cell

RISK ASSESSMENT

(QRA)

- **RISK ASSESSMENT**
- **DISASTER MANAGEMENT PLAN**

At

JAILAXMI CASTING AND ALLOYS PVT. LTD.

Gut No. 74, 75 of Pharola and Gut No. 53 of Mharola, Paithan, Aurangabad, Maharashtra, India

By

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CONTENTS

LIST OF ANNEXURE

SECTION 1: EXECUTIVE SUMMARY

M/s. Jailaxmi Casting and Alloys Pvt. Ltd., located at Gut No. 74, 75 of Pharola and Gut No. 53 of Mharola, Paithan, Aurangabad, Maharashtra, India.

The present proposal is for production augmentation project for MS, Stainless Steel & Alloy Steel Billet/Ingot Alloy Steel Bar, Rods, Flat Bars and Bright Bars from 345 TPD to 1575 TPD.

This QRA report is prepared for the above mentioned proposal towards compliance to TOR conditions and forms a part of the EIA report required for obtaining Environmental Clearance.

Risk assessment Methodology followed in preparation of this report is as per Technical EIA Guidance Manual for Induction, Electric Arc, Cupola Furnace, prepared for the Ministry of Environment and Forests Government of India.

Section 2: Describes scope of the work, and gives details of the proposed site activity, the storage arrangement and infrastructural facilities provided at site.

Section 3: Is devoted for identification of hazards the materials handled and processes used. MSDS of the substances taken for study.

Applicability of “The Manufacture Storage and Import of Hazardous Chemicals (MSIHC) Rules, 1989” formed under “The Environment Protection Act, 1986” these were amended in 1994 and 2000 checked for inventory. The inventory of hazardous chemicals does not exceed the criteria of threshold quantity as per Schedule 2 Parts I and Part II of these rules. Hence, the site is not classified as MAH (Major Accident Hazard) installation.

Relative ranking by DOW F & E Index, Fire Index as per MOND analysis are applied for storage of flammable substances area, decompositions products, reactivity and compatibility hazards are assessed.

Section 4: Consequence Analyses are carried out modeling relevant models in handling hot/ molten metal and fuels. Molten metal spill is considered as worst possible scenarios having potential for serious consequence are considered for further quantities risk estimation.

Section 5: Estimation of the event frequency of event is carried. Event tree analysis is carried out that gives. Fault tree developed for explosion at furnace due to feed material issues.

Section 6: The vulnerable zones as obtained during consequence analysis are superimposed on the satellite image of site plan termed as MARPLOT to assess the impact on the site activities and surroundings.

Section 7: The individual risk considering 200 employees engaged in site operations is estimated. The site is located in industrial park hence assuming the same population density as that of the site societal risk of fatality is estimated data collected for constructing F-N curve. It should be noted that the risk estimation is for unmitigated risk.

A series of risk mitigation measures are suggested in Section 8 of the report. These measures are of two types;

1) to reduce the probability of undesired event and
2) reducing the severity of the consequences.

As a part of risk mitigation measures in order to address the residual risk after providing risk mitigation measures following disaster control plans are prepared. Emergency Preparedness Plan, On Site Disaster Control Plan and Off Site Disaster Control Plan. In essence these plans are relevant to emergency level 1, 2 and 3 respectively. The offsite disaster control plan gives fact sheet and other dove tailing data for further use.

The study reveals that the risk posed by the proposed site activities are at reasonably acceptable level however, it should be noted it depends heavily upon the maintenance of the hardware and of the management procedures; neglect of either will lead to loss of protection and the rating will rise to the higher level.

SECTION 2: THE ASSIGNMENT

2.1 THE PROPOSAL

M/s. Jailaxmi Casting and Alloys Pvt. Ltd., located at Gut No. 74, 75 of Pharola and Gut No. 53 of Mharola, Paithan, Aurangabad, Maharashtra, India. The present proposal is for production augmentation project for MS, Stainless Steel & Alloy Steel Billet/Ingot Alloy Steel Bar, Rods, Flat Bars and Bright Bars from 345 TPD to 1575 TPD.

2.2 MANUFACTURING PROCESS

INDUCTION/ARC FURNACE

The company procures the raw material of various grade like MS, alloy steel scrap, sponge iron from various indigenous as well as import sources. These materials are melted into Induction and Arc furnace with the help of graphite electrode and oxygen blowing. Lime and dolomite is added during the process of melting. After melting process is completed liquid steel is transferred to ladle refining furnace for removal of inclusion in the steel and final chemistry is achieved with the addition of ferro alloys accordingly. Then the liquid steel is transferred to vacuum degassing station were vacuum is achieved at 1 milibar to removal of inclusion of oxygen, hydrogen and nitrogen.

CONTINUOUS CASTING MACHINE (CCM)

A billet Continuous-Casting Machine (CCM) is high-performance technology for producing high-quality steel products by continuous casting.

- Some of the advantage of CCM are as follows:
- High quality of the billet cast;
- High output capacity;
- High reliability.
- Casting a wide size range of products;
- Casting a wide grade range of products;
- Full casting process cycle, including;
- Preparation of steel teeming into molds;
- Steel teeming into molds with metal stream shrouding and unsurrounding;
- Billets cutting to cut-to-length Cooling and delivery of billets weighing.

ROLLING MILL DIVISION

Then these billets or ingots are rolled into various sizes as required by customer with the help of re-heating furnace. The billets are heated up to 1200 0C for deformation and pass through an arrangement called rolls for getting desire shape and sizes. Thereafter the bars and rounds or flat bars are inspected for any manufacturing defeats or size variation.

These bars exhibit a variation in microstructure in their cross section, having strong, tough, tempered marten site in the surface layer of the bar, an intermediate layer of marten site and binate, and a refined, tough and ductile ferrite and pearlite core.

When the cut ends of TMT bars are etched (a mixture of nitric acid and methanol), three distinct rings appear.

BRIGHT BARS DIVISION

As per customer requirement the same bars and rounds are further processed for manufacturing of bright bars which are either peeled off or drawn at draw bench. First the bars are shot blasted (no chemical process is used) and the surface scaling is cleaned the bars are drawn with the specials dies.

2.3 PROCESS FLOW CHART

FIGURE NO. 2.1: PROCESS FLOW CHART

Details	2.1.Induction/Arc/Re-heating Furnace		
Furnace No.	1 (Induction)	2 (Arc)	3 (Re-heating)
Capacity (T/ Heat)	25	30	20
Average Heat Time (Hrs)	2.5 hrs		Data Not Available
Raw Material	Scrap (%), Sponge iron (%) & Ferro Alloys		
Product	MS,SS & Alloy Billet, Bars, Rods	MS,SS & Alloy Billet, Bars, Rods& Bright Bars	MS,SS & Alloy Billet, Bars, Rods & Bright Bars
Slag Generation	5 to 10%	5 to 10%	5 to 10%
Containment System	Swivel Hood/ canopy hood	Swivel Hood/ canopy hood	Swivel Hood/ canopy hood
Air Pollution Control System	Cyclone followed by Bag Filter, spark arrestor of suction hood & ducting chimney.	Cyclone followed by Bag Filter, spark arrestor of suction hood & ducting chimney.	Cyclone followed by Bag Filter, spark arrestor of suction hood & ducting chimney.
Status	Existing	Proposed	Existing

2.4 RAW MATERIALS

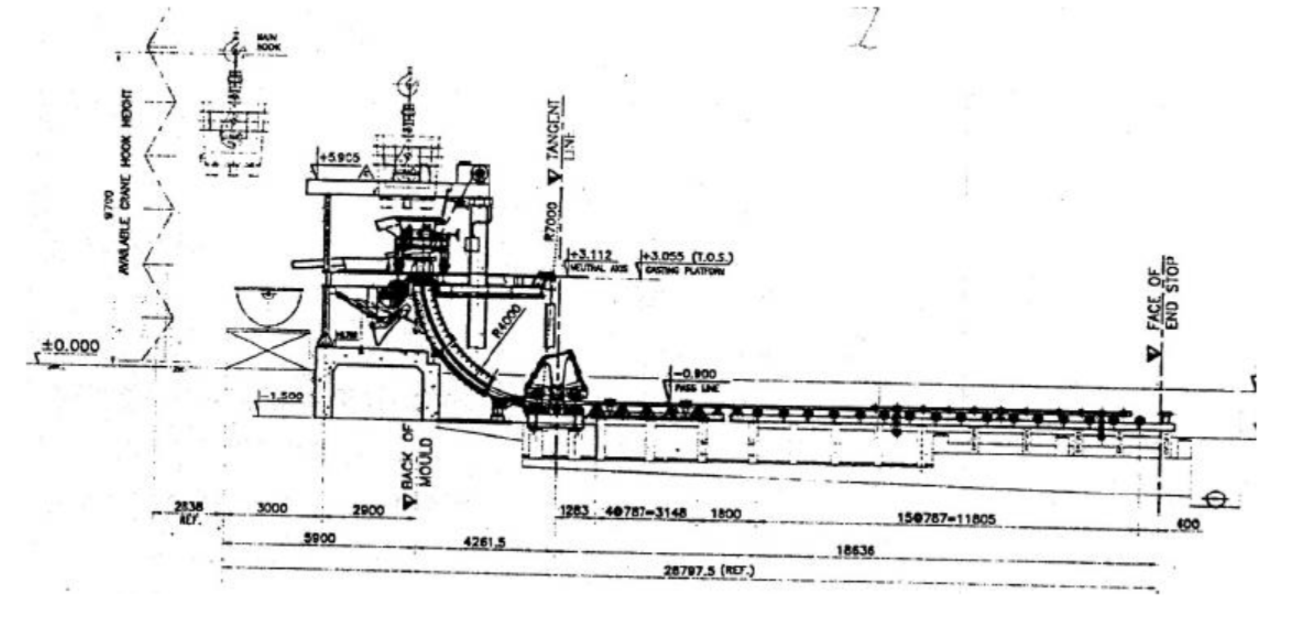
TABLE NO. 2.1: LIST RAW MATERIALS

SN	Name	Existing (TPD)	Proposed (TPD)	Total (TPD	Source	Transportation
1	Sponge Iron	95	229	324	Local	Road
2	Scrap	143	343	486	Local	Road
Ferro Alloys as						
3	FeMn	0.95	6.55	7.5	Local	Road
4	SiMn	0.25	1.75	2.0	Local	Road
5	Moly	0.06	0.44	0.5	Imported	Road
6	Ni	0.12	0.88	1.0	Imported	Road

TABLE NO. 2.2: LIST FINISH GOODS

SN	Particulars	Existing (TPD)	Proposed (TPD)	Total (TPD)
1	MS, SS & alloys billet/ingot	**220**	**530**	**750**
2	MS, SS & alloys bars & rods, flats bars	125	625	750
3	Proposed bright bars	--	75	75

FIGURE NO 2.2: CCM (TYPICAL)



FURNACE

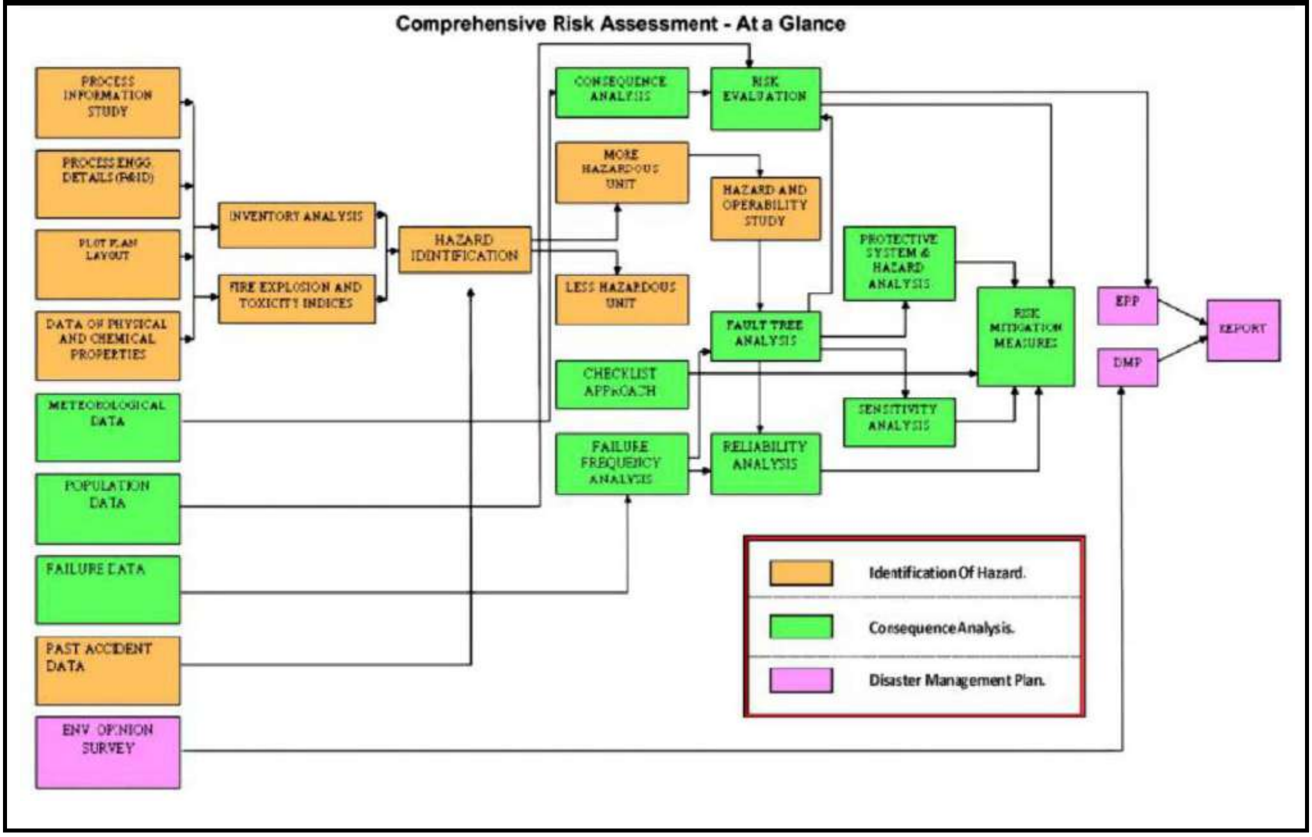
ROLLING MILL

INDUCTION/ARC FURNACE	CCM	ROLLING MILL
25 T Induction Furnace incl. PLC system for Average Demand., 30 MT Arc Furnace & 20 MT Reheating Furnace Controller and PLC based Power Optimizer15 MVA × 2 furnace duty and 2.5 MVA × 1 Auxiliary Transformer.	Billet Casting Machine 6/11 Mt. radius Three strand including Automatic Billet Shearing Machine Ladle 40/45 T capacity.	High Speed Bar Delivery system & Cooling Bed twin Channel 72 meter long Bar delivery equipment. Automatic cooling bed Cold Bar Shear.

2.5 METHODOLOGY

Methodology followed in preparation of this report is as per Technical EIA Guidance Manual for Induction, Electric Arc, Cupola Furnace, prepared for the Ministry of Environment and Forests Government of India.

FIGURE NO 2.3: RISK ASSESSMENT METHODOLOGY



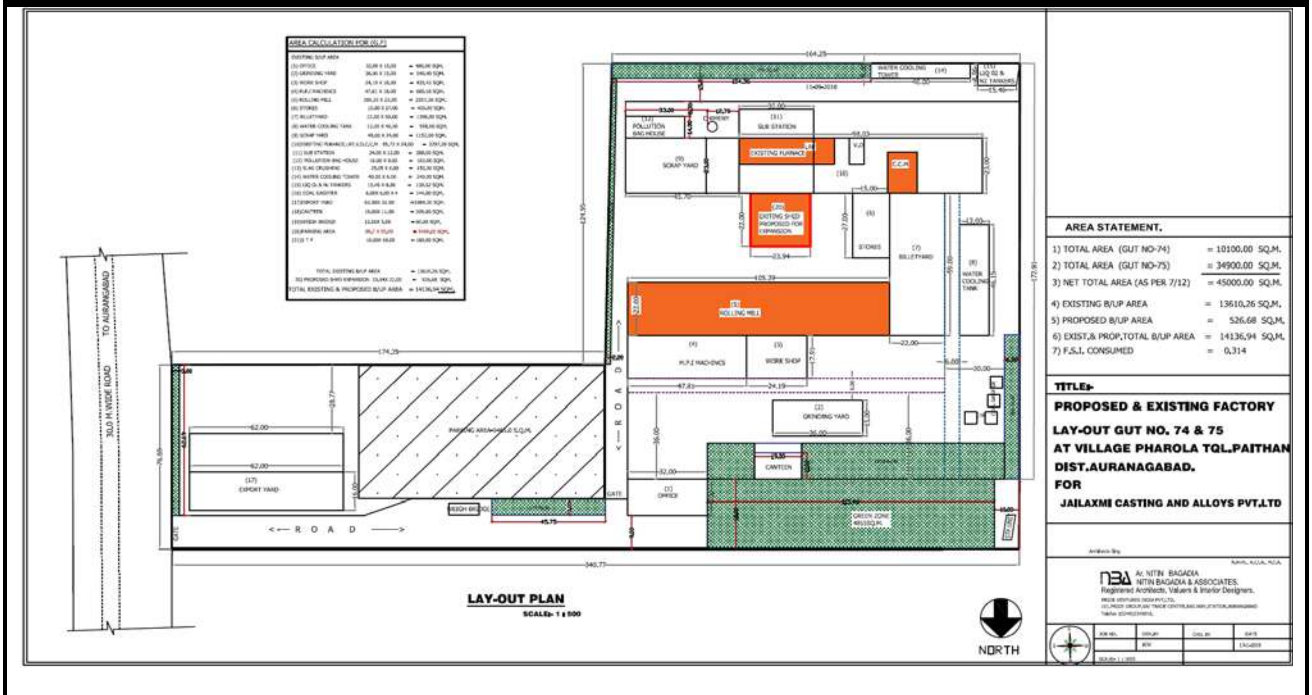
The major steps are as outlined below;

- Hazard Identification.
- Failure Frequency Analysis.
- Consequence Analysis.
- Impact Assessment.
- Protective System & Hazard Analysis.
- Risk Mitigation Measures.
- DMP.

SECTION 3: IDENTIFICATION OF HAZARDS

3.1 SITE OPERATIONS

FIGURE NO 2.3: HAZMAT MAP



Potential exposure to molten/hot metal area

TABLE NO 3.1: APPLICABILITY OF MSIHC RULES, 1989

Group		Material	Max. Storage Capacity (T)	Threshold Qty. Mt.*
5.6	Flammable Liquids.	Chemicals having 60°C < flash point < 90°C	Less than threshold*	5000

*Criteria used: "Manufacture Storage and Import of Hazardous Chemicals Rules, 1989".

The site is not Major Accident Hazards (MAH) Installation.

3.1.1 NODES

Identification of hazards by HAZOP Study under following nodes:

TABLE NO. 3.2: NODES FOR HAZOP STUDY

NODE 1	:	Induction/Arc Furnace
NODE 2	:	CCM
NODE 3	:	Hot Rolling Mill
NODE 4	:	Re-heating Furnace

3.1.2 MODES

Batch wise mode.

3.1.3 HIGHLIGHTS OF THE HAZOP STUDY

Following hazards are identified during HAZOP Study.

1. Slag drain out - spillage of liquid slag on water/ oil.
2. Injury to nearby persons due to flying spark.
3. Metal splash, heavy boiling due to foamy slag.
4. Working near hot atmosphere, UV rays, fumes during Coke injection.
5. Discharge of heat, UV rays, fumes during Slag draining in slag box.
6. Falling of person in slag pit.
7. Spillage of liquid slag on floor.
8. Working near hot atmosphere for temperature checking.
9. Working near hot atmosphere for sample collection.
10. Working near hot atmosphere & handling of hot electrode.
11. Shifting & storage of slag box to slag dumping area/ spillage of hot slag due to improperly stored slag boxes.
12. Splashing of hot liquid slag/ metal discharge of heat, UV rays, fumes while Tapping of LM in ladle.
13. Thermal radiation exposure during tapping addition Splashing of hot liquid slag/ metal during addition.
14. Thermal radiation exposure during slide gate sealing.
15. Thermal radiation exposure during slide gate opening during tapping.
16. Splashing of hot liquid slag/ metal during travel due to argon purging while ladle transfer to LF after tapping.
17. Top ten identified hazards/ events/ accident scenarios having risk rating (evaluating the ideated hazardous event on severity and Probability of the event on the scale 1 to 5 resulting in risk rating on the scale 1 to 25 during HAZOP Study) in 16 to 25 ranges are as follows:

TABLE NO. 3.3: TOP TEN IDENTIFIED HAZARDS

SN.	HAZARD
1	Thermal radiations from hot/ molten metal surface.
2	Oil Fire in part of the pit near the furnace.
3	Thermal radiations from flame during charging of furnace.
4	Fall of structure or building.
5	Health hazard due to working near hot/ molten metal.
6	Burn injury from molten metal splash/ contact.
7	Noise nuisance.
8	Health hazard due to dust, smoke, fumes and gases emissions at work place.
9	Mechanical injury in material handling.
10	Natural calamities such as flood, earth quake, cyclone etc.

Sr. No. 1 to 3: Events have potential of fire/ explosion/ toxic gas release, hence based on this exercise following accident scenarios are considered for Consequence Analysis.

SECTION 4: CONSEQUENCE ANALYSIS ACCIDENT

4.1 INTRODUCTION

4.1.1 LIKELY ACCIDENT SCENARIOS

TABLE NO. 4.1: LIKELY ACCIDENT SCENARIOS

1	Thermal radiations from hot/ molten metal surface.
2	Fire in part of the pit near the furnace.
3	Thermal radiations from flame during charging of furnace.

These accident scenarios are divided in two categories considering the consequence seriousness and occurrence frequency.

- **MAXIMUM CREDIBLE LOSS SCENARIO (MCLS).**
- **WORST POSSIBLE SCENARIO.**

4.1.2 MAXIMUM CREDIBLE LOSS SCENARIO (MCLS)

Maximum Credible Loss Scenario (MCLS) is one of the methodologies evolved to access the events in realistic and practical way. An MCLS can be described as the worst "credible" accident or as an accident with a maximum damage distance, which is still believed to be probable. The analysis, however, does not include a quantification of the probability of occurrence of an accident.

FIGURE NO. 4.1: HANDLING OF HOT METAL

The MCLS aims at identifying undesirable and hazardous events causing the Maximum damage to human beings.

The is large number of events as listed in HAZOP Study involving exposure to thermal radiation from molten metal, hot metal surfaces, hot fumes, hot surfaces etc. Hence, these events are considered as MCLS.

4.1.3 WORST POSSIBLE SCENARIO

Worst Case Scenario/ MCA (Maximum Credible Accident) Accident Scenario namely – Thermal Radiations from exposure to molten metal/ flame while charging at FURNACE is considered as Worst Case Scenario/ MCA (Maximum Credible Accident). Failure of a Oxygen 50 Mt. storage vessel is considered as MCA (Maximum Credible Scenario/ Worst Possible Accident Scenario).

4.2 ACCIDENT SCENARIO NO. 1: MCLS

THERMAL RADIATIONS FROM MOLTEN METAL SURFACE OF 0.8 m DIA.

The heat loss 'Q' from the hot surface of opening of the FURNACE is predominantly by radiation, so that following equation can be used for estimation of thermal radiations.

$$Q = A_r \times \sigma \times \left(T_g^4 - T_a^{\ 4}\right)$$

Where;

Q = Heat loss by radiation (W).
A_r = The area of radiation of the hot gas layer (m^2).
Σ = Stefan – Boltzmann constant.
= 5.67×10^{-8} W/m^2 K^4.
T_g = The absolute temperature of the hot gas (K).
= 1773 K.
T_a = The absolute temperature of the environment (K).
= 303 K.

It is estimated that the effective thermal radiation intensity 'Q' will be 555 KW/m^2. Thermal radiations at a distance from the centre of the open FURNACE will be as estimated as follows;

THERMAL RADIATION

The radiative flux qt on a target at a distance R (away from the center of fire) is given by:

$$Q_t = EFT$$

Where, F = Geometric View factor.
T = Atmospheric coefficient Transmissivity.
E = Radiation flux at the source.

TABLE NO. 4.2: THERMAL RADIATIONS FROM HOT METAL SURFACE

X_m	0.5	1	1.67	2	3
Thermal Radiation (KW/m^2)	11.6	6.9	4.0	2.7	1.6

4.3 ACCIDENT SCENARIO NO. 2:

FIRE IN PART OF THE PIT NEAR THE FURNACE

Accidental release of molten metal in pit will lead to pool fire of the oil/ combustibles (if any) in the pit near furnace.

EQUIVALENT POOL DIAMETER

The pool formed in part of the rectangular shape pit equivalent pool diameter can be estimated by following formula.

$$d_{eq} = \frac{4 \times \ Area \ \ of \ pool}{Circumferance}$$

Pit of equivalent pool diameter will be 2.6 meters.

Considering surface emissive power 40 KW/m^2 thermal radiations from the centre of the fire will be as follows:

RESULTS:

TABLE NO. 4.3: THERMAL RADIATIONS FROM FIRE AT PIT

THERMAL RADIATION LEVEL	EFFECT DISTANCE
Distance to 12.5 KW/M^2 (1% Lethality)	1.3 meters.
Distance to 4.0 KW/M^2 (Emergency action)	2.42 meters.

4.4 ACCIDENT SCENARIO NO. 3: MCA

TABLE NO. 4.4: THERMAL RADIATIONS FROM FLAME DURING CHARGING OF FURNACE

THERMAL RADIATION LEVEL	EFFECT DISTANCE
Distance to 10.0 KW/m^2. (Potentially lethal within 60 sec).	4.9 meters
Distance to 05.0 KW/m^2. (2nd degree burns within 60 sec).	7.2 meters
Distance to 02.0 KW/m^2. (Pain within 60 sec).	10.2 meters

THERMAL RADIATIONS FROM FLAME DURING CHARGING OF FURNACE

FIGURE NO 4.2: CHARGING FURNACE

Note 1 : The potential consequences from for identified hazardous scenarios have been estimated using software based on the "TNO Yellow Book". Method for calculation of the Physical Effects of the escape of Dangerous Material (Liquid & Gases) Published by the Directorate General of Labour, Ministry of Social affair, Netherlands (1979) and ALOHA/ PHAST It is an air dispersion model developed by Environmental Protection Agency (EPAUSA) used as a tool for predicting the movement and dispersion of gases. The stable atmospheric stability conditions, ambient temperature of 30^{o}C, wind speed was 1.5 m/s and humidity (50%), No inversion used for Consequence Analysis.

Note 2 : Apart from the maximum credible releases, the conservative approach appears in adoption of atmospheric conditions, used in the dispersion calculation. In general, the assumptions/ conditions will result in the largest damage distances. Hence, it must be remembered that this analysis will be pessimistic & conservative in approach & is only a planning tool. Its use should not be extended without understanding its limitations.

Note 3 : DISCLAIMER:

Information contained in this report is believed to be reliable but no representation; guarantee or warranties of any kind are made as to its accuracy, suitability for a particular application or results to be obtained from them. It is up to the manufacturer to ensure that the information contained in the report is relevant to the product manufactured/ handled or sold by him as the case may be. We make no warranties expressed or implied in respect of the adequacy of this document for any particular purpose.

SECTION 5: FAILURE FREQUENCY ANALYSIS

5.1 FAILURE FREQUENCY ASSESSMENT

The frequency assessment stage of the analysis involved defining the potential release sources and subsequently determining the likelihood (frequency) of the various releases. The failure frequencies were determined using failure item counts for each of the failure items identified and publicly available historical failure rate data. Ignition probability data was used to estimate the probability of a release subsequently being ignited.

5.1.1 Flange gasket failure/ gland failure. An accident/ event for gasket leakage/ failure can be termed as "quite probable". The hole size in a gasket failure may be that due to complete section between bolt holes or something much smaller. The hole size for a complete section failure of a gasket is usually calculated.

5.1.2 Failure of transfer line. The possible route of hazardous material going out of containment in open atmosphere is the rupture of a transfer line. The case of guillotine type failure of transfer line or bottom nozzle undergoing guillotine type of failure also is rather low. Failure frequency as per published literature for such lines is low and such events can be considered, "foreseeable".

5.1.3 Explosion in FURNACE is considered as one of the Worst Possible Scenario. It is to be noted that loss caused due to this event is very high but the probability is low; however, in case of neglect of charge preparation, maintenance or natural calamities such as earthquake the possibility exists. Such events are unlikely to happen and are not credible. Failure frequency of catastrophic rupture of such pressure vessel is very low i.e. 3 per million per year.

TABLE NO. 5.1:
TYPICAL FREQUENCY VALUES ASSIGNED TO INITIATING EVENTS

SN.	Accident Scenario	Frequency range from literature (per Year)	Value chosen for present study use in LOPA (per year)
1	Piping leak (10% section) – 100 m.	10^{-3} to 10^{-4}	1×10^{-3}
2	Gasket/packing blowout.	10^{-2} to 10^{-6}	1×10^{-2}
3	Unloading/ loading hose failure.	1 to 10^{-2}	1×10^{-1}
4	Regulator failure.	1 to 10^{-2}	1×10^{-1}
5	Small external fire. (aggregate causes).	10^{-1} to 10^{-2}	1×10^{-1}
6	Operator failure (to executive routine procedure, assuming well trained, unstressed, not fatigued).	10^{-1} to 10^{-3}	1×10^{-2}

5.1.4 The failure frequency indicated in above table is based on study made for well-maintained plants. Above table provides base failure frequency for each failure case but which is subjected to modification due to factors unique to a particular plant such as follows;

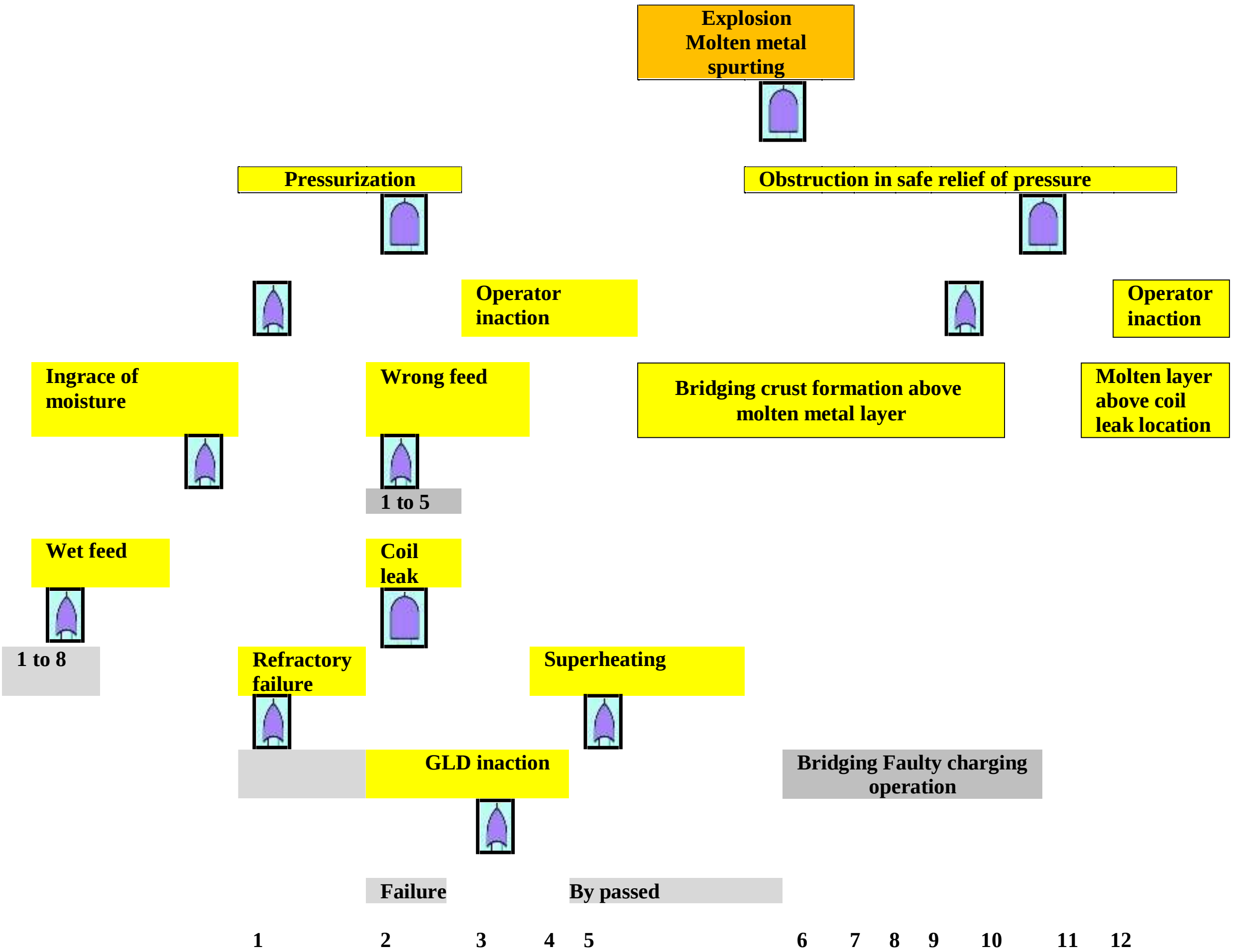
- Operator intervention,
- Presence of ignition sources etc.

TABLE 5.2: EVENT FAILURE FREQUENCY

SN.	Event	Event Frequency/ Yr
1	Oil release.	1×10^{-3}

It is reasonable to assume this change however it should be noted it depends heavily upon the maintenance of the hardware and of the management procedures; neglect of either will lead to loss of protection and the rating will rise to the original estimate (a) indicated above.

FAULT TREE ANALYSIS



Where;

	AND Gate	The resulting output event requires the simultaneous occurrence of all input events.
	OR Gate	The resulting output event requires the occurrence of any individual input event.

MOISTURE FROM FEED	
1	Wet or damp materials charge.
2	Easily fragmented charge may contain a thin layer of surface or absorbed moisture.
3	Charging of wet or damp tools or additives.
4	Ferro - alloy materials can absorb moisture from their surroundings.
5	Sampling spoons and slag rakes collect moisture as a thin film of condensation.
6	Introduction of ingots into the melt, as surface condensation comes in contact with molten metal.
7	Charging of cold charge that may contain a thin layer of surface or absorbed moisture.
8	Moisture condensation and splashing due to humidity from the open air. The greatest splashing hazards are likely to occur at the beginning of the work week or workday or after a shutdown. Allowing more time for the initial melt during these start-up periods can help reduce the potential for splashing hazards.

WRONG FEED	
1	**Charging of centrifugally cast scrap rolls:** There is possibility that a roll may contain a ductile inner core surrounded by a brittle outer layer. The different rates of expansion can cause the surface material to explosively separate from the roll injuring personnel and damaging equipment.
2	**Addition of sealed scrap:** Addition of Sections of tubing or piping that are sheared - closed on both ends) to the molten bath.
3	**Sealed Containers:** The air inside them can rapidly expand in the heat In extreme cases, the pressure buildup will be sufficient to breach the container wall or escape through a sheared-closed end. If this occurs, the forceful expulsion of gas can propel the hot scrap out of the furnace or smash it into the furnace lining.
4	Charging cans or containers containing oil to molten bath.
5	Charging drums or containers containing water into an empty but hot furnace the force of the explosion will eject the newly charged material and quite likely damage the refractory lining as well.

SUPERHEATING OF THE INDUCTION FURNACE	
1	Excessive metal stirring below the bridge, due to the small metal mass and high power density, will combine with the high metal temperatures to cause rapid lining erosion or possibly complete refractory failure.
2	**GLD** (ground leak detector) **not functioning or bypassed.**

COIL LEAK	
1	Coil failure Bridging followed by refractory failure affecting the coil and when cooling water comes in contact with the molten metal, the water instantaneously turns into steam.

2	Worn out/ poorly maintained coil failure.

REFRACTORY FAILURE	
1	Installation of the wrong refractory material for a particular application.
2	Inadequate or improper installation of refractory material.
3	Improper sintering of the refractory material.
4	Inadequate or improper preheating of used refractory from cold.
5	Failure to monitor normal lining wear and allowing the lining to become too thin.
6	Failure to properly maintain the furnace.
7	The sudden or cumulative effects of physical shocks and mechanical stress can lead to failure of refractory lining. Most refractory materials tend to be brittle and weak in tension.
8	The sudden or cumulative effects of excessive temperatures or thermal shocks or improper thermal cycling of lining. If furnace operating conditions heat or cool the lining beyond its specified range.
9	Highly abrasive materials, (Excessive Slag or dross buildup) slag and dross erode lining near the level of the molten metal. In extreme circumstances, this erosion may expose the induction coil, creating the risk of a water/ molten metal explosion.
10	Regular wear from the scraping of metal on the furnace walls.
11	Mechanical Stress due to difference in thermal expansion rates of the charge and refractory material.
12	Bulky charge material dropped into an empty furnace can easily cause the lining to crack upon impact. If a crack goes unnoticed, molten metal may penetrate, leading to a run-out with the possibility of a water/ molten metal explosion.

SECTION 6: IMPACT ASSESSMENT

Effect models are used for the impact analysis. These models used to determine how people are injured by exposure to heat, overpressure and toxic load. Effect models make use of a probit function. In probit function a link exists between the load and percentage of people exposed who suffer particular type of injury.

6.1 THERMAL RADIATION IMPACT

6.1.1 HEAT DISORDERS AND HEALTH EFFECTS

Heat Stroke

Heat Stroke occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. This condition is caused by a combination of highly variable factors, and its occurrence is difficult to predict. Heat stroke is a medical emergency. The primary signs and symptoms of heat stroke are confusion; irrational behavior; loss of consciousness; convulsions; a lack of sweating (usually); hot, dry skin; and an abnormally high body temperature, e.g., a rectal temperature of 41°C (105.8°F). If body temperature is too high, it causes death. The elevated metabolic temperatures caused by a combination of work load and environmental heat load, both of which contribute to heat stroke, are also highly variable and difficult to predict.

If a worker shows signs of possible heat stroke, professional medical treatment should be obtained immediately. The worker should be placed in a shady area and the outer clothing should be removed. The worker's skin should be wetted and air movement around the worker should be increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment.

Regardless of the worker's protests, no employee suspected of being ill from heat stroke should be sent home or left unattended unless a physician has specifically approved such an order.

Heat Exhaustion

The signs and symptoms of heat exhaustion are headache, nausea, vertigo, weakness, thirst, and giddiness. Fortunately, this condition responds readily to prompt treatment. Heat exhaustion should not be dismissed lightly, however, for several reasons. One is that the fainting associated with heat exhaustion can be dangerous because the victim may be operating machinery or controlling an operation that should not be left unattended; moreover, the victim may be injured when he or she faints. Also, the signs and symptoms seen in heat exhaustion are similar to those of heat stroke, a medical emergency.

Workers suffering from heat exhaustion should be removed from the hot environment and given fluid replacement. They should also be encouraged to get adequate rest.

Heat Cramps

Heat Cramps are usually caused by performing hard physical labor in a hot environment. These cramps have been attributed to an electrolyte imbalance caused by sweating. It is important to understand that cramps can be caused by both too much and too little salt. Cramps appear to be caused by the lack of water replenishment. Because sweat is a hypotonic solution (±0.3% NaCl), excess salt can build up in the body if the water lost through sweating is not replaced. Thirst cannot be relied on as a guide to the need for water; instead, water must be taken every 15 to 20 minutes in hot environments.

Under extreme conditions, such as working for 6 to 8 hours in heavy protective gear, a loss of sodium may occur. Recent studies have shown that drinking commercially available carbohydrate-electrolyte replacement liquids is effective in minimizing physiological disturbances during recovery.

Heat Collapse (“Fainting”)

Heat Collapse ("Fainting"). In heat collapse, the brain does not receive enough Oxygen because blood pools in the extremities. As a result, the exposed individual may lose consciousness. This reaction is similar to that of heat exhaustion and does not affect the body's heat balance. However, the onset of heat collapse is rapid and unpredictable. To prevent heat collapse, the worker should gradually become acclimatized to the hot environment.

Heat Rashes

Heat Rashes are the most common problem in hot work environments. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

Heat Fatigue

A factor that predisposes an individual to heat fatigue is lack of acclimatization. The use of a program of acclimatization and training for work in hot environments is advisable. The signs and symptoms of heat fatigue include impaired performance of skilled sensorimotor, mental, or vigilance jobs. There is no treatment for heat fatigue except to remove the heat stress before a more serious heat-related condition develops.

6.1.2 HEAT FLUX EXPOSURES

The effect of human exposure to a fire is a function of both the intensity of heat radiation and the duration of exposure. The harmful effect can be characterized by a thermal dose that is defined by the function $\left[t \times I^{\left(\frac{4}{3}\right)} \right]$.

Where,

Y	=	probit value,
I	=	heat radiation intensity, and
t	=	exposure duration.

The probit equation utilized is the Eisenberg equation.

$$Y = -14.9 + 2.56 \left\{ \ln \left[t \times I^{\left(\frac{4}{3}\right)} \right] \right\}$$

A probit function has been used to evaluate the likelihood of fatality for different heat flux exposures.

A radiation level of 12.5 KW/m^2 will give 1 % fatalities for short exposure periods of 30 seconds and 50 % fatalities for exposures of over 80 seconds.

TABLE NO. 6.1: FATAL THERMAL RADIATION EXPOSURE LEVELS

RADIATION LEVEL KW/m^2	SECONDS EXPOSURE FOR A % FATALITY LEVELS		
	1 %	50 %	99 %
1.6	500	1300	3200
4.0	150	370	930
12.5	30	80	200
37.5	8	20	50

TABLE NO. 6.2: EFFECTS OF THERMAL RADIATION ON UNPROTECTED SKIN

RADIATION LEVEL (KW/m^2)	DURATION PERIOD SECONDS BEFORE	
	Pain is Felt	Blistering Starts
22	02.0	03.0
18	02.5	04.3
11	05.0	08.5
08	08.0	13.5
05	16.0	25.0
2.5	40.0	65.0
Below 2.5	Prolonged exposure can.	be tolerated.

Continued exposure to heat flux of 4.0 KW/m^2 is considered sufficient to cause injury. Hence, injury risk was assessed based on exposure to this level of heat flux or greater. It is assumed that any person near fire can take shelter within 90 seconds. It is estimated that heat flux of distance from the centre of the fire. It is estimated that heat flux of 10.0 KW/m^2 and 4.0 KW/m^2 is likely up to 10 m and 13 m distance respectively from the centre of the pool fire of Oil.

6.1.3 PERSONNEL EXPOSURE

(Thermal impact excluding solar radiation).
Access limitation recommendation for various levels of thermal radiation Persons escape conditions used in this grid are as follows;

Where,

G	=	General public/ visitors	:	3 fps.
P	=	Plant personnel	:	8 fps.
M	=	Maintenance/ operators	:	12 fps.

TABLE NO. 6.3: DRESS CODE THERMAL DOSAGE TO THRESHOLD

DRESS CODE	THERMAL MASS OF CLOTHING (K)	TOTAL THERMAL DOSAGE TO THRESHOLD
	Btu/^{o}F-Ft ^{2}	Btu/Ft^2
Bare skin.	0	Varies
Light.	0.3	15
Heavy.	0.84	42
Multiplayer.	2.5	125

Recommendations are based on total dosage with prior exposure to 70^{o}F ambient. Higher ambient temperatures reduce available dosage and suggested distance to shelter for clothed personnel.

DOSAGE TO PAIN		
	Bare skin.	83.89 ($I^{0.4815}$)
	Clothed.	$K \times (120 - T_{amb})$

TABLE NO.6.4: THERMAL RADIATION PERSONS ESCAPE DISTANCE

Radiant Intensity KW/m^2	Estimated Subjective Stimulus Level	Dress Code	EXPOSURE	
			Duration Prior To Pain	Max Distance To Nearest Shelter, By Group
0.978	Heated.	Bare Skin.	65 sec.*	Unlimited.
		Light.	Unlimited.	Unlimited.
		Heavy.	Unlimited.	Unlimited.
		Multi Layer.	Unlimited.	Unlimited.
1.304	Discomfort.	Bare Skin.	42 sec.*	Unlimited.
		Light.	2.2.5 min.*	G=325ft; P=1100ft; M=Unlimited.
		Heavy.	Unlimited.	Unlimited.
		Multi Layer.	Unlimited.	Unlimited.

Radiant Intensity KW/m2	Estimated Subjective Stimulus Level	Dress Code	EXPOSURE	
			Duration Prior To Pain	Max Distance To Nearest Shelter, By Group
1.630	Discomfort with desire to remove from area.	Bare Skin.	30 sec.*	Unlimited.
		Light.	1.8 min.*	G = 325 ft; P = 865 ft; M = Unlimited.
		Heavy.	5 min.	G=1000 ft; P = Unlimited; M = Unlimited.
		Multi Layer.	15 min.	Unlimited.
2.450	Discomfort strong desire to remove from area.	Bare Skin.	17 sec.*	Unlimited.
		Light.	1.2 min.*	G = 215 ft; P = 575 ft; M = 865 ft.
		Heavy.	3.4 min.	G = 615 ft; P = Unlimited; M = Unlimited.
		Multi Layer.	10 min.	Unlimited.
3.260	Obvious need to remove from area.	Bare Skin.	Avoid.	Unlimited.
		Light.	54 sec.	G = Avoid; P = 430 ft; M = 650 ft.
		Heavy.	2.5 min.	G = Avoid; P=Unlimited; M = Unlimited.
		Multi Layer.	7.5 min.	G = Avoid; P=Unlimited; M = Unlimited.
4.890	Desire to escape.	Bare Skin.	Avoid.	Avoid.
		Light.	36 sec.	G = Avoid; P= 290 ft; M = 430 ft.
		Heavy.	1.68 min.	G = Avoid; P = 800 ft; M = Unlimited.
		Multi Layer.	5 min.	G = Avoid; P = Unlimited; M = Unlimited.
6.520	Obvious need for rapid escape.	Bare Skin.	Avoid.	Avoid.
		Light.	27 sec.	G = Avoid; P = Avoid; M = 325 ft.
		Heavy.	1.25 min.	G = Avoid; P = 600 ft; M = 900 ft.
		Multi Layer.	3.75 min.	G = Avoid; P = Unlimited; M = Unlimited.
9.780	Obvious need for urgent escape.	Bare Skin.	Avoid.	Avoid.
		Light.	18 sec.	G = Avoid; P = Avoid; M = 215 ft.
		Heavy.	5.0 min.	G = Avoid; P = 400 ft; M = 600 ft.
		Multi Layer.	2.5 min.	G = Avoid; P= Unlimited; M = Unlimited.

Time with * may be lengthened by physical activity.

6.1.4 STRUCTURE AND EQUIPMENT EXPOSURE

Thermal Stability

The thermal conditions surrounding materials affect them in a verity of ways. Foremost among these effects are the reactions which produce phase and micro structural changes. Another is stability of materials in relation to thermal stresses and the accompanying dimensional changes. Thermal cracking is possible whenever thermal variations produce volume changes.

Thermal Fatigue

Thermal fatigue also may occur in systems subjected to cycles of many sudden changes of temperature. Repeated cycles of rapid heating or drastic cooling tend to reduce the capacity of the material for plastic deformation therefore, favoring the formation of a as thermal crack.

6.2 OVER PRESSURE IMPACT

Vapor cloud explosion is not likely.

6.3 TOXICITY IMPACT

CARBON MONOXIDE

TABLE NO. 6.5: HEALTH EFFECTS OF EXPOSURE

CONCENTRATION		CONCENTRATION SYMPTOMS OF EXPOSURE
ppm in air	% COHb in blood	
1-3	0.7-0.8	Normal.
30-60	5-10	Exercise tolerance reduced; heavy smoker has these levels burden.
35	6	Time Weighted Average Exposure Value.
60-150	10-20	Frontal headache. Shortness of breath on exertion.
150-300	20-30	Throbbing headache, dizziness, nausea, manual dexterity.
300-650	30-50	Severe headache, nausea and vomiting, confusion.
700-1000	50-65	Coma, convulsions.
1000-2000	65-70	Heart and lung function impaired, fatal, if not treated.
Over 2000	>70	Unconsciousness and death.

Probit correlation for co – exposure fatality (Vulnerability Analysis).

The PROBIT equation for deaths resulting from Carbon Monoxide is as follows. The PROBIT variable P_r is computed from the following equation;

$$P_r = -37.98 + 3.7\left[\ln\left(C^1 \times T\right)\right]$$

P_r = Is the probit (probit = probability unit), the measure for the percentage of people exposed who incur a particular injury.

V = Causative variable. The causative factor represents the dose/ load V. (The causative variable is representative of the magnitude of the exposure).

$$V = Causative\ \ Variable$$

$$= \sum_{,} C^{1.0} T$$

Where;

C = Concentration (ppm).

T = Time interval (min).

n = Constant depend on the toxic substance which has value 1 in this case.

The concentration of Carbon Monoxide at shop floor is insignificant at shop floor to cause fatality however, it is advisable to introduce regular detection and monitoring system at shop floor.

SECTION 7: RISK ASSESSMENT

7.1 INDIVIDUAL RISK

Individual risk is defined by AIChE/ CCPS as risk to a person in the vicinity of a hazard. This includes the nature of the injury to the individual, the likelihood of the injury occurring and the time period over which the injury might occur. Individual risk can be estimated for the most exposed individual, for groups of individuals at particular places or for an average individual in an effect zone. For a given incident or set of incidents, these individual risk measures have different values.

Individual Risk due to incidence 'I' at a geographical location *x, y* is given as;

$$IR_{x,y} = \left(\frac{1}{N}\right) \sum IR_{x,y,i}$$

Where,

N is number of persons in the affect zone.

$$\text{INDIVIDUALRISK}\,(IR) = \left(\frac{1}{N}\right) \sum I_i \times F_i$$

Where;

N	=	number of persons (200 nos. at assembly point).
I	=	incident identification number.
I_i	=	impact of incident 'I'.
F_i	=	frequency of the 'i' incident.

Average individual risk (exposed hours/worked hours) individual risk of burn injury to personnel (assuming two persons working in the area) due to heat flux of 4.0 KW/m^2 estimated to be 2×10^{-5} at 13 m and the fatality risk $1{\times}10^{-6}$ due to heat flux of 10.0 KW/m^2. Isopleth being the counter of radius 10 m from the centre of pit oil pool fire.

TABLE 7.1: INDIVIDUAL FATALITY CRITERIA

Individual Fatality (IR)	Individual Fatality Criteria
1×10^{-4} per year	**This contour should remain on-site.**
1×10^{-5} per year	**This contour can extend into industrial developments only.**
1×10^{-6} per year	**This contour can extend into commercia l and industrial developments only.**

7.2 SOCIETAL RISK (F – N CURVE)

Societal risk criteria are generally presented as curves on F – N plots. Mathematically, the equation for an F – N criterion curve may be presented as; [Ball 19981].

$$F = k \times N^{-a}$$

Where,

F	=	the cumulative frequency of N or more fatalities.
N	=	the number of fatalities.
a	=	aversion factor (often between 1 and 2).
k	=	constant.

The slope of the societal risk criterion (when plotted on a log – log basis) is equal to " –a " and represents the degree of aversion to multi-fatality events embodied in the criterion. When the F – N curve slope is equal to -1, the risk criterion is termed 'risk neutral'. A risk criterion for which the curve slope is more negative than -1 is said to be more risk averse. An anchor point along the curve (e.g. N=10 fatalities, $F=10^{-3}$/year) and a slope (e.g. -1) is usually enough information to plot a risk criterion F – N curve. if any portion of the calculated F – N curve exceeds the criterion line, the societal risk is said to exceed that risk criterion. In the present case the slope is negative and the curve is well below the criterion line indicates insignificant societal risk.

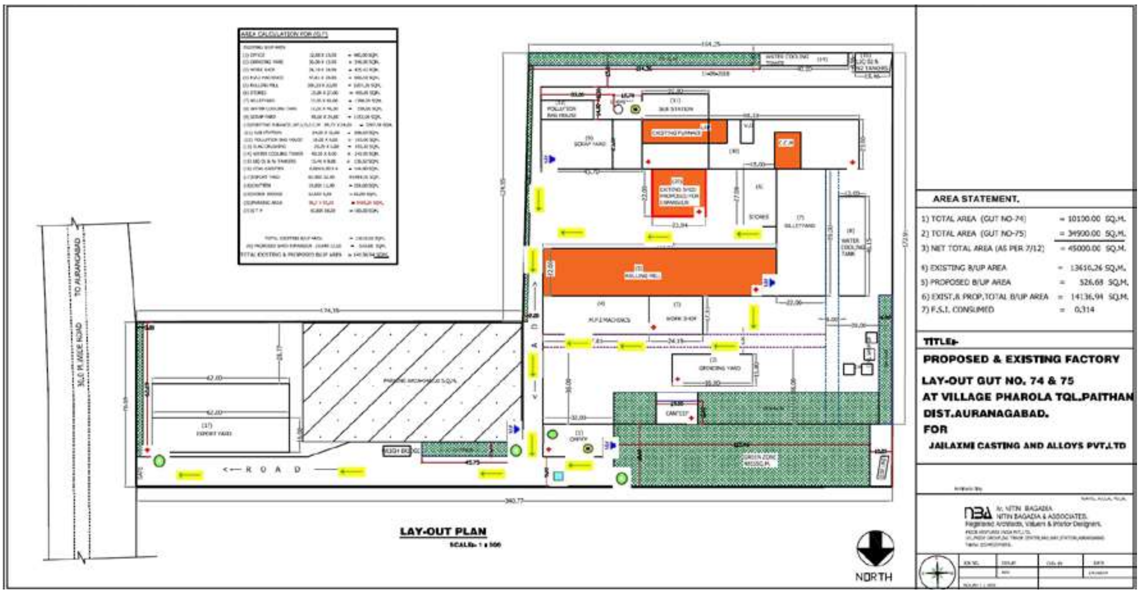
The estimated consequences of the thermal radiations are well contained within the premises of the factory and surrounding population is not likely to be affected.

SECTION 8: RISK MITIGATION MEASURES SUGGESTED

1. Induction furnaces should be provided with fume extraction and dedicated pollution control systems consisting of swiveling hood spark arrestor bag filter or any other suitable dust catcher ID fan and stack of suitable height.
2. A secondary fume extraction system with adequate side suction should be provided to prevent fugitive emissions during charging. The suction should be adequate to control fugitive emissions collected dust can be sold provided it does not exhibit the properties of hazardous waste.
3. Ensure over head tank full by installing alarms or water level controller.
4. Emergency furnace cooling water inlet valve should be closed when furnace is not operating to avoid emptying the over head tank. During normal operation of furnace Emergency furnace cooling water inlet valve and Furnace cooling water inlet valve should be in open position. These valves should be installed near the furnace platform for easy & prompt operation.
5. Check non return valves operation before starting the furnace.
6. Provide uniform level of furnace platform for all the furnaces, ensure the rails protruding with respect to ground are in the level of platform.
7. Insist on use of appropriate PPE (Personnel Protective Equipments) such as; heat and flame retardant clothing, lace less safety shoes, fire suit, aprons, jackets, caps, safety glasses, face shields, gloves, hard hats while working near the furnace. Maintain the PPE in working condition.
8. Provide mirror for viewing level of molten metal in furnace from distance.
9. Insist on regular removal of trash, spill oil from the pit near furnace.
10. Prohibit unauthorized entry to pit area display board to that effect.
11. Provide crane anti collusion device.
12. Avoid use of short length of the rod for sampling/ slag removal operation.
13. Provide safety training to workers on site operations. And carry out periodic medical surveillance of workers.
14. Structural members of the furnace shed and equipments are subjected to thermal stresses and may fail due to Thermal Fatigue. Introduce periodic inspection and structural stability checks.

15. A practical working document DMP for site as per the format specified under "The MSIHC Rules, 1989" is prepared. Emergency organization, roles and responsibilities are detailed in the plan.

FIGURE NO. 8.1: ON SITE DISASTER CONTROL PLAN



Siren	Assembly Point	First Aid	Water Storage
Emergency Control Centre	Escape Route	Wind direction Sack	Hazardous Area Fire/ Explosion/ toxic gas release

ANNEXURE 1: GLOSSARY

A calorie	:	A calorie is the amount of heat required to raise 1 gram of water 1°C (based on a standard temperature of 16.5 to 17.5 °C).
Acceptance Criteria (Risk)	:	Defines the level of risk to which an individual is exposed, as either tolerable (negligible risk), intolerable or within the ALARP region.
Conduction	:	Conduction is the transfer of heat between materials that contact each other Heat passes from the warmer material to the cooler material For example, a worker's skin can transfer heat to a contacting surface if that surface is cooler, and vice versa.
Consequence	:	This is the severity associated with an event in terms of toxic doses, fire or explosion etc., i.e. the potential effects of a hazardous event.
Convection	:	Convection is the transfer of heat in a moving fluid Air flowing past the body can cool the body if the air temperature is cool On the other hand, air that exceeds 35°C (95°F) can increase the heat load on the body.
Dry Bulb (DB)	:	Temperature is measured by a thermal sensor, such as an ordinary mercury-in-glass thermometer, that is shielded from direct radiant energy sources.
ERPG	:	The Emergency Response Planning Guidelines. ERPG 1: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor. ERPG 2: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action. ERPG 3: The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.
Evaporative Cooling	:	Evaporative cooling takes place when sweat evaporates from the skin High humidity reduces the rate of evaporation and thus reduces the effectiveness of the body's primary cooling mechanism.
Frequency	:	This is the number of occurrences of an event expressed per unit time. It is usually expressed as the likelihood of an event occurring within one year.
Globe Temperature	:	Globe temperature is the temperature inside a blackened, hollow, thin copper globe.
Hazard	:	A physical situation with the potential for human injury, damage to property, damage to the environment or some combination of these.
Hazardous Scenario	:	The identified isolatable sections and/or those which have been broken down into scenarios for specific items of equipment.
Heat	:	Heat is a measure of energy in terms of quantity.
IDLH	:	Immediately Dangerous To Life And Health. The maximum concentration would not cause any escape imparting symptoms or irreversible health effects to a person exposed for 30 minutes.

Individual Risk	: The frequency at which an individual may be expected to sustain a given level of harm from the realization of specified hazards.
Individual Risk Of Fatality	: Individual risk with "harm" measured in terms of fatality. It is calculated at a particular point for a stationary, unprotected person for 24 hours per day, 365 days per year. Normally measured in chances of fatality per million years.
Individual Risk Of Injury	: Similar to individual risk of fatality, however with "harm" measured in terms of injury.
Individual Risk Contours	: As IR (Individual Risk) is calculated at a point, calculating the IR at many points allows the plotting of IR contours, these being lines that indicate constant levels of risk. Most commonly used are the 1 chance per million-year contour and the 10 chances per million-year contour.
LEL	: Lower Flammability Limit. Expressed as % by volume of flammable gas in air. This is the minimum concentration of gas in air mixture which can ignite. Gas air mixtures below this concentration do not ignite.
Metabolic Heat	: Metabolic heat is a by-product of the body's activity.
Natural Wet Bulb (NWB) Temperature	: Natural Wet Bulb. (NWB) temperature is measured by exposing a wet sensor, such as a wet cotton wick fitted over the bulb of a thermometer, to the effects of evaporation and convection The term natural refers to the movement of air around the sensor.
Probability	: The expression for the likelihood of an occurrence of an event or an event sequence or the likelihood of the success or failure of an event on test or demand. By definition, probability must be expressed as a number between 0 and 1.
Quantitative Risk Assessment	: A Risk Assessment undertaken by combining quantitative evaluations of event frequency and consequence.
Radiation	: Radiation is the transfer of heat energy through space A worker whose body temperature is greater than the temperature of the surrounding surfaces radiates heat to these surfaces Hot surfaces and infrared light sources radiate heat that can increase the body's heat load
Risk Reduction	: The process of risk assessment coupled to a systematic consideration of potential control measures and a judgment on whether they are reasonably practicable to implement.
Risk	: The combination of frequency and consequences, the chance of an event happening that can cause specific consequences.
UFL	: Upper Flammability Limit. Expressed as % by volume of flammable gas in air. This is the maximum concentration of gas in air mixture which can ignite. Gas air mixtures above this concentration do not ignite.
Vapor Cloud Explosion	: An accidental release of flammable liquid or gas, there is possibility that it may form a cloud which can spread along the wind direction. Delayed ignition of the cloud away from the source of release results in Vapor cloud explosion (flash back) and associated blast/ over pressure effects.

ANNEXURE 2: ABBREVIATIONS

AIChE.	American Institute Of Chemical Engineers.
ALARP.	As Low As Reasonably Practicable.
BTU.	British Thermal Unit.
CCPS.	Centre For Chemical Process Safety.
DDGS.	Distilled Dried Grains Soluble.
DMP.	Disaster Management Plan
DWGS.	Distillers Wet Grain And Soluble.
ECC.	Emergency Control Centre.
EIA.	Environmental Impact Assessment.
EMP.	Environment Management Plan.
ENA.	Extra Neutral Alcohol.
F & E I.	Fire And Explosion Index.
FIG.	Figure.
HAZOP.	**Haz**ard **Op**erability.
HSD.	High Speed Diesel.
IDLH.	Immediately Dangerous To Life And Health.
IPL.	Independent Protection Layer.
KCal.	Kilocalories.
KLPD.	Kilo Litre Per Day.
lb.	Pound.
LOC.	Level Of Concentration.
LOPA.	Layers Of Protection Analysis.
MCA.	Maximum Credible Accident.
MF.	Material Factor.
MIDC.	Maharashtra Industrial Development Corporation.
MoEF.	Ministry Of Environment And Forests.
MSDS.	Material Safety Data Sheet.
MT.	Metric Ton.
NFPA.	National Fire Protection Association.
PFD.	Probability Of Failure On Demand.
PHA.	Preliminary Hazard Analysis.
QRA.	Quantitative Risk Assessment.
RH.	Risk Assessment And Hazard Management.
RS.	Rectified Spirit.
SIF.	Safety Integrated Function.
TEEL.	Temporary Emergency Exposure Limits.
UK.	United Kingdom.

ANNEXURE 3: REFERENCES

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