Introductions

• Terry White – PG&E
  • Director, Facility Integrity Management & Technical Services
  • Asset Family Owner, Measurement & Control (M&C) & Compression & Processing (C&P)

• Troy Rovella – PG&E
  • Manager, Station Assessments
1. Overview of PG&E
2. Pipeline vs. Station Differences
3. How We Identify, Evaluate and Manage Risk
   - At the Fleet Level
   - At the Station Level
   - At the Component Level
4. Opportunities
Pacific Gas & Electric Company

- One of the Largest Combined Gas & Electric Utilities in the United States
  - ~ 20,000 Employees
  - ~ 70,000 Square Mile Service Territory
  - ~ 4.3 Million Gas Customer Accounts
  - ~ 42,000 Miles of Distribution Pipe
  - ~ 6,700 Miles of Transmission Pipe
- 3 Storage Facilities (25% Ownership in a Fourth)
- 9 Compressor Stations
  - ~ 212,000 Horsepower
- ~ 450 Transmission Regulation / Metering Stations
- 3 Terminals
- PAS 55, ISO 55001, API 1173, RC 14001 Certified
Asset Families

Natural Gas System Overview

Asset Families

1. Gas Storage
2. Compression & Processing
3. Transmission Pipe
4. Measurement & Control
5. Distribution Mains
6. Distribution Services
7. Customer-connected Equipment
8. Compressed Natural Gas/ Liquefied Natural Gas

Natural Gas Wells

Regulator Stations
# Measurement & Control Asset Family

<table>
<thead>
<tr>
<th>Below Ground</th>
<th>Above Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Regulation / Metering Stations (~450)</td>
<td></td>
</tr>
<tr>
<td>District Regulator Station (~2,400)</td>
<td></td>
</tr>
</tbody>
</table>

## Additional Assets
- Terminals (3 Facilities)
- Distribution Farm Taps (~2400)
## Compression & Processing Asset Family

<table>
<thead>
<tr>
<th>Reciprocating Engines</th>
<th>Electric Motors</th>
<th>Gas Turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressor Stations</strong> (9 Facilities)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Processing Facilities (3 Storage Facilities) |
Stations are different than pipe and, therefore, require a different approach

- Pipeline focus is on integrity risks
- Station focus must address reliability and integrity risks
- Station design factor provides higher safety margin
- In aggregate, facilities have a significantly smaller footprint
  - Geographical overlay of the Potential Impact Radius (PIR) for PG&E’s stations is ~1% of its pipeline assets
  - Total pipe length of PG&E’s station piping is ~1% of its transmission pipe
  - ~60% of PG&E’s station features are accessible for inspection and maintenance as opposed to pipeline that is underground
Enterprise Integrated Planning Process

- ASME B31.8S
- Threats
- Asset Information
  - External
  - Internal
- RIBA risk score
- SME Input

Q4
- Risk Refresh

Q1
- Session D

Q2
- Session 1
  - Multi-year portfolio planning
  - Risk Register
    - Identify and prioritize Risks
    - Document Risks
    - Calibration Sessions

Q3
- Session 2
  - Detailed project analysis
  - Strategic Plan
    - Prioritize programs and projects
    - Shape program scope and pace
  - Execution Plan
    - Cost benefit
    - Resource constraints
    - Alternatives
Identifying, Evaluating and Managing Risk: Fleet Level
How We Identify, Evaluate and Manage Risk
Fleet Level

- Fleet level risk management tools
  - Risk Register: Identify, evaluate and prioritize risk
  - Threat Matrices: Identify fleet level mitigation programs
  - Additional assessment of risks and mitigations
    - Fault trees
    - Bow-ties
- Asset management
  - Asset Management Plans
  - Long-term compression investment plan
# How We Identify Risk

## Fleet Level

<table>
<thead>
<tr>
<th>Time-Dependent Threats</th>
<th>Stable Threats</th>
<th>Time Independent Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External Corrosion</strong></td>
<td><strong>Manufacturing Related Defects</strong></td>
<td><strong>Third Party / Mechanical Damage</strong></td>
</tr>
<tr>
<td><strong>Internal Corrosion</strong></td>
<td><strong>Welding / Fabrication Related</strong></td>
<td><strong>Incorrect Operations</strong></td>
</tr>
<tr>
<td><strong>Stress Corrosion Cracking</strong></td>
<td><strong>Equipment</strong></td>
<td><strong>Weather Related &amp; Outside Forces</strong></td>
</tr>
</tbody>
</table>

### Primary Causes

- **External Corrosion**
  - 1) Transitions
  - 2) Inadequate coating
  - 3) Atmospheric conditions

- **Internal Corrosion**
  - 1) Liquids
  - 2) Sulfur
  - 3) Erosion

- **Stress Corrosion Cracking**
  - Not a high risk for asset family

- **Manufacturing Related Defects**
  - 1) Poor quality manufacture
  - 2) Inadequate specifications
  - 3) Strength test documentation

- **Welding / Fabrication Related**
  - 1) Poor construction practices
  - 2) Inadequate QC/inspection

- **Equipment**
  - 1) Age, Obsolescence
  - 2) Incorrect sizing/design
  - 3) Maintenance related
  - 4) Sulfur
  - 5) Liquids entering the system
  - 6) Vault flooding (LP)

- **Third Party / Mechanical Damage**
  - 1) Vandalism
  - 2) Excavation Damage
  - 3) Vehicular Damage

- **Incorrect Operations**
  - 1) Inadequate procedures
  - 2) Human error
  - 3) Quality of station documentation
  - 4) Inadequate training
  - 5) Debris from pigging & hydrotesting

- **Weather Related & Outside Forces**
  - 1) Flooding
  - 2) Seismic events

### PG&E Data Sources

- Event data (Corrective Action Program)
- Maintenance information
- Condition assessments
- Equipment obsolescence information
- Outage data
- Root cause analyses
- Records reviews
- Subject matter expert perspectives

### Industry Data Sources

- PHMSA information
- INGAA / AGA information
- Benchmarks
- Third party reviews and assessments
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Impact</th>
<th>Description</th>
<th>Risk</th>
<th>Cost</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1 times per year</td>
<td>F = Regular (6)</td>
<td>Major Injuries or illness to public or employees.</td>
<td>Catastrophic</td>
<td>Negligible</td>
<td>Significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
</tr>
<tr>
<td>1 - 3 times per year</td>
<td>F = Rare (6)</td>
<td>Severe (6) or catastrophic (6) incidents, or breaches of data security that result in significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - 10 years</td>
<td>F = Regular (6)</td>
<td>Extensive (5) or catastrophic (6) damage to power system and equipment, or breaches of data security that result in significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 - 30 years</td>
<td>F = Rare (6)</td>
<td>Catastrophic (6) or extensive (5) damage to power system and equipment, or breaches of data security that result in significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 - 100 years</td>
<td>F = Catastrophic (6)</td>
<td>Catastrophic (6) or extensive (5) damage to power system and equipment, or breaches of data security that result in significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 + years</td>
<td>F = Catastrophic (6)</td>
<td>Catastrophic (6) or extensive (5) damage to power system and equipment, or breaches of data security that result in significant loss of customer load, cost of replacement energy, redistributed customer costs, amounting to total impact $100k to $5 million in customer costs, or 500% miss of equivalent forced outage factor and/or reliability target.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Facilities Integrity Management Plan (based on PRCI)

- Condition Assessment
  - Asset Register
  - SFL/ECA
  - Critical Digs
  - Operational Metrics
  - Maintenance Data
  - Corrosion Data
  - CAP
  - Benchmarking
  - Equipment Failure Data (MPRs)

- Risk Register/Session D
  - Peer Review
  - Station Specific and Threat Specific Risk Analysis (DNV-M&C)
  - RCC

- Performance Management
- Communications
- Management of Change
- Quality Control
- Design Assurance

FIMP Elements

- Asset Management Plans
  - Metrics and KPIs
  - ISO-55000 Cert
  - API 1173 Cert
  - RC140001 Cert
  - # of Features Captured in SFLs
  - # of Overpressure Events
  - Continual Evaluation Process

- Obsolescence Management
  - Change Management Procedures
  - SFL Update
  - Asset Register Update
  - Gov Process for Work ID

- Maintenance
  - Control Assessment
  - Obsolescence Mgmt
  - New Product Valid
  - Corrosion Progns
  - Painting Progns
  - Gas Quality
  - MAOP Governance
  - LT Compression Investment Plan
  - TIMP
  - DIMP
  - SCADA Installation
  - Vault Program
  - Sta Reliability Plans
  - S1/S2 Process
  - Critical Digs
  - GG Release Plan
  - Training
  - Vessel Inspection Program
  - PHA Item Resolution
  - Setpoints Database
  - OMOD Process

- Asset Management Plans
  - LT Compression Investment Plan
  - CAP
  - SAP
  -Obsolete/Problem Equipment Lists
  - Material problem Reports

- QA/QC
  - Process Safety PHA’s and PSSR’s
  - Incident Investigation/ RCA
  - Benchmarking
  - OQ
  - Lessons Learned
  - Construction Contaminant Elimination
  - Boroscope and Hi-res Videography of Facilities
  - Extent of Condition Analysis and Actions
Identifying, Evaluating and Managing Risk: Station Level
How We Identify, Evaluate and Manage Risk
Station Level

- Activities currently addressing risk on a station basis
  - Condition assessment
  - Operational testing and repairs
  - Process Safety Management
  - Project prioritization
  - Additional programs

Station Score Sheet

Component Score Sheet
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Station Target Scores Based on Consequence of Failure for Health & Safety and Reliability

How We Identify and Evaluate Risk
Station Level

Components in Station | COF for H&S or Reliability of 5 or Greater | COF for H&S and Reliability of Less Than 5 |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target Score</td>
<td>No. of Stations</td>
</tr>
<tr>
<td>Class 1 and 2 (Cat. X)</td>
<td>54.8</td>
<td>234</td>
</tr>
<tr>
<td>Class 1 Only (Cat. XA)</td>
<td>36.5</td>
<td>17</td>
</tr>
<tr>
<td>Class 2 Only (Cat. XB)</td>
<td>18.3</td>
<td>8</td>
</tr>
</tbody>
</table>

Average: 39
St Dev: 15
• Automated scoring of station condition assessment
• Risk calculated at the individual station level rather than the fleet level
  • Probability of failure based on equipment fragility data, asset condition, station configuration, location (seismic and liquefaction) and operational data
  • Consequence of failure based on occupancy counts and system connectivity
  • Updated annually
Identifying, Evaluating and Managing Risk: Component Level
Facility Integrity Verification Process (IVP)

- Sequenced to follow the completion of the company’s line pipe IVP
- Prioritized in alignment with ‘Pipeline vs. Station Differences’ on slide 8
- Multiple programs filed as part of PG&E’s 2015-2018 Gas Transmission and Storage Rate Case with the California Public Utility Commission

Engineering Critical Assessment – Phase 1 (ECA 1)

- Comprehensive evaluation of more than 80K distinct features to re-confirm MAOP and identify design related asset integrity issues
- Stations sequenced by relative risk ranking and operational constraints
- Involves the application of Sound Engineering Judgement
- Evaluation activities may include field investigations
- Non-conformances in design will be mitigated

<table>
<thead>
<tr>
<th>Feature Number</th>
<th>Feature</th>
<th>Feature Type</th>
<th>Job Number</th>
<th>Install Date</th>
<th>STPR Number</th>
<th>OD1 (in)</th>
<th>WT1 (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Pipe</td>
<td>No Casing</td>
<td>1956176</td>
<td>05/12/1993</td>
<td>2</td>
<td>16</td>
<td>0.656</td>
</tr>
<tr>
<td>22</td>
<td>Mfg Bend</td>
<td>Unknown</td>
<td>1956176</td>
<td>05/12/1993</td>
<td>2</td>
<td>16</td>
<td>0.656</td>
</tr>
<tr>
<td>23</td>
<td>Pipe</td>
<td>No Casing</td>
<td>1956176</td>
<td>05/12/1993</td>
<td>2</td>
<td>16</td>
<td>0.656</td>
</tr>
<tr>
<td>24</td>
<td>Reducer</td>
<td>Conc.-Std</td>
<td>1956176</td>
<td>05/12/1993</td>
<td>2</td>
<td>16</td>
<td>0.656</td>
</tr>
<tr>
<td>25</td>
<td>Tee</td>
<td>Reducing Tee</td>
<td>1956176</td>
<td>05/12/1993</td>
<td>2</td>
<td>20</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Engineering Critical Analysis - Calculated Results

<table>
<thead>
<tr>
<th>MAOP Computation and Selection</th>
<th>MAOP per Design (psig)</th>
<th>MAOP per Test (psig)</th>
<th>Limiting MAOP Value (psig)</th>
<th>%SMYS @ Limiting MAOP Value</th>
<th>Limiting MAOP Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1435</td>
<td>1333</td>
<td>1040</td>
<td>36.2%</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>1435</td>
<td>1333</td>
<td>1040</td>
<td>36.2%</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>1300</td>
<td>1333</td>
<td>1040</td>
<td>40.0%</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>1300</td>
<td>1333</td>
<td>1040</td>
<td>40.0%</td>
<td>R</td>
<td></td>
</tr>
</tbody>
</table>

Field Investigation: Markings identify flanges as 1930’s Vintage MWP 600 vs. MWP 720
How We Evaluate and Manage Risk
Component Level

**Engineering Critical Assessment – Phase 2 (ECA 2)**

- Mitigation of discrepancies in strength test coverage identified during ECA 1 via low-risk and non-disruptive methodologies
- Under development in partnership with industry experts across multiple disciplines
- Places greater emphasis on probabilistic, rather than deterministic, modeling

**Nondestructive Testing**

- Tensile properties
  - Yield strength
  - Tensile strength

**Destructive Testing**

- Steel Chemistry
  - C, Si, Mn, S, ...

- Microstructure and Toughness

**Field Chemical Analysis**

**Lab Chemical Analysis**

- Metallography and CVN Impact Testing

- Most probable grade
- Probabilistic material quality
- Remaining life

Evaluate benefits of NDE relative to hydrostatic strength testing
• Individual utilities have no or few occurrences of high consequence events limiting the ability to perform quantitative or probabilistic risk analysis. A universal set of industry level data is needed.

• Equipment failure rate data is not available to determine likelihood of failure. Determination of component or design risk is not precise.
How We Manage Risk
Fleet Level

Primary Causes of Failures

- Vandalism, terrorism
- Excavation Damage
- Vehicular Damage
- Cyber security

- Inadequate Procedures
- Human Error
- Quality of Station Doc.
- Inadequate training
- Debris from pigging, hydro-test

- Flooding
- Seismic events
- Lightning
- Subsidence

Primary Prevention Measures
(highest impact on risk reduction - from left to right)

- Hand Digging Inside Station
- Stand by System
- Relocation of Stations
- Physical Security
- Cyber-security
- More Robust Designs

- Guidance Documents
- Training
- Enhanced Training
- Improved Site Docs
- Design Process
- Process Safety
- Post-Work Inspections
- SCADA Visibility

- Design Process
- Standard Designs
- Emergency Preparedness Procedures
- Low Elevation Stations
- Station Assessment for Supports, etc.
- Seismic Assessment

Time Independent Threats

Third Party Damage
MC30, MC30.1, MC30.2

Incorrect Operations
MC3-MC6; MC8; MC11

Weather & Outside Forces
MC32

Reliability

Failure to Meet Customer Demand
- Inadequate Capacity
- Failure to properly coordinate clearances

- Clearance Processes and Tools
- Outage Management Tool
- Asset Management Plan (FIMP)

Emergency Response

Major Emergency or Disaster
- Inadequate/Incorrect EOC response
- Inadequate/Incorrect first responder response
- Inadequate/Incorrect gas control response
- Inadequate/Incorrect dispatch response
- Inadequate/Incorrect training

- Transmission Control Center
- Business Continuity Plans
- Gas Emergency Response Plans (GERP)
- Site Specific Plans
- Emergency Management Advancement Program (EMAP)
- GERP-Based Exercises

GREEN = Meets or exceeds industry best practices AND controls are adequate
RED = Does not meet industry best practices AND current controls are not adequate
AMBER = Partially meets industry best practices OR controls are being strengthened
WHITE = Are not doing now

Availability and the quality of the asset data:
complete partial weak
### How We Manage Risk

#### Fleet Level

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Preventative Controls/Mitigations</th>
<th>Event</th>
<th>Reactive Controls/Mitigations</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual Operations</td>
<td>Training - Employee Training</td>
<td>Loss of Containment (Explosion) Downstream of an M&amp;C Station due to Incorrect Operations</td>
<td>Failure Analysis</td>
<td>Fatality or Injury</td>
</tr>
<tr>
<td></td>
<td>Accurate drawings</td>
<td></td>
<td>Automated Valves</td>
<td>Significant Financial Impact</td>
</tr>
<tr>
<td></td>
<td>FIMP Implementations</td>
<td></td>
<td>Emergency Preparedness</td>
<td>Potential Outages</td>
</tr>
</tbody>
</table>

**Risk Description**

P95 Loss of containment (explosion) Downstream of an M&C Facility

**P95 Scenario**

The risk of an overpressure event caused by incorrect operation of a local transmission complex station or terminal station may result in failure of downstream assets with loss of containment.

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**Control effectiveness:**

- Green: Control is adequate
- Yellow: Control is being strengthened
- Red: Control is not adequate

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*Example*