CCPS GUIDELINES FOR INITIATING EVENTS AND INDEPENDENT PROTECTION LAYERS IN LAYER OF PROTECTION ANALYSIS

AN OVERVIEW
PART 1

SCOPE (OF THE BOOK)
CHANGES SINCE CCPS LOPA (2001)
INDEPENDENT PROTECTION LAYERS (IPL)
IPL CORE ATTRIBUTES/CHARACTERISTICS
DETAILED IPL INFORMATION

AGENDA
NOT a 2nd Edition on CCPS LOPA (2001)

Provide EXAMPLES of IEs and IPLs and useful GUIDANCE

SCOPE

Detailed IE and IPL Information

Pressure Relief System Use and Treatment

IPLs and Time Dependency

BPCS Credit Claims

CHANGES SINCE INITIAL LOPA CONCEPT BOOK
A device, system or action capable of **PREVENTING** a scenario from proceeding to an **undesired consequence** regardless of the initiating event or the action of any other protection layer associated with the scenario.

**INDEPENDENT PROTECTION LAYERS (IPLs)**

**PROTECTION LAYERS (PLs)**

Source: www.exida.com
TRAINING, CERTIFICATION AND PROCEDURES
TESTING INSPECTION AND MAINTENANCE
COMMUNICATIONS AND SIGNS
FIRE PROTECTION

SAFEGUARDS NOT TYPICALLY CREDITED AS IPLs

INDEPENDENCE
FUNCTIONALITY
INTEGRITY
RELIABILITY
AUDITABILITY
ACCESS SECURITY
MANAGEMENT OF CHANGE (MOC)

IPL CORE ATTRIBUTES
When the **effective performance** of one component is **dependent** upon the **successful** operation of another, the devices are **NOT INDEPENDENT**.

**INDEPENDENCE**

**EXAMPLE: LV1 MALFUNCTIONS OPEN**
INDEPENDENCE

EXAMPLE: INSULATION AND PRV

INDEPENDENCE

EXAMPLE: REVERSE FLOW
INDEPENDENCE - COMMON MODE FAILURE

EXAMPLE: CROSS/SAME TAP

INDEPENDENCE - COMMON MODE FAILURE

EXAMPLE: LOSS OF POWER
An IPL needs to **FUNCTION** in a way that **prevents or mitigates** the consequence of the scenario being studied.

**FUNCTIONALITY**

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**EXAMPLE: RELIEF VALVE SPEC**

<table>
<thead>
<tr>
<th>Design Basis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario:</strong> External fire / 1, on V-1411, Vessel - Horizontal, Option# 0</td>
<td>17289.4 lb/hr</td>
</tr>
<tr>
<td><strong>Sizing Method:</strong></td>
<td>API 520 Vapor Sizing</td>
</tr>
<tr>
<td><strong>Inlet pressure drop based on actual capacity</strong></td>
<td>Fluid Relieved</td>
</tr>
<tr>
<td><strong>Outlet pressure drop based on actual capacity</strong></td>
<td>Vapor</td>
</tr>
<tr>
<td><strong>Required Relief Rate</strong></td>
<td>17289.4 lb/hr</td>
</tr>
<tr>
<td><strong>Device Capacity</strong></td>
<td>36033.4 lb/hr</td>
</tr>
<tr>
<td><strong>Required Area</strong></td>
<td>1.39 in²</td>
</tr>
<tr>
<td><strong>Device Actual Area</strong></td>
<td>2.853 in²</td>
</tr>
<tr>
<td><strong>Inlet PDrop</strong></td>
<td>2 psi (2.25 % of Set)</td>
</tr>
<tr>
<td><strong>Outlet PDrop</strong></td>
<td>15.1 psi (16.97 % of Set)</td>
</tr>
<tr>
<td><strong>Outlet Flow Velocity</strong></td>
<td>186.21 ft/s</td>
</tr>
<tr>
<td><strong>Minimum Temperature</strong></td>
<td>Vapor MW 107.7 psig</td>
</tr>
<tr>
<td><strong>Temp Out of Device</strong></td>
<td>Vapor K 21.01 %</td>
</tr>
<tr>
<td><strong>Kc</strong></td>
<td>157.5 F</td>
</tr>
<tr>
<td><strong>Kv</strong></td>
<td>Mass % Vapor 100 %</td>
</tr>
</tbody>
</table>

**FUNCTIONALITY**
**FUNCTIONALITY**

**EXAMPLE: BLAST WALL/EXPLOSION PROOFING**

**PROCESS SAFETY TIME (PST)**

The **TIME PERIOD** between a failure occurring in the process or its control system and the occurrence of the hazardous event

**FUNCTIONALITY – TIME DEPENDENCY**
FUNCTIONALITY – TIME DEPENDENCY

EXAMPLE: LIQUID OVERFILL
IPL RESPONSE TIME (IRT)

The **time** for a given IPL to **DETECT** an **out-of-limit** condition and **COMPLETE** the actions intended to achieve a **SAFE STATE**

**FUNCTIONALITY – TIME DEPENDENCY**

**EXAMPLE: REVERSE FLOW**
PROCESS LAG TIME (PLT)

The **TIME** it takes for a process to **ACHIEVE** or **MAINTAIN** a **SAFE STATE**.
MAXIMUM SETPOINT (MSP)

“NEVER EXCEED, NEVER DEVIATE” setpoint

**FUNCTIONALITY – TIME DEPENDENCY**

<table>
<thead>
<tr>
<th>Time</th>
<th>Process Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRT</td>
<td>M1: IRT - Safety Margin</td>
</tr>
<tr>
<td>PLT</td>
<td>M2: PLT - Setpoint Range</td>
</tr>
</tbody>
</table>

**Figure 3.1.** Timeline for progression of a scenario.

Source: CCPS Guidelines for Initiating Events and Independent Protection Layers for Layer of Protection Analysis
$I_{RT_{\text{alarm}}} = t_{\text{Alarm}} + t_{\text{Operator}} + t_{\text{Process}}$

$t_{\text{Alarm}}$ is time to annunciate

$t_{\text{Operator}}$ is operator time to detect, diagnose and complete proper response steps.

$t_{\text{Process}}$ is time from abnormal to safe operating condition

**ALARM IPL – RESPONSE TIME**

A property of an IPL that is a **MEASURE** of its **capability** to satisfy its **specified requirements**

**INTEGRITY - DEPENDABILITY**
FACTORS

IPL LIMITED BY WEAKEST ELEMENT
HARDWARE / SOFTWARE DESIGN
OPERATING ENVIRONMENT
INSPECTION, TESTING AND PREVENTIVE MAINTENANCE (ITPM)

INTEGRITY OF EQUIPMENT

DEPENDENT ON
QUALITY DATA
ACCURATE INFORMATION
EFFECTIVE INTERFACES

INFLUENCED BY
EQUIPMENT HUMAN FACTORS
PROCEDURES
OPERATING ENVIRONMENT

INTEGRITY AS RELATED TO HUMAN IPLS
### REVEALED FAILURE
- OBVIOUS
- TYPICAL LOPA IC
- LEAD TO PROCESS DEVIATION

### UNREVEALED FAILURE
- NOT A PART OF NORMAL OPERATION
- TYPICAL FOR IPL
- **NOT** AN INITIATING CAUSE

### INTEGRITY - DEPENDABILITY

An attribute of a protection layer related to its equipment **OPERATING** as intended, under stated conditions, for a specific time period.

### RELIABILITY
\( f_{1c} = IEF_1 \times PFD_1 \)

- \( f_{1c} \) is frequency of the consequence occurring for scenario 1
- \( IEF_1 \) is frequency of IE for scenario 1
- \( PFD_1 \) is Probability of failure on demand of independent protection layer 1 for scenario 1

LOW DEMAND MODE
\[ f_{1c} = 0.1 \text{ demand/yr} \times 0.01/\text{demand} \]
\[ f_{1c} = 0.001 \text{ event/yr} \]

\( IEF_1 = 0.1 \text{ demand/yr for human error or mechanical pump failure (typ)} \)

\( PFD_1 = 0.01/\text{demand since the PSV is fully sized for the scenario and included in ITPM} \)

**Low Demand Mode**

**Auditability**

*Ability* of an organization to *inspect* procedures, records, previous validation assessments, and other documented information to *ensure* that design, testing, maintenance and operation continue to *conform* to *expectations*.
AUDITABILITY

Recommended to be periodically audited
Maintenance is performed as required and specified?
Documentation for design, proof test and maintenance is maintained?

AUDITABILITY – MAINTENANCE SYSTEMS
AUDITABILITY – PROCEDURES & TRAINING

OPERATING PROCEDURES UP TO DATE?
PERSONNEL TRAINED?
PERSONNEL TESTED?

AUDITABILITY – MANAGEMENT OF CHANGE

CHANGES PROPERLY REVIEWED?
CHANGES PROPERLY DOCUMENTED?
ACTIONS ITEMS GENERATED COMPLETED?
AUDITABILITY – LOPA APPROACH

PFDS UP-TO-DATE?
INITIATING EVENTS UP-TO-DATE?

ACCESS SECURITY

Includes the use of physical and/or administrative controls to reduce the CHANCES of unauthorized system changes which may impair a safety device.
### IPL Characteristics

**3 ENOUGHS**
- BIG ENOUGH?
- STRONG ENOUGH?
- FAST ENOUGH?

**3 D’S**
- DETECT
- DECIDE
- DEFLECT

**ALL IPLS ARE SAFEGUARDS, BUT NOT ALL SAFEGUARDS ARE IPLS**
PASSIVE IPL

An IPL that does **NOT** require an action to be taken in order to achieve its function aimed at reducing risk.

PASSIVE IPLS - DEFINITION

ASSUMPTION

Passive IPLs are **ONLY** applicable if the consequence is defined in the **ABSENCE** of the IPL.
Flame Arresters
Overflow Lines
Mechanical Stops
Secondary Containment Areas
Fire-resistant Insulation
Double-Walled Vessels
Blast-Resistant Buildings
Blast Wall

Passive IPL List

Passive IPLs – Flame Arresters
Passive IPLs – Flame Arresters

End-of-Line Deflagration Arrester

- Appropriate Location
- Proper Orientation
- Does not impose Flow Restrictions
- Undergoes adequate ITPM (Inspection, Testing, and Preventive Maintenance)
**In-Line Deflagration Arrester (Without Temperature Monitoring and Shutdown/Isolation)**

\[ \text{PFD} = 0.1 \]
\[ \text{OoM} = 1 \]

**Passive IPLs – Flame Arresters**

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**In-Line Deflagration Arrester (With Temperature Monitoring and Shutdown/Isolation)**

\[ \text{PFD} = 0.01 \]
\[ \text{OoM} = 2 \]

**Passive IPLs – Flame Arresters**
**IN-LINE DEFLAGRATION ARRESTER**

Piping between ignition source and arrester is less than the run-up distance required to sustain DDT

Proper Orientation

Does not impose Flow Restrictions

Temperature monitoring at the hot side

Undergoes adequate ITPM (per Manufacturer’s recommendations)

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**PASSIVE IPLs – FLAME ARRESTERS**

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**IN-LINE STABLE DETONATION ARRESTER (WITHOUT TEMPERATURE MONITORING AND SHUTDOWN/ISOLATION)**

PFD = 0.1

OoM = 1

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**PASSIVE IPLs – FLAME ARRESTERS**
IN-LINE STABLE DETONATION ARRESTER (WITH TEMPERATURE MONITORING AND SHUTDOWN/ISOLATION)

PFD = 0.01
OoM = 2

PASSIVE IPLS – FLAME ARRESTERS

IN-LINE STABLE DETONATION ARRESTER

Appropriate Location
Proper Orientation
Does not impose Flow Restrictions
Temperature monitoring at the hot side
Undergoes adequate ITPM (per Manufacturer’s recommendations)

PASSIVE IPLS – FLAME ARRESTERS
UNSTABLE (OVERDRIVEN) DETONATION ARRESTER (WITHOUT TEMPERATURE MONITORING AND SHUTDOWN/ISOLATION)

PFD = 0.01
OoM = 2

PASSIVE IPLS – FLAME ARRESTERS

UNSTABLE (OVERDRIVEN) DETONATION ARRESTER (WITH TEMPERATURE MONITORING AND SHUTDOWN/ISOLATION)

PFD = 0.001
OoM = 3

PASSIVE IPLS – FLAME ARRESTERS
UNSTABLE (OVERDRIVEN) DETONATION ARRESTER

Appropriate Location
Proper Orientation (Horizontal / Vertical)
Does not impose Flow Restrictions
Temperature monitoring at the hot side
Undergoes adequate ITPM (per Manufacturer’s recommendations)

PASSIVE IPLS – FLAME ARRESTERS

OVERFLOW LINE W/O FLOW IMPEDIMENTS

PFD = 0.001
OoM = 3

PASSIVE IPLS – OVERFLOW LINES
OVERFLOW LINE W/O FLOW IMPEDIMENTS

Clean Service (No Fouling/Plugging)
Ease of Accessibility for ITPM
Vertical rise does not impose hydraulic/dynamic head/pressure greater than the vessel MAWP
Undergoes adequate ITPM (per Manufacturer’s recommendations)

PASSIVE IPLS – OVERFLOW LINES

OVERFLOW LINE W/ PASSIVE FLUID OR RUPTURE DISK

PFD = 0.01
OoM = 2

PASSIVE IPLS – OVERFLOW LINES
OVERFLOW LINE W/ PASSIVE FLUID OR RUPTURE DISK

Clean Service (No Fouling/Plugging)
Ease of Accessibility for ITPM
Vertical rise does not impose hydraulic/dynamic head/pressure greater than the vessel MAWP
Rupture disk pressure setpoint is less than the vessel MAWP
Undergoes adequate ITPM (per Manufacturer’s recommendations)

PASSIVE IPLS – OVERFLOW LINES

OVERFLOW LINE W/ FLUID WITH POTENTIAL TO FREEZE

PFD = 0.1
OoM = 1

PASSIVE IPLS – OVERFLOW LINES
OVERFLOW LINE W/ FLUID WITH POTENTIAL TO FREEZE

Clean Service (No Fouling/Plugging)
Ease of Accessibility for ITPM
Vertical rise does not impose hydraulic/dynamic head/pressure greater than the vessel MAWP
Fluid seal is equipped with freeze-prevention mechanisms
Undergoes adequate ITPM (per Manufacturer’s recommendations)

PASSIVE IPLS – OVERFLOW LINES

DIKES, BERMRS, AND BUNDS

PFD = 0.01
OoM = 2

PASSIVE IPLS – SECONDARY CONTAINMENT
**DIKES, BERMS, AND BUNDS**

Sized adequately (If not, must provide enough PST and PFD then is equal to that of the leak detection alarm)

Dike heights sufficient to withstand hydraulic waves

Drain valves locked-closed and maintained

Cannot be taken as an IPL if the consequence takes into consideration this design feature

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**PASSIVE IPLS – SECONDARY CONTAINMENT**

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**DIKES, BERMS, AND BUNDS WITH REMOTE IMPOUNDMENT**

PFD = 0.01

OoM = 2

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**PASSIVE IPLS – SECONDARY CONTAINMENT**
DIKES, BERMS, AND BUNDS WITH REMOTE IMPOUNDMENT

- Sized adequately
- Dike heights sufficient to withstand hydraulic waves
- Rainwater is pumped from the impoundment to maintain adequate capacity
- Cannot be taken as an IPL if consequence takes secondary containment area into consideration

PASSIVE IPLS – SECONDARY CONTAINMENT

PERMANENT MECHANICAL STOP THAT LIMITS TRAVEL

\[
PFD = 0.01 \\
OoM = 2
\]

PASSIVE IPLS – MECHANICAL STOPS
**PERMANENT MECHANICAL STOP THAT LIMITS TRAVEL**

No Potential for slippage (stop is welded)

Undergoes visual inspection for corrosion/wear

Documentation of design basis to ensure retention during MOC

**PASSIVE IPLS – MECHANICAL STOPS**

**FIRE-RESISTANT INSULATION & CLADDING ON VESSEL**

PFD = 0.01

OoM = 2

**PASSIVE IPLS – INSULATION/CLADDING**
FIRE-RESISTANT INSULATION & CLADDING ON VESSEL

Heat-up time must be greater than the length of fire
Must be independent of other IPLs such as PSVs
Undergoes periodic mechanical/civil inspections

PASSIVE IPLS – INSULATION/CLADDING

DOUBLE-WALLED SYSTEMS

The PFD of a Double-Walled System is based on the PFD associated with the leak detection alarm IPL alerting personnel of the loss of primary containment scenario.

PASSIVE IPLS – DOUBLE-WALLED SYSTEMS
CONTAINMENT BUILDINGS

Although containment buildings can reduce the risk for those outside the building, they can increase the risk for those working inside the building.

PASSIVE IPLS – CONTAINMENT BUILDINGS

BLAST-RESISTANT BUILDING DESIGNS & BLAST (SACRIFICIAL WALLS) OR EXPLOSION BARRIERS

Common assumption: All people inside a well-maintained, blast-resistant enclosure that is properly designed for the maximum anticipated blast loading are fully protected.

PASSIVE IPLS – BLAST-RESISTANT STRUCTURES
QUESTIONS/COMMENTS?

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