CHEMISTRY THAT MATTERS™

DOW FIRE & EXPLOSION INDEX

BASIC UNDERSTANDING & PRACTICAL APPLICATION

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INTRODUCTION

The Fire & Explosion Risk Analysis System is a step-by-step objective evaluation of the realistic fire, explosion and reactivity potential of process equipment and its contents. The quantitative measurements used in the system are based on historic loss data and the energy potential of the material under study. Its purpose is to:

- Quantify the expected damage of potential fire, explosion and reactivity incidents in realistic terms – normal operating conditions. A Process Hazards Analysis (PHA) method should be utilized to evaluate abnormal operating conditions.
- Identify equipment that would be likely to contribute to the creation or escalation of an incident.
- Communicate the F&EI risk potential to management in quantitative terms.

BACKGROUND

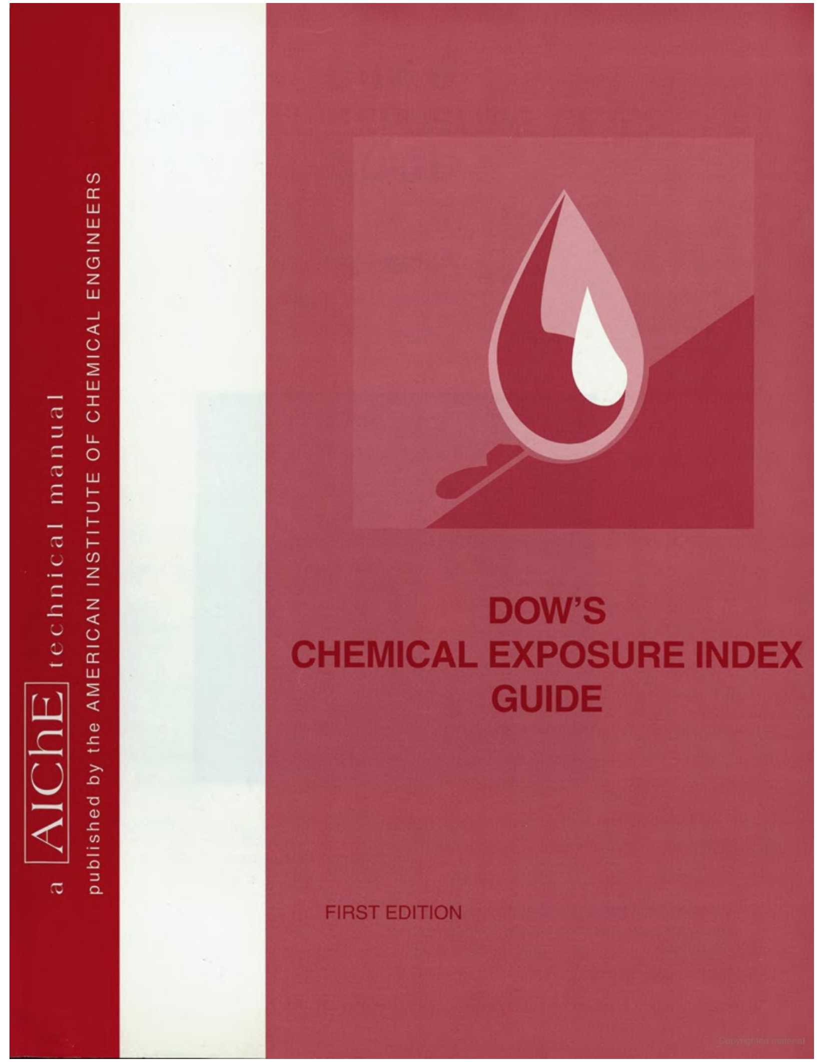
First developed at Dow Chemical in 1964 as a risk evaluation tool for potential fire and explosion in individual process units.

Over time it has evolved into a comprehensive index which provides a relative value to the risk determined.

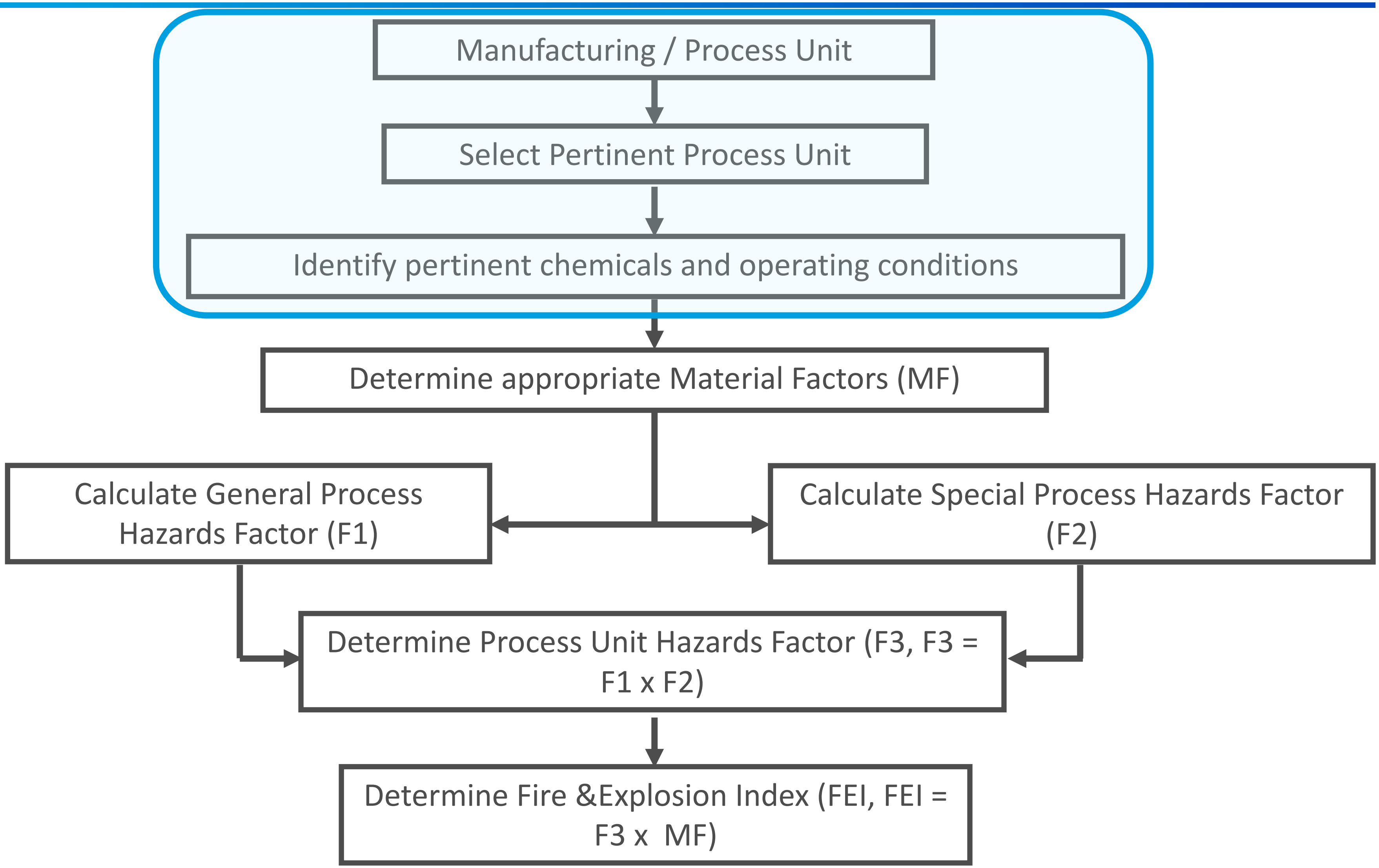
It is the leading hazard index recognized by the chemical industry and is an integral part of SABIC's Specialties Business Risk Management Overview process.

SABIC limits use to

- screening of comparative process to make "X"
- selecting a node's PHA method based on its F&EI score



PROCESS MAP


Manufacturing / Process Unit
Select Pertinent Process Unit
Identify pertinent chemicals and operating conditions
Determine appropriate Material Factors (MF)
Calculate General Process Hazards Factor (F1)
Calculate Special Process Hazards Factor (F2)
Determine Process Unit Hazards Factor (F3, F3 = F1 x F2)
Determine Fire &Explosion Index (FEI, FEI = F3 x MF)

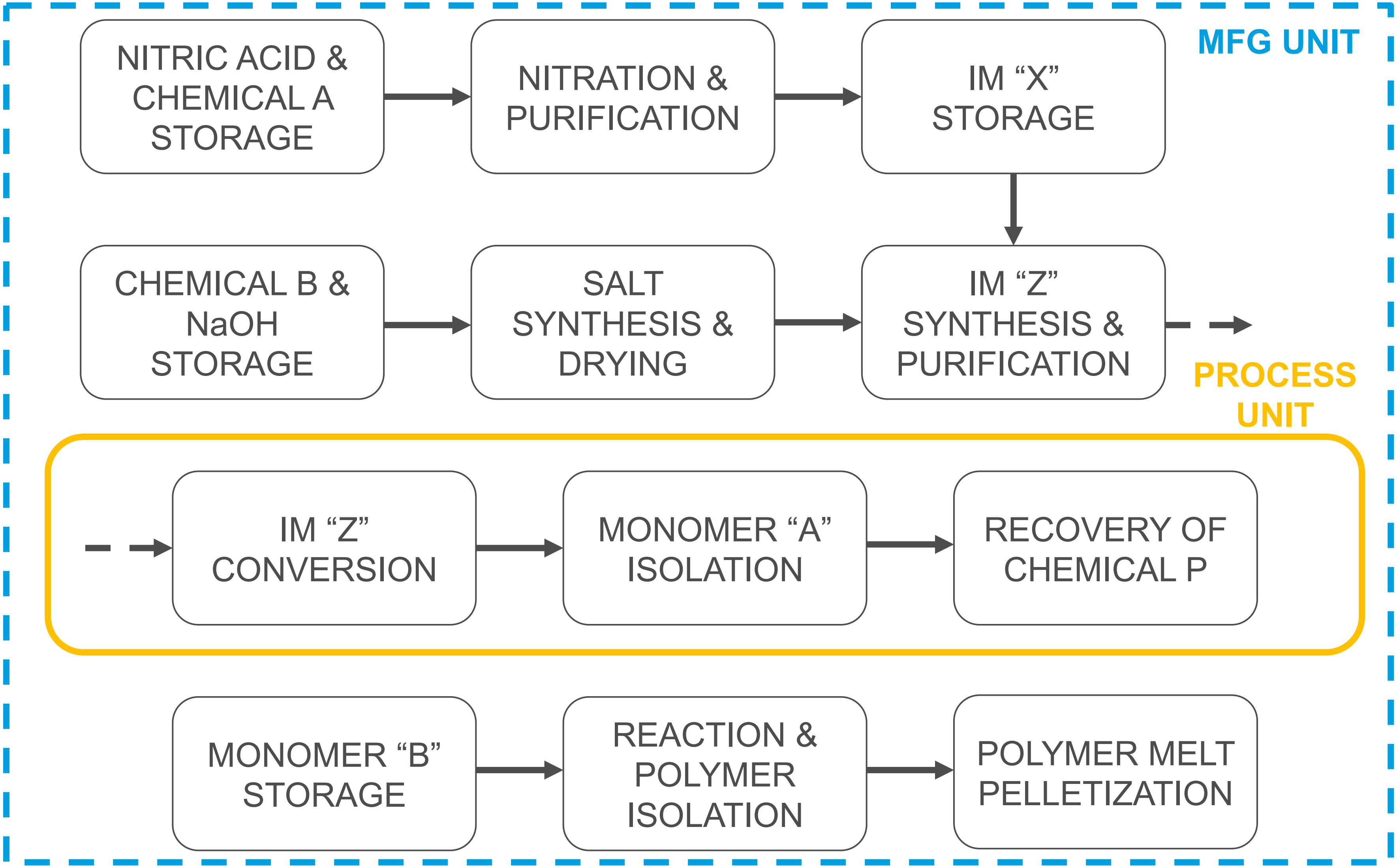
PROCESS UNIT DEFINITION

MANUFACTURING UNIT – the entire production facility including chemical processes, mechanical processes, warehouse, packaging lines, etc. A Manufacturing Unit will consist of several process units.

PROCESS UNIT – a logical grouping of process equipment or a process train; boundaries are set by logical termination points such as tanks, pumps, etc. For example, a supply line to a reactor could be included as part of the reactor but its storage system (pump, tank, etc) might not be, since the pump is a logical termination point. However, a series of cascading reactors would be considered as one unit unless there were pumps in between them.

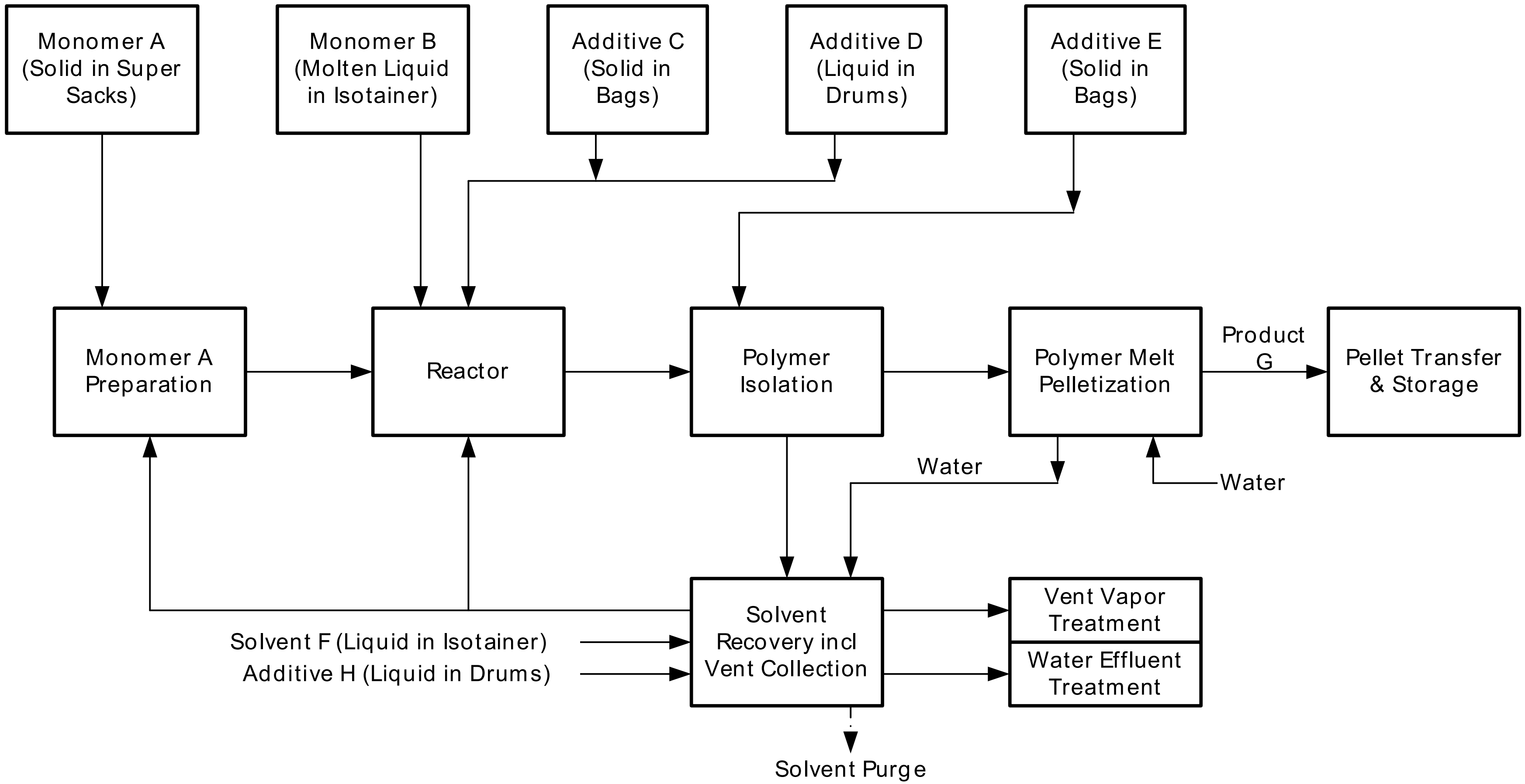
A PERTINENT PROCESS UNIT is one wherein chemicals, which can be involved in a fire or explosion, are processed.

INTEGRATED MANUFACTURING FACILITY BLOCK DIAGRAM



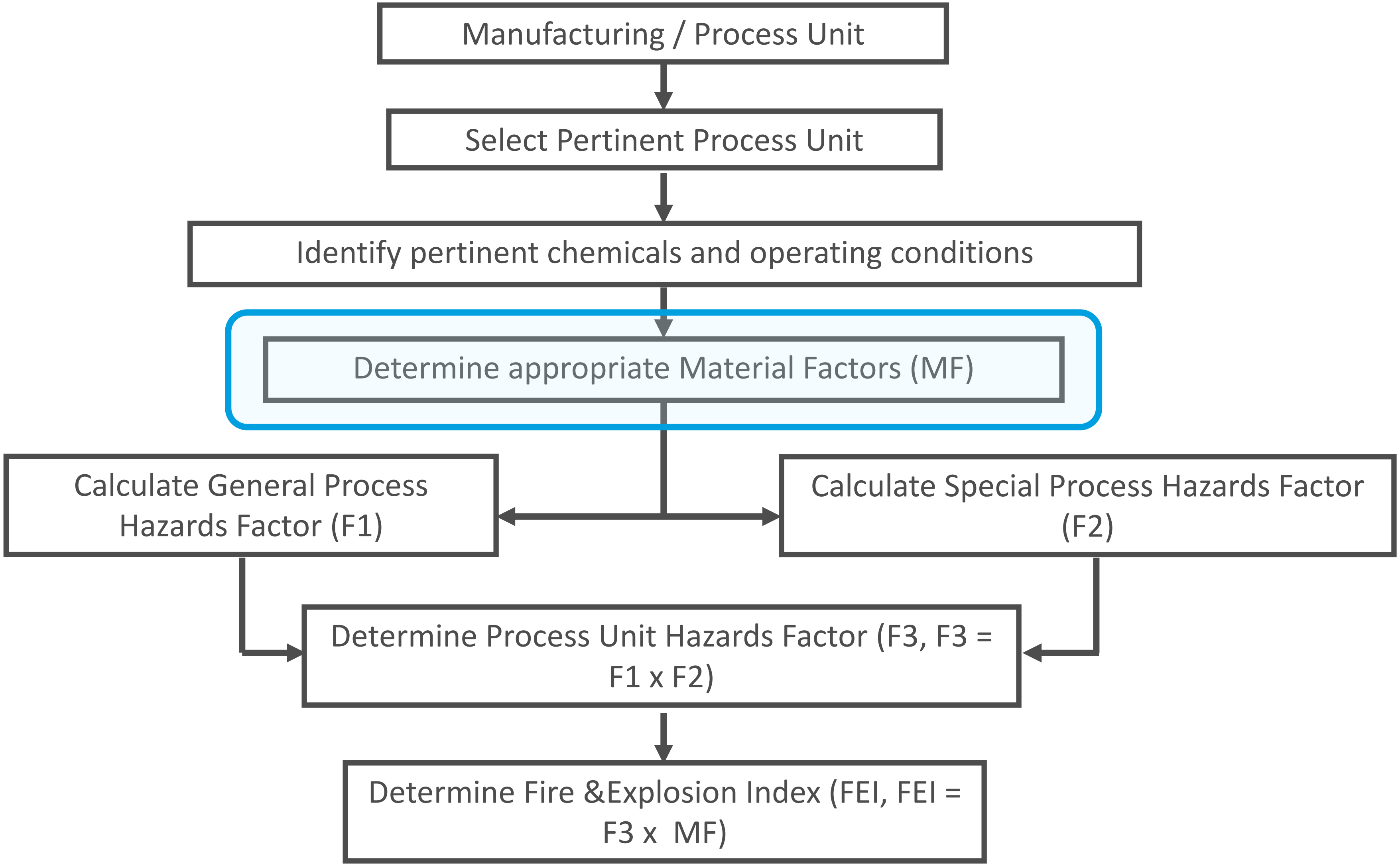
IM = Intermediate

PERTINENT PROCESS UNIT – BLOCK DIAGRAM



- Break pertinent process unit into nodes
- Define how nodes communicate with each other to derive alternative cases

PROCESS MAP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MATERIAL FACTORS (MF)

The Material Factor (MF) is a measure of the intrinsic rate of potential energy release from a fire or explosion produced by combustion or chemical reaction. Reference data and a methodology for MF determination are provided in the Guide.

MATERIAL FACTOR DETERMINATION GUIDE

Liquids & Gases Flammability or Combustibility[1]	NFPA 325M or 49	Reactivity or Instability				
		$N_R = 0$	$N_R = 1$	$N_R = 2$	$N_R = 3$	N
Non-combustible[2]	$N_F = 0$	1	14	24	29	
F.P. > 200 °F (> 93.3 °C)	$N_F = 1$	4	14	24	29	
F.P. > 100 °F (> 37.8 °C) ≤ 200 °F (≤ 93.3 °C)	$N_F = 2$	10	14	24	29	
F.P. ≥ 73 °F (≥ 22.8 °C) < 100 °F (< 37.8 °C) or F.P. < 73 °F (< 22.8 °C) & BP. ≥ 100 °F (≥ 37.8 °C)	$N_F = 3$	16	16	24	29	
F.P. < 73 °F (< 22.8 °C) & B.P. < 100 °F (< 37.8 °C)	$N_F = 4$	21	21	24	29	40
Combustible Dust or Mist[3]						
St-1 (K_{St} ≤ 200 bar m/sec)		16	16	24	29	40
St-2 (K_{St} = 201-300 bar m/sec)		21	21	24	29	40
St-3 (K_{St} > 300 bar m/sec)		24	24	24	29	40
Combustible Solids						
Dense > 40 mm thick[4]	$N_F = 1$	4	14	24	29	40
Open < 40 mm thick[5]	$N_F = 2$	10	14	24	29	40
Foam, fiber, powder, etc.[6]	$N_F = 3$	16	16	24	29	40

MATERIAL FACTOR TEMP. ADJUSTMENT	N_F	St	N_R
a. Enter N_F (St for dusts) and N_R.			
b. If temperature less than 140 °F (60 °C), go to "e."			
c. If temperature above flash point or if temperature greater than 140 °F (60 °C), enter "1" under N_F.			
d. If temperature above exotherm start (see paragraph below) or autoignition, enter "1" under N_R.			
e. Add each column, but enter 4 where total is 5.			
f. Using "e." and Table 1, determine Material Factor (MF) and enter on F&EI Form (page 5) and Manufacturing Unit Risk Analysis Summary (page 7).			

Note: 140 °F (60 °C) can be reached in storage due to layering and solar heat.

Flammability +

Reactivity +

Operating Temperature

MATERIAL FACTOR EXAMPLE - TOLUENE

<u>Toluene</u>	
NFPA H / F / R	2 / 3 / 0
Flashpoint, (°F / °C)	40 / 4
Boiling Point (°F / °C)	231 / 111
AIT (°F / °C)	896 / 480
Operating T & P (°F / psig)	250 / 20

MATERIAL FACTOR TEMP. ADJUSTMENT	N_F	St	N_R
a. Enter N_F (St for dusts) and N_R.	3		0
b. If temperature less than 140 °F (60 °C), go to "e."			
c. If temperature above flash point or if temperature greater than 140 °F (60 °C), enter "1" under N_F.	1		
d. If temperature above exotherm start (see paragraph below) or autoignition, enter "1" under N_R.			0
e. Add each column, but enter 4 where total is 5.	4		0
f. Using "e." and Table 1, determine Material Factor (MF) and enter on F&EI Form (page 5) and Manufacturing Unit Risk Analysis Summary (page 7).			

Note: 140 °F (60 °C) can be reached in storage due to layering and solar heat.

Adjustment for Operating T & P increases Material Factor from 16 to 21.

MATERIAL FACTOR DET

Liquids & Gases Flammability or Combustibility[1]	NFPA 325M or 49	$N_R = 0$
Non-combustible[2]	$N_F = 0$	1
F.P. > 200 °F (> 93.3 °C)	$N_F = 1$	4
F.P. > 100 °F (> 37.8 °C) ≤ 200 °F (≤ 93.3 °C)	$N_F = 2$	10
F.P. ≥ 73 °F (≥ 22.8 °C) < 100 °F (< 37.8 °C) or F.P. < 73 °F (< 22.8 °C) & BP. ≥ 100 °F (≥ 37.8 °C)	$N_F = 3$	16
F.P. < 73 °F (< 22.8 °C) & B.P. < 100 °F (< 37.8 °C)	$N_F = 4$	21
Combustible Dust or Mist[3]		
St-1 (K_{St} ≤ 200 bar m/sec)		16
St-2 (K_{St} = 201-300 bar m/sec)		21
St-3 (K_{St} > 300 bar m/sec)		24
Combustible Solids		
Dense > 40 mm thick[4]	$N_F = 1$	4
Open < 40 mm thick[5]	$N_F = 2$	10
Foam, fiber, powder, etc.[6]	$N_F = 3$	16

MATERIAL FACTOR EXAMPLE – BISPHENOL A (BPA)

Bisphenol A (BPA)

NFPA H / Kst / R	3 / 3 / 0
Flashpoint, (°F / °C)	405 / 207
Boiling Point (°F / °C)	865 / 361
AIT (°F / °C)	750 / 399
Operating T & P (°F / psig)	140 / 3

MATERIAL FACTOR TEMP. ADJUSTMENT	N_F	St	N_R
a. Enter N_F (St for dusts) and N_R.		3	0
b. If temperature less than 140 °F (60 °C), go to "e."			
c. If temperature above flash point or if temperature greater than 140 °F (60 °C), enter "1" under N_F.			
d. If temperature above exotherm start (see paragraph below) or autoignition, enter "1" under N_R.			0
e. Add each column, but enter 4 where total is 5.		3	0
f. Using "e." and Table 1, determine Material Factor (MF) and enter on F&EI Form (page 5) and Manufacturing Unit Risk Analysis Summary (page 7).			

Note: 140 °F (60 °C) can be reached in storage due to layering and solar heat.

Adjustment for Operating T & P not required Material Factor unchanged at 24

MATERIAL FACTOR DETI

Liquids & Gases Flammability or Combustibility[1]	NFPA 325M or 49	$N_R = 0$
Non-combustible[2]	$N_F = 0$	1
F.P. > 200 °F (> 93.3 °C)	$N_F = 1$	4
F.P. > 100 °F (> 37.8 °C) ≤ 200 °F (≤ 93.3 °C)	$N_F = 2$	10
F.P. ≥ 73 °F (≥ 22.8 °C) < 100 °F (< 37.8 °C) or F.P. < 73 °F (< 22.8 °C) & BP. ≥ 100 °F (≥ 37.8 °C)	$N_F = 3$	16
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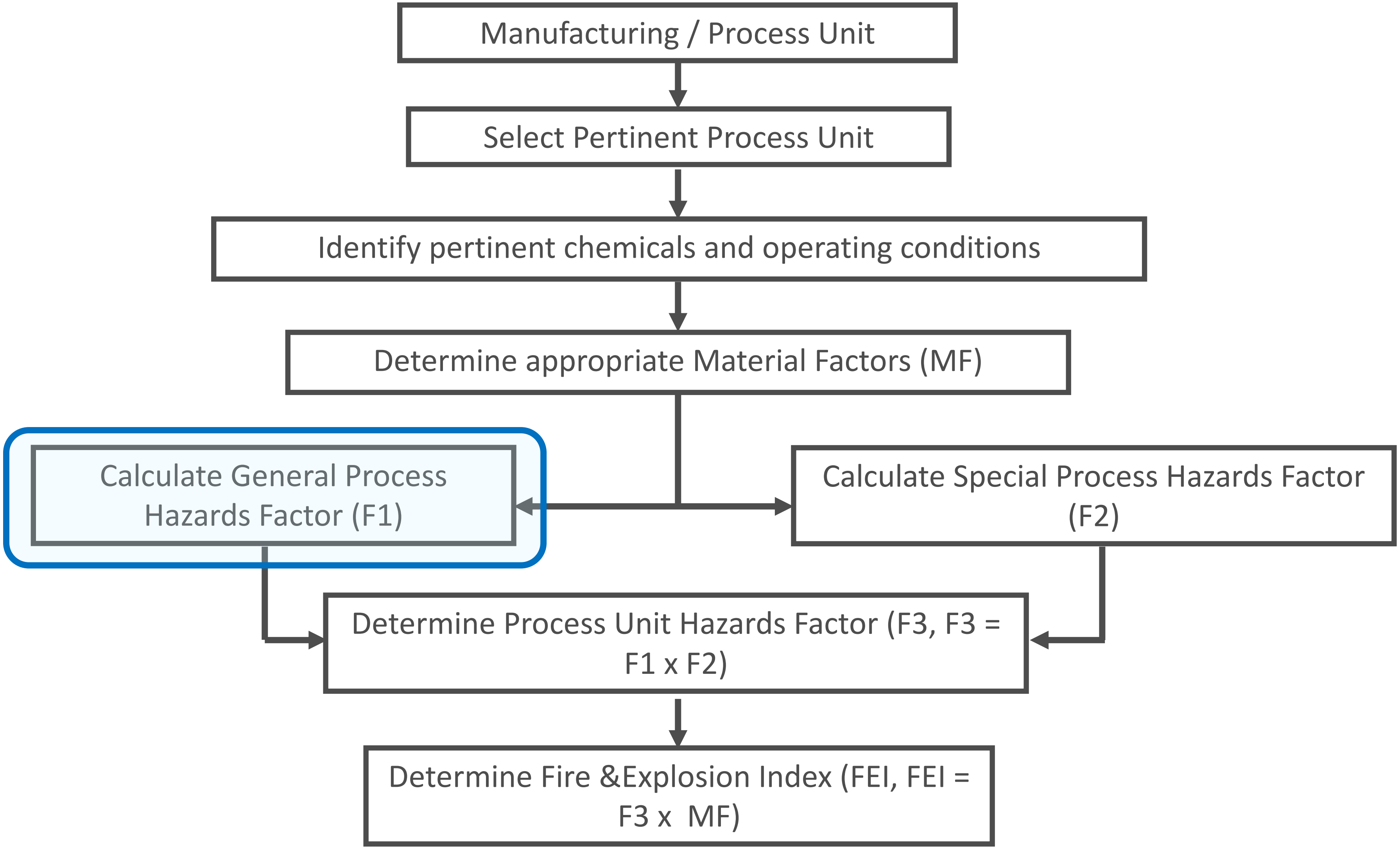
Combustible Dust or Mist[3]		
St-1 (K_{St} ≤ 200 bar m/sec)		16
St-2 (K_{St} = 201-300 bar m/sec)		21
St-3 (K_{St} > 300 bar m/sec)		24
Combustible Solids		
Dense > 40 mm thick[4]	$N_F = 1$	4
Open < 40 mm thick[5]	$N_F = 2$	10
Foam, fiber, powder, etc.[6]	$N_F = 3$	16

PROCESS MAP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Determine Process Unit Hazards Factor (F3, F3 = F1 x F2)
Determine Fire &Explosion Index (FEI, FEI = F3 x MF)

F1 GENERAL PROCESS HAZARD DEFINITION

General Process Hazards (F1) – factors that play a primary role in determining the magnitude of a loss incident. These have played large roles in loss incidents. Their relative contribution has been quantified into terms known as **penalty factors**. If the factor or condition is not present, then the penalty factor is zero.

- Exothermic Chemical Reactions, range from 0.3 to 1.25
- Endothermic Chemical Reactions, range from 0.2 to 0.4
- Material Handling & Transfer, range from 0.25 to 1.05
- Enclosed or Indoor Units, range from 0.25 to 0.9
- Access (for emergency equipment), range from 0.2 to 0.35
- Drainage and Spill Control, range from 0.25 to 0.5

The penalty factors are to be applied for the most hazardous normal operating conditions that might occur for the Material Factor assigned to the Pertinent Process Unit being analyzed. Only evaluate one hazard at a time. Example - if the MF is based on a flammable liquid, penalties for presence of a combustible dust are not taken. Execute new / alternative scenarios as needed.

F1 PENALTY FACTOR EXAMPLES

A. **Exothermic Chemical Reactions**

Take this penalty only if the Process Unit in question is a reactor in which a chemical reaction takes place. The reactivity hazard of the material being evaluated is inherent in the Material Factor.

1. B. **Endothermic Processes**

C. **Material Handling and Transfer**

This item is evaluated with regard to the potential for fire involving the pertinent Process Unit during the handling, transfer and warehousing of materials.

2.

1. Any loading or unloading operation involving Class I flammables or LPG-type materials where transfer lines are connected and disconnected receives a **penalty of 0.50.**
2. Where the introduction of air during manual addition of some ingredients into centrifuges, batch reactors or batch mixers may create a flammability or reactivity hazard, a **penalty of 0.50** is applied. ***Note:*** These penalties apply whether or not the equipment vapor space is inerted.
3. Ranges of penalties based on material fire hazards are applied to warehouse storage or yard storage of various items.
   a. A **penalty of 0.85** is applied for N_F = 3 or 4 flammable liquids or gases. This category includes drums, cylinders, portable flexible containers and aerosol cans.
   b. A **penalty of 0.65** is applied for N_F = 3 combustible solids as identified in Table 1, page 13.
   c. A **penalty of 0.40** is applied for N_F = 2 combustible solids as identified in Table 1.
   d. A **penalty of 0.25** is taken for combustible liquids (closed cup flash point above 100 °F (37.8 °C) and below 140 °F (60 °C)).

   If any of the above are stored on racks without in-rack sprinklers, **add 0.20 to the penalty.** This area of consideration is not for normal storage tanks.

e.
f.
3. CR
rea
Exa
a.
4. PA
rea
a.

F1 SCORING EXAMPLE – SOLID/LIQUID REACTION IN SOLVENT

Catalyzed reaction of non-volatile organic compounds in solvent at its normal BP

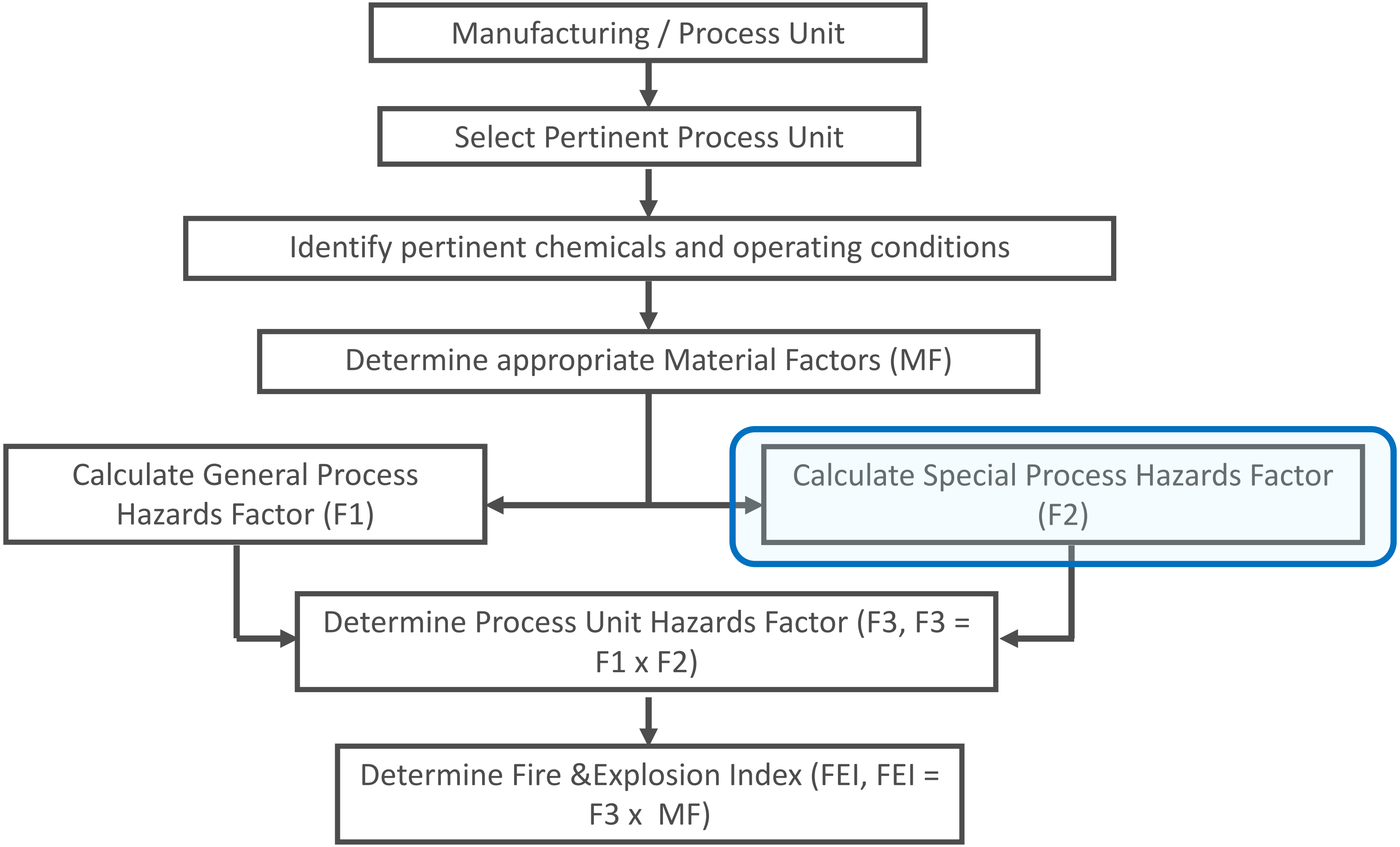
	MF	21	21	Base factor = 16; adjustment for operating temperature above flash point
1. General Process Hazards	Penalty Factor Range	Penalty Factor Used	Penalty Factor Used	
Base Factor	1	1	1	
A. Exothermic Chemical Reactions	0.3 - 1.25	0.3	0.3	penalty assessed for mildly exothermic
B. Endothermic Processes	0.2 - 0.4	0	0	
C. Material Handling and Transfer	0.25 - 1.05	0	0	no penalty - toluene storage (dry) considered an in-process vessel
D. Enclosed or Indoor Process Units	0.25 - 0.9	0	0.45	some cases incur penalty as process assumed to be in enclosed space but with adequate ventilation
E. Access	0.2 - 0.35	0	0	
F. Drainage and Spill Control	0.25 - 0.5	0.25	0.25	partial penalty to be taken as design of drainage a critical factor and design not yet finalized
General Process Hazards Factor (F_1)		1.55	2	

F1 SCORING EXAMPLE – NITRATION REACTION

Reaction of non-volatile organic in pure nitric acid at lower than ambient T

	MF	24	set by reactivity of materials
1. General Process Hazards	Penalty Factor Range	Penalty Factor Used	
Base Factor	1	1	
A. Exothermic Chemical Reactions	0.3 - 1.25	1.0	not typical nitration as organic concentration is only 10%; nitric acts as solvent as well as heat sink - the penalty factor could be 0.5 per guideline but 1.0 used as conservative
B. Endothermic Processes	0.2 - 0.4	0	
C. Material Handling and Transfer	0.25 - 1.05	0	penalty does not apply - no connections considered in the 'tank farm'
D. Enclosed or Indoor Process Units	0.25 - 0.9	0	this penalty is applied for flammable materials; penalty for reactive materials is encompassed by the MF
E. Access	0.2 - 0.35	0	
F. Drainage and Spill Control ______ gal or cu. M	0.25 - 0.5	0	penalty does not apply - combustible not flammable; operating temperature below
General Process Hazards Factor (F_1)		2	

PROCESS MAP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Identify pertinent chemicals and operating conditions
Determine appropriate Material Factors (MF)
Calculate General Process Hazards Factor (F1)
Calculate Special Process Hazards Factor (F2)
Determine Process Unit Hazards Factor (F3, F3 = F1 x F2)
Determine Fire &Explosion Index (FEI, FEI = F3 x MF)

F2 SPECIAL PROCESS HAZARDS DEFINITION

Special Process Hazards (F2) – factors that contribute primarily to the probability of a loss incident. They consist of specific process conditions that have shown themselves to be major causes of fire and explosions. Application is done in similar manner to F1.

- Toxic Materials, range from 0.2 to 0.8
- Sub-Atmospheric Pressure, penalty factor = 0.5
- Operation in or near Flammable Range, range from 0.3 to 0.8
- Dust Explosion, range from 0.25 to 2
- Relief Pressure, range from graph
- Low Temperature, range from 0.2 to 0.3
- Quantity of Flammable / Unstable Material, range from graph
- Corrosion and Erosion, range from 0.1 to 0.75
- Leakage – Joints and Packing, range from 0.1 to 1.5
- Use of Fired Equipment, range from graph
- Hot Oil Exchange System, range from 0.15 to 1.15
- Rotating Equipment, penalty factor = 0.5

F2 PENALTY FACTOR EXAMPLES

Thoroughly read and re-read

A. Toxic Material(s)

Toxic materials can complicate the response of emergency personnel, thereby reducing their ability to investigate or mitigate damage during an incident. Use **0.20 x N_H as the penalty**. For mixtures, use the componer

N_H is the hea
The N_H for n
assistance in

Listed below

N_H = 0 Ma
ord
N_H = 1 Ma
inc
N_H = 2 Ma
sib
tha
N_H = 3 Ma
the
N_H = 4 Ma

Note: These
tional loss. T

I. Leakage – Joints and Packing

Gaskets, seals of joints or shafts and packing can be sources of leaks of flammable or combustible materials, particularly where thermal and pressure cycling occurs. A penalty factor should be selected according to the design of the Process Unit under study and the material being used in the process. The following penalties should be applied:

1. Where the p
0.10.
2. For process
the penalty
3. For process
4 If the mater
intermittent
penalty is 0
5. For any Pro
1.50.

L. Rotating Equipment

This section recognizes the hazard exposure of Process Units incorporating large pieces of rotating equipment. Although formulas have not been developed for evaluating all types and sizes of rotating equipment, there is statistical evidence indicating that pumps and compressors beyond a certain size are likely to contribute to a loss incident.

A penalty of 0.50 is applied to Process Units that utilize or are:

1. A compressor in excess of 600 hp.
2. A pump in excess of 75 hp.
3. Agitators (mixers) and circulating pumps in which failure could create a process exotherm due to lack of cooling from interrupted mixing or circulation of coolant or due to interrupted and resumed mixing.
4. Other large high speed rotating equipment with a significant loss history; for example, centrifuges.

Once all of the special process hazards have been evaluated, a calculation is to be made of the sum of the base factor and all penalty factors applied in this section. The total is to be entered in the box labeled "Special Process Hazards Factor (F_2)" on the F&EI Form, page 5.

Apply consistently

F2 PENALTY FACTOR EXAMPLES, CONTINUED

FIGURE 2 - PRESSURE PENALTY FOR FLAMMABLE & COMBUSTIBLE LIQUIDS

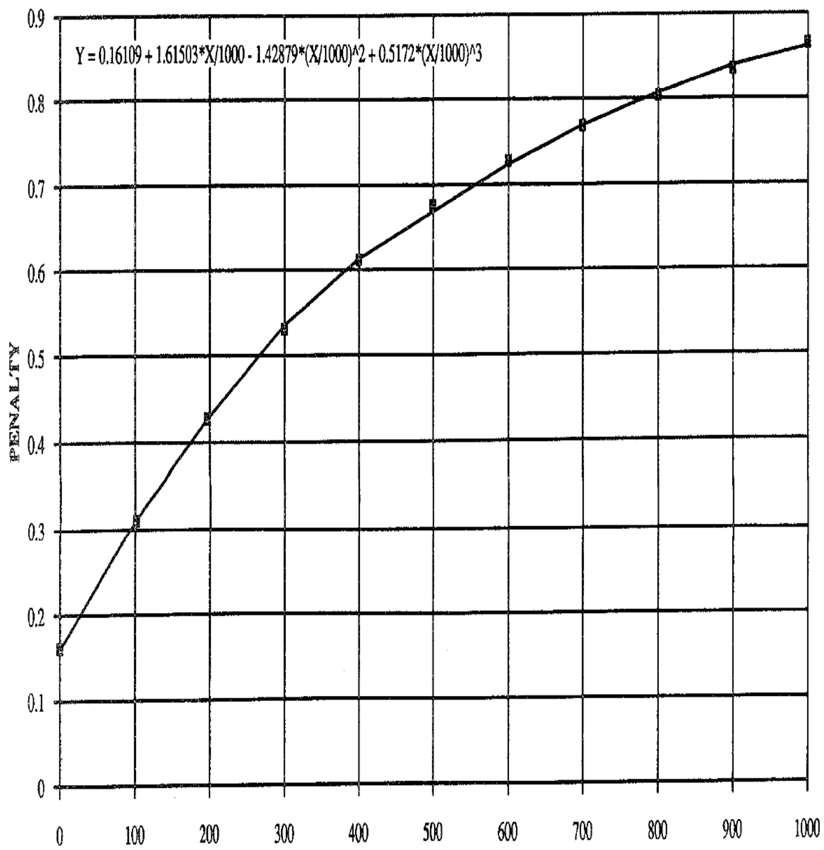
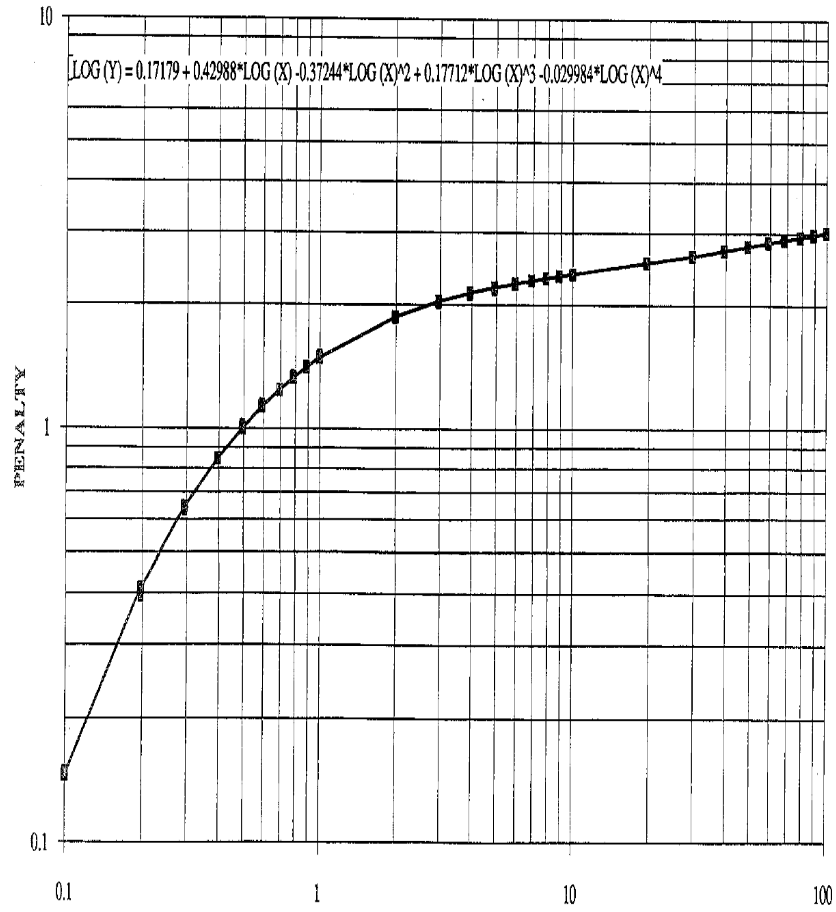


FIGURE 3 - LIQUIDS OR GASES IN PROCESS



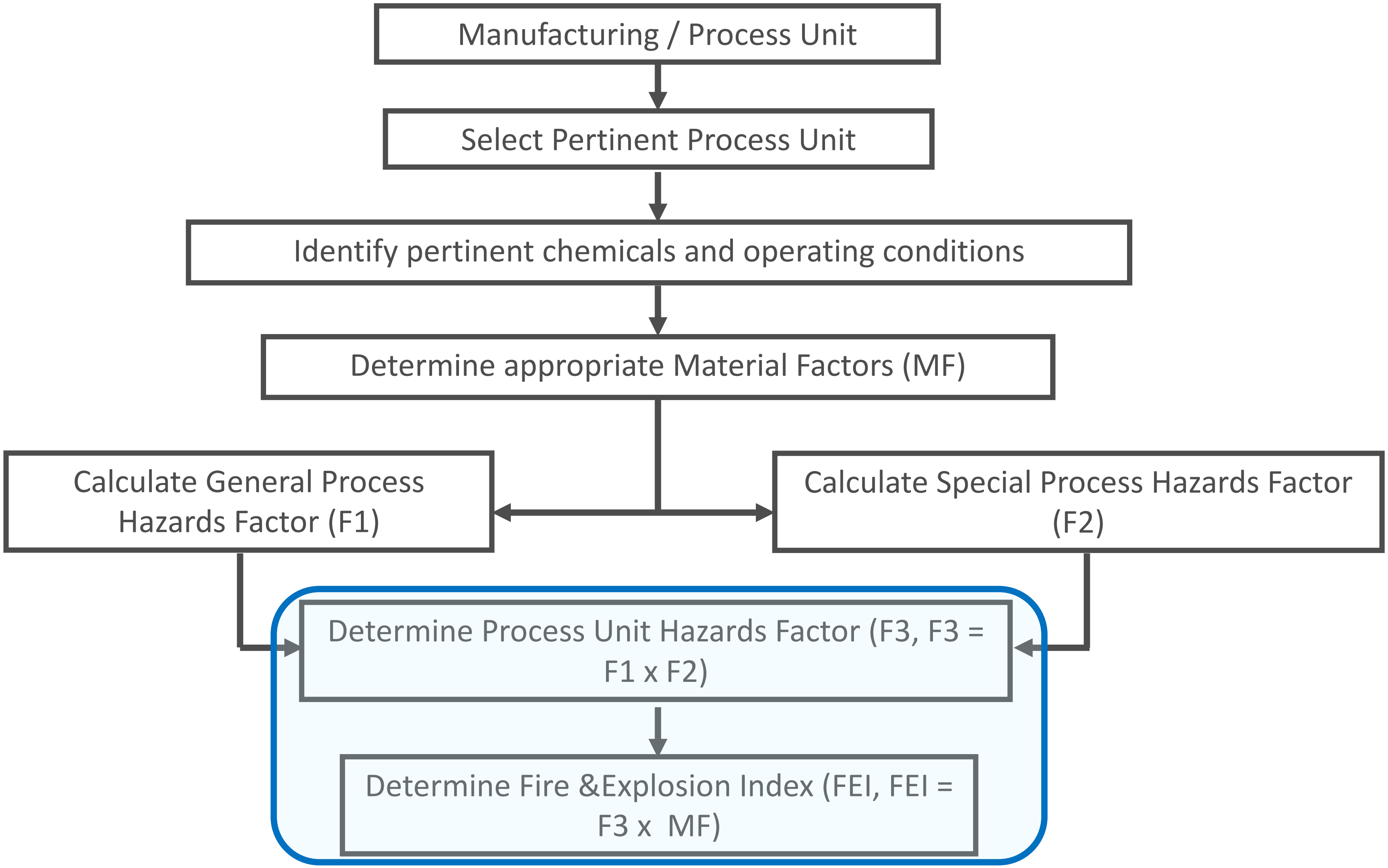
F2 SCORING EXAMPLE – SOLID/LIQUID REACTION IN SOLVENT

2. Special Process Hazards Base Factor				
		1	1	1	
A. Toxic Materials	0.2 - 0.8	0.4	0.4	Toluene Nh = 2
B. Sub-Atmospheric Pressure (<500 mr	0.5	0	0	does not apply
C. Operation in or near Flammable Range ___ Inerted				
1. Tank Farm Storage Flammable Liqui	0.5	0	0	
2. Process Upset or Purge Failure	0.3	0.3	0.3	System under constant nitrogen pressure and operating above toluene flash point
3. Always in Flammable Range	0.8	0	0	
D. Dust Explosion (See Table 3)	0.25 - 2.0	0	0	
E. Presssure (Fig 2) Operating Pressure 5 psig Relief Setting 75 psig		0.1	0.1	assumes new vessel will be at least rated for 75 psig
F. Low Temperature	0.2 - 0.3	0	0	
G. Quantity of Flammable/Unstable Material Quantity (lb, see cells to right) Hc = 17.3* 10^3 BTU/lb		133000	133000	all vessels in system can communicate with each other - reactors to wash vessel share common bottoms piping; gravity drain from reactors to wash vessel
1. Liquids or Gases in Process (Fig 3)		2.0	2.0	
2. Liquids or Gases in Storage (Fig 4)		0	0	
3. Combustible Solids in Storage, Dust in Process		0	0	
H. Corrosion and Erosion	0.1 - 0.75	0.1	0.1	some corrosion has occurred in vessel head space and vapor lines - mechanism is understood and material of construction altered to mitigate
I. Leakage - Joints and Packing	0.1 - 1.50	0.1	0.1	no pumps but each vessel equipped with agitator with shaft seal
J. Use of Fired Equipment		0	0	
K. Hot Oil Heat Exchange System	0.15 - 1.15	0	0	
L. Rotating Equipment	0.5	0	0	
Special Process Hazard Factor (F_2)		4.0	4.0	

F2 SCORING EXAMPLE – NITRATION REACTION

2. Special Process Hazards	Base Factor	1	1	
A. Toxic Materials		0.2 - 0.8	0.8	
B. Sub-Atmospheric Pressure (<500 mm Hg)		0.5	0	penalty does not apply
C. Operation in or near Flammable Range __Not inerted				
1. Tank Farm Storage Flammable Liquids		0.5	0	
2. Process Upset or Purge Failure		0.3	0	penalty does not apply - upset condition cannot result in temperatures greater than flashpoint of organics present
3. Always in Flammable Range		0.8	0	
D. Dust Explosion (See Table 3)		0.25 - 2.0	0	
E. Presssure (Fig 2) Operating Pressure 0 psig Relief Setting 5.9 psig			0.11	surge tank pressure rating - 5.9 psig; nitration reactor - 7.8 psig
F. Low Temperature		0.2 - 0.3	0	
G. Quantity of Flammable/Unstable Material	Quantity 15000 lb Hc = 8500 BTU/lb			basis - volume of nitration reactors (3) plus storage tank
1. Liquids or Gases in Process (Fig 3)			0.22	the NF is 1 or less. So this may not be a fire risk..
2. Liquids or Gases in Storage (Fig 4)			0	
3. Combustible Solids in Storage, Dust in Process (Fig 5)			0	
H. Corrosion and Erosion		0.1 - 0.75	0.1	wet nitric acid, not much corrosion since the beginning of the reactors
I. Leakage - Joints and Packing		0.1 - 1.50	0.3	penalty for 'frequent' leakage applied
J. Use of Fired Equipment			0	
K. Hot Oil Heat Exchange System		0.15 - 1.15	0	
L. Rotating Equipment		0.5	0	
Special Process Hazard Factor (F_2)			2.5	

PROCESS MAP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Determine Fire &Explosion Index (FEI, FEI = F3 x MF)

FIRE & EXPLOSION INDEX SUMMARY SHEET

Define operational state

Quantify F1 Hazards

Calculate F3

Digitize form to suit your needs

Input Material Factor

Quantify F2 Hazards

Calculate F&EI

FIRE & EXPLOSION INDEX

AREA / COUNTRY	DIVISION	LOCATION	DATE
SITE	MANUFACTURING UNIT	PROCESS UNIT	
PREPARED BY:	APPROVED BY: (Superintendent)	BUILDING	
REVIEWED BY: (Management)	REVIEWED BY: (Technology Center)	REVIEWED BY: (Safety & Loss Prevention)	
MATERIALS IN PROCESS UNIT			
STATE OF OPERATION __ DESIGN __ START UP __ NORMAL OPERATION __ SHUTDOWN	BASIC MATERIAL(S) FOR MATERIAL FACTOR		

MATERIAL FACTOR (See Table 1 or Appendices A or B) Note requirements when unit temperature over 140 °F (60 °C)		
1. General Process Hazards	**Penalty Factor Range**	**Penalty Factor Used(1)**
Base Factor	1.00	1.00
A. Exothermic Chemical Reactions	0.30 to 1.25	
B. Endothermic Processes	0.20 to 0.40	
C. Material Handling and Transfer	0.25 to 1.05	
D. Enclosed or Indoor Process Units	0.25 to 0.90	
E. Access	0.20 to 0.35	
F. Drainage and Spill Control ________ gal or cu.m.	0.25 to 0.50	
General Process Hazards Factor (F_1)		
2. Special Process Hazards		
Base Factor	1.00	1.00
A. Toxic Material(s)	0.20 to 0.80	
B. Sub-Atmospheric Pressure (< 500 mm Hg)	0.50	
C. Operation In or Near Flammable Range ____ Inerted ____ Not Inerted		
1. Tank Farms Storage Flammable Liquids	0.50	
2. Process Upset or Purge Failure	0.30	
3. Always in Flammable Range	0.80	
D. Dust Explosion (See Table 3)	0.25 to 2.00	
E. Pressure (See Figure 2) Operating Pressure ______ psig or kPa gauge Relief Setting ______ psig or kPa gauge		
F. Low Temperature	0.20 to 0.30	
G. Quantity of Flammable/Unstable Material: Quantity ____ lb or kg H_C = ____ BTU/lb or kcal/kg		
1. Liquids or Gases in Process (See Figure 3)		
2. Liquids or Gases in Storage (See Figure 4)		
3. Combustible Solids in Storage, Dust in Process (See Figure 5)		
H. Corrosion and Erosion	0.10 to 0.75	
I. Leakage – Joints and Packing	0.10 to 1.50	
J. Use of Fired Equipment (See Figure 6)		
K. Hot Oil Heat Exchange System (See Table 5)	0.15 to 1.15	
L. Rotating Equipment	0.50	
Special Process Hazards Factor (F_2)		
Process Unit Hazards Factor (F_1 x F_2) = F_3		
Fire and Explosion Index (F_3 x MF = F&EI)		

(1) For no penalty use 0.00.

QUALIFYING STATEMENTS

Application of Penalty Factors (F1 & F2) – The DOW F&EI guide should be carefully read and routinely referenced when determining Material Factors (MF) and applying Penalty Factors (F1 & F2). Good engineering judgement is a pre-requisite!

The DOW F&EI guide pertains to fire & explosion scenarios. Take care to avoid misapplying penalties. Ensure that the storage or release of a chemical will actually contribute to an event. For example, handling of a (non-flammable) nitric acid + organic mixture will likely not incur F2 Hazard penalties related to the Relief Pressure, Corrosion / Erosion or Leakage, since a release in and of itself might not lead to an event or assist in the continuation of an event. Although the presence of nitric acid would not be welcome, the Toxic Material F2 penalty is sufficient.

Chemicals which pose a hygiene hazard are handled via the **DOW Chemical Exposure Index (CEI) guide**. For example, the hazard associated with a release of NOx containing vapor may more aptly assessed by use of the CEI.

REMEMBER - IF IN DOUBT, READ THE GUIDE ONE MORE TIME!

CATEGORIZING THE F&EI RESULT

F&EI INDEX RANGE	DEGREE OF HAZARD	COMPANY CLASS	COMPANY PHA METHOD
1 - 60	Light	D	Checklist
61 - 96	Moderate	C	SWIFT
97 - 127	Intermediate	B	HAZOP or SWIFT
128 - 158	Heavy	A	HAZOP
159 - up	Severe		

PHA – Process Hazards Analysis, which is a systematic effort to identify and analyze hazards associated with the processing or handling of hazardous materials. Several methods are used in industry.

HAZOP – Hazard and Operability Study, wherein a complex process is broken down into nodes and then examined by a multi-functional team using standardized guidewords to surface hazard and operability concerns.

SWIFT – Structured What If Technique, similar to HAZOP but using standardized questions to surface hazard concerns.

>> Class A processes should be redesigned to achieve B rating or not used.

F&EI LOSS CONTROL CREDITS

Industrially proven loss control features have been shown to prevent incidents and/or reduce the likelihood / magnitude of an incident. (It is assumed that the process unit is designed per good engineering practice with use of recognized fabrication codes.)

There are 3 categories of loss control features.

Process Control Factor (C1) – total equals all applicable factors multiplied together

Emergency Power (maintain essential services)	0.98
Cooling (abnormal operation)	0.97 to 0.99
Explosion Control (suppression)	0.84
Explosion Control (deflagration containment)	0.98
Emergency Shutdown (redundant system)	0.98
Emergency Shutdown (large equipment monitoring)	0.96 to 0.99
Distributed Control system (degree of control)	0.93 to 0.99
Inert Gas	0.94 to 0.96
Operating Instructions (scorecard)	0.91 to 0.99
Reactive Chemical review (scope and breadth)	0.91 to 0.98
Process Hazards Analysis (style employed)	0.91 to 0.98

C1 Range (all factors multipled except explosion control) - 0.6 to 0.85

C1 LOSS CONTROL FACTOR EXAMPLES

Operating Instructions/Procedures – 0.91 to 0.99

Adequate written operating instructions and/or a fully documented operating discipline are an important part of maintaining satisf
point ratings, are considered to be th

1. Startup – 0.5
2. Routine shutdown – 0.5
3. Normal operating conditions –
4. Turndown operating conditior
5. Standby running conditions (u
6. Uprated operating conditions (
7. Restarting shortly after a shut
8. Restarting plant from a post-m
9. Maintenance procedures (worl
10. Emergency shutdown – 1.5
11. Manufacturing unit equipment
12. Foreseeable abnormal fault sit

To obtain a credit factor, add all the

The total points are represented by "

If all conditions have been covered,

As an alternative, it may be determin
best represents the completeness anc

Other Process Hazard Analysis – 0.91 to 0.98

Several other process hazard analysis tools can be used in addition to the F&EI evaluation. These include Quantitative Risk Assessments (QRA), Detailed Consequence Analysis, Fault Tree Analysis, Hazard and Operability (HAZOP) Studies, Failure Modes and Effects Analysis (FMEA), Environmental, Health, Safety, and Loss Prevention Reviews, "What If" Studies, Check List Evaluations and Management of Change Reviews.

The credit factors to be used for this area are as follows:

Quantitative Risk Assessment (QRA)	**0.91**
Detailed Consequence Analysis	**0.93**
Fault Tree Analysis	**0.93**
Hazard and Operability (HAZOP) Studies	**0.94**
Failure Modes and Effects Analysis (FMEA)	**0.94**
Environmental, Health, Safety, and Loss Prevention Reviews	**0.96**
"What If" Studies	**0.96**
Check List Evaluations	**0.98**
Management of Change Review	**0.98**

When any of these process hazard risk analysis programs are done on a regular part of operations, the full credit factor is to be used. If these analyses are only done on an occasional basis, a higher factor is to be used based on good engineering judgment. For full credit, the results should be shared with employees as is appropriate.

C2 & C3 LOSS CONTROL FACTORS

Material Isolation Factor (C2) –

Remote Control Valves (for isolation)	0.96 – 0.98
Dump / Blowdown	0.96 – 0.98
Drainage (away from process)	0.91 – 0.97
Interlocking (chemical reactivity, burners)	0.98

C2 Range (all factors credited and multiplied) – 0.82 to 0.92

Fire Protection Correction Factor (C3) –

Leak Detection (methods and degree of response)	0.94 – 0.98
Structural Steel (fireproofing or water cooling)	0.95 – 0.98
Fire Water Supply (pressure, quantity, supply method)	0.94 – 0.97
Special Systems (per listing)	0.91
Sprinkler Systems (per type and coverage area)	0.74 – 0.97
Water Curtain (mitigate vapor cloud ignition)	0.97 – 0.98
Foam (method dependent)	0.92 – 0.97
Hand Extinguishers / Monitor Guns	0.93 – 0.98
Cable Protection (per method employed)	0.94 – 0.98

C3 Range (only Leak, Steel, Firewater, Sprinkler at 0.84, and Cable) – 0.65 to 0.88

C2 & C3 LOSS CONTROL FACTOR EXAMPLES

Drainage – 0.91 to 0.97

To remove a large spill from a slope of at least 2% (1% on assuming that 100% of the con released plus 1 hr of deluge/spr tor of 0.91.

If drainage conditions are good equipment, a credit factor of 0.

If 50 ha

Fire Water supply – 0.94

When the delivery pressur delivery pressure is less th

St dir rec

A plant's supply of fire fi demand for a period of fou hazard operations. If this r

wa tha

Unless the fire water suppl of normal electric service factor can be applied. A di

Sprinkler Systems – 0.74 to 0.97

Deluge systems receive a credit factor of 0.97. A deluge system (open head) gets the minimum credit because such systems have many components, any one of which could fail completely or partially, producing a negative effect on the operation and effectiveness of the system. Also the deluge system is used in combination with other loss control features on relatively hazardous unit operations so its individual benefit is less.

Credit factors for wet pipe or dry pipe systems used in indoor manufacturing areas and warehouses are calculated as follows:

	Design		Credit Factor	
Occupancy	gpm/ft²	lpm/m²	Wet Pipe	Dry Pipe
Light	0.15-0.20	6.11-8.15	0.87	0.87
Ordinary	0.21-0.34	8.56-13.8	0.81	0.84
Extra Hazard	≥ 0.35	≥ 14.3	0.74	0.81

Wet and dry pipe sprinkler systems (closed head) are 99.9%-plus reliable, with very few of the variables encountered with deluge valves, which are subject to failure.

POSSIBLE FINAL F&EI OUTPUT – RISK ANALYSIS SUMMARY

The guideline provides methodology to estimate monetary losses due to equipment damage and business interruption. This information can then be rolled up into a "Process Unit Risk Summary". These methods are beyond the scope of this tutorial as most use an alternative means for these purposes.

PROCESS UNIT RISK ANALYSIS SUMMARY

1. Fire & Explosion Index (F&EI)........................ (See Front)		
2. Radius of Exposure ....(Figure 7)	ft or m	
3. Area of Exposure..	ft^2 or m^2	
4. Value of Area of Exposure		$MM
5. Damage Factor ....(Figure 8)		
6. Base Maximum Probable Property Damage – (Base MPPD) [4 x 5]		$MM
7. Loss Control Credit Factor............................(See Above)		
8. Actual Maximum Probable Property Damage – (Actual MPPD) [6 x 7]		$MM
9. Maximum Probable Days Outage – (MPDO)......(Figure 9)	days	
10. Business Interruption – (BI)		$MM

F&EI Index

Loss Control

The Loss Control Factor (item 7) is the product of the three individual loss control factors (C1, C2, C3). It could reasonably range from 0.35 to 0.75 depending on the breadth and scope of loss measures taken.

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