16th STS-AIChE

Southwest Process Technology Conference

Uncovering Relief System Design Deficiencies to Enhance Process Safety

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INGENERO
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AI-PSM

Sept 22-23, 2025, University of Houston

Speaker Bio

Akash Majumdar serves as Marketing Manager for North America at Ingenero, a leading engineering, digitalization, and process safety firm.

Since joining in 2020, he has supported projects across process safety, digitalization, engineering, and sustainability while developing new products and partnerships. He specializes in translating Ingenero's capabilities into market strategies for North American clients in refineries, chemical facilities, and related industries across the company's core service areas.

He holds a BS in Economics and Finance from Vanderbilt University and an MBA from Rice University.

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Speaker Bio

Michael Marshall, PE is an Oil & Gas industry consultant, and has over 40 years' experience working in the downstream, midstream and petrochemical industries. While working first with Chevron (10 years) and then Marathon Petroleum Company (23 years - retired), he progressed through various in-plant and corporate refining facility and project engineering, operations, maintenance, and equipment inspection/reliability supervisory and managerial positions. Mike has unique insight and expertise in areas of risk-based design relative to loss of containment (LOPC) damage mechanisms, safety systems and overpressure protection. Most notably, Mike has developed and implemented a novel asset integrity + process safety KPI management systems approach to track loss of primary containment (LOPC) incidents as well as a process optimization methodology based on root cause failure analysis (RCFA), which quantifies the economic impact and ROI of equipment anomalies and process safety events.

Mike graduated from Purdue University in 1981 with a degree in Civil Engineering and is a registered Professional Engineer.

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Agenda

1. **Introduction & Safety Context -** Importance of relief systems as last lines of defense
2. **Global Data Reality Check** - Industry-wide analysis of 80,000+ relief devices showing 25-35% deficiency rate
3. **Scale of the Challenge** - Resource requirements and complexity for comprehensive relief system analysis
4. **Common Relief System Deficiencies** - Inlet/outlet pressure losses, undersized devices, wrong set pressures
5. **Organizational Maturity Assessment -** Where is your organization on the risk management effectiveness scale?
6. **Integration with PSM Programs** - Connecting relief systems to broader Process Safety Management framework

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Historical Perspective - Learning from Tragedy

1 — 1870-1910: The Steam Age Crisis

Thousands of catastrophic steam boiler explosions plagued American industry. Pennsylvania mines alone experienced over 20 simultaneous explosions, killing hundreds of workers and devastating communities.

2 — 1911: ASME Response

The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee, leading to the groundbreaking ASME BPV Code that standardized safe design practices.

3 — 1955: API Standards

The American Petroleum Institute published the first comprehensive Pressure Relief Systems document (API 520/521), establishing industry-wide relief system design principles.

4 — 1976: DIERS Program

AIChE formed the Design Institute for Emergency Relief Systems to systematically study runaway chemical reactions and develop scientific approaches to relief system sizing.

5 — 1992: OSHA PSM Rule

OSHA enacted 1910.119 "Process Safety Management," establishing 14 interconnected PSM elements. Process Safety Information, including Relief System Design and Basis, became the foundation.

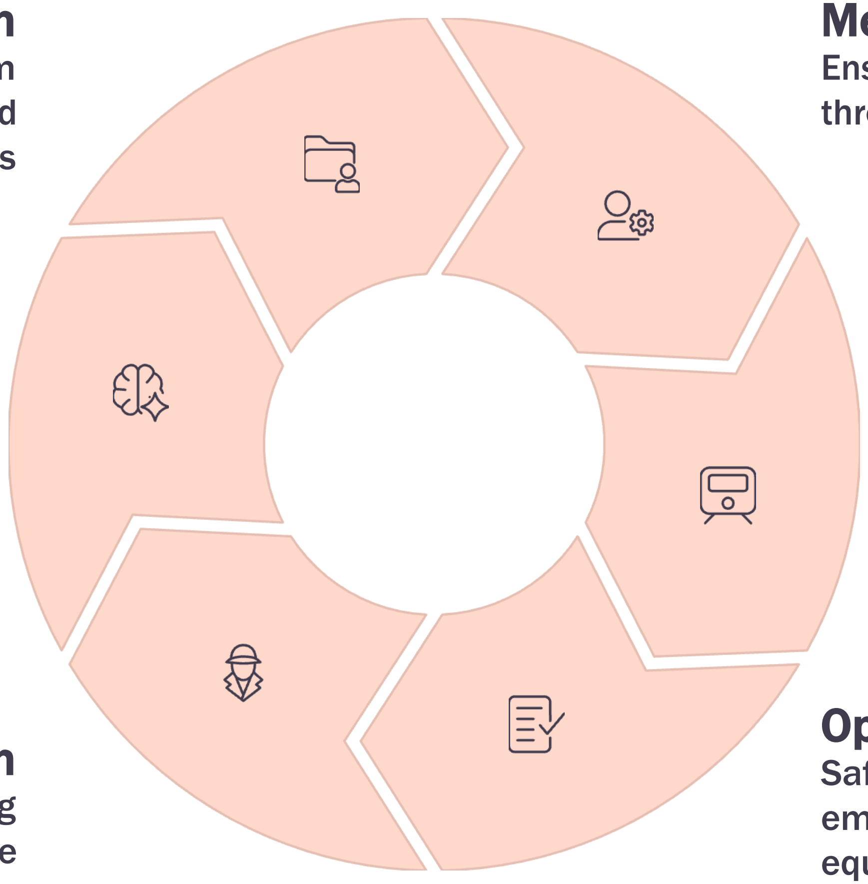
PSM Elements - An Interconnected System

The 14 PSM elements function as an integrated system where each component supports and reinforces the others.

Relief system design serves as critical Process Safety Information that enables all other elements to function effectively.

Process Safety Information
Foundation element including relief system design basis, process chemistry, and equipment specifications

Mechanical Integrity
Ensures relief systems perform as designed through testing, inspection, and maintenance



Management of Change
Process modifications require relief system revalidation to maintain protection integrity

Training & Competency
Personnel understand relief system operation, limitations, and emergency response procedures

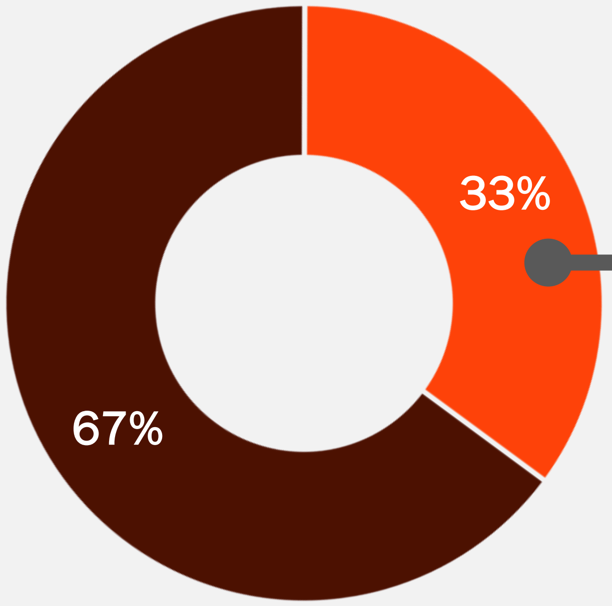
Incident Investigation
Relief system failures provide learning opportunities to prevent recurrence

Operating Procedures
Safe startup, normal operations, and emergency shutdown procedures protect equipment and personnel

The Reality Check – What Global Data Reveals

Industry-wide data based on ~80,000 relief devices reveals that **25-35% of relief devices have deficiencies**, with common issues including pressure losses and undersized devices.

Relief System Deficiency Distribution



Most Common Deficiencies

Inlet Line Pressure Loss – 12%
Excessive pressure drop in inlet piping

Outlet Line Pressure Loss – 7%
Inadequate discharge system design

Undersized Devices – 5%
Relief capacity below requirements

Wrong Set Pressure – 5%
Inappropriate pressure settings

No Protection – 4%
Missing relief devices entirely

A Deeper Look into Deficiencies

12%
Inlet Line Pressure Drop

ROOT CAUSES

- Low design pressure systems using wrong relief devices
- Rupture disks with excessive resistance
- Three-way valves causing high pressure drops
- Reduced port valves and inappropriate valve types
- Shared flow affecting multiple systems

MITIGATION STRATEGIES

- Ensure inlet pressure drop < 3% of set pressure
- Use full-bore isolation valves
- Minimize piping restrictions and fittings
- Proper relief device selection for system pressure

7%
Outlet Line Pressure Drop

ROOT CAUSES

- Wrong relief device type (conventional vs. balanced bellows)
- Failure to identify controlling backpressure scenarios
- Multiple devices discharging into common headers
- Inadequate flare header sizing
- Incorrect discharge locations

MITIGATION STRATEGIES

- Conventional PRVs: backpressure < 10% set pressure
- Balanced bellows PRVs: backpressure < 30% set pressure
- Verify against manufacturer performance curves
- Account for shared flow effects in outlet design

A Deeper Look into Deficiencies

5%
Undersized Devices

ROOT CAUSES

- Incomplete overpressure scenario identification
- Incorrect relief load calculations
- Failure to account for system interactions
- Using outdated or incorrect process data
- Not considering worst-case operating conditions

MITIGATION STRATEGIES

- Comprehensive overpressure scenario analysis
- Use process simulation data corresponding to maximum throughput
- Account for all credible upset conditions
- Verify relief capacity against actual requirements

5%
Wrong Set Pressure

ROOT CAUSES

- Incorrect MAWP determination
- Misunderstanding of accumulation allowances
- Failure to coordinate with other protection systems
- Changes in process conditions not reflected
- Inadequate design basis documentation

MITIGATION STRATEGIES

- Verify MAWP against vessel design conditions
- Follow code requirements for set pressure selection

Scale of the Challenge

350K

Barrels per Day

Typical large refinery capacity

10K

Equipment Items

Vessels, tanks, reactors requiring protection

4K

Relief Devices

Individual valves, disks, and systems

Each Device Requires Individual Analysis

Overpressure Scenarios

- Fire exposure analysis
- Blocked outlet conditions
- Control system failures
- Utility loss scenarios
- Runaway reactions

Relief Capacity Requirements

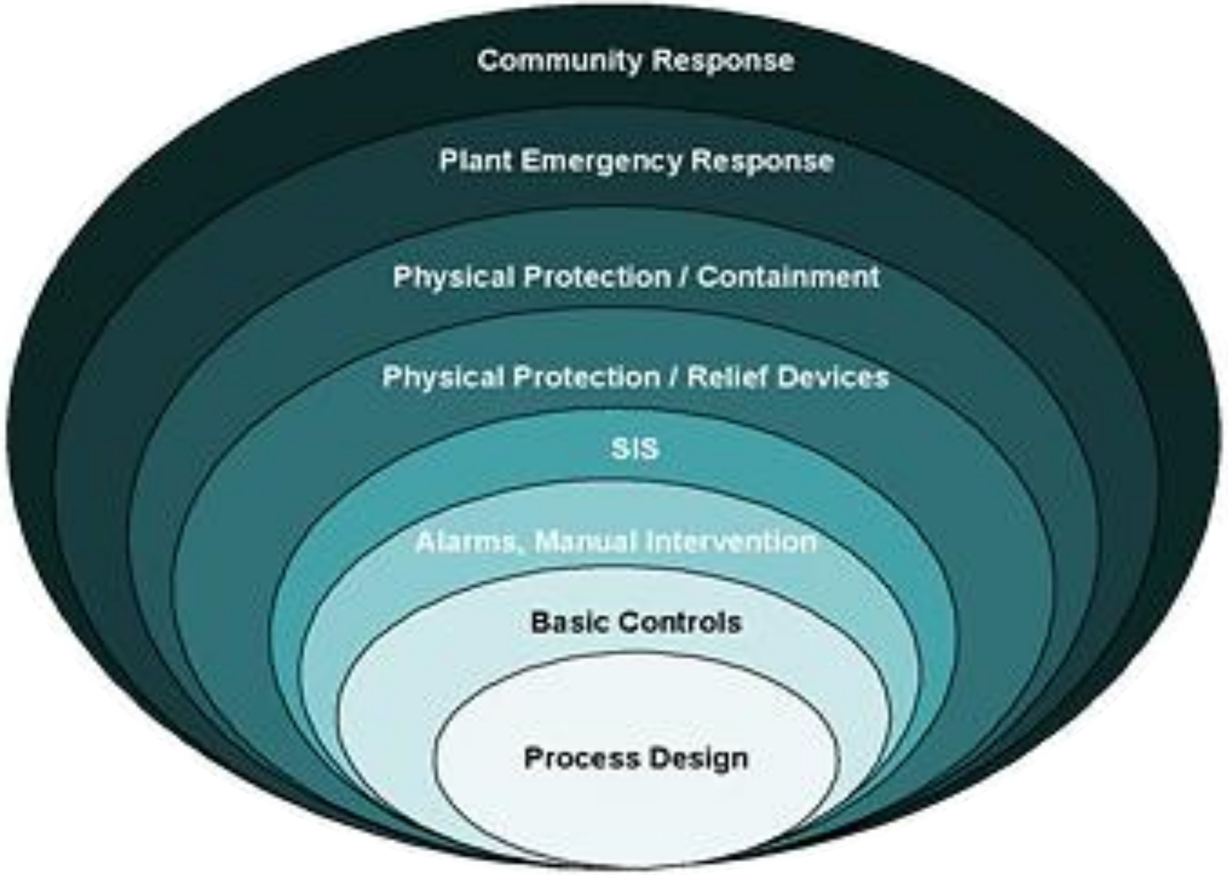
- Worst-case scenario identification
- Mass and energy balance calculations
- Two-phase flow considerations
- Temperature and pressure effects

System Integrity Verification

- Inlet pressure drop calculations
- Backpressure analysis
- Discharge system adequacy
- Material compatibility checks

⚠ **Resource Reality:** This comprehensive analysis requires multidisciplinary teams, significant time commitment, and specialized expertise that many facilities struggle to allocate effectively.

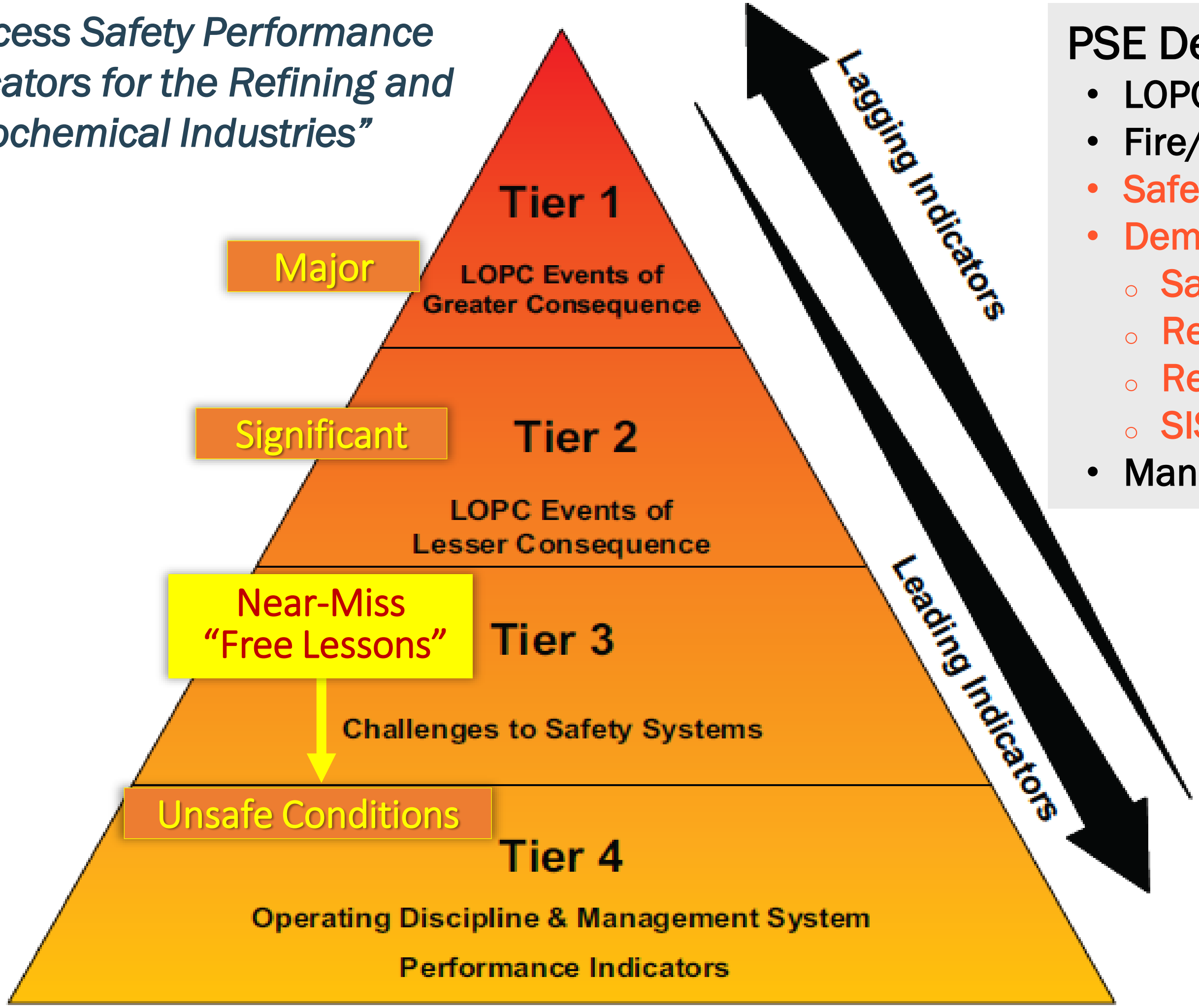
Pay Close Attention to Your Last Lines of Defense



- ✓ **Safe Operating Limits Exceeded**
- ✓ **Demands on Safety Systems**
  - Safety system failed to activate
  - Relief to atmosphere
  - Relief to flare
  - SIS/ESD initiated

API RP 754: PSE Reduction Trends have Plateaued since 2015

"Process Safety Performance Indicators for the Refining and Petrochemical Industries"



American Petroleum Institute

PSE Definition (Severity by Tier 1→ 4)

- LOPC = Spill/Release (by Threshold Quantity)
- Fire/Explosion + Repair Cost + Injury/Fatality
- Safe operating limits exceeded
- Demands on Safety Systems
  - Safety system fails to activate
  - Relief to atmosphere
  - Relief to flare
  - SIS/ESD initiated
- Management System Failure

Near-Miss "Free Lessons"

Expanded in 2016 to include midstream and upstream

- 101 refineries, 34 companies
- 118 chemicals, 25 companies
- Many hundreds internationally
- Non-participating companies are out-of-conformance with RAGAGEP

Where is Your Organization?

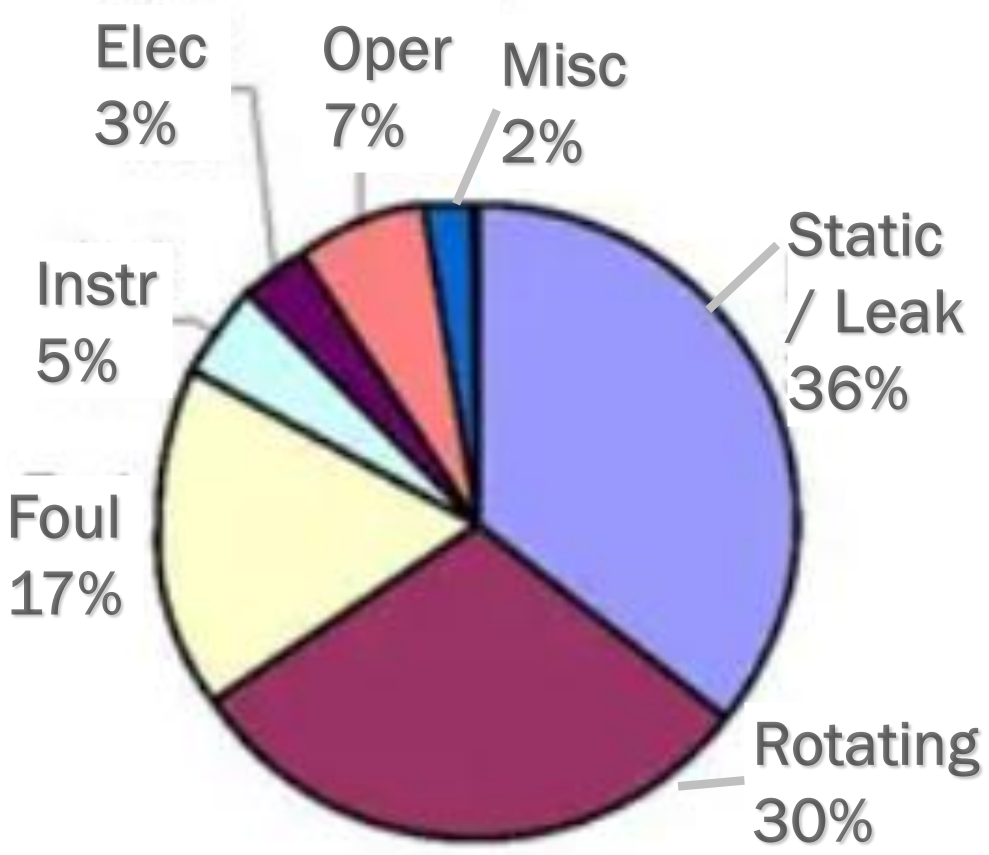
Operational Risk Management – Effectiveness & Maturity

1	2	3	4	5
Process safety events (PSEs) happen and we don't know why	We think we know why events are happening, so only perform root cause analysis for high severity incidents	We perform root cause analysis for all events, but don't make associations in the data for high level systemic analysis	We organize the data using tools and analytics, but don't look for patterns and can't predict when and where events might happen again	We use data-driven modeling with predictive algorithms, pattern recognition and machine learning to become safer and more reliable

Unit Downtime by Type

Becht Survey

Key Unit Unplanned Outages by Type [1980-2004]

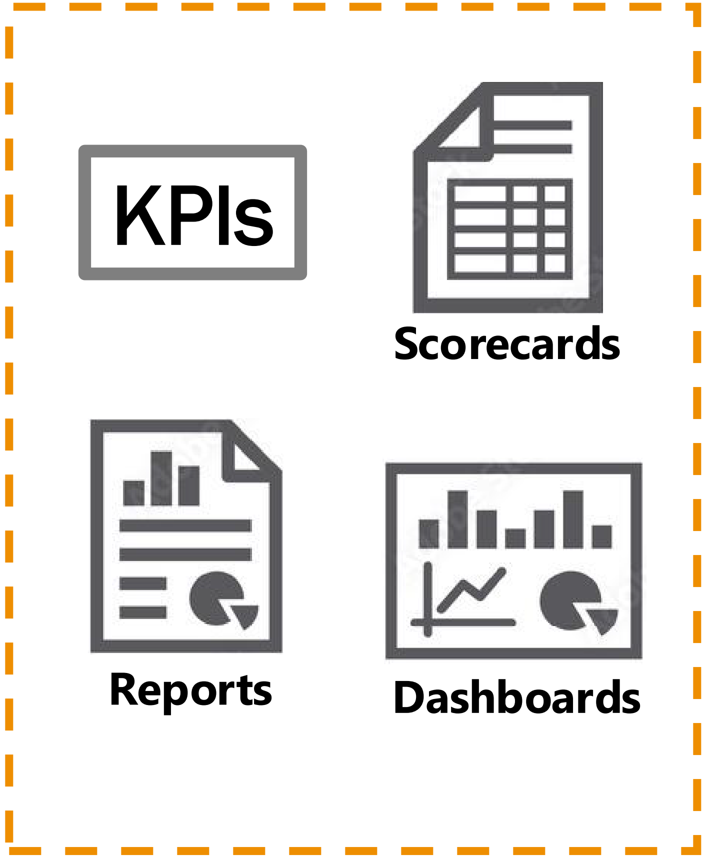


- Most LOPCs are “leaks not breaks”
- 40 to 50% of LOPC is due to equipment related damage mechanisms (API 571)
- 25 to 40% of failures are due to how facilities operate equipment
- KPI scorecard reports via spreadsheet are still widely used to track progress
- Lost production costs by equipment type, cause, human factors, failure mode/category/rate are not calculated
- Significant “systemic cause” loss findings are not shared enterprise-wide
- Need an all-assets solution to achieve best-in-class maintenance cost < 2 % RAV and mechanical availability > 97%

https://becht.com/becht-blog/entry/reliability-gap-assessment-a-critical-step-to-improve-unit-reliability/

API 754 KPIs Alone are Not Enough: Need AI-Driven Software Solution

- **Overwhelmed by hundreds of PSEs annually per facility**
  - PSM rule requires that all PSEs be triaged for “major” potential
- **Software with Managed Service…**AIM+PSM = AIPSM
  - Custom KPIs, dashboards, ad hoc queries, reports, and alerts
  - Normalizing data by performance and process parameters
  - Categorizing, prioritizing, and risk ranking by economic loss $LPO
  - Failure modes and process safety decision support functionality
  - AI / ML / APR / NLP “predictive modeling” capability
  - Systemic Enterprise-Wide RCFA Problem Solving *with ROI*



Use Case with ROI

Refining-Wide Benefits over Five Years

SAFETY: 27% reduction in PSM and environmental incidents

- 24% reduction in fires and explosions
- 39% reduction in spills and releases
- 48% reduction in near misses

AVAILABILITY: Improved equipment reliability and asset utilization

- Increased mechanical availability by 1.5% overall (up to 5% at some sites)
- Reduced production losses by 47%
- Reduced unplanned outages by 25%

} Savings of $20 million per year (four refineries)

COSTS: Reduced maintenance costs by 18%

- Achieved maintenance costs of 2% RAV at most sites (< 3% at others)

Every 1% gain in mechanical availability is worth $8 million per year in a typical 200,000 bpd refinery!

Key Takeaways

1. **Hidden Risk Reality**
   35% of relief systems have critical deficiencies

2. **Systematic Analysis Required**
   Equipment-by-equipment approach essential vs. random checks

3. **Proactive ROI**
   27% fewer incidents, $8M value per 1% availability gain

4. **Resources Matter**
   Need qualified teams + PSM integration

5. **Digital Transformation**
   AI-driven tools deliver $20M proven savings