



NTSB National Transportation Safety Board

*Office of Railroad, Pipeline and
Hazardous Materials Investigations*

Natural Gas Transmission Pipeline Rupture and Fire

San Bruno, California
September 9, 2010



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Opening Statement

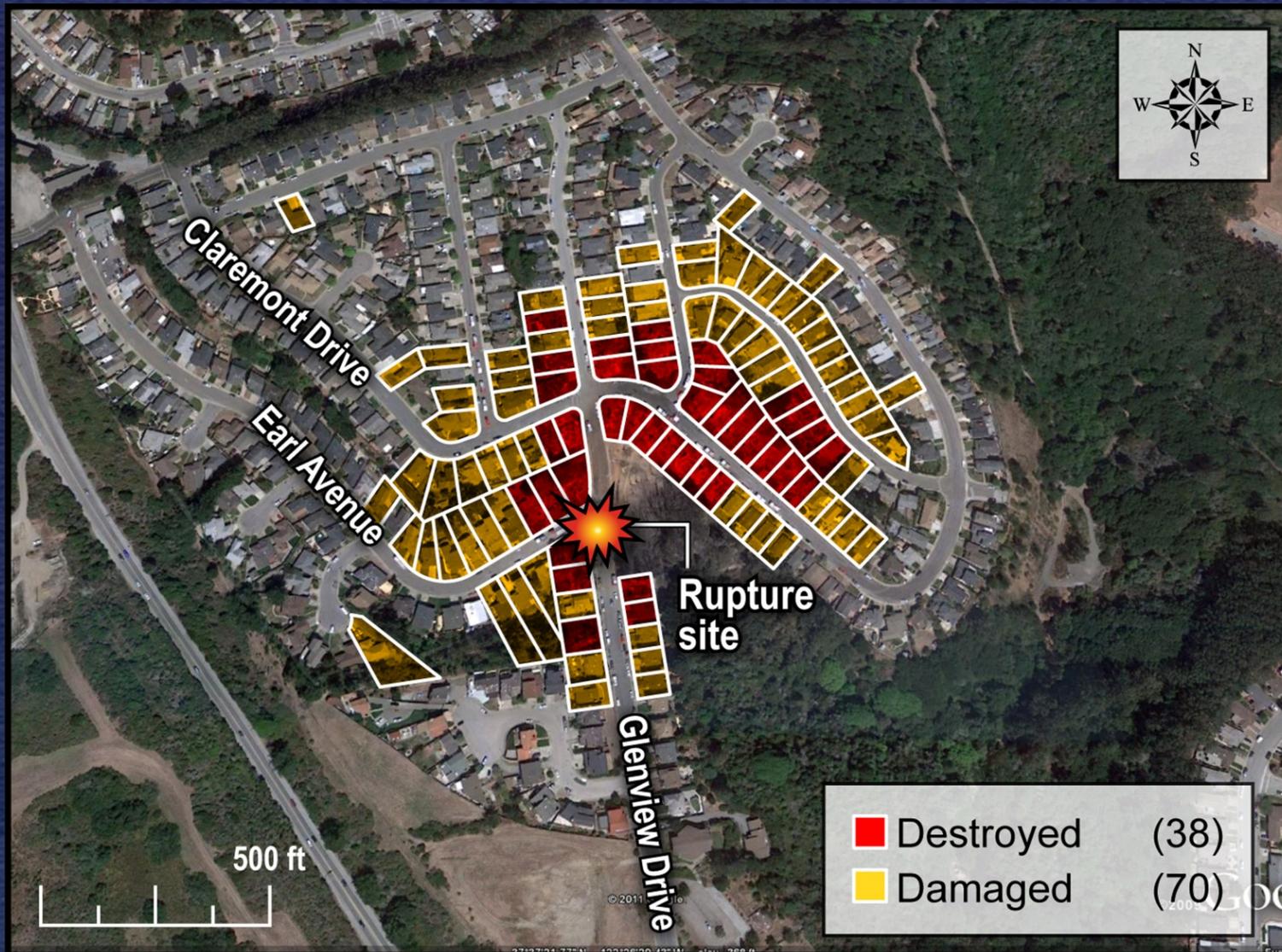
Ravindra Chhatre, P.E.
Investigator-in-Charge



Background

- Rupture located in Segment 180 of Line 132
- Line 132 owned and operated by PG&E
- PG&E's gas system includes
 - Over 42,000 miles of distribution pipelines
 - Over 5,700 miles of transmission pipelines

Overview of Property Damage





Witness Video

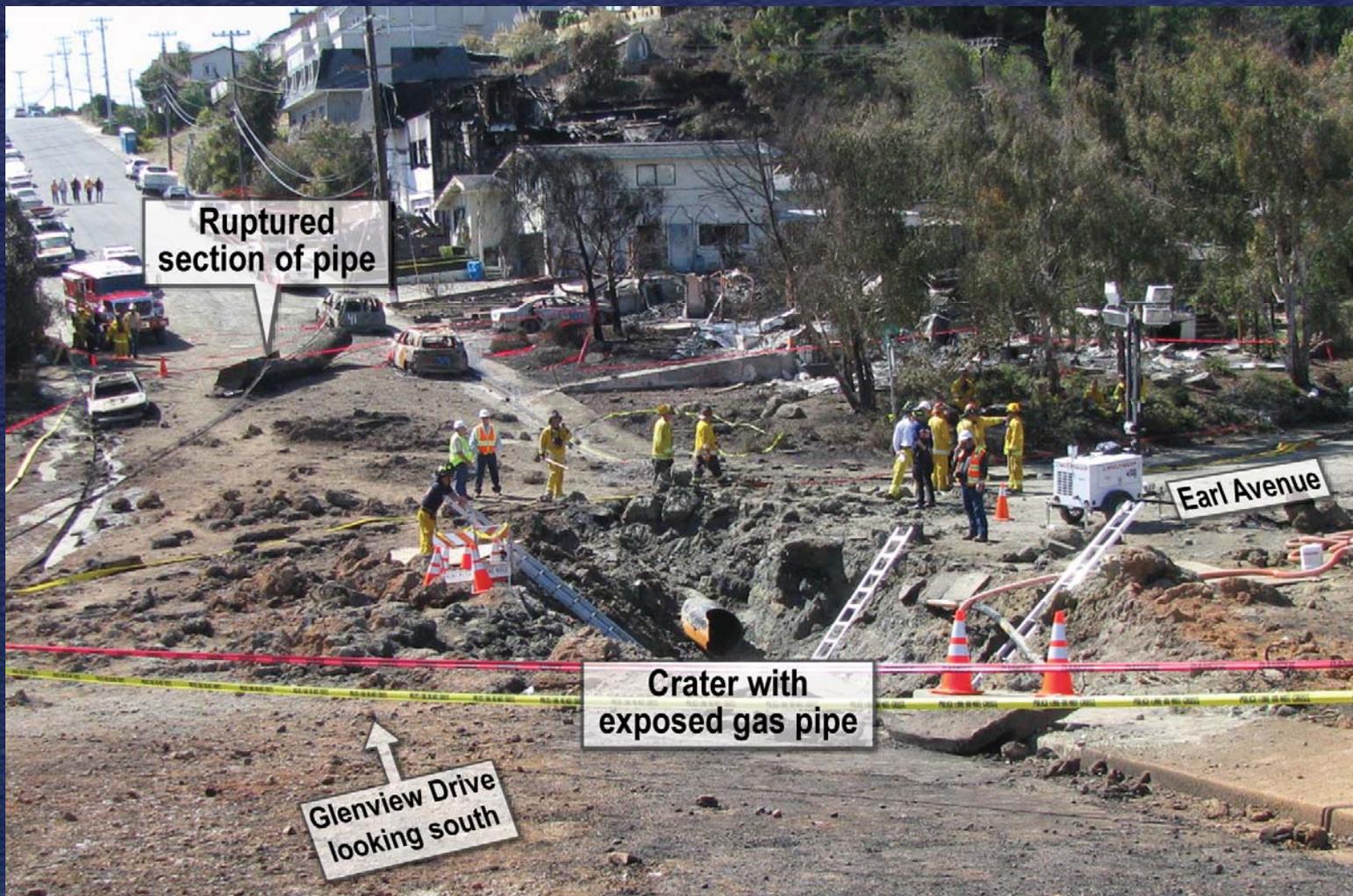


San Bruno, California
September 9, 2010

Photograph of Crater



Accident Scene



Pipeline Diagram





Segment 180 Details

- 30-inch diameter
- 0.375-inch thick wall
- Seamless
- API Grade X42, carbon steel
- 1,742 feet long and installed in 1956
- Some inaccurate information



Events Prior to Rupture

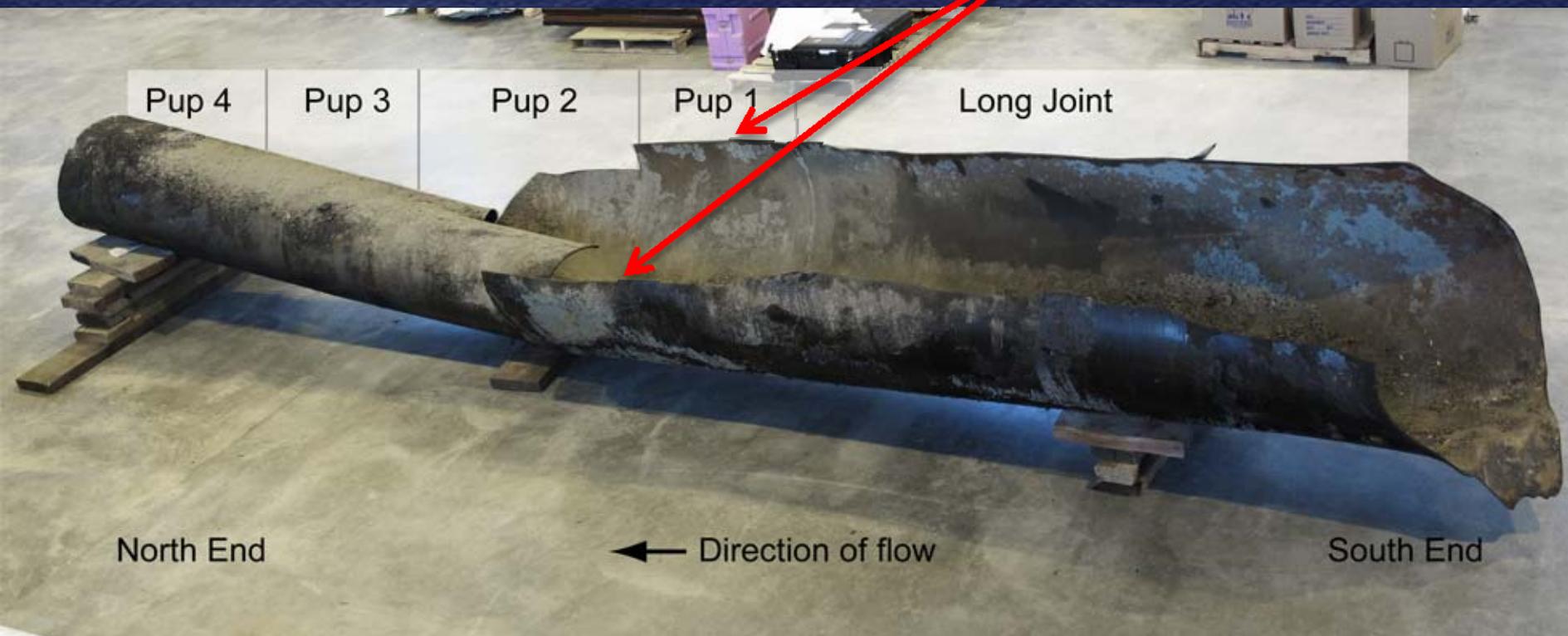
- Electrical work at Milpitas Terminal
- Power supply units experienced erratic voltage
- Line 132 discharge pressure at Milpitas Terminal increased to 396 psig

Event Timeline

- 5:45 p.m. Line 132 pressure exceeded 375 psig
- 6:11 p.m. Line 132 ruptures when pressure reached 386 psig
- 7:30 p.m. Upstream valve closed
- 7:46 p.m. Downstream valves closed

Ruptured Pipe Segment

Fracture Initiation





Safety Issues

- Multiple deficiencies in PG&E's operations
- Ineffective Federal and state oversight
- Inadequate Federal pipeline safety rules



Deficiencies in PG&E's Operation

- Systemic deficiencies
 - SCADA operation
 - Integrity management
 - Record-keeping
 - Emergency response
- Missed opportunities



Organizational Accidents

- Multiple contributing causes
- Involve people at numerous levels
- Pervasive lack of proactive measures
- Catastrophic events
- Require complex organizational changes



Previous Recommendations

- Pipeline and Hazardous Materials Safety Administration
- California Public Utilities Commission
- Pacific Gas and Electric Company





Parties to the Investigation

- Pacific Gas and Electric Company
- California Public Utilities Commission
- Pipeline and Hazardous Materials Safety Administration
- City of San Bruno
- Engineers and Scientists of California Local 20
- International Brotherhood of Electrical Workers Local 1245



Investigation Team

- Ravindra Chhatre Investigator-in-Charge
- Matthew Nicholson Operations Group
- Robert Hall Integrity Management
- Karl Gunther Operations Group
- Rick Narvell Human Performance
- Dana Sanzo Survival Factors
- Donald Kramer Metallurgy
- Nancy McAtee Fire Damage





Investigation Team

- Elias Kontanis Disaster Assistance
- Richard Downs Survival Factors
- Peter Knudson Public Affairs
- Steve Blackistone Government Affairs
- Ted Turpin On-scene Support
- Mary Arnold On-scene Support
- John Whitener Technical Support
- Michael Richards Meteorology





Investigation Team

- Lorenda Ward Public Hearing Officer
- Paul Stancil Technical Support
- Karen Bury Report Writer
- Kathleen Curry Co-report Writer/Editor
- Deborah Stocker Editorial Support
- Robert Trainor Technical Supervision
- Michael Budinski Technical Supervision
- Bob Beaton Technical Supervision





Investigation Team

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- Mike Brown Safety Recommendations
- Carl Schultheisz Technical Support
- Kalu Kelly Emeaba Technical Support
- Charles Koval Technical Support
- Obiora Agbim Technical Support
- Anton Stoytchev Technical Support
- William Young Technical Support



NTSB Headquarters Staff

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- Bob Combs



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Preaccident Events

Matthew Nicholson, P.E.

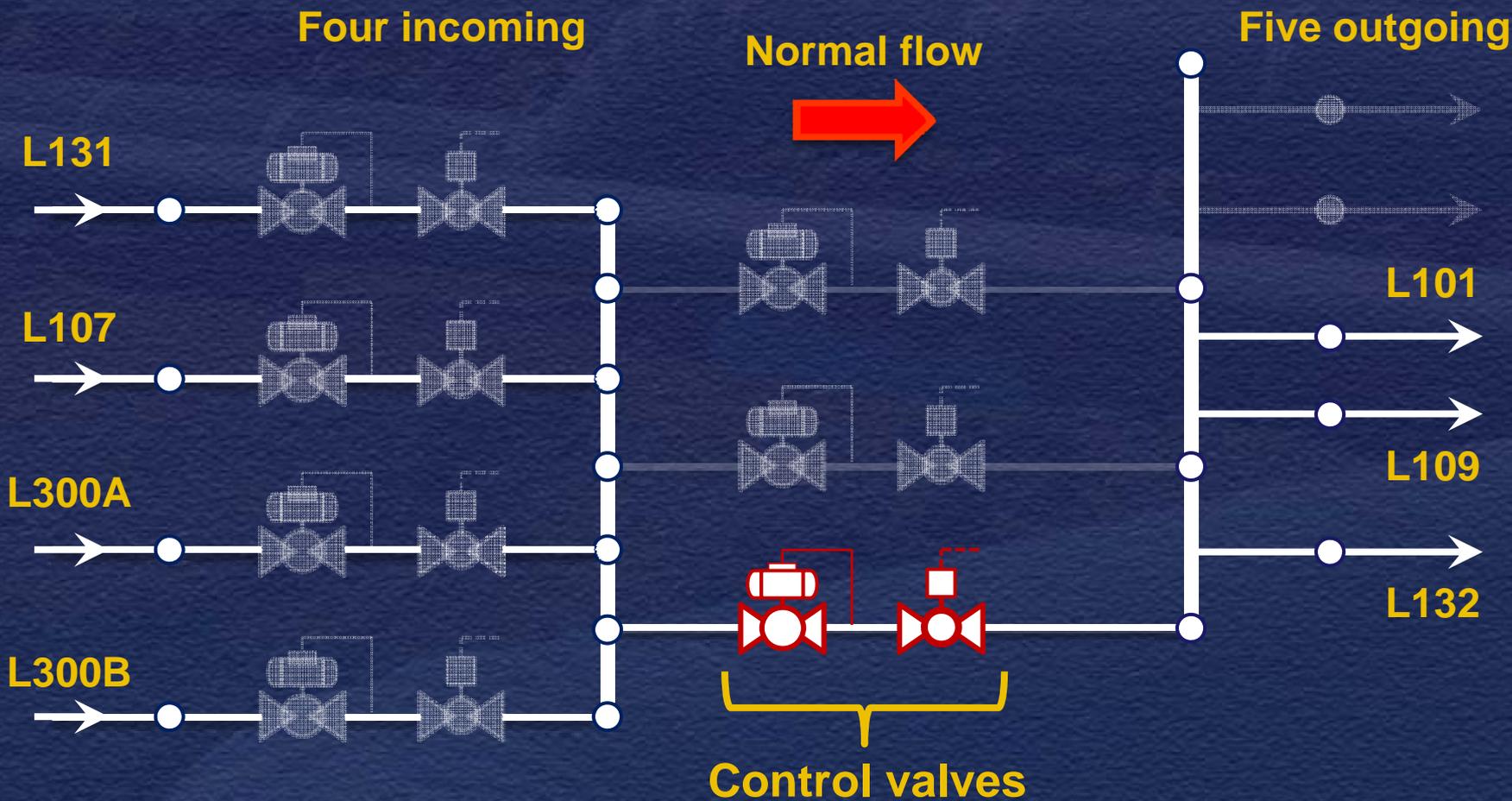
Milpitas Work

- Transferred critical electrical loads from distribution panel
- 4:40 p.m., Milpitas operational
- Unexpected power loss to local control panel
- Control panel not required for operations
- Milpitas workers decided to power local control panel on temporary source

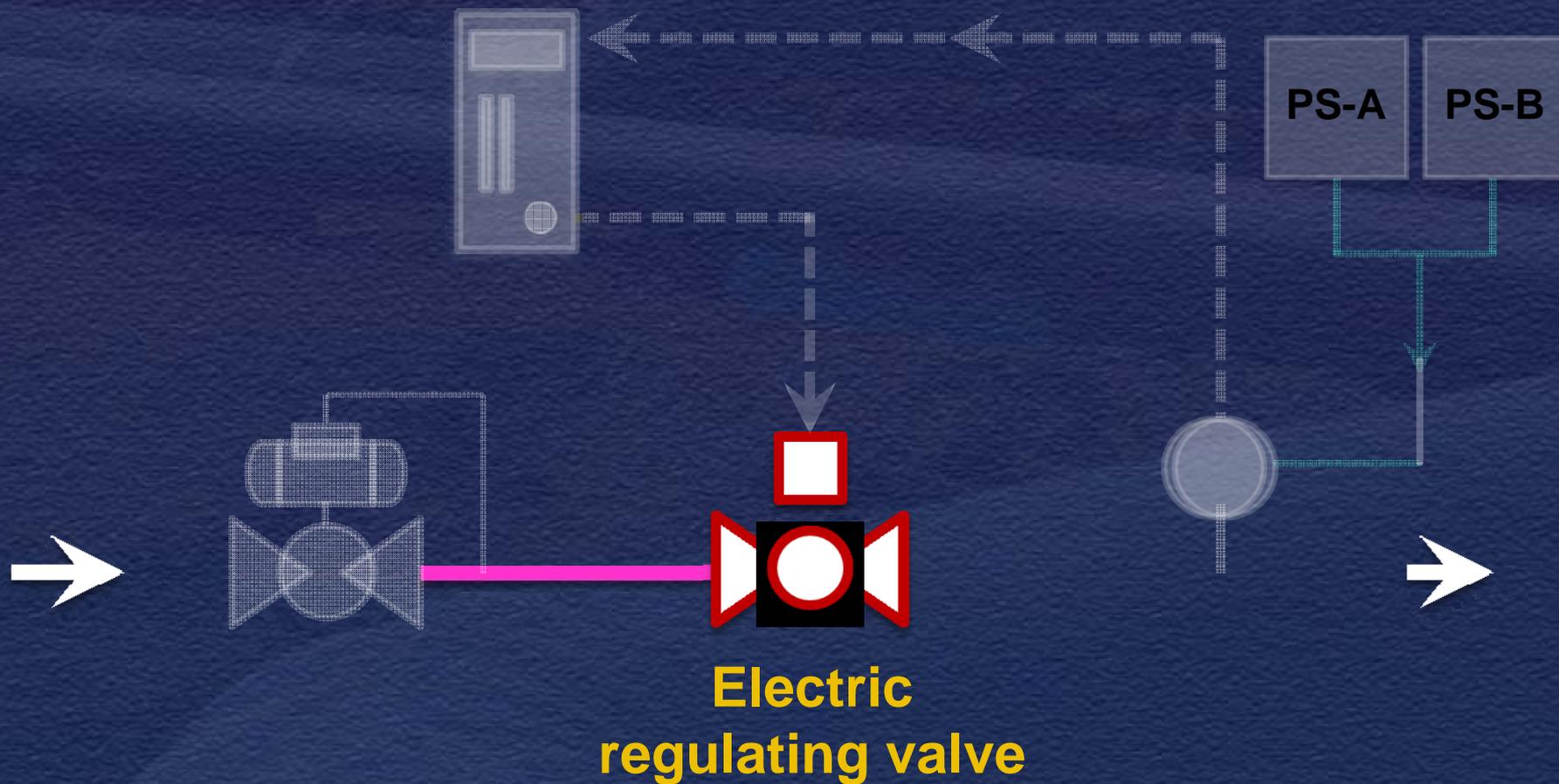
Milpitas Work

- Local control panel displays went blank
- Power supplies A and B inside panel
- Power output voltages low and erratic
- Power supplies A and B serve pressure transmitters for valve controllers
- Low signals from pressure transmitters caused regulating valves to fully open

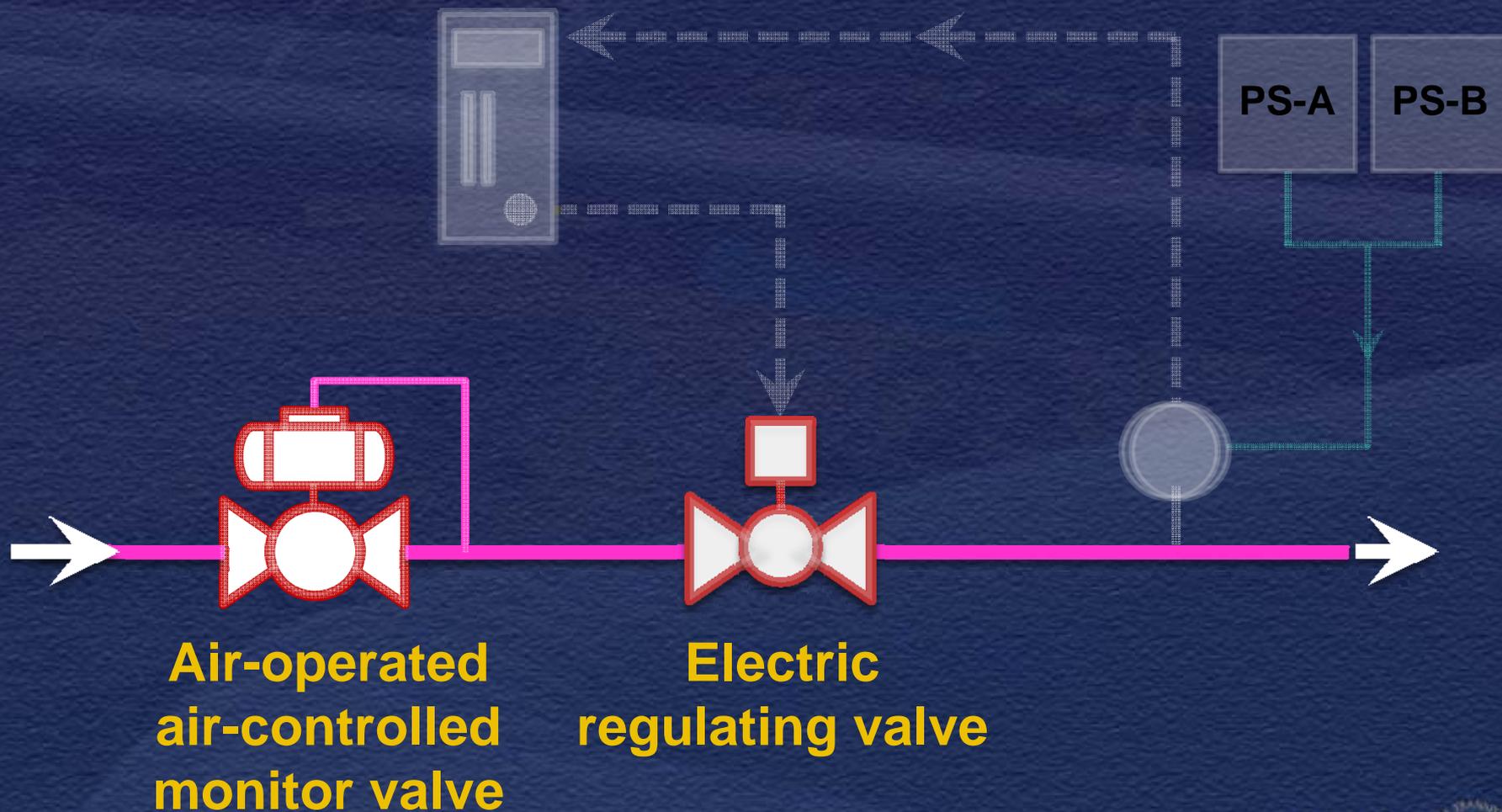
Milpitas Terminal



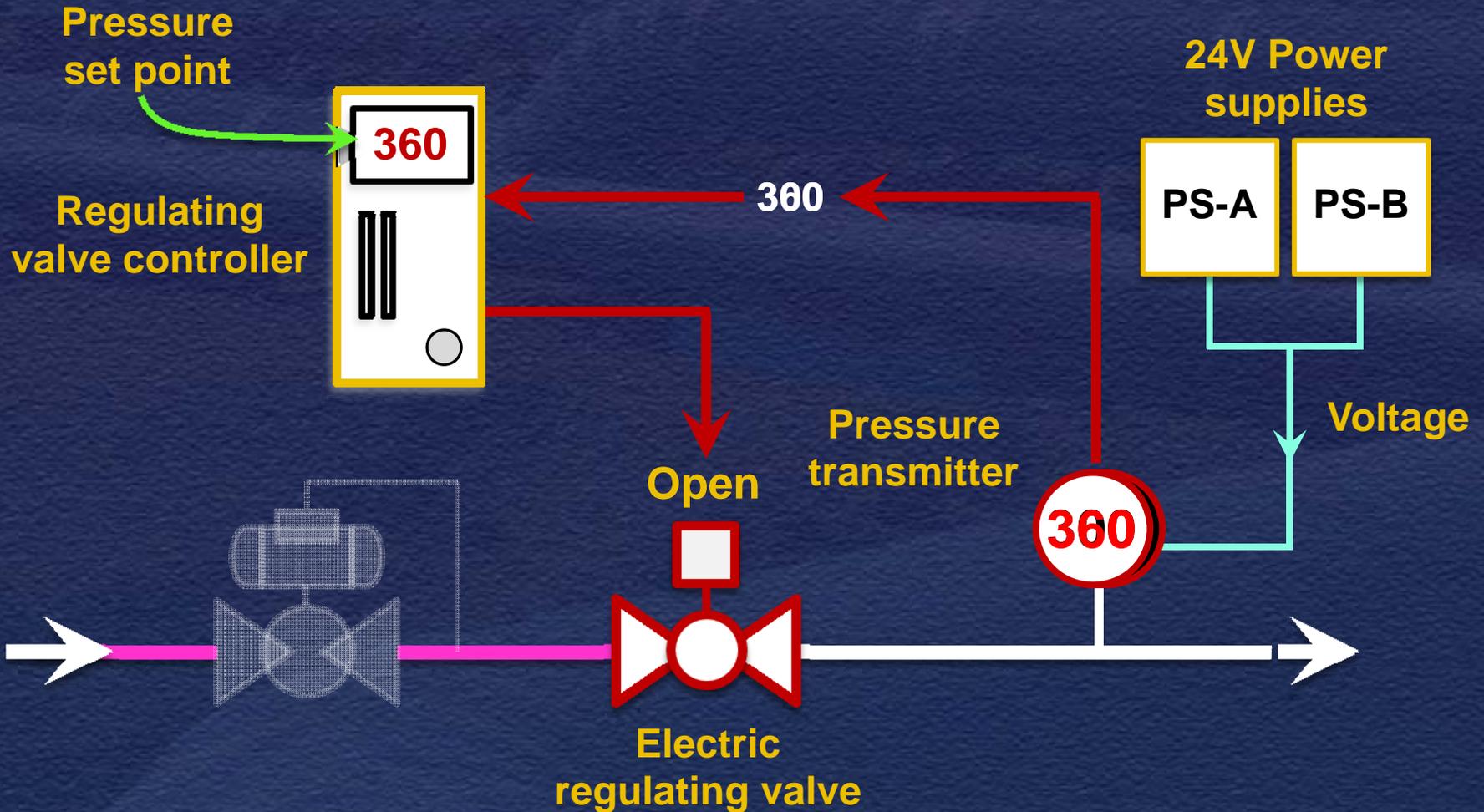
Pressure Control Valves



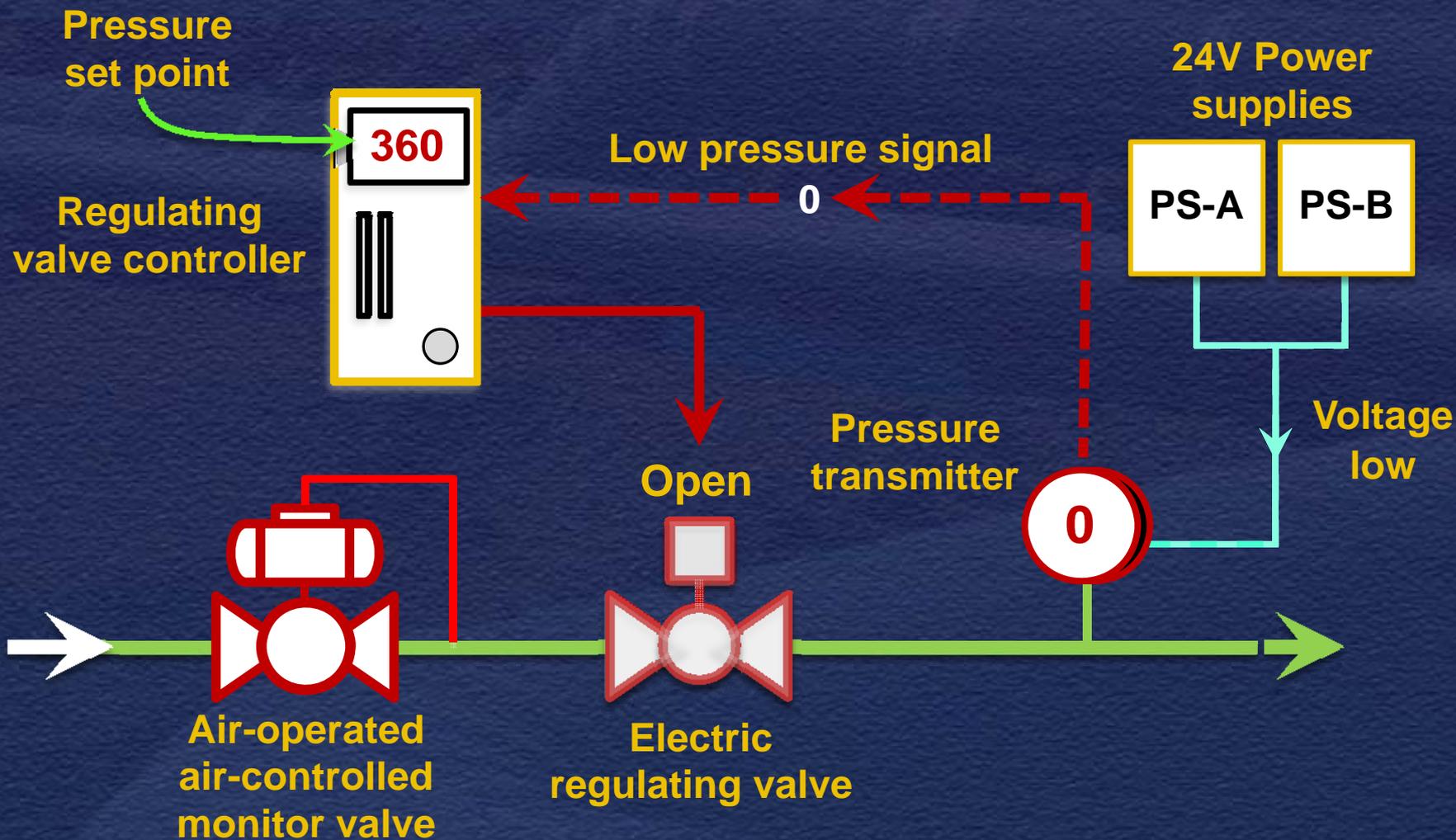
Pressure Control Valves



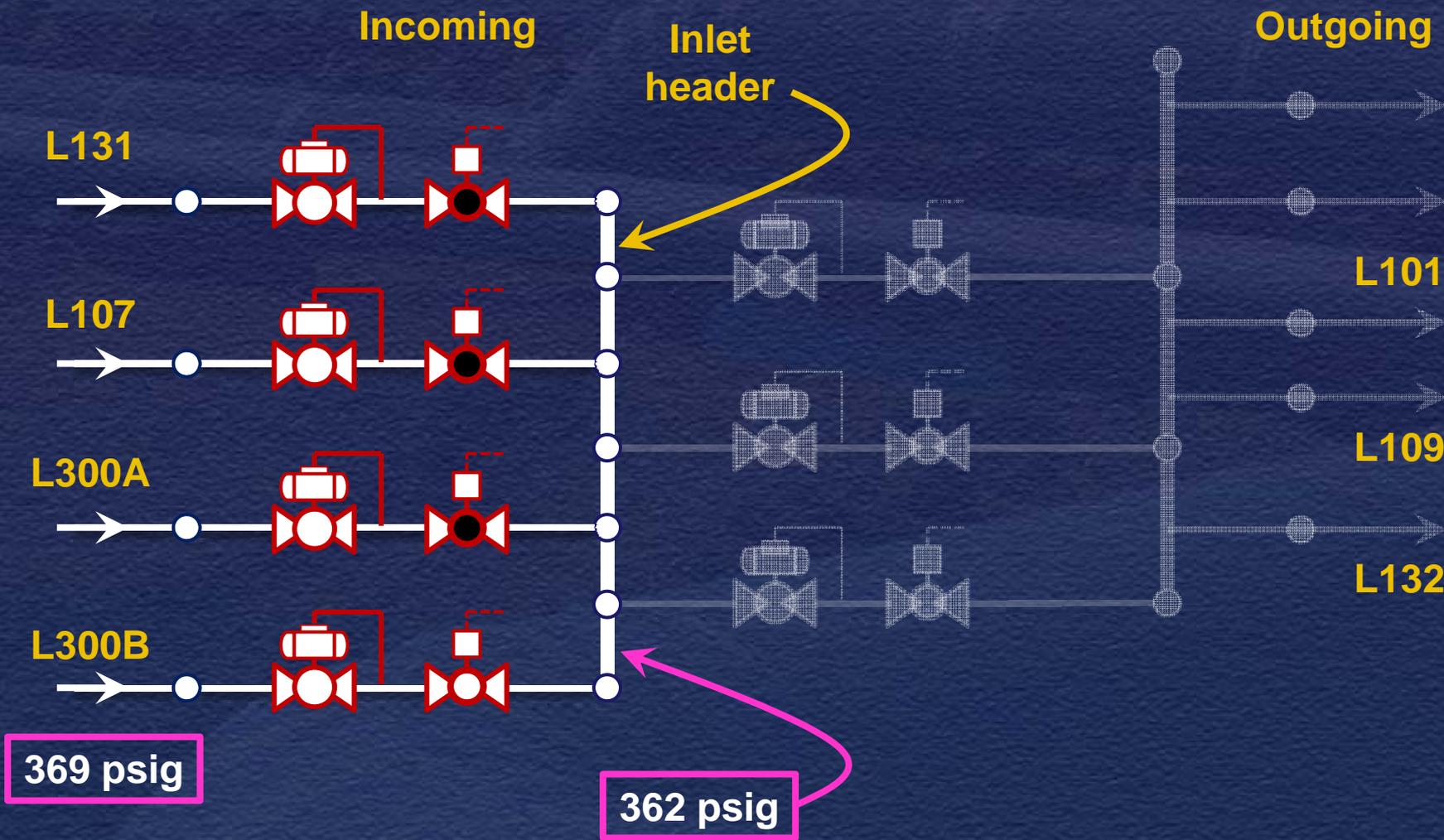
Regulating Valve (normal)



Regulating Valves (Sept. 9th)



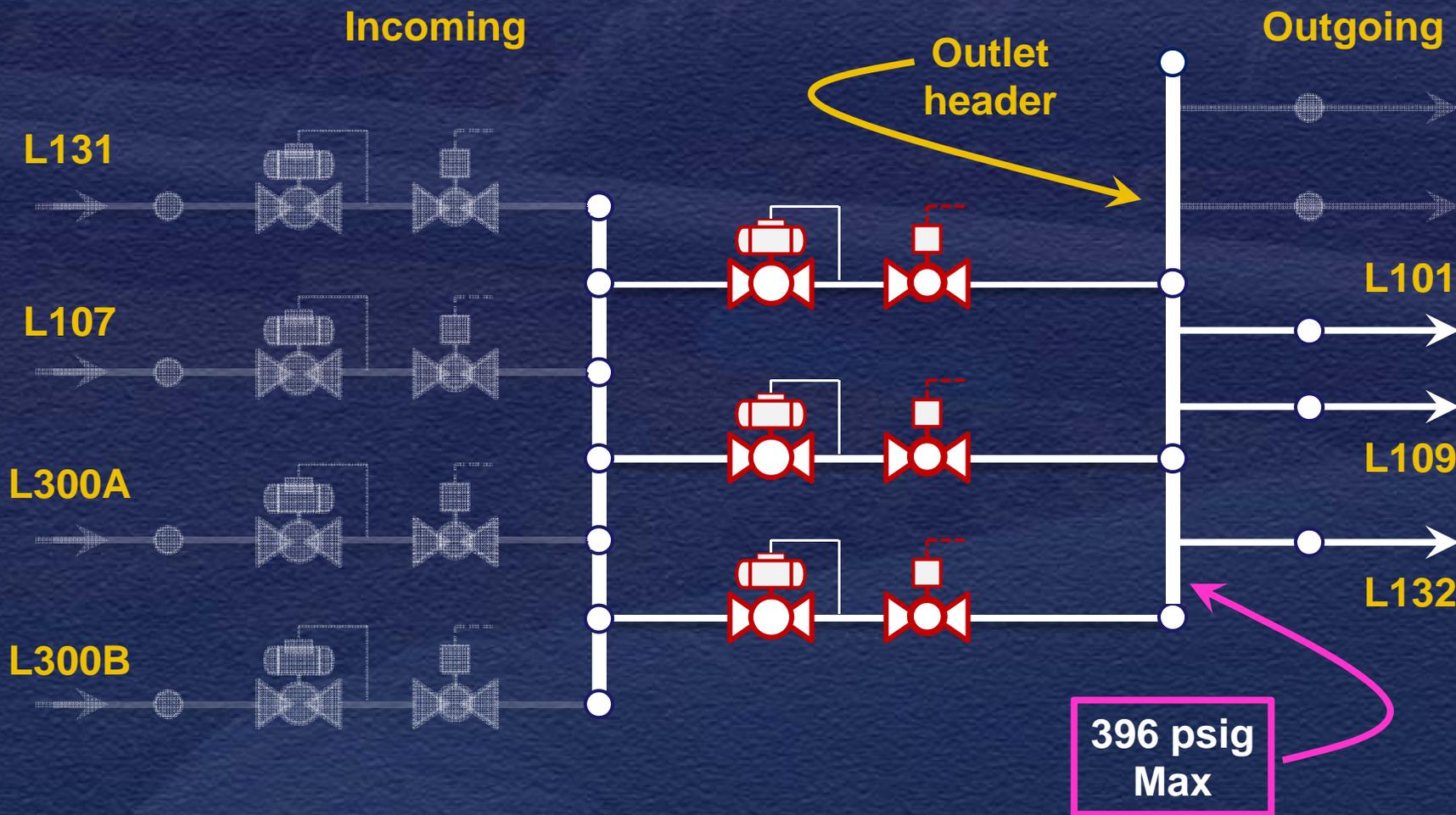
Milpitas Prior to 5:22 p.m.



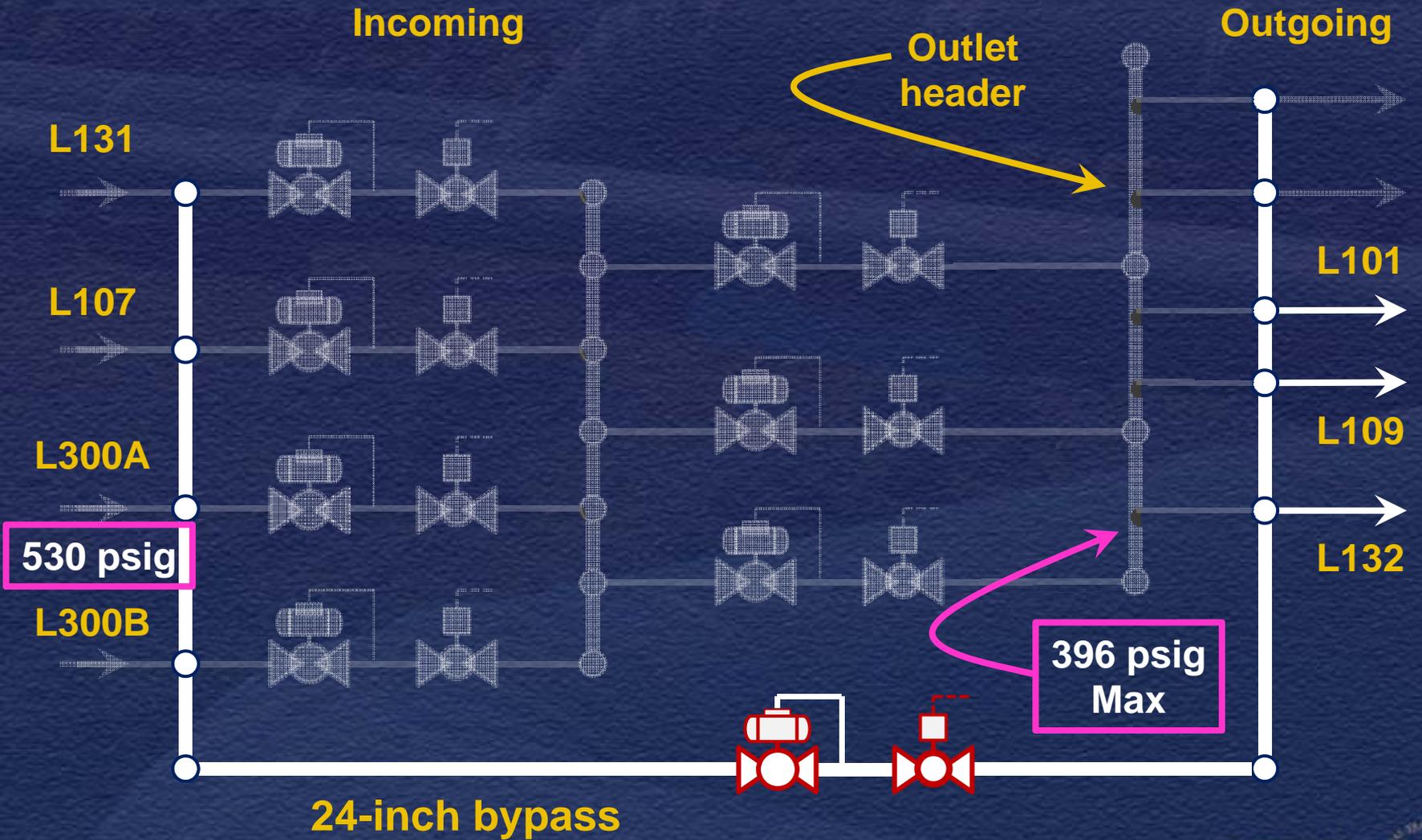
Milpitas Impacts



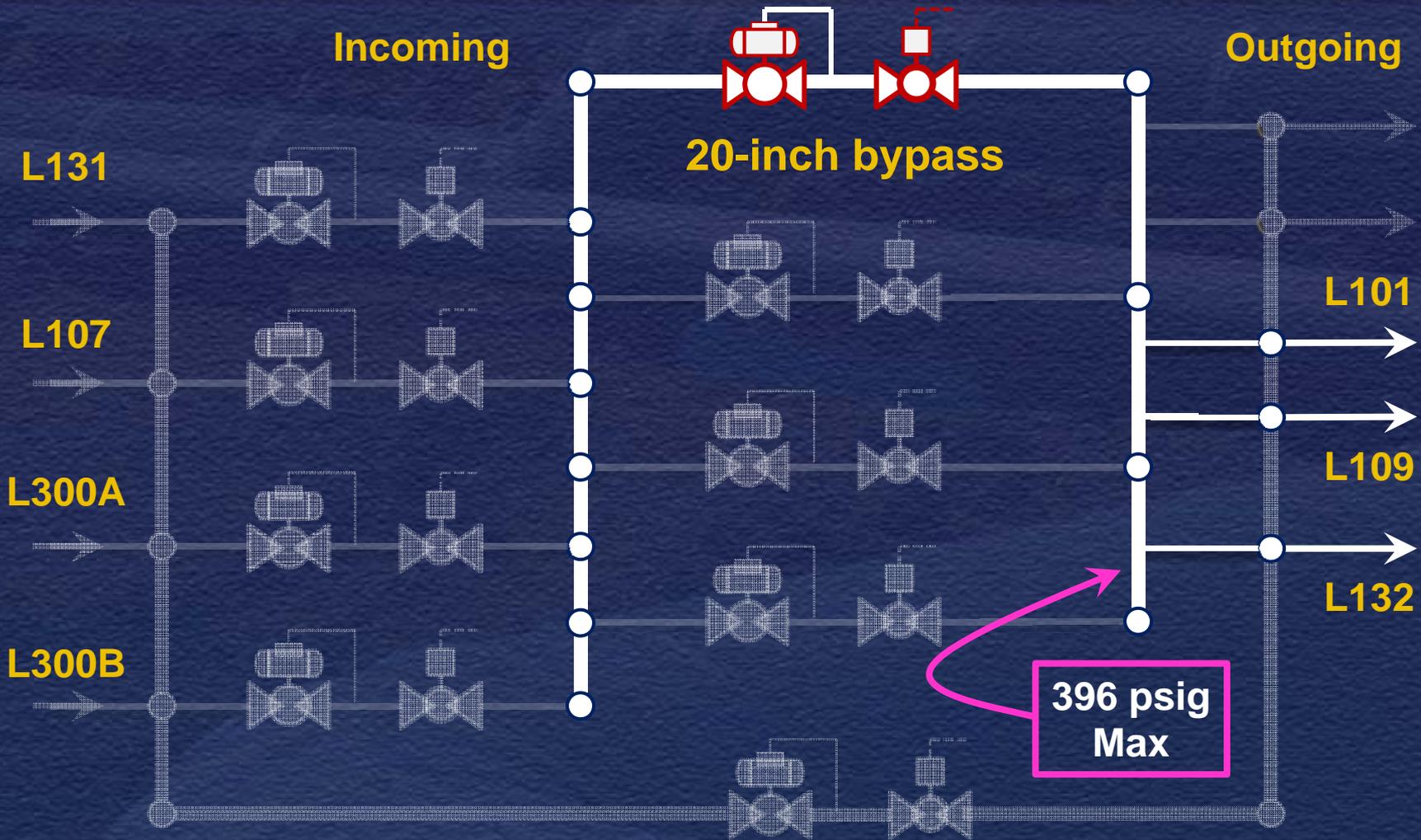
Milpitas Impacts



Milpitas Impacts



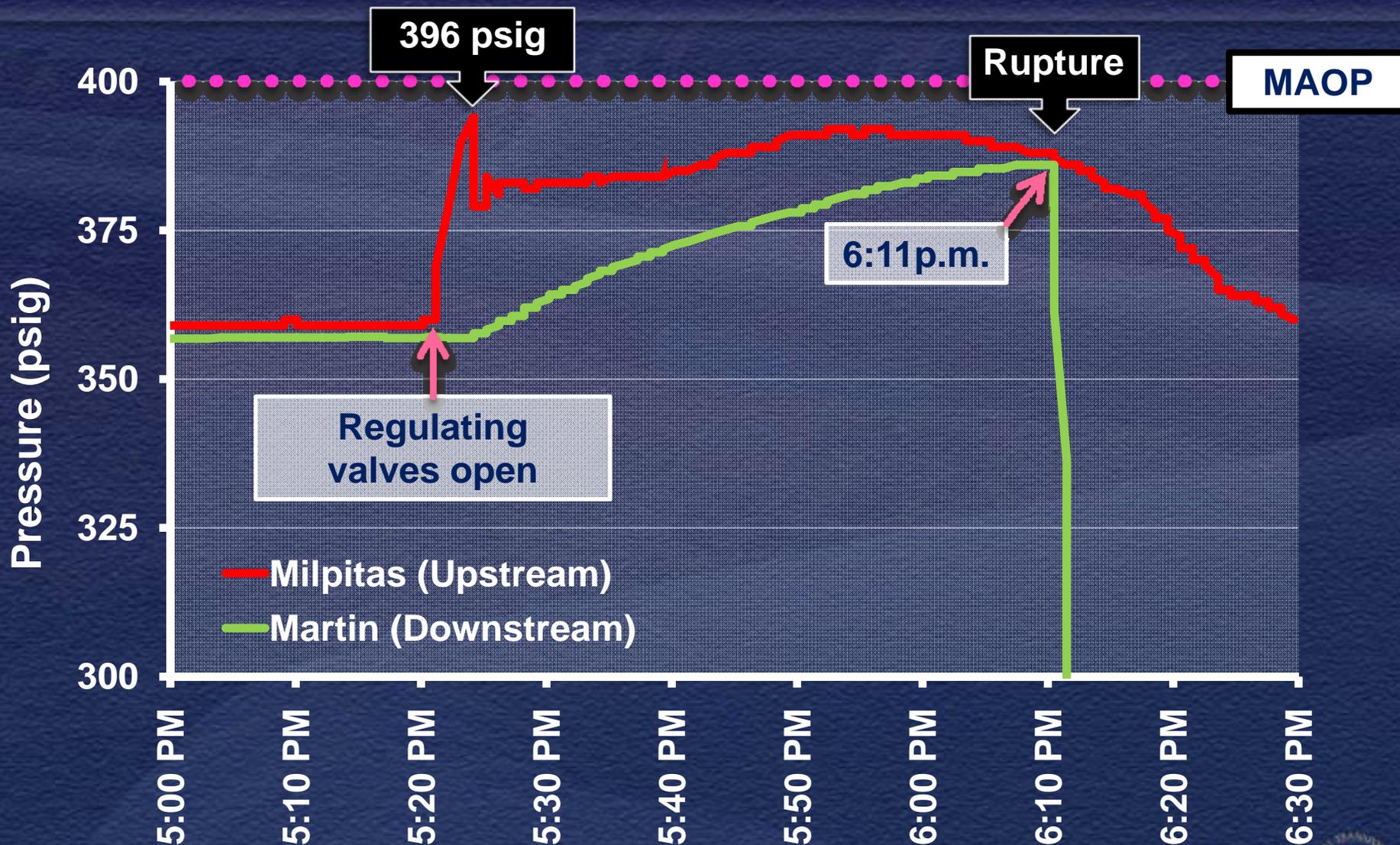
Milpitas Impacts



Milpitas Impacts

- 5:22 p.m., primary pressure control lost
- Monitor valves react to control pressure
- Milpitas technician notified at 5:25 p.m. by SCADA center of high pressures
- SCADA center no longer receiving accurate SCADA information
- SCADA center unprepared for loss of Milpitas control

Line 132 Pressure Trends



PG&E Line 132

Sept. 9, 2010, 6:11 p.m.

Martin Station

386 psig

Rupture

Segment 180

386.4 psig

386.8 psig

Milpitas Terminal

389 psig

L132

389 psig

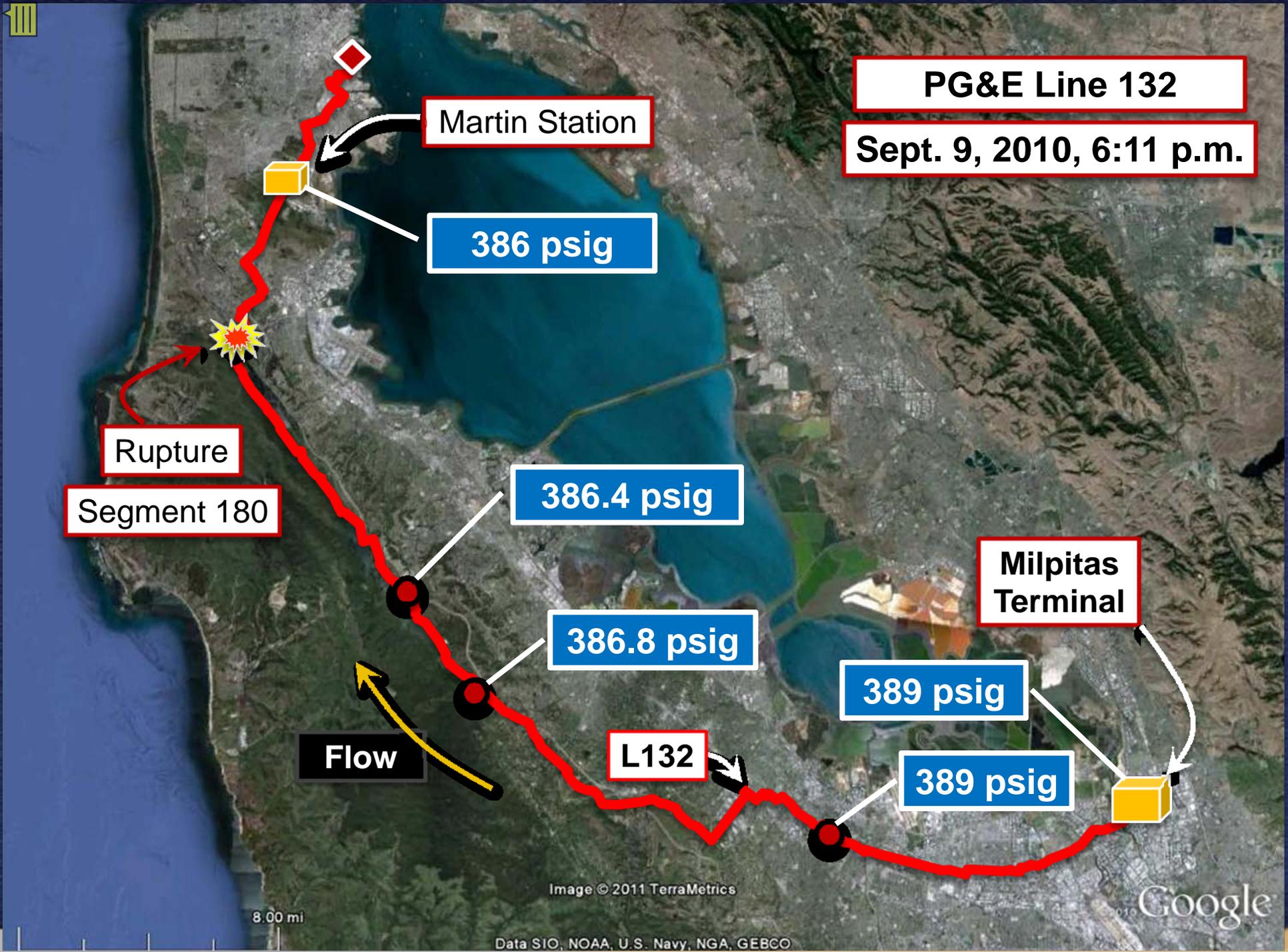
Flow

8.00 mi

Image © 2011 TerraMetrics

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google





Work Clearance

- Milpitas work clearance lacked adequate information
- Work clearance did not address risks or contingencies
- Reduced upstream pressure would have prevented impacts
- Work not stopped when repowering local control panel





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Metallurgical Evaluation

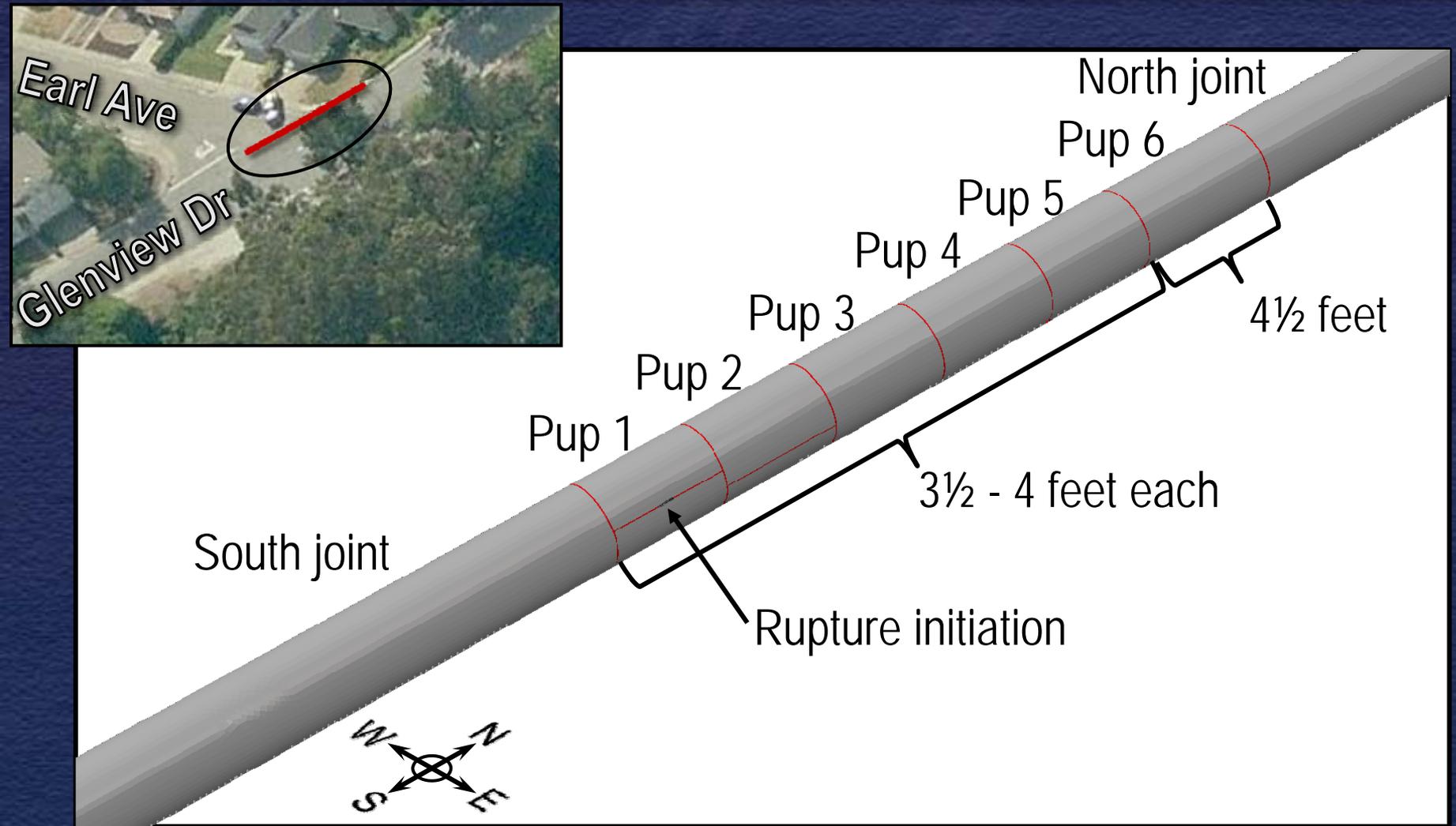
Donald Kramer, Ph.D.



Overview

- Construction of the pipeline
- Differences in pipe materials
- Rupture of the pipe
- Quality measures in 1956

Construction of the Pipe

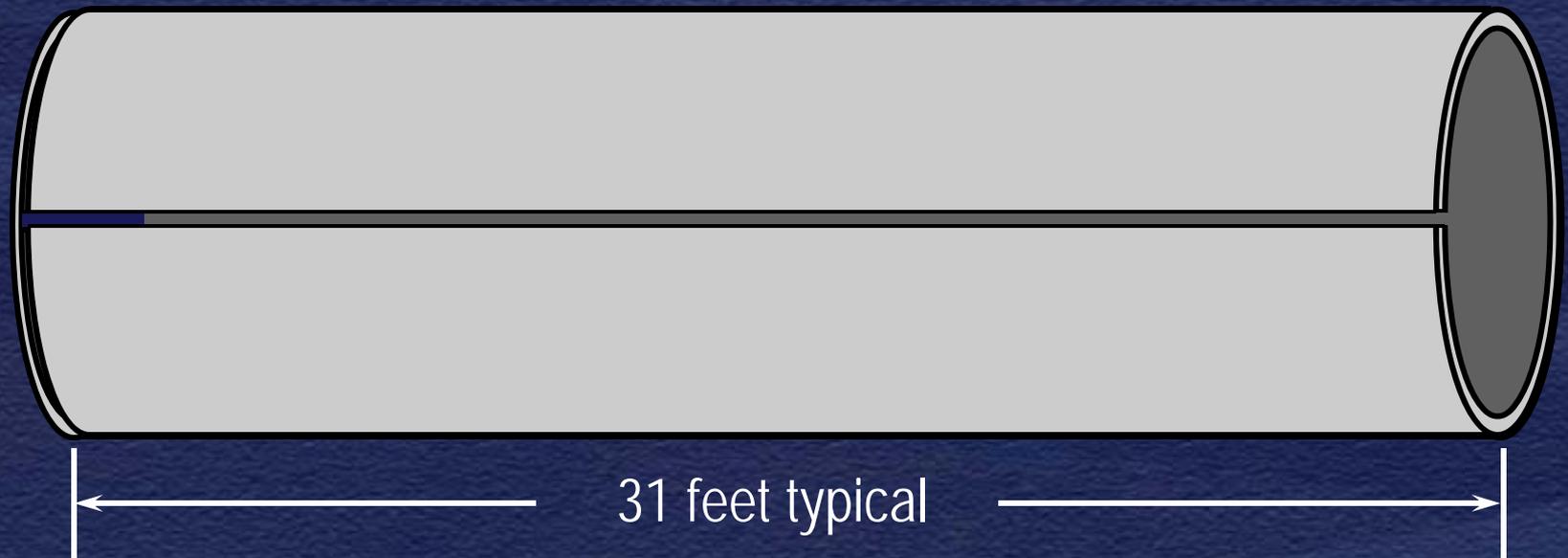




Pipe at Accident Site

- Pipe listed as X42 seamless
- Postrupture examination indicated presence of seam welded pipe
- PG&E believes pipe came from Consolidated Western Steel Corporation

X52 DSAW Pipe Characteristics



- Double submerged arc weld (DSA W)
- Each piece 31 feet long
- Minimum yield strength – 52,000 psi (X52)

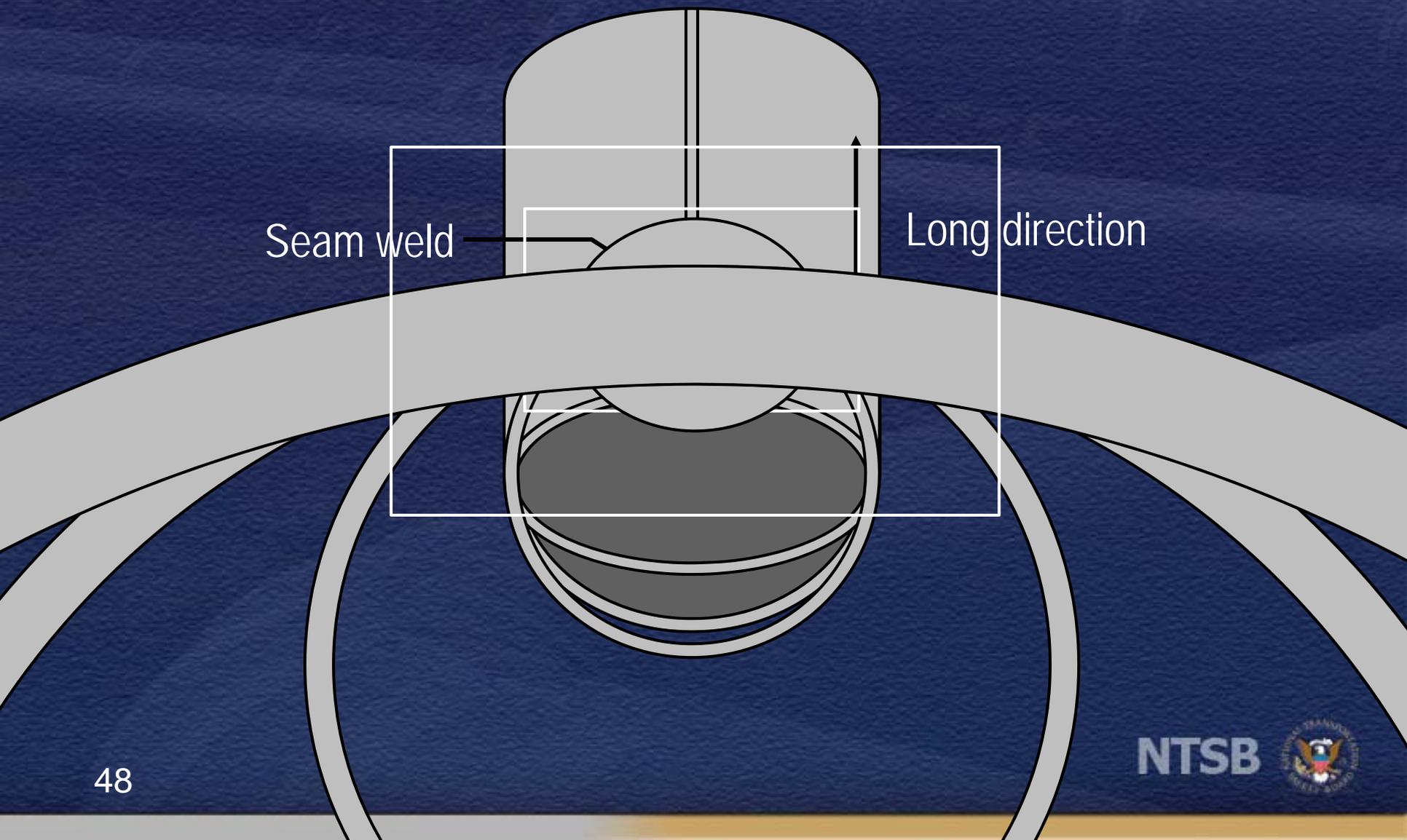
Comparison of Pipe Attributes

Section	DSAW seam weld	Rolling direction	Yield strength	Weld hardness
South joint	○	○	○	○
Pup 1	✗	✗	✗	✗
Pup 2	✗	✗	✗	✗
Pup 3	✗	✗	✗	✗
Pup 4	✗	?	✗	✗
Pup 5	✗	✗	✗	○
Pup 6	○	○	✗	○
North joint	○	○	○	○

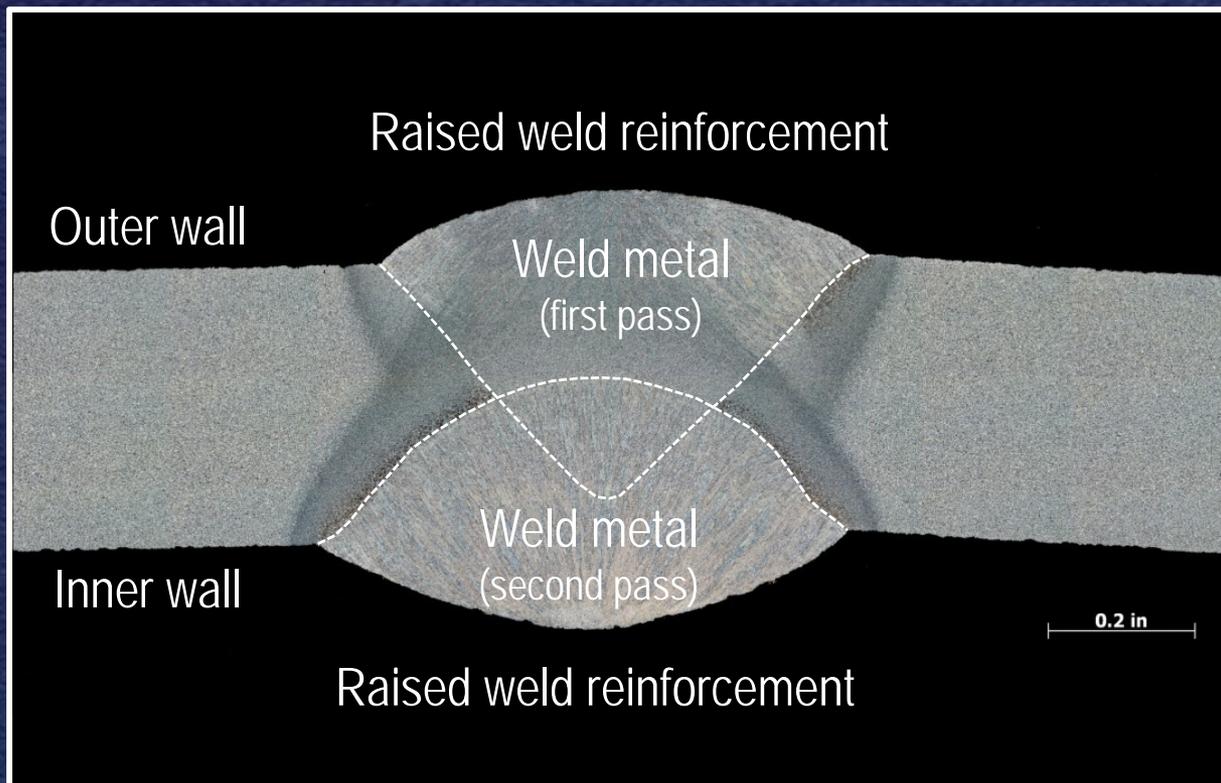
- None of the pups fully met PG&E's specification for pipe
- Pups 1–5 did not conform to any known specification
- Four pups originally fabricated as short pieces of pipe



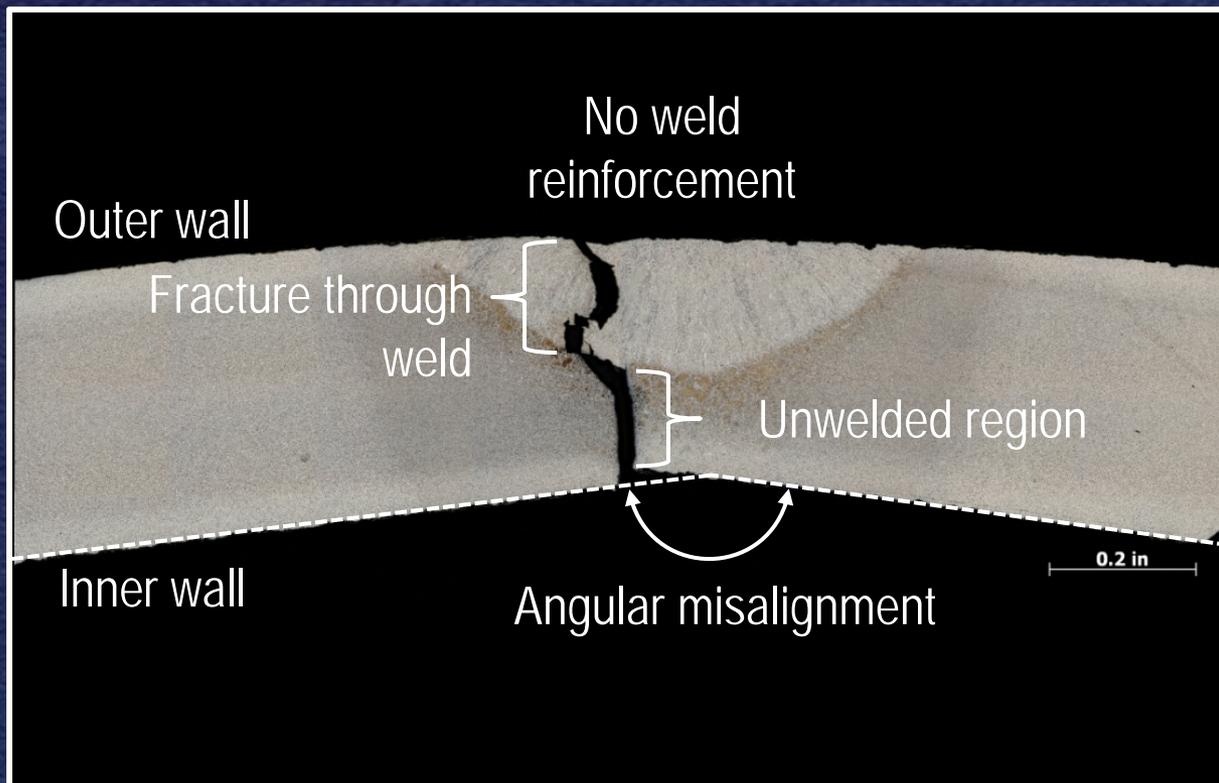
Weld Comparison



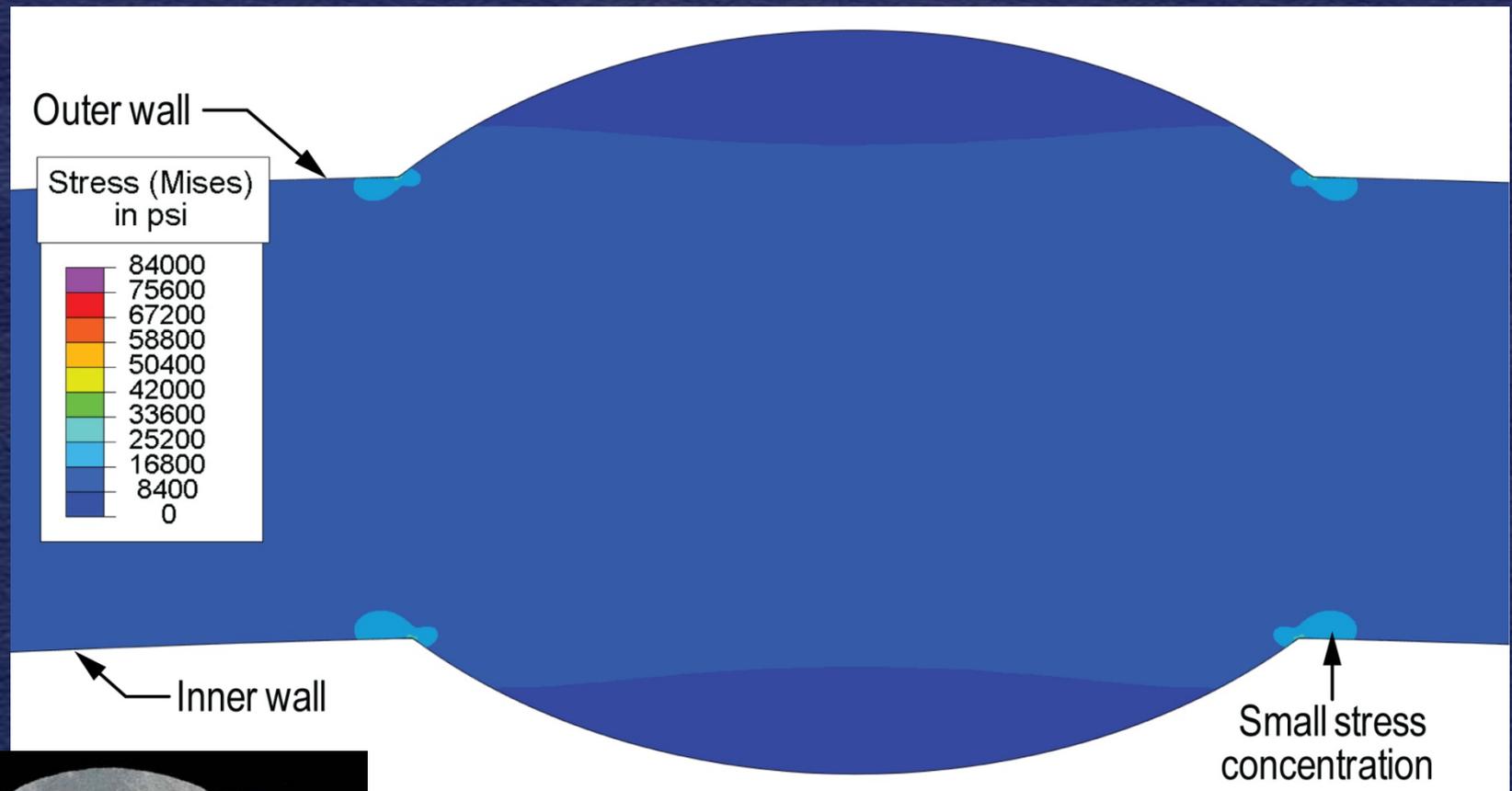
Typical DSAW Seam Weld



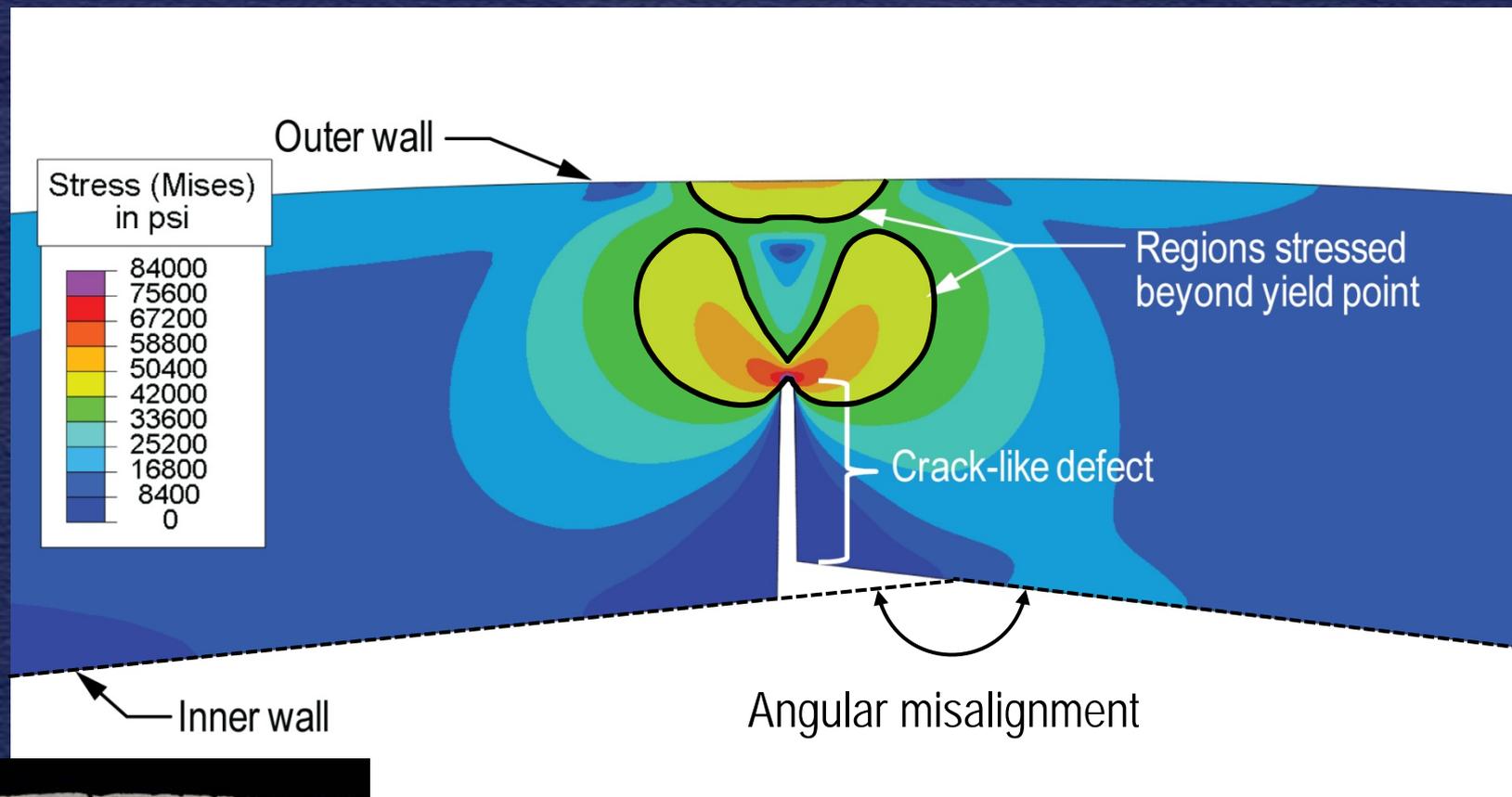
Incomplete Pup 1 Seam Weld



Stresses at DSAW Weld



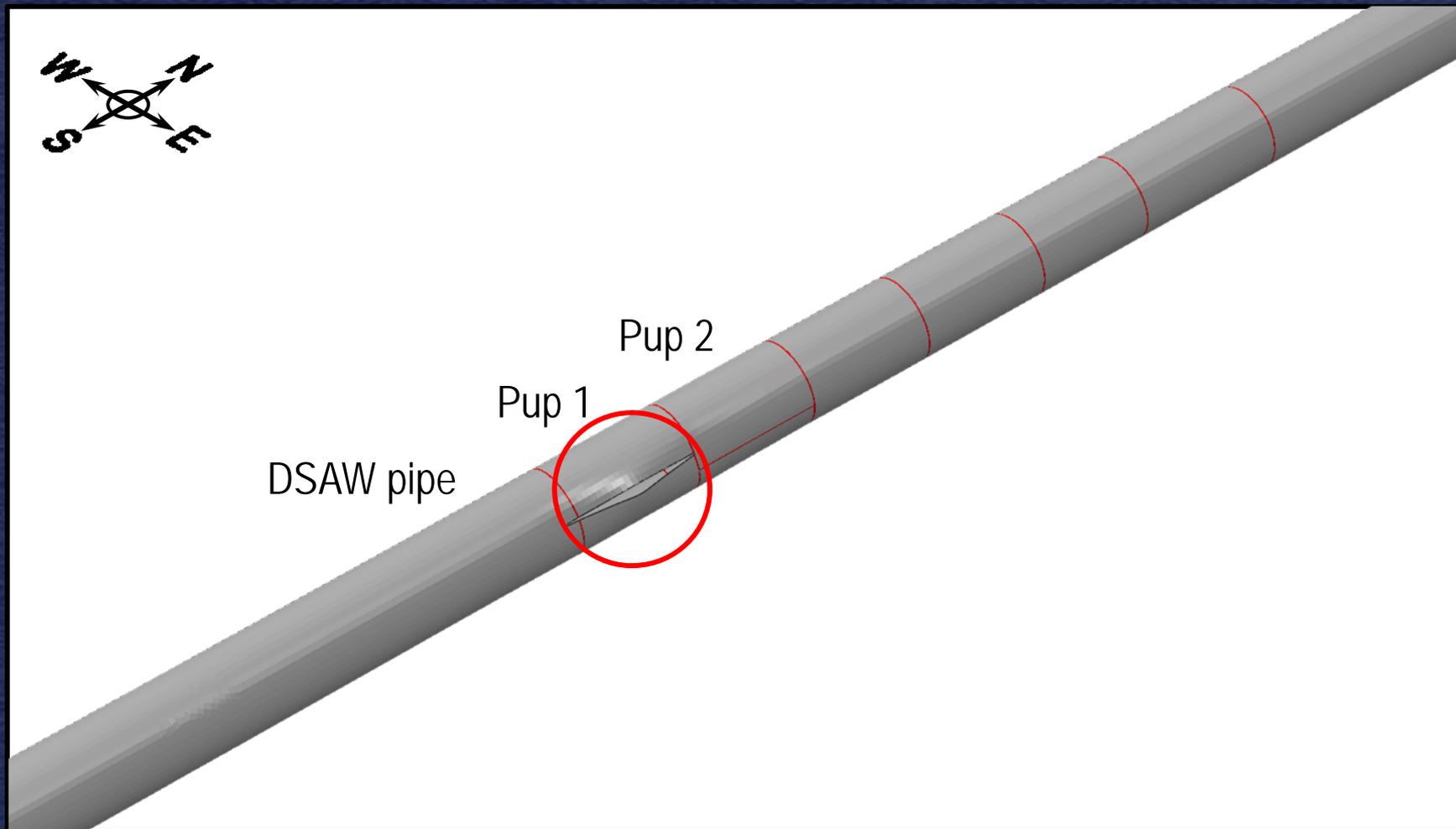
Stresses at Incomplete Weld



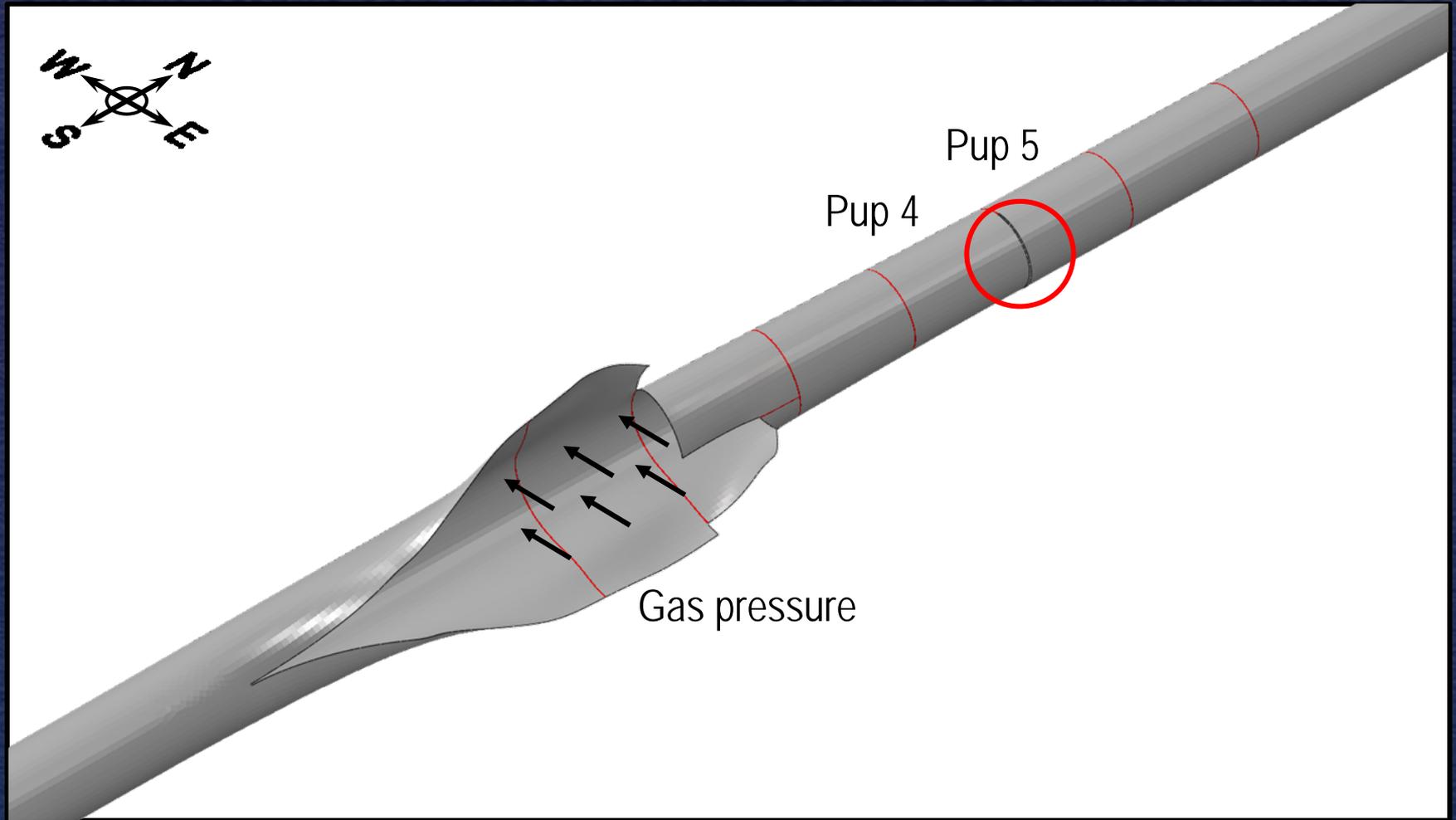
Effect of Weld Defect

- Consolidated Western subjected DSAW pipe to proof test
- Pups 1, 2, and 3 would not have withstood pipe mill proof test
- Pipeline may not have passed field hydrostatic pressure test in 1956

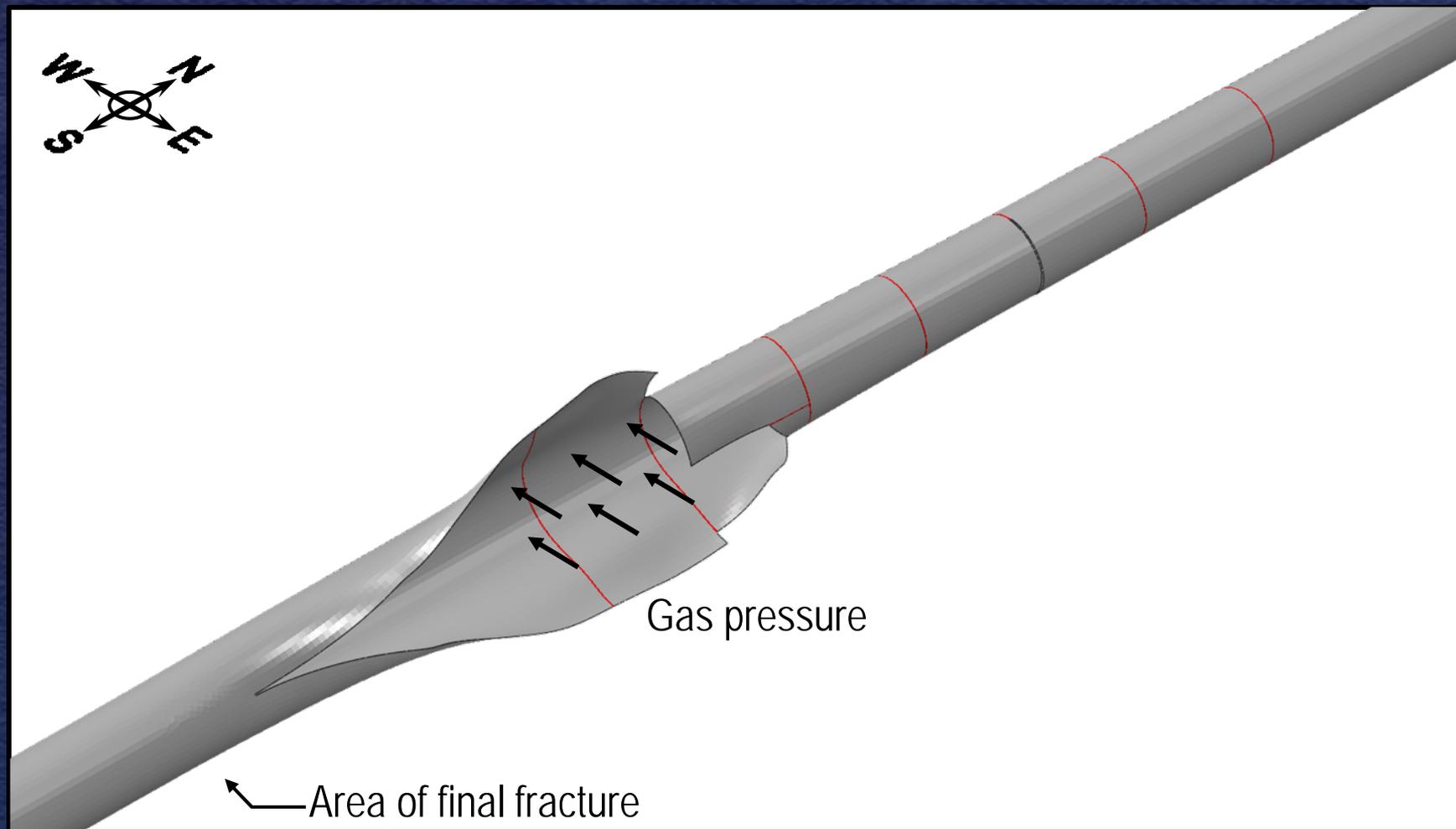
Rupture of the Pipe



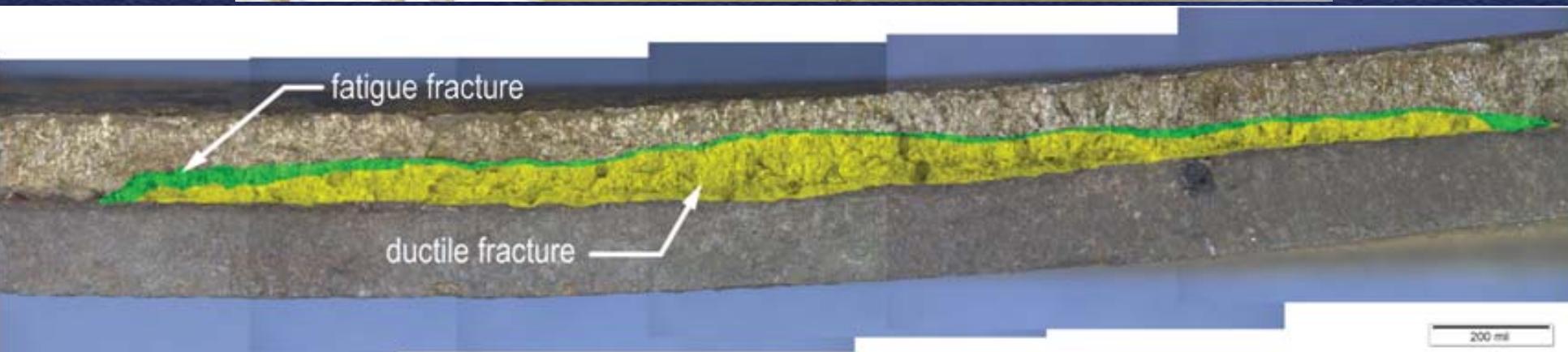
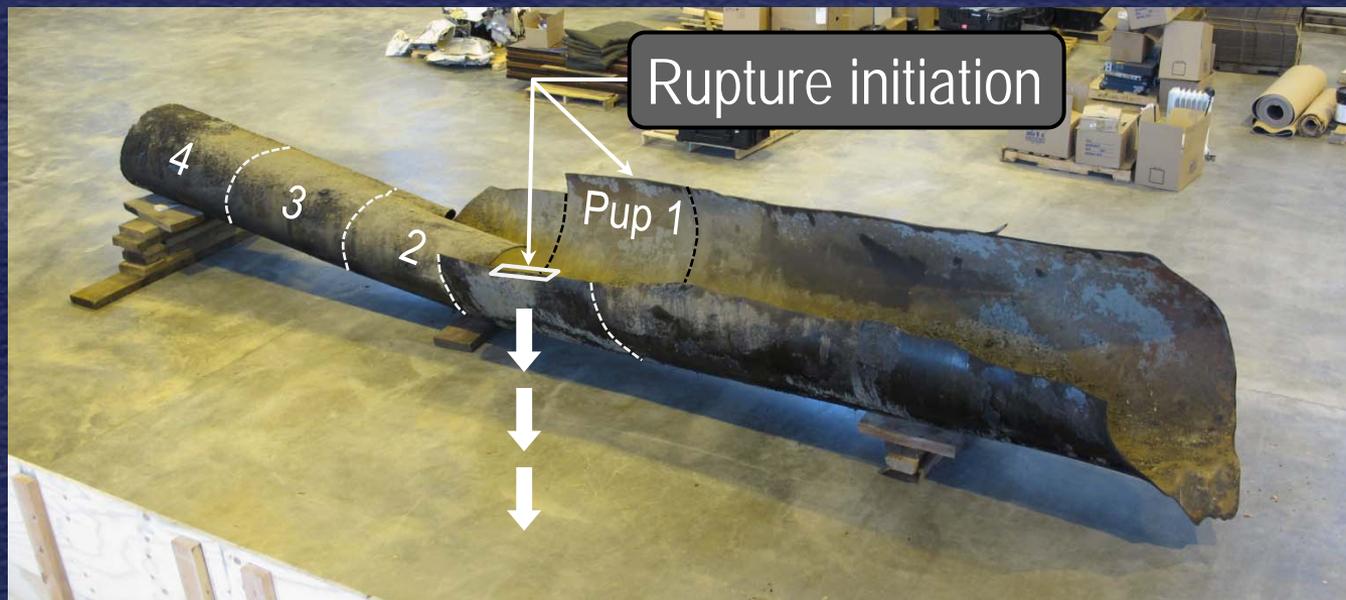
Rupture of the Pipe



Rupture of the Pipe



Rupture Initiation Site



Time of Crack Formation

- 386 psig maximum recorded pressure at rupture location
 - 2003 – 383 psig maximum
 - 2008 – 382 psig maximum
- 2008 Earl Avenue sewer replacement project excluded

Insufficient Quality Measures in 1956

- Seam weld defect on inside of pipe detectable by the unaided eye
- Inspection of inside of pipe not performed, misinterpreted, or ignored
- No radiography or hydrostatic pressure testing
- Undocumented pipe with different wall thickness

Summary of Findings

- As part of 1956 construction six pups installed at rupture location
- Five pups fabricated at an unknown facility to no known specification
- Rupture initiated at an improperly welded longitudinal seam in pup 1
- Defective weld detectable by the unaided eye



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PG&E Emergency Response

Matthew Nicholson, P.E.

Dispatch and SCADA Centers

- PG&E dispatch and SCADA centers physically and organizationally separate
- Dispatch center acts as interface for emergency and manages service calls
- SCADA center responds to alarms and manages transmission line operations

Gas Service Representative
Daly City 6:23 p.m.



Colma yard
6:50 p.m.
7:06 p.m.



6:15 p.m. SCADA center received low pressure alarm from Martin Station

6:18 p.m. Dispatch

7:42 p.m. Report from field that flames have diminished
communicate

Home
6:35 p.m.



Downstream valve
7:46 p.m.

Upstream valve
7:30 p.m.



Gas Service Representative on site
6:41 p.m.



1 Mile





Dispatch Center Functions

- Respond, assess and escalate gas emergencies
- Send field employee to incident location for assessment
- Contact SCADA center only if requested by on-scene field employee
- No direct notifications to emergency response agencies



SCADA Center Functions

- No written emergency response plan
- No clear process to dedicate SCADA operators to specific duties
- No defined regions or pipelines for SCADA operators
- Alarm response includes remote operation, contacting field operations, monitoring



Communication and Coordination

- Information not relayed through single point of contact or department
- Overlapping duties and differences in information relayed to operations
- Lack of a defined leadership and support responsibilities at SCADA center
- Gas emergency plan should incorporate SCADA center capabilities

Emergency Notifications

- PG&E did not notify emergency officials
- Procedures did not require notification in gas emergency
- Dispatch missed opportunity with police
- NTSB June 8, 2011, recommendations
 - Control rooms notify 911 with suspected pipeline rupture
 - Operators share system-specific information with emergency response agencies

Line Break Recognition

- SCADA center
 - Unable determine exact location using available SCADA information
 - Sufficient information in first 10 minutes
- Line 132 SCADA pressure or flow
 - Not at Healy Station (3/4 from rupture)
 - Not within 30-mile span after rupture
- Properly spaced instrumentation or advanced monitoring would have aided to identify location

Rapid Response

- Emergency response took 95 minutes
- SCADA center could have utilized RCVs
- Pressure drop sufficient for ASVs
- PG&E failed to evaluate risks properly
- ASVs and RCVs likely would have isolated ruptured section 1-hour earlier
- ASVs incorporating smart controllers and ability to operate like RCV

Summary

- Company gas emergency plan emphasizes assessment
- Gas emergency plan does not include comprehensive SCADA center procedure
- SCADA center had earliest knowledge but lacked organization and instrumentation
- No calls made to emergency responders
- SCADA center could have stopped gas an hour earlier with RCVs



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Pipeline Integrity Factors

Robert J. Hall, P.E.

MAOP

- Essential safety parameter
- Provides safety margin
- CPUC exempted pre-1961 pipelines from pressure testing
- DOT grandfathered untested pre-1970 pipelines
- Safety margins unknown



Line 132 MAOP

- 400 psig
- Would have failed a pressure test
- Had no safety margin



PG&E Integrity Management

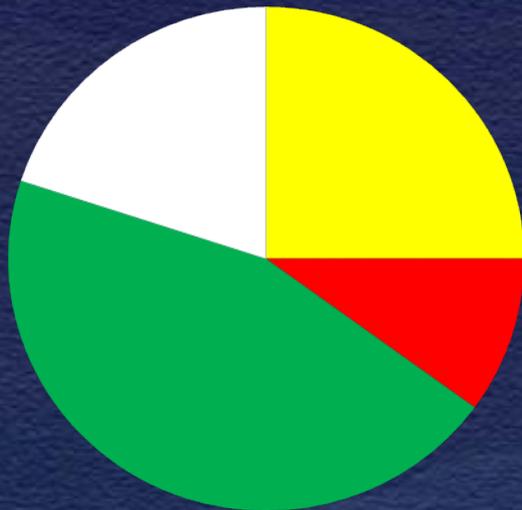
- Pipeline records
- Threat identification
- Threat assessment
- Program self-assessment

PG&E Pipeline Records

- Key pipeline parameters assumed
 - Wall thickness
 - Specified minimum yield strength
 - Depth of ground cover
- Obvious errors not corrected
- Assumptions not conservative

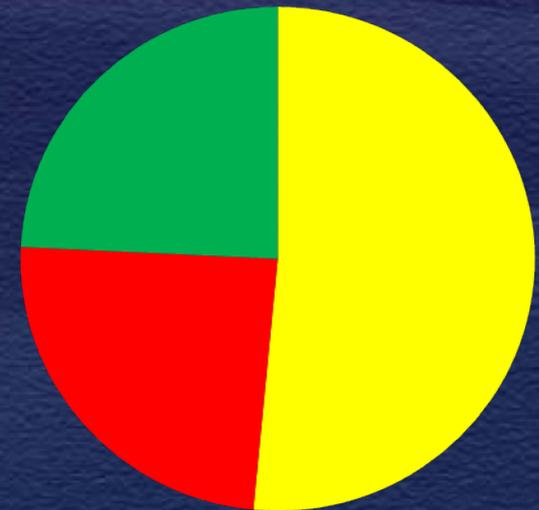
PG&E Threat Identification

Program



- External corrosion
- Design/manufacturing
- Third-party damage
- Ground movement

Actual



PG&E Threat Assessment

- Weld seam defects not considered
 - Manufacturing cracks
 - 1988 seam leak
- PG&E incorrectly considered seam defects stable
- Line 132 integrity assessment method could not find seam defects

In-Line Inspection Technology

- Could have detected the defective pipe in Line 132
- Used to detect many defects
 - Corrosion
 - Dents and gouges
 - Seam defects
- Tests entire segment
- Used to monitor defects



In-Line Inspection Technology

- Over 50 percent of gas transmission pipelines are not suitable for in-line inspection
- New tools under development
- Many older pipelines have not been in-line inspected



PG&E Self-Assessment

- PG&E collected and reported metrics to PHMSA and CPUC
- Program element effectiveness not measured
- Serious deficiencies not identified



PG&E Program Summary

- Incomplete and inaccurate records
- Understated construction threats
- Failed to consider known defects
- Employed an inappropriate assessment method
- Assumed seam defects stable
- Superficial self-assessments



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Oversight

Robert H. Trainor, P.E.



Performance-Based Programs

- Application of information to assess whether performance goals met
- Performance measurement—data measured, methods, and collection
- Evaluation—explain relationship between activities and outcomes

Performance-Based Pipeline Regulations

- Pipeline Safety Act of 2002
 - Conduct risk analyses of pipelines
 - Implement integrity management programs
- Performance goals basis of new regulations
- Regulations effective January 2004

Operator Self-Assessment

- Measure semiannually whether integrity management plans
 - Effective in assessing pipeline integrity
 - Protecting high consequence areas
- Implementation, execution, evaluation, and adjustment of plan



Challenges

- Evaluate the operator's technical justifications
- Easier with prescriptive regulations
- Struggling to make the transition
- Not applied performance-based approaches





Application to Pipeline Safety

- Operator
 - Develop integrity management plan
 - Execute the plan
 - Evaluate the effectiveness of the plan
- Regulator
 - Operator compliance
 - Self-assessment of oversight protocols



Meaningful Metrics

- Quantify results
- Measured against performance goals
- Provide comparisons enabling organizations to
 - Assess whether performance goals met
 - Identify cause of safety problems





Authority and Enforcement

- Issues stemming from the exercise of authority and enforcement
- CPUC—regulator for California
- PHMSA—monitor of state agencies



CPUC Lapses

- Failed to uncover pervasive longstanding problems
- Failure precluded taking enforcement actions
- Opportunities lost to
 - Identify needed corrective action
 - Follow through and ensure that corrective actions completed



PHMSA Actions

- Awarded superior ratings to CPUC's pipeline safety program
- Participation in 2005 training audit had no effect
 - Uncovering PG&E's systemic problems
 - Accurately assessing the quality of oversight exercised by CPUC

Authority

- PHMSA authority sufficient to
 - Enforce regulations
 - Address noncompliance
- CPUC authority less clear
 - Pipeline one of many regulated utilities
 - Potential conflict between rate setting and pipeline safety programs
 - No direct authority to issue violations or penalties



Enforcement

- Quality and effectiveness at Federal and state level in doubt
- Some operators able to ignore regulations without serious concern of meaningful enforcement actions





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