U.S. Army Environmental Center

HOT GAS DECONTAMINATION *of* EXPLOSIVES-CONTAMINATED ITEMS

PROCESS AND FACILITY CONCEPTUAL DESIGN

FINAL

Prepared for

U.S. ARMY ENVIRONMENTAL CENTER

Aberdeen Proving Ground, Maryland 21010-5401

Prepared by

THE TENNESSEE VALLEY AUTHORITY

ENVIRONMENTAL RESEARCH CENTER

Muscle Shoals, Alabama 35660-1010

JANUARY 1995

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A Partnership to Improve the Environment

TVA

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NOTICE

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ABBREVIATIONS

106mm	- U.S. Army, 106 millimeter artillery projectile
175mm	- U.S. Army, 175 millimeter artillery projectile
3"/5"	- U.S. Navy Projectile
AMCA	- Air Movement and Control Association
BMS	- Burner Management System
CEM	- Continuous Emissions Monitor
CO	- Carbon Monoxide
CO_2	- Carbon Dioxide
Comp A-3	- Explosive Made From RDX and Wax
Comp B	- Explosive Made From TNT, RDX, and Wax
CWP	- Contaminated Waste Processor
DRE	- Destruction and Removal Efficiency
HBX	- Explosive Made From TNT, RDX, Aluminum, Lecithin, and Wax
HGD	- Hot Gas Decontamination
HWAD	- Hawthorne Army Depot, Hawthorne, Nevada
ICM	- Instrumentation, Control, and Monitoring
ICS	- Instrumentation Control System
ID	- Induced Draft
lb/hr	- pound/hour
MK 25	- U.S. Navy Ship Mine
MK 54	- U.S. Navy Depth Bomb
NO_x	- Nitrogen Oxides
OIU	- Operator Interface Units
P&ID	- Process and Instrumentation Drawing
PLC	- Programmable Logic Controller
RDX	- Hexahydro - 1, 3, 5 - trinitro - 1, 3, 5 - triazine
RFW	- Roy F. Weston

SO_x	- Sulfur Oxides
TNT	- 2, 4, 6 - Trinitrotoluene
TVA	- The Tennessee Valley Authority
VAV	- Variable Air Volume
Yellow D	- Ammonium Picrate
°F	- Degrees Fahrenheit

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SECTION 1.0

INTRODUCTION

1.1 Background

The manufacture, handling, and loading of explosives at Army ammunition plants contaminates process equipment (such as pumps, tanks, and piping) with explosive residue. This residual contamination prevents the maintenance and repair of the equipment as well as its reuse or disposal as scrap. This contamination must be removed before any of this can be accomplished. In addition, many metal munition items, such as projectiles and mine casings, from which explosives have been removed (washout, meltout, or augered out) require additional decontamination (to "5X" standards) in order to dispose of them properly.

Previous pilot tests and studies completed by Weston in 1990 [(1)], have shown that metal components can be decontaminated by heating the items with a circulating hot gas, which volatilizes the explosives and destroys them in a high temperature thermal oxidizer.

These tests indicated that metal items contaminated with TNT and treated for six hours at a minimum temperature of 500°F are not characteristically hazardous and are appropriate for disposal or, potentially, for resale as scrap.

The Tennessee Valley Authority (TVA) commenced further testing of Hot Gas Decontamination (HGD) at Hawthorne Army Depot (HWAD) from June through

[(1)] Task Order - 2, Pilot Test of Hot Gas Decontamination of Explosives-Contaminated Equipment at Hawthorne Army Ammunition Plant (HWAAP). Hawthorne, Nevada: Roy F. Weston Inc., June 1990. Report No. CETHA-TE-CR-90036.

October 1994. Successful removal efficiencies of 99.99 percent or greater have been demonstrated for items contaminated with the following explosives at the test conditions

- RDX (3" and 5" projectiles), Comp A-3 (106 mm projectiles), TNT (3" projectiles), and Comp B (175 mm projectiles) at 550°F for six hours.
- HBX (3" projectiles) at 600°F for six hours.
- Yellow D (ammonium picrate) (3" and 5" projectiles) at 600°F for six hours (an additional six hours was required to remove a group of unidentified by-products, yet to be determined as hazardous).
- Explosives held in a tar-like hot melt sealant (common to naval munitions) at 700°F for 24 to 32 hours. This temperature and hold time were required to volatilize the hot melt as well as the explosive, a condition imposed when it was found that the hot melt would dissolve and retain the explosives when heated in contact with explosive residue. Items tested that were coated with hot melt were contaminated with HBX (MK 54 depth bomb) and TNT (MK 25 naval mine).

1.2 Report Structure

Based on these findings, TVA has been assigned the task of providing a conceptual design for a full-scale HGD facility. This report presents the detailed elements of this conceptual design, including the design considerations (Section 2.0), the process design (Section 3.0), operation, equipment design, and material handling (Sections 4.0, 5.0, and 6.0), and a capital and operating cost estimate (Section 8.0).

In addition, a conceptual design for retrofitting an existing Contaminated Waste Processor (CWP) to a hot gas decontamination process is presented (Section 7.0).

SECTION 2.0

DESIGN CONSIDERATIONS

2.1 Introduction

This section of the report is presented to provide the reader with background on the key factors and design concepts that were considered in the design of the decontamination chamber and supporting equipment.

For any oven-type heating application, such as the decontamination chamber proposed here, the rate of heat transfer to the product is critical to the process design and operation. The rate of heat transfer affects the process design because it determines the amount of heat which must be delivered to the decontamination chamber during the heatup process. This heat transfer rate directly affects the time required to heat the items to their "hold temperature," and therefore impacts the overall decontamination cycle time needed to process each batch load of items.

The metal items in the chamber will be heated by convective heat transfer only. In other words, the flowing hot air is the only means by which heat can be transferred to the metal items. This method is unlike direct-fired heating ovens, where gas burners fire directly into the oven and utilize both convection and radiant heat transfer. Heat losses also affect the amount of heat required by the chamber, as is discussed in the subsections below.

2.2 Decontamination Chamber Heat Requirement

The amount of heat required by the decontamination chamber is based on the following three forms of heat transfer or loss that occur in the chamber:

- Convective heat transfer from the circulating hot air to the metal items in the chamber. This includes the heat required to thermally degrade or sublimate the residual explosive.
- Conductive heat loss through the walls and ceiling of the decontamination chamber.
- Heat required to offset the infiltration of ambient air into the decontamination chamber through the door and car bottom seals.

Collectively, these three sources of heat consumption comprise the heat load (or heat requirement) of the decontamination chamber at any instant in time during operation of the chamber.

Convective heat transfer is governed by the classical thermodynamic heat transfer equation:

$$Hc = h \times A \times TD$$

where Hc = Convective heat transferred, btu/hr

where h = Convective heat transfer coefficient, btu/hr-sq. Ft.-F

where A = Surface Area, sq. ft.

Where TD = Temperature Difference, degrees Fahrenheit (°F).

With heating oven applications, the value of the convective heat transfer coefficient h is usually the most difficult of the above terms to accurately calculate or predict and control. As shown by the above equation, the larger this factor the faster the heat can be transferred to the items. The rate at which an item can absorb heat is dependent on the thermal conductivity of the material, the size and shape of the item, and the velocity and direction at which the convected air impinges the surface of the item. While heat absorption rates can be estimated for common materials based on charts and formulas, actual test work may be necessary to know the exact rate that a specific item can absorb heat.

The larger the surface area (A) that is exposed to the hot gas, the greater the rate of heat transfer. This becomes critical on items with low surface area to mass ratios. For two items with equal mass, the one with the largest surface area will heat up the fastest.

The greater the temperature difference between the hot gas and the item, the faster the rate of heat transfer. In a convective heating oven application (where the air is delivered at a constant temperature throughout the heatup cycle) as the item temperature increases, this temperature difference and corresponding rate of heat transfer will decrease. This produces a nonlinear decrease in heatup rate.

Contributing to the heat requirement of the decontamination chamber is the heat lost by conduction through the walls and ceiling of the chamber. For a well insulated chamber, this would normally amount to only a few percent of the total heat required. This conductive heat loss can be minimized by installing the proper type and thickness of insulation. Another factor to be considered regarding insulation is the thermal capacity of the insulation used. This is the amount of heat that is absorbed and held in the insulation. This affects heatup as well as cool down rates. As a design consideration, the type and thickness of insulation to install becomes an economic balance (or economic optimum point) between heat loss, thermal capacity, and insulation cost.

Since the chamber will be maintained at a slight negative pressure (0.1 to 0.2 inches w.g. vacuum) to prevent fugitive emissions of explosive-contaminated air, air infiltration must be accounted for at all openings. This heat loss is added to the other two forms of heat consumption (transfer to the items and the heat loss through the walls) to account for the total quantity of heat required to operate the chamber.

2.3 Construction Materials for High Temperature Applications

The two major factors which should be considered when a construction material is selected for service at elevated temperatures are oxidation resistance and mechanical strength.

Oxidation resistance of service materials is dependent on the properties of the oxide scale formed on the metal surface. If the scale is continuous and adhesive, then the metal exhibits good resistance to further oxidation. However, stress, temperature, temperature fluctuations, and corrosive species, such as sulfur compounds, reduce the scale protection.

When metal is subjected to prolonged air exposure at elevated temperatures, the most important alloying element for increasing oxidation resistance for steels is chromium. At a maximum service temperature of 900°F, plain carbon steels can be used without excessive oxidation. However, above 900°F additional chromium is required to avoid excessive oxidation. A minimum chromium content of 9 percent by weight is recommended for an operating temperature of 1200°F.

Metals deform more easily under load at elevated temperature due to creep. Thus, different design stress principles are required from those used for ambient temperature service. If service temperature is lower than the lowest creep temperature (the temperature at which creep starts taking place under load), tensile strength measured at the maximum service temperature is the controlling design parameter. If the service temperature is higher than the lowest creep temperature, then the creep (rupture) strength should be the controlling design parameter. The lowest creep temperature for carbon steel is approximately 800°F. For austenitic stainless steels, such as Type 304 and 316, the lowest creep temperature is approximately 1050°F.

2.4 Heat Transfer Model

Since the heat absorption rate of the items in the oven is of primary concern to sizing the heat source and to determining the heatup times, a computer model was created to predict the rate of heat absorption as well as the air temperature leaving the chamber, for a given chamber load capacity and configuration.

For this model, the following parameters were chosen:

Decontamination Chamber Size:	18' L x 7' W x 7' H
Items For Decontamination:	175 mm projectiles
Quantity:	336 each
Total Weight:	37,968 lbs.
Initial Item Temperature:	*45°F
Chamber Inlet Air:	4000 scfm @ 1200°F

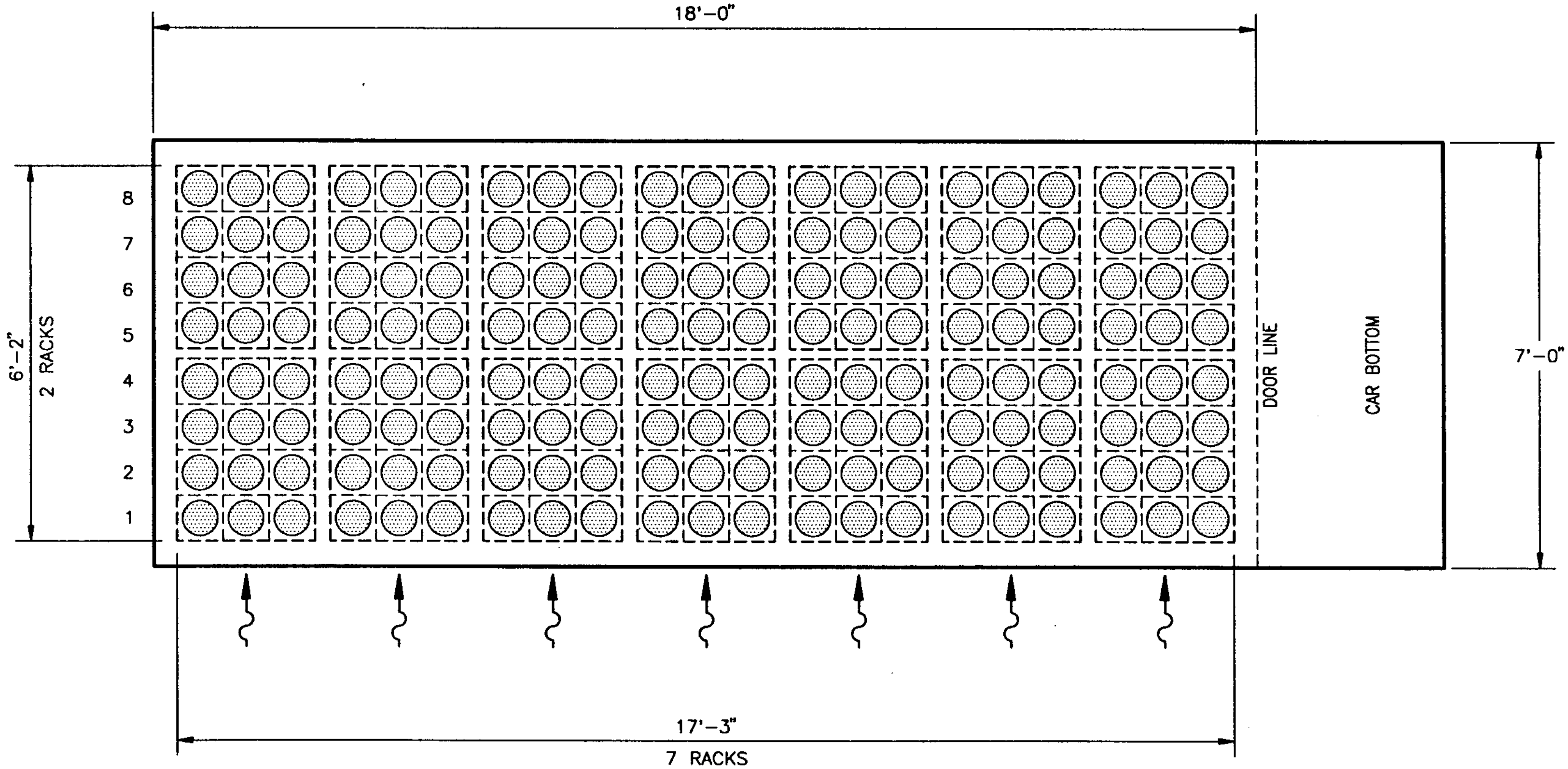
*45°F initial item temperature was chosen to correspond to a median ambient temperature.

The 175 mm projectiles were configured in an array of 21 rows across and 8 rows deep, stacked two high. Figure 2-1 shows the 175 mm projectile arrangement on the car bottom and the direction of air flow. This is considered a near optimum loading for these items and resulted in a volume utilization ratio of 0.36, and a cross-sectional area (with respect to the direction of air flow) utilization of 0.68. This type of an evenly spaced array of cylindrical items made it convenient to model since it resembles a tube bundle for a conventional process heat exchanger. Extra mass was added to the mass of the items to account for the racks that would be required to support the 175 mm projectiles in the desired array. Based on the geometry of the 175 mm projectiles and the spacing in the chamber, it was possible to calculate a convective heat transfer coefficient of 1.2 btu/hr-sq. ft.-°F. Although several assumptions had to be made to obtain this value of h, it is reasonable and consistent with published data. The value of h calculated from the test

CAR CAPACITY = 40,000 lbs

UNIT WEIGHT, 175mm PROJECTILES = 113 lbs

TOTAL WEIGHT, 336 PROJECTILES = 37,968 lbs



175mm ARRAY

NOTE: RACKS STACKED TWO HIGH

Figure 2-1. HEAT TRANSFER MODEL ITEM ARRANGEMENT

data of the chamber operation at HWAD by Weston was between the range of 1.17 and 1.82. Also, the value of h normally used in the design of air to air heat exchangers is in the range of from 3.5 to 5.0, and since the velocity in the chamber is considerably lower than in most air to air heat exchangers, the value of h for the model is expected to be lower.

The model also took into consideration the drop in air temperature from row to row of the array. This enabled the model to predict the temperature of each row of projectiles, the amount of heat absorbed, and the temperature of the air leaving the chamber at any point of time during the heatup mode.

Appendix A shows the complete model results (i.e., model parameters versus time in computer spreadsheet format). The model predicted that, for the chamber operating conditions and load shown above, a target temperature of 550°F would be reached in a heatup time of about three hours, and a target temperature of 800°F would be reached in about six hours. These would be considered adequate heatup times for most commercial oven operations requiring that item integrity be maintained.

Figure 2-2 summarizes the temperature profiles of the chamber inlet and outlet air, and the metal items in rows one and eight for the heatup process. Temperatures for the projectiles in rows 2 through 7 fall between row 1 and row 8 and are excluded for clarity.

The air inlet temperature remains constant throughout the process at 1200°F. The outlet air temperature increases as heatup of the items progresses. This is caused by the decrease in the temperature difference between the inlet air and the projectiles which yields less heat transfer and therefore a higher outlet air temperature.

Figure 2-2 also shows the non-linear heatup of the projectiles. The time required for the projectiles to heat from 45° to 550°F, a difference of 505 degrees, is three hours. An

CHAMBER TEMPERATURE PROFILE

COMPUTER MODEL HEAT UP

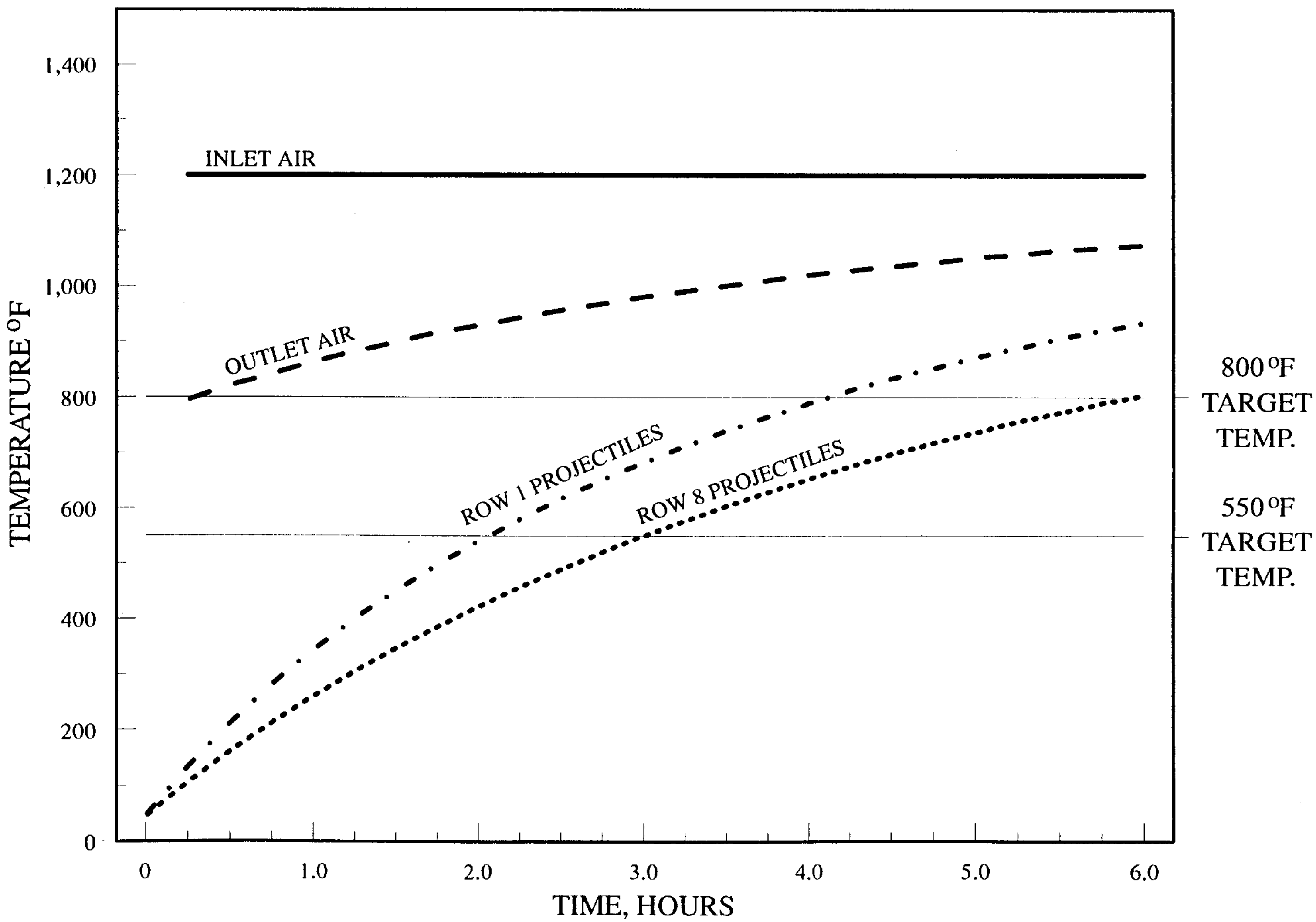


FIGURE 2-2

additional three hours is required to heat the projectiles from 550° to 800°F, a difference of just 250°F.

Also of interest is the temperature difference, or gradient, experienced between rows of the projectiles during heatup. This temperature gradient starts off low but increases to a value over 100°F between rows 1 and 8. This temperature gradient is somewhat over projected, since radiation heat transfer between rows will help to reduce this temperature differential. (This temperature gradient shall be reduced even further during the decontamination, or temperature hold, mode.)

Figure 2-3 shows how the heat absorption rate and the total heat absorbed by the items varies during the heatup process. As can be seen, the heat absorption by the items is a maximum at time zero, when the items are at their lowest temperature, and decreases as the items heat up. The total heat absorbed by the items continues to increase, but at a decreasing rate, as dictated by the decreasing heat absorption rate.

Once the "hold temperature" has been reached, the amount of heat required to maintain the items at this desired temperature is only that required to offset the heat loss through the walls and ceiling of the chamber, bring the infiltrating air up to the hold temperature, and to thermally degrade or sublimate the remaining residual explosive.

It should be noted that this heat transfer model for predicting heating energy requirements and heatup times is for a specific chamber loading, item, and configuration. The same quantity and type of item could be loaded into the chamber in a different configuration and produce quite different results. In addition, a chamber designed to handle different types of items as well as the many different arrangements that these items can be loaded into the chamber, can present a multitude of heat transfer rates resulting in differing chamber heat requirement rates and heatup times. Thus the model's primary value was in

CHAMBER HEAT ABSORBTION

HEAT TRANSFER MODEL HEAT UP

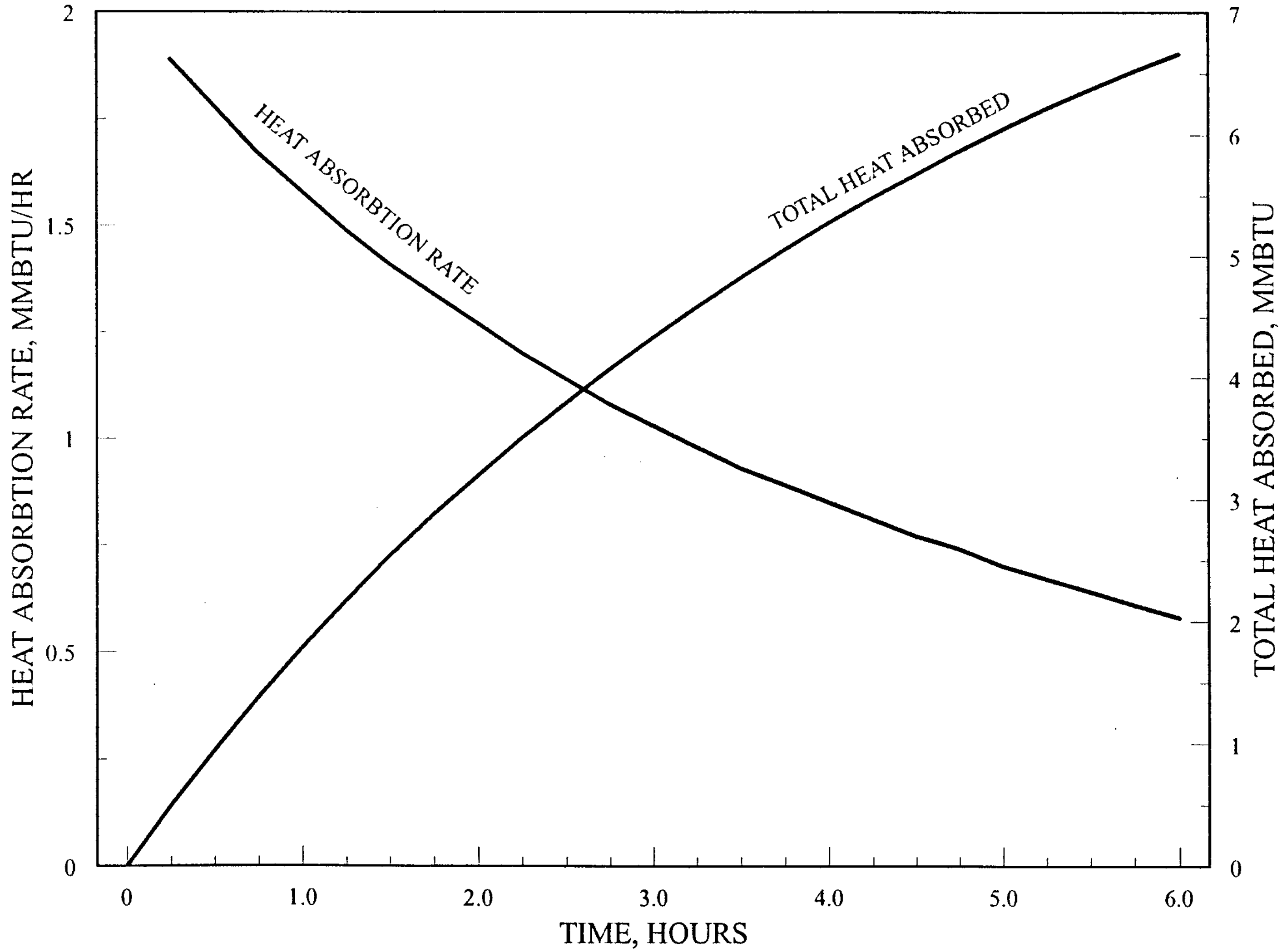


Figure 2-3

predicting heatup times for load arrangements that were considered to be typical and representative of the load arrangements that will be encountered in actual practice. It can be expected, however, that some loads (in actual practice) will require longer heatup times. Furthermore, the model's predictions of heatup times presented here do not account for poorly arranged loads. If the items are stacked such that large masses of material are isolated from hot air flow, then significantly longer heatup times will be needed to heat all items to the target temperature. Thus the model output is only representative of what is considered to be "optimum" load arrangements (which can be achieved with any form of item if care is taken to properly arrange the items during loading).

The predicted heatup and cooldown times from the model were combined with the decontamination hold time and the loading and unloading times, to predict a product throughput rate (in pounds per hour). These predictions are shown on a time chart given in Figure 2-4. As discussed further in Section 4.5, process cooldown may be eliminated depending on operational and/or safety considerations at each site.

This chart is based on a chamber product load of 37,968 pounds, a decontamination period of six hours, a 30 minute loading time, and a 30 minute unloading time.

2.5 Other Design Considerations

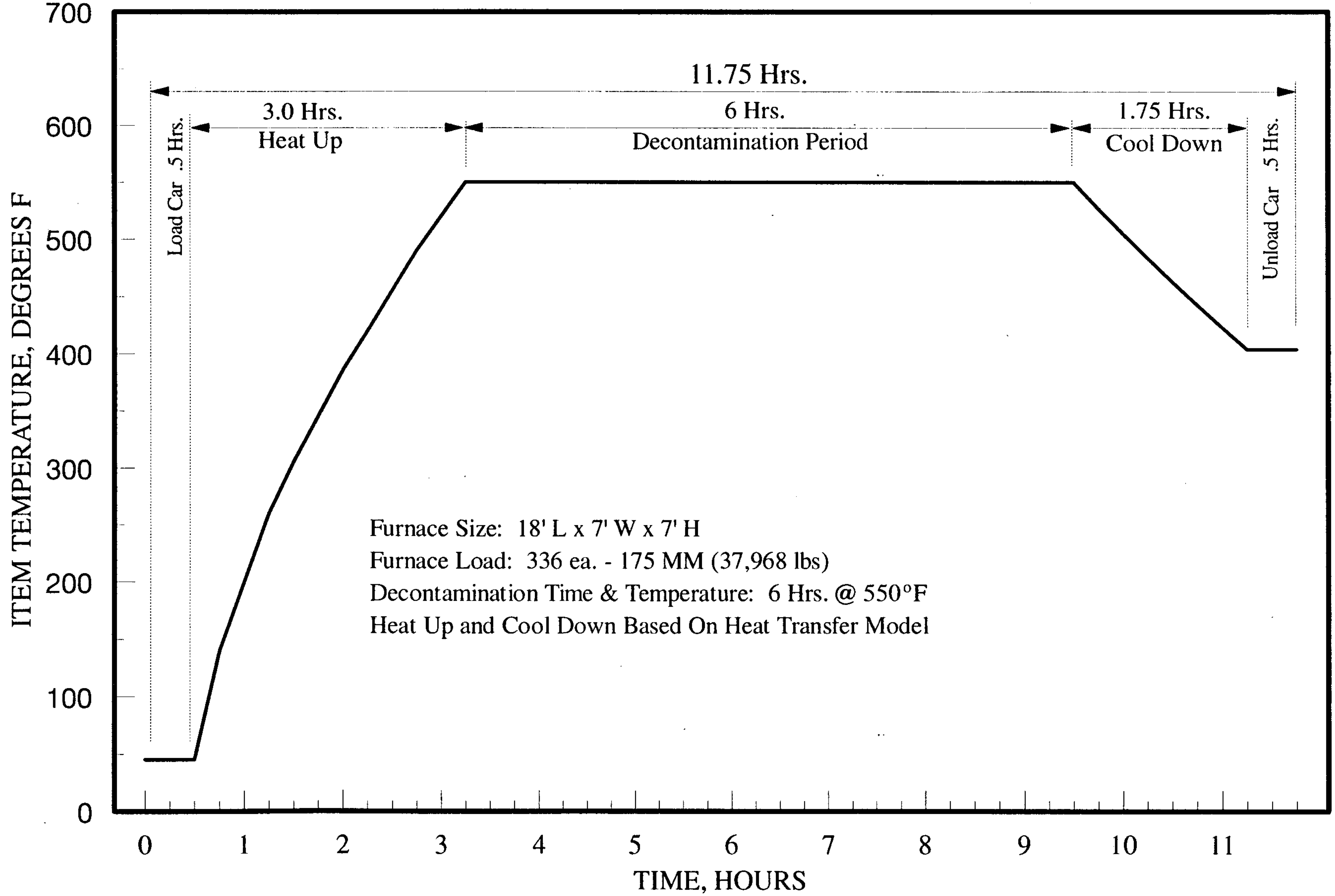
A key design consideration is the question of whether or not an item of rotating equipment, in particular, a fan, can be safely used in the presence of the explosive-contaminated air stream coming from the decontamination chamber. As will be seen in Section 3.0, the process design includes a fan (the chamber ID fan) in this location.

Consultation with an Army vapor phase explosive expert confirmed that the large quantity of air being circulated (4000 scfm) through the system will result in very low

ITEM TEMPERATURE PROFILE

DECONTAMINATION CYCLE

550°F / 6 HR. CASE



$$\text{Throughput} = \frac{37{,}968 \text{ lbs.}}{11.75 \text{ Hrs.}} = 3231 \frac{\text{lbs.}}{\text{Hr.}}$$

Figure 2-4

concentrations of explosive compounds. This coupled with the fact that the air is moving and not confined, are conditions that are not conducive to sustaining a detonation. The alternative to this fan location would be to locate the chamber ID fan downstream of the thermal oxidizer. This would result in the following operational and cost disadvantages:

- All of the thermal oxidizer exhaust gas must be passed through the ID fan in all modes, resulting in increased operating and maintenance cost.
- Splitting the exhaust gas flow and installing control dampers and two high temperature heat exchangers (rather than one as proposed) in parallel, resulting in a more complex control system, increased capital cost, and increased maintenance cost.
- More difficulty in maintaining the required negative pressure in the decontamination chamber during the decontamination mode of operation.

The main danger of rotating equipment in connection with explosives is the possibility of an initiation source forming, which could be generated from friction, spark, or even impact, if there is a mechanical failure. The risk of a spark can be reduced by specifying that the chamber ID fan be constructed in accordance with the Air Movement and Control Association (AMCA) standard 99-0401-86, Type C construction. The fan can be so constructed that a shift of the impeller or shaft will not permit two ferrous parts of the fan to rub or strike.

The buildup of explosives inside the system was monitored during the HGD testing at HWAD between June 23, 1994, and October 30, 1994. Surface wipes from the chamber liner and floor, and from inside the ductwork and ID fan were sampled at the end of each of thirty-two hot gas decontamination tests. These test samples were taken at eight control locations to determine the amount of explosive present after each test. The amount of explosive in a 160 sq. cm. area was below the "method detection limit (MDL)" for 214 of the 256 samples taken. The average quantity of residue for the remaining 42 samples was 1.5485E-05 mg/sq. cm.

In addition, wipe samples were taken after Tests 10, 20, 29, and 34 to determine if there was an accumulation of explosive residue during operation of the systems. These accumulative wipe samples were taken at the same locations as discussed in the above paragraph except the accumulative samples were offset from the test wipe locations. Explosive residues were detected in eight of thirty-two samples with three of the residues found at the "rail" sample location on the floor. The floor location could have been contaminated by personnel and forklift traffic during unloading of the test items from the chamber. The average quantity of residue for the eight samples was 1.1269E-05 mg/sq. cm. which is similar to the surface area amounts detected in the projectile extraction samples. Even though these samples showed random detectable quantities of explosives, there was no trend of accumulations of explosives over the thirty-two test performed.

For sample location and review of the data from the wipe samples, see "Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot", Report No. SFIM-AEC-ET-CR-95031 prepared by TVA.

CEM Control of Decontamination Hold Time

At the present, effective decontamination of metal items depends on ensuring that every item is subjected to the specified treatment conditions (550°F for six hours in the base case of 175 mm projectiles with residues of Comp B). Therefore the chamber must continue in the heatup mode until the lowest temperature item in the chamber reaches the designated decontamination temperature. The chamber temperature monitoring and control system will include a number of flexible temperature elements which can be inserted into or attached to items considered most likely to be heated the least. Temperature control of the chamber may then be based on the actual item found to be at the lowest temperature or it may be based on the temperature reading at a fixed location which can be correlated with that item. The detailed monitoring and control location will have to be established during initial operation with each new configuration of items in the chamber.

Observations at the prototype HGD unit at HWAD indicate that the progress of decontamination can be monitored by continuous emissions monitors (CEM) reading the composition of the gas stream leaving the chamber. It was seen that during early heatup that the gas stream contained low and relatively stable levels of hydrocarbons, NOx, and CO characteristic of oxidizer performance. (The HWAD HGD system uses direct recirculation of oxidizer flue gas for chamber heating.) Elevated readings for those compounds were observed during heatup (above 350°F) and early constant temperature treatment. CEM readings then declined back to the ranges seen shortly after startup. In several trials, those background readings were reached before the end of fixed time constant temperature treatment period.

A potential control approach based on this observation would be to install a CEM on the chamber discharge duct. Any one of the three types (HC, NO_X, and CO) used in the HWAD study would probably be adequate. All three readings displayed an increase, decrease, or spike at essentially the same time, within analyzer response time limits of a few minutes. For the explosives tested by TVA at HWAD, the NO_X monitor was the most active and provided the best overall response.

Under this approach, the system would be heated to the temperature appropriate for the explosive being decontaminated. Treatment time at that temperature would be variable, with cooldown beginning shortly after CEM readings returned to baseline values. In the system described here, using once-through circulation of indirectly heated air the baseline would be approximately zero.

Further work will be required to demonstrate the effectiveness of this approach to cycle control. If satisfactory, it would tailor the HGD treatment profile to the individual load being processed, taking into account the type, number, and degree of contamination of the items in the chamber. Overall, it would likely shorten average cycle times.

SECTION 3.0

PROCESS DESIGN

3.1 Introduction

The decontamination process contains the following three major elements:

(1) Decontamination of items.

(2) Thermal oxidation of the decontamination gas stream.

(3) Heat recovery for thermal efficiency.

This section describes how these three process elements were integrated into a final process design.

3.2 Process Description

To help the reader visualize and understand the factors that went into producing the final process design, this subsection provides a brief overview of how the process operates. To aid in the discussion, a process flow diagram (Figure 3-1) can be found at the end of this section.

Ambient air is heated in a heat recovery heat exchanger (using thermal oxidizer exhaust gas) and introduced into the decontamination chamber where explosive residues are volatilized into the air stream. Only fresh air is delivered to the decontamination chamber; none is recycled from internal process streams. A chamber ID fan (F-2) on the exhaust side of the decontamination chamber maintains a slight vacuum in the chamber to prevent contaminated air from leaking to the outside. The explosives in the contaminated air stream are destroyed by raising the air stream temperature to over 1800°F and maintaining a residence time of at least two seconds in a thermal oxidizer. A hydrocarbon fuel is combusted directly in the contaminated air stream to raise its temperature. (A combustion air blower is provided to start up and preheat the thermal oxidizer). The exhaust gases from the thermal oxidizer are routed to a stack.

A separate process loop provides heat recovery to indirectly heat the decontamination air. Hot air is drawn from the stack (by heat recovery ID fan [F-3], downstream) through an in-line mixing chamber, where ambient air is introduced to temper the air from 1800°F to about 1500°F. The lower temperature reduces materials costs for downstream equipment. The tempered air enters the heat recovery heat exchanger where heat is exchanged to heat the decontamination air stream. A variable speed controller on the heat recovery ID fan (F-3) is used to set the flow of tempered air so as to obtain the desired decontamination chamber inlet air temperature. (NOTE: Further discussion of temperature control is discussed in detail in Section 4.0). After heat exchange, the tempered air is routed back to the stack for exhaust to the atmosphere.

3.3 Design Criteria

The following criteria were used as the basis for the process design:

1. The process should be capable of heating metal items to a temperature between the range of 500° to 800°F and maintaining this temperature for long periods of time.

2. The decontamination chamber should be maintained at a negative pressure when loaded with washed out items at temperatures above ambient.

3. The decontamination chamber should be designed to accept a variety of items, from small caliber cartridges to large pieces of process equipment (i.e., tanks, pumps, piping, etc.).

4. The thermal oxidizer should be capable of treating the waste gas stream at a minimum temperature of 1800°F for a residence time of at least two seconds. The two second

residence time is based on similar explosive destruction experience and previous testing done on hot gas decontamination.

5. The process should be capable of cooling down the chamber contents, if deemed necessary, prior to removal.

6. Once-through heated air should be used in the decontamination chamber rather than any type of recirculated waste stream or flue gas.

7. The process should be capable of continuous automated operation without extended periods of time between cycles.

The process design is centered around the thermal oxidizer. Since the thermal oxidizer generates a large quantity of gas at 1800° to 2000°F during the waste stream oxidation process, it is possible to capture some of this energy to heat the items in the chamber. This is accomplished by passing the hot flue gas from the thermal oxidizer through a gas-to-gas surface area heat exchanger. Ambient air is heated in this heat exchanger and passed through the decontamination chamber to provide both the heat needed to increase the temperature of the items and to transport the vaporized explosive compounds to the thermal oxidizer. This is a much more efficient operation than one in which a separate dedicated burner is used to supply the heat needed for the chamber supply air.

A major input parameter for the process and equipment design is the mass flow rate of hot air to be circulated through the decontamination chamber. The larger this flow of air the faster the heat transfer and the shorter the heatup time. But higher mass flows also mean larger process equipment. This mass flow affects the size of the thermal oxidizer burner and retention chamber, fan sizes, the heat recovery heat exchanger, and the ductwork. The chamber supply air flow of 18,000 lbs/hr (4,000 scfm) that was chosen is based on adequate convective heat transfer (as predicted by the model in Subsection 2.4) and equipment and ductwork sizing. Another input parameter which affects heatup rate and equipment sizing is the chamber supply air temperature. As with the chamber supply air mass flow rate, the higher the chamber supply air temperature, the faster the heatup rate. But the higher the supply temperature, the larger the heat recovery heat exchanger has to be. Due to the relatively poor heat transfer properties of gases, the size (and cost) of this heat exchanger has to be considered. A chamber supply air temperature of between 1200° to 1300°F (depending on ambient temperature) was determined to be the highest temperature that would allow a reasonably economic heat exchanger size and also not allow the maximum temperature limit for the chamber ID fan (F-2) to be exceeded.

As discussed in Subsection 2.2, the amount of heat required by the decontamination chamber varies with different chamber loads, item configurations, and modes of operation. The chamber heat requirement, in turn, determines the chamber exit temperature and thus determines the temperature of the gas entering the thermal oxidizer. This temperature, combined with the mass flow, directly affects the fuel requirement of the thermal oxidizer burner system. Thus the fuel requirement was calculated separately for each particular mode of operation throughout the operating cycle to give an accurate estimate of the total fuel required by the process (see Subsection 8.4 for operating cost).

A commercially available computer modeling program (process model) was used to provide the remaining process design information. The process involves three different operating modes--heatup mode, decontamination mode, and cooldown mode. Each of these modes involves different heat requirements in the chamber. Figure 3-2 shows the relative heat absorption rate in the chamber for a complete decontamination cycle.

Given (1) the heat required by the chamber predicted from the heat transfer model, (2) the mass flow and temperature of the hot air to the chamber, and (3) the heat recovery heat exchanger design parameters, the process model would calculate the following:

- The fuel input required to heat the chamber outlet gas to the predetermined destruction temperature of 1800°F.

- The quantity of ambient air required to temper the thermal oxidizer outlet gas stream from 1800° to 1500°F (the maximum temperature under which moderate-cost stainless steel materials could be used in the heat recovery heat exchanger).
- The quantity of 1500°F tempered flue gas to be passed through the heat recovery heat exchanger to provide the chamber inlet temperature to meet the cycle demands.
- Mass flows and temperatures of all remaining streams.

The process flow is shown in Figure 3-1 with the mass flows and temperatures for each stream and operating mode shown in Table 3-1. Since all gas streams were considered to be low pressure, with little affect on the thermodynamic properties of the streams, the pressures of each stream were not included in the evaluation. Separate pressure calculation methods were used for sizing specific equipment such as fans, etc.

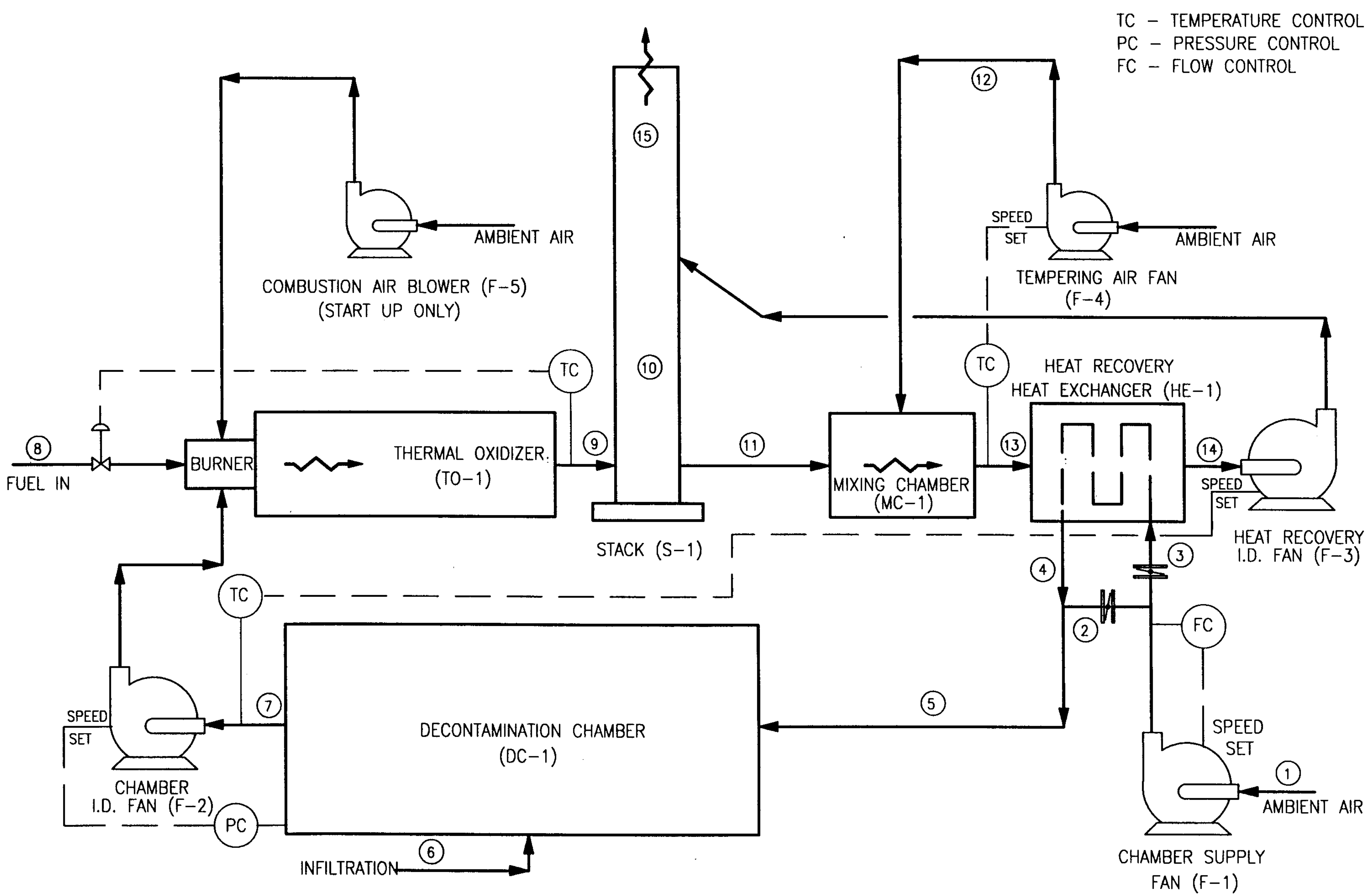


Figure 3–1. PROCESS FLOW DIAGRAM

Table 3-1
HOT GAS DECONTAMINATION - NEW FACILITY
Process Stream Flows (lb/hr) and Temperatures (°F)

	Ambient Air In		HRHE Bypass		HRHE In (Cold Side)		HRHE Out (Cold Side)		Chamber Inlet		Chamber Infiltration		Chamber Out (NOTE 1)		Fuel In	
	1		2		3		4		5		6		7		8	
	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp
Heat Up Mode																
- Start	18000	45	0	--	18000	45	18000	1263	18000	1263	1000	45	19000	701	335	--
- End	18000	45	0	--	18000	45	18000	1260	18000	1260	1000	45	19000	926	270	--
Decontamination Mode	18000	45	10080	45	7920	45	7920	1328	18000	631	1000	45	19000	595	365	--
Cool Down Mode																
- Start	18000	45	18000	45	0	--	0	--	18000	45	1000	45	19000	300	344	--
- End	18000	45	18000	45	0	--	0	--	18000	45	1000	45	19000	173	380	--

NOTE 1. Chamber outlet temperatures are based on a heat transfer model with optimum chamber loading capacity and configuration and therefore maximum heat transfer. Less than optimum heat transfer conditions will result in higher chamber outlet temperature, lower fuel usage rates, and longer heat up periods.

	Thermal Oxidizer Out		Heat Recovery Bypass		Mixer Inlet		Tempering Air		HRHE In (Hot Side)		HRHE Out (Hot Side)		Stack Out	
	9		10		11		12		13		14		15	
	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp
Heat Up Mode														
- Start	19335	1800	0	--	19335	1800	4539	45	23874	1500	23874	641	23874	641
- End	19270	1800	0	--	19270	1800	4452	45	23722	1500	23722	635	23722	635
Decontamination Mode	19365	1800	12587	1800	6778	1800	1591	45	8369	1500	8369	342	20956	1250
Cool Down Mode														
- Start	19344	1500	19344	1500	0	--	0	--	0	--	0	--	19344	1500
- End	19380	1500	19380	1500	0	--	0	--	0	--	0	--	19380	1500

DECONTAMINATION CHAMBER HEAT ABSORBTION RATE HEAT UP AND DECONTAMINATION MODES

550 °F / 6 HOUR CASE

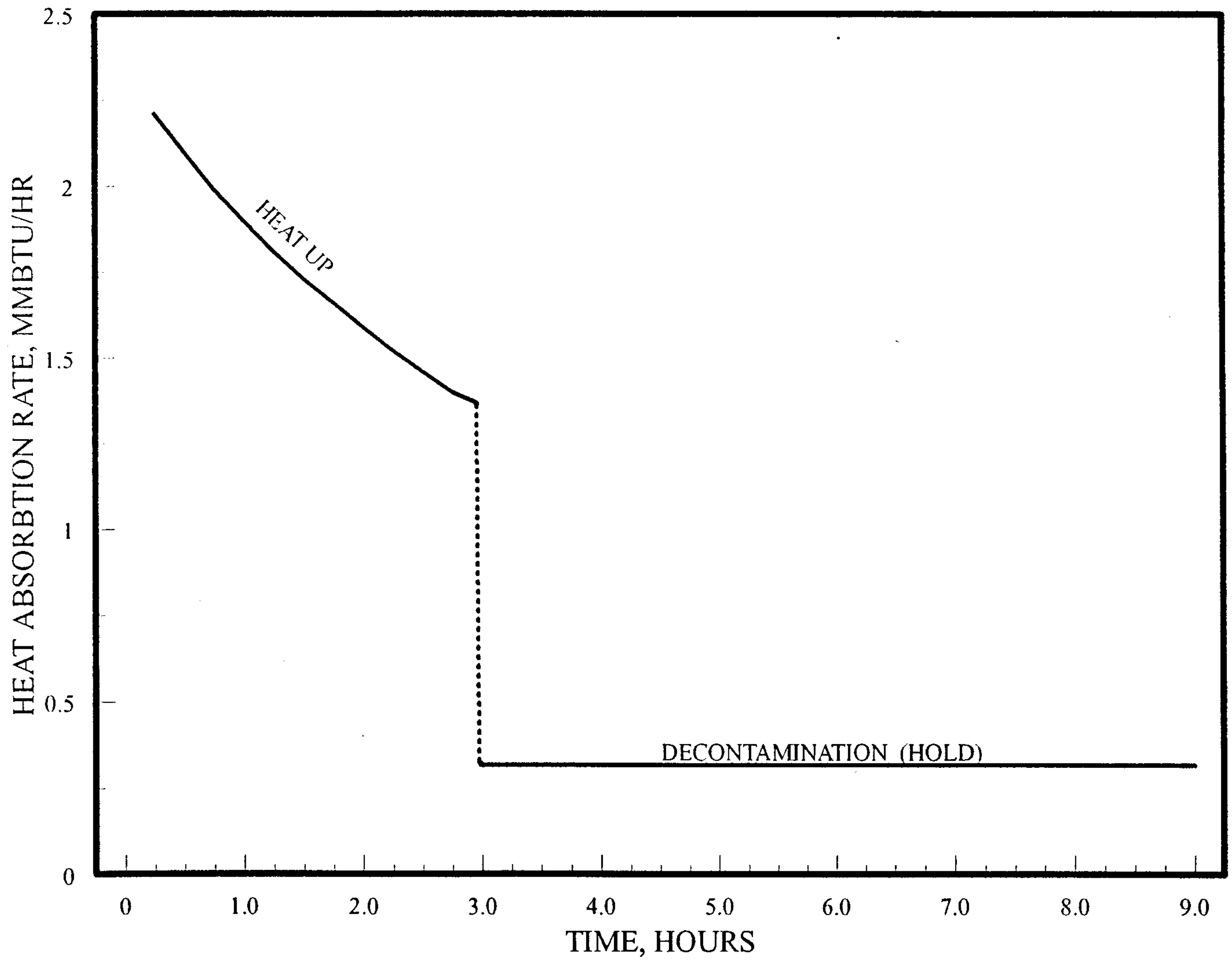


Figure 3-2

SECTION 4.0

OPERATING DESCRIPTION

4.1 Introduction

A cycle of operation is defined as the complete processing of a batch of items from loading to unloading. Within each cycle is several modes of operation in which the operating parameters of the process equipment change. This section of the report describes the operation of the decontamination plant in each of the modes of operation. See Figure 3-1 in Section 3.0 for the process flow diagram.

Proper programming and input of key operating parameters to the process logic controller (PLC) will allow automatic operation of the process for a complete decontamination cycle.

4.2 Equipment Heatup

Before any waste gas is passed through the thermal oxidizer, the thermal oxidizer should be brought up to operating temperature at a rate recommended by the manufacturer's instructions and as follows:

1. Purge the thermal oxidizer by running the combustion air blower long enough for five complete air changes within the oxidizer or for five minutes, whichever is longer. Air flow for purge must be 25 percent of maximum air flow through the thermal oxidizer.

2. Supply fuel to the thermal oxidizer at lightoff rate and ignite burner.

3. Slowly increase fuel and combustion air to allow heatup of thermal oxidizer at prescribed rate for materials of construction. Continue until a temperature of 1800°F is attained.

4. Begin heatup of heat recovery heat exchanger by starting heat recovery ID fan (F-3) at low speed. The tempering air fan and control loop must be energized to limit the hot gas temperature to the heat recovery heat exchanger to a maximum of 1500°F at all times. Continue until heat exchanger has reached a temperature of about 500°F (average metal temperature).

4.3 Chamber Heatup Mode

After the thermal oxidizer has reached its operating temperature, the car bottom loaded and placed in the chamber, and the chamber door closed, heatup of the chamber can begin. This is accomplished in the following sequence:

1. With the heat recovery heat exchanger at startup temperature (see Subsection 4.2, item 4), the chamber supply fan (F-1) should be started at low speed. The chamber ID fan (F-2) is started and set to control the chamber internal pressure at 0.1 to 0.2 inches w.g. negative pressure during the heatup mode.

2. Once adequate flow has been established from the chamber ID fan (F-2), the combustion air blower (F-5) can be cut off and the primary combustion air for the burner provided from a slip stream taken from the chamber ID fan (F-2). The furnishing of primary combustion air from the process air stream (in lieu of the separate combustion air blower) will save fuel consumption during the heat up and decontamination periods. The separate combustion air blower (F-5) is included to allow burner startup or hot standby when operation of the chamber ID fan (F-2) is not desirable.

3. Slowly increase chamber supply fan (F-1) and heat recovery ID fan (F-3) until the chamber supply air has reached its design flow and maximum temperature, while at the same time maintaining the temperature at the inlet of the heat recovery ID fan (F-3) between the range of 300° and 800°F. (800°F is the maximum design temperature of

the heat recovery ID fan while the 300°F minimum is for protection of the heat recovery heat exchanger from acid condensation corrosion.)

4. The chamber outlet air temperature must not exceed 1000°F in order to not exceed the chamber ID fan (F-2) design temperature. Chamber outlet air temperature is determined by chamber inlet air temperature and the amount of heat removed by the chamber load. High chamber outlet temperatures are more likely at the end of the heatup modes when the chamber items are at higher temperatures. This temperature limit is controlled by lowering the chamber inlet air temperature with the heat recovery system.

5. Also during this chamber heatup mode, the thermal oxidizer outlet temperature control circuit will control the fuel input to maintain the thermal oxidizer operating temperature.

6. Continue until the target decontamination temperature has been reached in the chamber.

4.4 Decontamination Mode

When the items are approaching the target decontamination temperature, the temperature of the chamber inlet air should be reduced to a value sufficient to maintain the items in the chamber at the target temperature. For 550°F decontamination temperature, a 600° to 650°F chamber inlet air temperature might be required. This is accomplished as follows:

1. During the decontamination mode (constant chamber temperature) the chamber supply air is to be maintained at the design air mass flow rate.

2. The heat recovery ID fan (F-3) control point is changed from the chamber outlet air temperature limit to the chamber internal temperature or chamber outlet temperature, depending on which point, in actual practice, provides the smoothest control.

3. As in the heatup cycle, the chamber ID fan (F-2) will maintain the pressure inside the chamber at 0.1 to 0.2 inches w.g. negative pressure.

4. The tempering air fan (F-4) will maintain the heat recovery heat exchanger inlet temperature at 1500°F maximum.

5. The chamber should be maintained at the decontamination temperature for the desired hold time.

4.5 Cooldown Mode

The capability of cooling the items prior to opening and unloading the chamber is provided in the process design. Whether or not this cooldown mode is needed in actual practice will be decided based on operational and/or safety considerations. Elimination of the cooldown step is feasible from an equipment operation standpoint. Operation of the chamber door and rail car removal is not expected to be restricted based on the chamber temperatures expected with the HGD process. Remote operation of the door and car drive can prevent heat exposure to personnel. Also, in lieu of the process cooldown provided, the hot items can be remotely unloaded from the car bottom and allowed to cool in a protected area.

The necessity and degree of cooling could be dependent on the temperature in the chamber at the end of the decontamination mode. A 550°F decontamination temperature might require no cooling or minimal cooling, whereas an 800°F temperature might require some cooling.

If cooldown of the chamber is desired, ambient air can be circulated through the chamber to remove heat from the items. Once the predetermined cooldown temperature has been reached, the chamber door can be raised and the car bottom removed from the chamber for unloading.

Two types of chamber cooldown cycles will be considered--(1) cold shutdown and (2) hot standby of the process equipment. If the process equipment is to be shutdown for an extended period of time, the process equipment (i.e., thermal oxidizer, heat recovery heat exchanger, etc.) will be returned to cold shutdown conditions. If another load of items is to be processed, as with a continuous operation, then the process equipment should be maintained near operating temperature to prevent having to ramp these components up to their operating temperature.

Cooldown Mode with Cold Shutdown

1. Lower the speed of the heat recovery ID fan (F-3) allowing the thermal oxidizer exhaust to exit via the stack, bypassing the heat recovery heat exchanger. Continue until heat recovery ID fan (F-3) is shutdown.

2. Open the heat recovery heat exchanger bypass damper (cold air side) and close the heat recovery heat exchanger inlet damper.

3. Ambient cooling air will be forced through the chamber by the chamber supply fan (F-1) and the chamber ID fan (F-2) at full speed.

4. After the decontamination chamber has cooled to a temperature that will not volatilize any residue, the thermal oxidizer burners are deenergized. The cooling air being drawn through the chamber is passed through the thermal oxidizer, without being heated, and out the stack.

5. During this cooldown process, all the HGD process equipment is cooled down along with the chamber.

6. This process is continued until the desired chamber (or item) temperature has been reached for chamber door opening and car removal.

Cooldown Mode with Hot Standby

1. Lower the speed of the heat recovery ID fan (F-3) allowing the thermal oxidizer exhaust to exit via the stack, bypassing the heat recovery heat exchanger. Continue until heat recovery ID fan (F-3) is shutdown.

2. Open the heat recovery heat exchanger bypass damper (cold air side) and close the heat recovery heat exchanger inlet damper.

3. Ambient cooling air will be forced through the chamber by the chamber supply fan (F-1) and the chamber ID fan (F-2) at full speed.

4. The cooling air from the chamber is circulated through the thermal oxidizer with the burner and controls energized. Since in the cooldown mode, the air circulated through the chamber will not contain explosives, the thermal oxidizer temperature will be reduced to 1500°F. This reduced temperature will save fuel in the cooldown-hot standby mode but still keep the thermal oxidizer near operating temperature for the next batch.

5. This process is continued until the desired chamber (or item) temperature has been reached to allow safe chamber door opening and car removal.

4.6 Emergency Shutdown

Any operating condition or failure of any component that results in heated gas from the decontamination chamber passing through the thermal oxidizer operating at less than the preset destruction temperature will require the process to be shutdown and the cycle terminated.

A process shut down during the heatup and decontamination modes will result in the chamber supply (F-1) and chamber ID (F-2) fans to shut down. With a sufficient drop in temperature, this could result in small quantities of explosives to settle out in the decontamination chamber and the ductwork between the chamber and thermal oxidizer. However, upon restart of the cycle, these small quantities of explosives would be re-vaporized and be processed through the thermal oxidizer as intended.

SECTION 5.0

EQUIPMENT DESIGN

5.1 Introduction

Each of the major process components is discussed in this section along with factors effecting their design and performance.

5.2 Decontamination Chamber

A car bottom chamber with a vertically operated door on one end was chosen for the decontamination chamber. A car bottom chamber has several advantages over a drive-in type chamber. The car bottom style, in which the top of the flat car bed (refractory lined) actually forms the floor of the chamber, excludes most of the mass of the rail car from having to be heated up in the chamber along with the items to be decontaminated. This saves in energy, heatup time, and in cooldown time of the chamber. One disadvantage of the car bottom style, compared to a drive-in type chamber, is that the area between the rail car and sides of the chamber presents additional area which must be sealed to prevent air infiltration or exfiltration. However, sealing systems are available which will minimize this concern.

The walls and ceiling of the chamber consist of plate steel construction with structural steel beams and channels for bracing. The chamber is internally lined with eight inches of ceramic fiber insulation.

During the hot gas decontamination testing by TVA at HWAD, pieces of insulation were placed throughout the chamber and sampled periodically for accumulation of explosives. Explosive residues were detected in only six of seventy-two samples with no sample location having more than one detectable result. The average quantity of residue for the six samples was 2.8460E-05 mg/cubic cm. Since the results varied randomly from test to test with no identifiable trend, it appears there was no accumulation of explosive residue. For this reason, an impervious inner metal liner is not deemed necessary in the design of the chamber.

For sample location and review of the data from the insulation samples, see "Demonstration Results of Hot Gas Decontamination for Explosives at Hawthorne Army Depot," Report No. SFIM-AEC-ET-CR-95031, prepared by TVA.

From a mechanical strength standpoint, the chamber should be designed to support its own weight, including insulation, withstand the conditions imposed by operation of the retractable car bottom and vertical door mechanism, and to withstand the design pressure differential of 0.25 inches water gauge negative pressure. Due to the considerations discussed in Subsection 2.5, design of the decontamination chamber to withstand explosions is not warranted.

A once-through cross flow air flow pattern has been chosen for the decontamination chamber. This means that the air will enter on one side of the chamber, flow across the items and exit out of the chamber on the opposite side. Air flow distribution across the chamber is controlled by a four zone, supply side variable air volume (VAV) control system (see Drawing B23156 in Appendix B). This VAV system will manually, or automatically, control the air flow between zones for matching varying heat requirements for each zone.

This air flow provides two functions, as the convective heat transfer medium and as the medium for capturing and moving the vaporized explosives to the thermal oxidizer to be destroyed.

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This air flow provides two functions, as the convective heat transfer medium and as the medium for capturing and moving the vaporized explosives to the thermal oxidizer to be destroyed.

The following load dimensions for the decontamination chamber were chosen for the conceptual design: 18' length x 7' wide x 7' high.

Since the chamber must be capable of holding different kinds, numbers, and weights of items to be decontaminated, this sizing of the chamber is somewhat arbitrary. The following is a list of factors that contributed to this sizing:

- For a cross-flow arrangement and a given air flow, to maintain high air flow velocities for maximum heat transfer, the smaller the cross flow area (length times height), the higher the velocity.
- Partial loads in the chambers can result in excessive air bypass and long heatup periods. Therefore the concept of building a large chamber to take care of the occasional large load with partial loads most of the time, will result in poor heat transfer and longer heatup periods.
- The volume represented by these dimensions, when loaded with an optimum array of 175 mm cartridges and holding racks, yields a weight of about 40 tons. This is near the maximum weight for which car bottom rail cars are normally designed.
- For the cross flow arrangement, a wider load will result in a larger temperature gradient of the items from the air inlet side of the chamber to the exit side.
- The seven foot width of the load chosen results in an overall chamber width, including header space, insulation, and support steel, of nearly twelve feet. This is near the maximum width that could be shop fabricated and shipped to the site by conventional methods for installation.

The dimensions used in this conceptual design should be reevaluated if a specific product type, quantity, and configuration were to be specified.

Although not published, most manufacturers of ceramic wool insulation indicate that a heatup rate of 250°F an hour should not be exceeded to avoid damage to their product. For this reason, for a 550°F target temperature, even if the heat absorption rate by the items will allow a heatup period of less than two hours, a minimum of two hours should be used. For a target temperature of 800°F, a minimum heatup period of three hours should be used.

5.3 <u>Thermal Oxidizer</u>

The purpose of the thermal oxidizer is to destroy the explosives in the waste gas stream by oxidation at a high temperature. The thermal oxidizer is made up of a burner attached to a mixing chamber, followed by another chamber, which is sized to retain the waste gas stream at the temperature and time required for complete oxidation.

The burner is sized for a given fuel type, mass input, and operating temperature. For TNT, the minimum temperature to assure destruction has been documented as 1500°F. As a safety factor, and to assure that other explosives will be oxidized as well, the operating temperature of the thermal oxidizer was set at 1800°F and the design temperature was set at 2000°F.

The type fuel used by the burner is a site-specific consideration. The burner can be specified as either a liquid fuel burner, (such as for operation with No. 2 fuel oil or diesel), as a natural gas burner, or as a dual fuel burner. If an adequate natural gas supply is available at the site and its cost is favorable, it is recommended that a dual fuel burner be provided. Even if an adequate natural gas supply is available at the site, due to the uncertainty of the supply and price of natural gas, a dual fuel burner should be provided for conversion to liquid fuel if needed. Another option would be to install a conversion package whenever fuel type change is required. Liquid fuel is used in the conceptual design process flow.

Based on similar explosive destruction experience, a two second residence time for adequate oxidation of the waste stream was chosen. Also previous testing done on hot gas decontamination has shown that residence times of less than one second provided a destruction and removal efficiency (DRE) of 99.99 percent (see Reference 1 on page 1-1).

Therefore, for the conceptual design a residence time of two seconds has been specified with the goal of obtaining a minimum DRE of 99.99 percent for explosives and their degradation products in the thermal oxidizer.

The portion of the thermal oxidizer which assures this residence time is a chamber of sufficient size or volume such that the high temperature gas is held for the specified time (two seconds) at the desired destruction temperature. It must be well insulated with an insulation capable of withstanding high temperatures (2000°F).

Also another major consideration is the type of insulation used, which could have a considerable impact on the heatup duration of the thermal oxidizer. Since it is desired to minimize the equipment heatup time, an insulation that will withstand a rapid heatup rate is desirable. This requirement prohibits the use of high temperature fire brick liners/insulation systems, which require a slower heatup rate of anywhere from 50° to 100°F per hour. Other insulation types, such as ceramic wool, has similar insulating properties, but can be subjected to higher heatup rates without damage. For ceramic wool insulated thermal oxidizers, a minimum equipment heatup time of around one hour should be expected.

Thermal oxidizers can be furnished as either vertical or horizontal units, or a combination. A horizontal unit was specified, which makes installation of the heat recovery equipment more practical.

5.4 Stack

The stack is used to exhaust the waste heat from the process. The stack and heat recovery loop (which contains the mixing chamber, heat recovery heat exchanger, and heat recovery ID fan) work together to recover the heat needed for the decontamination chamber and exhaust the remaining heat to the atmosphere. Since fans are available to provide the pressures needed to move the air, stack draft is not a design factor. Therefore, stack height is a site-specific consideration. Factors affecting stack height will be prevailing wind direction, proper heat dissipation, surrounding buildings, structures, etc. A stack height of 30 feet should be sufficient for most installation sites. The stack was equipped with a CEM system. This system is capable of monitoring all stack emissions and should be located above the heat recovery return duct tie in point.

The CEM system is capable of monitoring for the following compounds: hydrocarbons, SO_x, NO_x, CO_2, CO, and O_2. In addition the stack will be equipped with sample ports for stack gas and particulate sampling.

5.5 Mixing Chamber

The mixing chamber is designed to cool the hot flue gas from the thermal oxidizer by mixing it with ambient air. This cooling enables the heat recovery heat exchanger to be fabricated from standard stainless steel material and not from very expensive special high temperature metals. A maximum temperature of 1500°F is recommended for standard stainless steel metals in this application.

The mixer consists of a section of duct with a constriction designed to create high velocity and turbulence in the gas stream. Immediately downstream of the constriction, ambient air is injected from a fan through a series of nozzles that mixes the air with the turbulent gas stream. The quantity of ambient air injected determines the outlet temperature desired. A temperature sensor downstream of the mixing chamber will control the variable speed tempering air fan (F-4) to maintain the set point of the outlet mixture temperature.

5.6 Heat Recovery Heat Exchanger

The purpose of the heat recovery heat exchanger is to capture heat from the thermal oxidizer exhaust gas to heat up the items in the chamber. This is done with a high temperature gas-to-gas heat exchanger.

The flue gas leaves the thermal oxidizer at 1800° to 2000°F. Rather than waste this heat to the atmosphere, it is used to provide indirect heating of the air used to heat up the items in the chamber. Based on the heat transfer model in Subsection 2.4 and a hold time of six hours, this results in an energy savings of about 6.1 MMBtu compared to heating the chamber with a separate dedicated heat source.

5.7 Heat Recovery Induced Draft Fan

The heat recovery induced draft fan is used to remove hot gas from the stack and pull it through the heat recovery heat exchanger to heat up the supply air to the chamber. Since this heat requirement varies with the process cycle, a variable speed controller is utilized to vary the fan rpm and thus the flow and static pressure. When no heat is to be extracted, the fan is off and all of the flue gas passes out the stack. As heat is needed for chamber heatup, etc., the heat recovery ID fan is controlled to the desired flow to provide the desired chamber inlet temperature. This fan will be specified with high temperature construction techniques, including special material selection, cooling wheels, and thermal air breaks. As with the chamber ID fan, control circuits are provided to ensure that this fan does not exceed 800°F.

5.8 Instrumentation, Control, and Monitoring System

The function of the Instrumentation, Control, and Monitoring (ICM) system is to provide an efficient control and monitoring interface for plant operations by presenting visual and audible information of plant operating parameters, equipment status, and alarm conditions. Additionally, it provides automatic control of critical parameters (i.e., those parameters which require frequent operator attention). The system allows manual override operation of any automatic function when required. The system consists of process sensors, controllers (valves or fan motor speed controllers), programmable logic controllers, and computers.

In addition, proper programming and input of key operating parameters allows automatic operation of the process for a complete decontamination cycle.

Programmable Logic Controllers

The heart of the ICM is a pair of Programmable Logic Controllers (PLCs). One PLC is responsible for managing the thermal oxidizer and ensuring safe operation of all functions related to its safe operation. This PLC is referred to as the Burner Management System (BMS) controller. The remaining PLC is responsible for all ancillary monitoring and control functions within the hot gas decontamination system. This PLC is referred to as the Instrumentation Control System (ICS) controller. The PLCs control processes via electrically operated devices such as solenoid valves, motor starters, valve positioners, motor speed controls, etc., on the basis of a stored digital program of instructions using various input contacts and input signals from the process. Facility operators will interface with the PLCs through computers connected with the PLCs over a data highway. These specially equipped computers are referred to as Operator Interface Units (OIUs). All operator control access and information retrieval is through these units.

Operator Interface Units

The OIUs are IBM PC-type computers equipped with the required hardware to communicate with the PLCs and supplied with the proper PLC interface software to allow the graphical display of all monitoring and control functions. Screen graphics for every system in the facility are programmed into the computer using the supplied software. Graphic screen displays function like "pages" allowing the operator to choose between screen displays to view the entire process. At least two OIUs are provided to allow up to two operators to view different parts of the process simultaneously. The screen graphics make use of the computer mouse and keyboard to allow operator interface with the process. Hand switches, automatic/manual selections, process controllers, set point changes, alarms, and alarm acknowledgments are all accessible on the graphic screens with the mouse and keyboard.

Data Logging, Trending, Reports

Periodic printouts of flows, temperatures, pressures, etc., provide hard copy data for later analyzing or troubleshooting. Trending screens are available on the OIUs to give operators a graphical "feel" for process performance and direction. Data reports, alarm records, etc., can be printed periodically or stored on magnetic storage disks (floppies).

5.9 Ductwork and Insulation

As explained in Subsection 2.3, 900°F is the upper limit recommended for carbon steel due to its degradation from oxidation. Except for ambient air inlet ducts, all other ductwork associated with the hot gas decontamination process are subject to experiencing operating temperatures greater than 900°F. Therefore, all elevated temperature ductwork are constructed of 304 or 316 stainless steel. Process and Instrumentation Drawing (P&ID) F23140 in Appendix B reflects the material recommended for each ductwork section. Line numbers are used which indicate an SS (stainless steel) or CS (carbon steel) designation where applicable.

For ductwork fabricated from stainless steel sheet, a minimum wall thickness of 3/16" is recommended. The use of light weight stainless steel pipe, such as 5S or 10S, exceeds this minimum recommended wall thickness and is acceptable. However, the availability and cost of light weight stainless steel pipe and fittings is not normally cost effective compared to fabricated duct and fittings.

Insulation of the hot gas ducts is required to minimize process heat loss as well as for personnel protection. Also for the waste gas stream between the decontamination chamber and the thermal oxidizer, a proper insulation system is important to avoid any cold spots, which might have a tendency to condense explosives from the waste gas stream.

The following insulation system is recommended for all hot gas stream duct:

- Six-inch thickness of Kaowool blanket, 6 psf density, installed in no less than two overlapped layers, covered with 0.016 inch thick aluminum lagging.

SECTION 6.0

MATERIAL HANDLING

6.1 Introduction

Several methods of transporting, loading and unloading the items to and from the rail cars are presented in this section. These methods cover most of the situations that are expected to be encountered by the HGD process users. For a facility required to handle a variety of items (both small and large munitions items) as well as process equipment, the material handling equipment specified in this report should be flexible enough to handle all types of materials.

Two material handling schemes are discussed--single car bottom system and a dual car bottom system. Since the single rail car is simpler in design, construction, operation, and should be adequate for a majority of HGD facility applications and sites, it is the preferred system and is the basis for the cost estimate provided in Section 8.0.

6.2 Single Car Bottom

In a normal car bottom chamber design, the car bottom and drive system is usually designed to allow remote movement of the car bottom in and out of the chamber. The electric drive motor is mounted on the car with a take-up reel for the attached electrical cable. For this reason, the rail car's withdrawn position is limited to a close proximity to the chamber. This requires that the items to be loaded and unloaded from the rail car be transported to and from the loading/unloading position area of the car bottom right outside the chamber. The equipment and system proposed allows flexibility for adapting to the loading and unloading of many different types and sizes of items. (For purpose of discussion, the "loading of items" refers to larger individual items or racks and/or baskets filled with smaller items.)

See Drawing B23157 in Appendix B for a layout of the loading and unloading areas. Items transported to the facility by truck, etc., can be unloaded by forklift or jib crane and placed in the preloading area or staging area where they can be reached by the overhead crane. The preloading shed can be used for loading small individual items into racks or baskets as needed.

Munitions items which have been "washed out" should be loaded (at the washout area) into racks suitable for the decontamination chamber and then transported to the decontamination facility. This reduces labor cost in handling of the items and simplifies storage and inventory of the items.

As discussed in Subsection 2.4, heatup of the items in the decontamination chamber can be enhanced and heatup times decreased, by leaving some spacing between items. This is particularly applicable when placing small items into baskets. Dense packing of items with poor air circulation around each item can result in long heatup times, as well as cold spots.

A ten ton overhead crane is provided to transport the items from the preloading area to either the staging area or directly onto the car bottom. The items can also be loaded onto the car bottom by a forklift or hydraulic crane. However, loading items by one of these methods might present some interference problems in placement of items in the staging area and full access to the car bottom.

The remotely operated overhead crane equipped with an automatic connecting and disconnecting device would allow unloading of hot items from the car bottom without personnel hazards and/or discomfort. The items could be moved to the unloading area or to the cooling shed.

This method of material handling does present one disadvantage. It requires loading and unloading during "on-line" time. Only one car is available, and a new batch cannot be processed until unloading and reloading of the car takes place. With the proper design of holding racks and baskets, loading and unloading time should be minimized without adversely affecting total cycle time.

6.3 Dual Car Bottom

The problem of using "on-line" time to load and unload the car bottom could be minimized by having at least two rail cars with a rail switching station. While the first rail car is in the chamber being heated, the second car could be loaded with contaminated items. Once the decontamination cycle has been complete, the first rail car is removed to an unloading area, the rail switch toggled, and the second rail car moved into the chamber.

This option presents several disadvantages and design considerations as indicated below:

- For a non-pivoting eight wheel rail car, considerable area is required (long radius) to negotiate a switching station.
- An additional drive system would have to be included to move the car bottom from the normal "close proximity" position of the rail car through the switching station and to the loading/unloading area. This new drive system could make the remote operation of a hot load more difficult.
- Special care would have to be taken to stabilize the load during transportation of the rail car through the switching station and to the load/unload area.

The advantages of the dual car bottom system compared to the single system are:

- Off-line loading, cooling, and unloading.
- Scheduling of loading and unloading would be independent of chamber cycle time.

Due to the increase in capital cost and complexity of the dual car bottom system as compared to the single car bottom system and the relatively short load and unload times expected, the single car bottom system would be the best choice for most facilities. Therefore, only the single car bottom system is included in the arrangement drawings in Appendix B and the cost estimate in Appendix D.

SECTION 7.0

CONTAMINATED WASTE PROCESSOR (CWP) RETROFIT TO HGD

7.1 Introduction

CWPs are used at several Army facilities to dispose of explosive contaminated waste. They are used for elimination of combustible materials (wood, cardboard, etc.) as well as decontaminating noncombustibles (metals, etc.). These facilities consist of car bottom ovens equipped with gas-fired burners. Under normal operating conditions, the flue gas from the chamber passes through a heat exchanger, a cyclone, a baghouse, and a fan, and exits out the exhaust stack.

There are two sizes of CWPs presently in operation at Army facilities. These are referred to as "large unit" and "small unit," based on the size of the chamber. The large unit chamber has the inside dimensions of 7 feet high by 8 feet 2 inches wide by 21 feet six inches long. The small unit chamber has the inside dimensions of 6 feet high by 6 feet 11 inches wide by 13 feet long. The large unit is used for the basis of the conceptual design in this section and the cost estimate in Section 8.0

The material is loaded onto the withdrawn car bottom which is then moved into the chamber. A vertical door is closed to complete the enclosure. Two gas burners, which are mounted directly to the chamber wall, are used to heat the items in the chamber to combust or incinerate the explosives on the metal surfaces.

These facilities already have some of the same equipment required for a new hot gas decontamination facility. The CWP equipment which can be utilized in the HGD process includes the car bottom chambers, the material loading cranes and equipment, along with the buildings and other supporting facilities. Therefore a retrofit of one of these facilities to the hot gas decontamination process could save some of the capital cost of a new facility. Also, the retrofit will allow the facility to be used for either process (CWP or HGD) by only opening and closing process isolation valves.

7.2 Process Design

The process design for HGD for CWP retrofit is the same as that used for the conceptual design of a new facility as discussed in Section 3.0. Due to the desire to utilize existing inlet air piping into the CWP chamber, the chamber inlet air flow for the HGD process is restricted. As discussed in the process design of a new HGD facility, the air flow through the chamber and the maximum amount of heat it loses will dictate the size of the remaining equipment in the HGD process.

Refer to Subsection 3.2, Figure 3-1 for the process flow diagram and Table 7-1 for the stream information for the CWP retrofit. The thermal oxidizer outlet temperature for destruction of explosives will be the same as a new facility, 1800° to 2000°F. Less air flow through the chamber will result in all of the equipment being smaller in size when compared to the conceptual design of the a facility.

7.3 Equipment Design

All the major process equipment for the CWP retrofit will be the same as for a new facility, except smaller.

The only difference besides size is the method used to distribute the air flow to and from the chamber. In addition to the two burners, the CWP chambers are equipped with air inlet ports which are used for introducing additional air needed for complete combustion of combustible items. Rather than modify the CWP chambers with air distribution and return headers, the HGD process will utilize the existing air inlet and gas return system. The piping supplying this additional combustion air will be modified to accept the hot convection air to be used in the HGD process as shown on drawing B23143 in Appendix B. Valves will be installed to isolate the hot gas decontamination process to allow quick conversion back to the CWP process if desired.

The air inlet and the outlet are both located at the back of the chamber (opposite the loading door). The air inlet is located high with the outlet near the bottom of the chamber. It will be necessary for the hot air to enter the chamber and flow along the top of the chamber, down the front wall, and return along the car bottom through the items being heated. This air flow requirement will limit the loading of the chamber to about one half of its full height capacity (7 feet for the large units). Loading the chamber to its full height capacity could block the hot air from reaching the items near the front of the chamber and could result in items not being able to reach sufficient temperature for decontamination and/or excessive heatup times.

However, the loading of the chamber is more restricted by the load capacity of the existing car bottom of 10,000 pounds. To increase the throughput of the CWP retrofit, the existing CWP car bottoms should be replaced with car bottoms with a 20,000 pound load rating. This load rating will allow one layer of 175 mm projectiles (approximately 42 inches high, including racks) to be loaded onto the car bottom. This car bottom replacement is estimated to cost about $60,000 and is included in the capital cost figures of Section 8.0.

Table 7-1
HOT GAS DECONTAMINATION - CONTAMINATED WASTE PROCESSOR RETROFIT FACILITY (LARGE UNIT)
Process Stream Flows (lb/hr) and Temperatures (°F)

	Ambient Air In		HRHE Bypass		HRHE In (Cold Side)		HRHE Out (Cold Side)		Chamber Inlet		Chamber Infiltration		Chamber Out (NOTE 1)		Fuel In	
	1		2		3		4		5		6		7		8	
	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp
Heat Up Mode																
- Start	8000	45	0	--	8000	45	8000	1200	8000	1200	800	45	8800	664	160	--
- End	8000	45	0	--	8000	45	8000	1200	8000	1200	800	45	8800	881	128	--
Decontamination Mode	8000	45	4400	45	3600	45	3600	1279	8000	620	800	45	8800	556	175	--
Cool Down Mode																
- Start	8000	45	8000	45	0	--	0	--	8000	45	800	45	8800	186	174	--
- End	8000	45	8000	45	0	--	0	--	8000	45	800	45	8800	71	175	--

NOTE 1. Chamber outlet temperatures are based on a heat transfer model with optimum chamber loading capacity and configuration and therefore maximum heat transfer. Less than optimum heat transfer conditions will result in higher chamber outlet temperature, lower fuel usage rates, and longer heat up periods.

	Thermal Oxidizer Out		Heat Recovery Bypass		Mixer Inlet		Tempering Air		HRHE In (Hot Side)		HRHE Out (Hot Side)		Stack Out	
	9		10		11		12		13		14		15	
	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp	Flow	Temp
Heat Up Mode														
- Start	8960	1800	0	--	8960	1800	2122	45	11082	1500	11082	726	11082	726
- End	8928	1800	0	--	8928	1800	2010	45	10938	1500	10938	713	10938	713
Decontamination Mode	8975	1800	6013	1800	2962	1800	707	45	3669	1500	3669	349	7682	1284
Cool Down Mode														
- Start	8974	1500	8974	1500	0	--	0	--	0	--	0	--	8974	1500
- End	8975	1410	8975	1410	0	--	0	--	0	--	0	--	8975	1410

SECTION 8.0

COST ESTIMATE

8.1 Introduction

The capital and operating cost estimates are based on information and drawings contained throughout this report. The design is conceptual in nature. Additional estimates may need to be prepared for site specific conditions.

8.2 Assumptions

Various assumptions were made in compiling these costs. The following are listed for general reference:

- Normal site and soil conditions exist and is free and clear of any underground obstructions.
- Access to the construction site is unrestricted and maintenance and upgrading roadways is not required.
- Standard construction practices are employed.
- Union scale wage rates were used in calculating construction labor.
- All material and equipment shall be new.
- Security during construction and operation will be provided.
- Environmental permitting costs are not included.
- Site selection and surveying and/or site remediation costs are not included.
- Project management costs, other than contractor's site management, are not included.
- Standard estimating practices were used in all phases of the estimate.

- Sales taxes are not included in any cost elements.
- All cost figures are represented in 1994 dollars.
- A 20 percent contingency is included for all cost elements.
- Site-specific munition racks are not included.
- Costs for sampling and analysis is not included.
- Owner's cost for interest during construction is not included in these figures.

The following conditions exist or are available in a reasonable distance:

- Sanitary sewer
- Electrical power
- Potable water
- Storm drainage
- Standard gage rail line
- Hard surface roadway

8.3 Cost Sources

The capital costs were obtained from TVA's files, TVA's current requisitions and contracts, vendor quotes, both oral and written, estimating manuals and catalogs.

The subcontract costs indicated for process equipment for a new facility in Table 8-1 and for a CWP retrofit in Table 8-2 include manufacturer's engineering costs and the installation labor costs include freight to a non-specific job site and are not included in the freight and engineering sections of the estimate in Appendix D and Appendix E.

8.4 Capital Costs

As shown in Table 8-1, the total installed costs for a hot gas decontamination system to be constructed at a new facility is approximately $4,400,000 under the conditions stated in assumptions.

In Table 8-1 the following categories are defined as:

Equipment - Generally refers to individual pieces of process related equipment.

Bulk Material - Refers to concrete, form work, supports, piping materials, electrical conduit, cables, etc.

Labor - Installation or construction manual labor.

Subcontract - Refers to those items that are designed, fabricated, installed, and tested by a subcontractor.

Also in Table 8-1, Distributable Field Costs include temporary construction facilities, temporary construction services, construction supervision, construction equipment/small tools, and other miscellaneous project expenses.

Table 8-2 shows the capital cost for retrofit of an existing CWP facility to a hot gas decontamination system.

Table 8-1

SUMMARY OF CAPITAL COSTS

NEW FACILITY

ITEM #	AREA	EQUIPMENT	BULK MAT'L	LABOR	SUBCONTRACT	TOTAL
0001	Site Preparation & Improvement		$ 47,971	$ 69,824	$ 99,280	$ 217,075
0002	Foundations and Concrete		44,046	46,783		90,829
0003	Process Equipment	187,796	43,700	230,849	1,013,842	1,476,187
0004	Buildings		4,605	14,630	146,314	165,549
0005	Ductwork		12,286	44,379		56,665
0006	Duct Insulation		29,712	31,802		61,514
0007	Piping Systems		10,780	4,256		15,036
0008	Instrumentation		531,985	199,948		731,933
0009	Electrical		84,146	56,703		140,848
0010	Structural Supports		3,470	7,614		11,084
0011	Painting		1,248	7,028		8,276
4000	Distributable Field Costs		100,700	208,786	2,500	311,986
5000	Freight	5,634	24,418			30,052
6000	Sales Tax					
7000	Home Office Engineering			276,127		276,127
8000	Startup Expenses		19,805	70,068		89,873
9000	Contingency	38,686	187,813	239,746	252,387	718,633
9500	Escalation					
TOTAL PROJECT DIRECT COSTS		$232,116	$1,146,685	$1,508,545	$1,514,323	$4,401,668

Table 8-2

SUMMARY OF CAPITAL COSTS

CWP RETROFIT

ITEM #	AREA	EQUIPMENT	BULK MAT'L	LABOR	SUBCONTRACT	TOTAL
0001	Site Preparation & Improvement		$ 996	$ 1,570	$ 4,620	$ 7,186
0002	Foundations and Concrete		12,663	25,415		38,078
0003	Process Equipment		15,000	200,000	461,887	676,887
0004	Buildings					
0005	Ductwork		6,143	22,190		28,333
0006	Duct Insulation		14,856	15,901		30,757
0007	Piping Systems					
0008	Instrumentation		452,187	169,956		622,143
0009	Electrical		50,487	34,022		84,509
0010	Structural Supports		3,470	7,614		11,084
0011	Painting		548	3,456		4,004
4000	Distributable Field Costs		100,700	182,584	2,500	285,784
5000	Freight		16,691			16,691
6000	Sales Tax					
7000	Home Office Engineering			169,285		169,285
8000	Startup Expenses		4,466	59,644		64,110
9000	Contingency		134,748	166,399	93,801	394,948
9500	Escalation					
TOTAL PROJECT DIRECT COSTS			$812,955	$1,058,035	$562,808	$2,433,799

8.5 Operating Costs

The following is used to determine daily operating cost for a single operating cycle. The facility is capable of running two cycles per day.

Personnel (per cycle): Control room operator - 8 hours @ $18.00/hour

Material Handler - 4 hours @ $15.00/hour

Consumables (per cycle): DF2 Fuel - 553 gals. @ $.85/gallon (New Facility)

265 gals. @ $.85/gallon (CWP Retrofit)

Electricity - 1,384 KWH @ $.08/KWH(New Facility)

356 KWH @ $.08/KWH(CWP Retrofit)

Maintenance Labor: Annual cost is equal to one percent of total plant cost.

Maintenance Material: Annual cost is equal to 1/2 percent of total plant cost.

Cycle Information: 19 tons/cycle (New Facility)

10 tons/cycle (CWP retrofit)

12 hour cycle time.

365 cycles/year

Table 8-3

	NEW FACILITY	CWP RETROFIT
Operating Personnel	$204.00	$204.00
Consumables	580.77	246.08
Maintenance Labor	120.55	66.64
Maintenance Material	60.28	33.32
TOTAL	**$965.60**	**$550.04**

For a new facility, the total cost per ton is $50.82.

For a CWP retrofit, the total cost per ton is $55.00.

APPENDIX A

HEAT TRANSFER MODEL SPREADSHEET

This appendix contains the output data from the heat transfer model (described in Section 2-4) used to predict heatup time, throughput rate, fuel consumption, and operating cost. The model is based on an array of 175 mm projectiles as shown in Figure 2-1.

For each increment of time selected and for each row of items, the model calculates the following:

- The initial (TMI) and final (TMF) temperature of the metal items.
- The air temperature (TG) leaving each row.
- Amount of heat (HS) transferred to each row during the time increment of one minute.
- Total heat (HS ACCUM) transferred to each row from time equal zero.

The first page shows the input data used by the model, followed by the results of the calculation for each row based on time. The last page indicates the heat absorption rate and the total amount of heat absorbed by all eight rows with respect to time.

HOT GAS DECONTAMINATION
CHAMBER HEAT TRANSFER AND HEAT LOSS CALCULATION
COMPUTER MODEL

HL - TOTAL CHAMBER CONVECTIVE HEAT TRANSFER AND HEAT LOSS
HS - HEAT TRANSFER TO METAL ITEMS
HC - CONDUCTIVE HEAT LOSS THRU CHAMBER WALLS
HI - HEAT LOSS TO INFILTRATION

HL = HS + HC + HI = 2008415.77 26884 288640 = 2323939 BTU/HR @
86% 1% 12% TIME=1MIN

HS = U * A * (TG - TMI) = CM * WT. * (TMF - TMI)

U =	1.2	TMI =	45	CG =	0.26	BTU/#/F
A =	220	CM =	0.12	Q =	18000	PPH AIR FLOW
TG =	1200	WT. =	37968	ACFM =	12528	FT^3/MIN.

175 mm array, 21x8x2=336 @ 113 lbs.=37968 lbs.

ROW 1

TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT)
1	45.00	51.24	5082	5082	1135
15	127.54	133.07	4719	73455	1140
30	205.94	210.85	4374	141426	1144
45	275.84	280.24	4066	204531	1148
60	338.70	342.67	3790	263278	1151
75	395.59	399.19	3539	318091	1155
90	447.37	450.66	3312	369333	1158
105	494.72	497.73	3103	417317	1160
120	538.19	540.96	2912	462316	1163
135	578.23	580.78	2736	504568	1165
150	615.22	617.58	2573	544288	1167
165	649.48	651.67	2422	581663	1169
180	681.28	683.32	2282	616866	1171
195	710.87	712.77	2152	650048	1172
210	738.44	740.21	2031	681350	1174
225	764.17	765.83	1918	710897	1175
240	788.23	789.78	1812	738806	1177
255	810.75	812.20	1713	765182	1178
270	831.86	833.22	1620	790122	1179
285	851.66	852.93	1533	813716	1180
300	870.25	871.45	1451	836045	1181
315	887.73	888.86	1374	857187	1182
330	904.18	905.24	1302	877213	1183
343	917.66	918.66	1242	893715	1184

ROW 2

TIME (MIN.)	TMI (DEG. F	TMF (DEG. F	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT)
1	45.00	50.89	4795	4795	1073
15	123.14	128.39	4472	69462	1082
30	197.83	202.52	4163	134025	1091
45	264.82	269.05	3885	194212	1098
60	325.36	329.19	3635	250456	1105
75	380.40	383.89	3407	303125	1111
90	430.70	433.90	3198	352534	1117
105	476.87	479.82	3007	398954	1122
120	519.41	522.12	2830	442626	1126
135	558.72	561.23	2667	483761	1131
150	595.15	597.49	2516	522548	1135
165	629.00	631.17	2376	559155	1138
180	660.52	662.54	2245	593733	1142
195	689.92	691.81	2123	626421	1145
210	717.39	719.16	2009	657344	1148
225	743.11	744.76	1902	686615	1151
240	767.21	768.76	1802	714338	1154
255	789.83	791.29	1708	740611	1156
270	811.09	812.46	1620	765519	1158
285	831.08	832.37	1537	789147	1161
300	849.90	851.11	1459	811567	1163
315	867.64	868.78	1385	832851	1165
330	884.36	885.45	1315	853063	1166
343	898.10	899.13	1258	869761	1168

ROW 3

TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	50.56	4525	4525	1015
15	118.96	123.95	4238	65686	1028
30	190.12	194.60	3962	127012	1040
45	254.30	258.36	3713	184415	1050
60	312.59	316.29	3486	238263	1060
75	365.83	369.21	3279	288869	1069
90	414.67	417.79	3088	336505	1077
105	459.68	462.55	2913	381407	1084
120	501.29	503.95	2750	423784	1091
135	539.87	542.34	2600	463822	1097
150	575.73	578.03	2460	501686	1103
165	609.16	611.30	2329	537525	1109
180	640.36	642.37	2207	571474	1114
195	669.56	671.44	2093	603656	1118
210	696.91	698.67	1986	634183	1123
225	722.58	724.24	1885	663156	1127
240	746.71	748.26	1791	690670	1131
255	769.40	770.87	1702	716811	1134
270	790.78	792.16	1618	741660	1138
285	810.93	812.23	1539	765289	1141
300	829.95	831.18	1464	787767	1144
315	847.92	849.08	1394	809159	1147
330	864.90	866.00	1327	829524	1149
343	878.88	879.92	1272	846385	1152

ROW 4

TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	50.24	4270	4270	961
15	115.01	119.74	4016	62116	976
30	182.78	187.07	3771	120367	991
45	244.26	248.16	3547	175114	1005
60	300.37	303.94	3343	226666	1017
75	351.85	355.13	3155	275288	1028
90	399.27	402.30	2982	321212	1039
105	443.12	445.93	2821	364639	1048
120	483.80	486.41	2672	405753	1057
135	521.65	524.08	2533	444712	1065
150	556.94	559.21	2404	481664	1072
165	589.92	592.04	2282	516738	1079
180	620.80	622.79	2169	550054	1086
195	649.77	651.64	2062	581720	1092
210	676.98	678.74	1961	611836	1098
225	702.59	704.24	1867	640493	1103
240	726.70	728.26	1778	667775	1108
255	749.45	750.92	1693	693760	1113
270	770.92	772.31	1614	718520	1117
285	791.21	792.53	1539	742122	1121
300	810.41	811.65	1468	764628	1125
315	828.57	829.75	1400	786097	1129
330	845.79	846.90	1336	806581	1132
343	859.98	861.04	1283	823578	1135

ROW 5

TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	49.95	4029	4029	909
15	111.26	115.76	3806	58740	928
30	175.81	179.90	3589	114070	945
45	234.68	238.43	3389	166284	962
60	288.68	292.13	3206	215637	976
75	338.44	341.62	3036	262350	990
90	384.46	387.41	2879	306618	1002
105	427.18	429.92	2732	348615	1013
120	466.94	469.49	2596	388495	1024
135	504.04	506.43	2468	426397	1033
150	538.75	540.98	2348	462447	1042
165	571.28	573.38	2236	496759	1051
180	601.82	603.79	2130	529439	1059
195	630.54	632.40	2030	560580	1066
210	657.60	659.34	1936	590272	1073
225	683.11	684.76	1847	618596	1079
240	707.20	708.75	1763	645626	1085
255	729.97	731.44	1684	671432	1091
270	751.51	752.91	1608	696079	1096
285	771.92	773.24	1537	719627	1101
300	791.26	792.51	1469	742133	1106
315	809.60	810.79	1405	763648	1111
330	827.02	828.15	1343	784222	1115
343	841.41	842.49	1293	801327	1119

ROW 6

TIME (MIN.)	TMI (DEG. F)		HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	49.67	3801	3801	860
15	107.71	111.98	3607	55547	881
30	169.17	173.08	3415	108102	902
45	225.55	229.14	3238	157900	920
60	277.50	280.82	3074	205146	937
75	325.58	328.66	2921	250023	952
90	370.23	373.10	2779	292692	966
105	411.83	414.50	2646	333300	979
120	450.67	453.17	2521	371976	991
135	487.04	489.38	2403	408841	1002
150	521.15	523.35	2293	444001	1013
165	553.22	555.29	2189	477557	1023
180	583.40	585.35	2091	509598	1032
195	611.86	613.70	1998	540208	1040
210	638.73	640.47	1910	569465	1048
225	664.14	665.78	1826	597440	1056
240	688.17	689.73	1747	624200	1063
255	710.95	712.42	1672	649806	1070
270	732.54	733.94	1601	674316	1076
285	753.03	754.36	1533	697785	1082
300	772.50	773.76	1469	720263	1087
315	791.00	792.20	1407	741797	1093
330	808.60	809.74	1349	762432	1098
343	823.16	824.26	1300	779621	1102

ROW 7

TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	49.40	3587	3587	814
15	104.34	108.40	3419	52528	837
30	162.87	166.60	3251	102448	860
45	216.83	220.28	3094	149940	880
60	266.81	270.01	2948	195168	899
75	313.26	316.24	2811	238278	916
90	356.56	359.35	2682	279402	932
105	397.05	399.65	2561	318661	946
120	434.98	437.43	2448	356165	960
135	470.61	472.91	2340	392012	972
150	504.13	506.29	2239	426295	984
165	535.72	537.76	2142	459098	995
180	565.53	567.46	2051	490501	1005
195	593.72	595.54	1965	520574	1015
210	620.39	622.11	1883	549385	1024
225	645.66	647.29	1805	576998	1033
240	669.62	671.18	1730	603471	1041
255	692.38	693.85	1660	628858	1048
270	714.00	715.40	1592	653210	1055
285	734.56	735.89	1528	676577	1062
300	754.12	755.40	1467	699003	1069
315	772.76	773.97	1408	720530	1075
330	790.52	791.67	1352	741200	1080
343	805.24	806.34	1306	758449	1085

ROW 8

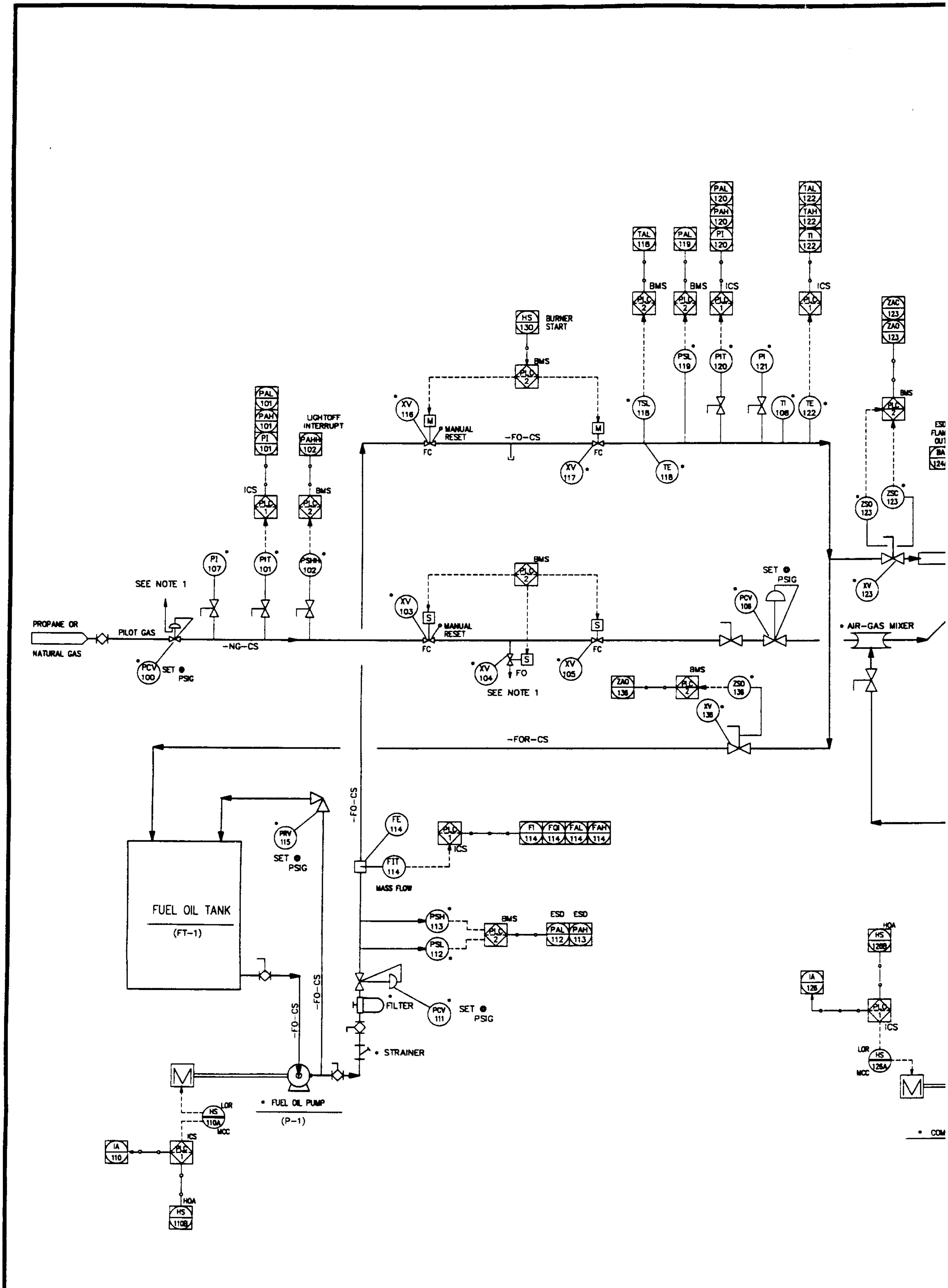
TIME (MIN.)	TMI (DEG. F)	TMF (DEG. F)	HS (BTUS)	HS ACCUM. (BTUS)	TG(EXIT) (DEG. F)
1	45.00	49.16	3385	3385	771
15	101.16	105.01	3240	49673	796
30	156.87	160.43	3094	97089	820
45	208.52	211.83	2956	142382	842
60	256.59	259.67	2826	185676	863
75	301.45	304.33	2704	227087	881
90	343.43	346.14	2589	266719	899
105	382.83	385.37	2480	304670	915
120	419.86	422.25	2376	341029	929
135	454.74	457.00	2278	375879	943
150	487.66	489.79	2185	409297	956
165	518.76	520.78	2096	441355	968
180	548.20	550.10	2012	472118	980
195	576.09	577.89	1932	501650	990
210	602.54	604.26	1855	530008	1000
225	627.66	629.29	1782	557246	1010
240	651.54	653.09	1712	583417	1019
255	674.25	675.73	1646	608567	1027
270	695.88	697.28	1582	632742	1035
285	716.48	717.82	1521	655985	1043
300	736.13	737.41	1463	678336	1050
315	754.88	756.09	1407	699833	1057
330	772.77	773.93	1354	720512	1063
343	787.63	788.75	1309	737799	1068

ROW 1 THRU 8

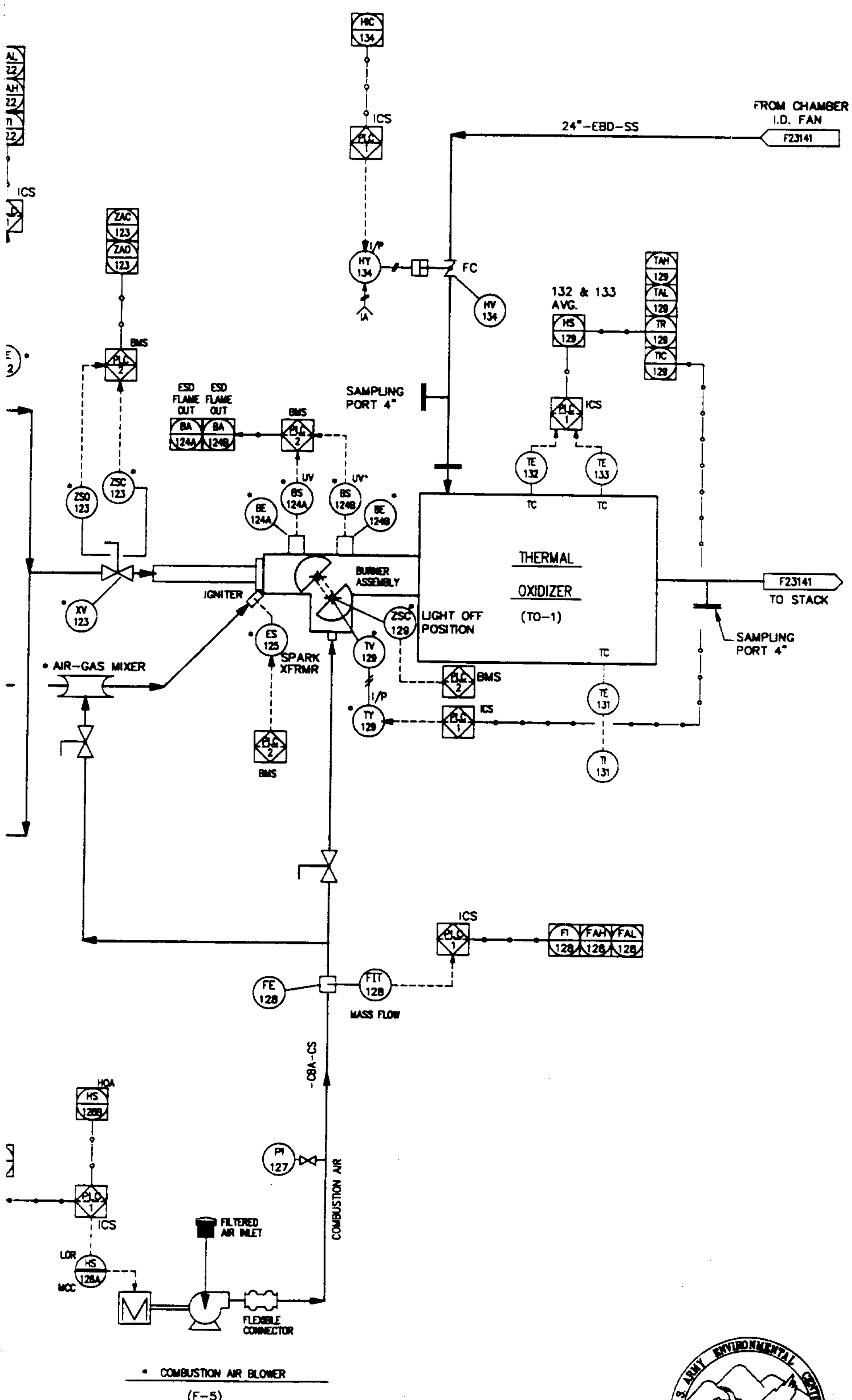
TIME (MIN.)	HEAT TRANSFER RATE MMBTU/HR	TOTAL HEAT TRANSFER MMBTU
1	2.01	0.03
15	1.89	0.49
30	1.78	0.94
45	1.67	1.37
60	1.58	1.78
75	1.49	2.16
90	1.41	2.53
105	1.34	2.87
120	1.27	3.19
135	1.20	3.50
150	1.14	3.79
165	1.08	4.07
180	1.03	4.33
195	0.98	4.58
210	0.93	4.82
225	0.89	5.05
240	0.85	5.27
255	0.81	5.48
270	0.77	5.67
285	0.74	5.86
300	0.70	6.04
315	0.67	6.21
330	0.64	6.37
343	0.62	6.51

APPENDIX B

P&ID AND ARRANGEMENT DRAWINGS



TENNESSEE VALLEY AUTHORITY



TENNESSEE VALLEY AUTHORITY

PIPING SYMBOLS LEGEND

PIPE LINE IDENTIFICATION

12"-HG-CS

- LINE SIZE
- COMMODITY SYMBOL
- PIPING MATERIAL

COMMODITY SYMBOL

HRD	HEAT RECOVERY DISCHARGE
CLA	COOLING AIR
EBD	EXHAUST BLOWER DISCHARGE
DCS	DECON CHAMBER SUPPLY
DCD	DECON CHAMBER DISCHARGE
HG	HOT GAS
EBB	EXHAUST BLOWER BYPASS
NG	NATURAL GAS
FO	FUEL OIL
FOR	FUEL OIL RETURN
CA	COMPRESSED AIR
CBA	COMBUSTION AIR
V	VENT
IA	INSTRUMENT AIR

PIPING, VALVES & FITTINGS

- SCREWED
- FLANGED
- SOCKET WELD
- GLOBE VALVE
- BALL VALVE
- PLUG VALVE
- GATE VALVE
- CHECK VALVE
- MANUAL BUTTERFLY
- AUTO. BUTTERFLY
- REGULATING NEEDLE VALVE
- CONTROL VALVE
- SELF OPERATED PRESS. REG. VLV.
- CONCENTRIC REDUCER
- ECCENTRIC REDUCER
- HALF COUPLING
- UNION
- STRAINER
- EXPANSION JOINT
- START UP STRAINER
- SAFETY SHOWER
- SIPHON
- TIE IN POINT
- PIPING, STEAM TRACED
- PIPING, JACKETED

INSTRUMENT SYMBOLS LEGEND

- ELECTRICAL SIGNAL
- PNEUMATIC SIGNAL OR SUPPLY
- CAPILLARY TUBING
- DATA HIGHWAY
- COMPUTER FUNCTION
- LOCALLY MOUNTED
- PROGRAMMABLE LOGIC CONTROLLER
- LOCATED IN MOTOR CONTROL CENTER
- AS — INSTRUMENT AIR SUPPLY
- SOLENOID
- PURGE
- INTERLOCK
- ORIFICE
- CHEMICAL SEAL
- VORTEX FLOWMETER

I\P CURRENT\PNEUMATIC
SP SET POINT
FO FAIL OPEN
FC FAIL CLOSED
HOA=HAND,OFF,AUTO
LOR=LOCAL,OFF,REMOTE
BMS=BURNER MANAGEMENT SYSTEM
ICS=INTEGRATED CONTROL SYSTEM
MCC=MOTOR CONTROL CENTER

NOTES

1. ALL FUEL GAS VENTS MUST BE PIPED TO A SAFE AREA PER, NFPA AND GOVERNMENT, STATE, CITY, AND LOCAL CODES. VENT LINES MUST BE RUN TO AN AREA APPROVED FOR A HEAVIER THAN AIR FLAMMABLE GAS IF PRORANE IS USED FOR PIOLT GAS. A 12' VERTICAL RUN TO RELEASE THE GAS TO THE ATMOSPHERE IS ADEQUATE FOR NATURAL GAS.
2. ITEMS MARKED "•" ARE FURNISHED WITH BURNER.

REFERENCE DRAWINGS

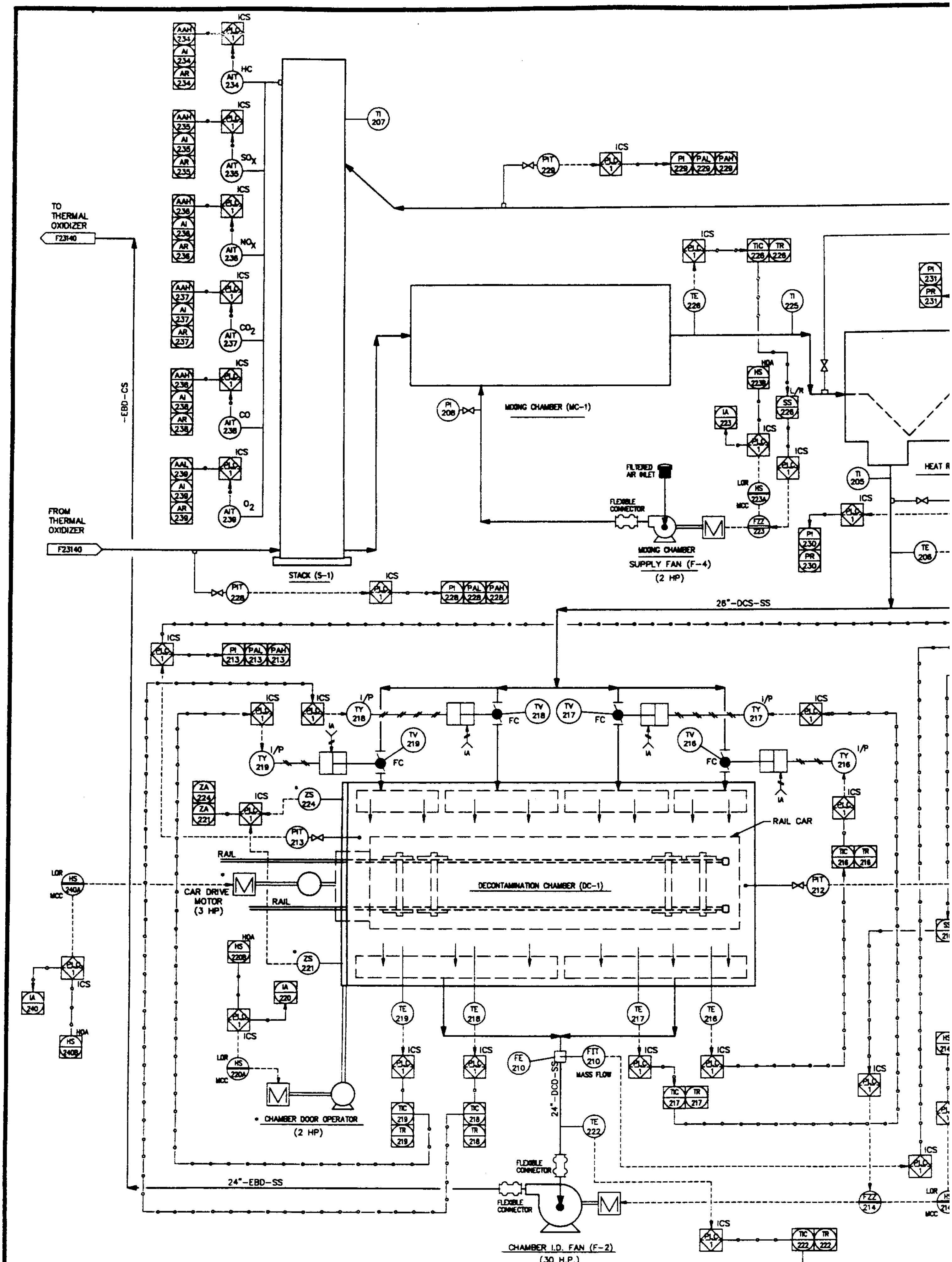
PROCESS AND INSTRUMENTATION DIAGRAM F23141
PROCESS AND INSTRUMENTATION DIAGRAM F23159

ENGINEERING SERVICES~WESTERN ENGINEERING
ENGINEERING DESIGN
MUSCLE SHOALS, ALABAMA

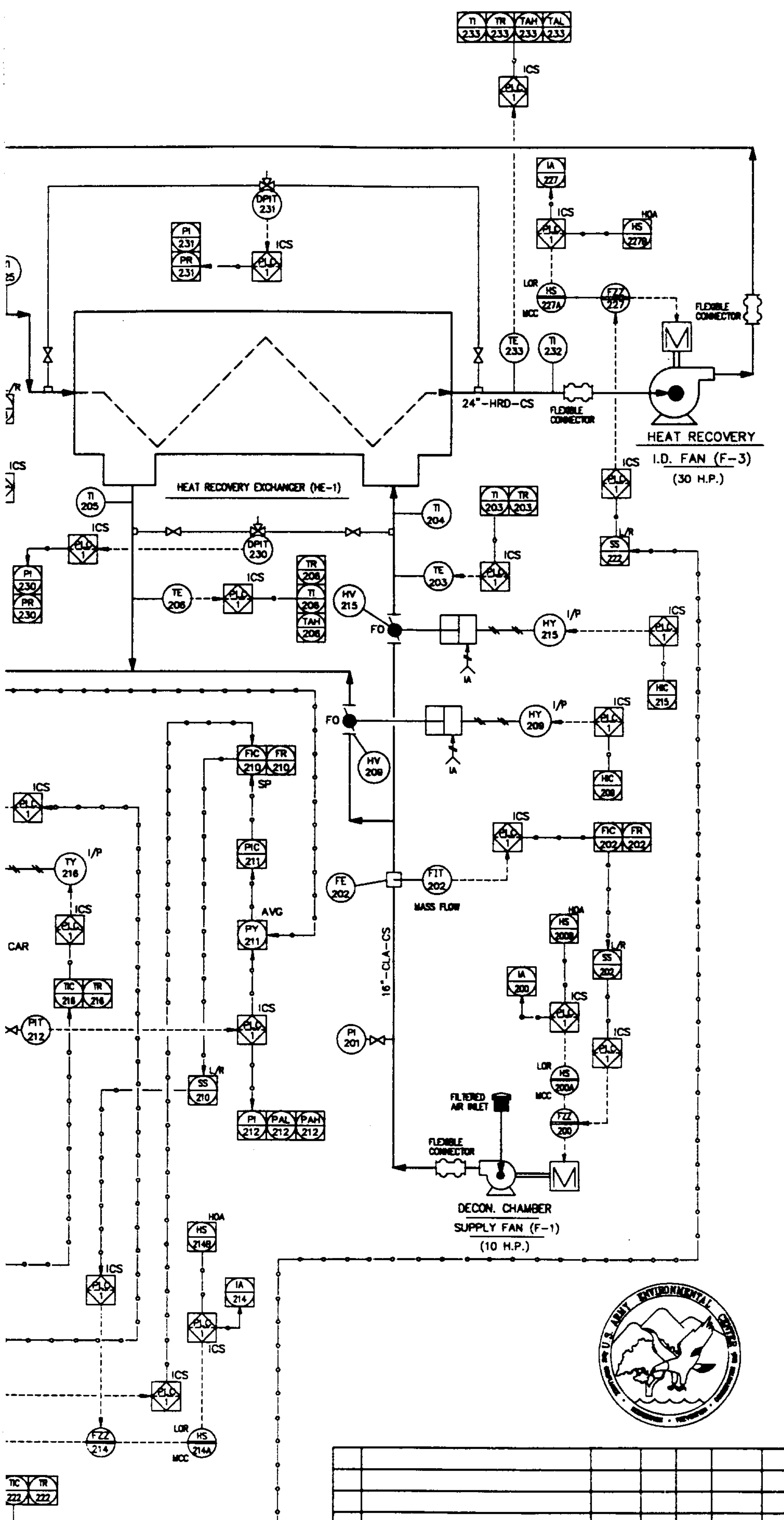
US ARMY ENVIRONMENTAL CENTER
HOT GAS DECON.-CONCEPTUAL DESIGN
PROCESS & INSTRUMENT DIAG. SH. 1

M. MYERS 4/29/94 DRAWN DATE	APPROVED DATE	SCALE NONE	
CHECKED NONE DATE	APPROVED DATE	WORK ORDER 0002WOD	
BILL OF MATERIAL	APPROVED DATE	F23140	R0

ISSUE	DESCRIPTION	DATE	MADE	CHECKED	APPROVED	DATE


TO THERMAL OXIDIZER
F23140
FROM THERMAL OXIDIZER
F23140
-EBD-CS
STACK (S-1)
MIXING CHAMBER (MC-1)
FILTERED AIR INLET
FLEXIBLE CONNECTOR
MIXING CHAMBER SUPPLY FAN (F-4)
(2 HP)
26"-DCS-SS
HEAT R
RAIL CAR
RAIL
CAR DRIVE MOTOR
(3 HP)
DECONTAMINATION CHAMBER (DC-1)
CHAMBER DOOR OPERATOR
(2 HP)
24"-EBD-SS
24"-DCD-SS
MASS FLOW
FLEXIBLE CONNECTOR
CHAMBER I.D. FAN (F-2)
(30 H.P.)
ICS
HC
SO_X
NO_X
CO_2
CO
O_2
I/P
FC
IA
HOA
LOR
MCC
L/R

TENNESSEE VALLEY AUTHORITY



PIPING SYMBOLS LEGEND

PIPE LINE IDENTIFICATION

12"–HG–CS

LINE SIZE
COMMODITY SYMBOL
PIPING MATERIAL

COMMODITY SYMBOL

HRD	HEAT RECOVERY DISCHARGE
CLA	COOLING AIR
EBD	EXHAUST BLOWER DISCHARGE
DCS	DECON CHAMBER SUPPLY
DCD	DECON CHAMBER DISCHARGE
DCB	DECON CHAMBER BYPASS
HG	HOT GAS
EBB	EXHAUST BLOWER BYPASS
NG	NATURAL GAS
FO	FUEL OIL
FOR	FUEL OIL RETURN
CA	COMPRESSED AIR
CBA	COMBUSTION AIR
V	VENT
IA	INSTRUMENT AIR

PIPING, VALVES & FITTINGS

- SCREWED
- FLANGED
- SOCKET WELD
- GLOBE VALVE
- BALL VALVE
- PLUG VALVE
- GATE VALVE
- CHECK VALVE
- MANUAL BUTTERFLY
- AUTO. BUTTERFLY
- REGULATING NEEDLE VALVE
- CONTROL VALVE
- SELF OPERATED PRESS. REG. VLV.
- CONCENTRIC REDUCER
- ECCENTRIC REDUCER
- HALF COUPLING
- UNION
- STRAINER
- EXPANSION JOINT
- START UP STRAINER
- SAFETY SHOWER
- SIPHON
- TIE IN POINT
- PIPING, STEAM TRACED
- PIPING, JACKETED

INSTRUMENT SYMBOLS LEGEND

- ELECTRICAL SIGNAL
- PNEUMATIC SIGNAL OR SUPPLY
- CAPILLARY TUBING
- DATA HIGHWAY
- COMPUTER FUNCTION
- LOCALLY MOUNTED
- PROGRAMMABLE LOGIC CONTROLLER
- MOUNTED IN MOTOR CONTROL CENTER
- INSTRUMENT AIR SUPPLY
- SOLENOID
- PURGE
- INTERLOCK
- ORIFICE
- CHEMICAL SEAL
- VORTEX FLOWMETER

I\P CURRENT\PNEUMATIC
SP SET POINT
FO FAIL OPEN
FC FAIL CLOSED
HOA=HAND,OFF,AUTO
LOR=LOCAL,OFF,REMOTE
BMS=BURNER MANAGEMENT SYSTEM
ICS=INTEGRATED CONTROL SYSTEM
MCC=MOTOR CONTROL CENTER
L/R=LOCAL/REMOTE

NOTES

1. ITEMS MARKED "*" ARE FURNISHED WITH DECONTAMINATION CHAMBER.

REFERENCE DRAWINGS

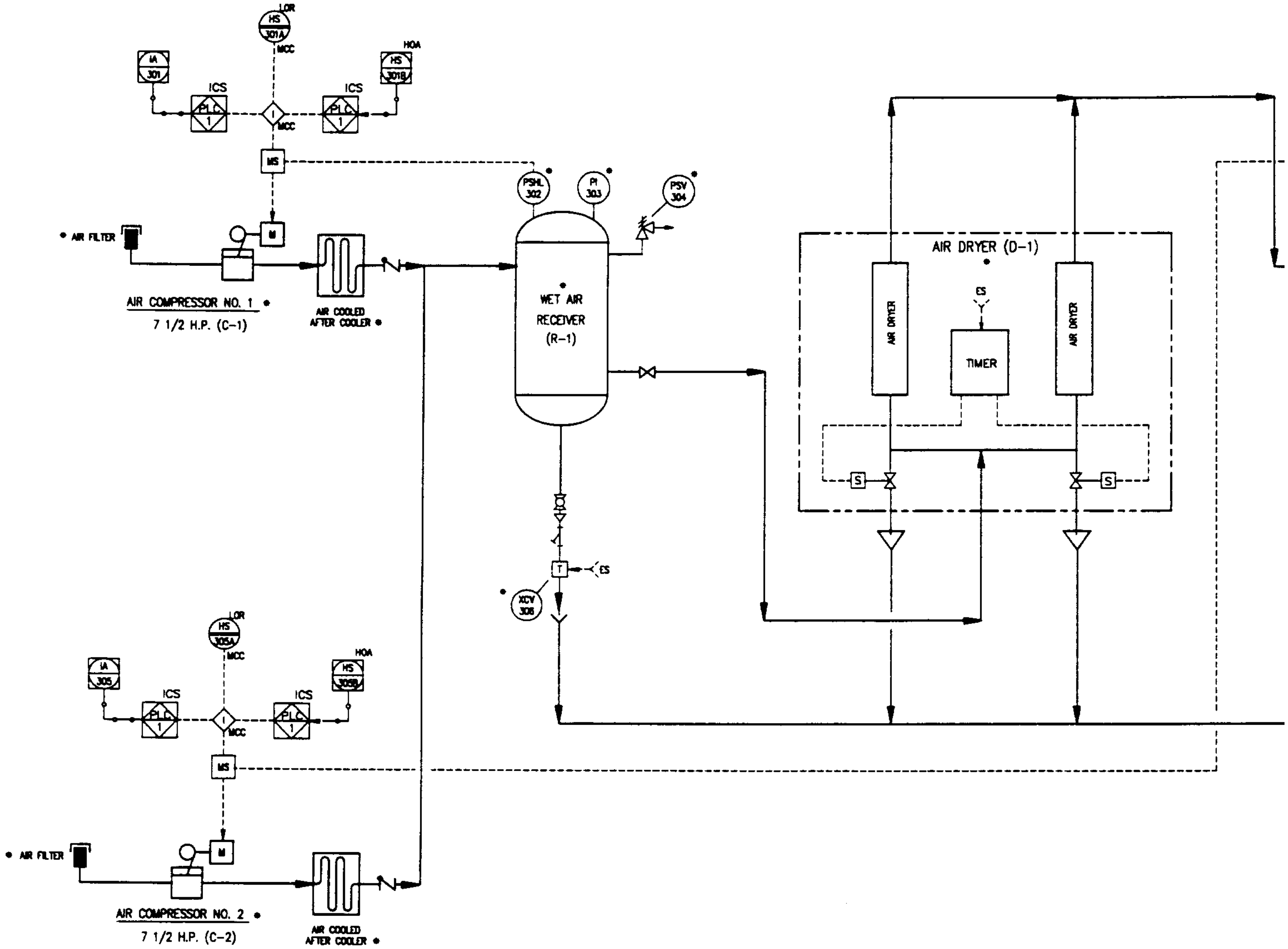
PROCESS AND INSTRUMENTATION DIAGRAM F23140
PROCESS AND INSTRUMENTATION DIAGRAM F23159

ENGINEERING SERVICES~WESTERN ENGINEERING
ENGINEERING DESIGN
MUSCLE SHOALS, ALABAMA

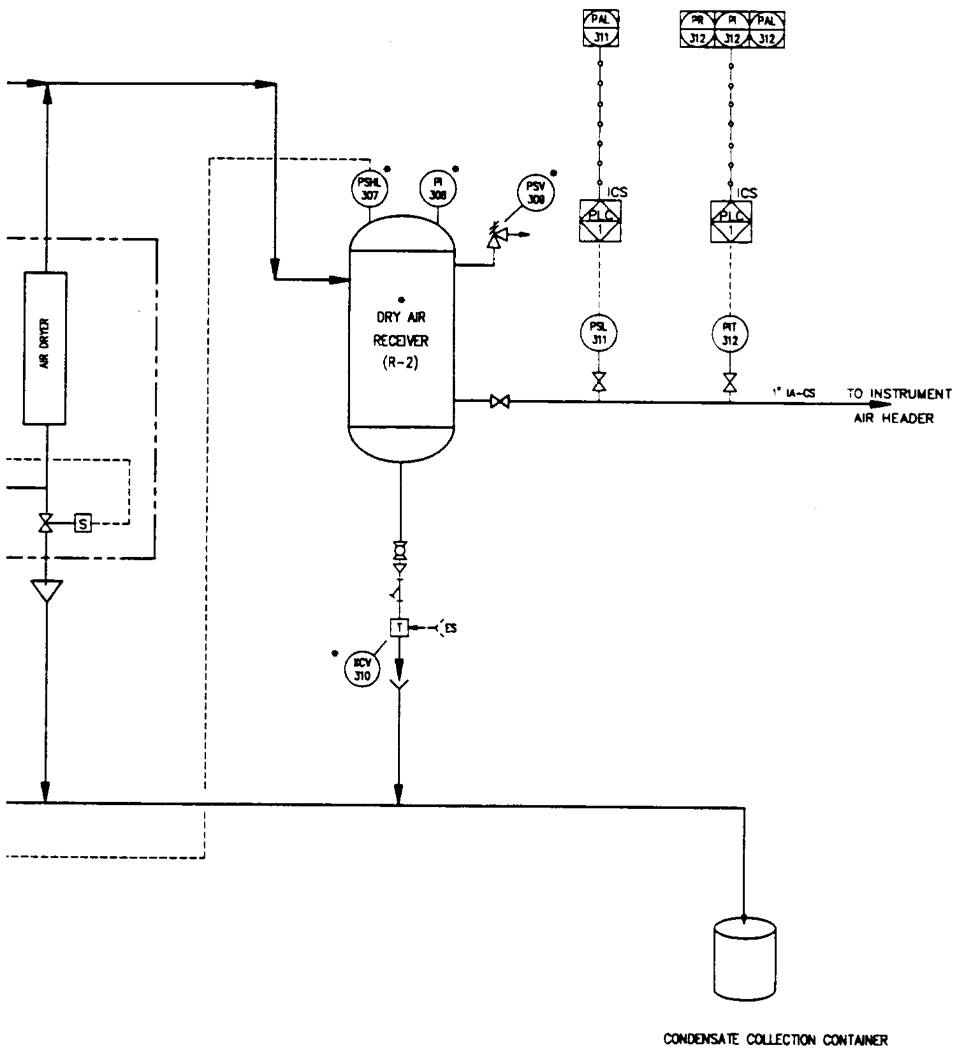
US ARMY ENVIRONMENTAL CENTER
HOT GAS DECON.–CONCEPTUAL DESIGN
PROCESS & INSTRUMENT DIAG. SH. 2

ISSUE	DESCRIPTION	DATE	MADE	CHECKED	APPROVED	DATE

M. MYERS 10/3/94 — DRAWN, DATE
CHECKED NONE — DATE
BILL OF MATERIAL, SHEETS
APPROVED, DATE
SCALE NONE
WORK ORDER 0002WOD
F23141 R0



INSTRUMENT AIR COMPRESSORS



TENNESSEE VALLEY AUTHORITY

PIPING SYMBOLS LEGEND

PIPE LINE IDENTIFICATION

12"-HG-CS

LINE SIZE

COMMODITY SYMBOL

PIPING MATERIAL

COMMODITY SYMBOL

CFD CARBON FILTER DISCHARGE
CLA COOLING AIR
EBD EXHAUST BLOWER DISCHARGE
FBD FUME BURNER DISCHARGE
FBS FUME BURNER SUPPLY
HG HOT GAS
MCD MIXING CHAMBER DISCHARGE
NG NATURAL GAS
RD RADIATOR DISCHARGE
RE RECIRCULATION AIR
CA COMPRESSED AIR
RG RETURN GAS
RI RADIATOR INLET
CD CONDENSATE
ST STEAM
V VENT
SCA SECONDARY CONTAINMENT AIR
IA INSTRUMENT AIR
CCD COLD CONDENSATE

PIPING, VALVES & FITTINGS

SCREWED
FLANGED
SOCKET WELD
GLOBE VALVE
BALL VALVE
PLUG VALVE
GATE VALVE
CHECK VALVE
MANUAL BUTTERFLY
AUTO. BUTTERFLY
REGULATING NEEDLE VALVE
CONTROL VALVE
SELF OPERATED PRESS. REG. VLV.
CONCENTRIC REDUCER
ECCENTRIC REDUCER
HALF COUPLING
UNION
STRAINER
EXPANSION JOINT
START UP STRAINER
SAFETY SHOWER
SIPHON
TIE IN POINT
PIPING, STEAM TRACED
PIPING, JACKETED

INSTRUMENT SYMBOLS LEGEND

ELECTRICAL SIGNAL
PNEUMATIC SIGNAL OR SUPPLY
CAPILLARY TUBING
ORIFICE
CHEMICAL SEAL
VORTEX FLOWMETER
COMPUTER FUNCTION
LOCALLY MOUNTED
PROGRAMMABLE LOGIC CONTROLLER
LOCATED IN MOTOR CONTROL CENTER
AS INSTRUMENT AIR SUPPLY
S SOLENOID
P PURGE
I INTERLOCK

I\P CURRENT\PNEUMATIC
SP SET POINT
FO FAIL OPEN
FC FAIL CLOSED
HOA=HAND,OFF,AUTO
LOR=LOCAL,OFF,REMOTE
BMS=BURNER MANAGEMENT SYSTEM
ICS=INTEGRATED CONTROL SYSTEM
MCC=MOTOR CONTROL CENTER

NOTES

1. ITEMS MARKED "•" ARE FURNISHED WITH COMPRESSORS.

REFERENCE DRAWINGS

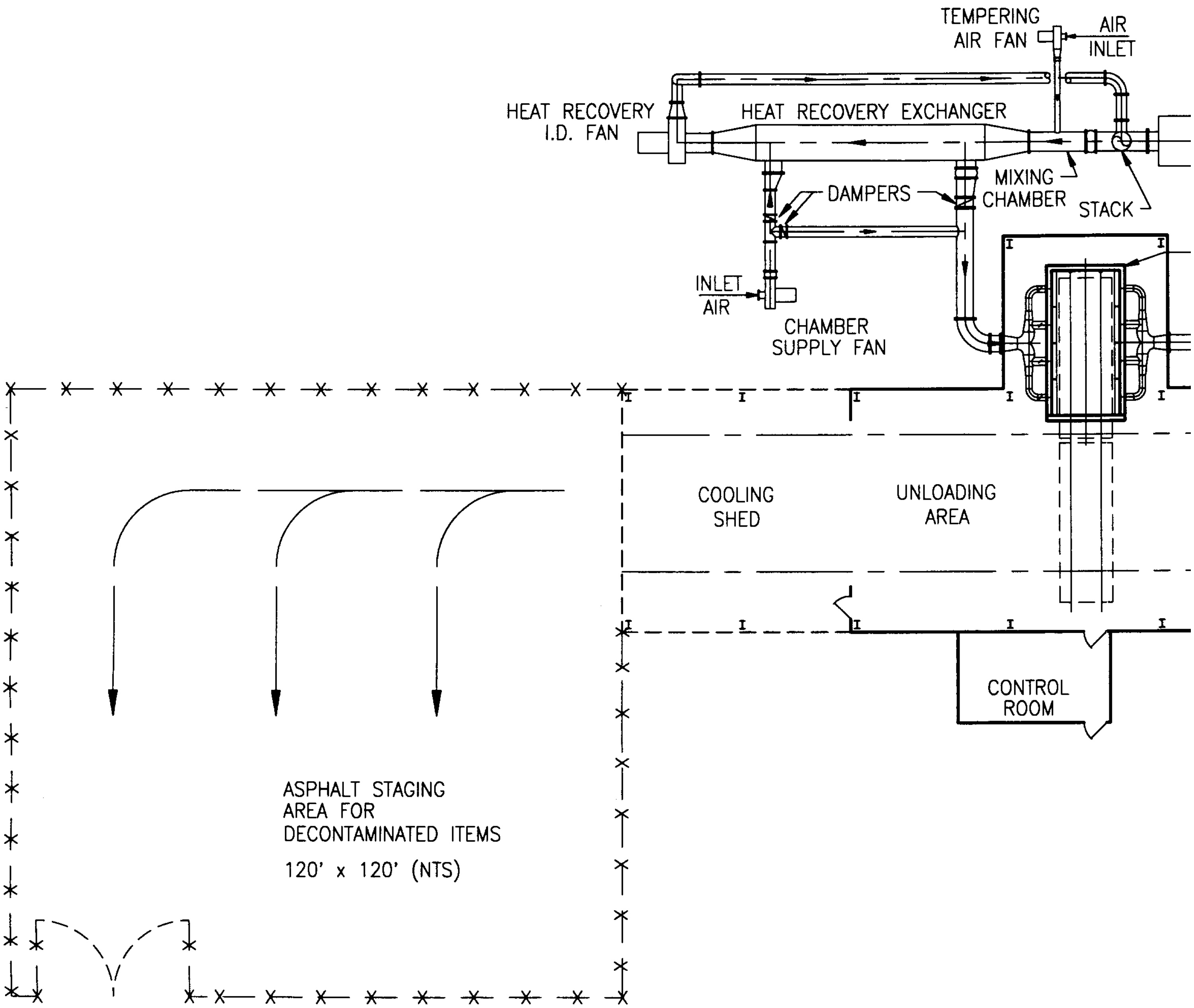
PROCESS AND INSTRUMENTATION DIAGRAM F23140
PROCESS AND INSTRUMENTATION DIAGRAM F23141

ENGINEERING SERVICES~WESTERN ENGINEERING
ENGINEERING DESIGN
MUSCLE SHOALS, ALABAMA

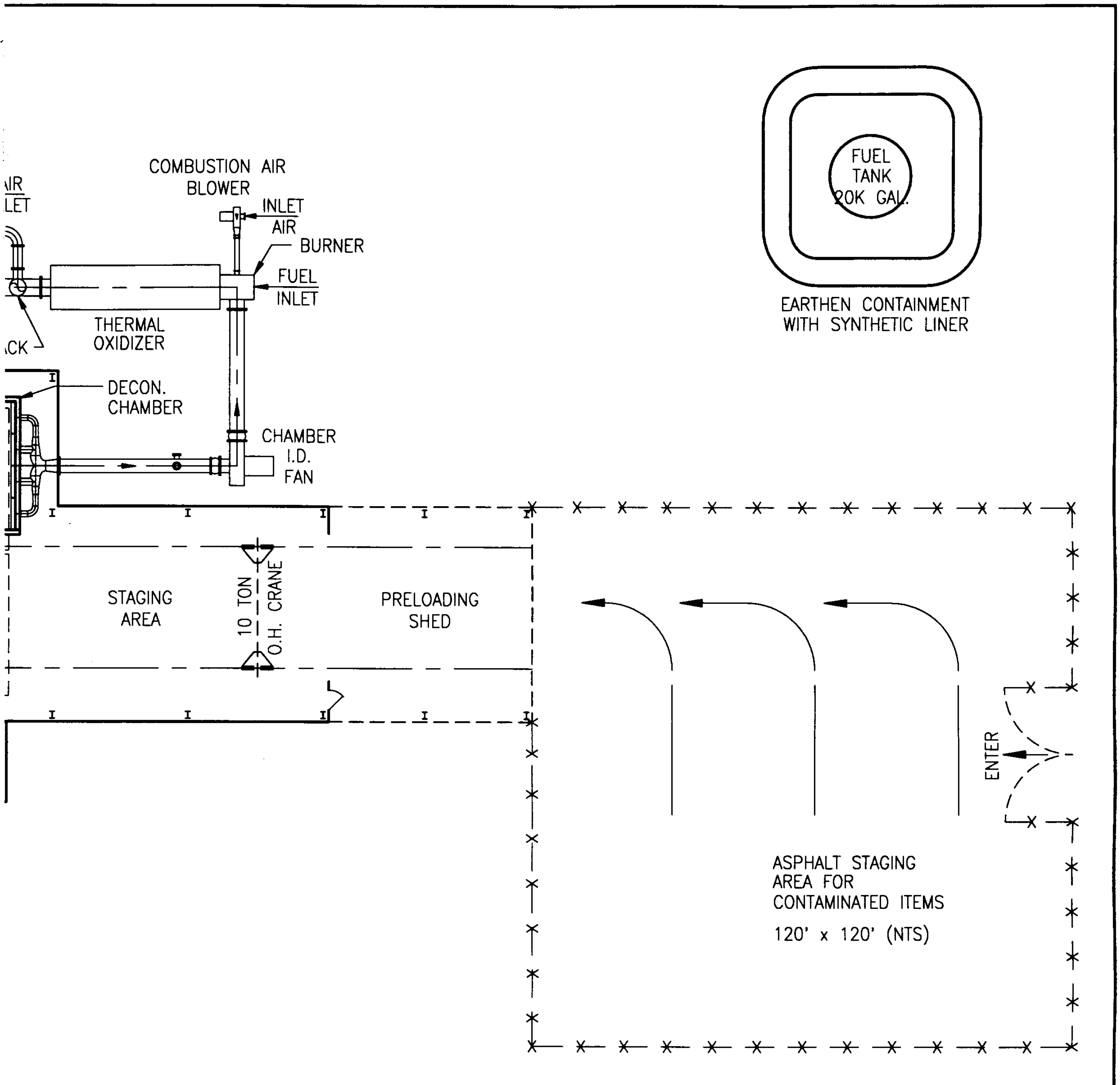
US ARMY ENVIRONMENTAL CENTER
HOT GAS DECON.-CONCEPTUAL DESIGN
PROCESS & INSTRUMENT DIAG. SH.3

M. MYERS 10/3/94					SCALE NONE		
DRAWN	DATE	APPROVED	DATE		WORK ORDER N87174		
CHECKED NONE	DATE	APPROVED	DATE		F23159	R0	
BILL OF MATERIAL	SUBMITTED	APPROVED	DATE				

ISSUE	DESCRIPTION	DATE	MADE	CHECKED	APPROVED	DATE



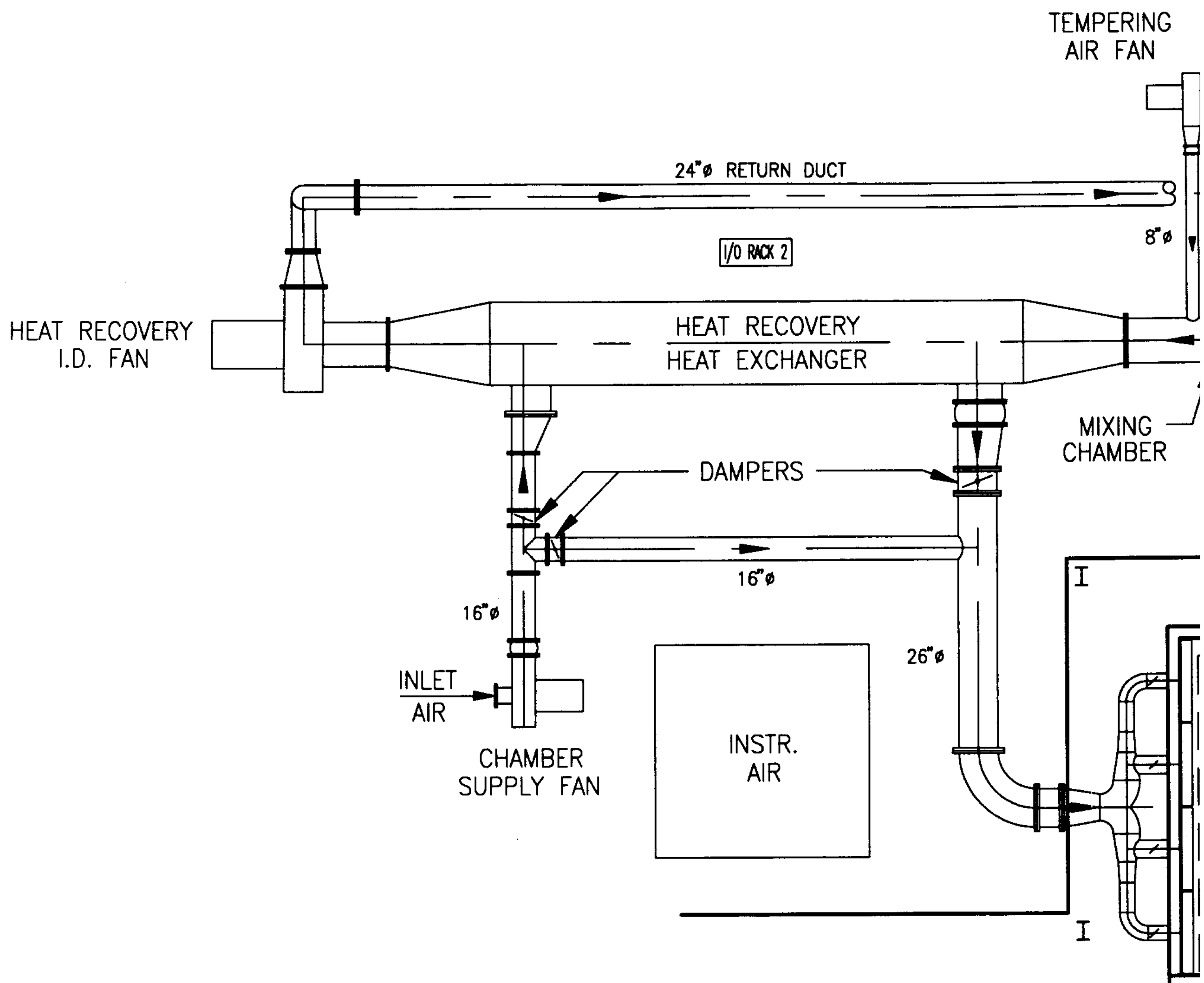
TOTAL FACILITY SIZE: 400 ft. X 200 ft. (APPROX. 1.8 ACRES)



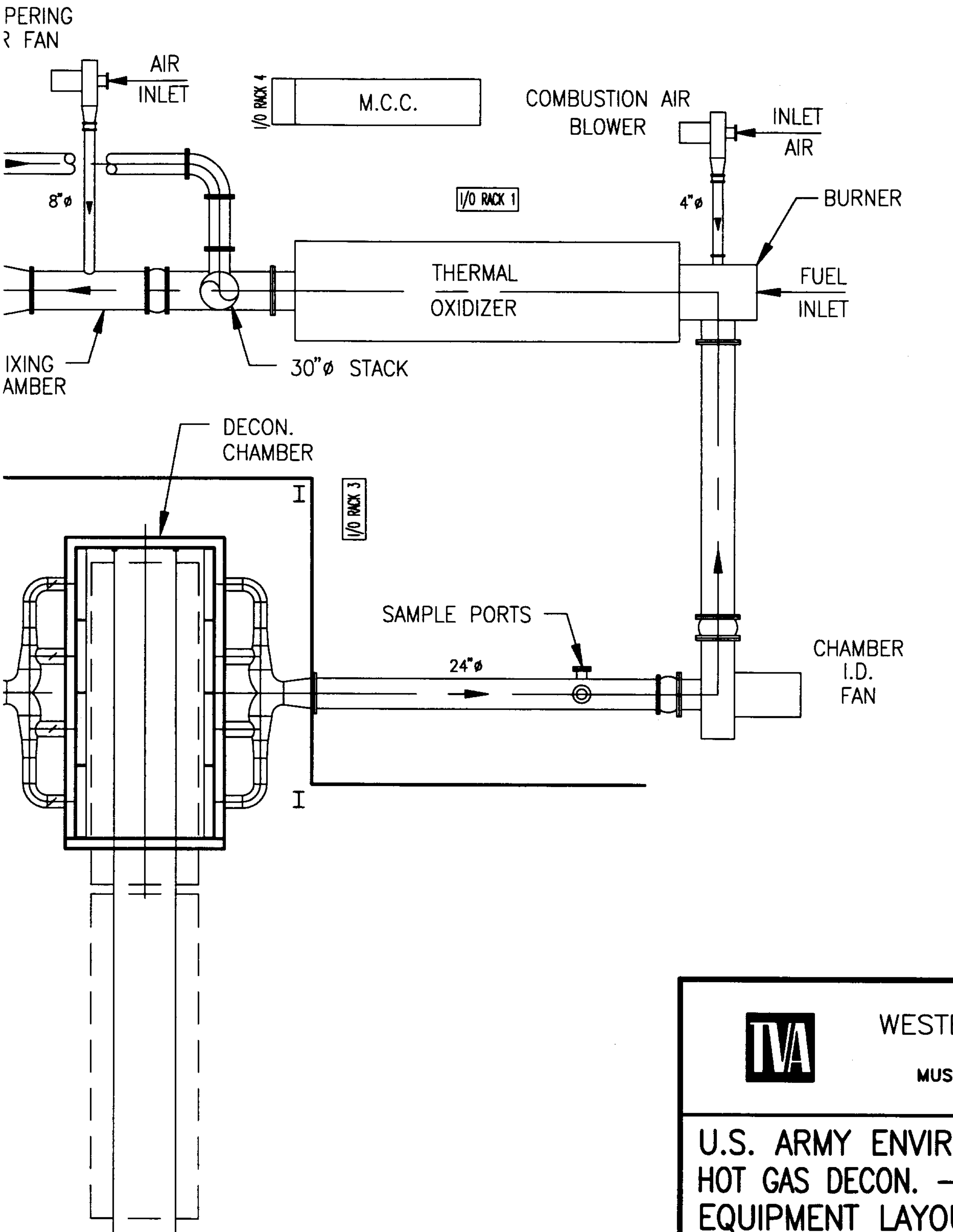
TVA WESTERN ENGINEERING DESIGN
MUSCLE SHOALS, ALABAMA

U.S. ARMY ENVIRONMENTAL CENTER
HOT GAS DECON. – CONCEPTUAL DESIGN
PLOT PLAN

L.E. HALE	6-13-94			SCALE 1" = 20' , UNLESS NOTED
DRAWN	DATE	APPROVED	DATE	WORK ORDER 0002WOD
CHECKED	DATE	APPROVED	DATE	CADD FILE NAME – DRAWING NO.
BILL OF MATERIALS	SHEETS	APPROVED	DATE	B23154



TEMPERING AIR FAN
24"ø RETURN DUCT
8"ø
I/O RACK 2
HEAT RECOVERY I.D. FAN
HEAT RECOVERY HEAT EXCHANGER
MIXING CHAMBER
DAMPERS
16"ø
16"ø
26"ø
INLET AIR
CHAMBER SUPPLY FAN
INSTR. AIR
I
I

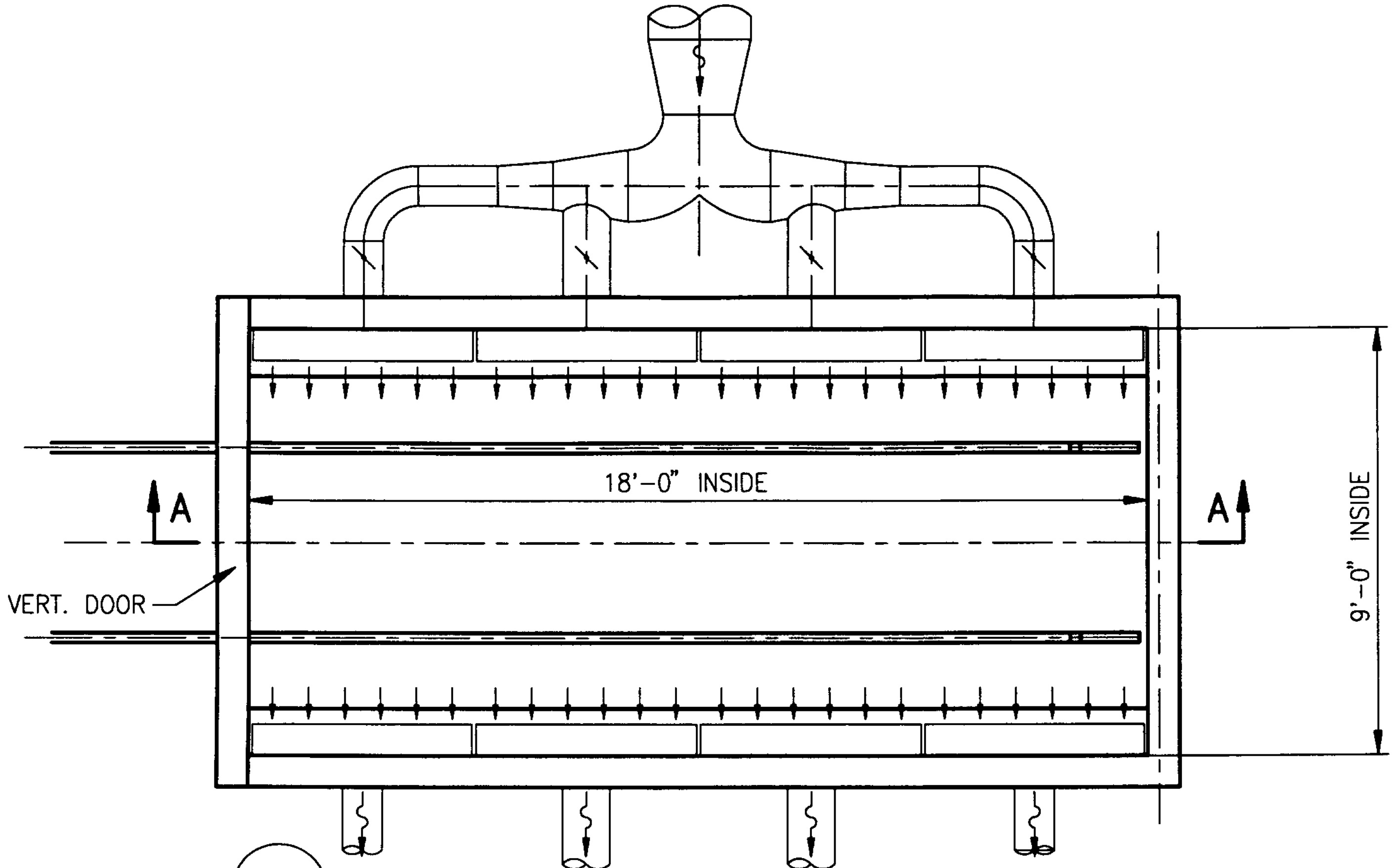


TVA

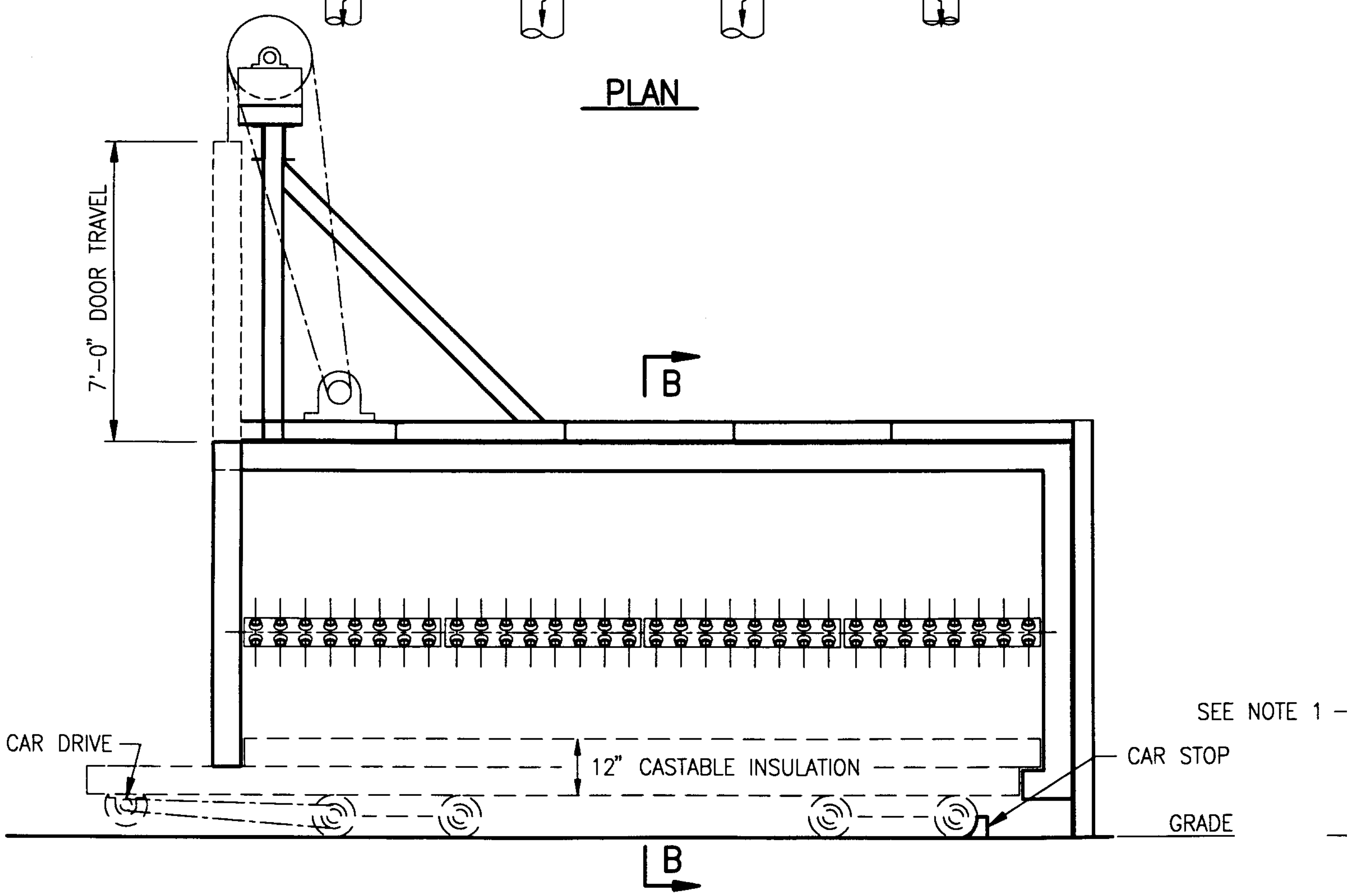
WESTERN ENGINEERING
DESIGN
MUSCLE SHOALS, ALABAMA

U.S. ARMY ENVIRONMENTAL CENTER
HOT GAS DECON. – CONCEPTUAL DESIGN
EQUIPMENT LAYOUT

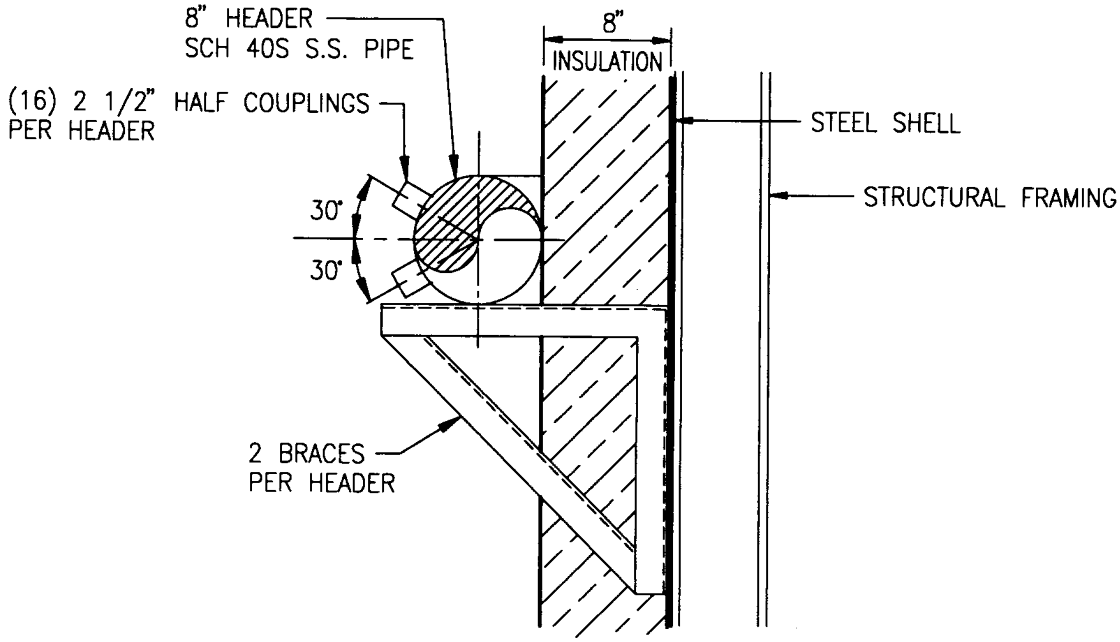
L.E. HALE	10-13-94			SCALE 1" = 10'
DRAWN	DATE	APPROVED	DATE	WORK ORDER 0002W00
CHECKED	DATE	APPROVED	DATE	CADD FILE NAME – DRAWING NO.
BILL OF MATERIALS	SHEETS	APPROVED	DATE	B23155



PLAN



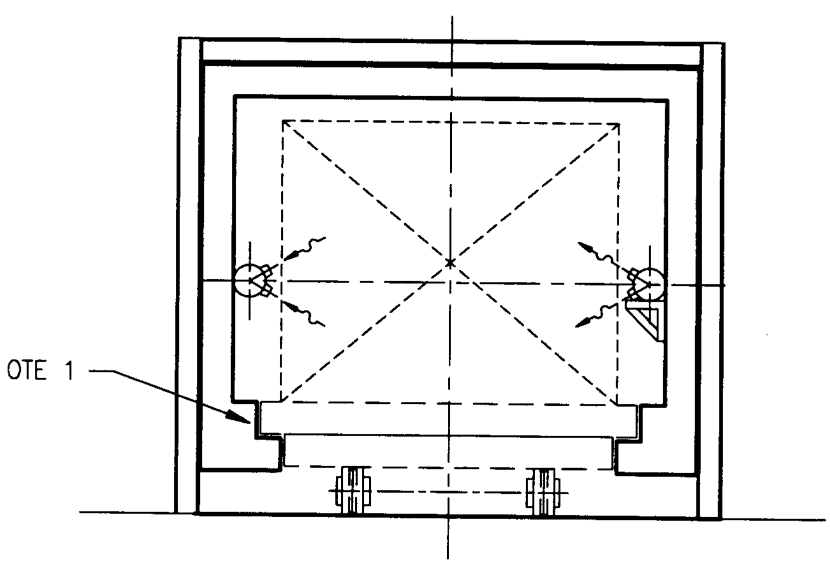
SECTION A-A



HEADER SUPPORT

NOTES:

1.) PNEUMATICALLY ACTUATED SEALS SHALL BE PROVIDED TO SEAL AGAINST BOTH SIDES AND END OF CAR BOTTOM.



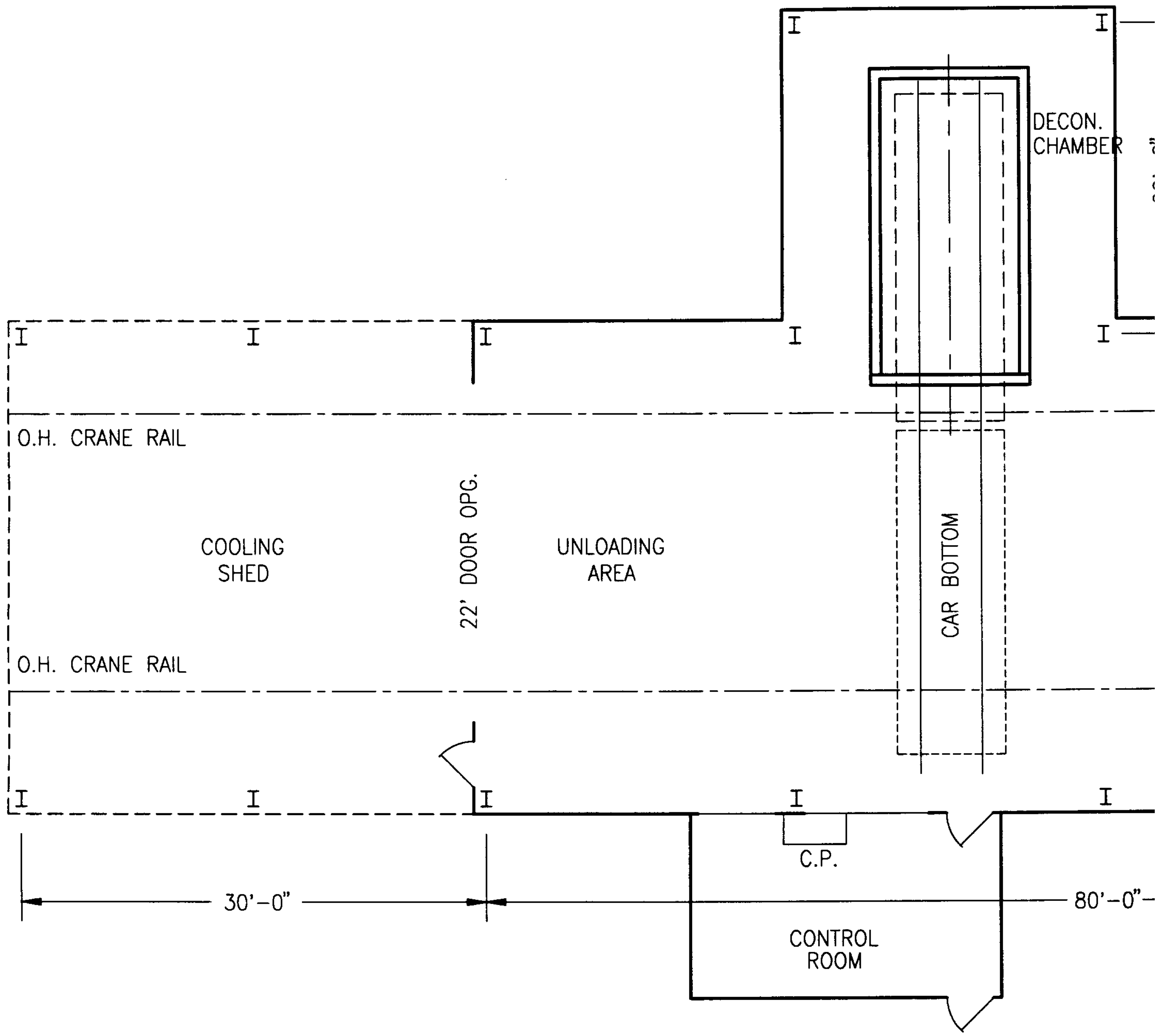
SECTION B-B

TVA

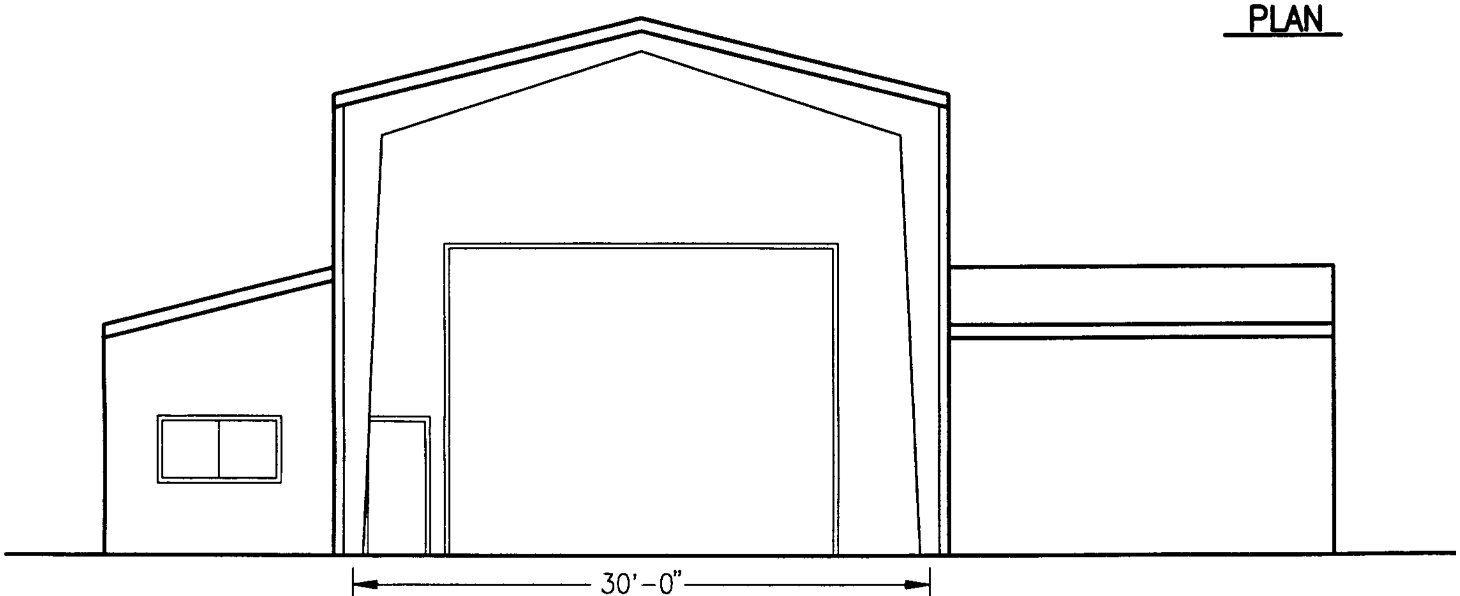
WESTERN ENGINEERING
DESIGN
MUSCLE SHOALS, ALABAMA

U.S. ARMY ENVIRONMENTAL CENTER
HOT GAS DECON. - CONCEPTUAL DESIGN
DECON. CHAMBER ARRANGEMENT

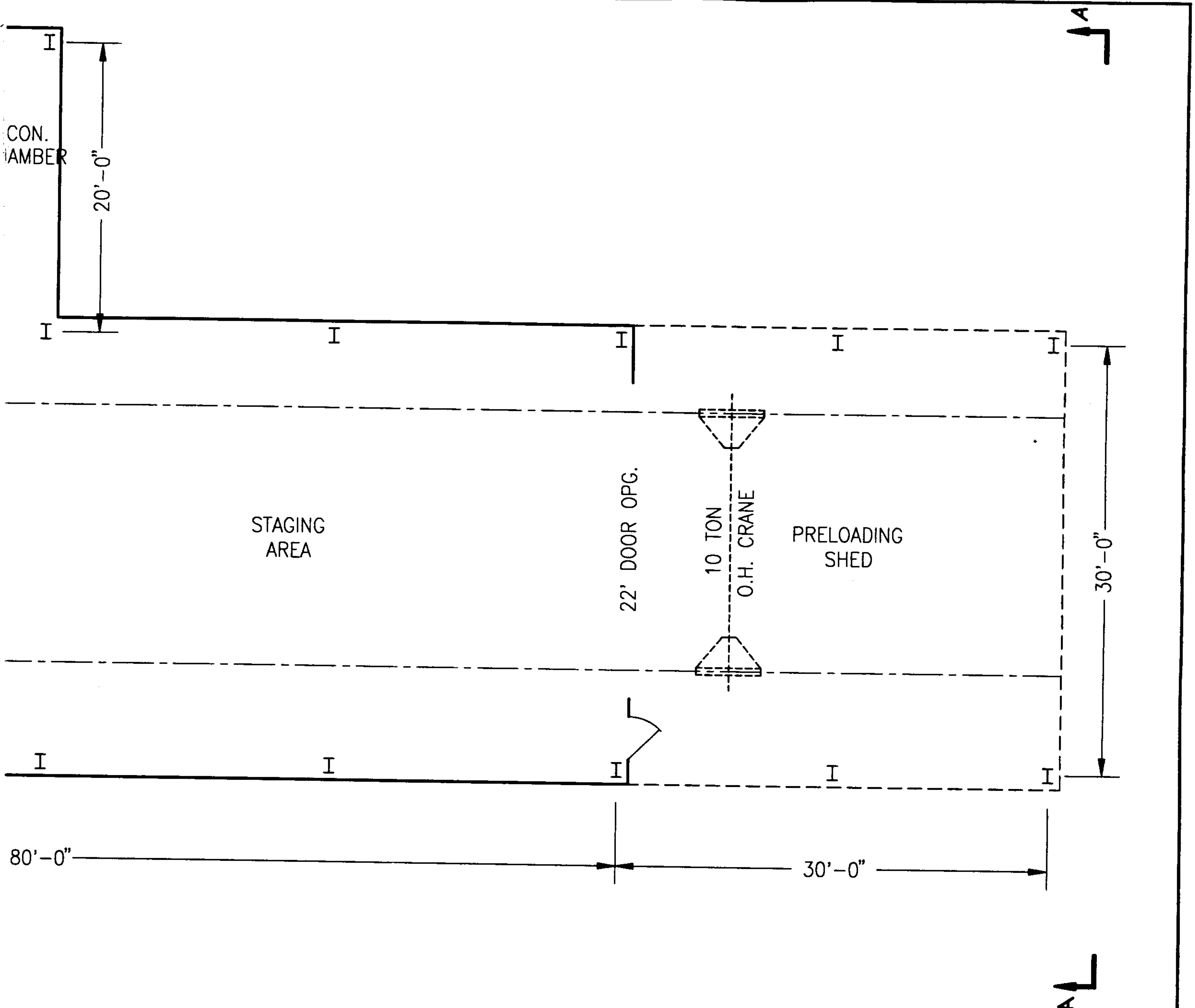
L.E. HALE	10/6/94			SCALE 1/4" = 1'-0"
DRAWN	DATE	APPROVED	DATE	WORK ORDER 0002WOD
CHECKED	DATE	APPROVED	DATE	CADD FILE NAME - DRAWING NO.
BILL OF MATERIALS	SHEETS	APPROVED	DATE	B23156



PLAN



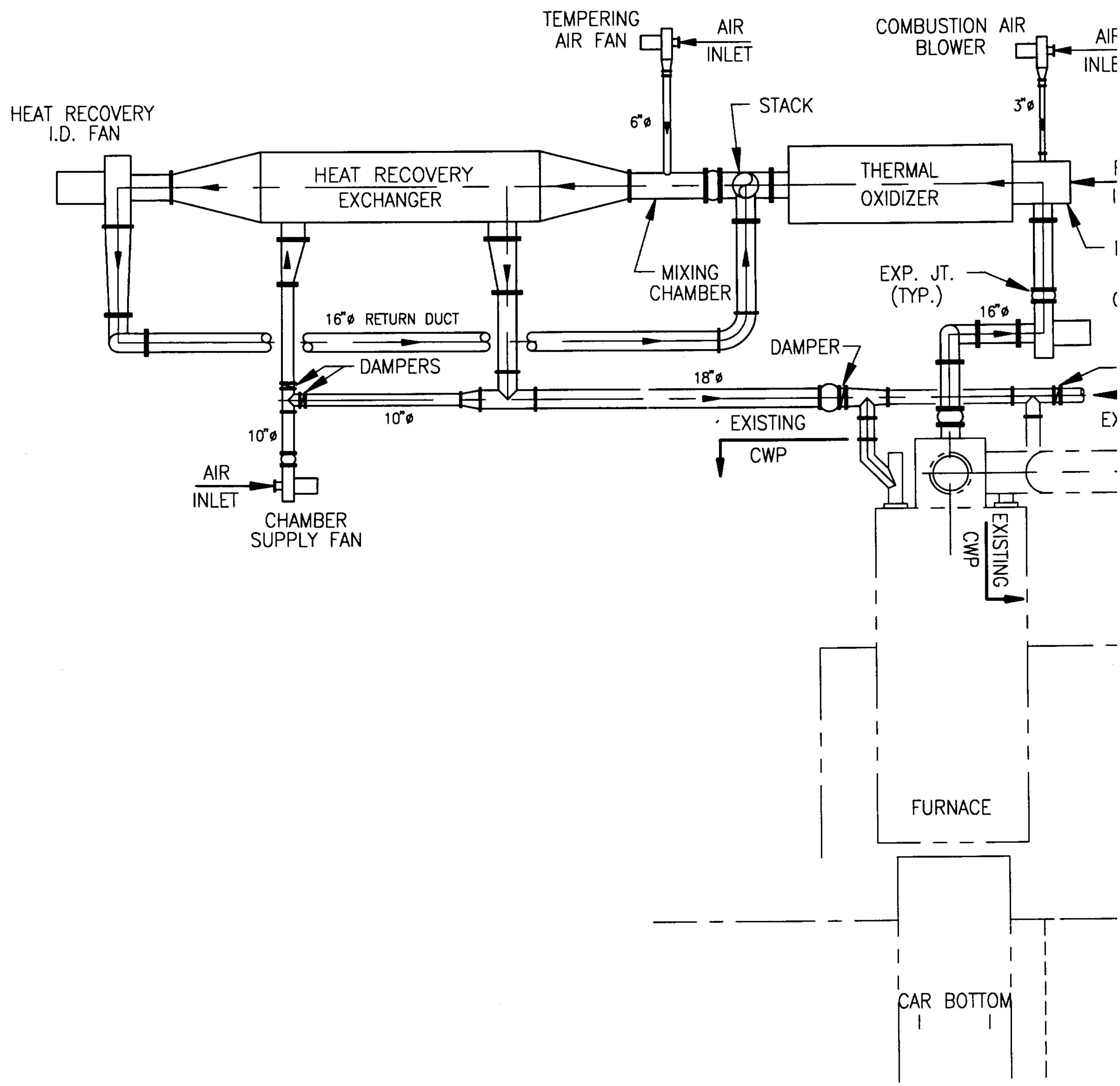
ELEVATION A-A



WESTERN ENGINEERING
DESIGN
MUSCLE SHOALS, ALABAMA

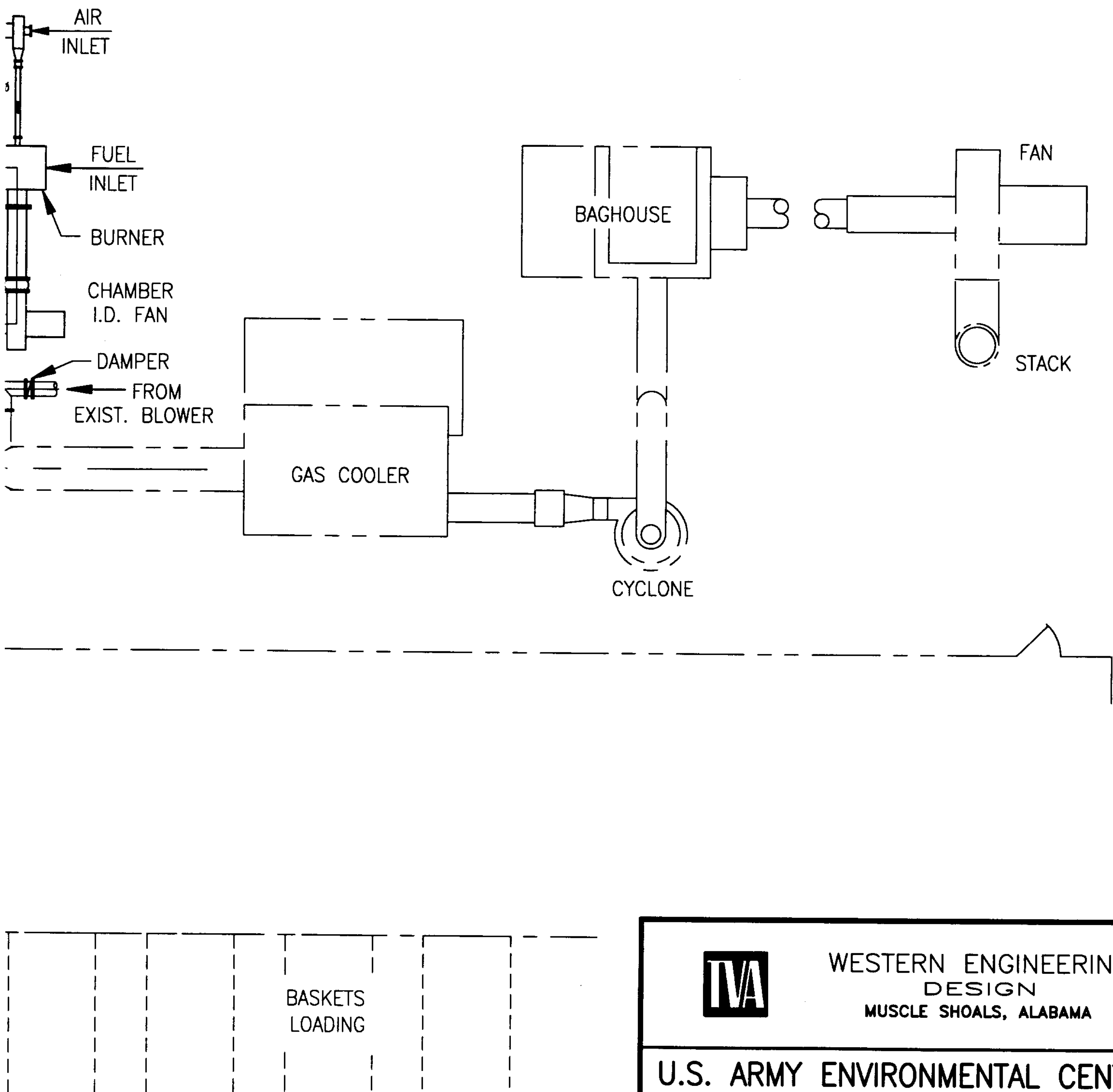
U.S. ARMY ENVIRONMENTAL CENTER
HOT GAS DECON. - CONCEPTUAL DESIGN
BUILDING PLAN & ELEVATION

L.E. HALE	10-14-94			SCALE 1" = 10'
DRAWN	DATE	APPROVED	DATE	WORK ORDER 0002WOO
CHECKED	DATE	APPROVED	DATE	CADD FILE NAME - DRAWING NO.
BILL OF MATERIALS	SHEETS	APPROVED	DATE	B23157



LEGEND:

— — — — DENOTES EXISTING EQUIPMENT



TVA WESTERN ENGINEERING DESIGN
MUSCLE SHOALS, ALABAMA

U.S. ARMY ENVIRONMENTAL CENTER
CONTAMINATED WASTE PROCESSOR RETROFIT
LARGE UNIT – EQUIPMENT LAYOUT

L.E. HALE	10-17-94			SCALE 1" = 10'
DRAWN	DATE	APPROVED	DATE	WORK ORDER 0002WOD
CHECKED	DATE	APPROVED	DATE	CADD FILE NAME – DRAWING NO.
BILL OF MATERIALS	SHEETS	APPROVED	DATE	B23143

APPENDIX C

MAJOR EQUIPMENT GENERAL SPECIFICATIONS

General specifications for the following major equipment is included in this appendix:

- C-1 Decontamination Chamber
- C-2 Thermal Oxidizer
- C-3 Heat Recovery Heat Exchanger
- C-4 Chamber Supply Fan, Chamber ID Fan, Heat Recovery ID Fan, Tempering Air Fan
- C-5 Programmable Controllers
- C-6 Variable Frequency Drive

These specifications are general in nature and do not include site specific information or requirements. They were used to obtain cost information and are provided here to give the reader some details on the equipment required to meet the conceptual design. They might also be helpful in preparing the site specific equipment specifications for a detailed design project.

GENERAL SPECIFICATION C-1

DECONTAMINATION CHAMBER
CARBOTTOM FURNACE (DC-1)

I. General

The equipment required in this specification is for heating metal items. The items are to be loaded onto a motor-driven carbottom and then moved into the chamber, in which a vertically operated door shall lower to complete the chamber containment. After seals around the bottom of the car have been clamped, the heat is applied. The heat is to be applied by external equipment through hot air ducted into the chamber.

II. Capacity and Performance

Charge Dimension and Weight

Maximum New Load Area - 7'-0" wide x 18'-0" long x 7'-0" high

Gross Load Weight - 80,000 lbs. (40 ton)

Product

Metal Items - ranging from demiled ammunition rounds to process equipment

Atmosphere

Air

Process

To heat metal items to predetermined temperatures and holding times for vaporization of traces of explosives

- Heat up by forced air convection at 250°F/Hr. to 800°F.
- Hold at temperature as required.
- Cool down by forced cooling air through chamber.

Maximum Furnace Temperature - 800°F

Operating Temperature Range - 400°F to 800°F

III. Technical Data

Heat Rating - (provided by others)

Number of Zones - 4

Car Drive Speed - Approximately 10 FPM

Door Speed - Approximately 14 FPM

IV. Dimensions

Hearth Area - 7'-0" wide x 18'-0" long x 7'-0" high

Track Width - By manufacturer

V. Utilities

Electricity - 480 volts, 3 Phase, 60 Hz.

Air - 80 Psig

VI. Description of Furnace

General

The furnace is a low thermal mass carbottom design with an external forced hot air heat source. The furnace shall have four zones of temperature control.

Casing

The casing shall be fabricated from 3/16" mild steel plates to form a rigid gas tight shell open at the bottom and at the entry end. The casing shell is rigidly braced and supported by structural steel beams and channels.

Insulation

The furnace walls and roof shall be lined with 8"-thick, 4 PCF density ceramic fiber insulation suitable for the rated temperature and firmly attached to the casing shell by welded studs.

Furnace Car

The furnace car shall be fabricated from mild steel plates suitably braced and rigidly supported by structural steel beams and channels. Eight flat, V-grooved, steel wheels, four on each side, support the car and work load and shall be mounted on heavy shafts in heavy duty pillow block bearings. A guide rail as recommended by the seller (possibly angle iron) shall be furnished and installed by the buyer for guiding and positioning the rail car into and out of the furnace.

To facilitate easy lubrication of the car wheel bearings, all lubrication connections shall be piped to the outside car periphery terminating in standard lube fittings.

The car shall be designed to support an 80,000 pound gross uniformly distributed total work load. In addition, the car shall be capable of supporting 20,000 pounds concentrated weight at midpoint.

The hearth of the car shall consist of two (2) sets of WF beams running the length of the car. Wheels shall be mounted between and support the set of WF beams. These WF beams support cross beams approximately every 18 inches. The grid assembly is covered with a 1/4-inch thick plate which is the supporting base for the car insulation. The car is insulated with approximately 12 inches of insulation. The insulation will consist of six inches of castable and a backup of 6-inch insulating brick.

A drive shall be included for driving the car in and out of the furnace. This equipment shall consist of a 3 Hp electric motor coupled to a heavy duty gear reducer, which, in turn is connected by means of roller chain and sprockets connected to the car. The motor shall be equipped with an electric brake. The motor and reducer shall be connected by a Dodge Flexidyne (or equal) coupling. This type coupling will allow the motor to develop full torque, but allows the car to start smoothly without jerking.

Door

The furnace shall be equipped with a vertically operated counter-balanced guillotine type door to seal off to the furnace on the sides and top and to the car at the bottom. The door shall be furnished with seals as required for the rated temperature of the furnace and shall be designed as to provide an effective seal upon closure via a levered locking mechanism actuated by the position and weight of the door. Also this position/weight actuated sealing mechanism shall be released upon lifting the door by the motor driven system.

A drive shall be included for raising and lowering the door for loading and unloading the furnace. This equipment shall consist of a 2 Hp electric motor coupled to a heavy duty gear reducer, which, in turn is connected by means of roller chain and sprockets to the car. The motor shall be equipped with an electric brake.

Car Seals

Car sealing shall be accomplished by ceramic fiber insulated hinged steel plates mounted along the lower edges of both sides and back of the furnace casing. The moveable plates will be actuated by a pneumatic cylinder(s) to compress against the car sides when the car is in the furnace. All necessary piping and solenoid valves and on-furnace wiring shall be furnished and mounted by the Seller with the piping terminating in a single point for connection to the Buyer's air supply.

Heating

Heat is supplied by an external heat source, to be supplied by others, and not included as a part of this specification. Heat up of the items will be accomplished by forced hot air convection. Hot air will be forced through the furnace via inlet headers on one side and removed via outlet headers on the opposite side providing a once through cross flow configuration. The 8-inch stainless steel inlet and outlet pipe headers, supports, and nozzles are to be fabricated as an integral part of the furnace side walls and shipped with unit.

The chamber is divided into four zones for controlling hot air flow and, therefore, heat and temperature distribution.

Cooling System

Cooling of the items in the furnace shall be accomplished by configuring the external system fans and dampers, to be supplied by others, to force ambient air across the hot items.

VII. Shipping

The equipment offered in this proposal shall be shipped as follows:

- The furnace and auxiliary equipment shall be insulated (as much as possible), piped and wired at the factory prior to shipment to the degree practical. Inlet and outlet headers shall be fabricated attached and supported to furnace and shipped in place. Castable refractory shall be installed in the field. Assembly of mechanical components shall be shipped assembled to the apparatus except those that must be removed for shipment.

- All items of the furnace and auxiliary equipment shall be completely finish painted in the factory.

GENERAL SPECIFICATION C-2

THERMAL OXIDIZER (TO-1)

I. Design Data

A. Process Description

A thermal oxidizer system shall be provided for the destruction of an explosive laden gas stream from a hot gas decontamination chamber. The waste gas stream as described below shall be pulled from the decontamination chamber via an ID fan and forced into the thermal oxidizer for combustion.

B. Conditions of Waste Gas to be Combusted

The explosive concentration of the waste gas stream will vary with each load type and size, with each cycle, as well as from start to end of each cycle. It is expected that for the worst case basis, the gas stream will be made up of 99 percent air and 1 percent explosive. Below is the influent waste gas stream and resulting heat release of the burner for the process stream:

	Flow	Temperature	Heat Release
	pph	°F	MMBTUH
Air Stream	19,000	550	8.0

II. Equipment Design

A. Burner

1. The burner shall maintain the required temperature in the afterburner (2000°F) for all cycles of operation. This will include adequate controls and instrumentation for a continuous ramped turndown during heat up cycle, and

between cycles of operation. Also a 10:1 turn-down will be required during equipment heat up and hot standby condition. The burner shall be complete including all required throat tiling, prepiped valve train, instrumentation, piping, combustion blower, and fittings and shop assembled as much as possible.

2. Burner fuel type shall be (---site specific---).

3. The burner shall be capable of sustained operation for all cycles specified.

4. Fuel tips shall be 316 SS (309 or 310 SS is acceptable).

5. The burner shall have flame safeguards or burner management logic.

6. One 2-inch NPT flame scanner ("Fire-Eye" or approved equal) shall be provided. The "Fire-Eye shall be oriented to sight the burner flame.

7. A minimum of two 4-inch diameter inspection ports shall be provided in the front of the burner to allow visual inspection of the fire box, burner and flame pattern during operation.

8. The following ancillary equipment and components are to be included with the burner:

   - Combustion air blower.
   - All fuel supply components and instruments.
   - All burner management controls and instrumentation

B. Afterburner (unfired)

1. The afterburner shall be complete with support saddles, manway, insulation, and waste gas inlet nozzles.

2. The afterburner shall be designed for a minimum combustion temperature of 2000°F at a minimum residence time of 2.0 seconds.

3. Excess air shall be 20 percent.

4. Heat loss from combustion chamber shall be 5 percent maximum.

5. The afterburner shall be designed and constructed to minimize equipment heat up time. A heat up time of 1 hour from cold condition to operating condition is required. This heat up should be accomplished with only the combustion air blower and fuel system in operation and prior to the introduction of the waste gas stream. Of special consideration should be the type of interior insulation which should consist of a low mass ceramic fiber insulation with appropriate rigidizer or coating to prevent surface erosion.

GENERAL SPECIFICATION C-3

HEAT RECOVERY HEAT EXCHANGER (HE-1)

I. General

An open channel air preheater (OCAP) shall be utilized for the gas-to-gas heat recovery application for the hot gas decontamination process. The OCAP heat exchanger shall consist of a series of stacked, parallel plates which form straight, open channels for the gas flow paths. They shall be supported by an external frame and sealed by patented compression assemblies to isolate the flue gas and air. The flue gas flow paths and the air flow paths are alternated every other channel.

II. Equipment

1. The OCAP shall be provided with four (4) cross-flow blocks as follows:
   - One (1) cross-flow block manufactured from type RA 253 MA stainless steel plates and internally insulated carbon steel casing.
   - Two (2) cross-flow blocks manufactured from 304 stainless steel plates and internally insulated carbon steel casing.
   - One (1) cross-flow block manufactured from aluminized steel plates and internally insulated carbon steel casing.
2. Support spool pieces with access doors between air preheater passes shall be provided for inspection and/or cleaning of the cold passes.
3. The external surfaces of all the OCAP blocks shall be sandblasted per SSPC-SP6 and primed with one coat of Carbo-Zinc 11, 1.5-3 mils DFT.

III. Testing

A leakage test shall be performed in manufacturer's shop before delivery by pressuring the heat exchanger blocks. The allowable test leakage in cold condition will be less than one percent at 20 inches w.c. differential pressure

IV. Guarantees

The following shall be guaranteed based on design conditions as specified:

1. Cold gas temperatures as specified
2. Hot gas pressure drop: inches H_2O within 5 percent
3. Cold gas pressure drop: inches H_2O with 5 percent
4. Gas/Gas heat exchanger leakage less than 1 percent

V. Operating Data

	Air Side	Flue Gas Side
Flow Rate, pph	18,000	24,000
Inlet Temperature, °F	45	1500
Outlet Temperature, °F	1200 min.	800 max.
Calculate Press. Drop In. of Water	4.5 max.	4.5 max.

GENERAL SPECIFICATION C-4

CHAMBER SUPPLY FAN (F-1)
CHAMBER ID FAN (F-2)
HEAT RECOVERY INDUCED DRAFT FAN (F-3)
TEMPERING AIR FAN (F-4)

I. General

The fan shall be single-width single inlet. Fan wheels shall utilize curved radial blades and tapered frontplates for optimum efficiency and inherent stability.

II. Performance

Fan ratings shall be based on tests made in accordance with AMCA Standard 210 and licensed to bear the AMCA Certified Ratings Seal for Air Performance. Only AMCA certified fans will be accepted. Fans shall have a sharply rising pressure characteristic extending throughout the operating range to assure quiet and stable operation.

III. Sound

Fan manufacturers shall provide sound power level ratings for fans tested and rated in accordance with AMCA Standards 300 and 301. Sound power ratings shall be in decibels (reference 10 ^-12 watts) in eight octave bands.

IV. Construction

Fan housings are to be heavy gauge, continuously welded construction . Housings with lock seams or partially welded construction are not acceptable. Housings are to be reinforced with rigid bracing to increase structural integrity and prevent vibration. Wheel and inlet diameters and outlet areas shall be in accordance with the standard dimensions adopted by AMCA for industrial centrifugal fans. Designs not in accordance with AMCA Standard 99-2402 are not acceptable.

V. Bearings

Bearings are to be heavy duty, grease lubricated precision anti-friction ball or spherical roller, self-aligning, pillow block design. Bearings shall be designed for an average minimum L-10 life of 250,000 hours when rated at the fan's maximum cataloged operating speed.

VI. Shaft

Shafts are to be ASTM A-108 steel grade 1040/1045, precision turned, ground and polished. Grade 1018 steel is not acceptable. The shaft's first critical speed shall be at least 130 percent of the fan's maximum operating speed. The drive end of the fan shaft shall be countersunk for tachometer readings.

VII. Paint

All fan surfaces are to be thoroughly prepared prior to coating with an industrial grade alkyd enamel. Surfaces of components not accessible after assembly shall be coated and allowed to dry prior to final assembly. Primer only will not be accepted.

VIII. Balance and Run Test

All fan wheels shall be dynamically balanced on precision balancers. Prior to shipment, completed fans shall receive a final balance test at the specified operating speed.

IX. Accessories

- Clean out door
- Low point drain and drain plug
- Flanged inlet and outlet
- Belt Guard

X. Aerodynamic Performance Information

Chamber Supply Fan (F-1)

4200 inlet acfm at 6.0 "SP at 95°F

New York Blower Size 20-294DH, or equal, Arrangement 1

1164 rpm

5.7 BHP @ 95°F

10 hp, 480/3/60 motor

Chamber ID Fan (F-2)

11,650 inlet acfm at 8.0 "SP at 1000°F

New York Blower Size 30-334DH, or equal, Arrangement 1

AMCA Standard 99-0401-86, Type C, Spark Resistant Construction

2049 rpm

21.7 BHP @ 1000°F

30 hp, 480/3/60 motor

Heat Recovery ID Fan (F-3)

12,680 inlet acfm at 8.0 "SP at 800°F

New York Blower Size 20-364DH, or equal, Arrangement 1

1705 rpm

23.4 BHP @ 800°F

30 hp, 480/3/60 motor

Tempering Air Fan (F-4)

1100 inlet acfm at 3.0 "SP at 95°F

New York Blower Size 20-194DH, or equal, Arrangement 1

1248 rpm

1.0 BHP @ 95°F

2 hp, 480/3/60 motor

GENERAL SPECIFICATION C-5

PROGRAMMABLE CONTROLLERS

I. Programmable Controllers - General

Programmable controllers (PLCs) shall be as specified herein and as on the drawings. The PLCs shall control processes via electrically operated devices such as solenoid valves, relays, motor starters, valve positioners, etc., on the basis of a stored digital program of instructions using various input contacts, analog input signals, and control signals from the Operator Interface Units. The PLC shall be supplied with the CPU, input/output scanner, input modules, output modules, memory, power supply, and all power and interface cables necessary to function as a complete and operable Programmable Controller system. PLCs shall be capable of communicating with each other and sending messages to each other over the system communication link. Programmable Controllers and associated modules and I/O electronics shall operate at an ambient temperature of 32 to 140°F. All system modules, main and expansion chassis shall be designed to provide for free air flow convection cooling. No internal fans or other means of cooling, except heat sinks, shall be permitted. The Programmable Controller system shall be designed to operate in a high electrical noise environment. The PLC shall have one dedicated serial port which supports RS-232-C, RS-422, and RS-423A signals. This port must be usable for programming purposes, allowing Programming Hardware Units to interface directly without the need for a special interface card.

II. Programming Method

The programming method shall be ladder logic instructions via an IBM PC compatible or equivalent programming terminal. The programming software shall be IBM PC compatible and include a PID loop configuration routine to simplify the configuration software. Programming software shall be provided by the same company that manufactures the PLCs or a licensed software subcontractor to the PLC manufacturer. Standard instructions shall include the following:

a. Relay type instructions

b. Timer and Counter instructions

c. Compare type instructions

d. Logical instructions

e. Conversion instructions

f. Mathematical instructions

g. Program control instructions

h. Process control instructions (PID - analog)

III. Programming Hardware Units

The programming hardware units shall consist of both Operator Interface Units (described below). They will use the software specified above. The programming hardware shall program the PLC over the system communications link. The programming hardware units must be certified by the PLC programming software company to be fully compatible with the programming software to perform all features of the software. Sufficient RAM type memory must be present to meet the PLC manufacturers recommendations for memory capacity. No specialized communication cards to allow the units to interface with the PLCs shall be required - units shall communicate with PLCs through serial communication port.

IV. Central Processing Units

Central Processing Units must be capable of interfacing with at least 1000 I/O points (any combination) through at least seven remote I/O racks and one resident rack. Communication system must allow remote I/O racks to be placed as far away from

Central Processing Unit as 2000 meters without requiring additional communications hardware. The communications baud rate to remote locations shall be at least 50K baud. The processors shall be Allen Bradley PLC-5/30 or approved equivalent. The memory shall be packaged in the same module with the processor. The memory shall consist of at least 30K words of battery backed RAM type memory and 30K words of EEPROM type memory. Battery system must be capable of retaining system memory for at least 100 days with no external power applied. The main chassis front panel shall include two-color indicators showing the following status information:

a. Program or Run mode of the CPU

b. The Fault status of the CPU

c. "Forces" active

d. Communications link status of remote I/O Processor mode shall be selected by a key switch mounted on the front panel of the CPU.

The key shall select the following modes:

a. Run - no ladder edits possible, program always executing

b. Program - programming allowed; program execution disabled

c. Remote - programming terminal determines mode and can make edits while program continues to run. Non-volatile memory shall store the operating system information to protect against loss in case of total power failure.

V. Inputs/Outputs

Programmable Controller System and Remote I/O racks shall be capable of accepting Input and Output modules for a wide range of signals including, but not limited to, the following:

a. Thermocouple inputs (types E, K, J, minimum)

b. RTD inputs (100 ohm platinum)

c. Low-level Analog inputs (4-20 ma or 1-5 VDC)

d. Discrete digital inputs (120 VAC)

e. Discrete digital inputs (24 VDC)

f. Analog outputs (4-20 ma or 1-5 VDC)

g. Discrete digital, Triac type outputs (120 VAC)

h. Discrete digital, Dry contact outputs (DC or AC)

i. Discrete digital, Low current DC outputs (24 VDC)

At least one type of discrete digital output module shall be sized so as to be capable of interfacing directly with size 4 motor starters (120 VAC coils) without interfacing relays. However, this requirement may be waived by contract supervisor.

VI. Power Supplies

Each processor shall be mounted in its own rack with its own power supply. Additionally, each remote I/O rack shall have its own power supply as well. For conformity, all power supplies shall be manufactured by the PLC manufacturer. Analog loop power supplies may be supplied by separate manufacturer, but must all be identical.

VII. Operator Interface Units

The system shall have at least two (2) Operator Interface Units (OIU). Each Operator Interface Unit shall consist of an IBM PC compatible computer, Intel 486 Processor, based with a math coprocessor. Each OIU must have 16 MB of RAM with an SVGA graphics card and a mouse. A minimum of 4 RS-232 serial and two parallel ports must be provided on each OIU. Additionally, each OIU shall be provided with a high density 3.5" floppy drive, and an integral hard disk and controller subsystem. The hard disk shall provide a minimum of 300 MB of formatted storage and have an access time of 20 milliseconds or less. The OIUs shall be supplied with SVGA monitors, capable of a display resolution of at least 1024 pixels X 768 pixels. Refresh rate shall be at least 72 times/second. The monitor's screen shall measure a minimum of 14 inches diagonally with a dot pitch no larger than 0.28 mm. The system shall provide two graphic printers. The printers shall have a wide carriage, with capability to print near letter quality in black and in color. Each printer shall have a minimum of 20 KB buffer capacity with easily replaceable print head and cassette ribbon assembly. Printers must be able to print the content and format of all CRT displays, including graphics. Any required communication cards to allow the units to interface with the PLCs along the communication highway must be provided.

VIII. Software - Supervisory Control and Data Acquisition

The system software shall be based on an accepted, commercially available operating system with a windowing package to allow split windows of operation. The Supervisory Control and Data Acquisition (SCADA) software must be capable of downloading data to commercially available, popular spreadsheet packages, such as Lotus 123, Excel, etc. SCADA software must include the development package as well as the run time package. Software package must be certified by PLC manufacturer to be an accepted programming package, suitable for smooth, glitch-free operation of PLC Software must provide the ability for printer assignments (data logging, activity logging, alarming, etc.), and multi-tasking. The monitor screen graphics must allow mouse interfacing for hand switches, operator cueing, operational permissives, alarm acknowledgments, set point adjustments, etc. Touch screen capability must be part of the development and run time packages. SCADA Software must include the following features:

a. Report writing

b. Alarming (on monitor screens as well as printers)

c. Trending

d. AutoCad graphics importing

e. Data Logging

f. Event Detection

g. Graphic screen designing

h. Derived Tagging

i. Mathematical manipulation of data

j. Proportional, Integral, and Derivative (PID) analog control loop capability with "auto-tuning" feature

k. Levels of security with password-limited access to system configuration screens

l. Access to all PLC input/output points

m. Software Drivers to allow interface with PLC

IX. Programmable Controller - Service

The supplier shall provide operating instruction manuals with adequate information pertaining to the following:

a. System specifications

b. Electrical power requirements

c. Application considerations

d. Assembly and installation instructions

e. Power up procedures

f. Troubleshooting procedures

g. Programming procedures

h. Explanation of internal fault diagnostics

i. Shut down procedures

j. Recommended spare parts

X. Programmable Controller - Technical Support

The supplier shall provide a network of field sales and support personnel located in key cities throughout the United States and internationally. The supplier shall also provide a field service department with experienced representatives stationed in major cities with the capability to provide telephone consultation for program and system development as well as start up assistance, prompt on-site service and field replacement stock. The supplier shall provide videotape training courses directed toward the operation and maintenance of the PLC.

XI. Programmable Controller - System Assembly

Supplier shall assume single source responsibility for system assembly. The supplier shall provide mounting and wiring of the programmable controller in a NEMA 12 enclosure with a sealed plastic window for observing the processor and I/O status indicating lights. The supplier shall wire all programmable controller inputs and outputs to customer-specified terminal blocks. Remote I/O racks will also be mounted and wired in similar cabinets with inputs and outputs wired to customer-specified terminal blocks.

GENERAL SPECIFICATION C-6

ADJUSTABLE FREQUENCY TYPE MOTOR SPEED CONTROLLERS

I. Adjustable Frequency AC Motor Controllers - General

Adjustable frequency controllers, also called Adjustable Frequency Drives (AFDs) shall be designed to control the speed of AC motors at their rated horsepower. All motors will be coupled to centrifugal fans, thus the controllers must be designed for variable torque applications. All motors will be 480 Volt, 3 phase, 60 cycle AC induction type motors. AFD internal power wiring shall be 600V rated. Controllers must be designed to control fan motors in continuous, industrial type service. Controllers will be required for the following fan motor applications:

a. Chamber Supply Fan - 10 hp

b. Chamber ID Fan - 75 hp

c. Heat Recovery ID Fan - 50 hp

II. Adjustable Frequency Drive - Design

AFD design shall be microprocessor based, with self-diagnostic circuitry and software. Controllers shall provide static conversion of the line power source AC frequency to a sine coded Pulse Width Modulated (PWM) adjustable frequency and voltage for control of motor speed. Self diagnostic checks shall provide operator with the following fault indications (minimum) which have initiated inverter trip:

a. Low line voltage
b. Thermal overload
c. Overcurrent
d. Logic faults

Additionally, the AFD shall include torque control circuitry to minimize nuisance tripping under conditions of rapid deceleration and/or overhauling loads, or when encountering high peak torque loads. The AFD and any auxiliary controls shall be housed, as a minimum, in a NEMA 12 enclosure. The AFD shall have the capability of communicating serially with a host computer or PLC via RS-485. Any parameter may be read or written via the serial port under any condition.

III. Adjustable Frequency Drive - Adjustments

Controller shall provide an adjustable frequency range of 0 - 60 Hz. Minimum speed shall be user-adjustable from 0 - 100 percent of maximum speed. Motor speed turndown shall be 25:1 (minimum). Deceleration control shall be user adjustable to provide motor braking. Braking torque shall be approximately 20 percent of rated motor torque. Controller shall allow remote control of motor speed by accepting a 4 - 20 ma analog input signal and producing a motor speed proportional to this input signal. Controller shall be equipped with an Automatic ON/OFF switch, easily controlled from the front of the controller which will choose between remote analog signal control of speed and local speed potentiometer on front panel. Controller shall also be designed to accept digital inputs to control such functions as Start and Stop.

APPENDIX D

COST ESTIMATE - NEW FACILITY

Site Preparation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0001	Site Preperation & Improvements						
	Clear and grub area	2 Acres		1,589	1,794		3,383
	Tree removal	2 Acres			3,120		3,120
	Excavation – Buildings	550 CY		3,486	5,496		8,982
	Excavation – Storage Tank	30 CY		498	785		1,283
	Excavation – Equip Found.	32 CY		996	1,570		2,566
	Excavation – Staging Areas	2,134 CY		13,446	21,199		34,645
	Utilities – Water line trench	85 Cy		401	954		1,354
	Utilities – Sewer line trench	285 CY		534	1,272		1,806
	Utilities – Sewer system	750 LF		1,013	1,000		2,013
	Utilities – Site drainage trench	560 CY		1,068	2,544		3,612
	Utilities – Drainage system	600 LF		14,172	13,584		27,756
	Utilities – Drainage basins	225 CY		401	954		1,354
	Paving	11,356 SY				33,230	33,230
	Fencing/Gates	1,200 LF				18,480	18,480
	Storage tank dike	600 LF		10,368	15,551		25,919
	Railway siding/switches	500 LF				47,570	47,570
TOTAL–SITE PREP & IMPROVEMENTS				$47,971	$69,824	$99,280	$217,075

Foundation and Concrete

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0002	Foundations and Concrete						
	Decontamination building	5,400 SF		31,383	21,368		52,751
	Process Equipment	50.25 CY		12,663	25,415		38,078
	TOTAL FOUNDATIONS AND CONCRETE			$44,046	$46,783		$90,829

Process equipment

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0003	Process Equipment						
	Decontamination chamber	Quote		7,500	10,000	320,000	337,500
	Thermal oxidizer system	Quote		15,000	200,000	627,242	842,242
	Jib cranes	2 ea	9,400	2,550	3,200		15,150
	Overhead crane	1 ea	56,595	12,550	3,920		73,065
	Fuel storage tank	1 ea	5,000	1,250	2,850	45,000	54,100
	Fuel oil pump	1 ea	2,450	250	752		3,452
	Air compressor/system	2 ea	7,066	900	1,034		9,000
	Fire suppression system	1 ea	4,900	1,500	564	21,600	28,564
	Fork lifts	2 ea	60,885				60,885
	Propane storage tank	1 ea	1,500	450	329		2,279
	Projectile handling device	1 ea	40,000	1,750	8,200		49,950
	TOTAL PROCESS EQUIPMENT		187,796	43,700	230,849	$1,013,842	$1,476,187

Buildings

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0004	Buildings						
	Decontamination building	1 lot				76,204	76,204
	Control room	1 lot		2,380	5,640	8,400	16,420
	Building heating/ventilation sys	1 ea		1,250	4,790	45,250	51,290
	Control room heating/AC sys	1 ea		975	4,200	16,460	21,635
	TOTAL BUILDINGS			$4,605	$14,630	$146,314	$165,549

Ductwork

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0005	Ductwork						
	SS ductwork for system	1 lot		6,142	26,887		33,029
	SS elbows	1 lot		2,814	11,168		13,982
	SS transitions	1 lot		3,330	6,324		9,654
	TOTAL DUCTWORK			$12,286	$44,379		$56,665

Duct insulation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0006	Duct insulation						
	Ductwork	1 lot		9,169	9,856		19,025
	Elbows	1 lot		7,687	8,286		15,973
	Transitions	1 lot		12,857	13,661		26,517
	TOTAL DUCT INSULATION			$29,712	$31,802		$61,514

Piping Systems

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0007	Piping Systems						
	DF2 supply	250 LF		355	282		637
	Water supply	750 LF		2,346	1,269		3,615
	Safety shower/eyewash	2 ea		3,667	624		4,291
	Restrooms in control room	2 ea		3,416	1,446		4,862
	Air piping & distribution	350 LF		761	494		1,255
	Gas (propane) system	100 LF		235	141		376
	TOTAL PIPING SYTEM			$10,780	$4,256		$15,036

Instrumentation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0008	Instrumentation						
	Control work stations	2 ea		38,000			38,000
	Control PLC	2 ea		130,000			130,000
	Motor control center	LS		52,500			52,500
	Stack gas analytical system	Quote		140,250			140,250
	Field pressure transmitters	7 ea		8,149			8,149
	Field flow elements	4 ea		12,604			12,604
	Field temperature elements	12 ea		2,320			2,320
	Control valves	7 ea		128,162			128,162
	Construction installation	1 lot			199,948		199,948
	Instrumentation wire, cable tray, tubing, fittings, etc	1 lot		20,000			20,000
	TOTAL INSTRUMENTATION			$531,985	$199,948		$731,933

Electrical

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0009	Electrical						
	Conduit	1 lot		3,663	5,394		9,056
	Conduit fittings	1 lot		1,155	4,634		5,789
	Power cable	1 lot		2,298	1,787		4,085
	Control cable	1 lot		850	503		1,353
	Lighting cable	1 lot		317	1,058		1,375
	Motor Starters	2 ea		320	171		491
	Receptacles/switches	1 lot		580	1,464		2,044
	Lighting fixtures	1 lot		6,200	2,287		8,487
	Exterior lighting standards	10 ea		5,365	4,878		10,243
	Lighting panel	1 ea		680	520		1,200
	Grounding system	1 lot		8,656	9,574		18,230
	Lightning protection	1 lot		17,247	5,732		22,979
	Substation	1 ea		11,925	1,951		13,876
	Transformer	1 ea		855	420		1,275
	MCC vertical section	1 ea		4,970	2,928		7,898
	Misc switches	1 lot		400	366		766
	Alarm system	1 lot		3,200	1,880		5,080
	Telephone system	1 lot		1,990	1,880		3,870
	Intercom system	1 lot		2,500	1,880		4,380
	Miscellaneous equipment	1 lot		10,976	7,396		18,372
	TOTAL ELECTRICAL			$84,146	$56,703		$140,848

Structural supports

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0010	Structural supports						
	Duct supports	1 Lot		1,920	3,008		4,928
	Structural supports	1 Lot		1,550	4,606		6,156
	Munitions racks	1 Lot					
	TOTAL STRUCTURAL SUPPORTS			$3,470	$7,614		$11,084

Painting

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0011	Painting						
	Supports	1 Lot		48	188		236
	Building interiors	1 Lot		200	1,880		2,080
	Storage tank	1 ea		450	1,128		1,578
	Process equipment	20 ea		200	1,504		1,704
	Safety signs	1 Lot		100	1,128		1,228
	Miscellaneous	1 Lot		250	1,200		1,450
	TOTAL PAINTING			$1,248	$7,028		$8,276

Distributable Field Costs

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
4000	Distributable Field Costs						
	Field Labor	1 Lot			53,536		53,536
	Temporary Buildings	1 Lot		4,200			4,200
	Temporary Roads, Walks, Etc	1 Lot		2,400			2,400
	Temporary Power	1 Lot		3,600			3,600
	Temporary Water, Air & Sewage	1 Lot		1,900		1,700	3,600
	Misc. Temporary Construction	1 Lot		1,600			1,600
	General & Final Job Cleanup	1 Lot		700			700
	Maintenance of Tools	1 Lot		2,900			2,900
	Material Handling & Warehouse	1 Lot		300			300
	Security	1 Lot					
	Unallocated Service Labor	1 Lot		200			200
	Welders Tests, Training	1 Lot				800	800
	Weather & Storm	1 Lot		200			200
	On & Off Expenses	1 Lot		4,500			4,500
	Surveying	1 Lot		9,500			9,500
	Scaffolding	1 Lot		4,700			4,700
	Construction Equip & Tools	1 Lot		13,900			13,900
	Tools w/ Freight	1 Lot		2,500			2,500
	Consumables Supplies	1 Lot		13,500			13,500
	Fuels and Lubes	1 Lot		1,600			1,600
	Purchased Utilities	1 Lot		450			450
	Office Equipment	1 Lot		10,400			10,400
	Non−Manual Travel	1 Lot		6,500			6,500
	Non−Manual Field Office	1 Lot			115,950		115,950
	Project Insurance	1 Lot		6,500			6,500
	Start−up Manuals	1 Lot			4,600		4,600
	Start−up Materials	1 Lot		4,650			4,650
	Start−up Travel	1 Lot		4,000			4,000
	Start−up Non−Manuals	1 Lot			34,700		34,700
	TOTAL DISTRIBUTABLE FIELD COSTS			$100,700	$208,786	$2,500	$311,986

Freight

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
5000	Freight						
	Freight	1 Lot	5,634	24,418			30,052
	TOTAL FREIGHT		$5,634	$24,418			$30,052

Sales Tax

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
6000	Sales Tax						
	Sales Tax	1 Lot					
	TOTAL SALES TAX						

Engineering

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
7000	Home Office Engineering						
	Home Office Engineering	1 Lot			276,127		276,127
	TOTAL HOME OFFICE ENGINEERING				$276,127		$276,127

Start up Expense

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
8000	Start up Expenses						
	Engineering	1 Lot			39,988		39,988
	Construction Labor	1 Lot			30,080		30,080
	Materials and equipment	1 Lot		9,285			9,285
	Consumables	1 Lot		10,520			10,520
	TOTAL STARTUP EXPENSES			$19,805	$70,068		$89,873

Contingency

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
9000	Contingency						
	Contingency (20%)	1 Lot	38,686	187,813	239,746	252,387	718,633
	TOTAL CONTINGENCY		$38,686	$187,813	$239,746	$252,387	$718,633

Escalation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
9500	Escalation						
	Escalation	1 Lot					
	TOTAL ESCALATION						

Escalation is not included in this estimate.

APPENDIX E

COST ESTIMATE - CWP RETROFIT

Site Preparation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0001	Site Preperation & Improvements						
	Clear and grub area						
	Tree removal						
	Excavation – Buildings						
	Excavation – Storage Tank						
	Excavation – Equip Found.	32 CY		996	1,570		2,566
	Excavation – Staging Areas						
	Utilities – Water line trench						
	Utilities – Sewer line trench						
	Utilities – Sewer system						
	Utilities – Site drainage trench						
	Utilities – Drainage system						
	Utilities – Drainage basins						
	Paving						
	Fencing/Gates	600 LF				4,620	4,620
	Storage tank dike						
	Railway siding/switches						
TOTAL–SITE PREP & IMPROVEMENTS				$996	$1,570	$4,620	$7,186

Foundation and Concrete

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0002	Foundations and Concrete						
	Decontamination building						
	Process Equipment	50.25 CY		12,663	25,415		38,078
	TOTAL FOUNDATIONS AND CONCRETE			$12,663	$25,415		$38,078

Process equipment

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0003	Process Equipment						
	Car Bottom					60,000	60,000
	Thermal oxidizer system	Quote		15,000	200,000	401,887	616,887
	Jib cranes						
	Overhead crane						
	Fuel storage tank						
	Fuel oil pump						
	Air compressor/system						
	Fire suppression system						
	Fork lifts						
	Propane storage tank						
	Projectile handling device						
	TOTAL PROCESS EQUIPMENT			15,000	200,000	$461,887	$676,887

Buildings

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0004	Buildings						
	Decontamination building						
	Control room						
	Building heating/ventilation sys						
	Control room heating/AC sys						
TOTAL BUILDINGS							

Ductwork

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0005	Ductwork						
	SS ductwork for system	1 lot		3,071	13,444		16,515
	SS elbows	1 lot		1,407	5,584		6,991
	SS transitions	1 lot		1,665	3,162		4,827
	TOTAL DUCTWORK			$6,143	$22,190		$28,333

Duct insulation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0006	Duct insulation						
	Ductwork	1 lot		4,584	4,928		9,512
	Elbows	1 lot		3,843	4,143		7,986
	Transitions	1 lot		6,428	6,830		13,259
	TOTAL DUCT INSULATION			$14,856	$15,901		$30,757

Piping Systems

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0007	Piping Systems						
	DF2 supply						
	Water supply						
	Safety shower/eyewash						
	Restrooms in control room						
	Air piping & distribution						
	Gas (propane) system						
	TOTAL PIPING SYTEM						

Instrumentation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0008	Instrumentation						
	Control work stations	2 ea		32,300			32,300
	Control PLC	2 ea		110,500			110,500
	Motor control center	LS		44,625			44,625
	Stack gas analytical system	Quote		119,213			119,213
	Field pressure transmitters	7 ea		6,927			6,927
	Field flow elements	4 ea		10,713			10,713
	Field temperature elements	12 ea		1,972			1,972
	Control valves	7 ea		108,938			108,938
	Construction installation	1 lot			169,956		169,956
	Instrumentation wire, cable tray, tubing, fittings, etc	1 lot		17,000			17,000
TOTAL INSTRUMENTATION				$452,187	$169,956		$622,143

Electrical

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0009	Electrical						
	Conduit	1 lot		3,663	5,394		9,056
	Conduit fittings	1 lot		1,155	4,634		5,789
	Power cable	1 lot		2,298	1,787		4,085
	Control cable	1 lot		850	503		1,353
	Lighting cable	1 lot		317	1,058		1,375
	Motor Starters	2 ea		320	171		491
	Receptacles/switches	1 lot		580	1,464		2,044
	Lighting fixtures	1 lot		6,200	2,287		8,487
	Exterior lighting standards	10 ea		5,365	4,878		10,243
	Lighting panel	1 ea		680	520		1,200
	Grounding system	1 lot		8,656	9,574		18,230
	Lightning protection	1 lot		17,247	5,732		22,979
	Substation	1 ea		11,925	1,951		13,876
	Transformer	1 ea		855	420		1,275
	MCC vertical section	1 ea		4,970	2,928		7,898
	Misc switches	1 lot		400	366		766
	Alarm system	1 lot		3,200	1,880		5,080
	Telephone system	1 lot		1,990	1,880		3,870
	Intercom system	1 lot		2,500	1,880		4,380
	Miscellaneous equipment	1 lot		10,976	7,396		18,372
	Adjustment for retrofit	(−40%)		(33,658)	(22,681)		(56,339)
	TOTAL ELECTRICAL			$50,487	$34,022		$84,509

Structural supports

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0010	Structural supports						
	Duct supports	1 Lot		1,920	3,008		4,928
	Structural supports	1 Lot		1,550	4,606		6,156
	Munitions racks	1 Lot					
	TOTAL STRUCTURAL SUPPORTS			$3,470	$7,614		$11,084

Painting

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
0011	Painting						
	Supports	1 Lot		48	188		236
	Building interiors						
	Storage tank						
	Process equipment	20 ea		200	1,504		1,704
	Safety signs	1 Lot		50	564		614
	Miscellaneous	1 Lot		250	1,200		1,450
	TOTAL PAINTING			$548	$3,456		$4,004

Distributable Field Costs

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
4000	Distributable Field Costs						
	Field Labor	1 Lot			36,009		36,009
	Temporary Buildings	1 Lot		4,200			4,200
	Temporary Roads, Walks, Etc	1 Lot		2,400			2,400
	Temporary Power	1 Lot		3,600			3,600
	Temporary Water, Air & Sewage	1 Lot		1,900		1,700	3,600
	Misc. Temporary Construction	1 Lot		1,600			1,600
	General & Final Job Cleanup	1 Lot		700			700
	Maintenance of Tools	1 Lot		2,900			2,900
	Material Handling & Warehouse	1 Lot		300			300
	Security	1 Lot					
	Unallocated Service Labor	1 Lot		200			200
	Welders Tests, Training	1 Lot				800	800
	Weather & Storm	1 Lot		200			200
	On & Off Expenses	1 Lot		4,500			4,500
	Surveying	1 Lot		9,500			9,500
	Scaffolding	1 Lot		4,700			4,700
	Construction Equip & Tools	1 Lot		13,900			13,900
	Tools w/ Freight	1 Lot		2,500			2,500
	Consumables Supplies	1 Lot		13,500			13,500
	Fuels and Lubes	1 Lot		1,600			1,600
	Purchased Utilities	1 Lot		450			450
	Office Equipment	1 Lot		10,400			10,400
	Non–Manual Travel	1 Lot		6,500			6,500
	Non–Manual Field Office	1 Lot			115,950		115,950
	Project Insurance	1 Lot		6,500			6,500
	Start–up Manuals	1 Lot			4,600		4,600
	Start–up Materials	1 Lot		4,650			4,650
	Start–up Travel	1 Lot		4,000			4,000
	Start–up Non–Manuals	1 Lot			26,025		26,025
	TOTAL DISTRIBUTABLE FIELD COSTS			$100,700	$182,584	$2,500	$285,784

Freight

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
5000	Freight						
	Freight	1 Lot		16,691			16,691
	TOTAL FREIGHT			$16,691			$16,691

Sales Tax

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
6000	Sales Tax						
	Sales Tax	1 Lot					
	TOTAL SALES TAX						

Engineering

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
7000	Home Office Engineering						
	Home Office Engineering	1 Lot			169,285		169,285
	TOTAL HOME OFFICE ENGINEERING				$169,285		$169,285

Start up Expense

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
8000	Start up Expenses						
	Engineering	1 Lot			33,324		33,324
	Construction Labor	1 Lot			26,320		26,320
	Materials and equipment	1 Lot					
	Consumables	1 Lot		4,466			4,466
	TOTAL STARTUP EXPENSES			$4,466	$59,644		$64,110

Contingency

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
9000	Contingency						
	Contingency (20%)	1 Lot		134,748	166,399	93,801	394,948
	TOTAL CONTINGENCY			$134,748	$166,399	$93,801	$394,948

Escalation

Item #	Area	Quantity	Equipment	Bulk Mat'l	Labor	Subcontract	TOTAL
9500	Escalation						
	Escalation	1 Lot					
	TOTAL ESCALATION						

Escalation is not included in this estimate.