Safety Design in Buildings

PERFORMANCE-BASED APPROACH TO FIRE SAFETY DESIGN IN PROCESS PLANTS

AESG

Peter van Gorp, Director of Fire and Life Safety | AESG

Peter Van Gorp has been working as a Fire Engineer for more than 25 years, of which 15 years have been spent in the Middle East. He handled building fire and life safety projects ranging from schools, hotels, hospitals to large shopping malls to multi occupancy high rise and industrial developments, from initial concept to assistance during construction.

Peter has also been involved in the fire safety system design and engineering, fire safety system construction supervision and site management and in assistance and witnessing of testing and commissioning of fire and life safety systems. He also has extensive experience in fire risk assessments ranging from qualitative fire risk assessments of refinery and chemical processes to quantitative fire risk assessments of installations.

In his role, he has conducted numerous risk assessments involving gas installations and involving the storage and handling of hazardous materials. Van Gorp holds a Masters in Applied Engineering Electro-Mechanics from H.I.K Belgium.

Learning Objectives

1. Performance-based fire engineering
    - Firewater system analysis
    - QRA
2. Scenario Based approach
3. Risk Based approach

What is Fire Engineering

- **Fire engineering** is the application of science and engineering principles to protect people, property, and their environments from the harmful and destructive effects of fire and smoke. It encompasses *fire protection engineering* which focuses on fire detection, suppression and mitigation and *fire safety engineering* which focuses on human behaviour and maintaining a tenable environment for evacuation from a fire.
- Fire engineering education
- Fire engineering in buildings and oil and gas

Performance Based Fire Engineering

- Performance Based Engineering is well established in the building fire engineering
  - Use of CFD smoke modeling as a tool to a deal with non-compliance with regards to travel distances or fire rating requirements
  - Use of evacuation modeling to demonstrate safe evacuation times in case of non compliant designs
- The use of Performance based Engineering which is getting accepted more and more with the various approving authorities in the middle east.
- Less known but widely applied is the use of Performance Based Fire Engineering in the Petroleum Industry.

Performance Based Fire Engineering

The SFPE Engineering Guide to Performance-Based Fire Protection defines performance-based design as follows:

"An engineering approach to fire protection design based on (1) established fire safety goals and objectives; (2) deterministic and probabilistic analysis of fire scenarios; and (3) quantitative assessment of design alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies, and performance criteria".

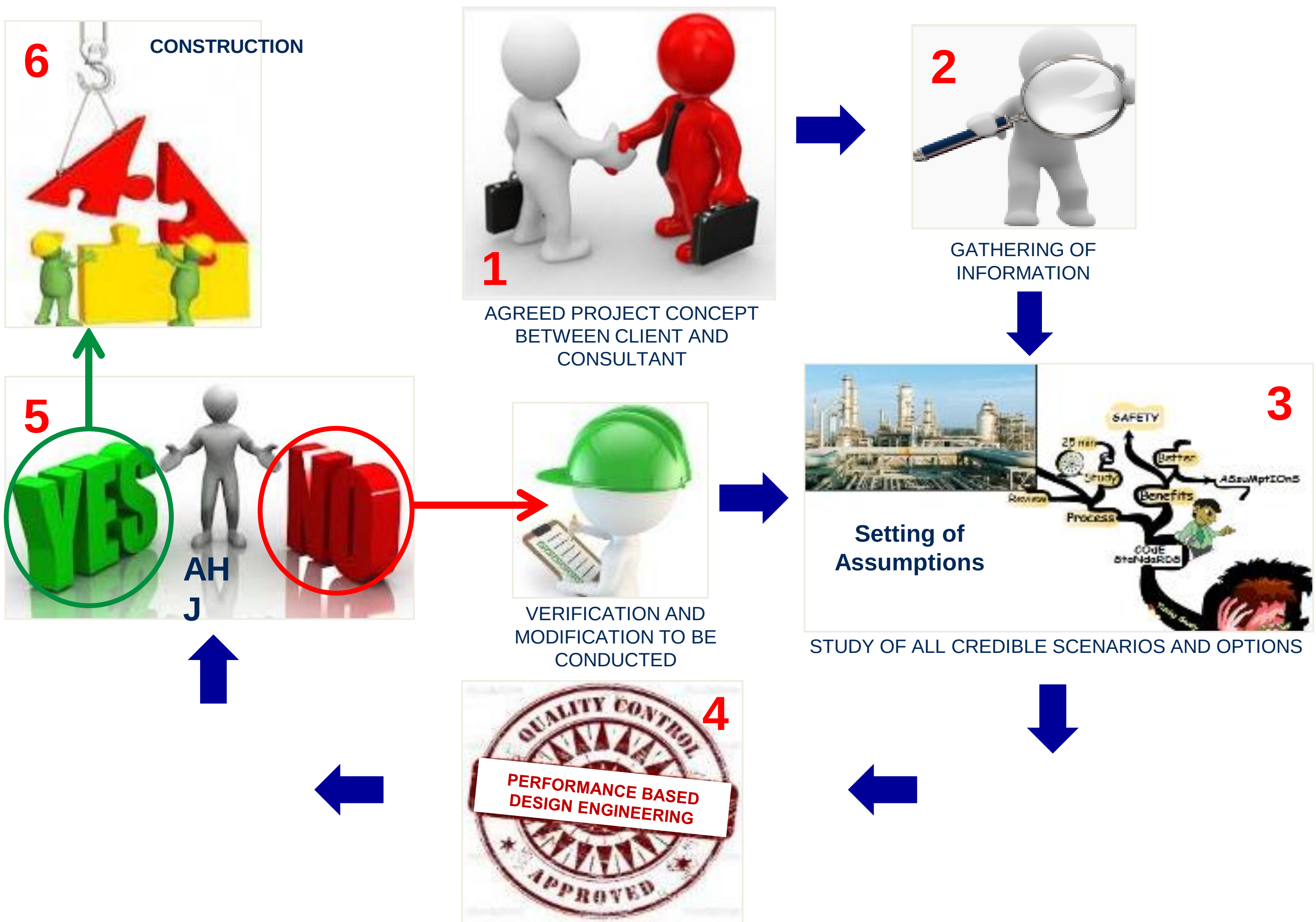
Performance Based Fire Engineering

- Fire Safety Goals & Objectives
  - Prevent spread of fire in the room of fire origin within a specified time.
  - Prevent loss of life by providing successful evacuation
  - Property Protection
- Deterministic & Probabilistic Analysis of Fire Scenarios
  - Fire or related phenomena (smoke, explosion;) are modeled or calculated and the results are analyzed

Probabilistic Analysis

  - Attempt to predict the likelihood of a fire event
- Quantitative Assessment of Design Alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies and performance criteria

Process of Performance Based Design Engineering



Process of Performance Based Design Engineering

AGREED PROJECT CONCEPT BETWEEN CLIENT AND CONSULTANT

- BRIEF DISCUSSION OF SCOPE
- PRELIMINARY PROJECT CONCEPT
- PROJECT STRATEGY

GATHERING OF INFORMATION

- SITE ASSESSMENT
- EXISTING UTILITIES VERIFICATION
- AVAILABLE FIRE PROTECTION & FIRE FIGHTING SYSTEM

- CODE & STANDARD REFERENCE
- ASSUMPTIONS REGISTER (To be agreed with the client)

Process of Performance Based Design Engineering

4

5

AHJ

VERIFICATION AND MODIFICATION TO BE CONDUCTED

6

CONSTRUCTION

- ENGINEERING DESIGN PREPARATION
- FORMULATION OF RECOMMENDATION
- REVIEW FOR APPROVAL AND QUALITY CONTROL
- FINALIZATION OF ENGINEERING DESIGN

- DISCUSSION ON BASIS
- INPUT REASSESSMENT
- REQUIRED MODIFICATION
- FINALIZATION AND RESUBMISSION

- IMPLEMENTATION

Example of Performance Based Engineering applied in Petroleum Industry

- Adequacy Assessment of Firewater Supply, Hydraulic Analysis and Fire Main Flow Testing

Flow chart

ASSESSMENT OF FIREWATER SUPPLY

SITE VISIT

FORMULATION OF ASSUMPTIONS

FIRE WATER DEMAND STUDY

HYDRAULIC ANALYSIS OF FIREWATER NETWORK

FIRE MAIN FLOW TESTING → **ENGINEERING DESIGN** → **EPC CONSTRUCTION**

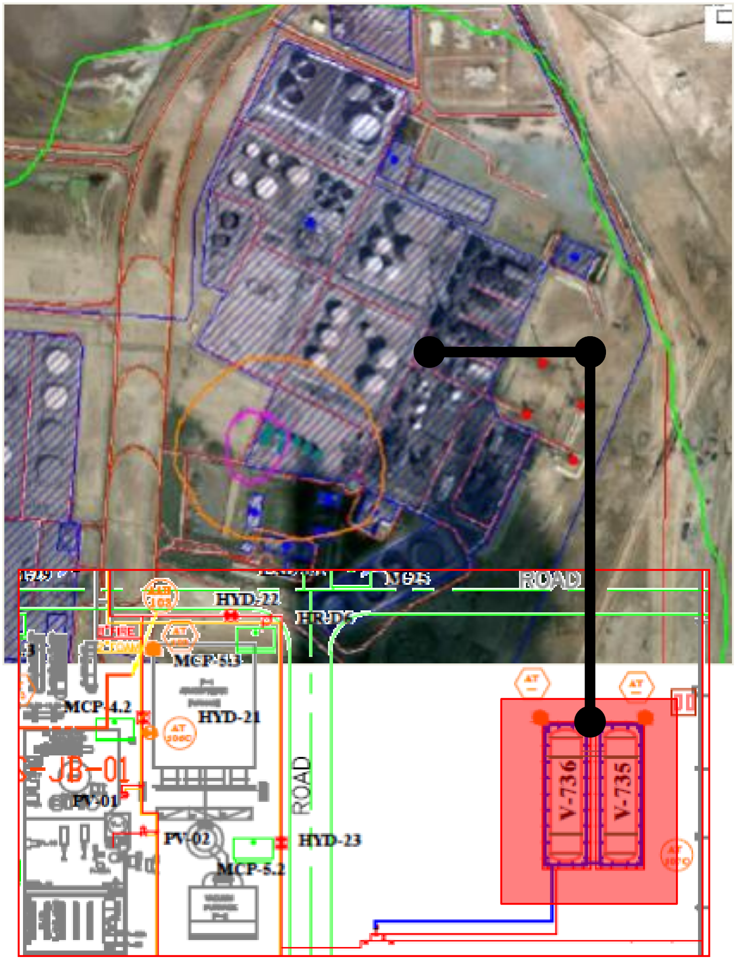
FORMULATION OF ASSUMPTIONS
- DEFINING WORST CASE SCENARIO

FIRE WATER DEMAND STUDY
- PROCESS AREA
- TANK FARM
- OTHER AREAS

HYDRAULIC ANALYSIS OF FIREWATER NETWORK
- BASIS
- METHODOLOGY
- FIRE PUMP
- FIRE WATER TANK
- FIRE WATER MAIN

FIRE MAIN FLOW TESTING
- PROCEDURE
- RISK ASSESSMENT AND JOB SAFETY ANALYSIS
- PREPARATION AND SITE TESTING

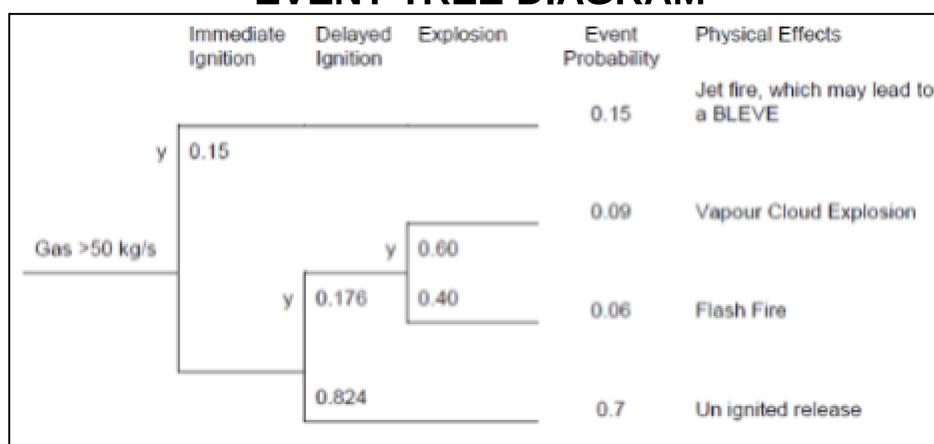
Sample of Quantitative Risk Assessment



IMPACT CRITERIA

Accident Hazards	Criteria	Unit	Assessment
Flash Fire	100%	LEL	100% Fatality due to engulfment
Thermal Flux	4.73	kW/m^2	Personnel injury within 30 sec of exposure
	12.5	kW/m^2	70% Fatality
	37.5	kW/m^2	100% Fatality
Overpressure	0.1	barg	Indicative of window glass breakages slight damage to buildings (1% lethality)
	0.3	barg	Indicative of pipe work and structural distortion, vehicle overturning, heavy building damage (repairable) (50% fatality)
	1.0	barg	Indicative of building destruction (100% fatality)

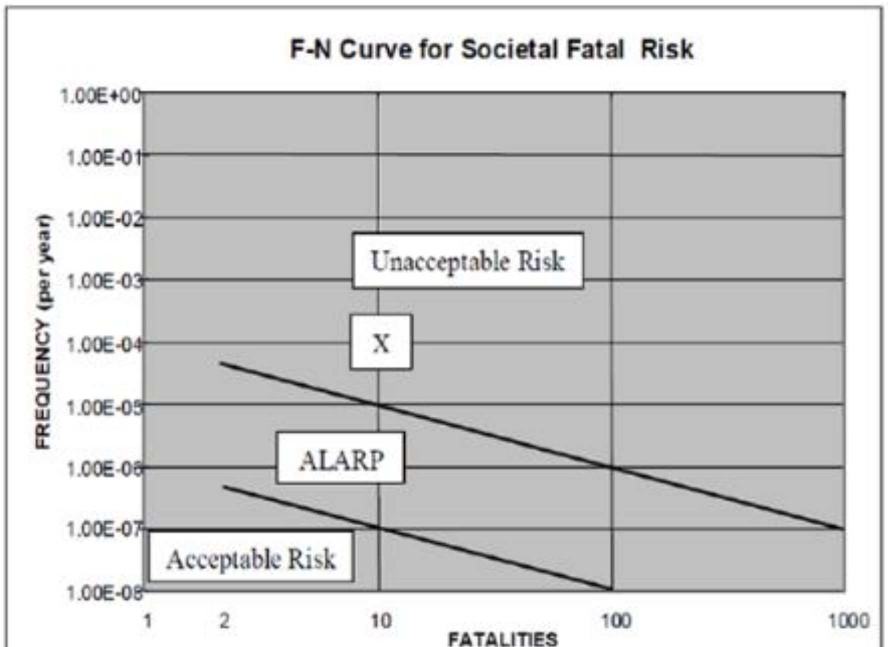
EVENT TREE DIAGRAM

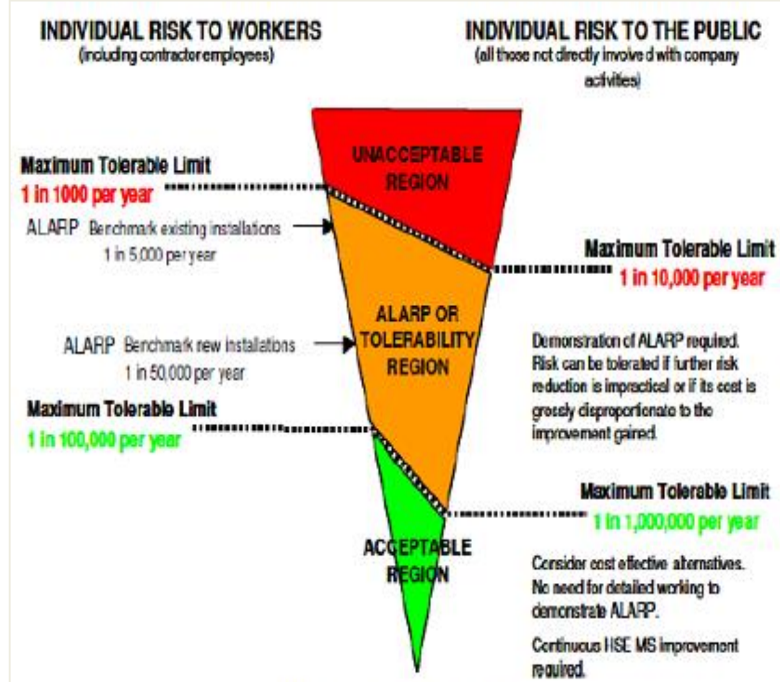


Sample of Quantitative Risk Assessment

FAILURE FREQUENCIES

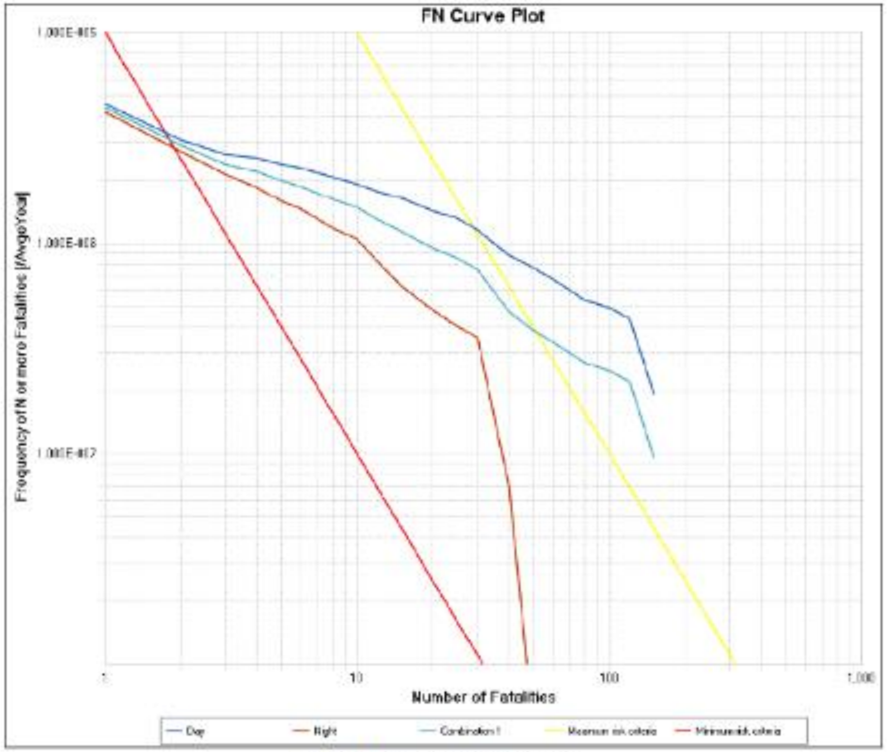
Hole Diameter Range (mm)	LPG/Butane/Propane Bullets & Spheres (per vessel per year)	Pumps (Centrifugal; inlets 50 to 150 mm) per pump per year
1 to 3	2.3×10^{-5}	1.3×10^{-3}
3 to 10	1.2×10^{-5}	5.6×10^{-4}
10 to 50	7.1×10^{-6}	2.4×10^{-4}
50 to 150	4.3×10^{-6}	8.3×10^{-5}
>150mm Catastrophic	4.7×10^{-6}	



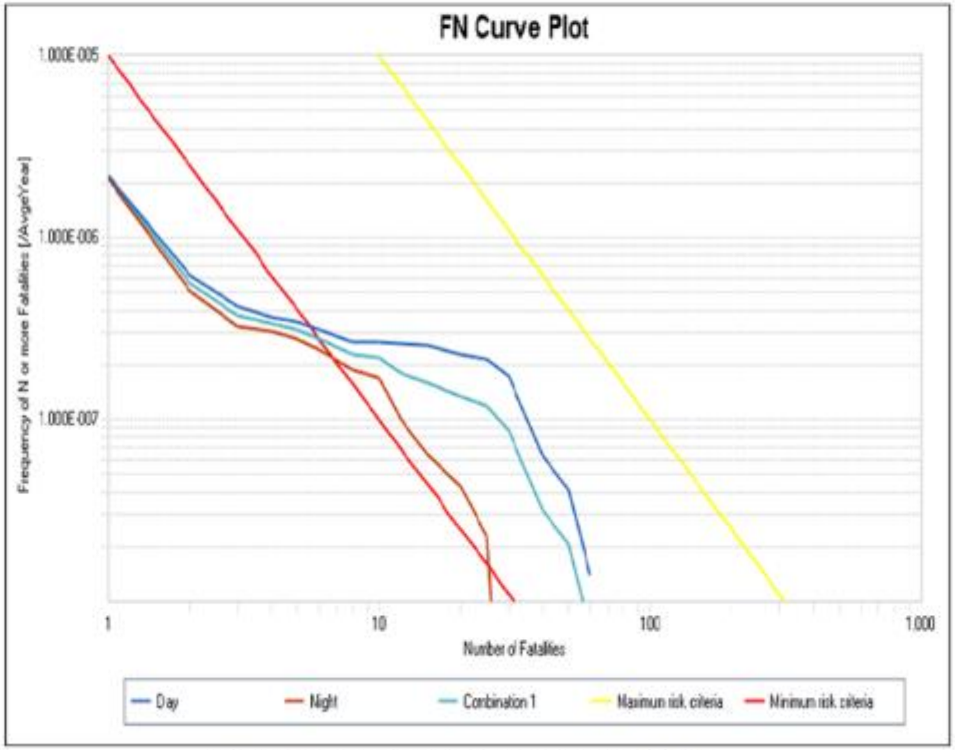


Risk Acceptance Criteria

Sample of Quantitative Risk Assessment



Societal Risk for Current Location

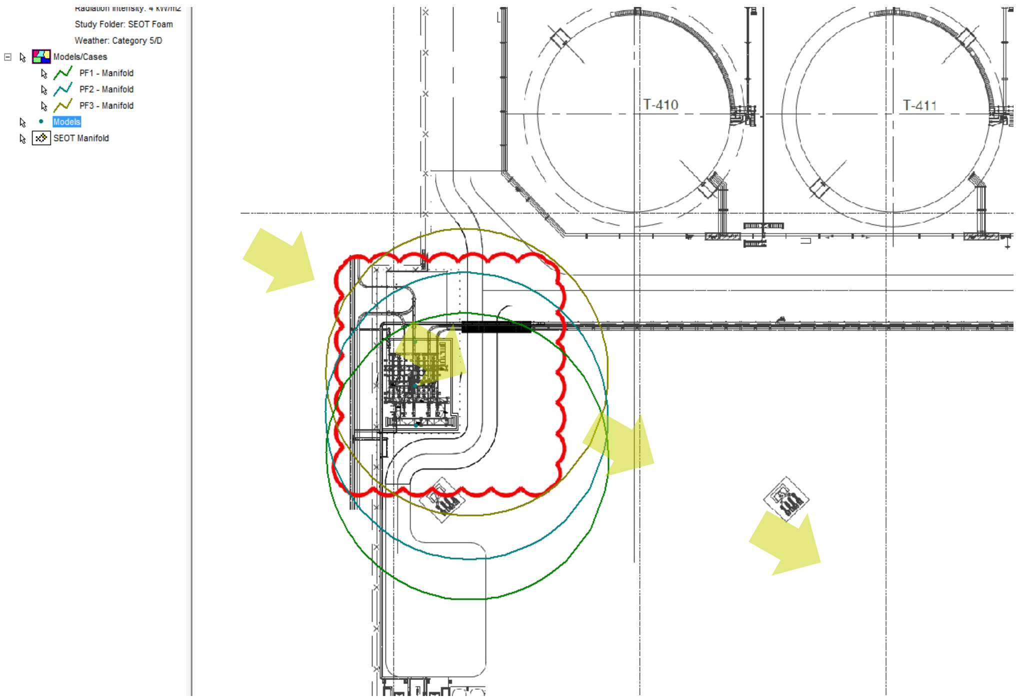


Societal Risk for Current location with separation wall

Scenario Based Fire Engineering

- Location of Foam/Water Monitors around manifolds or pumping stations
  - Perform heat radiation calculation of most credible fire scenario, using Heat Radiation Calculation Software, at the manifold to determine the accessibility of the 2 new monitors during fire conditions;
  - Preparation of the foam monitors layout;

Heat Radiation Calculation

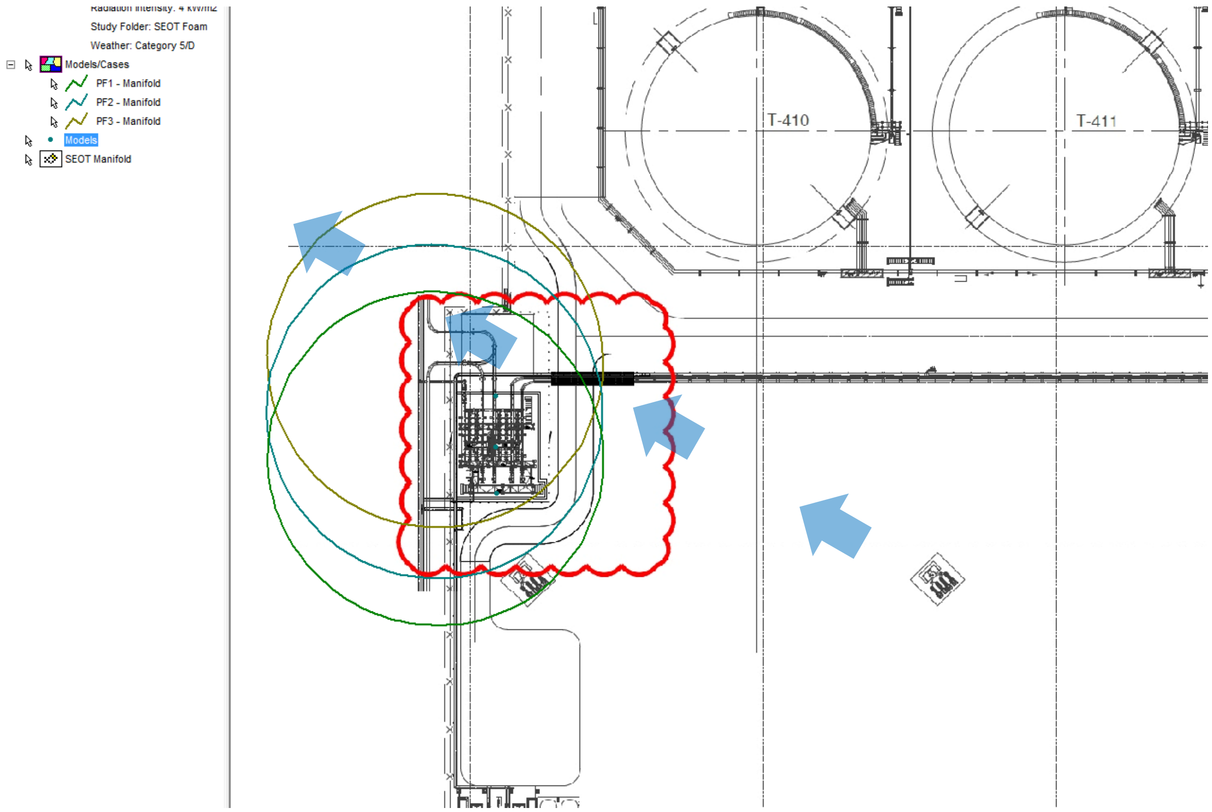


- Considering Prevailing Wind Direction

- Prevailing Wind Direction :
- NW to SE

- Thermal Radiation: 4 kw/m^2
- Effect Distance: 41 Meters

Heat Radiation Calculation

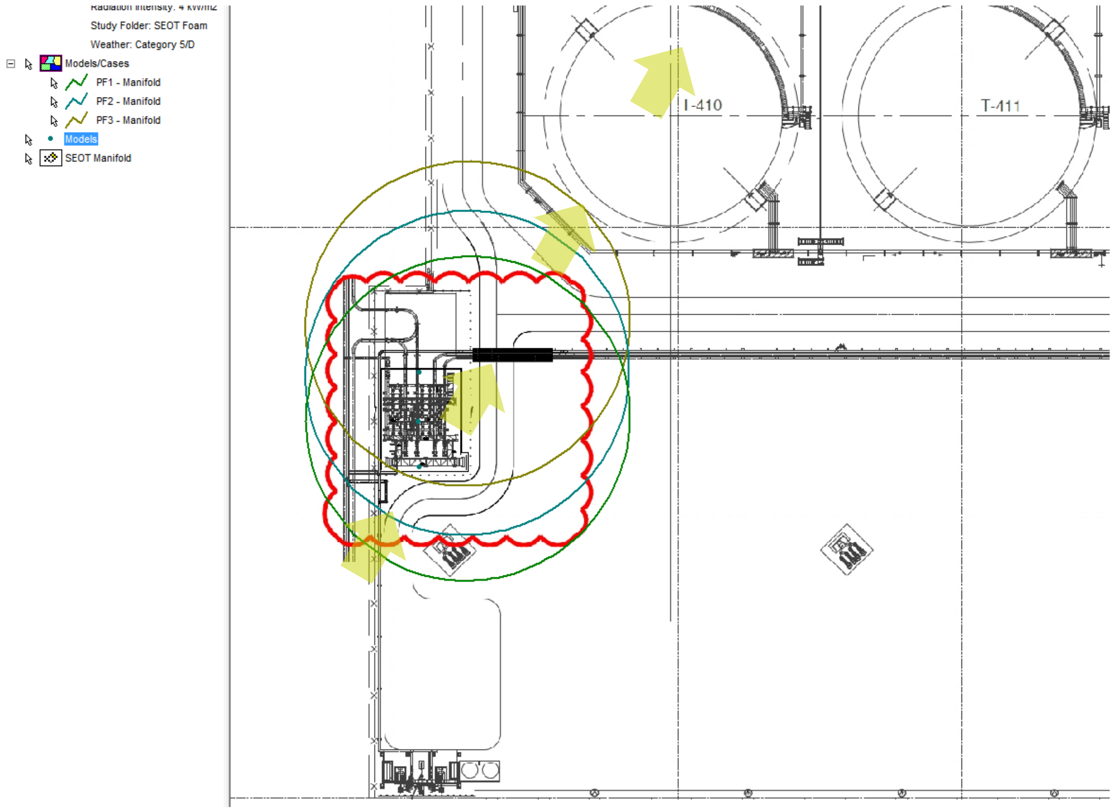


Against Prevailing Wind Direction

Thermal Radiation: 4 kw/m^2

Effect Distance: 41 Meters

Heat Radiation Calculation

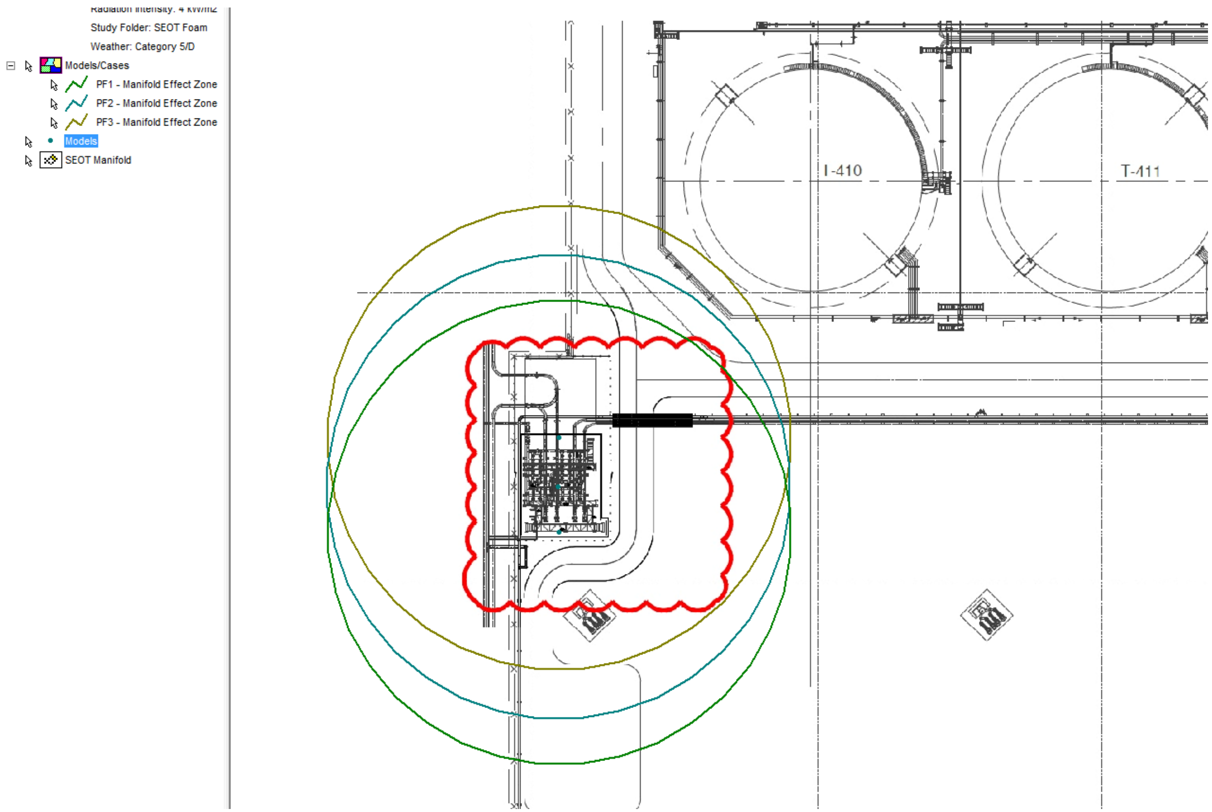


Wind towards Tank Pit 4

Thermal Radiation: 4 kw/m^2

Effect Distance: 41 Meters

Heat Radiation Calculation



All Wind Direction

Thermal Radiation: 4 kw/m²

Effect Distance: 41 Meters

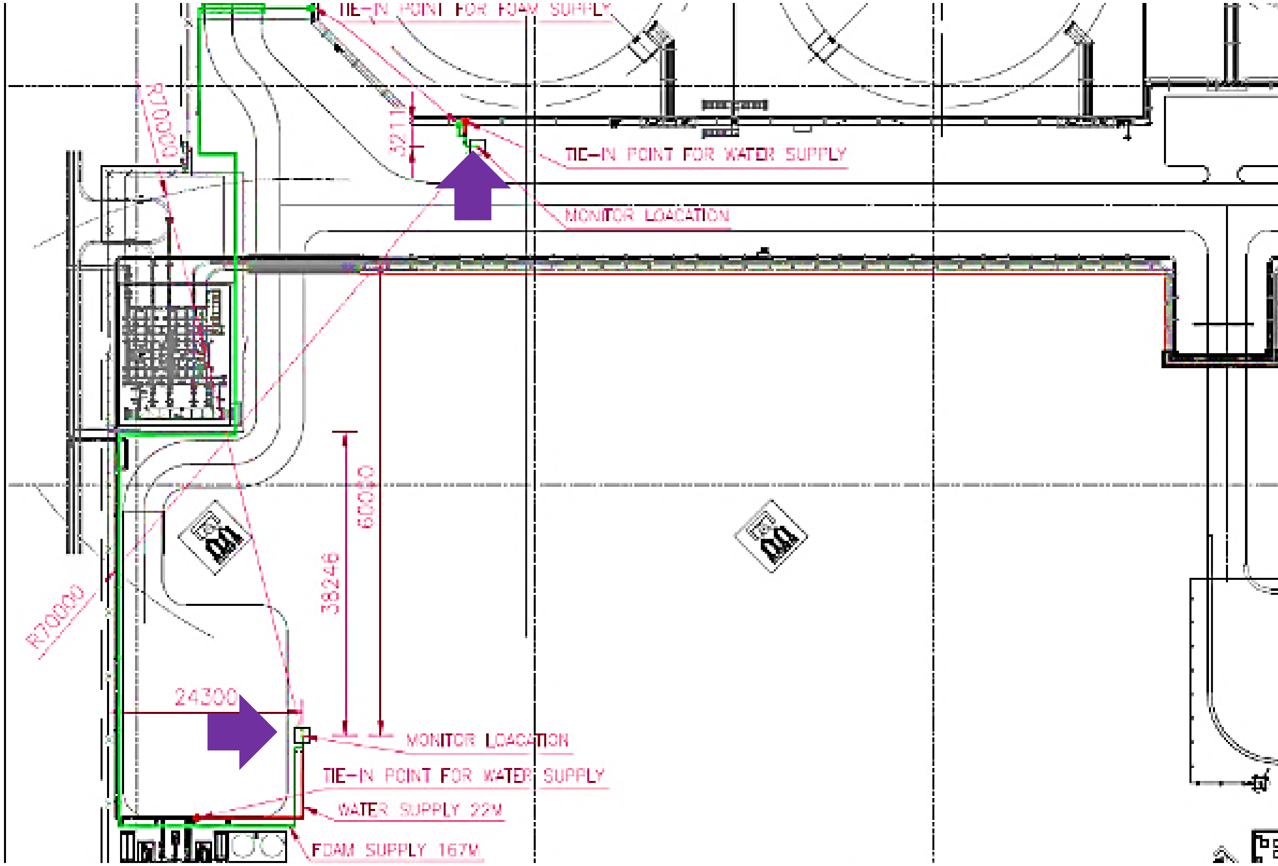
Proposed Location – Option 1

OPTION 1: Provision of two (2) nos. of fixed foam water monitors

- **Point 1:** Outside Tank Pit No. 4 near Tank No. 410 with tie-in for water and foam supply at the existing firewater and foam lines
- **Point 2:** To the south of New Manifold area and near the existing fire pump house at the berth.

  Tie-in for water supply at nearby firewater line at the fire pump house.

  Tie-in for foam supply will be from the foam line at Tank Pit No. 4.

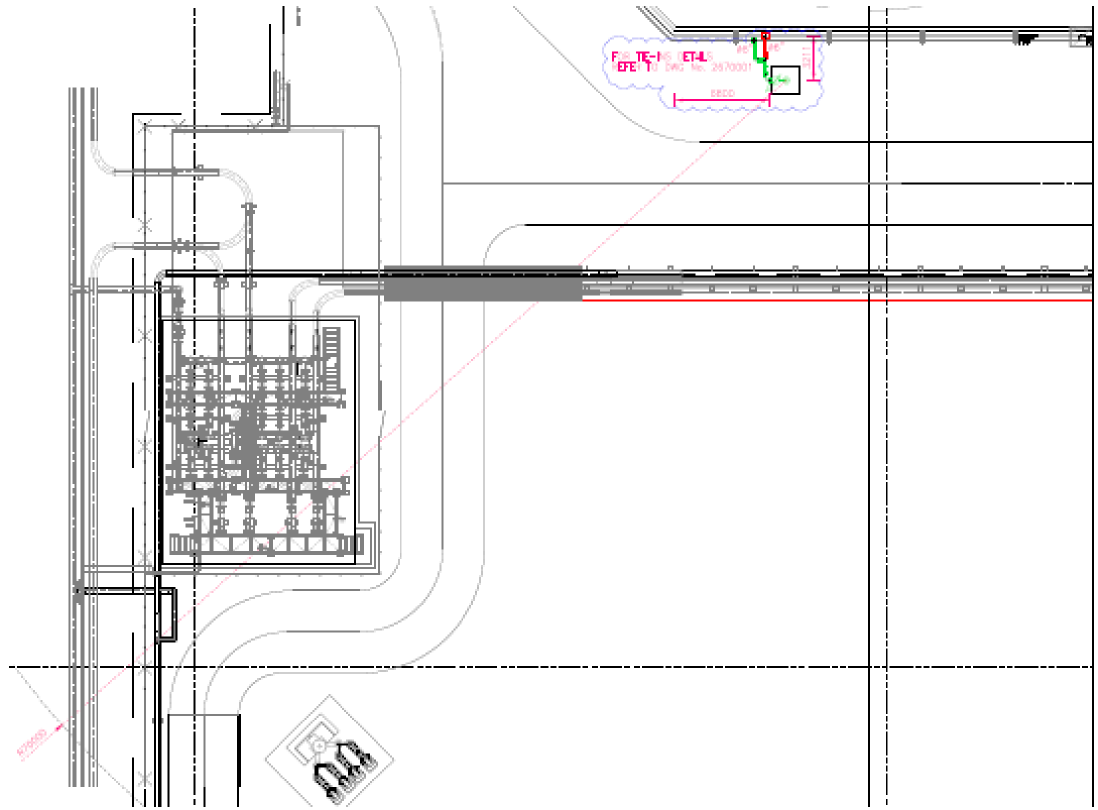


Proposed Location – Option 2

OPTION 2: Provision of one (1) fixed foam water monitor & one (1) mobile foam water monitor

- **Point 1:** Outside Tank Pit No. 4 near Tank No. 410 with tie-in for water and foam supply at the existing firewater and foam lines
- **Location of Mobile Foam Water Monitor:** To the south of New Manifold area and near the existing fire pump house at the berth.

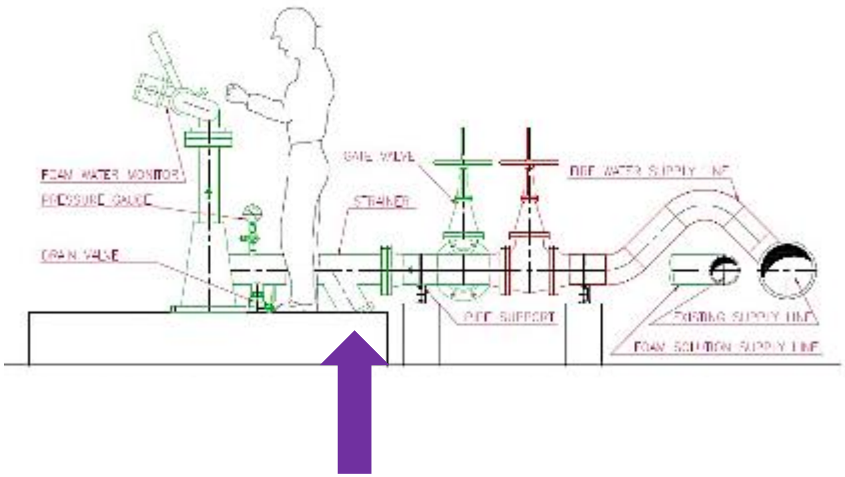
  Tie-in for water supply at nearby firewater line at the fire pump house.



Foam Monitor Specifications

- Manually Operated
- Designed to withstand a design pressure of **16 bar** and deliver **6000 l/m**.
- Rotation-Manual: **360°**
- Elevation-Manual: **-60° / +90°**
- Connection: **4in. ANSI 150 lbs**
- Body Material: **Stainless steel**
- Nozzle Material: **Bronze**
- Range: **Minimum 70m @ 6.9 bar**
- UL/ FM and DCD Approved

Typical Arrangement Detail



Y-Type Strainer

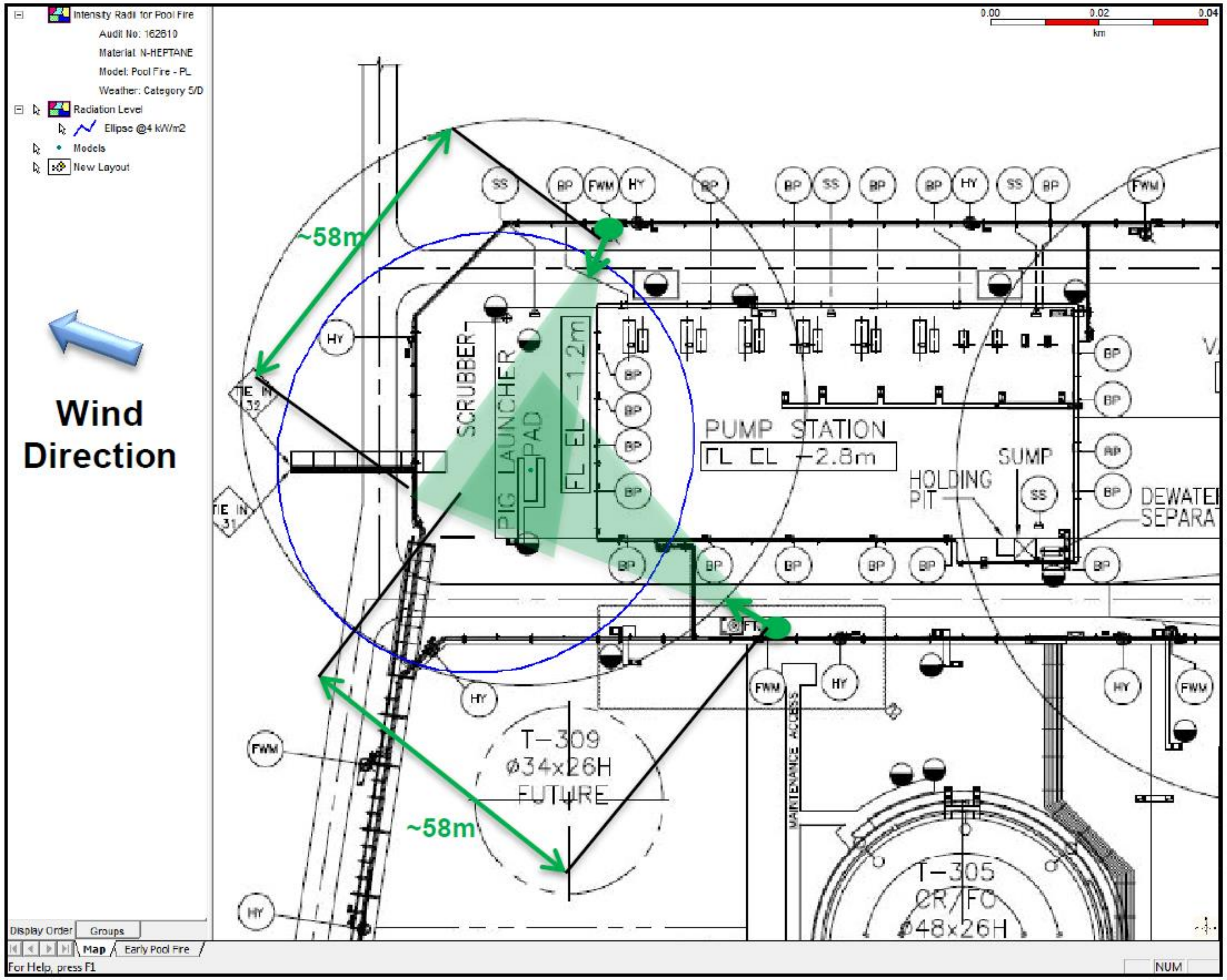
Y-Type strainer is Included in the current design

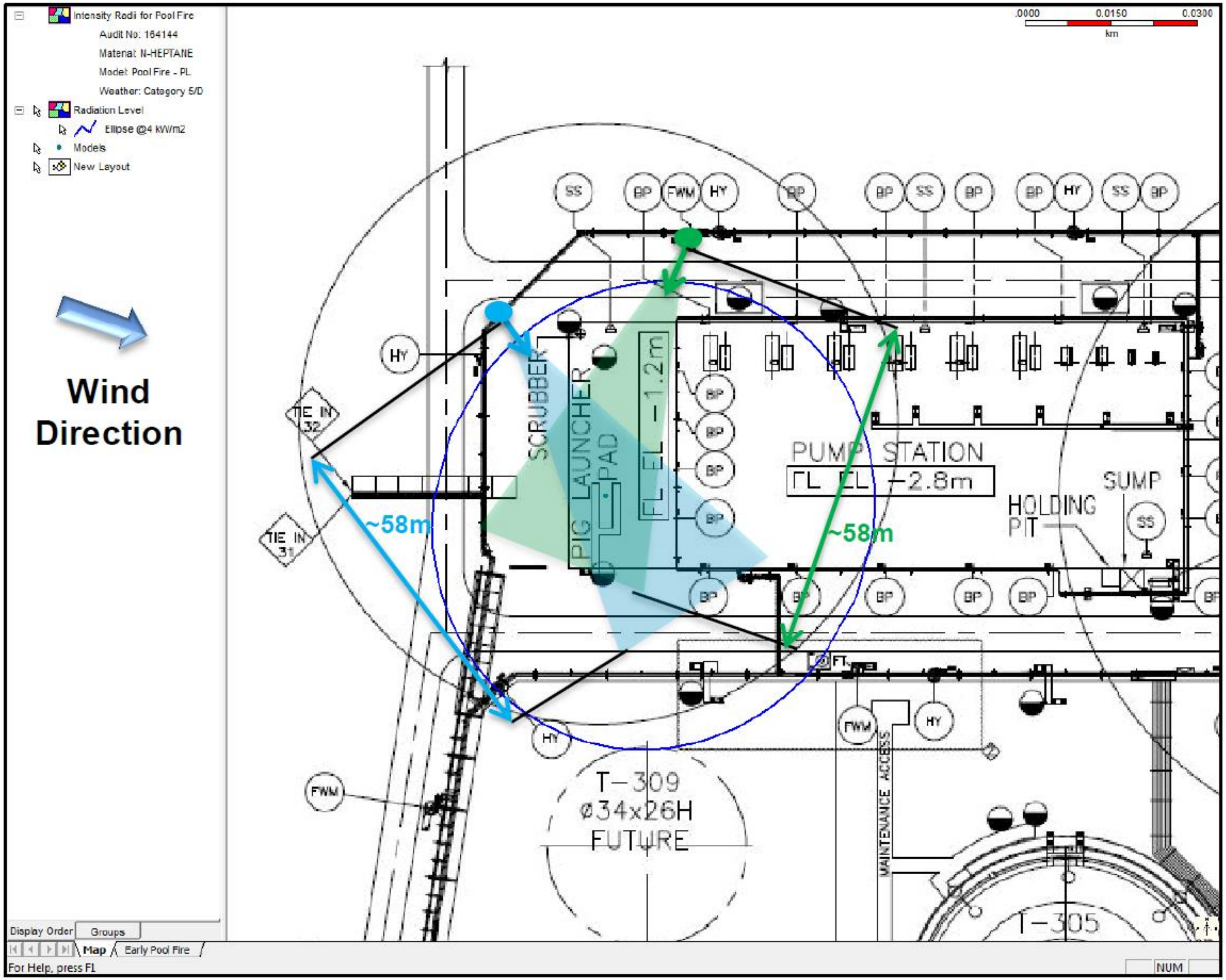
Foam Monitor Specifications

- High volume foam storage
- High capacity flow
- Extremely mobile
- Rugged construction with tandem axle, electric brakes and two rear stabilization jacks
- 5,000 lb (2,268 kg) gross vehicle weight rated trailer
- Hose bins on each side
- Monitor with low friction-loss and 3 in. valve with position indicator
- 4 in. inlet piping with 2.5 in. wye connection on each side
- Master Foam self-educting nozzle – 350, 500, or 750 GPM (1,325, 1,893, or 2,839 LPM)

- Constructed of high density polyethylene and protected by a rigid welded galvanized tubular steel grid
- Quick tote hold down for easy tote transfer

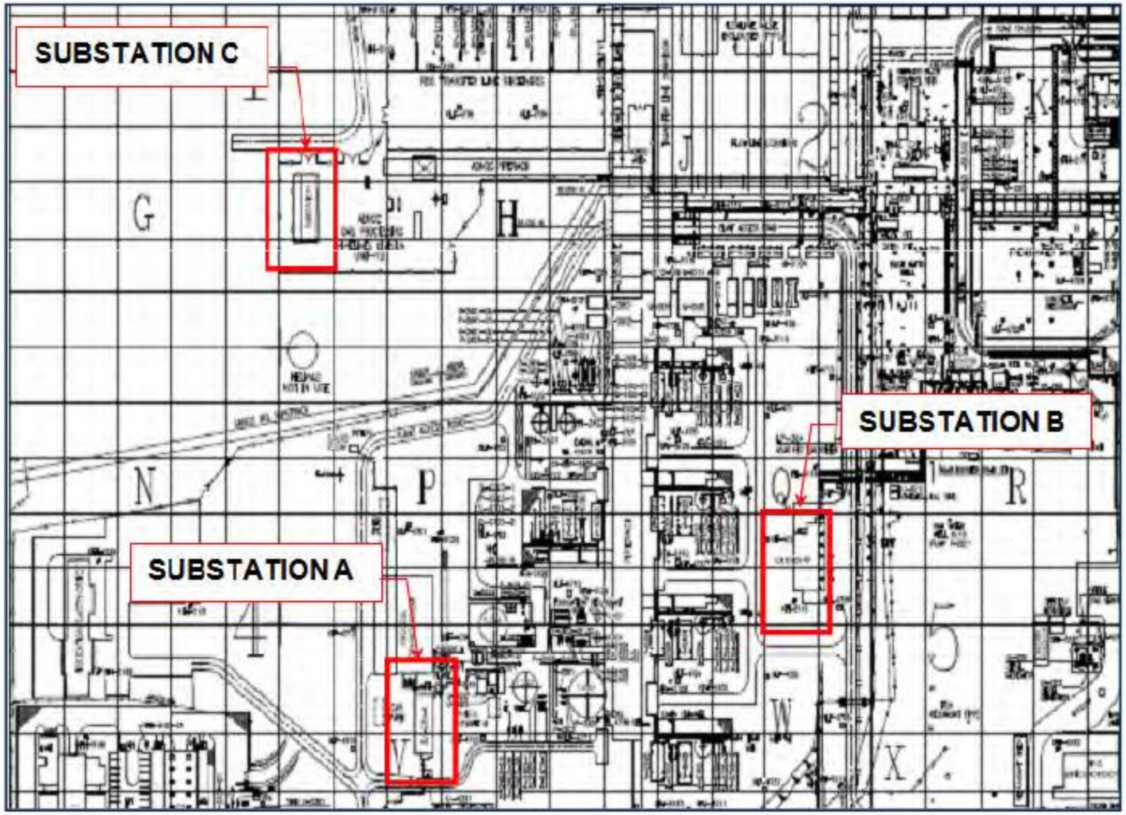
Another example of scenario based foam monitor location




Intensity Radii for Pool Fire
Audit No: 164144
Material: N-HEPTANE
Model: Pool Fire - PL
Weather: Category 5/D
Radiation Level
Ellipse @4 kW/m2
Models
New Layout
Wind Direction
~58m
~58m
SCRUBBER
PIG LAUNCHER PAD
FL EL -1.2m
PUMP STATION
FL EL -2.8m
SUMP
HOLDING PIT
TIE IN 32
TIE IN 31
T-309
ø34x26H
FUTURE
T-305
MAINTENANCE ACCESS
.0000
0.0150
0.0300
km
Display Order
Groups
Map
Early Pool Fire
For Help, press F1
NUM

Risk Based Approach

Electrical Substations & Transformers



- Proposed Options

•Provision of HSSD system

•Provision of Inert gas system

•Provision of Heat Detectors over Transformer

•Provision of fire rated wall between the transformers

Risk Based Approach

- Risk reduction analysis

Electrical Substations & transformers (substations A, B and C)

					Probability				
					A	B	C	D	E
Severity	People	Assets	Environ-ment	Repu-tation	Has occurred in world-wide industry but not in ADNOC	Has occurred in other ADNOC Group Company	Has occurred in specific ADNOC Group Company	Happens several times per year in specific ADNOC Group Company	Happens several times per year in same location or operation
5. Catastrophic	Multiple fatalities or permanent total disabilities	Extensive damage	Massive effect	Inter-national impact					
4. Severe	Single fatality or permanent total disability	Major damage	Major effect	National impact					
3. Critical	Major injury or health effects	Local damage	Localised effect	Consider-able impact					
2. Marginal	Minor injury or health effects	Minor damage	Minor effect	Minor impact					
1. Negligible	Slight injury or health effects	Slight damage	Slight effect	Slight impact					

HIGH RISK

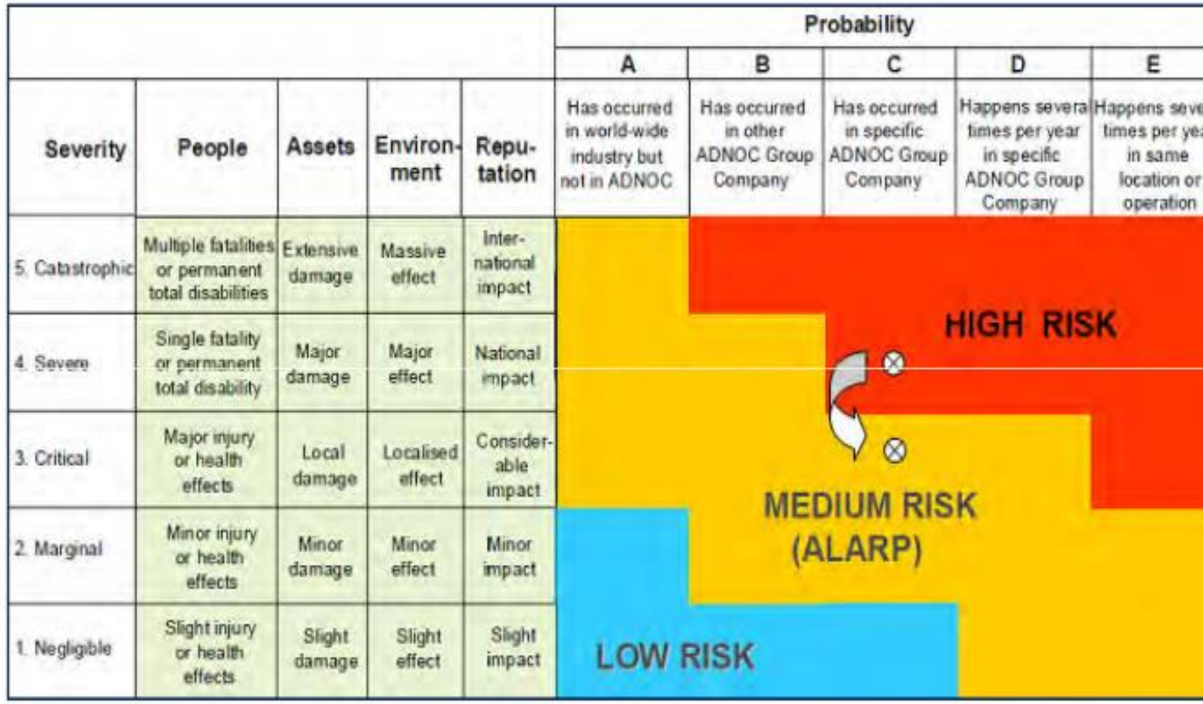
MEDIUM RISK (ALARP)

LOW RISK

RISK ANALYSIS	
By providing HSSD and gaseous flooding systems, you only slightly reduce that probability as an initiating fire will be detected by the currently installed ordinary type some detectors. Only in case of substations in remote areas, there is room for a larger risk reduction.	
PROBABILITY	SEVERITY
The probability classification is considered C in ADNOC matrix	The severity classification is considered 3 – Critical in the matrix. Severity is mainly with regard to Assets and downtime

- Risk reduction analysis

Electrical Substations & transformers (main power substations)



Severity	People	Assets	Environ-ment	Repu-tation	Probability A: Has occurred in world-wide industry but not in ADNOC	B: Has occurred in other ADNOC Group Company	C: Has occurred in specific ADNOC Group Company	D: Happens several times per year in specific ADNOC Group Company	E: Happens several times per year in same location or operation
5. Catastrophic	Multiple fatalities or permanent total disabilities	Extensive damage	Massive effect	Inter-national impact					
4. Severe	Single fatality or permanent total disability	Major damage	Major effect	National impact					
3. Critical	Major injury or health effects	Local damage	Localised effect	Consider-able impact					
2. Marginal	Minor injury or health effects	Minor damage	Minor effect	Minor impact					
1. Negligible	Slight injury or health effects	Slight damage	Slight effect	Slight impact					

RISK ANALYSIS	
The main power substations are more critical. In case an automatic fire suppression system is provided, the risk of an initial fire causing major downtime will be reduced significantly. As mentioned earlier the implementation of an HSSD system will not have a significant impact.	
PROBABILITY	SEVERITY
The probability classification is considered C in the matrix	The severity classification is considered 4 – Severe in the matrix. Severity is mainly with regard to Assets and downtime