Gas Operations

Root Cause Evaluation Report

SIF Potential - Deer Park Incident

Deer Park, CA

SAPN # 7034203

SIF Potential -Deer Park Incident

Deer Park, CA

Executive Summary

On August 10, 2016 at approximately 13:10 hours, a two person gas crew was replacing a frozen ¾ inch Nordstrom service valve at [redacted] in Deer Park, when a gas release and ignition event occurred. This resulted in injuries to the crew members, significant property damage to the home, DOT, OSHA and CPUC reportable event reports.

The two person Maintenance and Construction (M&C) crew was called out to replace an inoperable Nordstrom service valve. The experienced crew used a hammer method to repair the valve. This is a method that was routinely used by their department. However in 2014, during the update to the service valve maintenance procedure (TD-6100P-11) this method was recognized as creating a potential safety concern and the method was removed from the procedure. This updated procedure was targeted for use by field services and provided as information only for M&C. This update only involved Subject Matter Experts from Field Services and the changes were only communicated to Gas Service Representatives. Therefore the M&C crew was not aware of this identified safety concern.

Root Cause 1:

TD-6100P-11 was developed from utility procedure TD-6436P-27 "Gas Service Valve Inspection and Maintenance" without representation from the appropriate stakeholders and subject matter experts from all affected lines of business. The method for using a brass hammer to free a frozen valve in procedure TD-6436P-27 was eliminated as a process.

Cause Evaluation Team

Sandy Ralph, Quality Operations Specialist – CAP (Lead Investigation);

Katie Simone, Process Safety Engineer– PSM (Co-Investigator);

Raymond Thierry, Director - DIMP (RCE Sponsor);

Joe Ojeda, Gas T&D M&C - Superintendent (SME);

Alan Nadell, Gas Quality Management (SME);

Mike Sakaguchi, Work Methods and Procedures Specialist (SME);

Derek Cedars, Gas Safety (SME);

Joe Joaquim, M&C – Gas Mechanic (SME);

Contributing Cause 1:

M&C personnel have relied on experience for repairing inoperable service valves; no procedural guidance existed on the methods to replace an inoperable service valve with a broken tang.

Contributing Cause 2:

During the Job Site Safety Assessment review, the potential hazards of a gas release with a near-by ignition sources was not identified by the M&C crew.

CA1: Evaluate the Guidance Document Analysis (GDA) process for adequacy in identifying all affected stakeholders. If it is found to be inadequate, revise the GDA process to include a way to include all lines of businesses affected by procedures.

CA2: Revise TD-6100P-11, Meter Valve Maintenance, to add M&C and GC as part of the target audience.

CA3: Confirm that tailboard for the update from CA2 has been completed for all M&C employees.

CA4: Confirm that tailboard for the update from CA2 has been completed for all GC employees.

CA5: Revise TD-4150P-01, Valve Changer ¾" through 1 ¼" Service Valve Replacement to provide guidance on how to replace a service valve if it is not operational. This includes the determination of the safest way to deal with inoperable or damaged (e.g. broken tang), options should address how to control gas flow.

CA6: Update OQ 06-10 and OQ 06-23 to include a knowledge check for inoperable (a valve that is frozen or has a broken tang) valves and the updates to TD-4150P-01 above from CA5.

CA7: Develop a cross-functional team to identify other tasks that could involve or does involve the release of gas that are completed by field personnel without a documented process or procedure. Any gaps identified will be put into CAP to assess the risks and develop procedures or process as needed.

CA8: Update the Quality Management extent of condition questions to include the identification of tasks (see CA7) being performed without a documented process or procedure. As part of this, create a process within Quality Management to ensure that these findings are inputted into CAP.

CA9: Update the JSSA to include fields to identify the potential for release of gas, potential ignition sources, gas migration into structures, and how to mitigate these hazards.

This report prepared by Sandy Ralph and Katie Simone

Problem Statement

On August 10, 2016 at approximately 13:10 hours, a two person gas crew was replacing a frozen ¾ inch Nordstrom service valve at [redacted], in Deer Park, when a gas release and ignition event occurred. The result was injuries to the crew members, significant property damage to the home, DOT, OSHA and CPUC event reports.

Investigation and Analysis

A typical residential customer meter set, depicted in Figure 1, includes a Gas Shut-Off Valve upstream of the gas regulator and gas meter. One of the valves types in common use is a ¾" Nordstrom plug valve, seen in Figure 2.

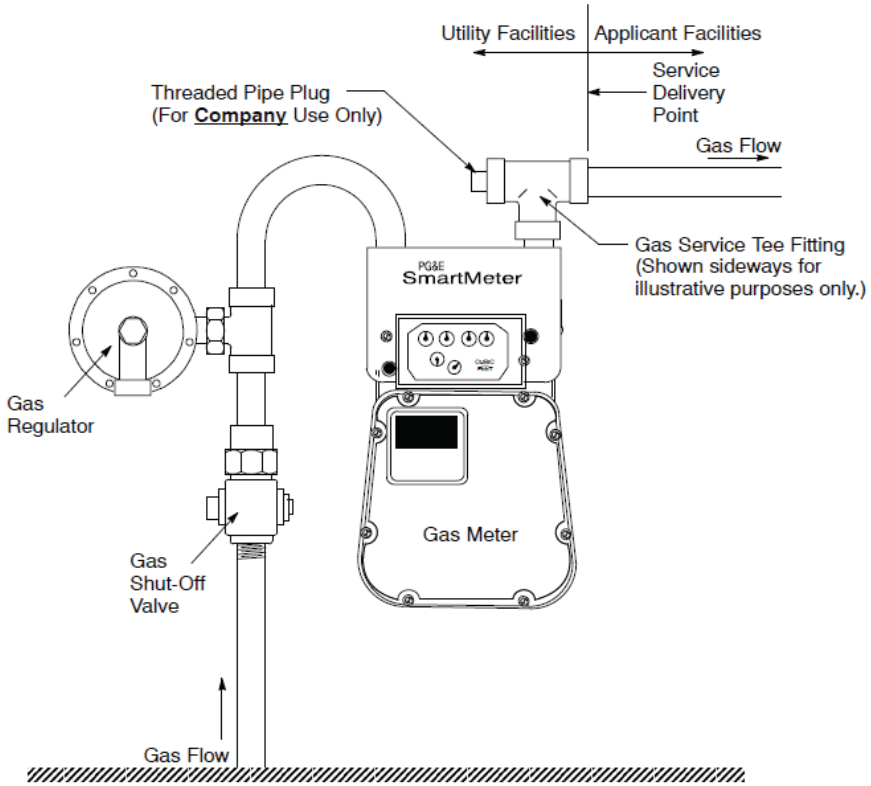


Figure 1: Typical Residential Meter Set

Figure 2: Typical ¾" Nordstrom Service Valve

The ¾" Nordstrom service valve is a plug valve that includes 4 components, the packing nut, spring, core and valve body, seen in Figure 3. The tang is a piece of the core that sticks out of the valve body and is the component that is used to turned the valve 90° to open or close the valve. A Nordstrom valve can become frozen or hard to turn. This can lead to damage to the tang when the valve is operated, potentially leaving a valve that cannot be shut off.

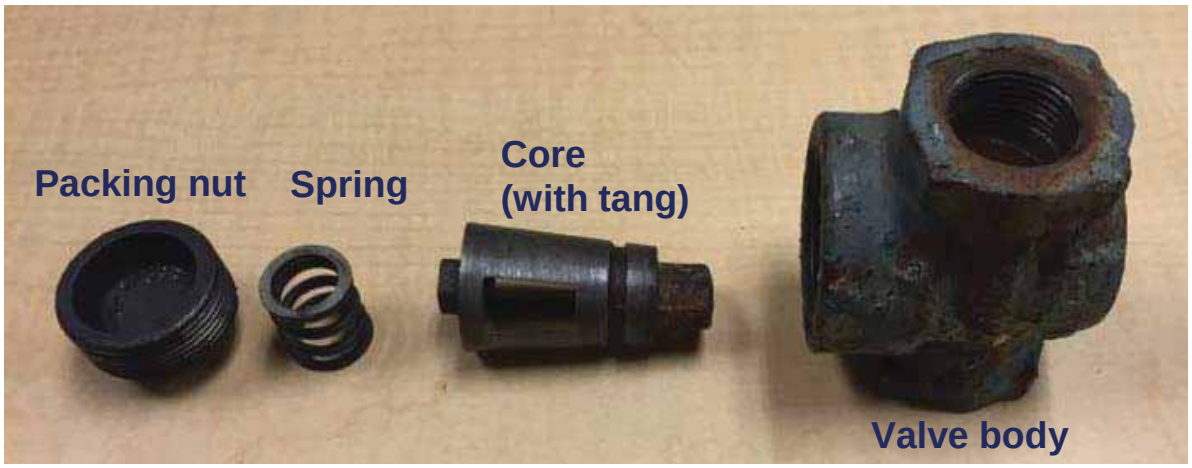


Figure 3: Typical ¾" Nordstrom Service Valve Components

The current procedure to perform maintenance on service (meter) valves is TD-6100P-11 "Meter Valve Maintenance (60 psig or less) Rev.0. TD-6100P-11 was revised in 2014 as a "Scrum Works are Tactile" also known as SWAT team's effort to update all procedures for Gas Service Representatives (GSRs). Gas Maintenance and Construction (M&C) crews and the supervisors are defined as "information only" in the Target Audience for this procedure. When a target audience is defined as "information only" they are not required to be briefed (tailboarded) on the updates. The following timeline outlines the changes that occurred with each revision to the procedures for gas service (meter) valves.

Gas Service (Meter) Valve Maintenance Procedure Timeline

November 10, 2010 - TD-6436P-27, “Gas Service Valve Inspection and Maintenance” Rev.0 published

- This procedure describes how to inspect and maintain gas service valves in the following occurrences:
  - Turning a service valve core.
  - Conducting a clock test to determine leakage downstream of the gas meter.
  - Suspecting gas leakage in the gas meter assembly.
- Target Audience: Field service personnel who service and maintain gas service valves.

March 9, 2011 – TD-6436P-27, “Gas Service Valve Inspection and Maintenance” Rev.1 published

- Target Audience: Field service personnel who service and maintain gas service valves.
- Introduces the documented steps to loosen the packing nut and use a brass hammer to tap on the valve core to loosen the core.

November 9, 2011 – TD-6436P-27 Rev. 2 published

- Revised to add valve stem retainer (VSR) tool to secure Nordstrom valve core when lubrication is required.
- Added note to observe the amount of pipe threads exposed on the packing nut before loosening the packing nut.

March 29, 2013 – TD-6436P-27 Rev. 3 published

- Added additional details and steps for when a packing nut has two threads or fewer exposed and if the packing nut has three exposed threads or more.

January 1, 2014 – TD-4430P-04 “Gas Valve Maintenance” Rev.1 published

- Note states for inspection and maintenance of gas service valves, see Gas Utility Procedure TD-6436P-27, “Gas Service Valve Inspection and Maintenance.”

July 30, 2014 – TD-6100P-11 Rev. 0 published and TD-6436P-27 Rev. 3 rescinded

- The document was revised to align to new organizational structure (Field Services moved from Customer Care to the M&C organization)
- The document was written for GSR’s and their supervisors to comply to and was information only for M&C crews.
- Replacing a Nordstrom valve that is hard to turn or leaking is now the preferred method.
- Removed guidance from the previous procedure TD-6436P-27 to use a brass hammer to hit the valve stems (tang) to loosen core. Added requirement to repair frozen core by lubrication or replace valve.
- Formal stakeholder review was not completed for this update.

Valve Procedure Observations

TD-4430P-04 "Gas Valve Maintenance" Rev.1 provides guidance to maintain all plug, ball, and gate valves to all maintenance and operations personnel who maintain plug, ball and gate valves. The Guidance Document Analysis (GDA) for this procedure states that all maintenance and construction (M&C) personnel are to comply with this procedure. Based on the information above, M&C personnel are instructed to follow TD-6436P-27 to maintain service valves; this procedure become obsolete in July of 2014 and replaced by TD-6100P-11. The method of loosening the packing nut and hitting the valve core with a brass hammer to loosen the valve core was removed in TD-6100P-11; however since M&C crews and their supervisor were only listed as "informational only" this change was not formally communicated to them.

The current TD-6100P-11 procedure states that for Nordstrom valves in the following conditions either with a broken/damaged valve stem (tang) or a broken/frozen/leaking core that cannot be repaired, the valves should be replaced. The procedure also states that if the GSR cannot replace the valve then they are to contact dispatch to arrange for an M&C crew to replace the valve per TD-4150P-01, "Valve Changer ¾" Through 1 ¼" Service Valve Replacement". TD-4150P-01 Rev. 1 published 1/29/2014 states in the Before You Start section of the procedure:

> "Verify service valve operation by turning valve tang back and forth 10° to 20 °. Service valve must be operational to perform this procedure."

TD-6100P-11 provides no instructions for inoperable or broken valves except to replace the valve and TD-4150P-01 only applies to valves that are operable. The procedures do not identify the process to assess and replace an inoperable or broken valve. The crew assigned to the job must determine how to replace the inoperable or broken valve using their experience and knowledge.

Event Description

On August 8, 2016 a Gas Service Representative (GSR) was given the job to respond to a customer call out for a broken valve at [redacted], Deer Park, California. The GSR arrived on-site and noticed that the Nordstrom valve had a tang that was mostly broken off. He attempted to turn the valve using channel locks on the partial tang, however the valve was frozen. In accordance with TD-6100P-11, the GSR called dispatch to request M&C personnel to come out to replace the broken valve.

The customer meter set at [redacted] is located in a semi-enclosed area, depicted in Figure 4.

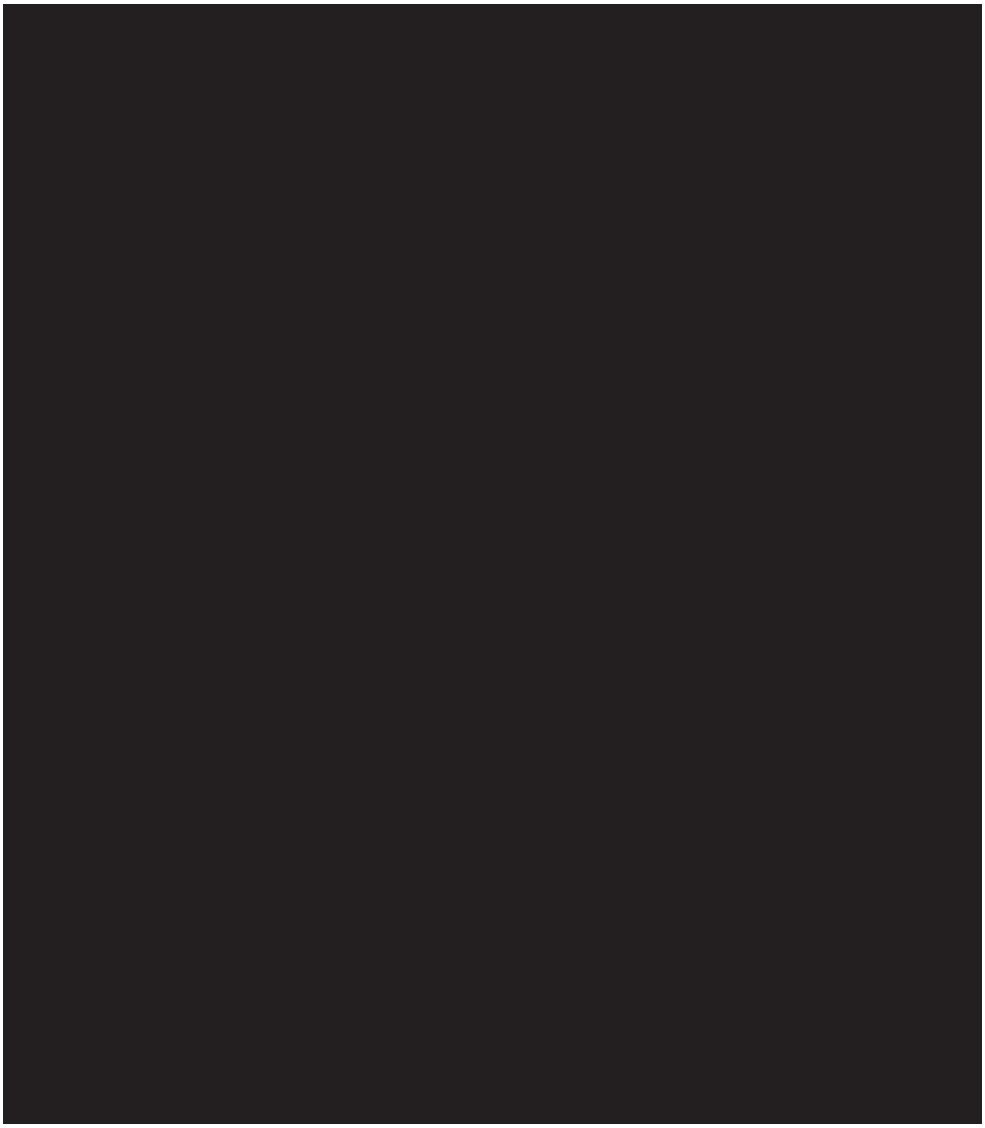


Figure 4: Diagram of customer meter set location

On August 10, 2016 the Napa M&C Supervisor received a call from dispatch with a request for M&C follow-up to the frozen valve with a broken tang. A two-man M&C crew, one Gas Mechanic and one Fitter Arc, were sent to the customer's house. The Gas Mechanic and Fitter Arc both had Operator Qualifications (OQ) for Operator Riser Valve Changer Equipment and Service Riser Thread Replacement (3/4" to 2") OQ 06-10 required to perform the steps in TD-4150P-01. A review of the exam for OQ 06-10 and valve changer training determined that Abnormal Operating Conditions (AOC) are not thoroughly addressed, specifically the AOC of either inoperable (frozen) or broken (partial tang) valve.

Upon arrival the two-man crew conducted a jobsite walk down and then completed a Job Site Safety Analysis (JSSA) which identified gas, tripping, and traffic as potential hazards for the job of changing a valve. They noted following procedures, watching your step, and awareness of cars as ways to mitigate the identified hazards. This was a routine job for the crew and they did not expect an uncontrolled release of gas, therefore did not identify any potential ignition sources as a hazard. As the Arc Fitter was bringing required tools from the truck, the Gas Mechanic assessed the valve. Finding the valve

frozen, the Gas Mechanic stated that he loosened the packing nut and then tapped the core with a hammer. In a second the packing nut backed off the valve and the core shot out of the valve body. Approximately 56 psig gas was released uncontrollably out of the valve body, which directly aligned with a water heater located 6' 4" away. Gas flow direction, depicted in Figure 5, would have been directed towards the water heater and the stucco wall.

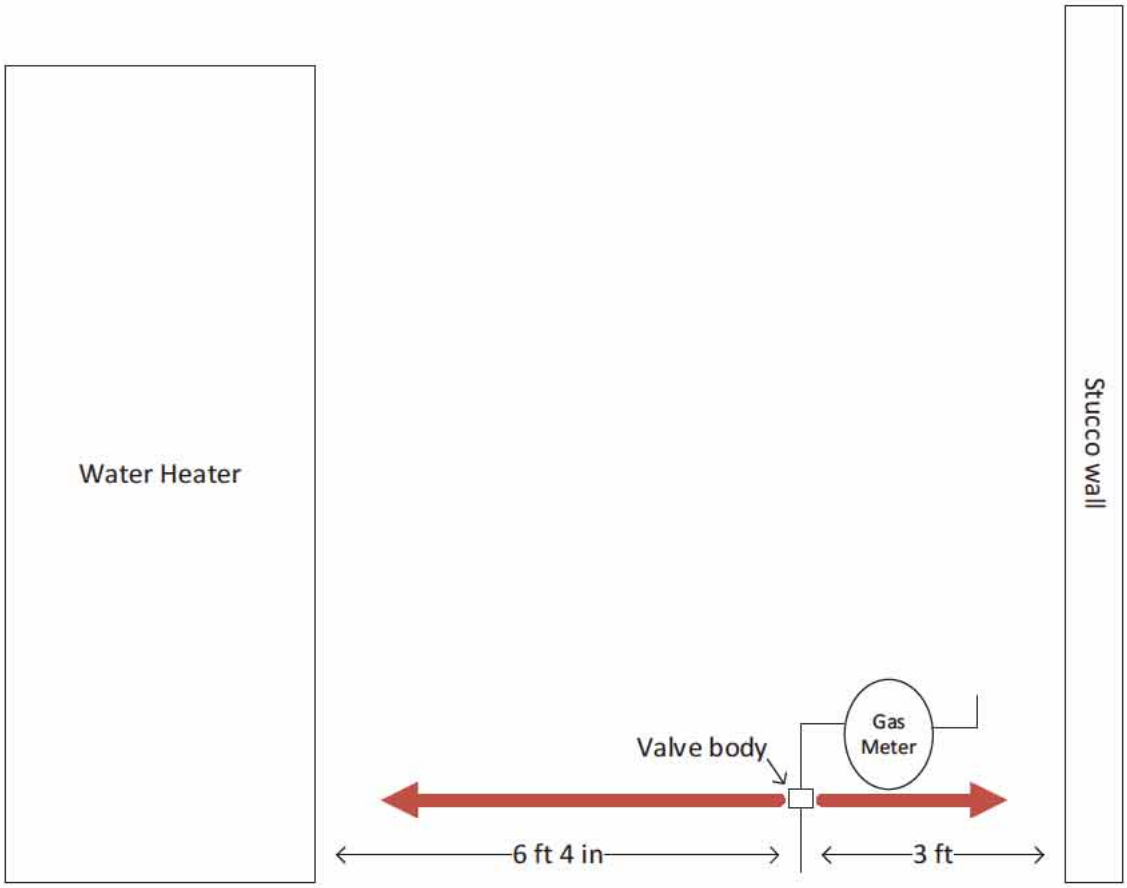


Figure 5: Assumed gas flow path of release

Almost instantly, the gas ignited, resulting in a fire. It cannot be confirmed what the source of ignition was, however there were multiple potential sources present in the semi-enclosed space, the water heater with a standing pilot, air conditioner, and customer's electrical panels. The Gas Mechanic used the fire extinguisher located on the jobsite, while the Fitter Arc called 9-1-1 as he ran back to the trucks for additional fire extinguishers. Unable to extinguish the fire and concerned for their safety, the crew relocated to a safe location. The Fitter Arc received minor 1st degree burns and the Gas Mechanic received 1st and 2nd degree burns on his arms. The fire department arrived on-site and controlled the fire from spreading. A secondary gas crew arrived to excavate and squeeze the service and stop the flow of gas, the fire department extinguished the fire, and the gas crew disconnected the gas service at the main. Photo of the meter set location after the fire is found in Figure 6. The service line feeding this customer was not equipped with an excess flow valve (EFV) because it was installed at a time when EFVs were not required (the gas service was installed 1949 and the service had not been reconstructed since then). Had an EFV been installed, it likely would have activated and stopped the release of gas.

Figure 6: Damage to customer house

As part of the investigation, Distribution Integrity Management Program (DIMP) performed an inspection of the valve to determine if there were any mechanical abnormalities with the Nordstrom Service Valve. The inspection concluded that the threads of the service valve were in good mechanical and operating condition, the valve tang was absent and what was left was corroded, and corrosion was observed on the valve components range from surface rust to moderate or severe corrosion. The full

report is included of Appendix E of this report. There is no indication that any mechanical abnormalities, excluding the broken tang, resulted in this service valve breaking and releasing gas.

Root Cause/Causal Factors

Root Cause 1:

TD-6100P-11 was developed from utility procedure TD-6436P-27 "Gas Service Valve Inspection and Maintenance" without representation from the appropriate stakeholders and subject matter experts from all affected lines of business. The method for using a brass hammer to free a frozen valve in procedure TD-6436P-27 was eliminated as a process.

- TD-4430P-04, Valve Maintenance, a procedure used by M&C, directs M&C personnel to use the GSR procedure TD-6436P-27, to maintain gas service valves.
- TD-6100P-11 replaced TD-6436P-27.
- The guidance that was written in TD-6436P-27 (obsoleted 7/30/2014) to use a brass hammer to loosen a frozen core was removed during the update to new procedure TD-6100P-11 due to recognized safety concerns of hitting old equipment with a hammer. The process included the use of a Valve Stem Restraint device. However, the restraint device requires an intact tang to function.
- No formal stakeholder review was completed for update to TD-6100P-11.
- M&C was included as "information only" in the target audience for TD-6100P-11.
- Information only target audience is not required to tailboard.

Contributing Cause 1:

M&C personnel have relied on experience for repairing inoperable service valves; no procedural guidance existed on the methods to replace an inoperable service valve with a broken tang.

- TD-4150P-01 only provides guidance to change operable valves. Before you start section states: "Verify service valve operation by turning valve tang back and forth 10° to 20°. Service valve must be operational to perform this procedure."
- TD-4150P-01 does not address what to do if you cannot meet the "Before you start" conditions.
- TD-6100P-11 written for GSRs requires that Nordstrom valves that are hard to turn, leaking, or broken are replaced and refers to TD-4150P-01 for steps to replace operable service valves.
- TD-4150P-01 does not reference TD-6100P-11.
- Valve changer training does not address replacing inoperable valves.
- Valve changer OQs (OQ 06-10 & OQ 06-23) do not address changing valves that are damaged, e.g. broken tang.

Contributing Cause 2:

During the Job Site Safety Assessment review, the potential hazards of a gas release with a near-by ignition sources was not identified by the M&C crew.

- Multiple potential sources of ignition were present on job site (water heater, customer electrical panel, air conditioner). Water heater had adequate spacing per Gas Design Standard J-15.1.

- This task has been performed successfully many times without incident, therefore the M&C crew was not expecting to have an uncontrolled release gas.

Immediate Corrective Actions

1. 5 MM stand-down was sent to all gas M&C and GSR personnel to cease replacing service valves with a broken tang or that are severely frozen. – Completed 8/12/2016

Recommended Corrective Actions

RC1:

CA1: Evaluate the Guidance Document Analysis (GDA) process for adequacy in identifying all affected stakeholders and revise, if necessary, the GDA process to include a way to include all lines of businesses affected by procedures.

Owner: Austin Hastings

Due Date: 11/11/2016

CA2: Revise TD-6100P-11, Meter Valve Maintenance, to add M&C and GC as part of the target audience.

Owner: Austin Hastings

Due Date: 12/2/2016

CA3: Confirm that tailboard for the update from CA2 has been completed for all M&C employees.

Owner: Dennis MacAleese

Due Date: 12/16/2016

CA4: Confirm that tailboard for the update from CA2 has been completed for all GC employees.

Owner: Peter Kenny

Due Date: 12/16/2016

CAP TASKS 1: Share lessons learned from this investigation as they relate to procedure updates with the Standards and Qualification department.

Owner: Austin Hastings

Due Date: 12/2/2016

CAP TASK 2: Conduct an all-hands call on lessons learned from Deer Park RCE for all gas ops field personnel (Gas T&D Operations and T&D Construction).

Owner: John Higgins

Due date 12/01/16

CAP TASK 3: Communicate the lessons learned from this RCE to all gas ops employees.

Owner: John Higgins

Due date 12/01/16

CC1:

CA5: Revise TD-4150P-01, Valve Changer ¾" through 1 ¼" Service Valve Replacement to provide guidance on how to replace a service valve if it is not operational. This includes the determination of the safest way to deal with inoperable or damaged (e.g. broken tang), options should address how to control gas flow.

Owner: Austin Hastings

Due Date: 3/10/2016

CA6: Update OQ 06-10 and OQ 06-23 to include a knowledge check for inoperable (a valve that is frozen or has a broken tang) valves and the updates to TD-4150P-01 above from CA5.

Owner: Mike Bradley

Due Date: 5/4/2017

Interim corrective action: Until CA5 & CA6 can be completed, revise the 5MM stand down to allow meter valve changes to occur given gas control is established upstream of the valve. – Complete 8/25/2016

Owner: Dennis MacAleese

CA7: Develop a cross-functional team to identify other tasks that could involve or does involve the release of gas that are completed by field personnel without a documented process or procedure. Any gaps identified will be put into CAP to assess the risks and develop procedures or process as needed.

Owner: Raymond Thierry

Due Date: 3/10/2017

CA8: Update the Quality Management extent of condition questions to include the identification of tasks (see CA7) being performed without a documented process or procedure. As part of this, create a process within Quality Management to ensure that these findings are inputted into CAP.

Owner: Jennifer Burrows

Due Date: 2/3/2017

CC2:

CA9: Update the JSSA to include fields to identify the potential for release of gas, potential ignition sources, and how to mitigate these hazards.

Owner: Derek Cedars

Due Date: 11/15/2016

Extent of Condition

Meter valves that are frozen or have broken or damaged tangs could fail and release gas if they are attempted to be replaced without upstream control of the gas. Changing a hard to turn valve by loosening the nut and impacting the top-face of the valve stem with a bronze/brass hammer was an obsolete practice; the elimination of that practice was not communicated to all affected personnel throughout the PG&E system.

Immediate corrective action 1 and interim action address this extent of condition.

Extent of Cause

- Other procedures related to tasks that could involve or does involve the release of gas may have been developed without representation from the appropriate stakeholders and subject matter experts (SMEs)

Analysis Tools and Methods

Hazard Barrier Target Analysis

Effect and Causal Factor Timeline

Fault Tree

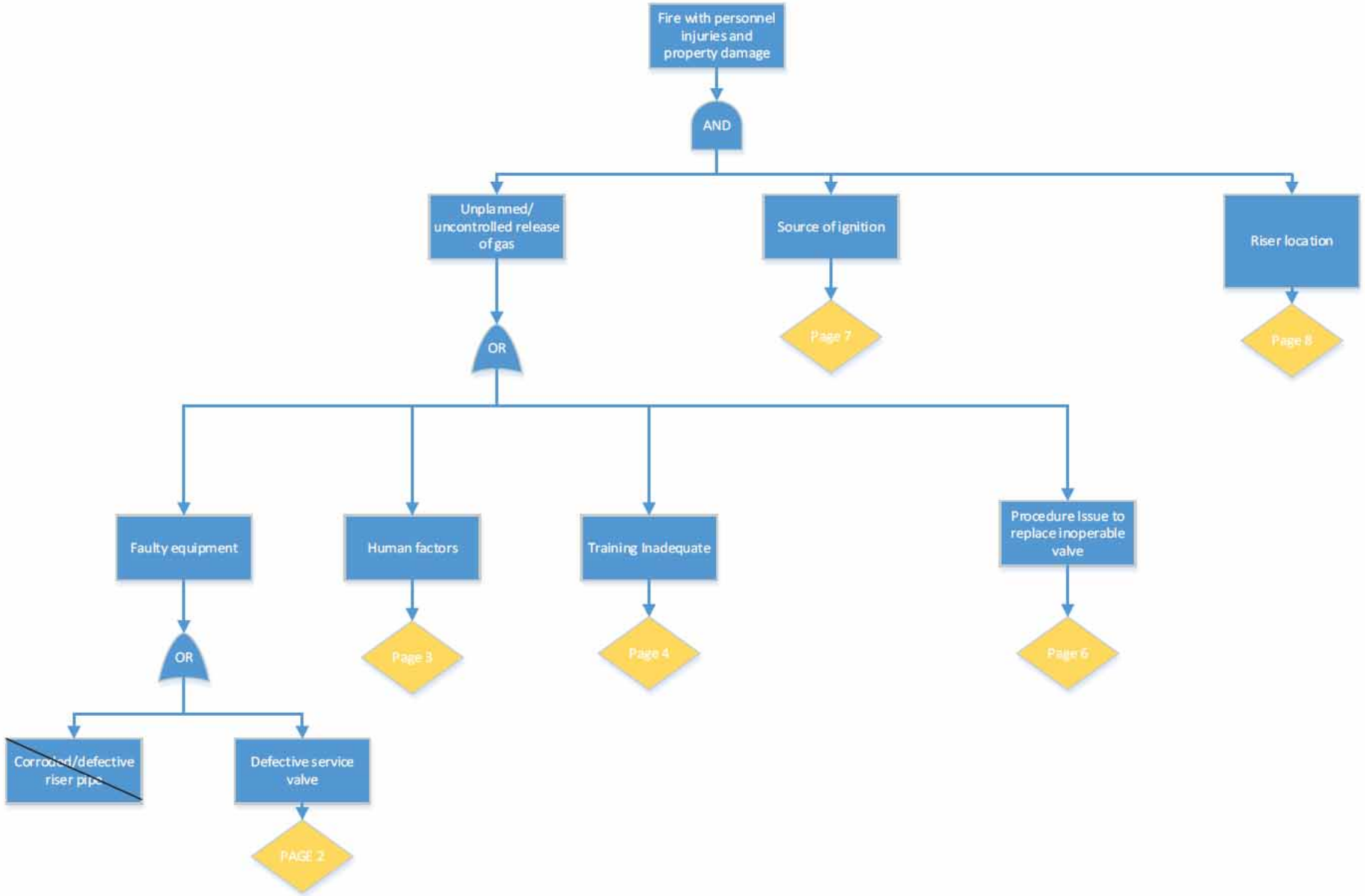
Appendices

Appendix A – Interviews and Qualifications
Appendix B – Fault Tree Analysis
Appendix C – Hazard Barrier Target Analysis
Appendix D – Effect and Causal Factor Timeline
Appendix E – DIMP Nordstrom Service Valve (Plug Type) Inspection Report

Appendix A – Interviews and Qualifications

Organization	Title	Role	Interviewed
Gas T&D M&C	Gas Mechanic	Crew onsite at time of event	8/11/16
Gas T&D M&C	Fitter Arc	Crew onsite at time of event	8/11/16
Gas Field Services	Gas Service Representative	GSR that first responded to customer's house	8/11/16

Appendix B – Fault Tree Analysis



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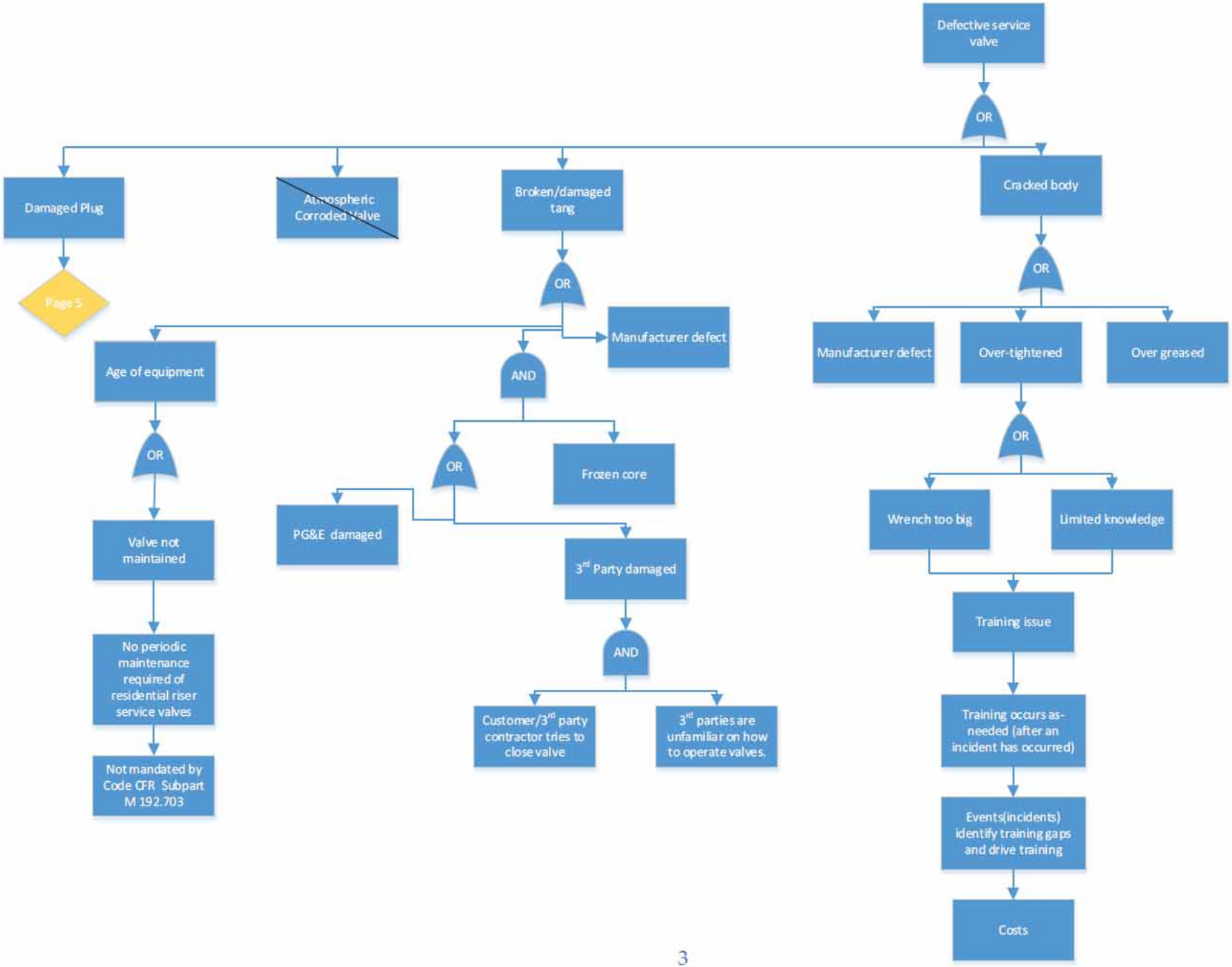

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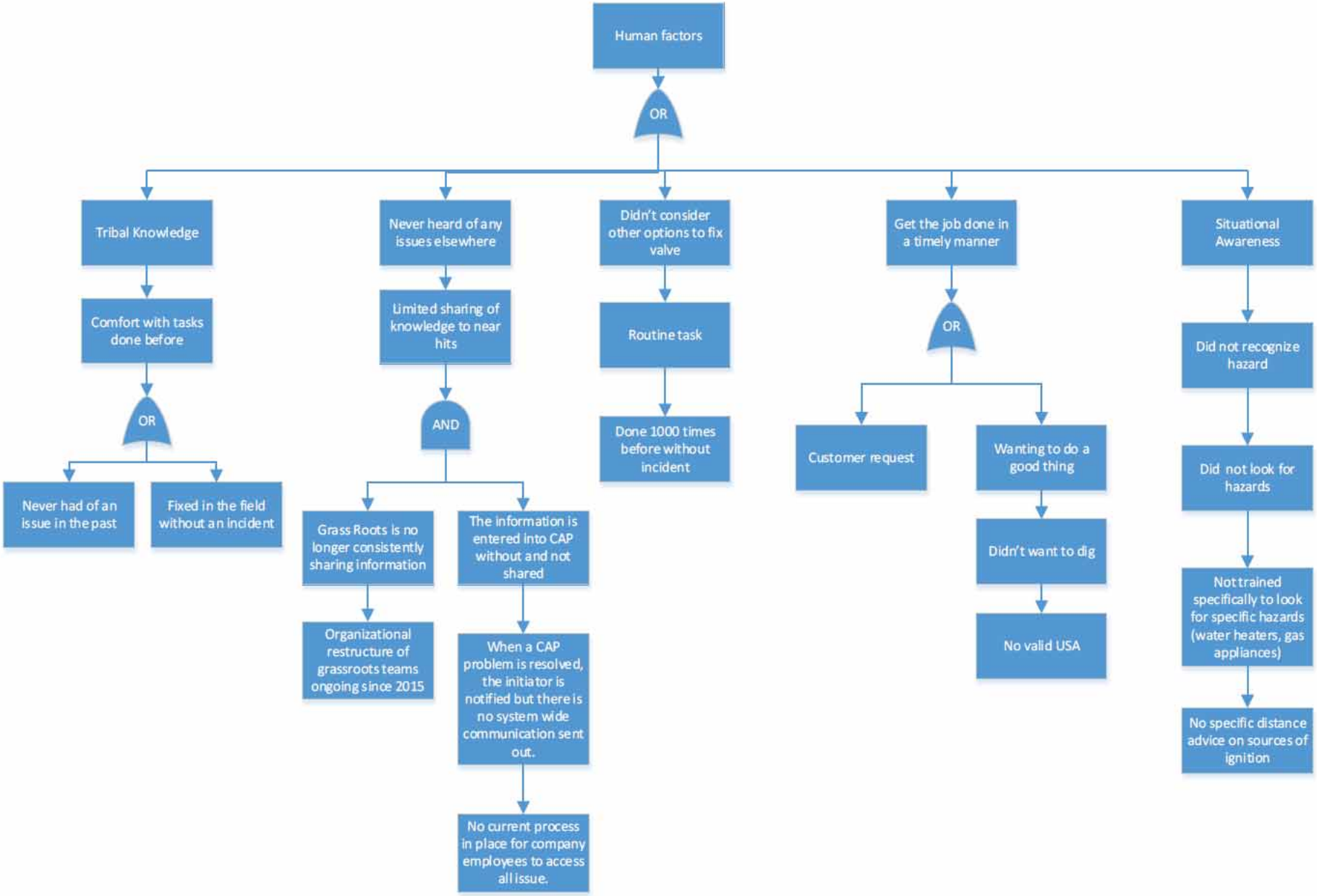

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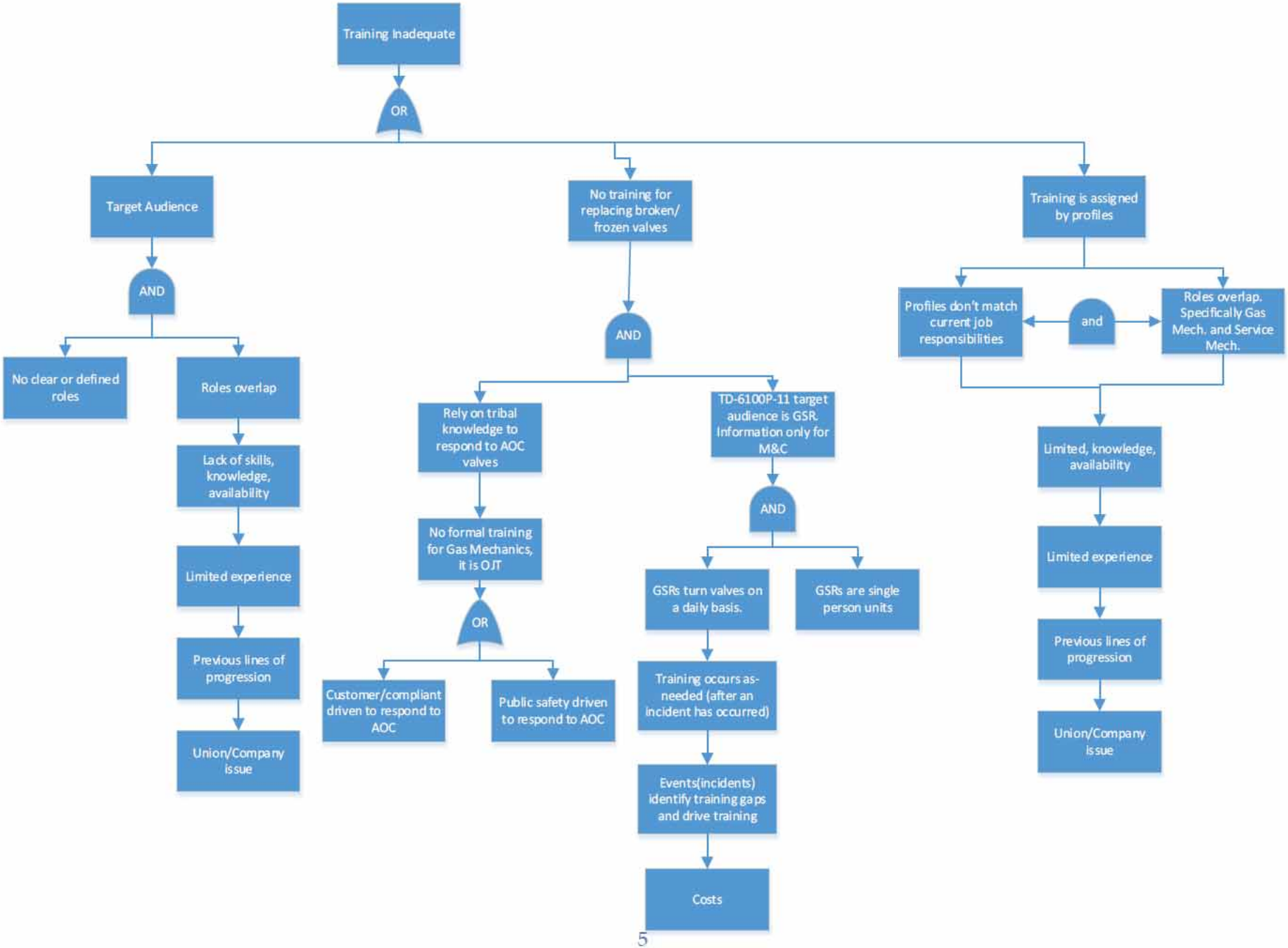

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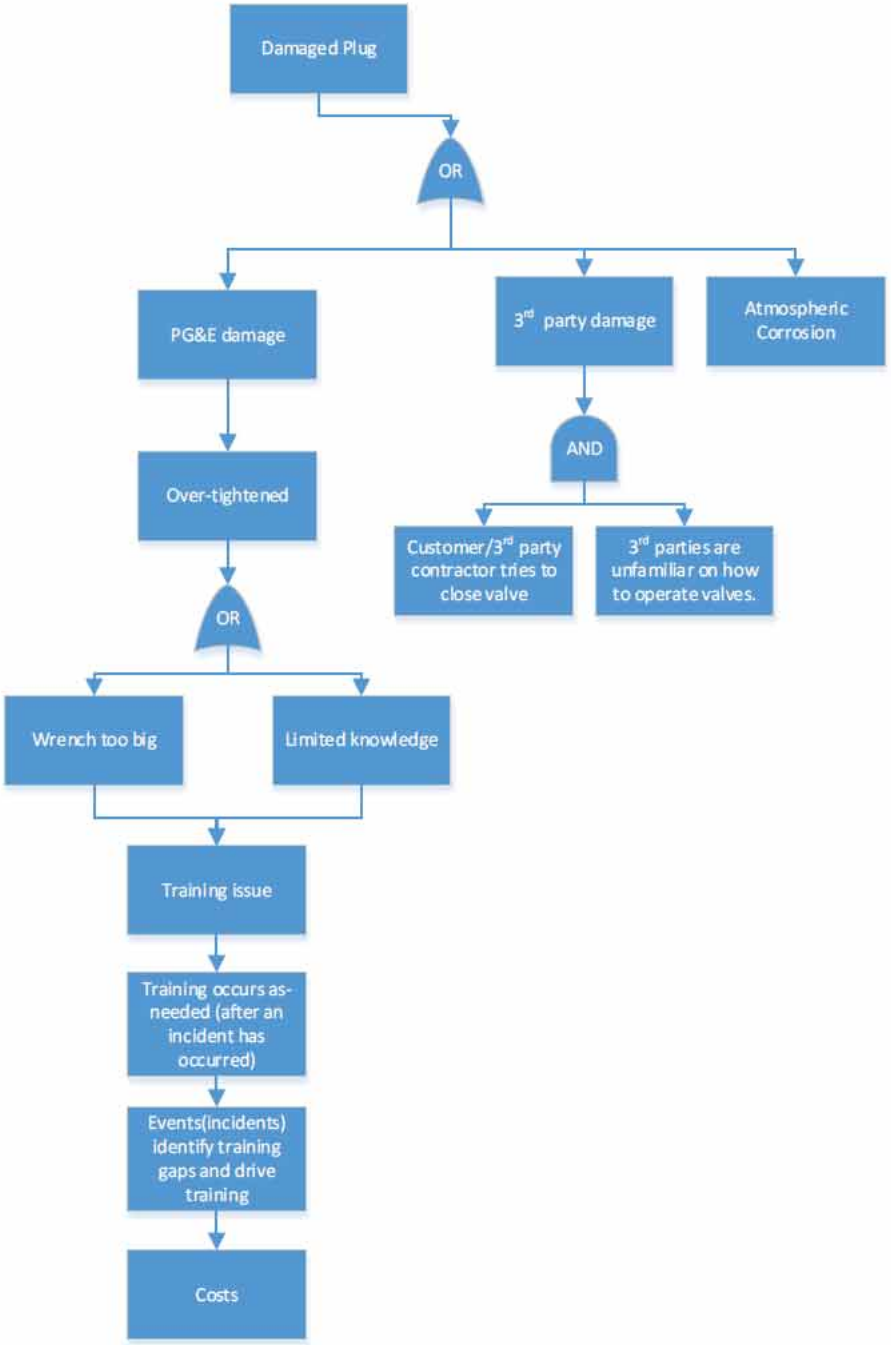

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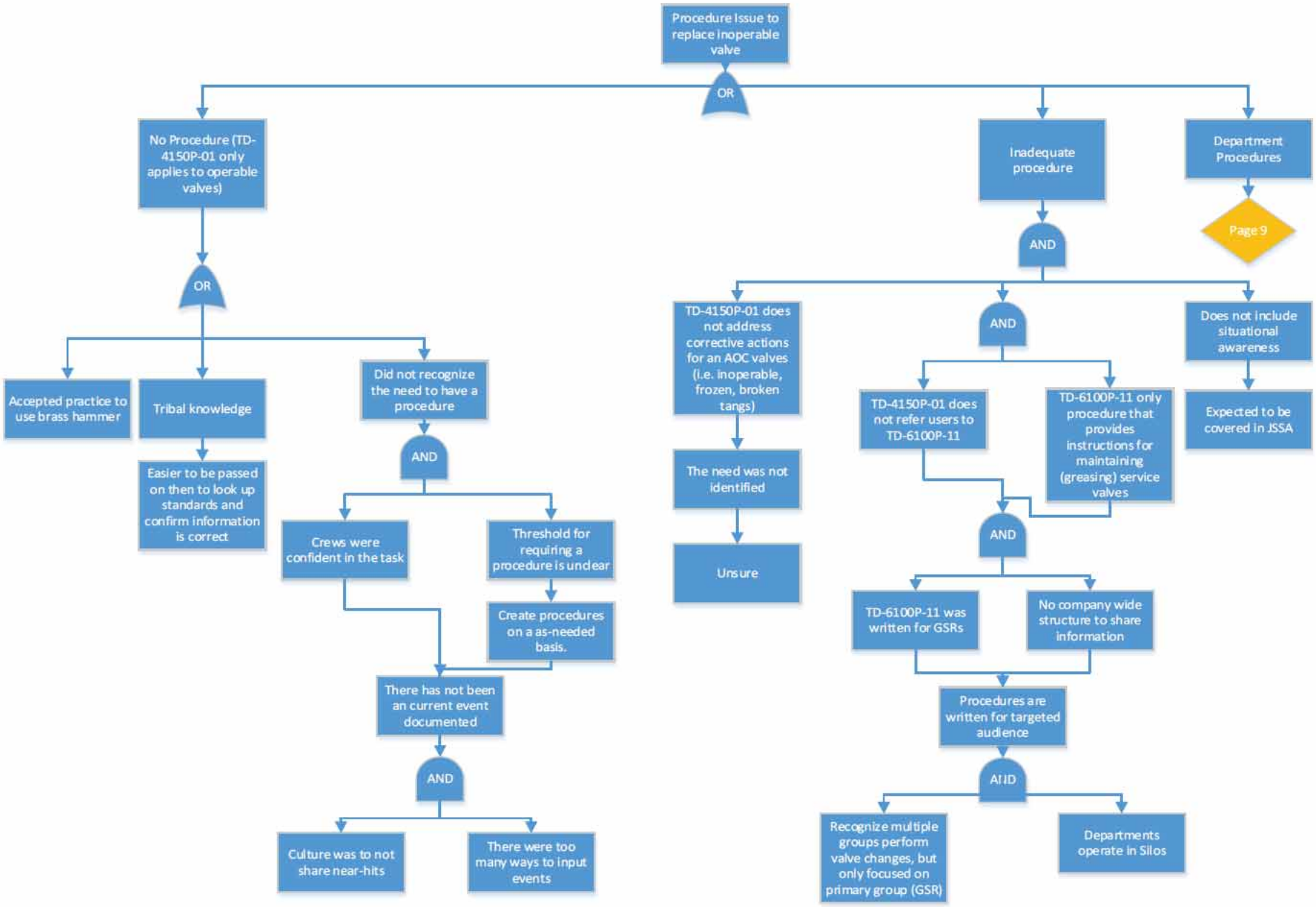

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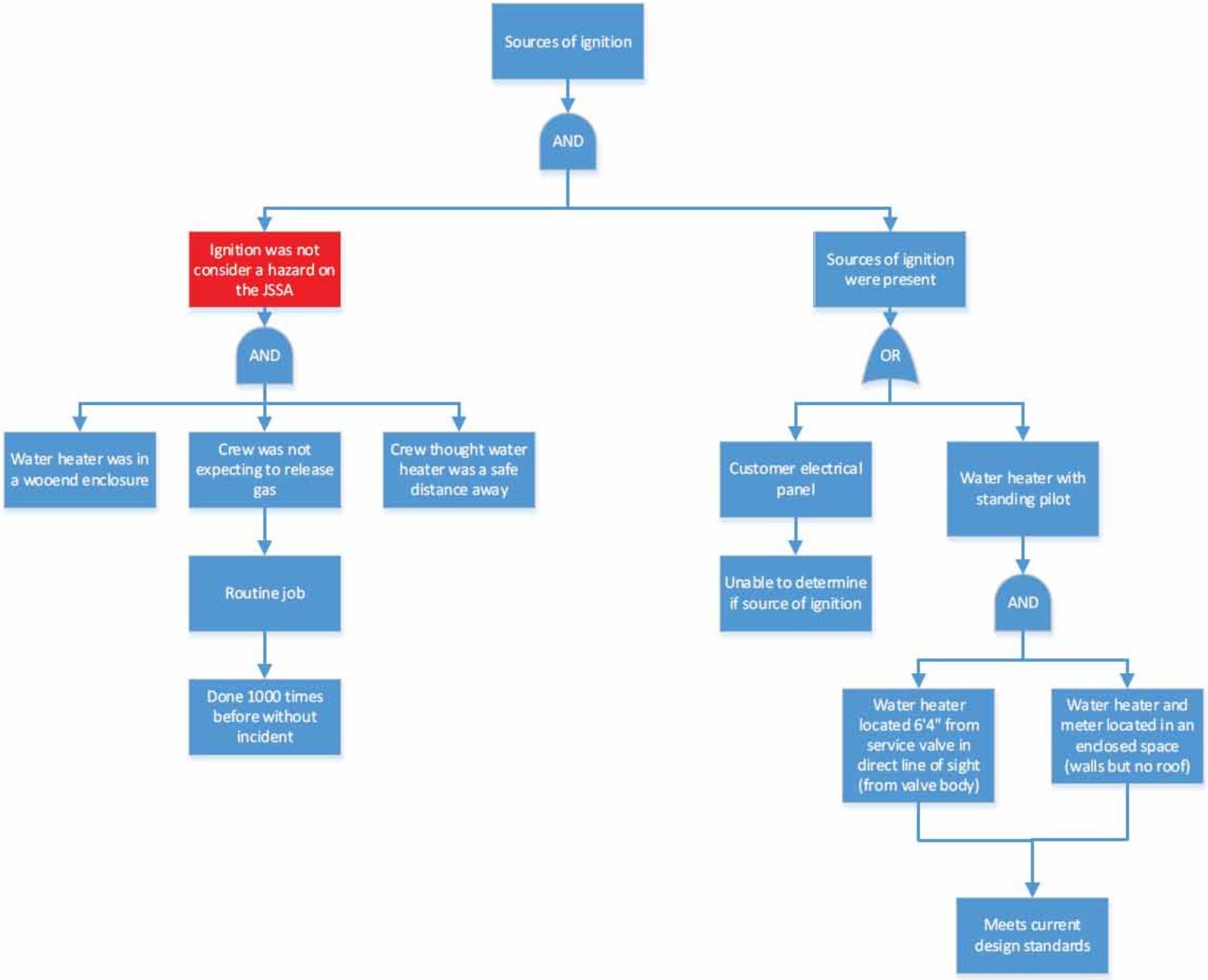

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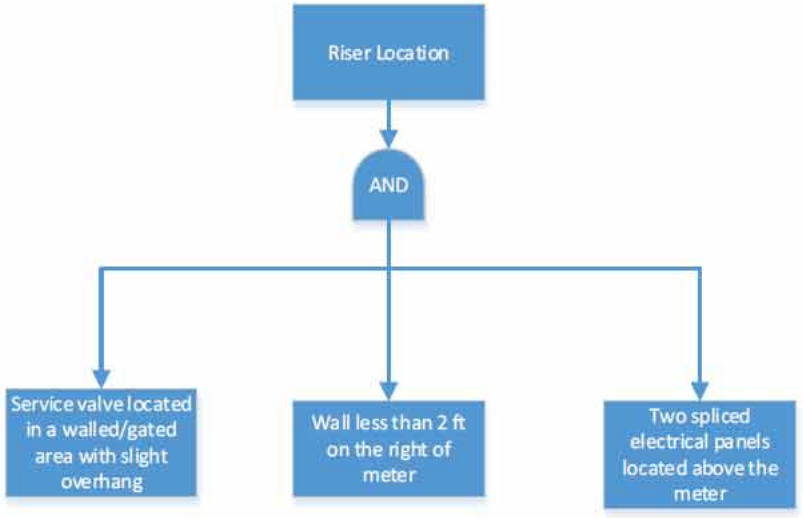

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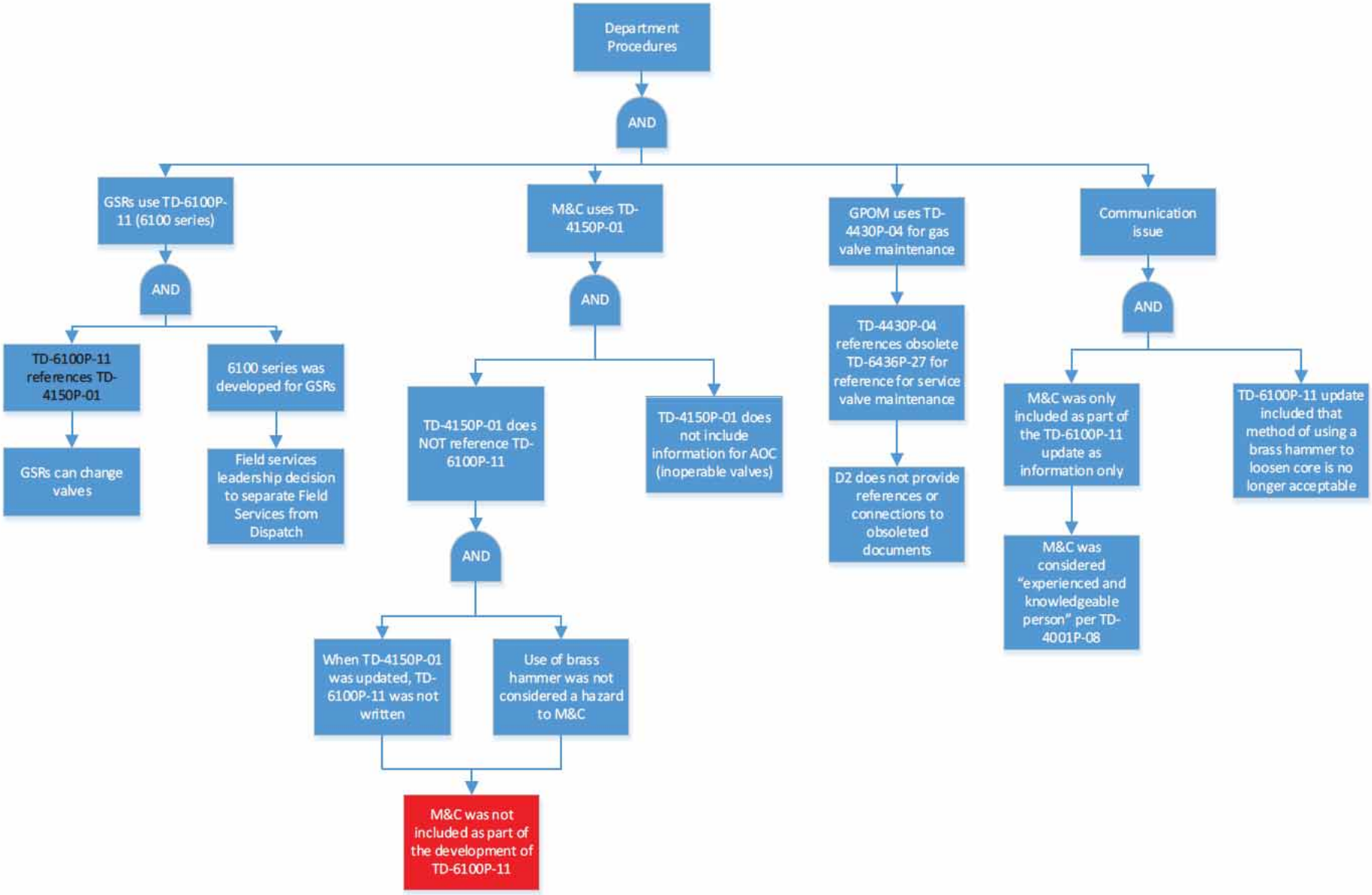


Appendix C – Hazard Barrier Target Analysis

Hazard	Barriers						Target	Evaluation or Comments
Unplanned/ uncontrolled release of gas	**Advertised Barriers**	**Safety Procedure Sequence Rating**	**Did Not Provide**	**Did Not Use**	**Failed**	**Did Not Fail**	Employees /public safety and Customer property	
	Standard/procedure to perform task of replacing Nordstrom valve with broken tang		X					TD-4150P-01 procedure only applies to valves that can be turned 10 to 20 deg. It states "Service valve must be operational to perform this procedure"
	Nordstrom plug				?	?		Analysis to determine
	Valve stem retainer			X				The tang was broken so this tool couldn't be used. If the tang had been intact the GSR could have used this tool to try to grease the valve.
	Training to perform task of replacing valve				X			Valve changing training or other training classes does not include training on specific abnormal operating conditions (AOC) and actions to follow (i.e what to do if valve is broken/frozen,

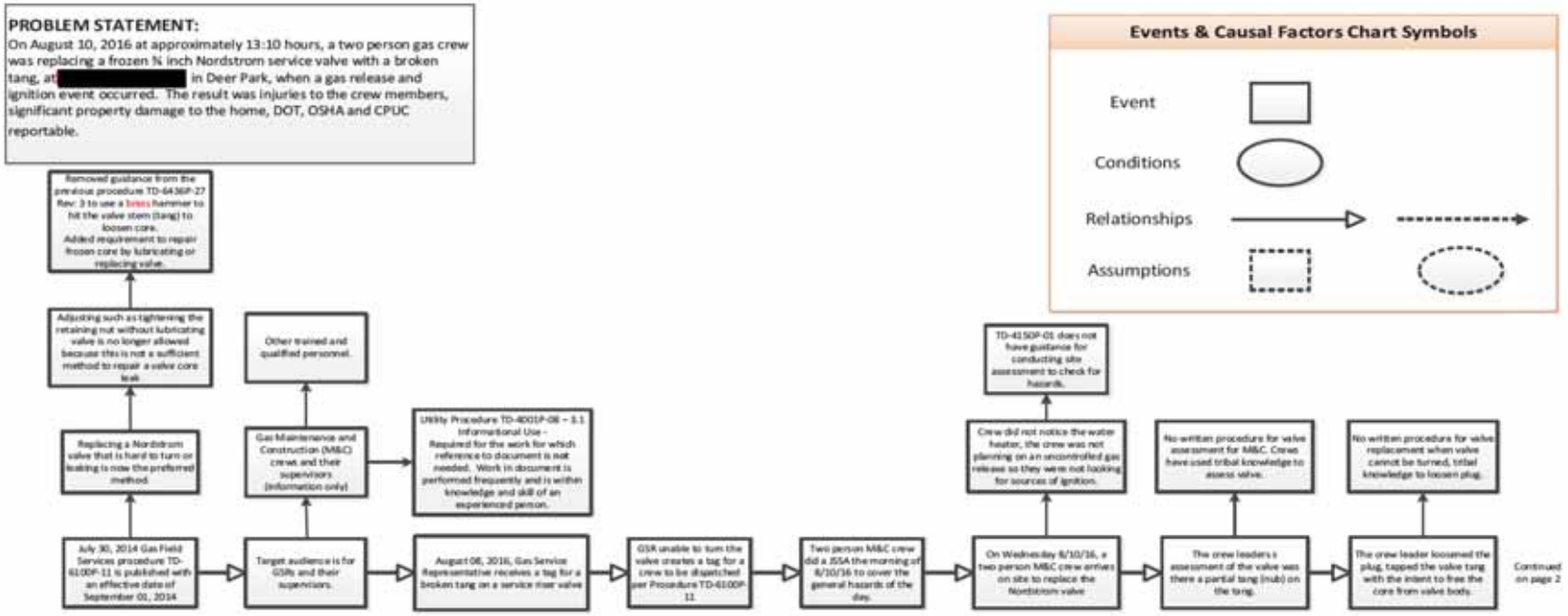
Hazard	Barriers						Target	Evaluation or Comments
Unplanned/ uncontrolled release of gas	**Advertised Barriers**	**Safety Procedure Sequence Rating**	**Did Not Provide**	**Did Not Use**	**Failed**	**Did Not Fail**	Employees /public safety and Customer property	
								tang is broken.)
	Required maintenance schedule of above ground residential service riser valves.		X					No known process in place.
	Identification of ignition sources and openings into structures. (situational awareness)			X				There is not a clear definition of "situational awareness" concerns in Utility Procedure TD-4150P-01
	PPE - gloves			X				Expectation to follow PPE matrix. Utility Procedure TD-4150P-01 does not require gloves (1/29/14) PPE Matrix requires gloves (10/15)

Appendix D – Effect and Causal Factor Timeline

Description

EVENTS & CAUSAL FACTOR ANALYSIS

PROBLEM STATEMENT:
On August 10, 2016 at approximately 13:10 hours, a two person gas crew was replacing a frozen ¾ inch Nordstrom service valve with a broken tang, at [redacted] in Deer Park, when a gas release and ignition event occurred. The result was injuries to the crew members, significant property damage to the home, DOT, OSHA and CPUC reportable.



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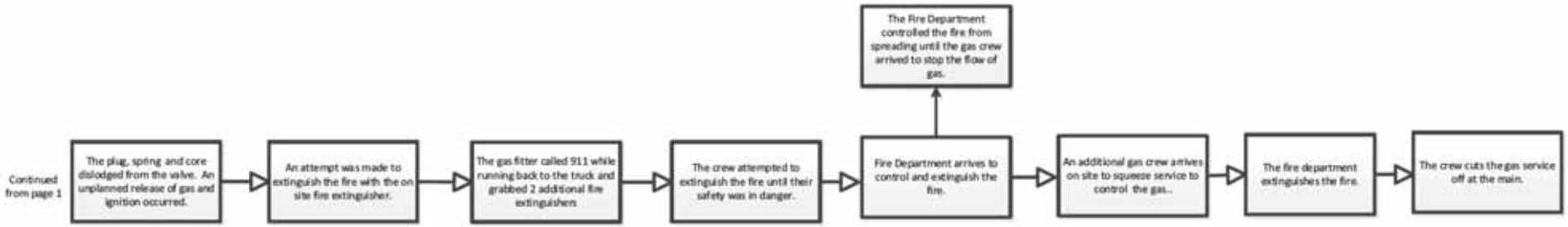

Appendix E – DIMP Nordstrom Service Valve (Plug Type) Inspection Report

NORDSTROM SERVICE VALVE (PLUG TYPE) INSPECTION

Distribution Integrity Management Program (DIMP)

Report issued: September 29, 2016

Prepared by:

Abisai Gonzalez
Sr. Engineer
DIMP Engineering

Reviewed by:

Mike Kerans
Manager
DIMP Engineering

1 As Found Service Valve

Initial Visual Inspection

The Nordstrom service valve was found with all its components (*spring, valve plug and square plug*) disassembled at the time of the inspection (*September 2, 2016 at 2:05 P.M.*) There was no evidence of exposed metal or corrosion removal on the tang surface indicating the use of tools for its operation. The as-found condition and appearance of the service valve components do not represent the condition of the components during service. The components were exposed to fire, water, and environmental elements which accelerated the corrosion and appearance.

Figure 1. As found service valve body and piping.

a b c

Figure 2. As found service valve components: (a) square plug, (b) valve plug, (c) spring.

2 Service Valve Dimension Analysis

Dimension Analysis

MEASUREMENTS	No. READS 1	2	3	4	5	Average
Plug head dimensions (in)	L 0.749 x W 0.720 x H 380					
Plug length (in)	0.578	0.561	0.566	0.56	0.568	0.567
Crest-to-crest (in)	0.0605	0.0605	0.0605	0.0605	0.0605	0.061
Plug thread count per inch	14	14	14	14	14	14
Major diameter (in)	1.401	1.391	1.399	1.39	1.4	1.396
Minor diameter (in)	1.367	1.358	1.357	1.355	1.36	1.359
Thread form	NPT	NPT	NPT	NPT	NPT	NPT
Thread depth (in)	0.0787	0.0787	0.0787	0.0787	0.0787	0.079
Pitch (in)	0.07	0.07	0.07	0.07	0.07	0.070
Number of turns required to remove plug	4	4	4	4	4	4
Number of turns required to fully install plug	4	4	4	4	4	4
Valve body cavity thread count per inch	14	14	14	14	14	14
Valve body cavity major diameter (in)	1.402	1.4	1.404	1.402	1.4	1.402
Valve body cavity minor diameter (in)	1.328	1.323	1.325	1.325	1.323	1.325
Valve body cavity depth (in)	0.635	0.628	0.63	0.625	0.63	0.630
Tang width (in)	N/A	N/A	N/A	N/A	N/A	N/A
Tang height (in)	N/A	N/A	N/A	N/A	N/A	N/A
Tang thickness (in)	N/A	N/A	N/A	N/A	N/A	N/A
Valve plug length (in)	1.734	1.734	1.736	1.734	1.735	1.735
Valve plug major diameter (in)	1.16	1.159	1.159	1.16	1.16	1.160
Valve plug minor diameter (in)	0.908	0.912	0.909	0.907	0.91	0.909
Spring length (in)	0.912	0.911	0.915	0.914	0.913	0.913
Spring major diameter (in)	0.795	0.794	0.794	0.795	0.794	0.794
Spring minor diameter (in)	0.569	0.579	0.576	0.578	0.576	0.576
Number of coils in spring	4	4	4	4	4	4
Spring wire thickness (in)	0.101	0.102	0.105	0.1	0.101	0.102
Spring color	Black	Black	Black	Black	Black	Black

N/A = Tang missing

Table 1. As found measurements.

3 Service Valve Inspection

Service Valve Body

The exterior area around the shutoff valve and piping was found to be scorched and blackened. There were no indications of exterior valve body damage.

Figure 3. As found service valve body (exterior).

Figure 4. As found service valve body cavity.

Service Valve Body Cavity

The interior of the valve body was found to be scorched and blackened. There were no indications of interior valve body damage.

The body cavity threads had no visible damages (cross-threading or damages on thread crests). Also, the threads had proper thread continuity. Overall, the threads were found in good mechanical condition. Moderate corrosion was found on the internal valve cavity, but no indication of corrosion on the threads. No evidence of grease or pipe sealant was found on the surface of the threads.

Figure 5. As found service valve body cavity.

Square Head Plug

The threads on the square plug had no visible damages (cross-threading or damages on thread crests). Also, the threads had proper thread continuity. Overall, the threads were found in good mechanical condition.

Moderate-to-severe corrosion was found on the external and internal body of the plug as well as throughout the entire threads. No evidence of grease or pipe sealant was found on the surface of the threads.

Figure 6. As found square head plug.

Valve Plug

No evidence of exposed metal or corrosion removal on the tang surface indicating the use of tools for its operation. The valve plug was found to have severe corrosion on its entire surface. The valve tang was almost completely absent and the section that was left was corroded. No evidence of grease was found on the surface of the plug.

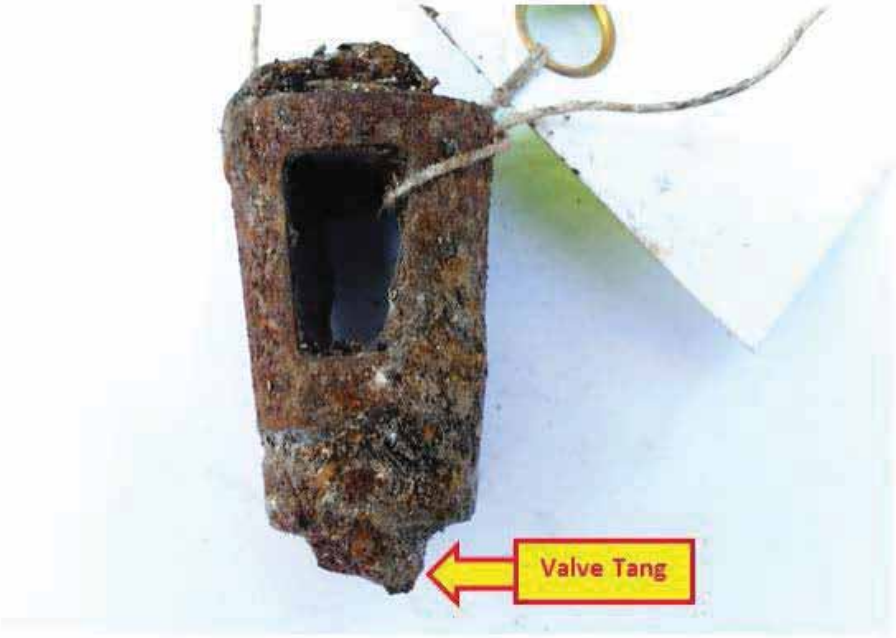

Figure 7. As found valve plug.

Spring

The spring was found to be covered in dry grease and debris imbedded in the coils. Nevertheless, no mechanical damage was found.

Figure 8. As found spring.

Service Valve Assembly

The spring, valve plug and square plug were installed as an assembly in order to check for proper component fit. It was found that all components fit properly to make the assembly.

Figure 9. Service valve assembly

Square Head Plug Tightening

With the spring in place it was found it takes four complete turns to make the bottom surface of the square plug level to the top surface of the valve body.

Figure 10. Square head plug level to the top surface of the valve body.

Square Head Plug Retention

With the spring in place it was found that a ¼ of a turn is the minimum thread engagement before the square plug falls out.

3 Conclusion

Overall, all threads of the service valve were found to be in good mechanical and operating condition. The valve tang was found to be almost completely absent and the section that was left was corroded. All the valve components were found to have either no indication of corrosion or moderate-to-severe corrosion.