Natural Gas Pipeline Explodes
San Bruno, CA
September 9, 2010

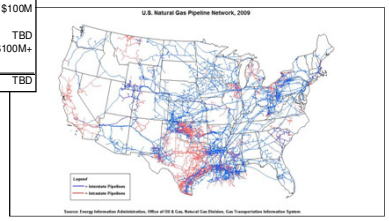
Step 1. Define the Problem

What	Problem(s)	Natural gas pipeline exploded, killing 8
When	Date	September 9, 2010
	Time	6:11 P.M.
Where	State, city	San Bruno, CA
	Task being performed	Normal operations - Gas being delivered via pipeline

Impact to the Goals

Safety	Eight fatalities	$100M
Environmental	Smoke, fire	TBD
Cust. Service	Disruption of natural gas service	$100M+
Property	Pipeline destroyed	This incident
Property	38 homes destroyed, 62 damaged	
Compliance	Pipes not in compliance with federal standards	
Production	Pending lawsuits	

Frequency: 57 pipe failures/year (2010) — Annualized Cost: TBD



Safety Goal Impacted ← Eight fatalities
Production Goal Impacted ← Pending lawsuits
Property Goal Impacted ← 38 homes destroyed, 62 damaged
Property Goal Impacted ← Pipeline destroyed
Environmental Goal Impacted ← Smoke, fire
Customer Service Goal Impacted ← Disruption of natural gas service

AND

Explosion ← Natural gas leak ← Steel pipe failed ← Natural gas pressure greater than steel strength

AND

Ignition source & oxygen present

Natural gas pressure greater than steel strength ← Maximum operating pressure for pipe was 375 psig
Evidence: NTSB Report

Possible Solutions: Verify actual pipe MAOPs match system MAOP

AND

Natural gas pressure greater than steel strength ← Slight surge in pressure to 386 psig
Evidence: NTSB Report

Slight surge in pressure to 386 psig ← Problem at Milpitas gas-line terminal

Problem at Milpitas gas-line terminal ← Regulating valve went full open ← Electric signal to valve lost ← Uninterruptable power supply (UPS) malfunctioned ← UPS was under maintenance
Evidence: PG&E Records

AND

Problem at Milpitas gas-line terminal ← Overprotection valve activated, maintaining pipe at 386 psig
Evidence: NTSB Report

Possible Solutions: Reduce system MAOP

Overprotection valve activated, maintaining pipe at 386 psig ← PG&E maximum allowable operating pressure was 400 psig
Evidence: NTSB Report

PG&E maximum allowable operating pressure was 400 psig ← Seamless pipes can withstand higher pressures ← Seams more susceptible to corrosion ← Steel inelastic and easily corroded
Evidence: Pipeline and Hazardous Materials Safety Administration

Possible Solutions: Replace with more durable material

AND

Seamless pipes can withstand higher pressures ← PG&E thought a seamless pipe was installed

Possible Solutions: Through records review

PG&E thought a seamless pipe was installed ← PG&E records incorrect and/or missing
Evidence: NTSB Statements

Possible Solutions: Use fewer pipe sections

Natural gas pressure greater than steel strength ← Pipes made from smaller pieces of metal
Evidence: NTSB Report

Pipes made from smaller pieces of metal ← Multiple short sections used to make bend ← Common manufacturing process in 1950s

AND

Multiple short sections used to make bend ← Pipes installed in 1956
Evidence: NTSB Report

AND

Natural gas pressure greater than steel strength ← Metal not fully joined together

Possible Solutions: Revise oversight & inspection process during welding process

Metal not fully joined together ← Welds inadequate ← Welds only 50-60% filled
Evidence: NTSB Report

AND

Welds inadequate ← Molten metal in welds flawed ← Grit and impurities present in metal
Evidence: NTSB Report

AND

Molten metal in welds flawed ← Weld metal too porous
Evidence: NTSB Report

AND

Molten metal in welds flawed ← Some welds only on outside of pipe
Evidence: NTSB Report

AND

Natural gas pressure greater than steel strength ← Metal failure due to fatigue
Evidence: NTSB Statements

Possible Solutions: Replace pipes

Metal failure due to fatigue ← Pipe near or beyond expected life span ← Pipes were 54 years old

AND

Pipe near or beyond expected life span ← Pipes have expected lifespan of 50 years
Evidence: MSNBC Article

AND/OR

Metal failure due to fatigue ← Pipe walls too thin ← Pipes not properly inspected ← Inspection robots can't go in old or bendy pipes
Evidence: PG&E Statements

AND

Pipes not properly inspected ← Pipes in San Bruno area "too twisty"
Evidence: PG&E Statements

Compliance Goal Impacted ← Pipes not in compliance with federal standards

Cause Map
Detail Level

ThinkReliability
Investigate Problems. Prevent Problems.
Houston, Texas 281-412-7766 ThinkReliability.com

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Why?

Effect ← Cause

NOTE: Read the Cause Map from left to right with the phrase "Was Caused By" in place of each arrow.