the system configuration. The calculated combined internal volume of the foaming component material containing portions of the system from the feed pump discharge to the dispensing gun with the maximum design length of delivery hose installed (i.e., 410 ft) is 2.93 gal and 1.48 gal with the normal configuration of 160 ft of hose. The system volume calculations are documented in BJC calculation CAM-7K2527-A019. The sizing of system components outside of the Foaming Component Protective Enclosure must be controlled to ensure that the performance will meet the functional safety requirement. This includes the PMDI component feed hose, proportioning machine PMDI component side internal volume, PMDI component delivery hose internal volume, and PMDI delivery hose whip and dispensing gun internal volume.

The Foaming Component Protective Enclosures provide mitigation of fire in external staging areas and application areas containing the unmixed foam components by preventing the PMDI material stored in the enclosure from being exposed to temperatures above the boiling point of the PMDI (~625°F) during a localized fire. Such enclosures are required for protection of the unmixed foaming components, both as



part of the Foam Delivery System trailers, where single drums of the material are used during foaming activities, and for protection of multiple drums of the materials when placed in staging areas outside of the buildings in preparation for use.

To protect the PMDI component materials from being exposed to temperatures exceeding their boiling point (~625°F) during a fire, the Foaming Component Protective Enclosure design features must meet the following functional requirements:

- The Foaming Component Protective Enclosure is designed to provide a protective barrier that is capable of maintaining the internal air temperature below 270°F for 1 hour during a fire involving combustible or flammable material in quantities within the Fire Protection Program limitations separated by a distance of at least 40 ft.
- The Foaming Component Protective Enclosure design that is built into the Foam Delivery System trailers includes a simple, direct-acting mechanical overpressure relief device(s) in the dry air line connected to the PMDI drum vapor space (DA2). The relief device must have a non-adjustable, factory set relief setpoint below 10 psig.
- The Foaming Component Protective Enclosure design used to stage unmixed PMDI polyurethane foam component material outside of the building includes a minimum spill containment capacity of 880 gal.

The 270°F design temperature limit for the Foaming Component Protective Enclosure is based on a limiting flash point temperature of 300°F for the Resin foam component material. The limiting temperature of 270°F also ensures that the flash point and boiling point of the PMDI material (390°F and 625°F, respectively) will not be exceeded. The ability of the protective enclosure to meet the functional requirements necessary to fulfill the safety function is validated by the Factory Mutual 2-hour fire rating certification for the containers, as documented in BJC Fire Protection Calculation CAF-7K2527-A497. The 2-hour fire rating design and testing requirements ensure that with an initial internal air temperature of 105°F the internal air temperature will stay below 134°F for a 1-hour period when exposed to an external fire involving combustible or flammable material in quantities within the Fire Protection Program limitations separated by a distance of at least 40 ft.

The pressure relief valve installed in the dry air supply line connected to the PMDI component material drums (DA2) will relieve pressure buildup resulting from the temperature rise in the enclosure during a fire event and therefore protect the PMDI drum from rupture. This feature preserves the ability of the protective enclosure to protect the PMDI material from being exposed to temperatures above 270°F, as described previously. The 10 psig design pressure limit provides a margin of safety below the design drum pressure of 43 psig. The setpoint of the currently installed relief valves is 5 ±1 psig. The installed relief valves are of a simple, direct-acting mechanical design. The setpoint is established by design and is non-adjustable.

The protective enclosure spill contaminant capacity of 880 gal provides sufficient capacity to contain a liquid volume equal to the combined volume of the sixteen 55-gal drums the enclosures are designed to store.

These credited Design Features are contained in BJC/OR-1248, *BJC List of Active Safety Systems (LASS) and List of Design Features (LDFs)*, and in BJC/OR-1547, *K-25 and K-27 Facilities Configuration Management Plan, East Tennessee Technology Park*. This puts the Design Features under configuration management and control to preclude any changes without appropriate review and approval under the Unreviewed Safety Question process and the Project Review Committee, which serves as the Configuration Control Board for changes to Design Features and Active Safety Systems.

## **2.6 SYSTEM CONTROL FEATURES**

### **2.6.1 System Monitoring**

The instrumentation, indicators, alarms, and related information, as noted previously, are provided to operations personnel through the monitoring screen on the proportioning machine, as well as the external visual and audible alarms. Visual alarms are green for “OK” status, amber for “trouble” indication, and red and audible for “shutdown.” These alarms are mounted on the machine and on the exterior side of the trailer. When the status light is green, all monitored functions are within the preset ranges, and the machine is ready for foam application. It is anticipated that a foaming crew member will be in close proximity to the trailer to observe external system alarms, but it is not a requirement because the proportioning machine will cease functioning in the event of an off-normal condition.

In addition to the safety shutdowns described in Sect. 2.5, the following “Tolerance” alarms and associated shutdowns are provided by the PLC for the following conditions:

- PMDI-to-poly proportioning pump outlet pressure differential out of tolerance,
- PMDI and poly component preheater temperature differential out of tolerance,
- PMDI hose temperature differential out of tolerance, and
- PMDI-to-poly component delivery hose flow differential out of tolerance.

Should any of the operating parameters fail outside of the set limits, a visual and audible warning will occur. If the out-of-tolerance condition is not corrected within the established dwell time (as discussed below), the unit will shut down and the HMI will default to the Alarm Status Screen to inform the operator of the fault condition. A message text will prompt the operator with suggestions to analyze and clear the fault condition. The machine cannot be returned to normal operation until the fault is cleared and reset. The Alarm History Screen will track historical alarm data for future reference.

The PLC logic includes programmable dwell time settings that must be exceeded before the PLC will initiate a system shutdown following detection of an out-of-tolerance condition. These dwell times are utilized to preclude spurious system shutdowns from normal system operational transients while still providing initiation of an automatic shut-off in a period of time that ensures safe operation.

If an alarm condition cannot be cleared, the machine will be required to be taken out of service to make repairs.

### **2.6.2 Control Capability and Locations**

The proportioning machine is operated and controlled by the PLC with a full-color graphic operator interface (i.e., HMI). The normal functional controls such as ON/OFF switches and control parameter adjustments are made through the HMI touch screen. The trailer-mounted air compressor and air dryer are controlled locally with ON/OFF switches mounted on the equipment.

The PLC controls provide the capability to momentarily energize the air control valve or proportioning pump manually (via the PLC), regardless of any low-pressure shutdown conditions in the respective lines. This feature allows raising the feed line pressure or delivery line pressure above the associated low-pressure shutdown setpoint during system startup or recovery from a low-pressure condition. This manual control function requires the operator to sustain contact with the control screen for the length of time necessary to raise/restore pressure (i.e., similar to a momentary contact switch). Similarly, the PLC controls include the capability to enable or disable the out-of-tolerance shutdown features by depressing

an “Enable” or “Disable” button on the HMI. This feature disables all of the out-of-tolerance shutdowns to allow system startup. This Enable/Disable feature does not affect any of the designed safety shutdowns (i.e., Faults)

The main ON/OFF switch is located on the left side of the front panel. It controls power to all circuits and can be locked in the OFF position for lockout/tagout if machine maintenance is required. There is a separate ON switch for the control power circuit, which is located on the lower right side of the front panel. There is a STOP switch on the upper right of the front panel for emergency stop only. Status indicator lights (green, amber, and red) are located on top of the machine and on each exterior side of the trailers. The touch screen (i.e., HMI) is located in the center of the front. The normal functional controls, such as ON/OFF switches and control parameter adjustments, are made through the HMI touch screen. The vendor equipment manual details the various video screens and options available. The system is designed such that when the correct operating parameters are set and a system-ready green light is illuminated, no changes by the operators will be required. The trailer-mounted air compressor and air dryer are controlled locally with ON/OFF switches mounted on the equipment.

### **2.6.3 Automatic and Manual Actions**

The system, equipment, and component manual operations consist of turning the machine ON/OFF; starting up and securing the system air compressor and air dryer; starting and securing the hydraulic pump, primary heaters, and hose heaters from the HMI; scrolling through the data screens on the HMI to validate correct settings and monitor equipment operating parameters; and squeezing the trigger to dispense the foam once the machine has been set up.

The self-monitoring system alerts the operators to important conditions that require attention after the system is activated. The alerts (visual and audible) are automatic and are triggered by indications that the system conditions have fallen outside those parameters set by the operator. Conditions that would trigger alerts are those noted in Sects. 2.5 and 2.6.1. These alerts require manual interface with the system, either to adjust operating ranges or to correct any malfunction as indicated by the monitoring screens. Alerts could be as simple as a low-pressure indication on a feed line, temperatures outside of the desired range, and an indication of a line break.

Alerts are activated either to notify the operator of a condition that needs attention to optimize foam production or to shut off the machine if a condition exists that makes foam production impossible or continued operation damaging to the system. The alerts can be triggered by both internal mechanisms (e.g., wear out of seals, electrical failures, and overheating) and external mechanisms (e.g., severing of air, hydraulic, product feed, or delivery hoses). The system has been preset such that, in the event of a line break, no more than 1.6 gal of each material could be emitted from the system.

### **2.6.4 Setpoints and Ranges**

For this equipment, the parameter and setpoints are controlled by the system PLC as follows:

- |  |            |
|--|------------|
| • PMDI and Poly Component Preheater High-Temperature Fault                       | 200°F      |
| • PMDI and Poly Proportioning Pump High Outlet Pressure Fault                    | 2200 psig  |
| • PMDI and Poly Proportioning Pump Low Inlet Pressure Fault                      | 30-40 psig |
| • PMDI and Poly Proportioning Pump Low Outlet Pressure Out of Tolerance          | 500 psig   |
| • PMDI and Poly Proportioning Pump Outlet Pressure Differential Out of Tolerance | 500 psig   |
| • PMDI-to-Poly Component Delivery Hose Flow Differential Out of Tolerance        | 1:1 ± 5%   |
| • PMDI Hose Heater (TSU) Temperature Out of Tolerance                            | ±5°F       |
| • PMDI and Poly Component Preheater Temperature Differential Out of Tolerance    | ±5°F       |

- Hydraulic Pump Overpressure Safety Switch 2800 psig
- PMDI and Poly Component Preheater Temperature Normal Control Temp 100°F
- Hose Heater Temperature Normal Control Temp 100°F

Setpoints for these parameters can be changed by an authorized administrator to facilitate a changed condition such as foam component temperature, which may require a change in the inlet pressure to efficiently move the material through the piping. Current setpoints optimize foam production but also meet the requirements for automatic shutoff to facilitate meeting TSR conditions in the event of a line failure (spill limited to 1.6 gal) by virtue of a maximum 8-second shut-off delay time. Making any changes to these setpoints requires entry into the setup mode and therefore subsequent functional testing and documentation addressed in KD-2000, *Surveillance and Inspection Program*, and BJC/OR-1547, *K-25 and K-27 Facilities Configuration Management Plan*.

#### **2.6.5 Interlocks, Bypasses, and Permissives**

The PLC controls provide the capability to momentarily energize the air control valve or proportioning pump manually (via the PLC), regardless of any low-pressure shutdown conditions in the respective lines. This feature allows raising the feed line pressure or delivery line pressure above the associated low-pressure shutdown setpoint during system startup or recovery from a low-pressure condition. This manual control function requires the operator to sustain contact with the control screen for the length of time necessary to raise/restore pressure (i.e., similar to a momentary contact switch). Similarly, the PLC controls include the capability to enable or disable the out-of-tolerance shutdown features by depressing an Enable or Disable button on the HMI. This feature disables all of the out-of-tolerance shutdowns to allow system startup or operation outside of normal parameters if desired. This Enable/Disable feature does not affect any of the designed safety shutdowns (i.e., Faults).

### **3. OPERATIONS**

#### **3.1 INITIAL CONFIGURATION (PRE-STARTUP)**

The six foaming systems were configured and assembled by the manufacturer (Gusmer). The vendor for this equipment, North Carolina Foam Industries, has verified that the system was assembled correctly and that system pre-start checks were performed. In general, this included connecting power to the trailers, checking equipment rotation direction, connecting foam component material drums into the system, and verifying equipment settings using the touch screen monitor. This pre-start check was performed on all six units.

The pre-start checks were completed and all systems were deemed fully operational. Having completed the pre-start checks, the foaming system will be subjected to a system startup, under the normal operations mode, on an as-needed basis. BJC procedure KD-3005, Gusmer® H20/35 Pro-TEC Proportioning Unit and Foaming System Trailer, has been developed to provide instructions to operate the equipment in such a manner as to be compliant with the manufacturer's manuals and with any applicable Safety Basis document for the facility.

#### **3.2 SYSTEM STARTUP**

System startup follows specific steps that are required to be performed prior to energizing the Proportioning Unit. The specific steps are detailed in BJC procedure KD-3005.

#### **3.3 NORMAL OPERATIONS**

Normal operations would follow the system startup steps as specified in the foam system procedure, KD-3005. The operator will go through the various status and machine control screen steps to start the machine. The Foam Delivery System, in the normal operating mode, will indicate that all conditions meet the preset ranges by illuminating the green lights. This means that all temperatures and pressures are within their preset range (see Sect. 2.6.4) and that all conditions are met to produce foam at the appropriate ratio. As part of a routine system performance check, test shots, injecting foam into a test bucket or bag, are performed after the proportioning machine indicates the system is fully operational, but prior to foam installation in the target PGE/P. Any change to the system output is facilitated by using the HMI touch screen, selecting the desired screens/function, and inputting the alternative value.

The proportioning machine has electronic memory capacity to record component usage and trending data. There are three separate screens for trending (i.e., temperature, pressure, and ratio), and these screens provide real-time data. Each time a new screen is selected, the previous data are erased and replaced by new real-time data. Historical data can be viewed on a data logger screen, but the data are retained only while the machine is ON.

#### **3.4 OFF-NORMAL OPERATIONS**

The system is not intended to be operated in an off-normal condition. The system parameters are set and monitored by the machine to optimize foam production and to alert the operator to any off-normal

condition so that it can be corrected. Alerts to off-normal conditions initiated by the Foam Delivery System proportioning machine are in both an audible and a visual mode. An amber light and an audible alert indicate that a parameter is outside the preset range. A red light and an audible alert indicate that a monitored parameter is such that a machine shutdown has occurred. The operator must scroll through the machine alarm status screen to identify the cause of the alarms and to take the appropriate action to clear the fault(s) until normal operation status is achieved.

### 3.5 SYSTEM SHUTDOWN

Proper shutdown of the system requires operator interface with the touch screen monitor. The full sequence is detailed in procedure KD-3005. Major steps in this process include proper shutdown of the hydraulic pump to a RETRACT position, closing valves on the gun coupling block to isolate foam feed material from mixing chamber, turning off power to heat sources and motors, and closing inlet supply hoses (material feed and air). Feed material may remain in the drums, hoses, and equipment for long periods (up to 6 months) as long as no material is exposed to the atmosphere because moisture has a detrimental effect on the material. The self-cleaning feature of the gun head mixing chamber allows for extended shutdowns with no clogging of the gun. This feature is the result of the close tolerances between the mixing chamber wall and the piston that opens/closes the foam component ports in the wall and then pushes out all foam when the trigger is released.

### 3.6 ADMINISTRATIVE CONTROLS

Administrative Controls related to the foaming operation are set forth in Sect. 5.0 of the TSR (TSR-ET-K25/K27-0002). These requirements do not directly affect the Foam Delivery System design or operating parameters, and include:

1. limitations on the amount of foam component material that can be inside the building or staging areas at any given time,
2. staffing requirements during foaming operations,
3. handling requirements for unmixed foaming component materials, and
4. controls for the protection of the foaming materials and system during D&D activities

Specific Administrative Controls contained in the TSR are as follows:

1. Specific Administrative Control 5.5.1.a. – *The amount of unmixed PMDI polyurethane foam component material shall be limited to two 55-gallon drums in a FOAMING OPERATION AREA.*

The purpose of this requirement is to limit the amount of the unmixed PMDI polyurethane foam component material in any one foaming location, thereby reducing the consequences of a fire impacting this material. Two drums of the unmixed PMDI polyurethane foam component material (not to exceed a nominal 110 gallons) are allowed to account for activities during drum exchanges (typically one heel and one full). Only one drum of the unmixed PMDI polyurethane foam component material is normally present at each foaming station when not performing an exchange.

2. Specific Administrative Control 5.5.1.b. – *Movement of drums of unmixed PMDI polyurethane*

*foam component material...shall be done using propane-fueled, electric-powered, or hand-operated transfer equipment.*

The purpose of this requirement is to reduce the likelihood of a fire in the event of a vehicle accident when moving the foam component material by eliminating diesel or gasoline as a spilled fuel source capable of ignition.

3. *Specific Administrative Control 5.5.1.c. – Concrete Vehicle Barriers (e.g., Jersey barriers) shall be used to protect drums of unmixed PMDI polyurethane foam component material (including spent drums)... while in ESAs (within 50 ft of roadways).*

The purpose of this requirement is to protect the foam component materials staged in external areas from vehicle impact. These barriers prevent the vehicle from impacting the material or slow it down enough to allow the foam component container to maintain its integrity and mitigate the consequences of the impact. Barriers are arranged to preclude a direct vehicle path to the material. Space between barriers and temporary relocation to allow access for vehicles used to move the material are acceptable.

4. *Specific Administrative Control 5.5.1.e – Drums of unmixed PMDI polyurethane foam component material shall not be stored or staged within 100 ft of above ground natural gas line segments.*

The foam component materials must be at least 100 ft from above ground natural gas line segments so that they are not affected by the pressure wave or by the ensuing fire caused by failure of the gas line. The foam component material location is within the control of the Project, while the isolation of the gas line is not. This control prohibits the storage or staging of foam component materials in the area that could be potentially impacted by a natural gas line explosion and/or fire. This reduces the quantity of the subject materials involved in the explosion. The spacing restriction does not apply to foam component material in the process of movement or transport.

5. *Specific Administrative Control 5.5.1.f. – The inventory of material that may be moved in a single movement is limited to: ...one 55 gallon drum of PMDI polyurethane foam component material...*

The purpose of this requirement is to reduce the amount of foam component materials that can be involved in an accident during movement activities.

6. *Specific Administrative Control 5.5.2.e. – Unless ATTENDED or a Fire Watch is established, flammable material storage (outside of flammable storage cabinets), and extended storage (e.g., overnight) of gasoline, diesel, and propane powered vehicles shall be prohibited within 50 ft (or equivalent as specified by an FPE) of...Foaming Component Protective Enclosure(s) containing drums of unmixed PMDI polyurethane foam component material...*

This control applies to both flammable liquids and gasses (e.g., propane) that are not associated with facility equipment or systems (e.g., installed systems, Foam Delivery System, hydraulic power units or propane powered material handling equipment). Separation distance prevents involvement of foam component material in a fire. Flammable material storage need not be limited when the material is ATTENDED or a Fire Watch is established. Establishment of a Fire Watch or the presence of the work crew reduces the likelihood that a fire can be initiated or will spread. The radiant heat at the 50-ft separation distance is not sufficient to cause a thermal release of material. A separation distance of 50 ft

will limit the heat input from a fire sufficiently to keep the internal air temperature in the Foaming Component Protective Enclosure from exceeding the design temperature limit of the Design Feature Section 6.3 of the TSR. An FPE can evaluate individual configurations to determine equivalency or authorize alternate configurations that are documented to preserve the safety function. The spacing restriction does not apply to foam component material in the process of movement or transport.

7. Specific Administrative Control 5.5.2.f. – *Hotwork activities and ignition sources shall be controlled within 35 ft of ...unmixed PMDI polyurethane foam component material, including the application hose and staged drums.*

The purpose of this requirement is to establish a buffer zone within which controls are established to minimize the potential for a fire involving the foam component material. The spacing restriction does not apply to foam component material in the process of movement or transport.

8. Specific Administrative Control 5.5.2.g. – *Open flame or plasma arc cutting techniques shall be prohibited on equipment that has been stabilized with polyurethane foam.*

Cured polyurethane foam can give off toxic gases when exposed to high temperatures. The purpose for this requirement is to ensure that any cutting of materials that have been filled with polyurethane foam does not take place with open flame or plasma arc cutting techniques, thus preventing the emission of these gases.

9. Specific Administrative Control 5.5.2.h. – *An Activity Hazard Analysis/Job Hazard Analysis shall address any hotwork on piping or equipment that has been treated with polyurethane foam, specifically addressing the hotwork interface with the polyurethane foam.*

The purpose for this requirement is to ensure hotwork, other than open flame or plasma arc cutting techniques, is evaluated, and controlled to minimize the risk of fire. Controls for such activities will be developed on a case-by-case basis and will be included in the work package.

10. Specific Administrative Control 5.5.2.i. – *Drums of unmixed PMDI polyurethane foam component material shall be staged in a Foaming Component Protective Enclosure...*

The purpose for this requirement is to ensure that the unmixed PMDI polyurethane foam component material is staged in a way that prevents a potential fire from impacting the material and resulting in significant consequences. This is not intended to preclude having the enclosure doors open for short periods of time during foam application, to allow access for such things as routine equipment maintenance, polyurethane foam component material drum change out, or troubleshooting, as long as the doors can be promptly shut in the event of a fire. A Fire Watch will be posted whenever the enclosure doors are open. The unmixed PMDI polyurethane foam component material is applied through a hose from the Foaming Component Protective Enclosure. This requirement also minimizes the release of PMDI during a fire.

11. Specific Administrative Control 5.5.2.j – *A Fire Watch shall be present at any time the unmixed PMDI polyurethane drum(s) is/are not protected by the Foaming Component Protective Enclosure (e.g., when doors open or drum in transfer or movement outside of enclosure).*

The unmixed PMDI polyurethane foam component material drums are not being protected from a fire when not inside a secure protective enclosure. Therefore, when the doors of the enclosure are open (e.g., during polyurethane foam component material drum change out, or troubleshooting) or the drum(s) is/are outside the enclosure for exchange or movement, a Fire Watch will be posted near the drum to watch for unsafe conditions and provide early notification, fire suppression activities, and/or mitigation response activities (e.g., close doors).

12. Specific Administrative Control 5.5.2.k. – *Equipment/vehicle refueling shall not be performed within 50 ft of any of the following:... Foaming Component Protective Enclosure(s) containing*



*drum(s) of unmixed PMDI polyurethane foam component material ...*

Separation distance reduces the potential for involvement of the foam component material in a fire. Separation from refueling activities removes the fuel source (including fuel trucks) from the foam component material area. A spill is not expected to maintain sufficient depth at 50 ft to sustain a fire that will compromise foam component material. The radiant heat produced by flammable material or combustible liquid at the 50-ft separation distance is not sufficient to cause a thermal release of material. A separation distance of 50 ft will limit the heat input from a fire sufficiently to keep the internal air temperature in the Foaming Component Protective Enclosure from exceeding the design temperature limit of the Design Feature Section 6.3 of the TSR. This control applies to flammable gasses (e.g., propane) as well as flammable or combustible liquids. The spacing restriction does not apply to foam component material in the process of movement or transport.

13. Administrative Control 5.5.2.l. – *No more than two Foam Delivery System hoses containing unmixed PMDI polyurethane foam component material may be within 25 ft of an individual combustible storage load as defined in 5.5.2.a or 5.5.2.b as applicable.*

The purpose of this requirement is to limit the amount of unmixed PMDI polyurethane foam component material potentially involved in a fire from the same combustible source, thereby reducing the consequences of a fire impacting this material. The combustible storage load size (i.e., 5.5.2.a or 5.5.2.b) will be based on the location of the equipment.

14. Administrative Control 5.5.2.o. – *Unless ATTENDED or a Fire Watch is established, a minimum spacing of at least 50 ft (or equivalent as specified by an FPE) is required between COMBUSTIBLE LIQUID container(s) holding ≥ 6 gallons and each of the following: ... Foaming Component Protective Enclosure(s) containing drums of unmixed PMDI polyurethane foam component material....*

Establishment of a Fire Watch or the presence of the work crew reduces the likelihood that a fire can be initiated or will spread. When the work crew or a fire watch is not present, the separation distance provides mitigation of any potential release of the foam component material in the event of a fire and potential fire propagation to adjacent combustible material. Not requiring the control for volumes < 6 gallons allows the use of safety cans without an attendant or fire watch. Volumes of COMBUSTIBLE LIQUID < 6 gallons will not contribute significantly to a fire. The radiant heat produced by a pool fire involving two 55-gallon drums of COMBUSTIBLE LIQUID is not sufficient to cause a thermal release of material or ignition of an adjacent combustible or flammable material storage location at a distance of 50 ft, even assuming some running of the liquid pool. A separation distance of 50 ft will limit the heat input from a fire sufficiently to keep the internal air temperature in the Foaming Component Protective Enclosure from exceeding the design temperature limit of the Design Feature Section 6.3 of the TSR. An FPE can evaluate individual configurations to determine equivalency or authorize alternate configurations that are documented to preserve the safety function. The spacing restriction does not apply to foam component material in the process of movement or transport.

15. Administrative Control 5.5.2.q. – *Movement of COMBUSTIBLE LIQUID container(s) holding ≥ 6 gallons within 50 ft (or equivalent as specified by an FPE) of... Foaming Component Protective Enclosure(s) containing drums of unmixed PMDI polyurethane foam component material... shall be done using propane-fueled, electric-powered, or hand-operated transfer equipment and shall be ATTENDED.*

The purpose of this requirement is to reduce the potential for an event involving COMBUSTIBLE LIQUID, the foam component material and a vehicle fire during movement activities. Not requiring the control for volumes < 6 gallons allows the use of safety cans without an attendant. Volumes of

COMBUSTIBLE LIQUID < 6 gallons will not contribute significantly to a fire. A separation distance of 50 ft will limit the heat input from a fire sufficiently to keep the internal air temperature in the Foaming Component Protective Enclosure from exceeding the design temperature limit of the Design Features Section 6.3 of the TSR. Limiting movements to use of propane-fueled, electric-powered, or hand-operated transfer equipment eliminates diesel or gasoline as a spilled fuel source capable of ignition. The requirement for the movement to be ATTENDED reduces the likelihood that a fire can be initiated or will spread. An FPE can evaluate individual configurations to determine equivalency or authorize alternate configurations that are documented to preserve the safety function.

16. *Administrative Control 5.5.2.r. – Except as allowed by SAC 5.5.2.c, or stored in a closed Combustible Material Container, solid combustible material in excess of DE MINIMIS levels shall be prohibited within 40 ft of Foaming Component Protective Enclosure(s) containing drum(s) of unmixed PMDI polyurethane foam component material.*

Foaming Component Protective Enclosures are intended to prevent a potential fire initiated outside of the enclosure from involving the unmixed PMDI polyurethane foam component material stored within the enclosure. The established Foaming Component Protective Enclosure design criteria is based on a known heat input from the external fire source. A separation distance of 40 ft from any solid combustible materials in excess of DE MINIMIS levels will limit the heat input from a fire sufficiently to keep the internal air temperature in the Foaming Component Protective Enclosure from exceeding the design temperature limit of Design Feature Section 6.3 of the TSR. Solid combustible materials stored in a Combustible Material Container with a closed lid are not considered a combustible storage load for purposes of application of this combustible material control. Solid combustible materials contained in this fashion will not significantly contribute to the fuel loading in the event of a localized fire. The spacing restriction does not apply to material in the process of movement or transport. When SAC 5.5.2.c is in effect, solid combustible materials are ATTENDED or a Fire Watch is established. Establishment of a Fire Watch or the presence of the work crew reduces the likelihood that a fire can be initiated or will spread.

The TSR also contains programmatic Administrative Controls under identified Safety Management Programs (SMPs) for the Foam Delivery System operation as follows:

1. 5.6.2.5 Initial Testing, In-Service Surveillance, and Maintenance Program  
The Initial Testing, In-Service Surveillance, and Maintenance Program shall establish a requirement that the overpressure relief device in the dry air line connected to the PMDI drum vapor space in the Foam Delivery System trailers is replaced every two years after being placed into service.
2. 5.6.2.6 Fire Protection Program  
The Fire Protection Program establishes requirements for:
  - Activities involving hotwork or ignition sources on the K-25 BUILDING or K-27 BUILDING roof while the associated building contains any of the following:...drums of unmixed PMDI polyurethane foam component material, shall require that a Fire Watch be provided on the roof, as well as on the operating floor directly below, or as otherwise specified by an FPE.
3. 5.6.2.7 Procedures and Training Program  
The Procedures and Training Program shall establish a requirement for application of foam to be done only by trained personnel.
4. 5.6.2.9 Configuration Management Program  
General credit was assumed in the DSA for the Configuration Management Program to ensure

configuration control for SS Structures, Systems, and Components, and Design Features that are controlled at the highest level. Items identified include the following Design Features:

- Concrete Vehicle Barriers (placement of barriers to protect material staged or stored outside);
- Foaming Component Protective Enclosures; and
- Foam Delivery System, including foaming system features (e.g., system volume-related devices and automatic shut-off feature-related devices including changes in PLC shutdown parameters or vendor software modifications).

#### 5. 5.6.2.10 Conduct of Operations Program

Conduct of Operations is founded upon a Work Control Program (WCP) that ensures work is carried out in a formal and systematic approach that embodies commitment to safety and excellence in operations and to continuous performance improvement. The WCP shall establish requirements for the application of polyurethane foam to include the criteria specified below:

- For work activities involving the application of Polyurethane foam:
  - For pours into equipment that do not exceed 24 in. in all dimensions:
    - Work packages that install the polyurethane foam in the process gas equipment include a documented evaluation that the polyurethane foam material, when poured, cannot exceed 24 in. in all dimensions.
    - Connected equipment with the potential to exceed 24 in. in all dimensions (e.g., cold traps) will be positively isolated (e.g., double valve isolation, air gap, blank) from the process gas equipment being treated.
  - For pours into equipment that may exceed 24 in. in all dimensions:
    - Pours greater than 24 in. in all dimensions will follow vendor's recommended application guidelines limiting the pour height (by limiting the volume of foam required as determined by calculation), ensuring an adequate cure time between pours, providing adequate mixing of the combined components, and application of the foam in the correct ratio.
- The WCP shall establish a requirement that an adequate buffer zone (100 ft) be established between the K-25 and K-27 Buildings demolition activities and drums of unmixed PMDI polyurethane foam component material.
- The WCP shall establish a requirement that work packages involving critical lifts have a Critical Lift Plan when lifting over a staging area containing drums of unmixed PMDI polyurethane foam component material.

#### 6. 5.6.2.12 Quality Assurance

The Quality Assurance Program (QAP) ensures a conceptual and programmatic framework for quality improvement, work processes, and management assessments. The following element of the QAP is credited and implemented in a facility procedure:

- Access to the Foam Delivery System PLC setup mode shall be password protected.
- The Foam Delivery System PLC software shall be designed and controlled to meet software QA requirements.

## **4. TESTING AND MAINTENANCE**

All testing and maintenance of the Foam Delivery System are contained in Project procedures KD-3005 and KD-2000.

### **4.1 TEMPORARY CONFIGURATIONS**

There are no temporary configurations anticipated for the Foam Delivery System.

### **4.2 TSR-REQUIRED SURVEILLANCES**

Quarterly functional testing is specified in Surveillance Requirement 4.3.1.1 of TSR-ET-K25/K27-0002. This surveillance requires functionally testing the system to ensure continued operability of the Foam Delivery System automatic shut-off. This functional testing is performed and documented in accordance with instructions detailed in procedure KD-3005. The functional test consists of initiation of a low-pressure condition in the PMDI feed line and delivery line and confirmation that closure of the solenoid operated control valve in the PMDI feed pump air supply occurs within 8 seconds in both instances. Verification of the actual actuation point of the low-pressure shut-offs and accuracy of the pressure transducers is not considered necessary. Performance of the functional test also is required anytime the password protected PLC setup mode is accessed or after equipment vendor accessing of the Foam Delivery System PLC to confirm that the settings, which could affect operability of the automatic shut-off, have not been inadvertently changed.

Calibration of the pressure transducers is not required. The TSR Bases state "Based on the limited life of the project and standard commercial design accuracy of the pressure transducers (typically  $\pm 3\%$  of full range) is considered capable of staying within 10% inaccuracy range without periodic calibration." Similarly, use of calibrated measuring and test equipment, such as stopwatches, is not required. DSA Sect. 4.4.6.4 states, "The design of these components involves response times on the order of tens of milliseconds and hundreds of milliseconds and therefore even when combined and accounting for potential degradation between performance of functional testing the system is capable of performance well within the 10-second timeframe."

A check of the Foam Delivery System HMI for error indications associated with the feed or delivery line pressure transducers is specified in Surveillance Requirement 4.3.1.1 of TSR-ET-K25/K27-0002. This surveillance is required to be performed weekly or at startup of the Foam Delivery System unit anytime foaming has not been performed with the unit within 48 hours. This functional testing is performed and documented in accordance with instructions detailed in procedure KD-3005. The surveillance is performed when the PLC and associated controls are initially energized, by observing the HMI screen, checking for any error or fault messages, and verifying normal expected system parameters. Fault indications or abnormal readings will be appropriately evaluated for effect on the operability of the Foam Delivery System automatic shut-off.

### **4.3 NON-TSR INSPECTIONS, TESTING, AND MAINTENANCE**

Periodic inspection requirements are provided in procedure KD-3005, as described under Sect. 4.4. There are no specific component or system alignment conditions associated with this equipment that can defeat the safety function of the equipment. Therefore, independent verification per BJC-FS-1027, *Independent Verification*, is not required for any activities associated with this equipment.

#### **4.4 MAINTENANCE**

The Foam Delivery System operators will perform any required maintenance on the system. There is no intention to utilize outside maintenance personnel. Periodic routine maintenance is described in procedure KD-3005 and detailed instructions are contained in the vendor equipment manuals. Maintenance includes daily, weekly, monthly, quarterly, and annual inspections and functional testing. Daily inspection includes general checks of hoses and fittings, y-strainer screen cleaning, compressor/dryer checks, and pump lubricant checks. Weekly maintenance involves a more detailed inspection of the air compressor. Monthly maintenance includes accumulator and air dryer inspection. Quarterly inspection/maintenance is limited to the air compressor. Annual maintenance involves disassembling of the proportioning machine, changing fluid, and maintaining the air dryer as described in the manual. Compliance with KD-2000 requires replacement of the dry air pressure relief valves every two years and subsequent functionality testing and documentation.

##### **4.4.1 Post-Maintenance Testing**

Post-maintenance testing is limited to individual equipment function/leak testing. Any testing required, following a maintenance action, will be as determined by the designated System Engineer.

##### **4.4.2 Post-Modification Testing**

Post-modification testing will be as determined by the designated System Engineer, but as a minimum will include performance of the functional test specified in KD-2000.

## **5. SUPPLEMENTAL INFORMATION**

Operators specifically trained on the equipment and its maintenance requirements will operate the Foam Delivery System. Operations using this equipment will follow work packages that specify other associated permits, training, and procedures that must be complied with in the execution of the work. The Configuration Management Program and Safety Basis documentation reviews or revisions are required if the system, as described herein, is altered.

Supplemental information, provided by the manufacturer of the foaming equipment, is provided in the vendor manuals listed in Appendices A and B. Appendix C contains a listing of system procedures.

**APPENDIX A:  
SOURCE DOCUMENTS**

1. *Documented Safety Analysis for the K-25 and K-27 Buildings at East Tennessee Technology Park, Oak Ridge, Tennessee, DSA-ET-K25/K27-0001.*
2. *Technical Safety Requirements for the East Tennessee Technology Park K-25 and K-27 Facilities, TSR-ET-K25/K27-0002.*
3. *Safety Evaluation Report for the Documented Safety Analysis and Technical Safety Requirements for the D&D Activities for the K-25 and K-27 Facilities, SER-K25/K27-D&D-SBT-03-19.*
4. *K-25 and K-27 Facilities Configuration Management Plan, BJC/OR-1547.*
5. *BJC List of Active Safety Systems (LASS) and List of Design Features (LDF), BJC/OR-1248.*
6. *Surveillance and Inspection Program, KD-2000.*
7. *Gusmer® H20/35 Pro-TEC Proportioning Unit and Foaming System Trailer, KD-3005.*
8. *Procurement, Control, Evaluation, and Use of Components and Parts, KD-1013.*
9. *Independent Verification, BJC-FS-1027.*
10. *Foaming Trailer Protective Enclosure Heat Transfer Calculation, BJC Calculation No. CAF-7K2527-A013.*
11. *Volume calculations for PMDI in foaming system outside of component enclosure, BJC Calculation No. CAM-7K2527-A019.*
12. *Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Operating Manual, 61942-H-1.*
13. *Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Parts Identification Manual, 61942-H-ID.*
14. *Gusmer Corporation Model GX-14 Pour Head, Operating Manual, 33943-I.*
15. *Gusmer Corporation Model GX-14 Pour Head, Parts Identification Manual, 33943-ID.*
16. *Gusmer Corporation 2:1 Ratio Transfer Pump, Operating Manual with Parts Identification, OP232-INST.*
17. *Gusmer Corporation Model OP 1 55 Air Dryer, Operating Instruction and Parts Identification Manual, OP155-INST.*
18. *Software Quality Assurance Plan for the Gusmer® H20/35 Pro-TEC Foam Delivery System at the East Tennessee Technology Park, BJC/OR-2210.*
19. *Foam Enclosure Adjustment for Reduced Flash Point Calculation, BJC Calculation No. CAF-7K2527-A497, Rev. 1.*



**APPENDIX B:**  
**SYSTEM DRAWINGS AND LISTS**

**BJC Controlled Drawings:**

M1E702500A720, Foaming Trailer Equipment Layout

J1E702500A001, Process Foaming System Process Flow Diagram

M1E702500A721, Process Foaming System Installation Isometric

E1E702500A125, Electrical Foaming System Single Line Diagram

C1E702500A114, Foam Storage Building

**Vendor drawings and figures as contained in the following manuals:**

1. *Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Operating Manual, 61942-H-1.*
2. *Gusmer Corporation H-20/35 Pro-Tec Proportioning Unit with Hydraulic Power Pack, Parts Identification Manual, 61942-H-ID.*
3. *Gusmer Corporation Model GX-14 Pour Head, Operating Manual, 33943-1.*
4. *Gusmer Corporation Model GX-14 Pour Head, Parts Identification Manual, 33943-ID.*
5. *Gusmer Corporation 2:1 Ratio Transfer Pump, Operating Manual with Parts Identification, OP232-INST.*
6. *Gusmer Corporation Model OP 1 55 Air Dryer, Operating Instruction and Parts Identification Manual, OP155-INST.*

## **APPENDIX C: SYSTEM PROCEDURES**

### **Operating and Maintenance Procedures**

1. *Gusmer® H20/35 Pro-TEC Proportioning Unit and Foaming System Trailer*, KD-3005.

### **Surveillance and Test Procedures**

1. *Surveillance and Inspection Program*, KD-2000.

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