SNC·LAVALIN

ATKINS

Member of the SNC-Lavalin Group

Optimising HAZOP in Design and Operations

Conor Crowley, C.Eng. F.I.Chem.E.

Our values are the essence of our company's identity. They represent how we act, speak and behave together, and how we engage with our clients and stakeholders.

SAFETY	*We put safety at the heart of everything we do, to safeguard people, assets and the environment.*
INTEGRITY	*We do the right thing, no matter what, and are accountable for our actions.*
COLLABORATION	*We work together and embrace each other's unique contribution to deliver amazing results for all.*
INNOVATION	*We redefine engineering by thinking boldly, proudly and differently.*

Conor Crowley

Process Safety Team Lead, Aberdeen

Quick Biography…

- From Cork, Ireland
- Studied Chemical Engineering in Cork, Graduated 1991
- Joined Marathon Oil as a Safety Engineer
- Joined what is now Atkins/SNC Lavalin 20 years ago
- Mix of process, process safety, risk-based decision making and IT work over the 20 years.

HAZOP Experience

- Scribe and Safety Engineer in Marathon FSA HAZOPs.
- Trained as HAZOP Chair in 1995
- Led a range of HAZOPs from ½ day to full revalidation HAZOPs over the intervening 23 years.
- Approved HAZOP chair for two major international operators.

The HAZOP as a technique

Definitions

HAZOP	Hazard and Operability Study
LOPA	Layers of Protection Analysis
Node	A sub-section of a plant (e.g. a separator, a compressor, a suction scrubber).
MOC	Management of Change Process
CTR	Cost, Time, Resource Sheet
Incident	Where a plant operates outside its safe design envelope
Accident	Where an incident harms people or the environment

Why HAZOP? (the conventional story)

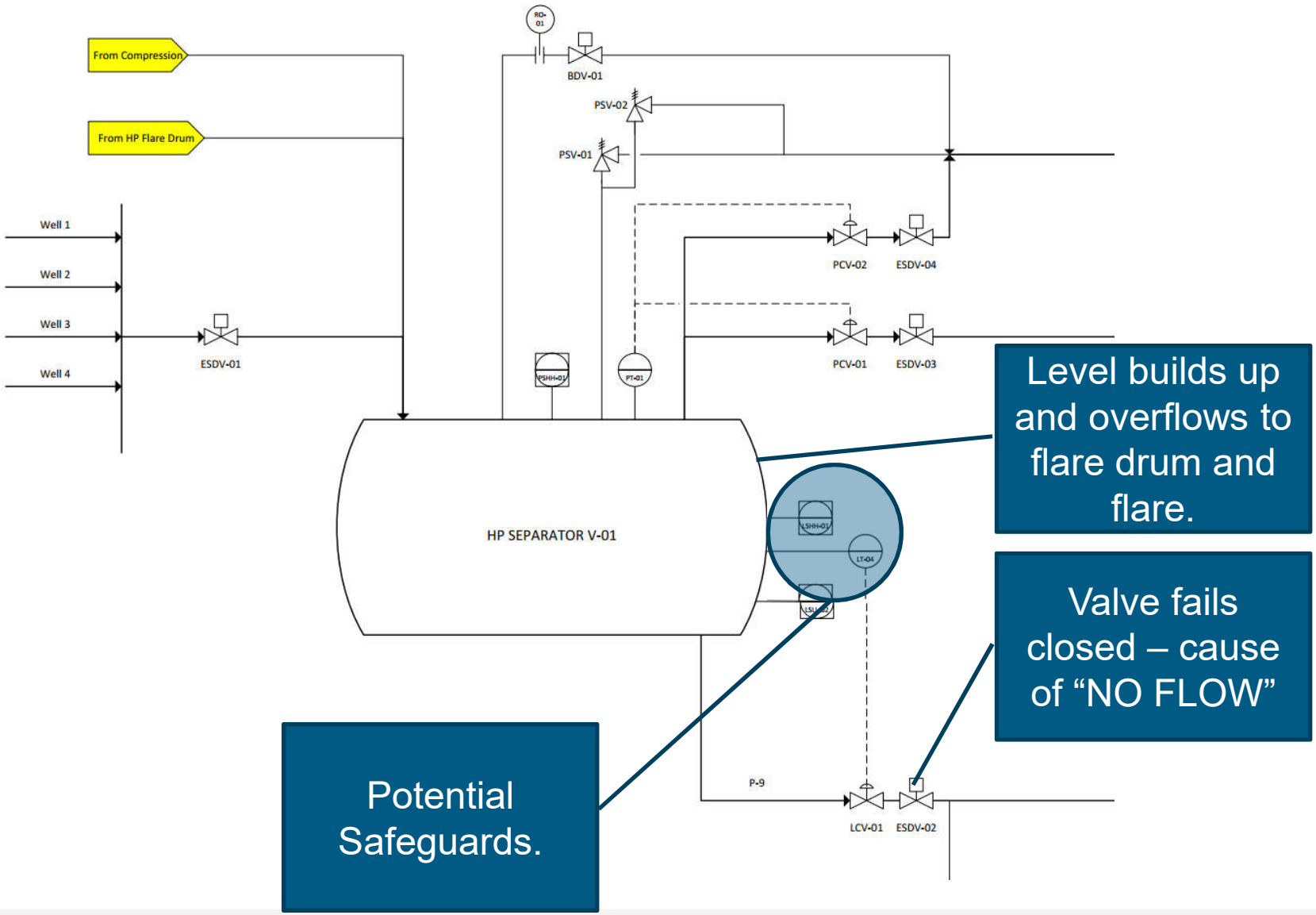
- HAZOP stems from work done in the 1960's in ICI to help in hazard identification of complex plants
  - 1974 – Flixborough (Nypro UK – not ICI!)
  - Uncontrolled change in a cyclohexane plant lead to explosion
    - Bypass of reactor number 5 – 20" bypass failed, releasing cyclohexane.
    - 18 fatalities when control room destroyed
    - 28 fatalities and 36 injuries on site
    - Fifty-three injuries offsite, and property damage.
- Since 1980's requirement to be taught in undergraduate chemical engineering courses
  - De-facto standard approach to detailed hazard identification and globally recognised design verification technique.

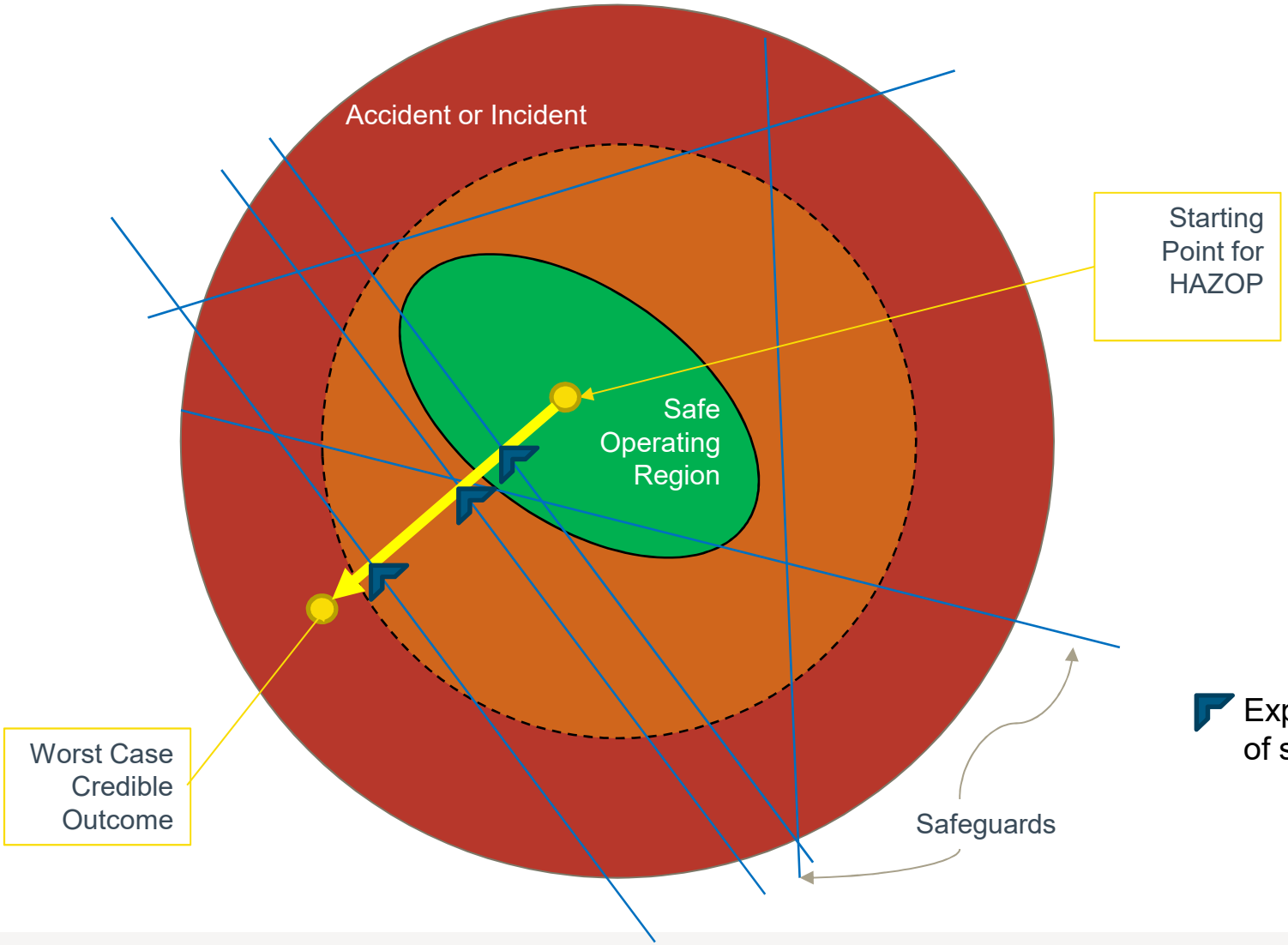
How does it work?

Plant is asserted to be safe at “steady-state”.

Deviation from this steady-state may cause hazards.

- Break the plant down into smaller parts (nodes) and examine each in turn
- Identify a cause of deviation from steady state (e.g. “can I get NO FLOW?”)
- Determine what the consequence of that deviation would be
  - normally looking for “worst case credible consequences”.
- Identify any safeguards against the cause/consequence
- Qualitatively determine if the risk is managed appropriately, or propose recommendations to address.


From Compression
From HP Flare Drum
Well 1
Well 2
Well 3
Well 4
ESDV-01
BDV-01
PSV-02
PSV-01
PCV-02
ESDV-04
PCV-01
ESDV-03
HP SEPARATOR V-01
P-9
LCV-01
ESDV-02
Level builds up and overflows to flare drum and flare.
Valve fails closed – cause of "NO FLOW"
Potential Safeguards.



Expected action point of safeguard

Strengths of HAZOP

- Widely used across industry, especially at detailed design stage.
- Detailed review of the design using a structured brainstorm
- Should allow generation of main threats to a design.

- For a HAZOP (with thanks to Drew Rae)

  (a) HAZOP often leads to design changes;

  (b) the changes are plausibly improvements; and

  (c) the changes probably wouldn't have happened if not for the HAZOP.

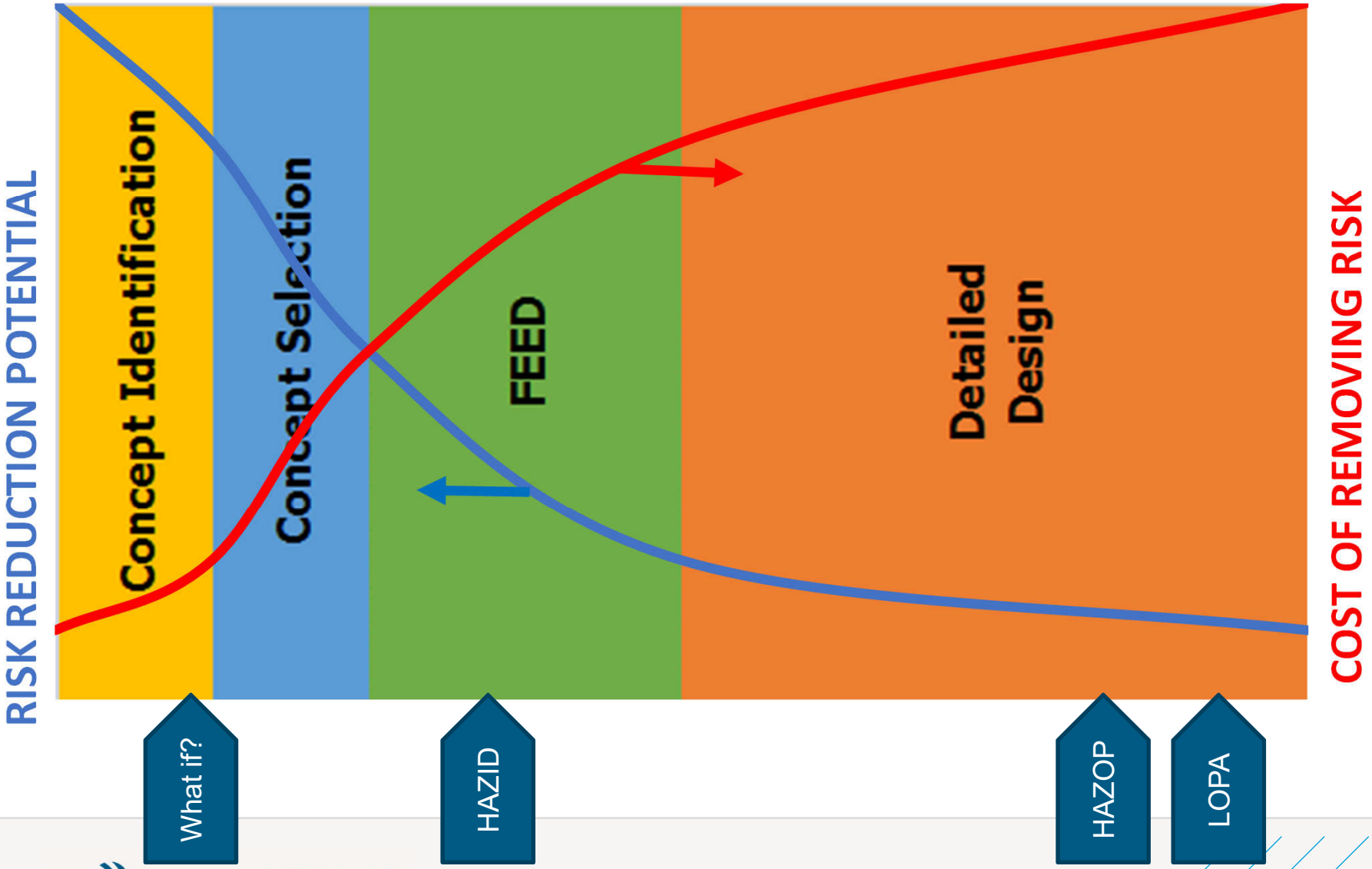
  This is a very strong claim to be able to make for a safety technique. Most techniques fail at (a).

Weaknesses of HAZOP

- Can be long, involve large numbers of people, and as a result are expensive.
- Not always reproduceable
  - Dependent on the quality of the team and their knowledge of other similar plants.
- Slow and tedious
- Not easy to align actual accidents and incidents with the accident model used.
  - Multiple causes, or additional accident influencing factors.
  - Typical initiating causes happen at frequency above 1 in 10 years, maybe above 1 in 100 years with degradation/common cause failures.
  - Often, actual incidents are not identified in HAZOP, or at least in HAZOP format, unless there have already been similar incidents on the plant.

HAZOP in Design

Ability to Influence Risk vs Project Phase



HAZOP in Design

Greenfield and Brownfield – should be a key part of the design process.

- Also a critical part of the Management of Change process where applicable.

Note that HAZOP is a design assessment tool, not a design process.

We should not be designing in HAZOP.

- Design should be mature enough that key decisions on safeguards and hazards have been considered.

However, we should have used our knowledge of the hazards, and their consequence, as part of our design.

- DESIGN BY HAZOP MINDSET?

Strengths in Design

- Accepted part of design by management, cementing some form of hazard assessment into the design process.
- Multidisciplinary review with operations staff included gives a rounded picture of the risks.
- Accepted methodology (but does this guarantee success?)
- Rigorous Process.

Weaknesses in design

- For MOC/Brownfield, you can end up with “cloud blindness” – focusing only on the physical changes within the project boundary, rather than wider implications
- Difficult to keep consistent
- Tendency to postpone hard decisions until after HAZOP (and even LOPA), when issues are known and visible before the HAZOP takes place.
- Larger HAZOPs with more attendees can result in poor overall contributions.
  - More time speaking might not mean more contribution, not speaking at all might mean no contribution.
- Not a CTR/Scope generator.

How can we make Design HAZOP better?

Engineering Preparation

- Design engineers should already know the worst case credible consequences associated with their design
- These hazards should have been addressed with an “inherent safety” approach, rather than assuming a trip will do the job in the LOPA.
- If a trip is likely to be used, it should already exist in the design, be known to be feasible and effective, and its functionality understood before the HAZOP.

Optimism Bias

- “What have we missed?”, not “Look how big the report is, aren’t we great?”

How can we make Design HAZOP better?

Team Size

- Needs to be controlled – no 20 person HAZOPs. (a 10 person HAZOP will be more productive and half the cost!)

Brownfield Design

- Node boundaries should extend outside the clouds to the existing HAZOP boundaries, unless no HAZOP exists.

A HAZOP Report is not a "write-only document".

- View of the fundamental hazards
- List of outstanding improvements – ALARP?
- Will be revisited if there is ever an incident.

HAZOP in Operations

Why Revalidate your HAZOP?

In some jurisdictions, it's mandatory.

- With no safety case, process hazard analysis centres on the HAZOP

Elsewhere, it's recommended in by many companies because of changes including:

- Changes to well flowrates, conditions
- Cumulative impact of creeping change of small modifications
- Equipment ageing and obsolescence
- Equipment mothballed or decommissioned
- Operating experience and changes in operating approach

In goal-setting jurisdictions, it fits into the ongoing obligation to understand risk and demonstrate ALARP.

- Brings together engineers and operations people to discuss impact on major hazards and operability problems
- Confirms/challenges current risk profile

BUT

- Resource intensive in delivery and output.

The “Perfect” HAZOP

Would have:

- Examined all credible single-item causes and related degradations
- Considered the full range of demands on a system
- Taken all consequences to the worst-case credible, and
- Consider the effectiveness and sufficiency of all safeguards
- Reflected how the plant is run by the different operators in different situations

The not-perfect HAZOP

Suggested Optimised Approach (1)

Limited value to carrying out a full HAZOP of all unit operations

- Processes in place to monitor plant degradation, corrosion, integrity
- Expensive, with limited scope and budget for improvement

Agree a subset of nodes to carry out full reviews based on:

- Underlying inherent risk
  - a gas lift system at 200 bar - Full Review
  - Potable water system – does it warrant full review?
  - Other nodes can be reviewed offline, and screened for impact
- Number of high potential incidents
- Degree of change since previous HAZOP
- Degree of unease of operations
- Impact and close-out of recommendations

Suggested Optimised Approach (2)

For the subset of nodes not carried out in full review (offline nodes)

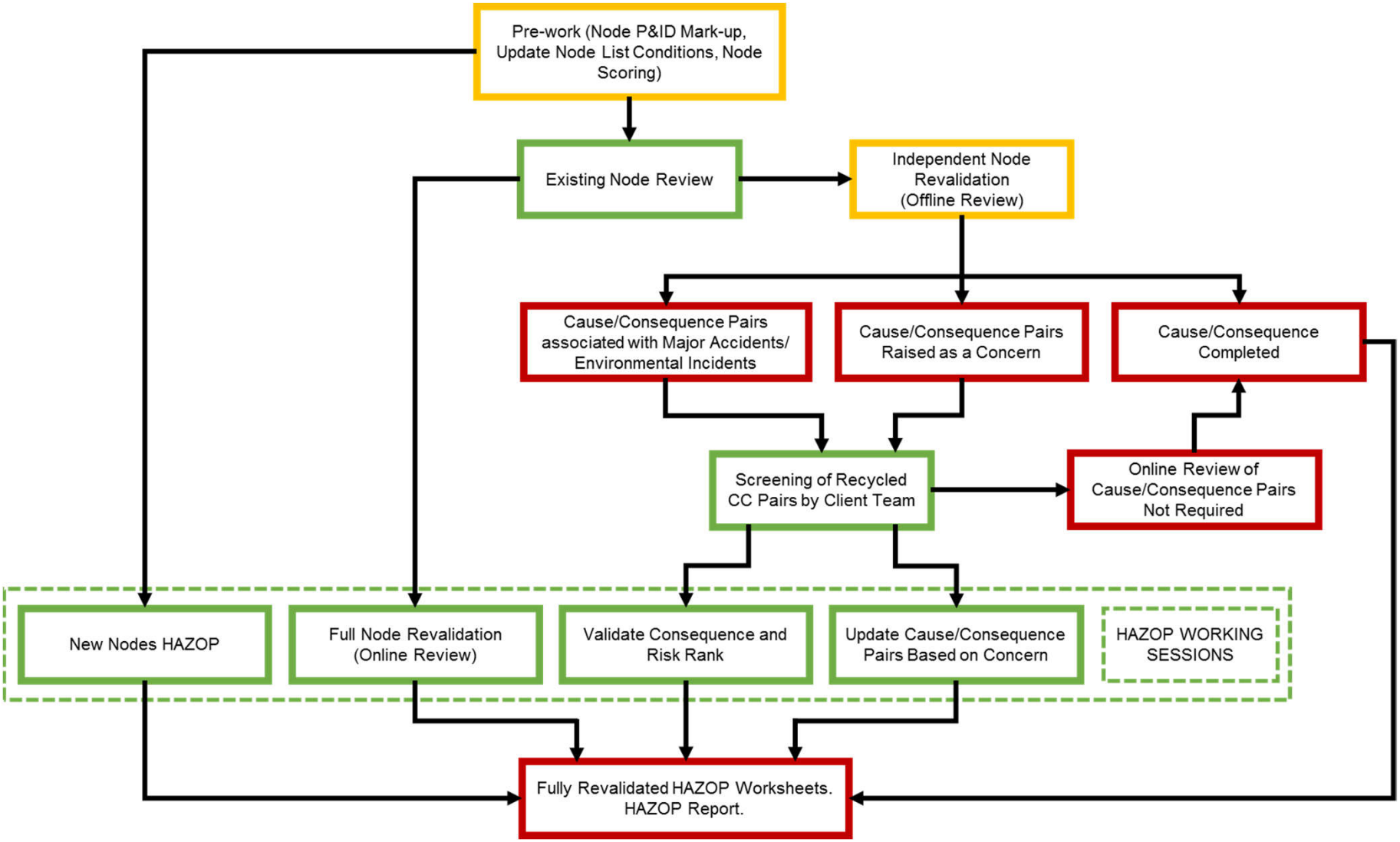
- Review of existing HAZOP by experienced engineer to consider whether the major accident hazards are represented in line with expectation.
- Escalate any high consequence events for review by full-teams, targeted on identified causes
- Review any recommendations to ensure effective closeout/risk reduction and escalate if unsatisfactory

Use risk ranking to Drive Actions

- Demonstrable benefit needed to justify cost – use matrices to screen ALARP decisions.

Use the interface between full-team nodes and “offline” nodes intelligently

- Often use “Cause in Node, Consequence Anywhere” as a ruleset.
- The boundary between the node should be considered as a source of deviations, and considered by the full team.


Pre-work (Node P&ID Mark-up, Update Node List Conditions, Node Scoring)
Existing Node Review
Independent Node Revalidation (Offline Review)
Cause/Consequence Pairs associated with Major Accidents/ Environmental Incidents
Cause/Consequence Pairs Raised as a Concern
Cause/Consequence Completed
Screening of Recycled CC Pairs by Client Team
Online Review of Cause/Consequence Pairs Not Required
New Nodes HAZOP
Full Node Revalidation (Online Review)
Validate Consequence and Risk Rank
Update Cause/Consequence Pairs Based on Concern
HAZOP WORKING SESSIONS
Fully Revalidated HAZOP Worksheets. HAZOP Report.

Benefits & Challenges of Optimised Approach

Benefits:

Shorter, more targeted HAZOP Sessions.

- 40-50% reduction in time required – freeing up key resources

Not ignoring other lower-priority nodes

- Allows improvements in knowledge and approach to HAZOP to be reflected in revised document
- Allows significant risks to be escalated to the full-team review.
- Use the money saved for risk reduction.

Overall, reduction in 25-45% in external costs if using consultant.

Limitations:

Not as full coverage of system as full HAZOP.

- May miss an issue that a full team might identify
- May miss an issue that a full team wouldn't identify anyway.

Left with the worry that you've missed something.

- Probably a good way to leave any HAZOP anyway.

The Future of HAZOP

SNC·LAVALIN

ATKINS
Member of the SNC-Lavalin Group

The perils of prediction….

"We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. Don't let yourself be lulled into inaction."

BILL GATES

My Prediction of the future of HAZOP

I've been chairing HAZOPs for more than 20 years on and off now.

In twenty years time, I won't be sitting in a meeting room, reciting

"Can you tell me any causes of 'No Flow'?"

We won't be, and let me tell you why….

Where HAZOP came from

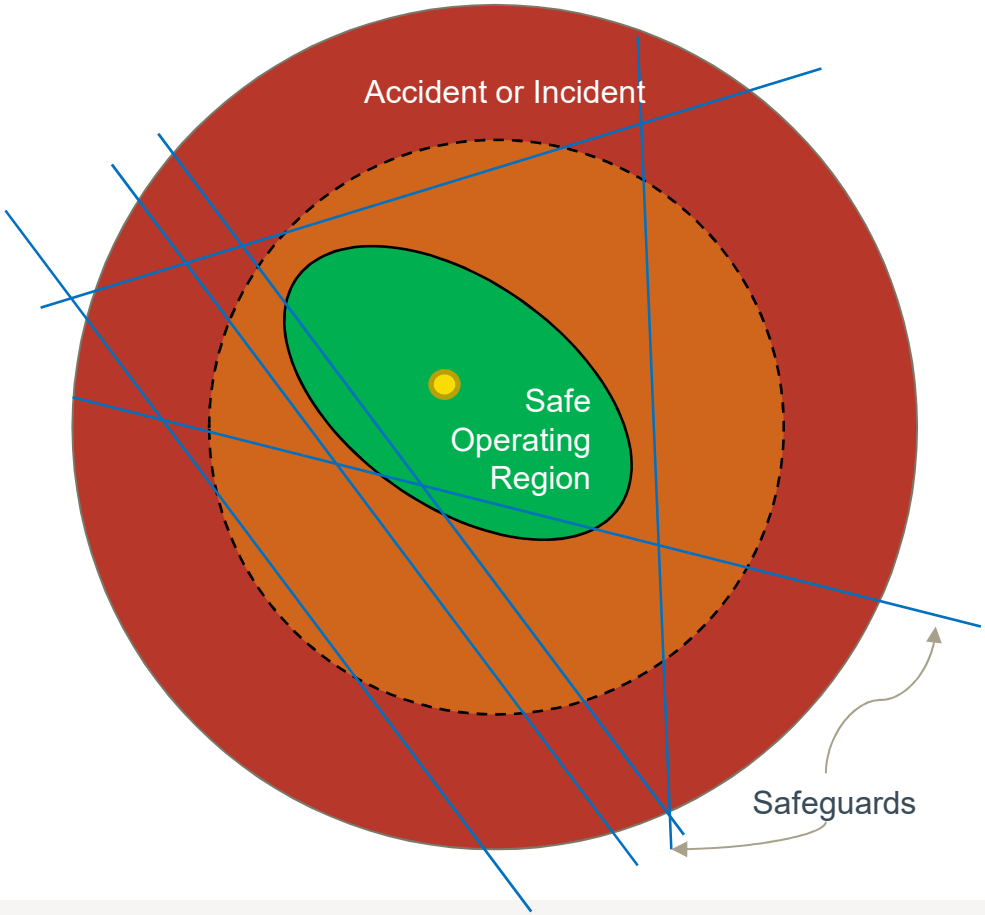
Design in the 1960's

- Before pocket calculators
- Before desktop computers
- Before widely available process simulation
- And so on…

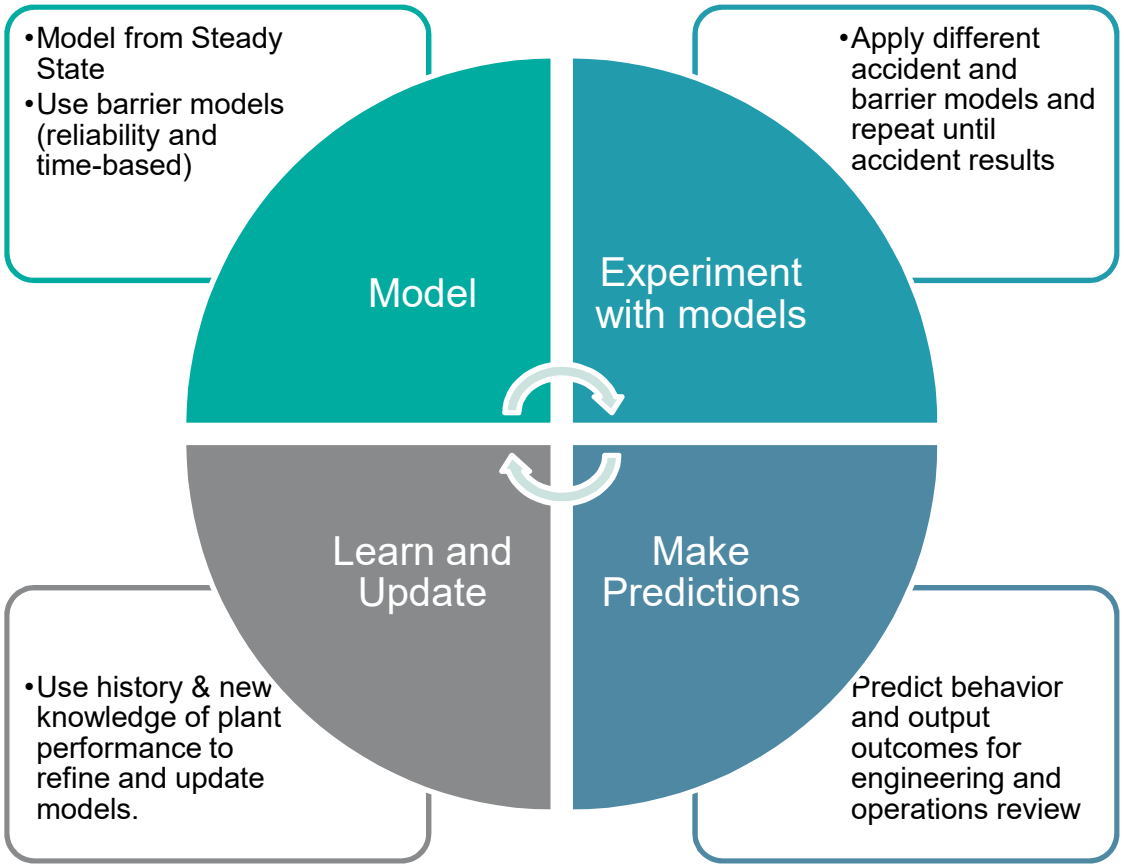
Adopted in 1970s and is now regarded as common practice.

- Is it reasonable to assume that there is no better way to manage our design risks?
- Should we be constrained to an accident model that is easier to understand, when there are other accident models that could give additional insight

Computer-assisted case generation



HAZOP of the Future….



What do we need to create a post-HAZOP world?

The ability to have high-definition models of our plants, and their interactions

- We already have these for the processing side.
- Underlying physics, chemistry, thermodynamics and chemical behaviour can be understood and modelled.

The ability to use these models to predict unacceptable deviations.

- We could use multiple accident model types here, single deviation, barrier degradation, system safety (STAMP) approaches, domino, etc.

What do we need to create a post-HAZOP world?

The ability to get good predictions of chains of events, and their outcomes.

- Without piling worst-case on top of worst-case, we can get a good view of the highest risks, not just the highest consequences.
- The ability of safeguards to influence the outcome of events, and how these reduce the risk

The ability to use actual plant performance to validate our models

- Actual performance of safeguards can be handled, and incorporated.
- ‘Big Data’ and analytics can manage much of this now, and can only improve.

The courage to try it, and refine it until it works.

- We’re already experimenting with this, but can’t get there on our own.

Where will us humans be involved in a Post HAZOP world?

- We can use “HAZOP” time to consider the outcomes of the review, and continuous monitoring of the plant will flag up issues as they arrive.
- Conversations between operators and designers will still be required to flag up where things are not working well.
- With many more accident scenarios considered, we will be better able to focus our investment in safety improvements that work, and optimise spend on doing enough

Summary

In design

- We need to do our utmost to design the plant so the formal HAZOP meeting is a confirmation tool, not a design tool

In operation

- We need to be clear where we think the changes have come, where the risk is, and spend our assessment money wisely.

In years to come

- The ideas behind HAZOP will be applied to our design processes
- We will then spend our “HAZOP” time to consider the outcomes of the review, and continuous monitoring of the plant will flag up issues as they arrive.

Questions?