BURN PITS
CRITERIA FOR
DESIGN, SIZING, SITE SELECTION AND CONSTRUCTION

PREAMBLE

This specification is intended as a guideline for the design of Burn Pit type flares.

For the purposes of this specification/guideline, a Burn Pit is defined as a shallow depression or pool structure intended to catch and store hydrocarbon liquids which are discharged from units such as processing plants, pipelines or pumping stations with the intention that they shall be burned naturally and openly and with no smoke suppression or other assistance.

Most Burn Pits are intended to handle a combination of liquid and vapor relief from a common pipe inlet. This inlet is referenced herein as the Flare Burner.

This specification is intended to cover "**containment structures**, which are designed to retain all liquids within the pit.

Simple excavations without the use of any proper building materials have, historically been common in extremely remote locations. Since the election of a simple excavation is usually made for economic reasons and in order to avoid consideration of specifications and design parameters, there are no appropriate associated conditions.

This type of "non-containment" structure is NOT normally recommended and any decision to proceed with such a design must be made carefully. The engineer is reminded of an implied ethical duty to make informed and technically suitable decisions regarding the design and construction issues surrounding a simple excavation using considerations similar to the general guidelines of this specification and bearing in mind the environmental considerations described herein.

This document is still in the course of preparation and the author disavows specific involvement in any designs produced by others with the aid of this proof text.
Cooperative contributions to this document from within the Engineering community are welcomed and encouraged. Contact the author at *flareman_xs@netzero.net or flareman@flareman.com*

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1 - DESIGN

1.1 - LOCATING THE BURN PIT

1.1.1 GENERAL

The location of a Burn Pit should be carefully selected giving due consideration to a variety of factors. Any Burn Pit should be sited:

- Outside of all normal work areas and operational plant.
- Where smoke and the associated thermal plume will not be a hazard to personnel or traffic, or cause damage to equipment.
- Clear of all buildings and public vehicle parking lots for a distance of at least 300 ft (91m).
- Clear of residential areas for at least 1000 ft (305m).
- Where neither local nor general environmental considerations, as outlined herein, limit placement.

1.1.2 LOCAL ENVIRONMENTAL FACTORS

The site selection shall be made with regard to the following near-field considerations.

1.1.2.1 Radiation

At maximum rate, the anticipated thermal radiation levels from the Burn Pit must be calculated in accordance with generally accepted methods. Radiation profiles for both liquid-supported and gas-supported flames should be independently considered.
In cases where independent sources of gas and liquid flames operate concurrently, the thermal and mass flow characteristics of the liquid supported flame should be adjusted in the calculations to account for the the additional input of the gas which can burn only at the outer perimeter of the liquid flame together with the vaporized liquid.

Liquid case radiation levels must be calculated on the basis of the **maximum possible burning rate** for the Burn Area, regardless of the design liquid input rate.

Tolerable radiation levels may be determined using standard guidelines such as ANSI/API Standard 521.
(See also http://www.geocities.com/flareman_xs/Thermal/personnel_access_table.PDF)

1.1.2.2 Plume Rise and Temperature

For the maximum liquid burning and gas burning cases, the estimated plume rise, trajectory and temperature shall be calculated for a variety of wind and stability cases. Grossly asymmetric fires result from the effect of fuel drifting in the Burn Area under the influence of wind forces. This sometimes tends to reduce fire area and subsequent heat input and plume rise, but causes excessive smoke. Plume rise is also frequently limited for higher wind speeds, and this can cause a plume of smoke and hot gas to be carried across equipment or buildings inside and beyond the boundary fence.

1.1.2.3 Wind Direction

Radiation levels and Plume trajectories should consider that winds are possible from all directions. In certain cases where appropriate historical data is available indicating relative frequency and strength of wind with respect to direction, it may be possible to make special allowance for winds of extremely low probability.

1.1.2.4 Sterile Area

The area surrounding the immediate liquid burn area surface and within or below the possible path of a windblown gas flame or within reach of the windblown liquid supported flame, or within a radiant profile of 2500 Btu/ft2_h, must be treated as a sterile area and shall not contain organic materials which may ignite and represent a growing source of flame.

1.1.3 GENERAL ENVIRONMENTAL FACTORS

The site selection process should consider the following matters:

1.1.3.1 Environmental and Fire Regulations

A detailed review of applicable Federal, State and local environmental and fire regulations is necessary for the effective planning, design and operation of a Burn Pit. Many jurisdictions have regulations that impose effluent discharge limits, air quality operating restrictions, and facility fire prevention inspection programs. Advanced knowledge of these requirements will help avoid delays in construction and the curtailment or termination of operations. Additionally, both near and long-term land requirements for the Pit and the intended use of adjacent lands should be identified and addressed early in the site selection process.

1.1.3.2 Topography

Relatively flat land offers both improved run-off control and lower site preparation.

1.1.3.2 Ground Water contamination

Studies for the avoidance of Ground Water contamination shall be a priority consideration covering, as a minimum, the following aspects:

a. **Type of liquid fuel**: The specific chemical nature of the liquid discharge must be reviewed to determine the level of toxicity and or bio-hazard created in the event of Ground Water contamination.

b. **Proximity to Water Supply Wells:** Water wells in the vicinity should be protected by siting the Pit as far as possible from them. For example, the outside perimeter of the completed facility should be at least 500 ft (153m) from the nearest well when sited in soil having low permeability. More separation is needed in high permeability soils. Geological studies of the local area should be conducted to determine the extent of the aquifers. In addition, hydro-geologic reports should be obtained to determine such properties of the aquifers as their depth and direction of flow. The completed facility shall include a means to monitor for, and to prevent movement of contaminants into those wells, in the event that the burn area structure becomes defective.
Coordination with the Federal and State Environmental Protection Agencies may be required if there is a potential for contamination of a sole or principal drinking water resource aquifer.

c. **Permeability of the Local Soil:** The natural presence, or the artificial addition of a low permeability, confining layer such as clay or silt below the Burn Area structure and its immediate area helps to lessen the downward migration of liquid hydrocarbon fuel.

d. **Location of Flood Plains:** The bottom of the Pit should be sited above the 100 year flood plain. This lessens the possibility of washing contaminates out of containment areas and degrading the local soil and ground water.

e. **Mitigation of Effluent Discharge to Nearby Streams:** Burn Pits should include containment measures to accommodate the accidental release of hydrocarbon fuels and subsequent flow into nearby streams.
Any effluent discharge into "navigable waters" may require a permit.

f. **Control of Hydrocarbon Fuel Quantities:** The greatest harm to ground water and soil quality is attributed to liquid fuels released directly onto the soil during operations. Hence, the simplest mitigation measure for maintaining ground water and soil quality is to reduce the amount of fuel placed in the Burn Area. Therefore, recycling of liquids should be practiced as much as possible, and indiscriminate use of the Pit discouraged.

1.1.4 ADDITIONAL DESIGN CONSIDERATIONS

Additional considerations in determination of suitable placement and subsequent pit design should include the following:

1.1.4.1 Elevation of the Pit Bottom

The level of the pit bottom should be at an elevation which will not permit emergence of hydrocarbon liquid onto a ground surface in such a manner which would permit natural drainage or run-off into a hazardous or populated location. Consequently, it must be below the lowest natural grade elevation within the pit confines.

1.1.4.2 Pit Drainage

The floor of the pit shall slope naturally toward the burner and pilot location. The lowest point in the pit shall be roughly adjacent to the burner, and hydrocarbon liquid at this point shall be readily ignitable from the burner or locally mounted dedicated pilot burners.

1.1.4.3 Storm Water Drainage

A drain will be required for storm water run-off and drainage. This drain will need to run downwards from the lowest point in the pit to an environmentally suitable soak-away or into the plant oily water system. A soak-away must be treated as a potential source of hydrocarbon and fitted with hydrocarbon detectors (see also "monitoring well and drain"), where this is deemed appropriate by a safety review. The overflow for the drain line should be set at a suitable control level which ensures a safe liquid level in the Burn Area, and should be slightly higher than the top elevation of crushed stone in a pit constructed with a flexible membrane liner [FML].

1.1.4.4 Pit Level Control

A water supply should be furnished wherever practical, to enable a seal to be maintained in the drain line and prevent discharge of hydrocarbon into the drain system.

1.1.4.5. Elevation of the Burner Outlet

The discharge point of the burner and dedicated pilots shall be above the maximum possible control elevation of liquids in the pit but close enough to the liquid surface to ensure ignition of heavy liquids.

1.2 - FLARE BURNER

1.2.1 SIZING

Sizing of the burner (fluid discharge) pipe should take account of the following factors.

1.2.1.1 The **available pressure** in the pipe is used to drive both the vapor and the liquid from the burner. Pressure losses in the burner shall be computed with consideration to vapor **and** liquid flows. The maximum pressure loss should be expected for greatest vapor quantity.

1.2.1.2 **Lightest Molecular Weight Fluids** At low flow rates, some low MW fluids may vaporize in the incoming line. Accordingly, the various possible cases must be reviewed to check their vapor pressures at the highest possible local ambient temperatures plus an allowance for radiant or conductive heat transfer through the flare pipe. Any fluids which could potentially change phase to vapor should be sized as vapor flow in the flare line and associated flare tip or discharge tip into the pit.

1.2.1.3 **Combined Liquid/Vapor Flow**. For any given flow condition some of the stream will remain as liquid. The volumetric proportion of liquid in the total flow reduces the available flow area for the vapor.

1.2.1.4 **Discharge velocities** should take account of practical line sizing for liquid and two phase flows.
High velocity liquid discharge is discouraged in order to avoid both "projectile" flows which can escape the designated burn area and turbulent "splatter" of unburned liquids.
Pipe sizes based on vapor flow alone may be selected on the basis of ANSI/API STD-521 and (EPA) 40 CFR 60.18, if no proven proprietary sizing techniques are available.

1.2.2 DRAINAGE into the Pit

The incoming flare line should drain naturally into the pit. If desired, the incoming line may include a liquid trap which prevents ingress of air back into an inactive line. Such traps should be accessible for cleaning. The safety of the system must not be conditional on the action of the trap unless a level is maintained and guaranteed by "fail-safe" controls.

1.2.3 PROTECTION from Liquid-supported Flame

Any exposed items or those projecting over the liquid pool or Burn Area are likely to be destroyed or at least severely damaged by exposure to heat and flame lick. All burner pipes and associated equipment within the outer limits of a berm, or within one pool diameter of any Burn Area without a berm, shall be fully protected by burying or covering with a non-conductive and inorganic material. The points at which these pipes emerge to the pit should, preferably, be enclosed in and supported by a specially formed protective refractory block.

1.2.4 MATERIALS of Construction

Burner materials and piping in the immediate vicinity of the Burn Area should, as a minimum, be made from an 18/8 Cr/Ni stainless steel.
Parts exposed to flame lick should, as a minimum, be made from a 20/12 Cr/Ni stainless steel.

1.2.5 IGNITION

1.2.5.1 **Ignition of the Burner** - should be assured by provision of at least one dedicated, permanently burning pilot burner. The pilot burner shall be located sufficiently close to the vapor outlet that ignition is assured.

1.2.5.2 **Ignition of the Liquid Pool** - from the burner pilot may be assumed for all liquid releases for which the flash point is less than ambient temperature.
Ignition of liquid pools where the flash point of the liquid is above the ambient temperature requires direct flame impingement on the liquid surface by either of the following:

a. a guaranteed, vapor-supported flame from the main burner, or
b. at least two (2) dedicated, continuous burning pilot burners.

1.2.5.3 **Ignition of the Pilot Burner(s)** should be accomplished reliably from a location remote from the Burn Area. Acceptable remote ignition may be by Flame Front generator or by direct electrical ignition suitably designed for the harsh environment.
NOTE: Conventional, High Tension spark plugs are prone to fail in exposed locations and should not be used for direct electrical ignition.

1.2.6 PILOT FLAME MONITORING/DETECTION

The pilot(s) shall be provided with permanent flame monitoring by inclusion of a thermocouple.
Flame detection by optical (UV or IR) detectors or by ionization probe is not reliable in this environment and shall not be used without a full design review and permission of the engineer.

1.3 - BURN AREA

1.3.1 STERILE AREA

The primary section of the Burn Pit is the Sterile Burn Area. This comprises the area designated to receive and contain the relief and the extended zone immediately surrounding the flame. This area will be subjected to extremely high heat loads and flame lick and must be completely free of any organic materials. See also 1.1.2.4.

1.3.2 SIZING

The Burn Area must be sized to accommodate the maximum possible discharge, treated independently as liquid or vapor.

1.3.2.1. **Peak Liquid Discharge Rate:** The surface of the Burn Area shall normally be at least sufficient to support a flame burning continuously at the maximum fluid input rate, without accumulation, except as noted under section 1.3.2.3.

1.3.2.2 **Regression Rate** : The surface regression (burning) rate of the liquid should be calculated from previous experience or using a proven formula based on the heat of combustion of the fluid and the enthalpy of vaporization.
Typical regression rates for hydrocarbons range from 0.1 to 0.4 inches per minute. As a common average value for first order estimates, 0.3 inches per minute may be used.

1.3.2.3 **Limited Liquid Quantity:** If the fluid input is limited by process factors, to a known maximum, then the surface of the Burn area may be reduced, providing that:-

(a) the total volume content of the Burn Area is at least equal to the known maximum volume input plus allowances for environmental factors such as fouling and storm water, and

(b) the length of burn time required for total consumption of the fluid is less than the minimum possible interval between two consecutive reliefs.

1.3.2.4 **Peak Vapor Inflow:** The length of the gaseous diffusion flame from the fluid discharge pipe or tip shall be determined by accepted methods.
A reasonable estimation of the 3-D flame may be obtained from formulae available in the paper "A Proposed Comprehensive Model for flare Flames and Plumes - AIChE Paper 2006" at http://www.geocities.com/flareman_xs/Thermal/shore_buo_flame_model_r2.pdf
or by interpolation of curves in ANSI/API STD-521.

An approximation should be made of the maximum forward, sideways and backward reaches of the flame, assuming conservation of momentum, and an estimate of flame position obtained for various wind speeds and directions. Any area within at least 20 ft of the ground which could be engulfed in the gas flame should be considered to be within the confines of the sterile Burn area.

Vapor flows which occur in concert with, or otherwise concurrently with liquid discharge should generally be considered to form part of the vaporized liquid contributing to the liquid-supported flame and may not produce a definable or recognizable gas-supported flame.

1.3.3 SHAPE of the BURN AREA POOL

Any shape of Burn Area pool is acceptable, provided that the Burn Area sizing requirements are met. Circular pools are most economic with regard to space utilization but tend to produce the longest flames and most smoke, whereas rectangular pools can reduce flame height but create asymmetric radiation patterns. A complex combination of shapes, such as diamond or pear-drop is probably the most suitable.

1.3.4 BURNER LOCATION

The Liquid/Vapor is input to the pool via the Flare Burner. The burner should be located conveniently with respect to pipeline access and connection. In order to minimize the flame lick on the burner and associated piping and maximize the air input to the vapor flame, the burner should preferably be located at a corner position of a non-circular pool.

1.3.5 PREVAILING WIND

Some allowance shall be made for the major prevailing wind speed and directions. Normally, the burner input axis is best at 90 deg or less to the prevailing winds such that winds do not blow directly toward the open end of the burner tip.

Notwithstanding the prevailing wind direction, layout of the sterile burn area shall take into consideration all possible wind speeds and directions.

1.4 - BERMS

1.4.1 DESIGN

A berm is a generally raised area surrounding the main Burn area structure. Berms serve largely to define the outer edges of the Burn Pit and, if properly designed, arrest the flow of wind-blown vapors away from the burn area preventing an uncontrolled migration of flame.
Concurrently the berm serves as a reminder to personnel of the nature of the local area usage and can be used for personnel exclusion.
The berm will afford some small measure of personnel protection from radiant heat of small flames in the burn area but its use <u>must not</u> preclude an appropriate radiant heat study based on the maximum potential vapor and liquid supported, wind-blown flames.

1.4.2 SLOPE

The slope of the berm shall be determined by its intended purpose.
A berm which is intended predominantly for personnel exclusion should be set at the maximum stable angle of incline of the backfill and should be provided with a designated means of access, such as permanent concrete steps, over and into the Burn Area.

An interior slope greater than 1:1 is not recommended as this could inhibit air entry to the base of the flame.
An exterior slope less than 1 in 2 (vertical:horizontal) in combination with a low total vertical height (less than 6 ft) may not be sufficient to arrest the migration of wind-blown flames.

Those parts of a berm which must also be used as an access way into the Burn Area shall provide a gentle, non-hazardous footing for fully clothed operatives entering and exiting the Burn Area structure or for machinery access. To provide such footing, slopes shall range from 1:4 to 1:2 (vertical :horizontal) and shall be located in a position determined by the engineer to represent the least hazard due to flame migration.

1.4.3 "INNER-RING" Section

The inner ring section is a quasi-horizontal section of the burn pit around the inner perimeter of the berm and slightly higher than the normal liquid level of the pit. To ensure satisfactory combustion at the surface of the pit, the total flat width across the "inner-ring" of any raised berm shall be sufficient to allow full flow of the theoretical combustion air required to support the liquid flame.

1.5 - FORMULAE

1.5.1 LIQUID SURFACE REGRESSION

A representative rate may be estimated from the basis provided by the US Bureau of Mines Publication BOM-6099.

	V	=	V_o * LCV / LV	- inches/min
where	LCV	=	Calorific value of liquid stream	- Btu/lb
	LV	=	Latent heat of Vaporization	- Btu/lb
	V_o	=	0.003 * [1 - exp(-m * D)]	
	D	=	pool "diameter"	- feet
	m	=	3 * (MW) $^{-1/3}$ (approx)	
	MW	=	ave molecular weight of vapor/liquid inflow	

(Rates calculated in this way would seem to be realistic or slightly conservative when compared with other texts such as "Large Scale LNG and LPG Pool Fires"; Minzer and Eyre; I Chem E #71.)

1.5.2 LIQUID FLAME SIZE

Physical flame size is a function of the actual pool diameter and may be estimated by the method of Minzer and Eyre.

	H_F	=	K_H * D	- ft
where	K_H	=	$50 * [\ m^1 / rho_A / ((\ g * D\ )^{(0.5)})\ ]^{(0.61)}$	
	m^1	=	liquid consumption rate = (V / 720) * rho_L	- lb/sec/sq.ft
	rho_L	=	liquid density	- lb/cu.ft
	rho_A	=	air density	- lb/cu.ft
	g	=	gravitational constant = 32.174	- ft/sec2

1.5.3 LIQUID FLAME TILT ANGLE

For radiation calculations, flame tilt due to wind may be estimated as follows:

h	=	wind-blown flame tilt angle (from vertical)	
Cosine (**h**)	=	1 / [sq. root (U^*)] for U^* greater than 1	
Cosine (**h**)	=	1 for U^* less than 1	
U*	=	$U_w / [(m^1 \times g \times D)/ rho_V\ ]^{(1/3)}$	
rho_V	=	hydrocarbon vapor density	- lb/cu.ft
U_w	=	wind speed	- fps

In addition, possible wind blown flame lick across the ground should be assumed over a distance of one pool diameter for any pool without a defining containment berm.

1.5.4 LIQUID POOL RADIANT OUTPUT

Radiant output can be estimated from

	Hr	=	$P_P * H_F$ * S	
where	P_P	=	perimeter of burn area	- ft
	H_F	=	Flame height	- ft
	S	=	characteristic average superficial heat density (not fraction of heat) This value to be interpolated on the basis of expected flame condition.	

Higher values of S reflect a clear bright orange flame whereas the lower levels reflect high soot loading as might be expected from a large diameter pool, burning heavier fluid.

Typical values of S	LNG	180 - 120 kW/sq.m	(rev .. was W.sq.m)
	LPG	80 - 40 kW/sq.m	(rev .. was W.sq.m)
	Kerosine	60 - 25 kW/sq.m	(rev .. was W.sq.m)

Near field distribution of radiant intensity will tend to be linear at an intensity equal to S.

Far field distribution may be assumed to be spherical based on the geometric center of the tilted flame cylinder and using the standard formulae of API RP-521 adjusted for the appropriate value of S.

For irregularly shaped burn areas, different faces may require different value of S and distant field values need to be adjusted to reflect the effects of longer or shorter visible flame faces.

1.5.5 GAS FLAME SIZE AND POSITION

A comprehensive procedure for estimation of a wind blown flame position may be obtained from the formulae and procedures available in "A Proposed Comprehensive Model for flare Flames and Plumes 2006" at http://www.geocities.com/flareman_xs/Thermal/shore_buo_flame_model_r2.pdf

1.5.6 GAS FLAME RADIATION

Radiant output may be assumed to be spherical based on the geometric center of the windblown flame and using the standard formulae of ANSI/API STD-521 for spherical distribution. Estimation of radiant fraction should be made on a similarly conventional basis or use a published estimation procedure such as that provided in "Making the Flare Safe", downloadable from http://www.geocities.com/flareman_xs/Systems/makingtheflaresafe.pdf

Vapor flows which occur in concert with, or otherwise concurrently with liquid discharge should generally be considered to form part of the vaporized liquid contributing to the liquid-supported flame and may not produce a definable or recognizable gas-supported flame.

2 - BURN-PIT CONSTRUCTION

2.1 SELECTION OF CONSTRUCTION METHOD

2.1.1 There are two (2) usual **building material alternatives** for the Burn Area containment structure:

a The use of **concrete,** or other hard-facing material, as the primary building material.

b The use of **flexible membrane liners** as the primary building material.

2.1.2 Simple excavations without the use of any proper building materials have, historically been common in extremely remote locations. Since the election of a simple excavation is usually made for economic reasons and in order to avoid consideration of specifications and design parameters, there are no appropriate associated conditions.

This type of "non-containment" structure is NOT normally recommended and any decision to proceed with such a design must be made carefully. The engineer is reminded of an implied ethical duty to make informed and technically suitable decisions regarding the design and construction issues surrounding a simple excavation using considerations similar to the general guidelines of this specification and bearing in mind the environmental considerations described herein.

2.2 CONCRETE ALTERNATIVE

2.2.1. **Basic Design**

The basic design consists of a refractory concrete floor and wall with a secondary means of containment under the structure to safeguard the environment from a defective surface.

2.2.2 **Design Service Temperature**

The design service temperature of the Burn Area structure shall be 2100 F (1150 deg C).

2.2.3. **Containment Structure Floor and Walls**

a. **Material** for the structural floor and connected inner walls of the liquid containment structure shall be air-entrained Portland cement concrete that is reinforced and cast-in-place in accordance with specifications for Cast-in-Place Concrete.

b **Slope** of the floors shall be arranged generally to channel hydrocarbon liquids towards the flame and pilot locations and also locally to channel storm water towards any drains, thereby simplifying routine maintenance and structural inspections.

2.2.4 **Protective Over-layer**

A protective overlying layer shall be provided for a Portland cement concrete structure. This shall be either refractory concrete or brick, or a crushed stone alternative.

a. **Refractory**: a refractory layer with three (3) inch minimum depth, taking into account the slope of the floor. This may be either cast or gunned refractory concrete or pre-cast shapes or brick, in accordance with the specification provided herein.

b. **Crushed Stone**: a minimum depth of twelve (12) inches covering the entire center of the designated burn area. Crushed Stone should be in accordance with the specifications provided herein.

2.2.5 Drains

a. **Floor drains** and sumps shall be fitted with a screen or a comparable device to preclude the migration of crushed stones into the drain.

b. A **secondary, under-drain** system shall be placed below the floor to relieve the buildup of hydraulic pressures beneath the Burn Area structure and collect leaking fluids if the floor fractures. If a perforated drain pipe is placed, it shall be wrapped in a geo-textile fabric to prevent migration of foundation materials.

2.2.6. Refractory Concrete Curbs and coverings

Exposed ,non-containment and non-structural parts of the pit which attain greater service temperatures and are exposed to frequent and sporadic flame impingement, such as the "inner ring", shall be specified as Refractory in lieu of Portland cement concretes. Alternatively, there is an added benefit in specifying pre-fabricated sections, such as brick, as this allows uniformity of quality control in manufacturing.

a Brick sections or preformed shapes shall be per the section of this specification covering materials.

b Castable refractories shall be in accordance with American Society for Testing & Materials (ASTM) C401 (Standard Classification of Castable Refractories) and the section on Refractory Concrete.
   i. Castable mixes shall be complete and pre-bagged.
   ii. Refractory concrete field mixes that require the addition of supplementary aggregates or binder shall not be allowed.

a. **Perimeter Curb Height:** The top of the curb shall be at least 6 inches above the maximum possible liquid level in the pit, bearing in mind surface rise due to storm water run-off into the pit. The height difference between the top of any curb and any adjoining walking/access surface shall not exceed 8 inches (20cm).

b. **Perimeter Curb Width:** The minimum width at the top of the curb shall be at least 6 inches (15cm). To ensure satisfactory combustion at the surface of the pit, the total flat width across the concrete curb and its immediate surround inside any raised berm shall be sufficient to allow full flow of the theoretical combustion air required to support the liquid flame.

c. **Perimeter Curb Slope:** The concrete curb (and berm) shall slope towards the Burn Area structure to collect accidental spills, rainfall and snow-melts.

2.2.7 Berm

If a berm is installed, it may be treated as a secondary liquid containment for overflow, only insofar that it is constructed to be impermeable in a manner such as that described for flexible Burn Area structures. Berms not so designed are only beneficial for flame containment, personnel exclusion and limited radiation protection.
Construction of a berm shall be generally in accord with the descriptions of Berms provided herein.

2.2.8. Monitoring Well and Drain

A monitoring well shall house a leak detection device in any sump which is connected to the storm water and level control drain system.

2.3 FLEXIBLE MEMBRANE LINER ALTERNATIVE

2.3.1. Basic Design

The basic design consists of a sealed three-layer system of

- two (2) high density polyethylene (HDPE) flexible membrane liners (FML), separated by an interior drainage flow net (see Fig. 2) and all laid over a geo-textile protective layer.

The system continues downward and beyond the Burn Area structure to function as a collection system to accumulate, detect and permit removal of any leaked fluids.

2.3.2. Design Service Temperature

The design service temperature of the burn area structure shall be 2100 deg F (1150 deg C).

2.3.3 Containment Structure Floor and Walls

a **Material** for the sloped floor and walls of the Burn Area Containment Structure shall be a composite construction, fabricated from two layers of HDPE FML's that are sealed (seamed) and separated from each other by a materially compatible interior drainage flow net. HDPE FML's shall be in accordance with the section on Flexible Membrane Liners.

The general composition of the system shall be

i Upper, **primary HDPE FML** which functions as the primary holding basin of fluids and shall be sized in accordance with the specifications for Burn Pit sizing. The primary FML shall be sealed to the secondary FML.

ii **Interior Drainage Flow-Net:** The interior drainage flow-net separates the primary and secondary HDPE Flexible Membrane Liners to provide leaked fluids flow paths for detection at the monitoring well. The design pattern of the net shall allow multi-directional flow paths, for collected fluids, to the detection device. Flow-nets shall end below the berm, next to the sealed perimeter of the two HDPE FML's.

Interior drainage flow-nets shall be in accordance with the section on Drainage Flow-Nets.

iii Lower **secondary HDPE FML** which collects and channels leaked fluids for detection. The secondary liner shall have the ability to contain at least 100% of the volume of the upper primary liner and shall be sealed to the primary liner.

The FML system shall extend to the immediate area surrounding the burn area structure proper and shall be properly anchored below the berm and covered with backfill material. Berm and backfill material shall be in accordance with the later descriptions herein.

b **Slope** of the wall shall follow the HDPE FML manufacturer's recommendation for wall stability. Natural drainage shall be to a single lowest point of the system of liners which shall be located outside of the burn area structure where a monitoring well houses a leak detection device.

c **Depth** of the FML system below the bed and "inner-ring" shall be arranged to suit the drainage requirements and the burn-pit liquid hold-up specifications but shall not be less than eighteen (18) inches below the surface at any point.

2.3.4 Protective under-layer

A geo-textile fabric shall be placed over the foundation material to protect the secondary liner from foundation material. The fabric shall end under the inner ring section, defined in the Berm descriptions. Geo-textile filter fabrics shall be in accordance with the section on Geo-textile Filter Fabrics.

2.3.5 Protective over-layer

A protective overlayer for the FML shall be provided primarily by an overlying layer of sand and crushed stones and also by the" inner-ring" section of the surrounding berm. The construction shall generally be

a. **Sand**: minimum six (6) inches (15 cm), placed immediately above the primary liner. The sand protects the primary liner from being punctured by intruding crushed stones and exploratory maintenance

b. **Geo-textile filter fabric**: placed directly above the sand layer to stop the intermingling of crushed stones with the sand layer. The fabric shall end under the "inner- ring" section, defined in the Berm descriptions. Geo-textile filter fabrics shall be in accordance with the section on Geo-textile Filter Fabrics.

c. **Crushed Stone**: minimum twelve (12) inches (30 cm) covering the entire center of the designated burn area.) This material is placed within the burn area structure to function as a quick drainage medium, level walking surface, and a heat absorbent shield for the membrane. For liquid filled pits, crushed stones additionally help to counteract the drifting of fuel by wind forces.

2.3.6 Berm

A berm shall be installed as part of the general construction. The berm may be treated as a secondary liquid containment for overflow only insofar that it is constructed to be impermeable by the inclusion of a FML.
Sections of the berm beyond and above the edges of the FML, or without any FML, are only beneficial for flame containment, personnel exclusion and limited radiation protection.
Construction of a berm shall be generally in accord with the descriptions provided herein.

2.3.7 "Inner-ring"

The inner part of the of the berm shall be treated as similarly to a curb to provide a level walking access to the burn area. It may continue to slope slightly downward from the inside toe of the designated berm for the required horizontal width. It shall be composed of the same backfill material as the berm and marks the maximum level of the liquid fuel and water sub-layer mixture. At the innermost point, it shall have a minimum depth of 18 inches (46 cm) to protect the primary liner from heat.
The "inner-ring" need not be raised above the level of the interior crushed stone bed for pits designed for continuous relief rate burning.
For pits with a requirement for liquid hold-up and extended residual burning periods, the "inner-ring" should, as a minimum, be level with the maximum intended liquid level in the burn area.

2.3.8 Drains

a **Above the primary liner** the drainage system shall preclude the removal of sand and crushed stones; e.g., drain covers with filters, use of perforated drain pipes. Drain components subjected to fuel shall have positive seal joints as compared to rubber gaskets. Polymer drain components (plastics) shall be compatible with fuel characteristics and expected temperatures.

b. A **secondary, under-drain system** shall be placed below the floor to relieve the buildup of hydraulic pressures beneath the Burn Area structure and collect leaking fluids if the floor fractures. If a perforated drain pipe is placed, it shall be wrapped in a geo-textile fabric to prevent migration of foundation materials.

2.3.9 Monitoring Well and Trench

A monitoring well shall house a leak detection device in a sump within a trench that is composed of the same HDPE FML material used for the burn area structure. The trench shall extend beyond the burn area structure and slope continuously downward to the monitoring well.

The trench may additionally be used as an avenue for a non-penetrating entrance to the liner system by fuel, water supply lines and ignition devices if these are required.

3 - MATERIALS FOR USE IN THE BURN PIT

3.1 GENERAL

The various materials to be used in the construction of the burn pit shall be known to be suitable for the intended service.

3.2 BACKFILL MATERIALS

The backfill material specified shall be uniformly graded, free of friable soluble materials, clay loam and silt and other debris, and shall contain a high percentage of fines which serve to:

- provide a protective heat-absorbing blanket for the primary liner, and
- limit any fluid mixture's downward penetration into the inner toe of the berm by more readily conveying fluids toward the lower, more porous crushed stone layer.

Typical screening profile for Berm and Inner-Ring backfill			
Sieve Size	**% Passing by Wt**	**Sieve Size**	**% Passing by Wt**
2 inch	100	No. 4	35 - 60
1 inch	95 - 100	No. 10	22 - 50
3/4 inch	80 - 100	No. 16	15 - 35
5/8 inch	75 - 100	No. 40	15 - 30
3/8 inch	50 - 85	No. 200	5 - 10

3.3 CRUSHED STONE

3.3.1 Type

Selection of aggregate shall be made from locally available materials with due recognition of the thermal properties of the stone and its behavior when exposed to long-term heating which may make it generally undesirable for this application.

Note:
- Chalk, limestone, sand stone and similar materials break down very quickly under the combines action of weathering and heating.
- Aggregates containing quartz are prone to fracture since they experience large volume change well below the design service temperature.
- Aggregates which may contain trapped moisture can become missiles when exposed to high temperatures.

3.3.2. Size

The crushed stones shall be angular, well graded, and free of shale, clay, friable materials and debris. Grading shall be in accordance with ASTM C136.

Nominal aggregate size	maximum 1-1/2 inches (3.8 cm): minimum ½ inch (1.3 cm).
Suitable standard sizes	ASTM D448 # 4 (Standard Classification for Sizes of Aggregate for Road and Bridge Construction) ASTM C33 #4 and #5.

3.4 SAND

Sand shall be of natural river bank. or manufactured sand, washed free of silt, clay, loam, friable or soluble materials, and organic matter, graded in accordance with ASTM C136 (Standard Method for Sieve analysis of Fine and Coarse Aggregates), within the recommended limits of "Fine Aggregate" category of ASTM C33 Standard Specification for Concrete Aggregates (Optional Para. 5.2 is acceptable).

3.5 CAST-IN-PLACE CONCRETE

3.5.1 Material Acceptance

a **Type**

Portland cement concrete Type I (normal),
Type II (for exposure to sulfate-bearing solid and seawater)
or Type III (high early strength)
in accordance with in accordance with ASTM C94, Standard Specification for Ready-Mixed Concrete and ASTM C150, Specification for Portland cement.

b **Strength**

The minimum 28-day compressive strength shall be 4000 psi for liquid containment structures.

c **Placement**

Upon placement, concrete shall have a slump of 1 to 4 inches (per ACI-211) and percentage air determined in accordance with paragraph 4.5.1 of ACI 318.

3.5.2. Practices

Concrete design shall be in accordance with ACI 318, unless otherwise directed by the engineer.
Regions subject to moderate or high seismic risks shall note Appendix A of ACI 318, Special Provisions for Seismic Design.

Hot weather and cold weather concreting practices shall be in accordance with ACI 305R, Hot Weather Concreting, and ACI 306R, Cold Weather Concreting.
Special emphasis shall be observed during

a placement - concrete shall be deposited continuously in layers of such thickness that no concrete will be deposited on concrete which has hardened sufficiently to cause seams or planes of weakness, and

b curing of concrete - controlled curing is one of the best precautions to make concrete watertight.

3.5.3 Clean Water

Water shall be clean and potable.

3.5.4 Aggregates

The nominal maximum aggregate size shall be 3/4 inch in accordance with ASTM C33; [e.g., coarse aggregate size number 67]. The material shall be free of injurious amounts of shale, alkali, organic matter, loam, or other deleterious substances.
Paragraph 5.3.2 of ACI 211 shall be observed. In no event shall the nominal maximum size exceed 1/5th of the narrowest dimension between sides of forms.

3.5.5 Admixtures

Air-entrained admixtures shall comply with ASTM C260, Standard Specification for Air-Entraining Admixtures for Concrete. Calcium chloride shall not be used as an admixture. All other chemical admixtures and mineral admixtures shall meet the appropriate standard specifications set forth by ASTM.

3.5.6 Non-Shrink Grout

Grout shall be a non-shrink grout in accordance with U. S. Army Corps of Engineers CRD-C-621, Handbook for Concrete and Cement, Specification for Non-Shrink Grout, unless otherwise specified by the engineer.

3.5.7 Surface Finish

Surface finishing shall proceed only after surface water has disappeared and concrete has set sufficiently to support the weight of workers and equipment. Surface shall dry naturally and not be dusted with dry cement or sand. A power-drive float machine shall be used to float surface of the Burn Area floor to produce a finish true to elevations and slopes with a uniform granular texture. Hand floats shall be used in areas inaccessible to power-driven floats. Surfaces shall be leveled to within 1/4 inch in 10 ft in all directions, unless otherwise specified by the engineer. Area designated for personnel or other traffic shall be broomed with a flexible bristle broom to produce a non-slip texture in a direction transverse to that of traffic or at right angles to the slope of the surface.

3.5.8 Cementitious Waterproofing

Cementitious waterproofing shall be provided on the “positive” inside surfaces of concrete containment structures. Materials used for waterproofing shall follow manufacturer’s application instructions to ensure proper penetration and closure of concrete capillary tracts to produce the desired waterproofing effects. The selected cementitious waterproofing system shall become permanent, and be non-toxic, inorganic, free of calcium chloride and sodium based compounds.

3.5.9 Fuel-resistant Concrete Joint Sealant

The engineer shall specify one of the following fuel-resistant concrete joint sealants:

a. ASTM D 1854
b. ASTM D 3569
c. ASTM D 3581
d. Federal Specification SS-S-200

3.6 REFRACTORY CONCRETE

3.6.1 Material Acceptance

Castable refractory concretes shall be a Class B or C (regular, not an insulating type castable), in accordance with ASTM C 401. Additional requirements may be specified by the manufacturer to offset the rapid heating and cooling stress cycle; e.g., fast-fire variety castable to offset explosive spalling.

3.6.2 Practices

All construction practices and materials for placement, anchorage, finishing, curing, drying, firing of refractory castable concrete, shall be as specified by the refractory manufacturer. Since refractories behave differently when compared to Portland Cement concretes, contractor shall have prior construction experience with the product or be properly supervised by the refractory manufacturer.

3.7. PRE-FORMED REFRACTORY SHAPES [BRICK]

Refractory Brick used for the protective over-layer of the Burn Pit shall be of commercial manufacture medium duty Firebrick meeting or exceeding the following specifications

- porosity	<=	25%
- low iron		low
- operating temperature	>=	2300 degF
- alumina content	>=	40%
- density	>=	120 pcf
- modulus of rupture	>=	800 psi
- cold crushing strength	>=	2000 psi

3.8 STRUCTURAL STEEL

3.8.1 Material Acceptance and Storage

All reinforcing structural steel, including metal accessories necessary for placing, spacing, supporting and fastening reinforcement, shall conform to the levels of quality specified to perform the functions intended. Upon delivery, these items shall be checked for conformance to specifications and then properly stored from dirt, grease and the environment.

3.8.2 Practices

All steel design, fabrication and erection shall be in accordance with the American Institute of Steel Construction (AICS), Specification for Design, Fabrication and Erection of Structural Steel for Building, and with the AISC, Code of Standard Practice for Steel Buildings and Bridges, unless otherwise directed by the engineer.

3.8.3 **Steel Reinforcing Bars and Welded Wire Fabric**: Tolerances and placement for reinforcing bars, welded wire fabric and metal devices necessary for lacing, spacing, supporting and fastening reinforcement shall conform to the American Concrete Institute (ACI) 318-83, Building Code requirements for Reinforced Concrete. For corrosion protection of rebars, protective coatings such as epoxy coatings are recommended. If specified, they shall be in accordance with ASTM A-775, Specification for Epoxy-coated Reinforcing Steel Bars.

3.8.4 **Welding:** Welding practices shall be in accordance with AWS D1.1, Structural Welding Code - Steel, and appropriate AISC welding specifications, unless otherwise directed by the engineer. Welders shall be qualified in accordance with AWS D1.1, Structural Welding Code - Steel.

3.9 FLEXIBLE MEMBRANE LINER

3.9.1. Material Acceptance

The liner shall be a high-density polyethylene (HDPE) flexible membrane liner (FML) of a non-extractable plasticizer quality. The selected liner shall be certified by the National Sanitation Foundation (NSF) or equivalent. It shall be of first quality, virgin materials designed and manufactured specifically for the purpose, properties and performances required. All defects shall be corrected prior to delivery. all necessary liner anchorage, penetrating hardware and interface components required for complete installation shall be included.

3.9.2 Practices

Liner installation shall follow manufacturer's instructions and practices. Contractors shall have either prior installation experience for the type of liner material selected or an experience level of installation, as approved by the applicable State; e.g., State Department of Natural Resources.

3.9.3 Performance Properties

The liner shall have:

a **Thickness:** A minimum nominal gauge thickness of 80 mils (0.080 inch) or greater, determined in accordance with ASTM D 1593, Standard Specification for Non-rigid Vinyl Chloride Plastic sheeting, for unreinforced fabrics, or ASTM D 751, Standard Method of Testing Coated Fabrics, for reinforced fabrics.

b **Standards:** The specific material property standards including applicable appendices of ANSI/NSF Standard #54, Flexible Membrane Liners, latest edition.

c **EPA Tests:** The material compatibility tests of Environmental Protection Agency (EPA) Test 9090 for the hydrocarbon fuels to be burned in the pit.

d **Permeability:** A maximum permeability rate of either 0.25 $oz/ft^2/day$ (3.3 $cm^3/m^2/hr$) for the hydrocarbon fuel to be contained, or the established permeability test criteria of the applicable State; e.g., State Department of Natural Resources), or local authority. Permeability tests may be in accordance with ASTM E 96, Standard Test Method for Water Vapor Transmission of Materials, performed with the type of hydrocarbon fuel to be contained.

e **Chemical Compatibility** with other chemicals that the liner will contact, such as those found in the supporting soil.

f **Low Temperature Resistance** of -40 deg F (-40 deg C) and a high temperature resistance of 240 deg F (116 deg C) without performance failure.

g **Resistance to Exposure:** A high resistance to abrasion, humidity, rot, mildew, vermin, bacterial deterioration and sunlight (UV).

3.9.4 Bonded Seams

a **Strength:** Factory and field seams shall have seam strengths that exceed parent material and permanently marked with an identification number.

b **Integrity:** Factory and field welded seams shall be made by dielectric, extrusion welding, or thermal methods, followed by testing and certified by the manufacturer to be leak free. Verification of seam integrity shall be in accordance with ANSI/NSK Standard #54 for FML, latest revision.

c **Properties:** Factory seaming of joints shall have the liner physical property requirements of ANSI/NSF Standard #54, latest revision, and the chemical compatibility shear and peel directional tests of Appendix D, Part L.

d **Field Seams:** Field seaming of joints and of penetrating objects shall be performed and repaired in accordance with applicable parts of Appendix C, Section VI of ANSI/NSF Standard #54, latest revision.

3.9.5 Interface Components, Liner Tubes, Sleeves, etc.

All liner penetrations shall be materially compatible with the liner and tested for tightness by a hydrostatic, vacuum, ultrasonics, or an air jet test.

3.9.6 Installation

Liner installation shall meet the following requirements and manufacturer's practices and techniques:

a **Sub-grade:** the sub-grade supporting the liner shall be properly prepared within four inches (10 cm) of the receiving surface to be lined.. This entails removal of

i foreign matter such as vegetation, debris, water, snow, ice;

ii all hard objects such as angular, broken or sharp-edged stones, particularly stones larger than two inches (5 cm) in diameter.

b **Sub-base:** The sub-base shall be uniformly compacted to ensure against liner settlement and to provide a uniformly sloped surface(s) for interior drains and the leak monitoring FML trench. Compaction shall be 95% of that obtained in accordance with Method d of ASTM D 698, Moisture-Density Relations of Soils and Soil-Aggregate Mixtures using 5.5 Lb Rammer and 12 inch Drop. Optimum moisture content of backfill materials shall be maintained to achieve the required compaction density. Backfilling shall not be accomplished over a porous, wet, spongy or frozen sub-base.

c **Underside Protection:** Protection of the underside of the secondary FML shall be accomplished by placing on the subgrade at least six inches (15 cm) of sand, pea gravel or a geotextile padding of at least 15 mils (0.015 inch). Placement of the above materials shall not be accomplished over a porous, wet, spongy or frozen subgrade.

d **Bridging:** There shall be no bridging or stressed conditions in the liner.

e **Adjacent Surfaces:** Concrete or other rigid surfaces adjacent to liner shall have all rough edges and projections removed. Extruded expansion materials and joint sealers shall also be removed and flushed with the concrete surface

3.10 FML MONITORING TRENCH

3.10.1 Prior to Placement

Prior to the installing of the monitoring trench that leads to the leak detection device, the following shall be performed:

a The cut of the trench shall be made sufficiently wide to enable installation of the flexible liner material, and, if included, pipes and utilities, and to permit inspection.

b All large stones or other hard materials which could hamper the leak detection function, penetrate the liner trench, or impede consistent backfilling or compaction to specified elevations and densities shall be removed.

c The location and elevation of the sump housing the leak detection device shall be verified.

3.10.2 After Placement

Once the liner trench material has been installed, all trenches shall be backfilled by a method that does not disturb elevations or damage the liner trench, leak detection device, pipes and utility lines. Hand tamping shall be performed in areas inaccessible to compaction equipment.

3.10.3 Repairs

Tears, punctures or other defects shall be repaired by the installer at no additional cost to the purchaser.

3.11 DRAINAGE FLOW NET

3.11.1 Material Acceptance

The drainage flow net between the double layered liner system shall:

a Be manufactured of a material satisfactory for the intended service. A suitable reference test is published by the US Environmental Protection Agency (EPA) as Test 9090, for hydrocarbon fuels.

b Be compatible with the double liner system.

c Withstand bearing loads to provide effective flow characteristics to monitoring well; i.e., hydraulic transmissivity.

3.11.2 Practices

a Supply and installation contractors shall have demonstrable prior installation experience or else be at an experience level approved by the jurisdiction having authority; [e.g. State Department of Natural Resources].

b Installation shall be in accordance with manufacturer's recommendations and the following requirements:

- i Drainage flow nets shall terminate near the perimeter ends of the double layered liner system under the berm.
- ii Tears, punctures, or other defects shall be repaired by the installer at no additional cost to the purchaser.

3.12 GEO-TEXTILE FILTER FABRIC

3.12.1 Material Acceptance

The geo-textile filter fabric shall have the following properties:

a A woven or non-woven fabric compatible with hydrocarbon fuels.

b A minimum puncture strength equal to 120 pounds, tested in accordance with ASTM D-751, Standard Method of Testing Coated Fabrics, modified by using 5/16 inch diameter cylinder.

c Equivalent opening size in fabric:-

minimum 100 / maximum 50, as determined by Corps of Engineers Guide, Specification number CW-02215, for Geo-textiles used as Filters.

d Minimum weight of fabric equal to or greater than 8 oz/y^2 (270 g/m^2) determined in accordance with ASTM D 3776, Standard Test Method for Mass per Unit (Weight) of Woven Fabric.

3.12.2 Practices

Installation shall be in accordance with manufacturer's recommendations and the following requirements:

a Prior to placing the fabric, the receiving foundation material shall be properly compacted and have surface gradients and elevations verified.

b Fabric applied to a surface shall have sufficient slack to prevent tearing when overhead layer of crushed stone material is placed.

c Fabric edges shall be lapped a minimum of 12 inches (30 cm) to prevent separation of overlapped edges when the overhead layer of crushed stone material is placed.

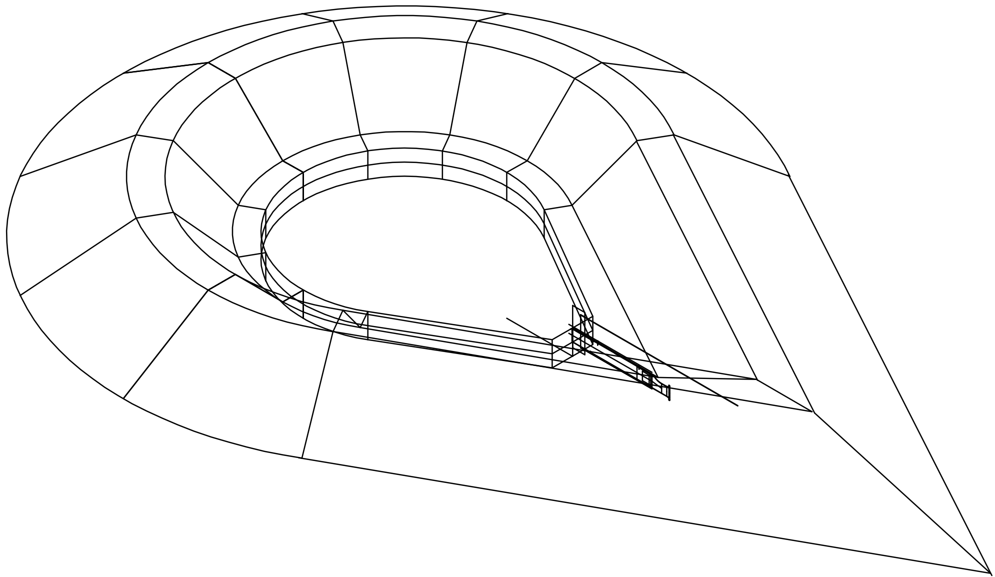
d A minimum of 6 inch crushed stone cover shall be placed over fabric prior to operating equipment on covered area.

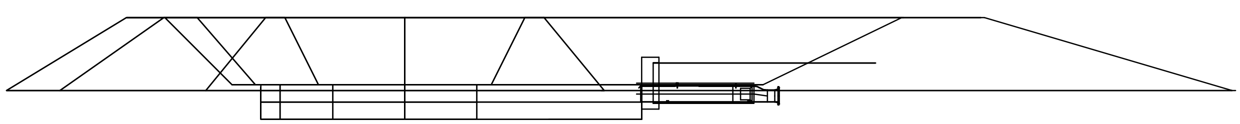
e End joints of the fabric shall be placed 2 feet (61 cm) into the "inner ring section".

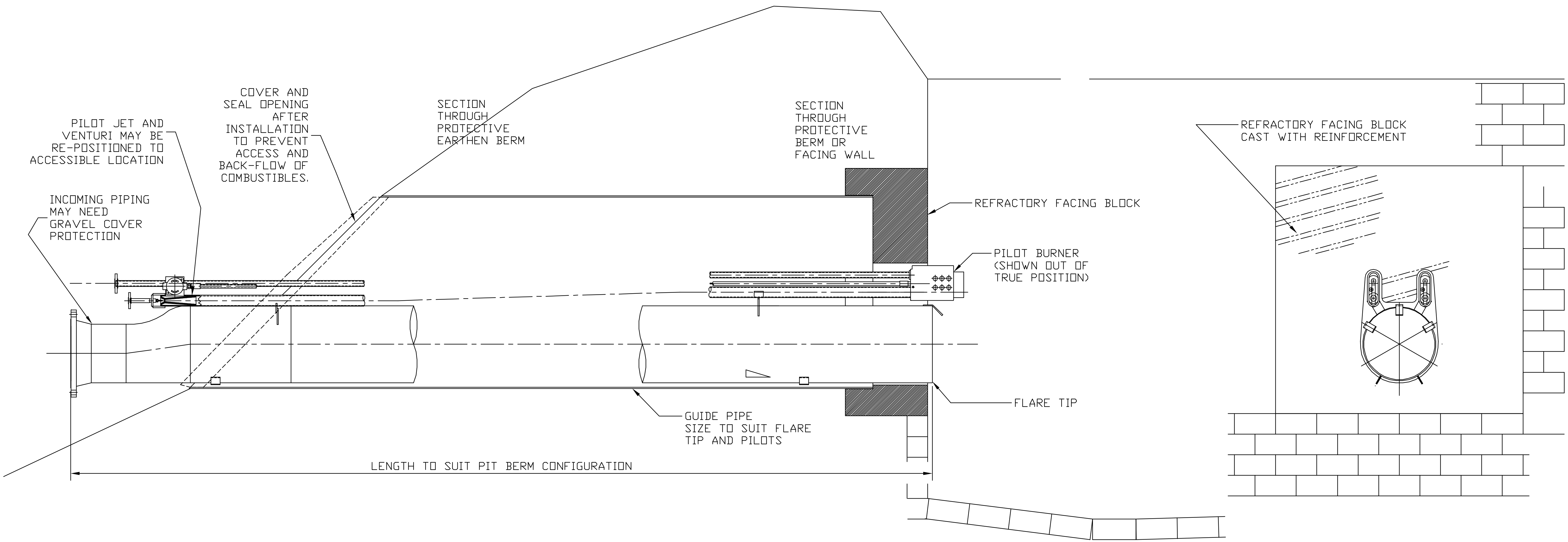
f Tears, punctures or other defects shall be repaired by the installer at no additional cost to the purchaser.

3.13 ELECTRICAL SYSTEMS

All furnished electrical systems, equipment, wiring installation and testing shall comply with latest revisions of NFPA 70, National Electrical Code (NEC), and other applicable State and local regulations. Where codes and/or standards conflict, the more stringent shall apply.



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COVER AND
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CAST WITH REINFORCEMENT
INCOMING PIPING
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(SHOWN OUT OF
TRUE POSITION)
FLARE TIP
GUIDE PIPE
SIZE TO SUIT FLARE
TIP AND PILOTS
LENGTH TO SUIT PIT BERM CONFIGURATION