Developing Preliminary PFP Schemes for HC Facilities

Introducing the PFPNet Design Fires Guidance Document

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Agenda

1. Presentation on the Guidance Document (40 mins)
2. Call for "testing" support (5 mins)
3. Questions and Discussion (10 min)

Introduction

PFPNet Publications

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- PFPNet develops and publishes a wide range of Guidance Documents, Position Statements, Specifications etc.
- PFPNet membership requested: a method for rapidly developing a PFP specification based on limited information.

The Design Fires Project

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- PFPNet awarded a contract to a consortium of Fire and Risk Safety Engineers in early 2021, to develop the Guidance Document.
- Draft completed in summer 2022, after extensive internal PFPNet review.

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Motivation for the Guidance Document

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- Early information is more effective & is better able to influence design.
- However, PFP discussions in early phases of a Project are typically:
  - either "pushed off" & dealt with later
    - accounted for in generic costs, weights, expected protection of a facility
  - or are based on prescriptive methods, which often leads to:
    - conservative specifications;
    - overlooked fire types;
    - non-coordinated protective scheme (PFP as an afterthought)
- The "industry" has had success in developing tools/approaches for improving facility design & safety at early stages – but PFP has largely been overlooked.
- Furthermore, there are significant gaps, differences, and contradictions in the current standards etc.
- "More knowledge for informed decision making!"

Purpose of the Guidance Document

“Provide practical guidance on how to make an initial, risk-based PFP specification for a hydrocarbon facility, based on a generic set of fire risk scenarios.”

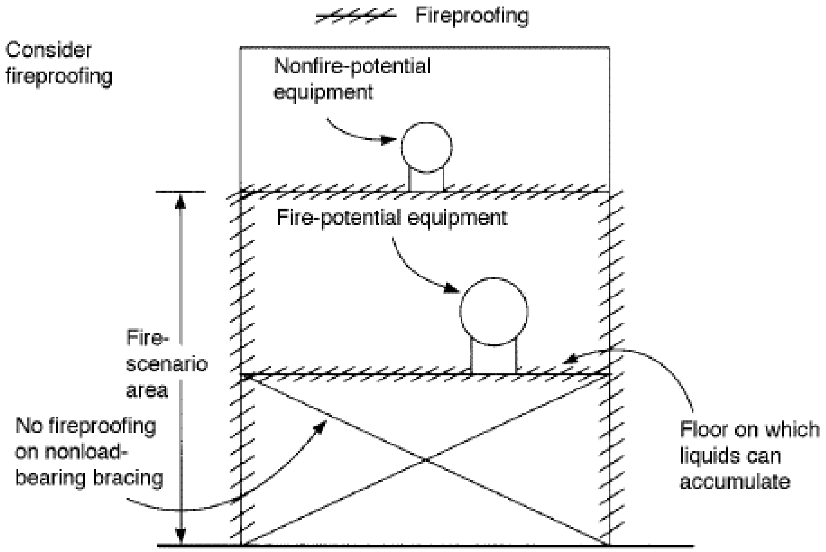
Key aspects:

- Risk-based approach, based on generic fire data.
- Links PFP requirements to the facility design and its associated fire hazards.
- Use for early-stage design or for existing facilities where details are limited.
- Applicable to a wide range of facility and process types.
- No detailed calculations are required.

What the guidance is not …

- NOT a replacement for:
  - regulatory (prescriptive) requirements;
  - detailed fire risk & structural assessments;
  - input from experienced fire and structural engineers.

- NOT a specification of:
  - fire protection requirements;
  - risk threshold to be used by projects.



Ref.: API 2218

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Guidance Document Contents

1. Introduction and Scope of the Guidance Document
2. The Guidance
    - Overview of Design Fire Curves and Use
    - Calculation of Fire Protection Requirements
    - Implementation examples
    - Discussion on PFP Selection and Specification Development
3. Appendices
    - Fire curves for each facility type
    - Detailed background information on fires and PFP specification
    - Literature review
    - Summary of development


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Guidance on Design Fire Scenarios for Selecting PFP Systems

PFPNET2021-008
Issue 01
December 2021

Guidance Methodology

Methodology

The Guidance needs to cope with a long list of variables, including:

- A wide range of "types" of facilities (different layouts, equipment, inventory types, etc.)
- Wide variation in fire type, shape, duration and heat flux.
- Numerous approaches to quantifying the impact of fire on a facility.
- Significant variation in offshore/onshore design approach to fire risk (protection philosophies, risk tolerability etc.).

Photographs courtesy of DNV Spadeadam Research & Testing.

Adopted Approach

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After internal discussion with PFPNet members and technical contributors, the following risk-based approach was adopted:

1. Compile a set of sample facilities, for which detailed FRA data was available.
2. Classify each facility by type (e.g., “Offshore Fixed”).
3. Break each facility down into modules, and classify each module by type (e.g., “Compression module”).
4. Extract fire size curves as a function of time, and at 3 tolerability frequencies ($10^{-4}/yr\,;\ 5\text{x}10^{-5}/yr\,;\ 10^{-5}/yr$).
5. Group data by facility and module type; process to extract generic fire curves for each type.
6. Use these as the basis for the assessment of the Fire Protection Requirements.

The following slides dig into some of the detail of the above steps.

Sample Facilities and Their FRAs

- Fire Risk Assessments (FRAs) from 23 facilities were processed.
- Each contained 5-20 modules, 75-200 leak event scenarios, 3+ hole sizes.
- This represents 100's of process modules, and 100,000's of fire scenarios.
- The facilities covered a wide range of facility type, size and operating conditions.
- FRAs mostly followed a similar approach; some of the onshore facilities used a simpler ignition model.

Label	Description	Typical module size (m^2)	Inlet P (barg)	Key plant P (barg)	Export gas P (barg)	FRA freq database	FRA ignition model
FPSO-1	FPSO, with turret & spread-moored designs	499	30	20	254	HCRD	UKOOA
FPSO-2	Turret moored FPSO	621	49	19	306	HCRD	UKOOA
Semi-1	Offshore semisubmersible	2,500	55	28	124	HCRD	UKOOA
Gas-1	Gas conditioning plant, offshore semisub	1,593	95	91	197	HCRD	UKOOA
LNG-1	Onshore LNG liquefaction plant	1,640	18	80	49	HCRD	UKOOA
LNG-2	Onshore liquefaction, compression and storage facility.	650	11	35	5	HCRD Modified	UKOOA
Chem-1	Large scale chemical storage and terminal.	1750	8	8	5	HCRD Modified	UKOOA
FPU-1	Three deck, offshore FPU.	450	150	23	240	HCRD	UKOOA
Chem-2	Chemical plant, include reactor and processing modules.	400	15	15	7.5	HCRD	UKOOA

Example of some of the facilities that were processed.

Facility & Module types

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Facilities were grouped into broad classes, with similar equipment type and process conditions:

- **Offshore facility**
  - **fixed**: production, compression modules
  - **floating**: production, compression modules
  - **all**: utilities, risers, chemical injection
- **Onshore facility**
  - **all**: storage/transfer, reaction/processing, vapour systems, loading/unloading
- **LNG facility**
  - **all**: production/liquefaction, compression, FEED/risers

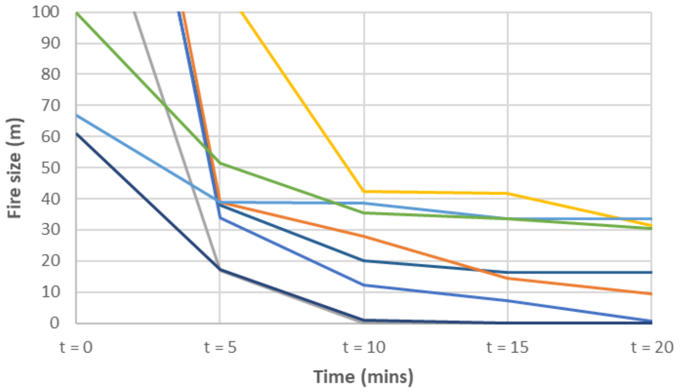
Fire Impact Assessment

- FRAs typically consider a range of fire effects, eg:
  - flame impingement on equipment
  - radiation envelope, for personnel exposure, ER viability etc.
- **Here**:
  - only interested in equipment/structural survivability;
  - focus on high heat-flux, flame impingement events;
  - (see the Guidance Document for discussion of compartment fires).
- **Fire impact** of an inventory is based on:
  - fire flame size – i.e., its ability to impact directly upon a target;
  - fire duration – i.e., the amount of energy that it imparts to the target, and therefore the temperature rise in the target;
  - a risk tolerability frequency.
- These can be used in a risk-based method to identify locations around the inventory that could be subjected to a significant thermal dose.

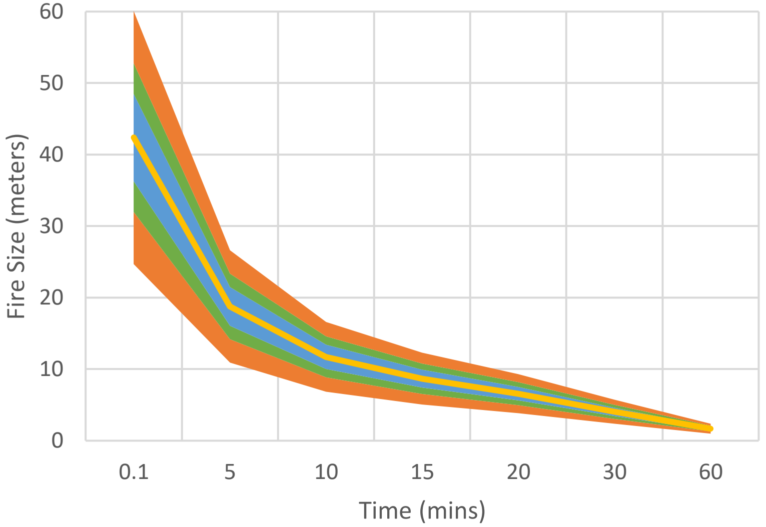
Design Fire Curve Development

- **Fire size exceedance curves** were extracted from the facility FRAs, and used to plot curves of fire size against time.
- Data was grouped by facility and module type, for each risk tolerability frequency.
- Note the variation, which is mainly a reflection of the different facility designs
- Data was processed to extract (for each facility type, module type & risk frequency):
  - an average curve;
  - curves at higher and lower confidence intervals
- These are called the “Design Fire Curves”.

10^{-5}/yr fire sizes, Offshore/floating production modules



10^{-4}/yr design fire curves



The Design Fire Curves

Facility & module type descriptions

- Fire Curves are provided for a range of module types, to represent range of different fire hazards.
- The Guidance Document provides a detailed description of these:

Facility type	Facility Category	Included Module Types and Process Areas	Description	Fire Types
Offshore	**Fixed** These represent facilities generally found in shallow water with concrete, steel, or wooden legs and foundations that are anchored directly to the sea floor. This includes but is not limited to: jackets, caissons, compliant towers, and jack-up rigs.	**Production**	Includes production fluid processing skids and equipment such as separation vessels, exchangers, pumps, and manifolds where liquid and 2-phase compositions are expected.	Jet/Spray Pool
		Compression	Includes vapour containing modules used for compression including compressors and associated recycle and gas side of coolers / exchangers.	Jet/Spray
	Floating These represent facilities generally found in deep(er) water with varying floating and anchoring system designs. This includes but is not limited to: FPUs, FPSOs, TLPs, and Semi-Subs.	**Production**	Includes production fluid processing skids and equipment such as separation vessels, exchangers, pumps, and manifolds where liquid and 2-phase compositions are expected.	Jet/Spray Pool
		Compression	Includes vapour containing modules used for compression including compressors and associated recycle and gas side of coolers / exchangers.	Jet/Spray
	All Represents all offshore facility types. These are common processes across a variety of offshore facilities which generally have similar sizes, conditions, and equipment.	**Utilities**	Includes fuel gas, power generation, and supplemental support systems such as diesel and aviation fuel skids.	Jet/Spray Pool
		Chemical Injection	Includes chemical injection and additive such as methanol injection. Equipment includes storage, pumps, and injection manifolds. Note, the jet/spray side of chemical injection is recommended to be addressed through the appropriate fixed or floating Production Design Fire Scenarios.	Pool
		Risers	Includes incoming production riser systems, outgoing produced oil and gas risers, injection risers, and lift gas injection risers. Note, the riser scenarios included in the fire scenarios are based on systems which utilize isolation (e.g., SSIV). Un-isolated (or cases where SSIV location is sufficiently far that the releases could be considered un-isolated) riser releases are considered a special case and should consider larger fires and longer durations as outlined in the implementation of the Guidance.	Jet/Spray Pool

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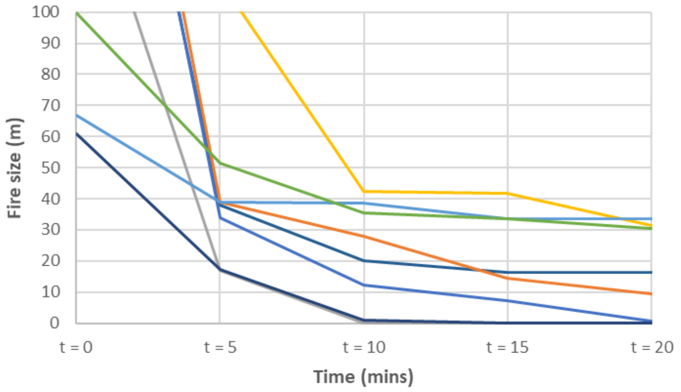
Facility & module type descriptions

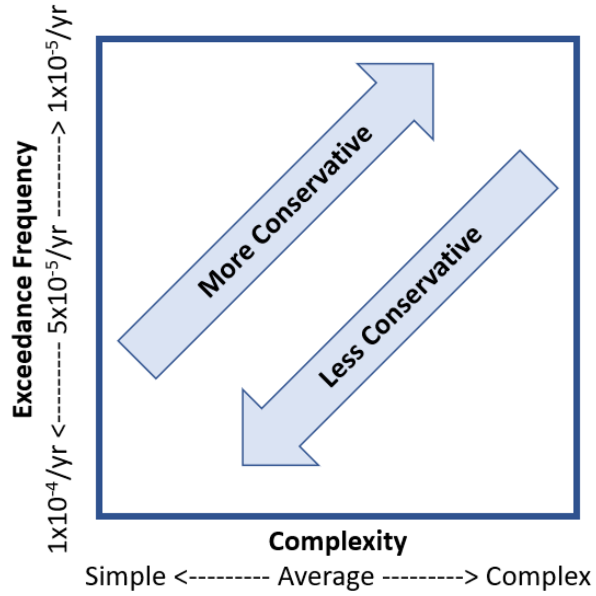
Facility Type	Facility Category	Included Module Types and Process Areas	Description	Fire Types
Onshore	**All** These represent a sample of facility types and process operations that would be found at various onshore facilities. Examples of these include chemical plants with storage and blending, gas processing and handling, reaction and column processes, loading and unloading systems for rail, truck, and marine. Note that onshore facilities have large variation when compared to offshore facility types. The selection of curves is provided as a sample of primary processes likely to have fire scenarios that may be considered for protection.	**Storage and Transfer**	Includes transfer pumping and storage control equipment such as valving, manifolds, and recycle systems. This selection is not representative of fires resulting from atmospheric storage tank fires.	Jet/Spray Pool
		Reaction and Processing	Includes scenarios resulting from active processing systems such as reactors and columns, as well as releases from associated feed systems and process loops (i.e., heat exchangers).	Jet/Spray Pool
		Vapour Systems	Includes vapour handling systems such as recycle compressors, vapour recovery unts, and drying systems.	Jet/Spray
		Loading/ Unloading	Includes product handling processes for marine, rail, and truck loading systems, specifically pumps, flexible hoses and hard lines.	Jet/Spray Pool
LNG	**All** These represent the main processes for LNG facilities. Both on- and offshore systems are included, as design, construction, and operating conditions between facility types have significant similarities. Note, for regassification facilities it is recommended that either Onshore-Vapour Systems, LNG-Feed/Risers, or LNG-Compression Design Fire Curves be used. Selection should be based on that curve which best represents the equipment, design, and conditions in the module.	**Production/ Liquefaction**	Includes production and liquefaction processes related to the conversion of vapour to liquified natural gas. Note, the pool fires included are a function of LNG releases and not directly representative of materials used within a specific cryogenic process. Fire from cryogenic processes which utilize flammable materials should be addressed by selecting the a "best fit" curve set from the list.	Jet/Spray Pool
		Compression	Includes vapour containing modules used for compression including compressors and associated recycle and gas side of coolers / exchangers. Note, can be used for gas production facilities.	Jet/Spray
		Feed/ Risers	Includes incoming feed gas streams (e.g., pipelines and pipeline equipment) and risers into LNG facilities. Note, can be used for gas production facilities.	Jet/Spray

"Complexity" measure

- Significant variability in fire exceedance curves, due to:
  - facility size and design
  - isolation and BD capabilities/philosophies
  - Project Risk Tolerance
  - etc.
- Projects may choose levels of risk tolerance.
- Needed a simple measure that could wrap up these effects, in a manner suitable for this type of high level analysis.
- Defined a Complexity measure:
  - Complex – more conservative analysis and/or larger module with higher than average equipment levels.
  - Simple – less conservative analysis and/or smaller/simpler module.
  - Average – typical level of conservatism and module equipment levels.

10^{-5}/yr fire sizes, Offshore/floating production modules



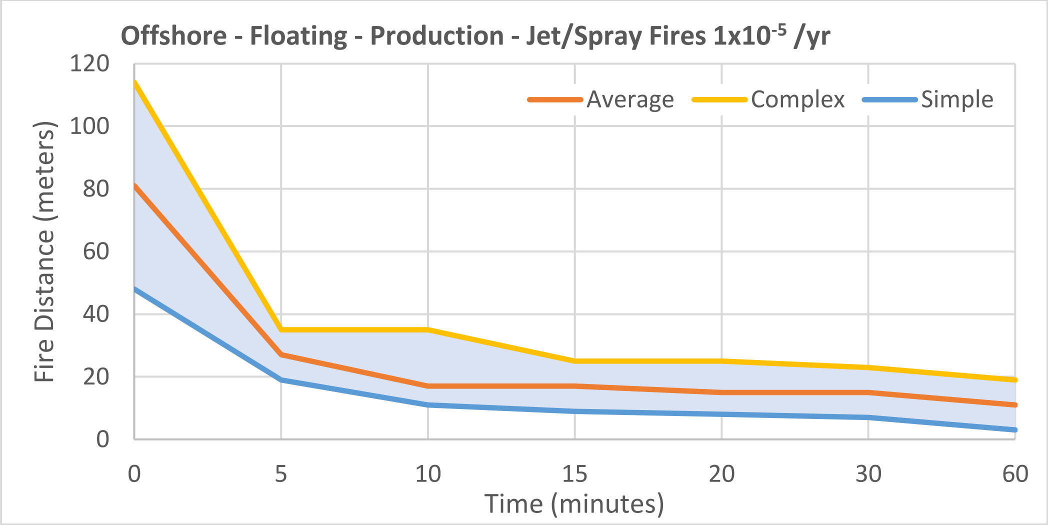


“Complexity” measure

- Again, detailed description provided in the Guidance Note:

Complexity Selection	Description
Complex	Large modules - relative to facility but on a scale of 1000m^2 or greater (sum of all levels or footprint). - or Includes multiple trains of equipment or multiple large vessels, process items and/or complex connected piping. - or Has large inventory or limited isolation and blowdown capabilities (expected durations greater than 15 mins - e.g., 15 mins to 50% of operating pressure). - or Project is utilizing a more Conservative Design Approach
Average	Average modules - relative to facility but on a scale of 250-1000m^2 (sum of all levels or footprint). - or Average equipment layout with 1-3 major vessels/process items. - or Has average inventory, isolated from incoming and outgoing streams at well as major vessel sources.
Simple	Small modules - relative to facility but on a scale of 250m^2 or less (sum of all levels or footprint). - or Includes small or limited process vessels and limited leak sources. - or Has limited inventory or above average isolation and blowdown capabilities (less than 15 min design approach that is typical for design using API 521).

Example Design Fire Scenario Curve



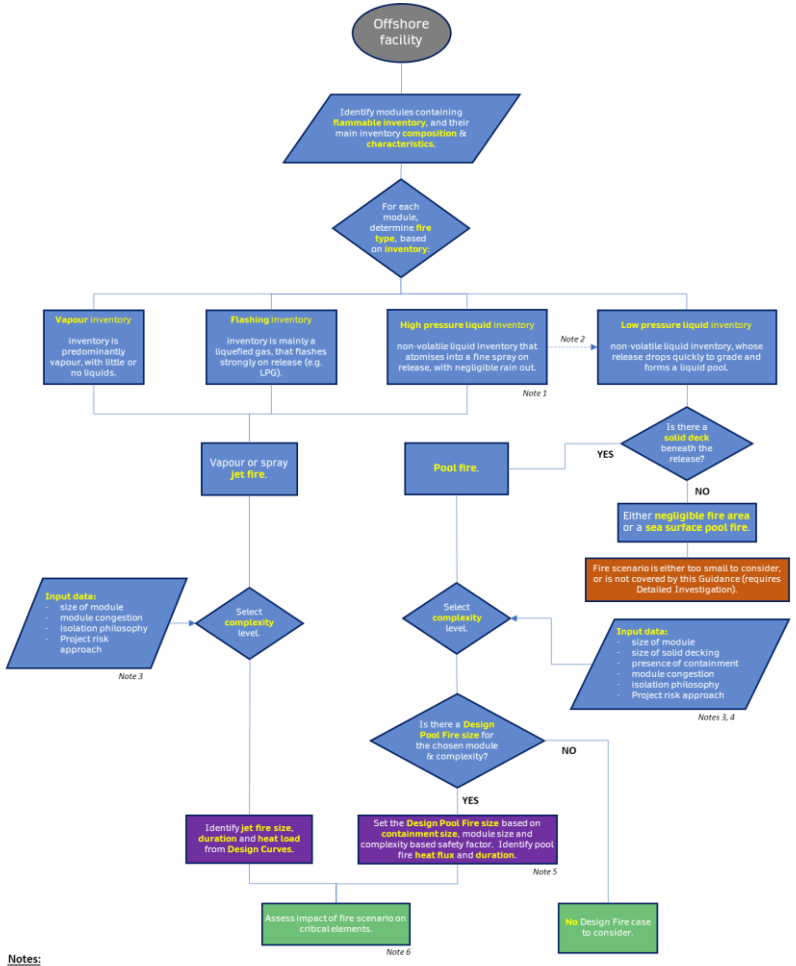
Offshore - Floating - Production Module - Jet/Spray Fires (Length - meters)								
Complexity	**Exceedance Period**	**Time (mins)**						
		0	**5**	**10**	**15**	**20**	**30**	**60**
Complex	1E-5 /yr	114	35	35	25	25	23	19
Average		81	27	17	17	15	15	11
Simple		48	19	11	9	8	7	3

- Complex and Simple complexity assigned to the high and low confidence curves.
- So have 3 curves for each facility/ module/risk level.
- Use these (and tabularised data) to estimate fire size as a function of time.
- Separate curves for jet, pool fires.
- The Guidance Document also provides suggestions on the Heat Flux for each fire type.

Overview of the Assessment Procedure

Overview of the Approach

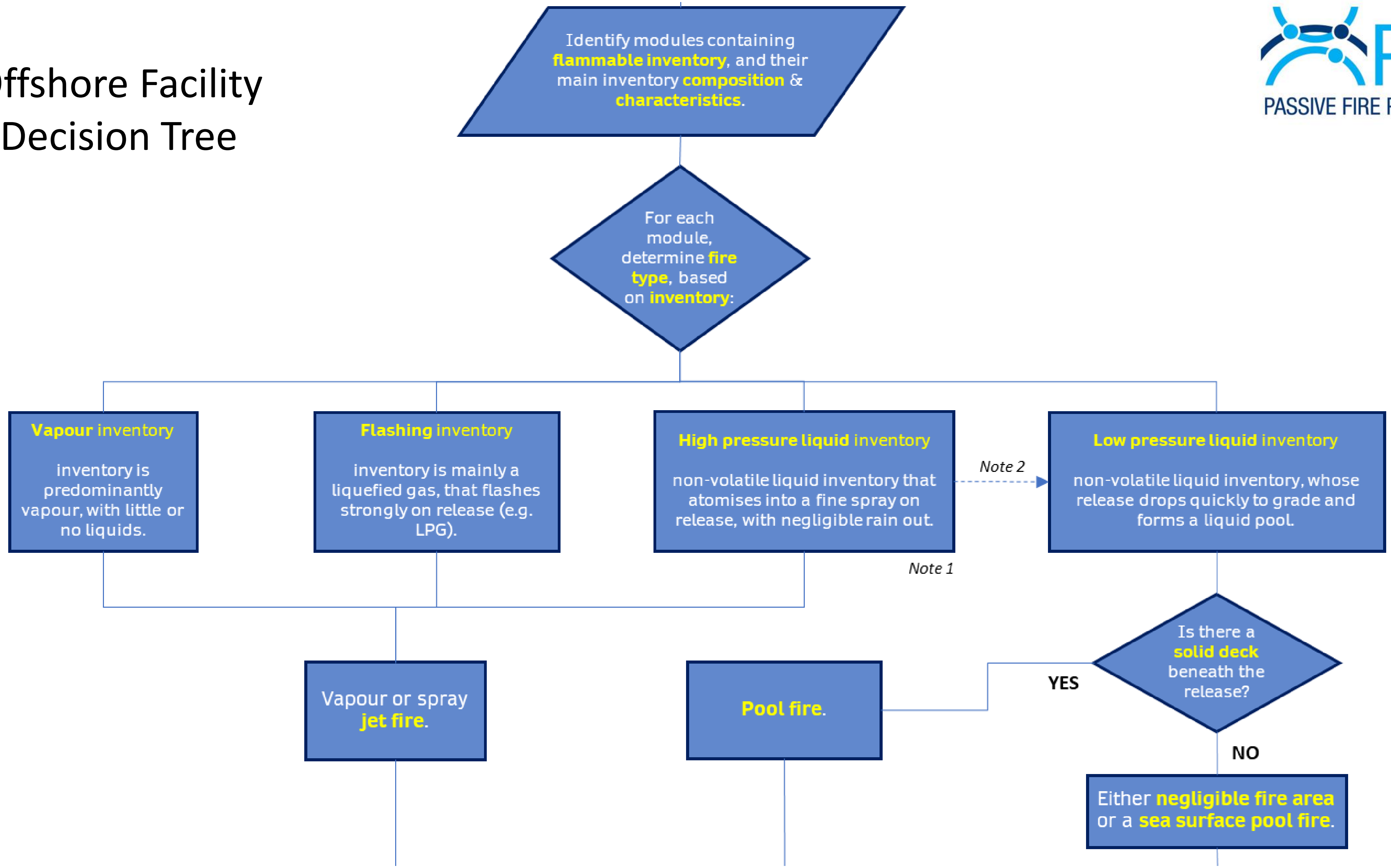
- The Guidance has been distilled down into a “Decision Tree” flowchart, that guides the user through the procedure.
- Separate Decision Tree flowcharts are provided for Offshore and Onshore facilities, to reflect the differences in some of the design practices and physical differences.
- For an LNG facility, use either the Onshore or Offshore chart, depending on the nature of the facility.



Notes:

1. See Section 3.1 for discussion of how to judge whether inventory pressure is “high” to generate a liquid spray release rather than a pool.
2. Liquid inventories that start as high pressure releases may transition to low pressure, as the section depressurises - see Section 3.1 for discussion of jet fire to pool fire transition.
3. For module congestion, consider for example: the number of major vessels, heat exchangers, pumps and compressors, valves etc.; the likely amount of piping etc. (refer to Table 3-3).
4. Pool containment can occur with bunding, deck coaming, sloped deck, or the presence of large obstacles such as a compressor enclosure.
5. See Section 3.2.1 for discussion on how to select the pool fire size, heat flux, and fire duration.
6. The User should use informed judgement to ensure that the Fire Decay Curve that is used in this assessment is applicable to their Facility, and should be conservative on the fire decay rate, and therefore the fire duration, where there is uncertainty.

Offshore Facility Decision Tree



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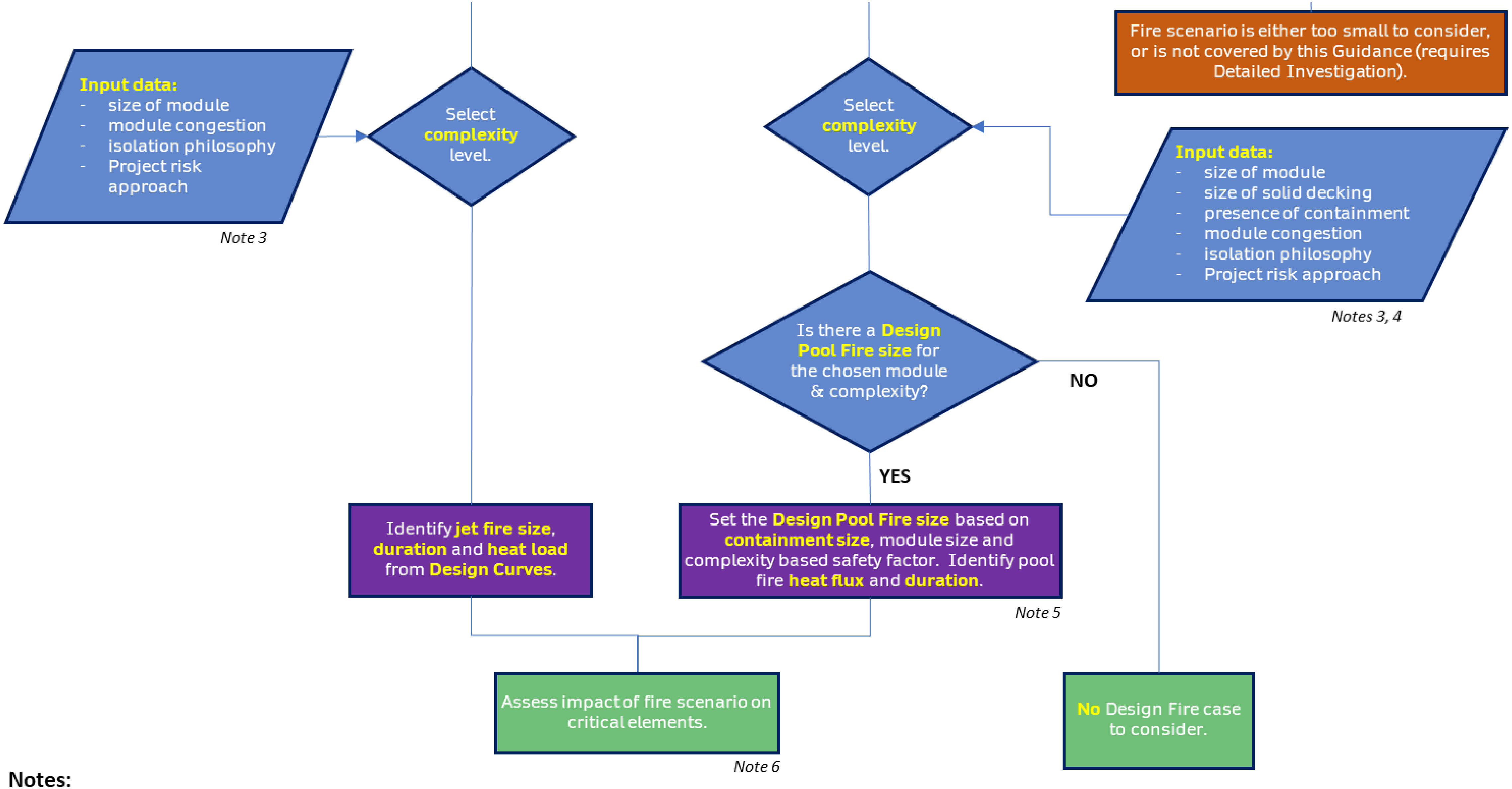


Notes:

1. See Section 3.1 for discussion of how to judge whether inventory pressure is “high” to generate a liquid spray release rather than a pool.

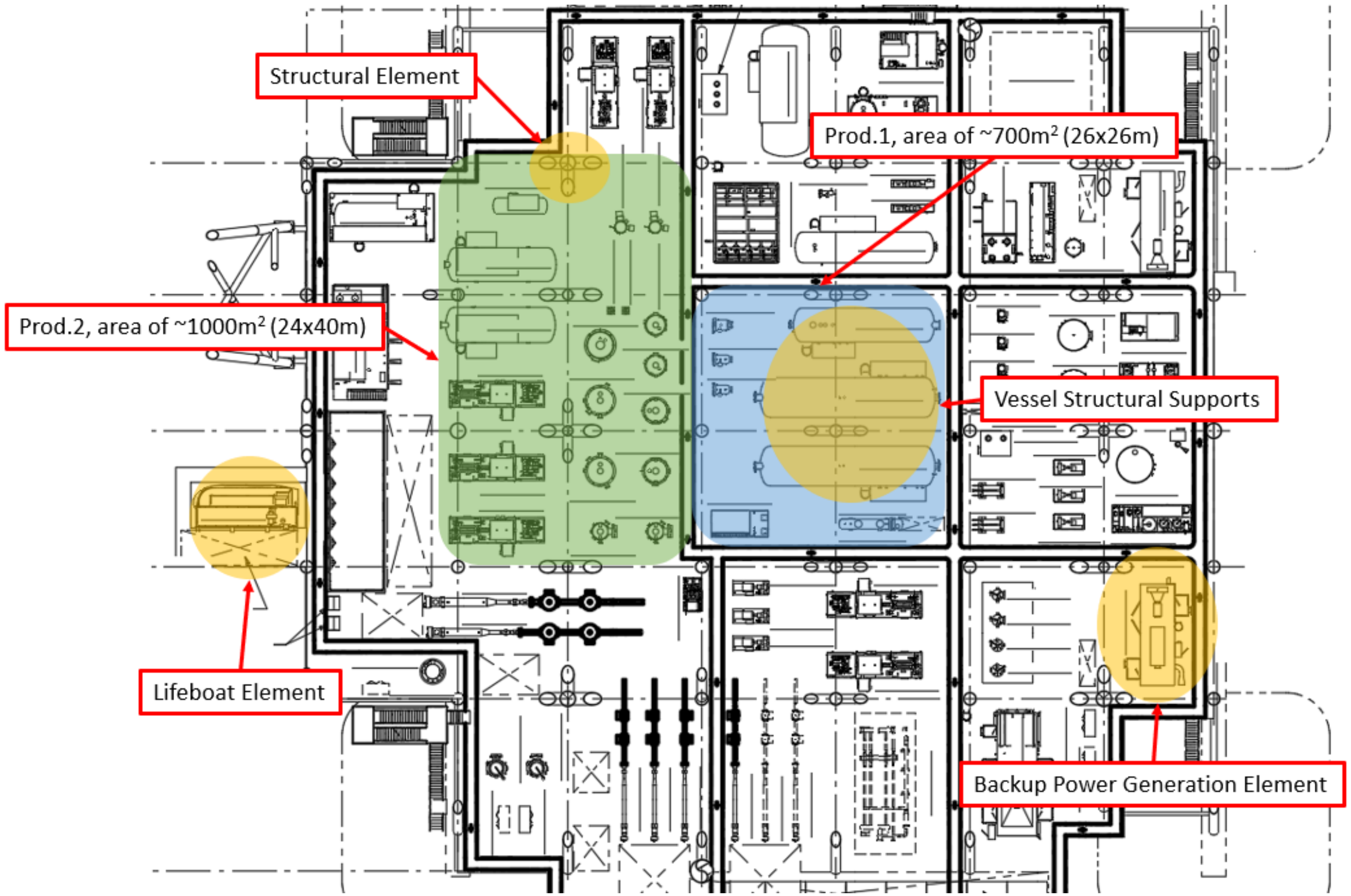
Example Application

Example Application

- Take the example of an offshore floating production unit (FPU), with 2 decks (production and upper).
- Here, consider production deck only (deck above is plated).
- Protection Philosophy for this project is:
  - $10^{-4}/yr$ risk tolerability for key structural elements;
  - $10^{-5}/yr$ risk tolerability for EER facilities, e.g., the lifeboat;
  - $20\ min$ minimum endurance time required for the above critical elements.
- No significant novelty or complexity in the design ⇨ typical level of Project Design Conservatism is to be applied.

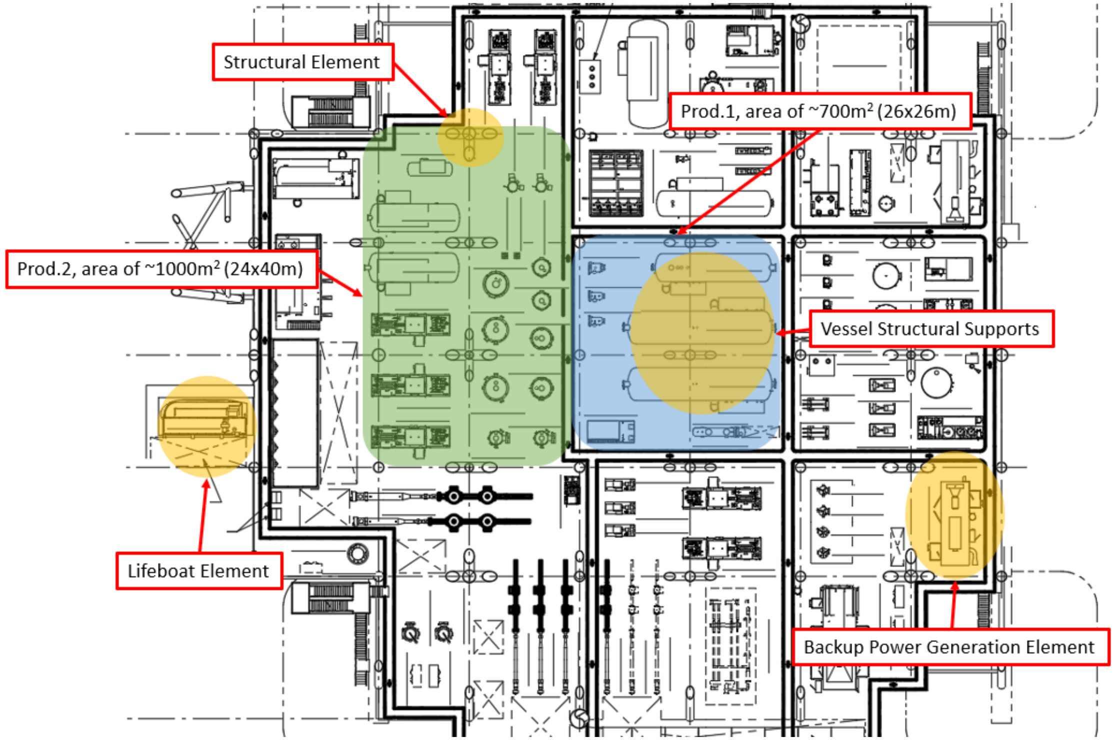
Example Application

- Start with layout drawing.
- Identify relevant modules and their types:
  - **Prod1** ⇨ production module;
  - **Prod2** ⇨ production and compression equipment (use worst case fire curve)
- Identify Critical elements (lifeboat, emergency power generator, major structural supports)



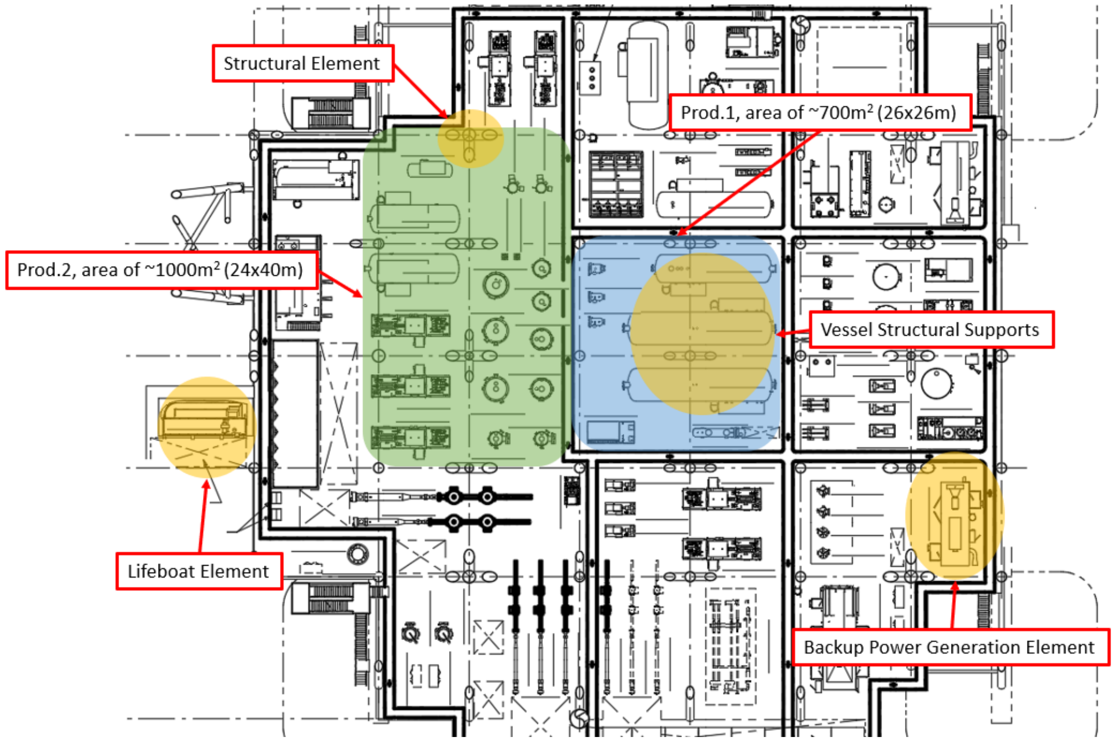
Example Application (cont.)

- Identify flammable inventory types and key features:
  - **Prod1** – LP and MP separation, plated deck with curbing ⇨ both jet fires & pool fires will be considered;
  - **Prod2** – HP separation and gas compression equipment ⇨ only jet fires will be considered.



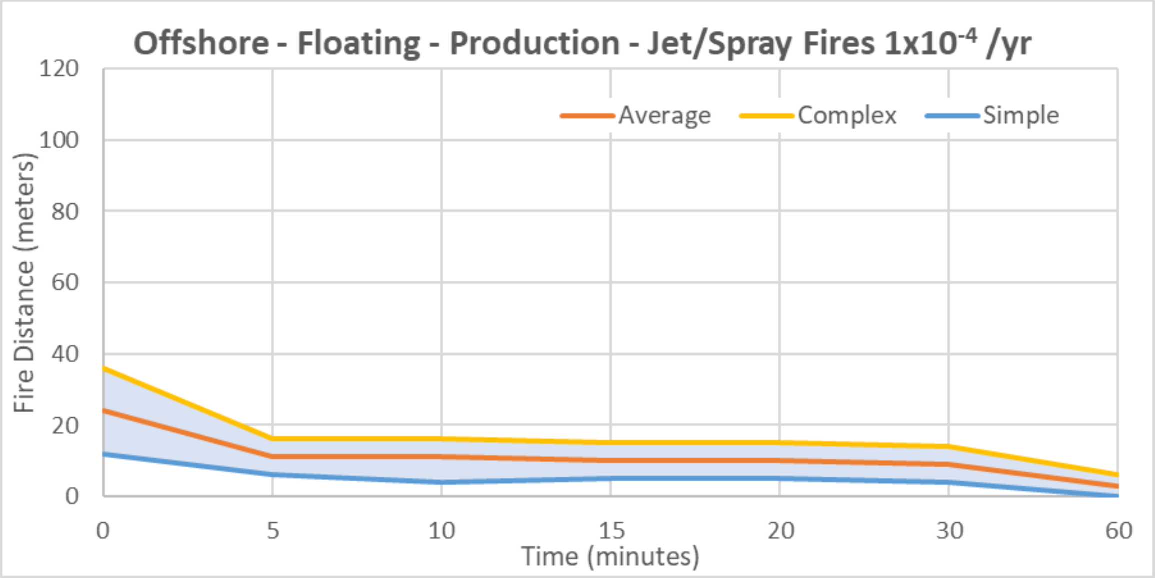
Example Application (cont.)

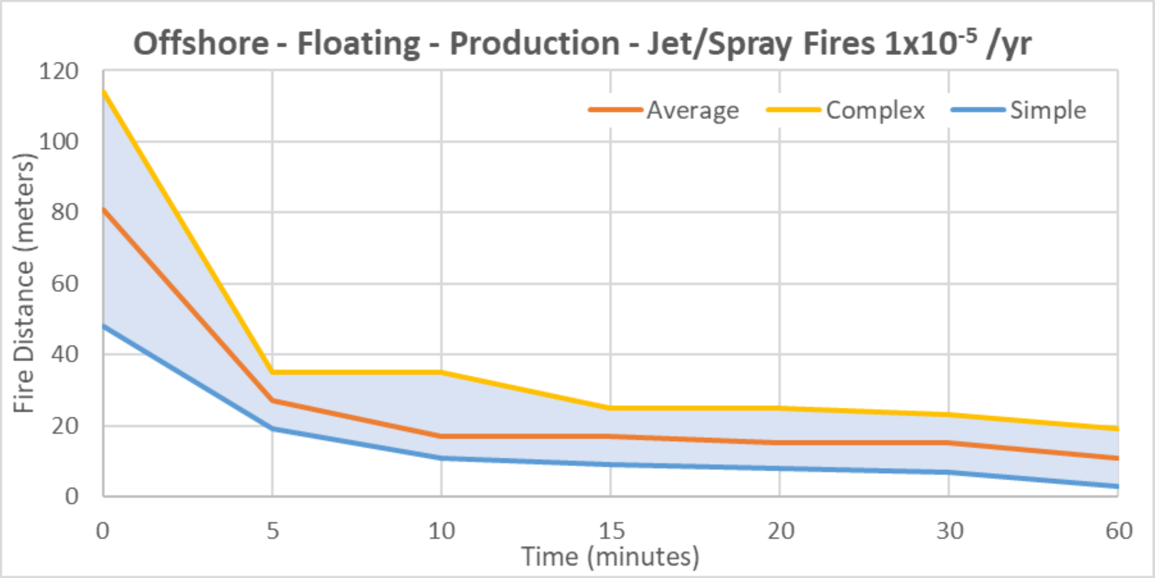
- Assess "complexity" of each module:
  - **Prod1**: 3 vessels with typical levels of piping, isolation, BD ➪ Average complexity
  - **Prod2**: multiple vessels, with extensive piping interconnection ➪ Complex complexity



Example Application (cont.)

- Assess Jet fire impact for **Prod1**:
  - Use Offshore–Floating–Production–Jet/Spray Fire Curves at 10^{-4} and $10^{-5}/yr$ frequencies.
  - Read off fire sizes as a function of time, from the Average complexity curves (data is also tabulated in the Document).





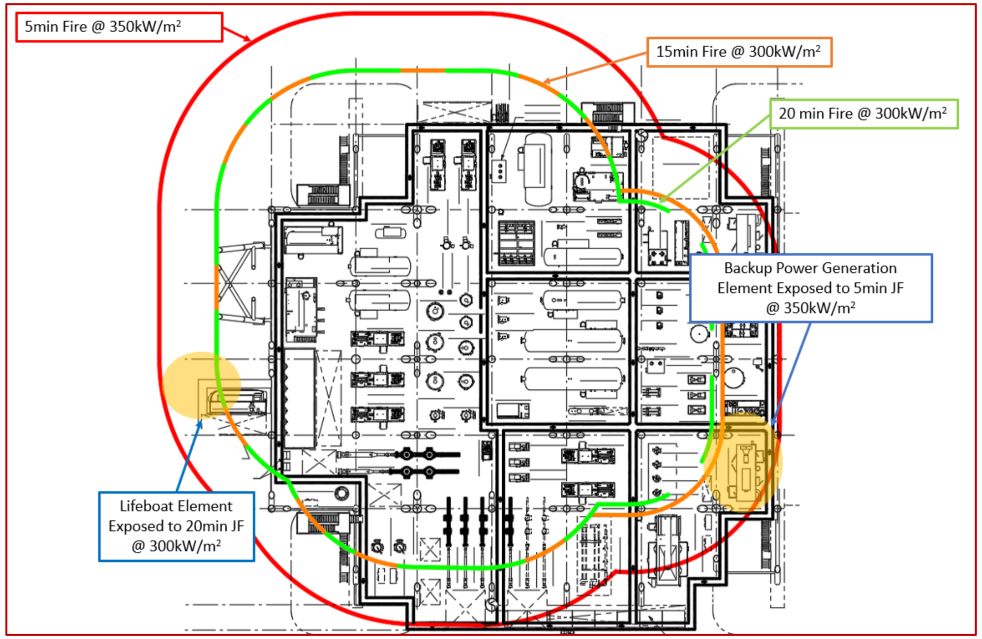
Example Application (cont.)

- Do the same for **Prod2** module and tabulate the data.
- Estimate likely heat flux level, e.g., using the correlation in the Guidance Document Appendix.

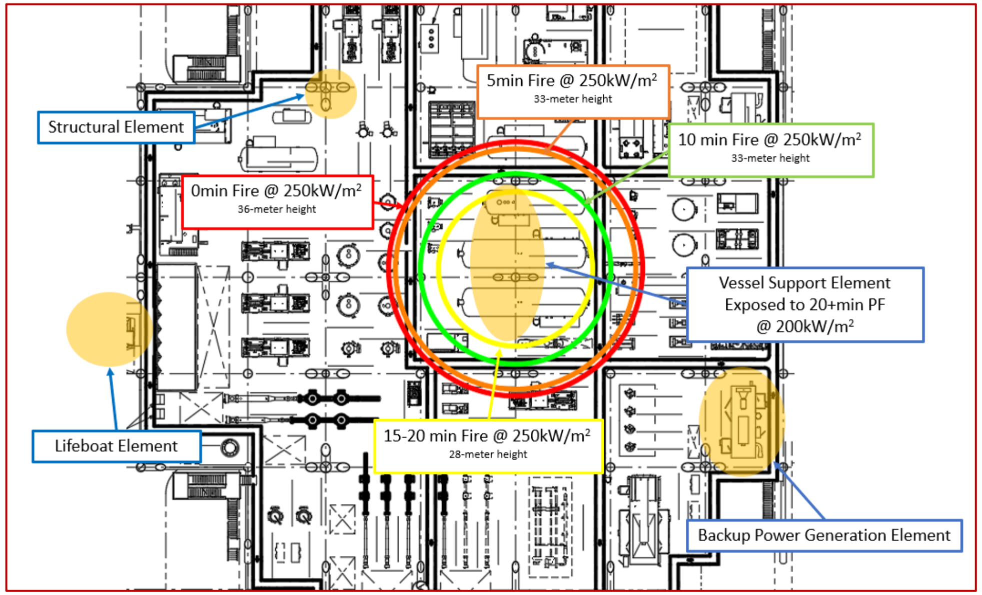
Module / Complexity	Exceedance Level (/yr)	Jet Fire Length (m) / maximum heat flux (kW/m^2)						
		Time (mins)						
		0	5	10	15	20	30	60
Prod.1 Average	$1x10^{-4}$	24/ 300	11/ 200	11/ 200	10/ 200	10/ 200	9/ 200	3/ 200
	$1x10^{-5}$	81/ 400	27/ 350	17/ 300	17/ 300	15/ 300	15/ 300	11/ 200
Prod.2 Complex	$1x10^{-4}$	36/ 350	16/ 300	16/ 300	15/ 300	15/ 300	14/ 300	6/ 200
	$1x10^{-5}$	114/ 400	35/ 350	35/ 350	25/ 300	25/ 300	23/ 300	19/ 300

Example Application (cont.)

- Assess the jet fire threat to the critical elements by either:
  - using tabulated distances to the critical items;
  - or mapping the fire sizes onto the layout drawing.



- Do the same for the pool fires.



Example Application (cont.)

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- Use this, and estimated fire endurance times, to assess:
  - the fire impact on each critical element;
  - minimum required protection time.

Key Vulnerable Element	Natural Endurance Time (min)	Exposure Time (min)	Minimum Protection Time (min)
Lifeboat	<1	20	20
Structural Member	10	20	10
Backup Power Generation	5	5-15	10
Vessel Supports (in Prod. 1)	2	JF / 20	JF / 18
		PF / 20	PF / 18
Main Deck Decking (above Production Deck)	20	JF / 20	JF / 0
		PF / 20	PF / 0

- High level guidance on the ensuing PFP Selection is included in the Document

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Testing of the Document

Testing the Process

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- The document has been intensively reviewed within PFPNet … but we think that a "road test" would be invaluable to check that:
  - it is practical to use;
  - it produces output that is sensible.
- Looking for organisations or individuals who would like to take part in a test of the document.
- PFPNet has a Test Package of 2 example facilities (1 offshore, 1 onshore), with:
  - the Guidance Document;
  - all the information that is needed for the analysis of the 2 facilities;
  - some basic instructions on how to conduct the analysis;
  - checksheets to allow the Users to record their decision making process.
- The results will then be reviewed to see whether further polising is required of the Guidance Document.
- We are still looking for volunteers, please! … contact: simon.thurlbeck@pfpnet.com

Q&A

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