



Final Report:
**Safety Evaluation of the Chevron
Richmond Refinery**

August 16, 2016

Final Report: **Safety Evaluation of the Chevron Richmond Refinery**

Conducted on behalf of
Contra Costa Health Services Hazardous Materials Programs
by:

Process Improvement Institute, Inc.
1321 Waterside Lane
Knoxville, TN 37922 USA
Phone: +1-865-675-3458
Fax: +1-865-622-6800
www.piii.com

May 16, 2015

NOTICE

Contra Costa Health Services Hazardous Materials Programs (shortened in this report to CCHMP) contracted Process Improvement Institute, Inc. (PII) to lead and to document the Safety Evaluation of the Chevron Refinery in Richmond, CA. To accomplish this, an audit team of PII staff, supported and overseen by CCHMP staff, reviewed documents, interviewed selected personnel, performed surveys, and performed field visits in order to identify existing process safety practices at the refinery. PII prepared this report to document the results of the Safety Evaluation for the benefit of CCHMP and the people of the communities that they represent. Neither PII, CCHMP, nor any person acting in their behalf makes any warranty (express or implied), or assumes any liability to any third party, with respect to the use of any information or methods disclosed in this report. Any third-party recipient of this report, by acceptance or use of this report, releases PII and CCHMP from liability for any direct, indirect, consequential, or special loss or damage, whether arising in contract, tort (including negligence), or otherwise.

PII and its employees, subcontractors, consultants, and other assigns cannot, individually or collectively, predict what will happen in the future. Although the Safety Evaluation team made a reasonable effort, based on the scope of work and the information provided by Chevron and its employees, to evaluate the safety implementation, management systems, and culture at the Richmond Refinery, it is statistically likely that there are potential findings and deficiencies that are not addressed in this study. If the recommendations of this study are followed, the frequency and/or consequences of accidents and abnormal events should decrease; however, even if all the recommendations are followed, accidents and abnormal events may still occur in the refinery. Chevron should independently evaluate the recommendations made in this study (and alternatives to them) to ensure that implementing them will not create unacceptable risks and that safe practices and management of change procedures are followed when any change is implemented. This work was performed in accordance with our understanding of best practices in process safety implementation. PII accepts no liability for any regulatory action or legal liability that may occur at the Richmond Refinery or at any other Chevron USA facility.

ACRONYM USE – Because of its technical nature, acronyms are used throughout this report. The technical term is spelled out at first use and the acronym is used thereafter. Readers may consult the glossary in the appendices for acronym definitions.

TABLE OF CONTENTS

NOTICE.....	III
TABLE OF CONTENTS	IV
1 EXECUTIVE SUMMARY	1
2 INTRODUCTION.....	5
2.1 Objectives.....	5
2.2 Background	5
2.3 Project Timing and Project Report Considerations.....	5
2.4 Why Is Process Safety Culture Important.....	6
2.5 What Is Process Safety Culture	7
2.6 What Are Human Factors (HF)	7
2.6.1 Definitions Related to Human Factors.....	8
2.6.2 Types of Human Error.....	8
2.6.3 Human Factor Categories	9
2.6.4 Statistical Limits of Control of Human Error Rates	11
2.7 What Is Process Safety Management (PSM) and What Are Best Practices in PSM	12
3 SCOPE AND APPROACH	15
3.1 Overview	15
3.2 Workgroup Definitions	16
3.3 Evaluation of Management Systems and Human Factors	16
3.4 Evaluation of Process Safety Culture	17
3.4.1 Field Observation (Site Data).....	17
3.4.2 Individual Interviews	17
3.4.3 Written Process Safety Culture Surveys	18
3.5 Data Collection Process and Limitations	18
3.5.1 Document Request and Auditor Review Process	19
3.5.2 Individual Safety Culture Interviews, Random Selection Process	19
3.5.3 Third-Party Influence on the Field Data Collection.....	20
3.5.4 General Fulfillment of Interviews, Walk-downs, Control Room Visits, and General Data Requests	21
3.5.5 Constrained and Guarded Responses.....	21
3.5.6 Overall Limitations of Data Collected and Results.....	21
4 EVALUATION AND FINDINGS	23
4.1 Process Safety Management Systems.....	23

4.1.1	Leadership, Vision and Goals Alignment	23
4.1.2	Employee Involvement in Process Safety Management	25
4.1.3	Process Safety Information.....	27
4.1.4	Process Hazard Analysis.....	27
4.1.5	Mechanical Integrity (MI)	32
4.1.6	Training.....	45
4.1.7	Operating Procedures.....	49
4.1.8	Incident Investigation (Root Cause Analysis).....	53
4.2	Human Factors	60
4.2.1	Procedure Clarity	61
4.2.2	Verbal Communication	62
4.2.3	Fitness for Duty (FFD)	63
4.2.4	Human-Machine Interface (HMI)	65
4.2.5	Control of Dependent Error Rates	66
4.2.6	Task Design and Staffing.....	66
4.2.7	Risk Analysis of Human Factors	67
4.2.8	Analysis of Human Factors during Investigation of Losses and Near Loss Incidents	69
4.3	Process Safety Culture	69
4.3.1	Process Safety Culture — Qualitative Analysis	69
4.3.2	Process Safety Culture — Findings/Observations from Process Safety Implementation Evidence	70
4.3.3	Process Safety Culture — Findings/Observations from Individual Safety Culture Interviews.....	73
4.3.4	Process Safety Culture — Findings/Observations from Safety Culture Written Survey	85
4.4	Summary of Results From the Written Survey	105
5	CONCLUSIONS	106
5.1	Summary of Recommendations.....	106
6	APPENDICES	115
6.1	Recommended Reading.....	115
6.2	Scope of Work for the Safety Evaluation	117
6.3	Comments and Responses from Public	120
6.4	Glossary of Terms, Acronyms, and Abbreviations	121
6.5	References (End Notes)	124

1 EXECUTIVE SUMMARY

In August of 2012, a release of hydrocarbon liquids occurred at Chevron Richmond Refinery. The release vaporized and eventually ignited. This resulted in possible offsite impact from the unburned hydrocarbon vapors and from smoke and combustion byproducts from the ensuing fire. Because of this, Contra Costa Health Services Hazardous Materials Programs (shortened in this report to CCHMP) commissioned a third-party safety evaluation of the refinery's management system and safety culture.

An Oversight Committee was formed with representatives from the community, the City of Richmond Fire and Planning Departments, the United Steel Workers Local 5 Union representing the workers at Chevron Richmond Refinery, the Building Trades Unions, and Contra Costa Health Services. Mr. Randall Sawyer, Chief Officer for Contra Costa Health Services Environmental Health and Hazardous Materials Programs, chairs the Oversight Committee.

The objectives of this Safety Evaluation are to complete a thorough review of the management practices (management systems and human factors) and safety culture at the Chevron Richmond Refinery. Poor control in these critical areas can and does lead to process safety accidents. With respect to process safety management systems, this evaluation specifically focused on Mechanical Integrity, Operating Procedures, Training, Management of Change (including management of organizational change), Process Safety Information, Pre Start-Up Safety Reviews, Incident Investigation, Employee Participation, and Process Hazard Analysis. The management systems review includes how Chevron follows through on action items from incident investigations (internal and external), audits (internal and external), process hazard analyses, and actions to address enforcement citations.

Process Improvement Institute, Inc. (PII) conducted this evaluation. PII performed it in parallel with the Industrial Safety Ordinance (ISO) and California Accidental Release Prevention (Cal ARP) Program audits conducted by CCHMP every three years.

PII is expert in both human factors and process safety management. PII also has a significant understanding of safety culture at all types of chemical and petrochemical processing plants. All PII staff on this project have served in key leadership roles at manufacturing sites and at corporate levels. Mr. William Bridges, President of PII, is the project manager.

To minimize the impact on refinery operations and to optimize data collection and staffing requirements, PII staff worked in close collaboration with CCHMP staff to conduct document reviews, interview subject matter experts, obtain field observations, and conduct safety culture interviews. PII oversaw the administration of a written process safety culture survey of the facility for Chevron personnel and contract workers. Any potential regulatory compliance issues were referred to CCHMP for determination. Any potential issues related to best practice management systems, safety culture, and those human factors not covered in the county ISO were referred to PII for determination.

Three to four PII staff were on-site each day for a total of four weeks. An average of two CCHMP staff per day provided supplemental support while PII was on-site and completed additional assigned tasks when PII was not there (i.e., during the ISO and Cal ARP Audit by CCHMP staff). This provided additional data collection capabilities for PII's charter. It also provided an opportunity to cross-train CCHMP staff in process safety culture evaluation, horizontal auditing methods, and procedure/human-factors walk-downs in the field.

Details of the data collection can be found in the remainder of this report. In summary, the on-site portion of the data collection was completed on schedule within the four on-site weeks

projected. The data collection was slower than expected in many cases, but thanks to the supplemental data gathered by CCHMP staff, the schedule was maintained.

The data collected falls into the following categories:

- Interviews of 65 subject matter experts (SMEs) related to how process safety works or is supposed to work at the Richmond Refinery
- Walk-down of 38 operating procedures in the units (1) to determine procedure accuracy and clarity and (2) to review the control of human factors in the process units
- Live navigations of databases for specific evidence of items such as inspection, test, and preventive maintenance and incident data
- Review and evaluation with operations personnel of actual shift handovers
- Review with control board operators of human factors issues in the control rooms
- Evaluation of operator response to critical alarms
- Reading/review of standards and procedures at the Richmond Refinery
- Review of process safety work products such as Process Hazard Analysis (PHA) reports and recommendations and resolutions, completed investigations, completed inspection/maintenance reports, etc.; several hundred such documents were reviewed
- Interviews of about 100 staff related to their impressions on process safety implementation, leadership, and ultimately process safety culture at the refinery
- Written survey related to process safety culture at the refinery

PII completed most of the review of the site-specific documentation outside of the facility, via access to temporary read-only databases set up by Chevron for this purpose. The databases were populated with approximately 1,200 documents based on specific requests from PII. An additional **33** requested documents were uploaded to the data site in early 2015.

Details of the conclusions and recommendations can be found in the remainder of this report. In general, PII found that the Chevron Richmond Refinery, with the help of Chevron USA (CUSA), has established a renewed and vigorous effort to implement effective controls of process safety issues to reduce the likelihood of process safety accidents at the site. The management of the site has a clearly stated vision for achieving this goal. Moreover, it has reorganized to better position its in-house expertise to address the weaknesses at the site. Although we do not know the budgets for the refinery, they appear to have significant and perhaps sufficient support from CUSA to achieve the goals.

From the data collection, PII found many areas for improvement in control of process safety at the refinery. Site staff and management already recognized many of the weaknesses identified by PII, but additional weaknesses either were not recognized or were not part of the ongoing improvement activities for process safety at the site. Chevron Richmond should focus on the key issues summarized below:

- Improve operating procedures accuracy. Currently, less than 40% (based on detailed evaluation of a sample of the operating procedures) are accurate enough and clear enough to fulfill the role of written procedures in controlling human error.
- Expand the risk analyses (PHAs) for the refinery units to more fully address hazards during all modes of operation. In particular, the current PHAs do not adequately find and address accident scenarios that can occur during non-routine operations such as startup, shutdown, and online maintenance. If these scenarios are missed, then the units will likely not have sufficient safeguards in place to prevent those accidents. The refinery has extensive programs outside of PHAs to identify issues caused by damage mechanisms (such as corrosion and erosion of process equipment), and the PHAs cover damage mechanisms to some degree. However, PII believes this portion of the analysis can also be improved to ensure sufficient safeguarding and isolations in subsystems throughout each refinery unit.
- Greatly increase the reporting and investigating of process safety near misses (called near loss incidents at Chevron) to find root causes that will eventually lead to accidents (process safety loss incidents). The current reporting is 30 to 50 times lower than best in class. A near-term goal would be to increase near miss reporting and subsequent root cause analysis by a factor of 10. To facilitate this change, the site should:
 - Train more operators and maintenance craft-persons on root cause analysis methods,
 - Streamline the methods and requirements for such reporting and analysis, and
 - Allow workers to take more of a leadership role in this data collection and analysis activity.

Further, the site needs to adopt only best in class methods for investigations to minimize assigning blame to the worker for human error. Building trust between workers and management is key to closing this observed gap.

- Implement more effective control of human factors, especially miscommunication on radios, fatigue, labeling (and other human-machine interface issues), and procedure clarity. Note that the site has good control of many human factors, especially when compared to all but one of the other 30+ refineries that PII staff have evaluated.
- Improve the mechanical integrity programs across the refinery. Many initiatives are ongoing at the refinery related to this concern. But there are still weaknesses. Specific improvements identified include:
 - Make sure corrosion and other damage mechanisms are thoroughly identified and corrected. Weaknesses in the related programs are evident from a review of the current maintenance and inspection activities and programs that control the identification and correction of corrosion.
 - Make sure that all components related to causes and safeguards listed in the PHAs are properly maintained and inspected, including safety-related instruments.
 - Complete the positive identification of the materials of construction in each unit. Without this baseline effort, the site will not know which components and welds are inadvertently of the wrong material or grade. Such deficiencies have caused many accidents in other refineries and petrochemical plants.

- Implement a more formal program (such as for performing drills of response to critical process alarms and retention of the results of such drills) to ensure that operators can effectively respond to process alarms within the process safety time available for response.
- Expand the Stop Work Authority (SWA) program to include process safety-incident prevention. Currently, workers are very reluctant to request a shutdown of a process unit (and perhaps the cascading of that shutdown to a shutdown of the entire refinery) or to delay a restart. This is true even if they feel there are legitimate process safety concerns. The SWA program appears to be effective for occupational (personal) safety activities (such as during maintenance), but it did not appear (from data collected by PII) to be effectively implemented for process safety concerns.

Addressing the issues above will require changes to policies and procedures at the management system level. Also, more process safety activities will need to be delegated to workers. This, in turn, will drive improvements in the actual process safety culture (i.e., how things are done when no one is watching). Significant improvement in each of the areas above is possible within one year of receipt of this report. (It will be almost two years since PII originally made Chevron aware of the preliminary findings and recommendations.) Other sites have closed similar gaps in that period (about two years).

However, closing some gaps may take more than two years. This includes, for example, expanding the coverage/scope of the PHA for each unit and or completing the improvements necessary in the site's control of mechanical integrity issues. Therefore, the refinery should work with CUSA to develop a plan to address these gaps as soon as possible. This schedule should be shared with the public, along with ongoing resolution of the issues listed in more detail in the following sections of this report.

- End of Section 1, Executive Summary -

2 INTRODUCTION

2.1 OBJECTIVES¹

The objectives of this Safety Evaluation of the Chevron Richmond Refinery are to conduct a review of the management practices (management systems and human factors) and safety culture at the refinery. The deliverables for this project include a draft and final report for the initial study and a report of the follow-up evaluation to determine how the findings of this initial report are addressed.

2.2 BACKGROUND²

Because of the 2012 fire at Chevron Richmond Refinery's Crude Unit, communities adjacent to the refinery, the Richmond City Council, the Contra Costa County Board of Supervisors, and Contra Costa Health Services are concerned about the safe operation of the refinery.

In response, the City of Richmond representatives and Contra Costa Health Services staff arranged for a third-party evaluation at this refinery. This evaluation is not an investigation of any specific incidents, and it is not a Process Safety Management (PSM) audit. Rather, it is an overall review of the management systems in place at the refinery to manage process safety and an evaluation of the safety culture existing at the refinery.

PII was contracted to conduct this evaluation. William Bridges, President of PII, is the contractor project manager for the evaluation. Randall L. Sawyer is the client project manager for the evaluation. Mr. Sawyer is Chief Officer of the Contra Costa Environmental Health and Hazardous Materials Programs and Chair of the Chevron Richmond Refinery Safety Evaluation Oversight Committee.

The Chevron Richmond Refinery has the capacity to refine approximately 245,000 barrels of crude oil per day. It employs a workforce of approximately 1,200 employees, including management, staff, maintenance, and operating personnel. It has over 32 process units and covers approximately 2,900 acres.

2.3 PROJECT TIMING AND PROJECT REPORT CONSIDERATIONS

Key dates for this project:

- Project initiation within CCHMP – 4/5/2013
- Project request for proposal – 5/23/2013
- Project award – 8/1/2013
- Observations, interviews and data collection – 9/23 through 11/6/2013
- Draft Report issued for internal review and for review by Chevron USA (CUSA) – June 23, 2014
- Comments received from CUSA September 2014, January 7-8, 2015, and follow-on information throughout March 2015

- Revised Draft sent to CCHMP on June 2014 and May 2015.
- Revised Draft sent to Oversight Committee on xxx, 2015.

This report summarizes the observations, interviews, and other data collection activities conducted by PII in late 2013 and early 2014 (supplemented by more data collection on specific issues in March 2015). The report represents the technical evaluation and conclusions of Process Improvement Institute (PII) based on the data collected.

After this evaluation was initiated but before it was concluded, Chevron Richmond Refinery announced revisions to policies and practices intended to improve process safety performance at the refinery. Therefore, the conclusions, findings and recommendations of this Safety Evaluation report may not reflect progress in the PSM program and safety culture that these revisions are targeted to achieve. A follow-up evaluation is scheduled at the refinery to determine the closure of each recommendation.

2.4 WHY IS PROCESS SAFETY CULTURE IMPORTANT³

On April 2, 2010, the Tesoro Anacortes (WA) refinery experienced a catastrophic rupture of a heat exchanger, fatally injuring seven Tesoro employees working in the immediate vicinity. (Process Safety Culture – Making This a Reality)⁴ The Draft Investigation Report⁵ lists “Process Safety Culture” as a key issue and offers the following observations about Tesoro’s culture at the time of the accident:

- “Refinery management had normalized the occurrences of hazardous conditions,”
- “The refinery process safety culture required proof of danger rather than proof of effective safety implementation.”

On March 23, 2005, the BP Texas City (TX) refinery experienced the most serious U.S. workplace disaster of the past two decades, resulting in 15 deaths and more than 170 injuries. The Baker Panel reported that deficiencies in “BP’s corporate safety culture, corporate oversight of process safety, and process safety management systems” were contributing factors to this and other incidents that had previously occurred at BP facilities. (Baker Report)⁶

On January 28, 1986, the space shuttle Challenger exploded killing all seven astronauts on board. The Rogers Commission reported that NASA’s organizational culture failed to prevent this accident. Seventeen years later, on February 1, 2003, the space shuttle Columbia disintegrated upon reentry of the Earth’s atmosphere, killing all seven astronauts on board. The Columbia Accident Investigation Board (CAIB) reported that, “In our view, the NASA organizational culture had as much to do with this accident as the foam.” The CAIB also found “disturbing parallels remaining” from 17 years earlier, making the determination that “NASA had not learned from the lessons of Challenger.”⁷

History is filled with tragic life-altering and -ending events that can be traced back to phrases like, “we’ve been doing it this way for years” or “this way is good enough” or “this is what our industry peer group is doing.” On the other hand, there is a correlation between improving safety culture and decreasing the number and severity of accidents.⁸

2.5 WHAT IS PROCESS SAFETY CULTURE

Merriam-Webster defines “culture” as “the set of shared attitudes, values, goals and practices that characterizes an institution or organization.” Safety culture is a measure of the importance that individuals and organizations exhibit toward working safely. It is the summation of attitudes that people display and the actions they perform late on a Saturday night when no one is watching. An organization can influence employees to embrace positive, shared safety values with consistent policies and practices and by leading through example.⁹

The best definition of process safety culture, and the one used by PII for this evaluation, is:

Safety Culture is not what we feel; it is what we as an organization do. The site leaders (management) create the culture by what they do and what they pay attention to. The repetition by leadership of doing the right thing and making the right decision establishes the culture at a site.

This definition is very similar to one stated by Andrew Hopkins and others.¹⁰ It also matches the lessons learned by the former operations managers and plant managers at PII. And it matches the observations collected from more than 100 sites where PII staff have deeply evaluated process safety implementation.

Therefore, process safety culture is best measured by determining how well process safety is implemented at a site and by considering the decisions leaders at the site make to ensure process safety is implemented effectively.

In June 2006, the Contra Costa County Board of Supervisors recognized the importance of a strong process safety culture in minimizing accidents. An amendment was adopted to the Contra Costa County and later to the City of Richmond Industrial Safety Ordinances (ISO) requiring that all covered facilities perform an initial Safety Culture Assessment (SCA) within one year of the issuance of the guidance document, and at least once every five years thereafter.¹¹

2.6 WHAT ARE HUMAN FACTORS (HF)

All accidents (or nearly all, if you consider that we either cannot guard against or choose not to guard against some natural phenomena) result from human error. This is because humans govern and accomplish all of the activities necessary to control the risk of accidents. Humans influence other humans in the process – not only do humans cause accidents (unintentionally) by making errors directly related to the process itself, but they also cause errors by allowing (“creating”) deficiencies in the design and the implementation of management systems. That is, we make errors in authorities, accountabilities, procedures, feedback, proof documents, and continual improvement provisions. Ultimately, these management systems govern the human error rate that directly contacts or directly influences the process.^{12,13}

***ALL accidental losses
(except for natural
disasters) begin with a
human error***

Recent major accidents have highlighted the need for increased focus on Human Factors. The United States Chemical Safety and Hazard Investigation Board (CSB) cited human factor deficiencies as one of the main contributors to the catastrophic accident at the BP Texas City Refinery in March 2005.¹⁴ The human factor deficiencies included lack of control of worker

fatigue, poor human-system-interface design, poor communication by radio/phone, out-of-date and inaccurate operating procedures, and poor (no) communication between workers at shift handover. The CSB has cited similar issues from many other accidents and has urged industry and the United States Occupational Safety and Health Administration (U.S.OSHA) (the regulator) to pay much more attention to human factors. As a result, the recent U.S.OSHA National Emphasis Program for Refineries included human factors as one of the 12 core elements it reviewed in detail across many of the 148 oil refineries in the USA.¹⁵

Implementing human factor engineering and policies to prevent accidents is not a new concept. Nearly all (or all, from a more complete perspective) of the causes and root causes of major accidents in the past 30 years have been the result of poor control of human factors. This has been cited in many root cause analysis reports and papers concerning these major accidents.¹⁶

PSM systems based on OSHA's PSM standard¹⁷ are likely lacking the fundamental human factor standards that, if applied across the applicable PSM elements, would work together to reduce human error. Note that Chevron Richmond's 2013 PSM program is closely modeled after the Cal ARP¹⁸ (which copies its process safety elements from the OSHA PSM standard). Human Factors have been a key element of Contra Costa County's ISO and City of Richmond's Industrial Safety Ordinance (RISO) since both were originally adopted. In 2006, CCHMP expanded ISO where Human Factors are to be considered. That was adopted in the RISO in 2013.¹⁹

The *Risk Based Process Safety (RBPS)* industry standard²⁰ from the Center for Chemical Process Safety (CCPS), a division of the American Institute of Chemical Engineers (AIChE), does include human factor standards. However, these are presented under several PSM elements instead of under a stand-alone human factor element.²¹ This does not provide a needed road map to help companies transition to RBPS from the minimum PSM systems defined in OSHA's PSM standard. One starting point for this transition could be implementing a human factor element comprised of the human factor categories missing from most PSM systems (especially from those based on the OSHA PSM standard). The human factors elements required in RISO from CCHMP are a good initial set of human factors to start with.²²

2.6.1 Definitions Related to Human Factors²³

- In the context of this report, **Human Error** means the errors that are made during direct interface or direct influence of the process.
- **Human Factors** are those aspects of the process and related systems that make it more likely for the human to make a mistake that in turn causes or could cause a deviation in the process or could lead in some indirect way to the increased probability of an accidental loss.
- **Management systems** are the administrative controls that an organization puts in place to manage the people and workflow related to the process under consideration. So these systems inherently attempt to control human factors.

2.6.2 Types of Human Error

Not all errors will be prevented. Since the beginning of time, humans have tried to control human error rate with more or less success. Human errors have been measured for hundreds of years. Psychologists have studied why humans make mistakes and have gradually built a science around human error probability. Today, the best models for control of human error in the workplace are generally agreed to depend on control of human factors. (In turn, these have grown out of what was previously denoted as "performance shaping factors.")²⁴

In simplest terms, there are only two types of human error: *Errors of Omission* (someone skips a required or necessary step) and *Errors of Commission* (someone performs the step wrong). In addition, these errors occur either inadvertently (unintentional error) or they occur because the worker believes his or her way is a better way (intentional error, but not intentional harm). Intentional errors can usually be thought of as errors in judgment. Some believe a “lack of awareness of the risk” causes these errors. In actual practice, the worker who commits an intentional error is usually well aware of the hazard. However, they believe they have/know a better way to accomplish a task, or they believe there are already too many layers of protection (so bypassing one layer will not cause any harm).²⁵

Regardless of type or category of human error, an organization can and should exert considerable control of the errors. In general, PSM is focused on maintaining these human errors at a tolerable level because:

- All accidents happen due to errors made by humans, including premature failure of equipment. There are a myriad of management systems to control these human errors and to limit their impact on safety, environment, and quality/production.
- When these management systems have weaknesses, near misses occur.
- When enough near misses occur, accidents/losses occur.²⁶

2.6.3 Human Factor Categories²⁷

Human errors are sometimes mistakenly called procedural errors. This is not any truer than saying all equipment errors are due to design errors. Over the past five decades of research and observation in the workplace on human error, we have learned that human error probability depends on many factors. These factors (described in more detail in *Human Factors Missing from PSM*²⁸) include:

- Procedure accuracy and procedure clarity (the number one most-cited root cause of accidents):
 1. A procedure typically needs to have 95% or better accuracy to help reduce human error; workers ignore procedures less than 70% accurate.
 2. A procedure must clearly convey the information (there are about 25 rules for structuring and formatting procedures to accomplish this), and the procedure must be convenient to use.
 3. Checklist features – These should be included whenever they can be effectively enforced.
- Training, knowledge, and skills
 1. Employees must be selected with the necessary skills before being hired or assigned to a department.
 2. Initial Training – There must be effective, demonstration-based training for each task, both proactive (startup of a unit) and reactive (response to an alarm).
 3. Ongoing validation of human action is required and usually must be repeated (in either actual performance or in drills/practice) at least once per year.
 4. Documentation – The performance of the humans must be documented and reviewed to allow for improvements, as needed.

- **Fitness for Duty** – This includes control of many sub-factors such as fatigue (a factor in a great many accidents), stress, illness and medications, and substance abuse.
- **Workload Management** – Too little workload and one's mind becomes bored and looks for distraction; too many tasks per hour can increase human error, as one becomes overwhelmed.
- **Personal Stress** – In addition to stress from workload and fitness for duty issues, stress caused by anxiety at work or by issues at home can increase human error rates.
- **Communication** – Miscommunication (of an instruction, set of instructions or of the status of a process) is the second or third most common cause of human error in the workplace. There are proven management systems for controlling communication errors.
- **Work Environment** – Factors to optimize include lighting, noise, temperature, humidity, ventilation, and distractions.
- **Human System Interface** – Factors to control include layout of equipment, displays, controls and their integration to displays, alarm nature, frequency, sounds or signals, and control of alarm overload, labeling, color-coding, fool-proofing measures, etc.
- **Task Complexity** – Complexity of a task or job is proportional to the:
 1. Number of choices available for making a wrong selection among similar items (such as number of similar switches, number of similar valves, number of similar size and shaped icons);
 2. Number of parallel tasks that may distract the worker from the task at hand (leading to either an initiating event or failure of a protection layer);
 3. Number of individuals involved in the task; and
 4. Judgment or calculation/interpolation, if required.

For most chemical process environments, the complexity of the task is relatively low (one action per step). But for response actions (human independent protection layers [IPLs] – see Section 2.7) other tasks are almost always underway when the out-of-bounds reading occurs or the alarm is activated.

For use of a human response action as an independent layer of protection (IPL), in addition to the human factors listed, the human must have (1) sufficient time to perform the action and (2) the physical capability to perform the action.

Human factors must be controlled over the long-term, especially during non-routine modes of operation, such as a maintenance outage. For instance, if the workers are fatigued following many extra hours of work in a two-week period leading up to restart of a process, then the human error rates can increase by a factor of 10 times or 20 times by the end of the outage and into startup.

Revealed versus Unrevealed Errors for Humans.²⁹ As with equipment failures, human errors can lead to a revealed fault in the system (the flow does not start, for instance) or to an unrevealed fault (the block valve downstream of a control valve is left closed, but the failure is not revealed until the control is needed/used). If the error is revealed, then the error can be corrected or compensated for. If the restoration/correction time for a revealed error is sufficiently short, then the probability of being in the failed state is much less than for an unrevealed failure that is only discovered upon testing or inspection.

2.6.4 Statistical Limits of Control of Human Error Rates

It is important to understand that with excellent control of all human factors (requiring excellent design and implementation of management systems for each human factor), a company can approach the observed lower limits for human error.³⁰ The first detailed report of the lower limits was by Alan Swain and H Guttman (NUREG-1278, 1983) and by others.³¹ In general, we have found it best to use the following average error probabilities:

Error Probability for Rule-Based Tasks (that are not responses to alarms):³² This is for actions that do not have to be accomplished within a specific span of time to be effective. Of course, there is always pressure from the organization (business goals) to accomplish tasks in a timely, efficient manner. The values below are the lower limits for human error rates, assuming excellent control of human factors. These are expressed as the probability of making a mistake on any given step of a task:

- 1/100 – Process industry; routine tasks performed 1/week to 1/year. *This rate assumes excellent control of all human factors. At most places we visit, the workers, managers and engineers believe this is achievable, but not yet achieved.*
- 1/200 – Pilots in the airline industry; routine tasks performed multiple times a day with excellent control of human factors. *This average has been measured by a few clients in the airline industry, but for obvious reasons they do not like to report this statistic.*
- 1/1000 – Process industry; routine tasks performed 1/day or more. *This is about the probability of someone running a stop sign or stop light.*

Example: One of the auditors has been working at client sites for 100 days a year for 24 years. This requires use of a laptop each of those days. The laptop is also used in a hotel each evening after work; this is normally with the power cord attached. Therefore, there have been 2,400 opportunities to mistakenly leave the power cord in the hotel room (instead of taking it to the client site). Overall, the power cord has been left in the hotel room four times for an error rate of 1/600. So far, the related error of leaving the power cord at the client site has not occurred, but there have been about three near misses.

Coupled Error Rates^{33,34} This is the probability of repeating an error, i.e., performing a second task wrong after the first task (the same task or one with the same goal) was done wrong:

- 1/7 to 1/20 – If the same tasks are separated in time and if visual cues are not present to reinforce the mistake path. *This error rate assumes a baseline error rate of 1/100 with excellent human factors.*
- 1/2 to 1/1 – If the same tasks are performed back-to-back and a strong visual cue is present.
- Two or more people become the same as one person (with respect to counting of errors from the group), if people are working together for more than three days. (This is because of the trust that can rapidly build.)

Response Action (time-driven) Error Rate:³⁵ This is the probability that the correct action will NOT be completed within the time necessary.

- 1/1 – If practiced/drilled once per year and there is not sufficient time to accomplish the response task.
- 1/10 – If practiced/drilled once per year and there is sufficient time (theoretically) to accomplish the response task.
- 1/100 – If practiced/drilled once per week and there is sufficient time to accomplish response task.

As mentioned earlier, the lower limit rates assume excellent (but not perfect) control of human factors. Note that airline pilots have a lower error rate than what we have measured in the process industry. This is due, in part, to the much tighter control by the airlines and regulators on factors such as fitness-for-duty (control of fatigue, control of substance abuse, etc.).

Excellent control of human factors is not achieved in most organizations. In those cases, the human error rates will be higher than the lower limit, perhaps as much as 20 times higher.

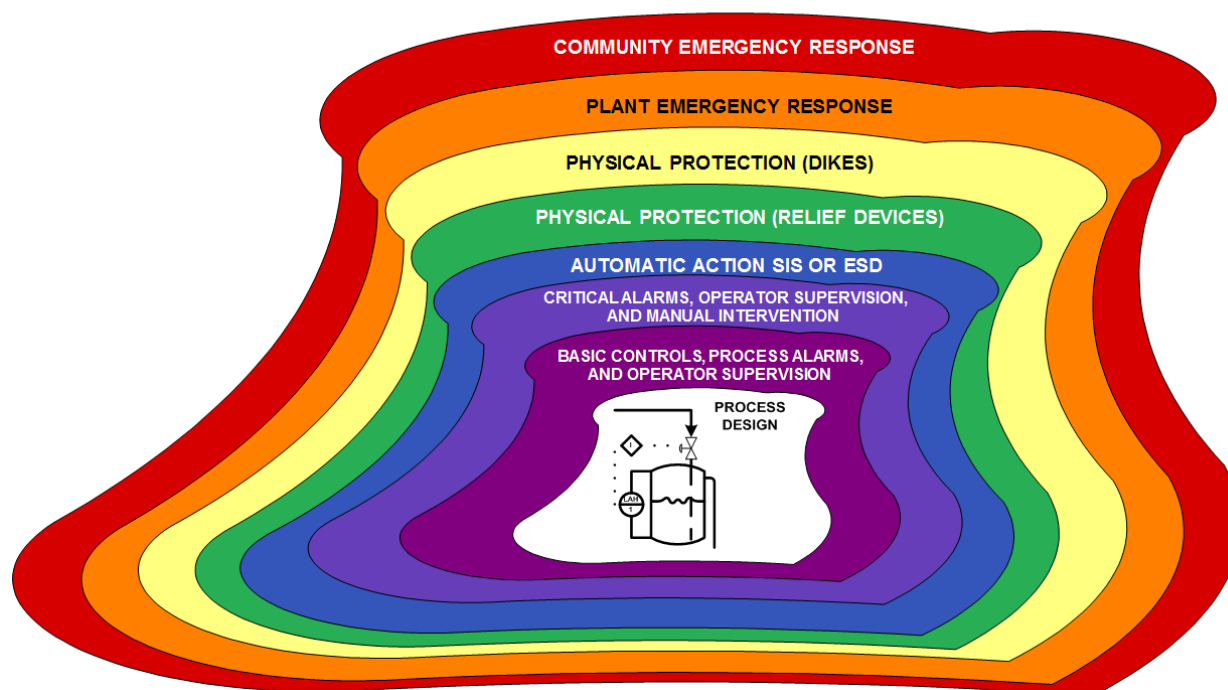
2.7 WHAT IS PROCESS SAFETY MANAGEMENT (PSM) AND WHAT ARE BEST PRACTICES IN PSM

Process Safety Management (PSM) is a collection of management systems and their implementation intended to control the risk of major accidents. PSM focuses on preventing the accidents that originate from process hazards (such as release and explosion of flammable gases or liquids, release of toxic materials, etc.).³⁶ This differs significantly from **occupational safety**, which focuses instead on preventing personal injury to workers from activities related to a task (such as getting particulate in eyes, injury from a falling object, falling from heights, etc.). PSM systems have been in place for more than 40 years in the toxic chemical industry, with the first formal industry-wide standard (covering refineries as well) being issued by the CCPS in 1985.³⁷

PSM must be coupled with process safety engineering, which is the design of equipment to meet the needs of controlling process safety. In some cases, process safety engineering can yield a process that is inherently safe (meaning, the hazard has been eliminated or cannot credibly cause an accident of concern). Process safety is very different from occupational safety in that process safety issues typically arise from the nature of a complex process. Because of the nature of the hazards of such processes and the equipment and design used in such processes, it is possible to design and use multiple protection layers against many accident scenarios. The exceptions to the multiple layers of protection concept are mechanical failures of piping, vessels, or components because of damage mechanisms such as corrosion, erosion, stress cracking, metal fatigue, etc.

Many types of protective layers are possible. A scenario may require one or many protection layers depending on the process complexity and potential severity of a consequence. Note that for a given possible accident scenario, only one layer must work successfully for the consequence to be prevented. However, since no layer is perfectly effective, sufficient protection layers must be provided to render the risk of the accident tolerable. For scenarios such as overpressure, over-temperatures, overflows, blowdown of high-pressure gases and liquids to low-pressure rated systems, etc., the multiple protections can include the ones shown in the following figure:³⁸

Layers of Defense Against a Possible Accident



Extracted from *Layer of Protection Analysis (LOPA)*, 2001, CCPS/AIChE

So, one goal of process safety is to design and provide enough layers of protection and then maintain each layer sufficiently to assure that the risk of the accident is tolerable.

From the start, there was strong emphasis on human factors within process safety, since Human Factors was one of the original 12 elements of the CCPS 1985 standard.³⁹ CCPS revised their PSM standard in 2007, renaming it *Risk Based Process Safety (RBPS)*⁴⁰, and now instead of one global element on human factors, the direct control of human factors is spread throughout six elements. Unfortunately, not having a specific element titled “Human Factors” likely diminishes its importance for those companies that are not very familiar already with human factors. For example, if there were an element specifically focused on human factors, then industry would likely invest more in research of how to optimize human factors, how to avoid miscommunication, how to optimize displays, researching the best rules for designing human system interfaces, and researching the best rules for writing work instructions.⁴¹

Private industry and research bodies (including universities) are conducting research on some of these human factors, but to date most of the current data has come from the nuclear power industry, U.S. Department of Energy, aviation industry, and various militaries around the world.

The RBPS elements that address many of the human factors are:

- Process Safety Culture
- Workforce Involvement
- Operating Procedures
- Training and Performance
- Operating Readiness
- Conduct of Operations

The PSM standard that was issued by U.S.OSHA (29 CFR 1910.119) in 1992 (and has been essentially unchanged since) and the parallel U.S. Environmental Protection Agency Risk Management Plan (RMP) regulations (and identical Cal ARP standards) contain many of the core elements of process safety, such as operating procedures and requirements for process hazard analyses (PHAs). However, these two regulations are missing many critical elements addressed in the CCPS standard. For instance, neither regulation specifically requires elements for the control of human factors. The only direct reference to the term “human factors” is mentioned in paragraph (e), PHA, which states that the PHA team must consider human factors (presumably in the review of the causes and the quality of the safeguards). The other requirement that alludes to human factors is in Operating Procedures (see paragraph (f)), which states “procedures must be written clearly and understandably.” Paragraph (g) defines standards for training but does not directly address how to design training programs to address control of human factors.

In summary, PSM systems based on compliance with OSHA’s PSM and EPA’s RMP regulations (and based on API Recommended Practice 750, the PSM standard that immediately preceded the government regulations) control human factors mostly through the operating procedures, training, and PHA element requirements. These regulation-based and API-based PSM systems typically lack the fundamental human factors controls that work together to reduce human error.⁴²

In addition to limited focus on human factors, the OSHA PSM and EPA RMP regulations and API PSM standard do not have elements for:

- Leadership and Accountability
- Project Management
- Facility Siting
- Key Performance Measurement & Tracking

These elements are necessary for any complete control of process safety.

- End of Section 2, Introduction -

3 SCOPE AND APPROACH

3.1 OVERVIEW

Process Improvement Institute, Inc. (PII) conducted this evaluation in parallel with the Industrial Safety Ordinance (ISO) and California Accidental Release Prevention (Cal ARP) Program audits conducted by the CCHMP every three years. To minimize the impact on refinery staff and operations and to optimize data collection and staffing requirements, PII staff worked in close coordination with CCHMP staff to review documents, interview subject matter experts, obtain field observations, and conduct safety culture interviews. PII also oversaw the administration of a written safety culture survey for Chevron and contractor personnel. Any potential regulatory compliance issues were referred to CCHMP for determination. Any potential issues related to best practice management systems, safety culture, and those human factors not covered in the county ISO were referred to PII for determination.

Three to four PII staff were on-site each day for a total of four weeks. An average of two CCHMP staff per day provided supplemental support while PII was on-site and completed additional assigned tasks when PII was not there. This provided additional data collection capabilities. It also offered an opportunity to cross-train CCHMP staff in process safety culture evaluation, horizontal auditing methods, and procedure/human-factors walk-downs in the field.

The evaluation team developed and carried out the following plan to do this process safety evaluation:

- Multiple visits through units with Chevron Richmond Refinery personnel by PII personnel
- Interviews of a randomly selected sample of refinery personnel
- A written process safety culture survey conducted among Richmond Refinery employees and contractors (based on the Baker Report survey, which was developed after the large accident in 2005 at the BP Texas City Refinery)
- Targeted document reviews (to accomplish an evaluation, not an audit)
- Comparative evaluation of Richmond Refinery policies and practices to refinery and chemical industry best practices
- Meetings with Chevron Richmond PSM leadership staff

PII acknowledges Chevron Richmond's cooperation and assistance throughout this evaluation process.

PII and CCHMP staff wanted to understand WHAT the refinery does to control process safety, WHO does what in process safety, and HOW they use data to track process safety performance. The evaluation team sought to understand the WHY behind observed deficiencies in process safety performance to make recommendations that can enable Chevron Richmond to improve their performance.

As chartered to do, the team from PII typically based its findings and recommendations on industry best practices for reducing the risk of catastrophic accidents. "Industry" in this case means all industries with high hazards. Some best practices cut across dissimilar industries; for instance, all industries have to deal with human error and management of human factors to reduce human error rates; so best practices for human factors tend to have more sources. On

the other hand, best practices for mechanical integrity and process hazard analysis tend to be more industry-group specific.

Note that many industry standards and textbooks are referred to as Recognized and Generally Accepted Good Engineering Practices (RAGAGEP). However, many times RAGAGEP is actually “what the companies will agree to put in print” and are not always best practices. Adherence to best practices should result in improved process safety performance. However, note that many best practices and RAGAGEP do not necessarily have legal effect. The team’s judgments are based on the information developed during the course of this safety evaluation, the collective experience and expertise of the evaluation team members, and their understanding of best practices for process safety, human factors, and safety culture.

3.2 WORKGROUP DEFINITIONS

The following Workgroup definitions will be used in this Safety Evaluation report:

- Management – refinery leadership team, managers and supervisors
- Non-represented employee – technical (including engineers), office, and other staff
- Represented employee – operators and maintenance craft employees with third-party (union) representation
- Contractors – non-Chevron employees authorized to conduct activities at Richmond Refinery long-term and short-term.

3.3 EVALUATION OF MANAGEMENT SYSTEMS AND HUMAN FACTORS

PII evaluated the refinery’s management systems and human factors through technical interviews with Chevron Richmond Refinery subject matter experts, live navigation of refinery database systems, reviews of electronic and paper documents, field walk-downs of operating procedures, field verifications of PHA recommendation closures, demonstration of response to alarms, observation of shift exchange, observation of control room human factors, observation of control board operator simulator training, and observation of PHA sessions. These activities are summarized in the adjoining table and further explained in the following information:

SME Technical Interviews: *Subject matter expert (SME) interviews are with individuals responsible for specific processes, policies, and programs.*

Operating Procedure Walk-downs: *A walk-down analysis of a significant operating task explained and demonstrated by an operator who is familiar with and routinely performs this task. The analysis includes an evaluation of procedure accuracy (Are steps accurate? In the correct sequence? Complete?), procedure quality (Easy to keep your place? Clearly understood steps?), and general human factors (equipment and controls layout, labeling, functionality, equipment design, work environment).*

Live Navigations of Databases: *Interactive, guided review of databases and other online resources looking for specific supporting evidence of items such as inspection, test, and*

On-Site Data Collection Activities: Management Systems and Human Factors	
Refinery SME Technical Interviews	65
Operating Procedure Walk-downs	38
Live Navigation of Databases	16
Shift Exchange Observations	2
Control Room HF Walk-downs	6
Alarm Response Demonstrations	16
CBO Simulator Training	1
PHA Recommendations Verified	28
PHA Sessions Observed	2
PHA Reports Reviewed	14
Total Documents Received	1,242
Document Pages Received	~17,000

preventive maintenance (ITPM), inspection records, SOPs, Contractor Reviews, and Training Materials. Many of the instrumentation and mechanical features searched out were taken from the Cause and Safeguard entries in the corresponding Unit's PHA.

Shift Exchange Observations: Live review and evaluation with operations personnel of the shift exchange process including checklists, document reviews, control panel walk-downs, facility status discussions, and general briefings using a Shift Turnover Checklist adapted from DOE-STD-1038-93 Guide to Good Practices for Operations Turnover.⁴³

Control Room HF Walk-downs: Live review with control board operators evaluating control system human factors such as graphical user interfaces, system grouping and control, alarm management policies, and interlock bypassing protocol.

Alarm Response Demonstrations: Live evaluation of operator response to critical alarms drawn from high consequence scenarios identified in the process hazard analysis (PHA) report. The evaluation includes situational awareness, required response, process safety time (PST), training, drills, and process feedback.

3.4 EVALUATION OF PROCESS SAFETY CULTURE

PII evaluated the refinery's process safety culture through a combination of field/site observations and discussions, structured interviews, and a written survey. The adjoining table summarizes these data-collection activities. They are listed in the order of value (importance) of the data in making a determination of the strength (health) of the process safety culture at the Chevron Richmond Refinery.

On-Site Data Collection Activities: Process Safety Culture	
1. Field Observations and Verifications (Site Data) Related to Process Safety Culture (see Table 1)	>17,000
2. Safety Culture Individual Interviews	96
3. Written Process Safety Culture Surveys:	
• Represented Workers	489
• Individual Contributors	350
• First and Second Line Supervisors	175
• Managers	61
• Other/Non-Data	120
• Total Surveys Completed	1195
• Overall Response Rate	54%

3.4.1 Field Observation (Site Data)

Field observations are considered the strongest process safety culture indicators (1) since safety culture is, as mentioned earlier, what the site/company actually does and (2) since this data is derived from actual implementation of process safety programs and can be observed (verified) with limited bias.

3.4.2 Individual Interviews

Safety culture interviews are considered a stronger measure of process safety culture than the written survey, because, unlike surveys, the interviewers can follow initial questions with more questions to gain clarity and to get specific examples from the interviewees. Participants for the safety culture interviews were randomly selected from a blind (names redacted) list of Chevron Richmond Refinery employees. A representative sample was drawn from each of four categories: (1) operations, (2) maintenance, (3) technical, and (4) managers/supervisors. Refinery employees were given the opportunity to decline participation, and many declined. When this occurred, an alternate employee was selected from the blind list.

Each interview was conducted by a staff member (PII or CCHMP) trained to ask questions (introduction, open-ended questioning, active listening, covering a list of key issues, asking for

examples) with minimal interviewer bias (avoid judgment and approval, stay neutral, stay on task by reframing questions and asking for examples of the point made by the interviewee).

In some cases, third parties were present to observe and document the interview process. Salaried employees were asked if they wanted a CUSA legal representative present. They were also given the opportunity to have a pool attorney or their personal legal counsel present. Most salaried employees chose to have a CUSA lawyer present. Represented employees were also given the option to have a union representative present. Most hourly employees chose to participate in the interview without representation. CUSA legal staff was not in interviews with hourly (represented) employees.

There were seven (7) general categories of interview topics for each interview:

- Accountability (are responsibilities well defined, the challenges for meeting them)
- Learning (employee and trainer competence, time allocated to training, too much, too little, scheduling and cancellations)
- Corrective action program (issues are addressed, responses timely and appropriate)
- Commitment (stated and demonstrated management support, importance of process safety, employee personal involvement)
- Reporting and the environment for raising concerns (near misses, willingness, practices, hesitation, and retaliation)
- Change Management (refinery reorganizations, organizational change planning and preparedness, effective implementation)
- Work control, work practices (empowerment, being able to stop processes, direct instructions, procedure quality)

Specific discussions within each category were left to what the employee wanted to discuss about the process safety implementation and therefore safety culture of the refinery. The interviewer ensured that each 1-hour interview covered all seven general categories.

3.4.3 Written Process Safety Culture Surveys

PII based the written process safety survey primarily on the instrument used by the Baker Panel in evaluating safety culture at BP following their catastrophic accident in March 2005. The written survey questions were reviewed and minimally customized to better align with Chevron Richmond-specific terminology and organizational structure. Towers Watson (TW) formatted the surveys onto paper and for access from the Internet via computers from work, home, or iPad (the latter provided by PII for this purpose). TW administered the surveys for five weeks and collected the data. TW was directed by all parties to make sure only Richmond Refinery employees and contractors participated in the survey and that the unique identifier of each participant was not identifiable to a specific response. PII received the raw data from the survey after the unique employee identifiers were stripped from the data set.

3.5 DATA COLLECTION PROCESS AND LIMITATIONS

It is important to note that Chevron staff continued to be generally cooperative and responsive throughout this evaluation. However, given the nature and significance (breadth) of ongoing inquiries being made in other investigations during this Process Safety and Safety Culture Evaluation, multiple factors influenced and limited our data collection process.

3.5.1 Document Request and Auditor Review Process

To address Chevron USA confidentiality practices for this safety evaluation, an electronic database was established where requested documents were made available for PII staff's review through a secure web login process. A formal document request process was implemented in which PII auditors made a written request for a specific document (information) or group of documents. The requested information was reviewed by CUSA's legal team, converted into an electronic format, and posted to the Richmond Safety Evaluation document data site. Information requests were generally fulfilled within three business days, although miscommunication using the written request procedure resulted in frequent errors and subsequent retries, delaying posting of the requested documents.

Once posted, documents were available to PII staff for electronic review as images on a page-by-page basis. Navigating within the web-based data site contents (>17,000 pages) page by page increased auditing review time significantly. Collection of (and conventional review of) data site documents was restricted – downloading, printing, copying, notations/mark-ups, sorting, and collective search features were not activated. A document (information) index was maintained on the CUSA data site to catalog these document requests. The data site's unwieldy document numbering method also increased the time it took auditors to locate a specific document.

Process safety tracking information was available online in various Chevron Richmond Refinery databases: CHESM, IMPACT EOM, MOC/PSSR, Meridium, Maximo, and Active Learner. PII reviewed these databases with advance scheduling for "Live Navigation" meetings with Chevron subject matter experts (SME) and a CUSA legal representative. Screenshots were not provided immediately but they were made available for review afterward through the formal document request process; these were uploaded to the data site mentioned above.

These factors made it time-consuming to obtain and review Chevron Richmond Refinery process safety management and safety culture data. CUSA legal representatives accompanying auditors' data collection activities and Chevron legal staff's document review before granting access to auditors were also factors when considering potential bias in and limits to the data collected.

3.5.2 Individual Safety Culture Interviews, Random Selection Process

PII auditors requested individual interviews based on an employee list provided by CUSA, which contained only information about job positions and roles. Employees' names were redacted and unavailable to auditors. PII used a random number generator to request the specific individuals from the list, and CUSA management representatives contacted these people to arrange the interviews.

Individuals were informed that the interview process was voluntary and that they were not required to participate. Many of the first-selection operators and maintenance employees (about 75%) were either unavailable due to scheduling or chose not to participate; reasons for declining were not disclosed to PII. When this occurred, CUSA staff chose alternates from the random list provided by PII. The high number of operators and maintenance employees declining to participate in individual safety culture interviews could be an indicator of (1) problems in the process safety culture (e.g., lack of employee buy-in to programs, lack of local management support, or fear of retaliation), or (2) burnout by the employees after repeated interviews from other investigations in the past 1.5 years.

3.5.3 Third-Party Influence on the Field Data Collection

CUSA Richmond management representatives, union representatives, and third-party process safety consultants (other than PII or CCHMP staff) were present at various times while PII (and CCHMP) staff walked down operating procedures. In some cases during walk-downs, CUSA salaried staff actively coached operators in their response to questions. In other cases, there was no direct interaction, but it was apparent to auditors that the presence of CUSA Richmond management representative(s) caused operators to be more guarded and reserved about the information they shared. The influence of union representatives did not appear to inhibit operator responses. Generally, union representatives encouraged “frank, free, and open” discussion of any concerns, but their influence on safety evaluation data collected remains difficult to accurately gauge. These third-party influences diminished over time as the audit process matured and higher trust was established. Eventually, CUSA Richmond management representative(s) and union representative(s) maintained distance and participated in field discussion(s) only when asked.

The third-party process safety consulting staff, contracted by Chevron, participated during the first and second weeks of on-site data collection by PII auditors despite PII staff’s objections. During the third and fourth weeks of operating procedure walk-downs in the field, one CUSA Richmond management representative was assigned as a “safety” escort for auditors with one or no union representative present. Note that operators told PII staff that, in the past, they had themselves been the “safety” escort for their units. Chevron stated that they wanted management representatives present to ensure a safe over-watch, since the unit operators were distracted while sharing data with the auditors.

In the last two weeks of walk-downs in the field, management representatives kept their distance and did not seem to influence the data collected. Procedure walk-down data that auditors collected during the second two-week period (with only one management representative present as a safety escort) indicated about the same result in procedure accuracy as the data collected in the first two weeks, when company attorneys, management, and third-party Chevron-hired consultants were all present. This finding supports use of data collected during the first two weeks of procedure walk-downs, notwithstanding potential third-party influences.

CUSA legal representatives were present in 15 out of 16 database live navigations, all the Richmond SME technical interviews, and all the non-represented staff safety culture interviews. Non-represented staff attended private individual meetings before each interview – PII staff was not allowed to participate in or observe these preliminary meetings. PII was told that non-represented staff were asked if they wanted a CUSA attorney present, and all accepted this offer. Non-represented employees were also given the opportunity to include their own “private” attorney in the interviews or data collection. The few non-represented SMEs that were provided access to a Chevron-paid “pool attorney” (to represent the interest of that non-represented SME) chose to have a pool attorney present for their interviews by PII and CCHMP staff. Those who were not provided a pool attorney did not have a private attorney present, with the exception of one manager who had retained his own attorney.

PII was told that the non-represented employees were not told specifically that the Chevron attorneys represented Chevron’s interest and not the employee’s personal interest. (The attorneys work for Chevron. They were not legal representatives for the employees.) Represented employees were asked if they wanted a union representative present, and most declined. All employees were told that their participation was voluntary and that they could decline to participate without retribution. According to CUSA Richmond management, about 75% of the operators and maintenance staff (initially selected at random by PII to be interviewed) declined (discussed earlier See 3.5.2).

3.5.4 General Fulfillment of Interviews, Walk-downs, Control Room Visits, and General Data Requests

CUSA Richmond management complied with PII's specific requests for access, information and documents, providing controlled access within two to three days in most instances (note previous discussion; see 3.5.1). CUSA staff members provided excellent coordination of daily schedules for PII staff with refinery staff. This coordination was better than similar situations we have experienced elsewhere.

CUSA Richmond management provided technical staff to help in the implementation of the Safety Culture Survey. Process Safety Culture written survey logistics were initially complicated by technical issues with Internet connections and limited access to iPads (provided by PII) for entry of data. By the second and third week that the survey was online, these issues were remedied, and the survey period was extended one week (to a total of five weeks) to allow more staff to participate. Survey technical issues did not seem to affect Safety Culture survey results.

3.5.5 Constrained and Guarded Responses

During many of the interviews with non-represented employees, employee responses appeared to be constrained and guarded. PII auditors have extensive experience conducting interviews for near miss investigations, incident investigations, and safety audits. Based on this experience, we perceived barriers to freely exchanging information during these interviews. Potential barriers may be because of:

- The content of the individual meetings with Chevron legal staff before each interview (See 3.5.3),
- The presence of CUSA legal representatives during the interview (does not apply to represented employees),
- The presence of the PII or CCHMP staff conducting the interviews,
- Concern about pending legal and regulatory actions against the refinery,
- The potential for personal liability, or
- The perceived potential negative impact on their careers, or other reason(s).

Regardless of the reason (barrier) for the perceived reluctance to openly share, responses from non-represented employees may reflect some bias because these staff were very cautious in what they said.

Many operators and maintenance staff expressed mistrust of how the survey results would be used, citing the potential to negatively impact their jobs in the future. CUSA Richmond management and PII interviewers clearly communicated that participation in the written survey was voluntary and anonymous. Some employees expressed concerns about survey anonymity with survey results and activity routed through the CUSA network. Therefore, PII supplied iPads through which employees could take the survey. They could also complete it via home computers. Union representatives and staff were actively supportive, encouraging represented workers to participate, to be forthcoming with information, and to trust the validity of the data collection and survey process.

3.5.6 Overall Limitations of Data Collected and Results

The evaluation team wants to clarify what its findings do and do not represent. The data collection process was designed to achieve the objectives of a safety evaluation. This report presents findings and provides recommendations to assist Chevron Richmond Refinery and CCHMP to address gaps that PII identified after reviewing a representative number of documents, field observations, live operating systems/data and management practices. As described earlier, Chevron provided specific documentation and access to information based on

PII requests for examples of PSM documentation. This project was not scoped to conduct an extensive audit of the Richmond Refinery Process Safety Management system(s) and should not be interpreted as such.

Data from the process safety culture written survey is subject to the limitation that it reflects the opinions, beliefs, and impressions of the respondents (note Section 3.5.2 discussion earlier), especially since there was not an opportunity for respondents to ask for clarifications of questions nor for the reviewers to ask follow-on questions of the respondents.

The refinery information that the PII team considered reflects varying degrees of ambiguity and interpretation on the part of PII professionals. While addressing this project's scope and developing these report findings and recommendations, the review team does not/did not try to provide exhaustive proofs and does not/did not attempt to eliminate all factual ambiguities encountered during this review.

- End of Section 3, Scope and Approach -

4 EVALUATION AND FINDINGS

4.1 PROCESS SAFETY MANAGEMENT SYSTEMS

According to the Center for Chemical Process Safety (CCPS), a division of American Institute of Chemical Engineers (AIChE), a process-safety management system is “focused on prevention of, preparedness for, mitigation of, response to, or restoration from catastrophic releases of chemicals or energy from a process associated with a facility.” Furthermore, “management system” means, “a formally established and documented set of activities designed to produce specific results in a consistent manner on a sustainable basis.” [“Guidelines for Risk Based Process Safety”]⁴⁴ Process Safety Management systems are comprehensive sets of policies, procedures, and practices designed to ensure that barriers to episodic incidents are in place, in use, and effective.⁴⁵

The OSHA PSM standard, 29 CFR 1910.119, defines the minimum regulatory requirements. It contains 14 elements that must be addressed. There are parallel requirements in U.S.EPA 40 CFR 68 (and nearly identical regulations in Cal ARP requirements enforced by the CCHMP). PSM federal and state regulations are missing many key elements of best practices in process safety, as discussed in Section 2.5. This Safety Evaluation for the Chevron Richmond Refinery is based on industry best practices, many of which are documented in *Risk Based Process Safety*. These best practices extend beyond the minimum foundation of PSM found in the federal and state regulations. CCHMP staff conducted an assessment at the same time as this safety evaluation. Any compliance deviations they found were documented separately by CCHMP from this Safety Evaluation.

4.1.1 Leadership, Vision and Goals Alignment

Competent and active process safety leadership is vital to ensure that risks are effectively managed. Process safety leadership requires senior–management-level involvement and process safety proficiency at all levels of the refinery organization. Further, management vision, visibility and promotion of process safety leadership is essential to set a positive and proactive safety culture throughout the organization.⁴⁶

Over the past 20 years, the refining industry has experienced numerous process safety incidents resulting in significant loss of life, environmental pollution, and property damage. Studies by the refining industry, government agencies, petroleum associations, and independent think tanks determined that leadership is a

<i>Process Safety Management vs. Process Safety Leadership</i>	
<i>Process Safety Management – implements systems and controls in PSM compliance. Follows the basic management directives to Plan, Organize, Direct, and Control.</i>	<i>Process Safety Leadership – implements best practices to create, share, align, and achieve the vision of the company. Inspire and motivate people to achieve excellence, empower people to engage, participate, and contribute to the organization's success, and ensure accountability through clear roles and consequence.</i>
<i>Managers do the RIGHT things!</i>	<i>Leaders do the RIGHT things RIGHT!</i>

key issue in managing process safety and preventing incidents at refineries and chemical plants. Success in any performance variable (process safety, personal safety, reliability, environmental performance, profitability, etc.) requires consistent and visible leadership. Leadership also requires that individual employees hold themselves accountable, and once established, hold coworkers accountable for driving process-safety performance improvement.

The most important role of a good leader in a site comprised of experienced and skilled staff is to instill trust. People look to their managers, not just to assign tasks, but also to define for them

a purpose. Moreover, managers must organize (energize, empower) workers, not just to maximize efficiency, but also to nurture skills, develop talent and inspire results.

The CUSA Richmond Refinery recently received new leadership with a new General Manager (GM) on June 2013. He also held a supporting role at the refinery during on-site audits conducted in January 2013. He has worked in various positions throughout the corporation. He brings 28 years of experience in Maintenance, Operations and Commercial divisions within the company, including prior experience at Richmond.

Several members of the refinery's leadership team are also relatively new in their roles, although each brings significant experience and expertise. Additional organizational changes are underway at all levels of management (as of late 2013). The most prominent organizational change is the addition of an Optimization Operations Assistant (OOA) to the shift leadership structure, allowing the Shift Team Leaders (STL) additional time in the field to focus on face-to-face communications.

A significant increase in professional hiring is also continuing as the HSE, PSM, MI, and engineering departments expand to meet requirements for the refinery's process safety goals and objectives. At the time of this safety evaluation, many of the technical and supervisory staff interviewed were in newly created roles, implementing new business processes and procedures.

According to the GM, the current reorganization pairs experienced and well-respected leaders with technically adept (but many times, less experienced) personnel to complement and learn from one another. Changes in the STL/OOA positions are a good example of this: A technical representative from process engineering may be teamed with an experienced operator to ensure that all aspects of the STL/OOA role are covered (plant credibility and expertise, technical competence, and personnel focus). Similar deployments are taking place in other areas of process safety implementation. Technical roles will periodically rotate (every two to three years) with the idea that they will grow into management positions in the future (ensuring that these are seen as mission critical roles). Non-technical roles will ensure stability and credibility in key leadership positions. The current organizational transition was to be completed by first quarter of 2014. PII has not yet collected new data on the status.

Frequent changes in leadership have been cited numerous times across the refining industry as a detrimental factor to process safety. This has resulted in a variety of problems. These include:

- Low trust,
- Poor communication,
- Frequent and shifting changes in direction and priorities,
- Inconsistent goals and objectives, and
- Questionable decisions based on short-term gains rather than long-term risk management at a refinery. (CSB Report, BP Texas City)⁴⁷, (Baker Report)⁴⁸

Interviews with refinery leadership, staff, and employees show significant confidence in most members of the current leadership team. The new GM has clearly defined the company's vision, and communicated refinery goals and objectives through a variety of different means. Some of the more visible organizational changes, such as the STL/OOA roles, PSM, Learning & Development (L&D), and MI staffing, are broadly understood, supported, and welcomed.

Focus has been maintained through the Operational Excellence Reliability Intelligence (OERI) metrics and key performance indicators (KPI) dashboards. In addition, a noticeable improvement in informal communications has occurred via town hall meetings, face-to-face discussions, and management's visibility in the units.

Alignment with this vision is improving, but it is not yet 100%. In the Safety Culture Interviews, feedback received from hourly and salaried staff showed distinct differences (see section on

Process Safety Culture). Many represented employees are encouraged by recent leadership actions, but skepticism remains. This is particularly evident with union leaders, where trust remains to be established (as of late 2013). Represented employee survey responses and individual interviews indicate that some managers, supervisors, and engineers still do not listen to or encourage input from hourly employees.

These differences in perspective between represented employees and management may stem from several factors. These could include differences in access to and communication with refinery leadership, understanding of refinery goals, or an employee's past experience with changes and events at the refinery (e.g., some said, "What management says is not always what management does"). Many of the salaried employees interviewed were new employees who do not have the same history and longevity as their hourly counterparts. Also, note previous discussion: 3.5.5 Constrained and Guarded Responses.

This organization is clearly in a state of transition. Much has occurred over the last 18 months (as of late 2013). The ultimate success of, and the long-term commitment to, the current leadership plan remains to be seen.

Some specific deficiencies noted by PII related to documentation of the recent organization changes are:

- The review team noted that an action item from the Richmond Refinery Chevron Corporate internal RISO Audit Report (2013) reported that the refinery organization chart needs to list current Process Safety Sponsors (including newly added RISO process safety elements)
- The review team noted that an action item from the Richmond Refinery Chevron Corporate internal RISO Audit Report (2013) reported that the 2013 Site Safety Plan did not include new process safety elements added per RISO.

Chevron Richmond Refinery staff say they will track these action items to closure.

4.1.2 Employee Involvement in Process Safety Management

The OSHA PSM standard⁴⁹ requires that employers develop a written action plan for the implementation of employee participation, consult with employees and their representatives on the conduct and development of process hazard analyses and development of other elements of process safety management, and provide to employees and their representatives access to process hazard analyses and to all other information required to be developed.

CUSA Richmond appears to go beyond these minimum PSM requirements in many areas. Policies and Refinery Instructions establish safety committees, such as the Joint Safety and Health Committee, the Human Factors team, and the PSM Steering Committee, on which employees may participate. There are also two union sponsored Triangle of Prevention (TOP) representatives, two full-time union Health and Safety representatives, and numerous others on special assignment who participate in procedure writing and review, training, process hazard analysis, MOC hazard evaluations, and incident investigations. All employees undergo annual training and retraining in roles related to process safety topics, and all operators are involved in monthly "hypotheticals." These are table-top drills that test and review their ability to respond appropriately to an emergency.

Employees are also actively involved in occupational safety oriented programs such as the Loss Prevention System (LPS), the Incident and Injury Free program (IIF), Loss Prevention Observations (LPO), Stop Work Authority (SWA), and near miss reporting (Green Cards).

Document reviews and interviews indicate that CUSA's PSM program would benefit from a larger cross-section of operation and maintenance employees participating in PSM activities.

Currently, the same represented employees participate in multiple activities. For example, hourly employee participation in PHAs is often by special assignment trainers who keep their positions for three years. PHAs would be an excellent opportunity to involve a broader cross-section of SMEs in process safety related processes.

Stop Work Authority is a widely used and highly regarded process at Chevron Richmond. SMEs and represented workers verbally provided numerous instances where the SWA was used effectively for tasks that involved personal (occupational) safety concerns. Written examples show examples of such SWAs as well. They gave no examples (verbally or in writing) of SWAs used for process safety considerations (such as for preventing a process from starting back up or to shut down a process). (This is also true for most other process plants audited by PII where a program similar to SWA was in place.) CUSA's PSM program would benefit with increased application of the SWA program for process safety near misses.

Richmond has a 20-year history of having operator hourly employees in departmental PSM leadership roles such as the WPIA (Work Process Improvement Coordinator). The WPIA assists with MOC hazard reviews, ensures accuracy of updates to MOC process safety information and PSSRs. Selected hourly employees write and validate operating procedures and conduct periodic audits.

The most effective organizations provide a broader range of opportunities for employees to become involved in process safety activities. Some organizations provide advanced PSM training and then assign hourly employees in departmental PSM leadership roles to lead MOC hazard reviews and PSSRs, write and validate operating procedures, conduct periodic audits, and lead incident investigations (loss and near loss incidents). At least one refinery has found success in a 2-year rotation of one operator from each unit into a PSM support role that includes procedure writing, MOC leadership, and PHA of procedures.⁵⁰ Chevron should consider involving more operators and maintenance employees in WPIA assignments, in MOC hazard reviews, and in ensuring maintenance and operating procedures are accurate. Chevron should also consider involving more hourly employees in leading investigations of incidents (loss and near loss incidents).

Identifying a potential process incident before it occurs and preventing the incident requires a high level of participation by hourly employees and SMEs. Effective organizations establish a goal in the range of 20-100 for the ratio of near loss to loss incidents (10 to 50 times the current rate at the Chevron Richmond Refinery). These organizations manage the increased investigation load by training 15% of their staff (primarily hourly employees) to lead and participate in investigations. To promote wider employee participation (buy-in), management establishes a barrier-free incident reporting process, which specifies that discipline will not be administered as the result of a loss or near loss investigation (except in the rare case of sabotage or intentional cause of harm).⁵¹

Recommendation 1

CUSA Richmond should expand operators' and maintenance craft-persons' involvement in leading roles in process safety activities. Increase the number of operators and craft-persons involved in these activities, too. For example, involve more operators and maintenance crafts-persons in:

- **Writing and validating procedures,**
- **Leading process hazard evaluations of small MOCs,**
- **Participating in PHAs (particularly using a broader selection of operators), and**

- **Leading incident investigations.**

4.1.3 Process Safety Information

Site-wide, PII found Piping and Instrument Diagrams (P&IDs) to be up to date, accurate, well used, and well understood by operations staff. Following any maintenance or project activities, operators conduct independent operational readiness reviews before start up, a practice commonly known at the refinery as “Yellow Lining.” Any corrections necessary are immediately sent to engineering to be updated. PII found this practice to be consistent across all operating areas and business units.

PII found process safety information (such as operating procedures, safe operating limits and consequences of deviation, material safety data sheets, drawings, and equipment specifications) to be readily available to the operators by both paper and electronic systems available in the control rooms. There was ample evidence that these documents are easily accessible and frequently used. (Note: see sections 4.1.4 through 4.1.7 for additional comments addressing Process Safety Information)

Based on review of MOC documents and interviews of SMEs, CUSA does not update PSI (i.e., modified P&ID of record) while a temporary change (MOC) is in effect. Temporary changes can be in effect for various periods. Therefore, the changes for active/open MOC #1 must be available/archived in a manner that ensures future MOCs (i.e., #2, #3, which are evaluated for implementation) identify and reflect changes in effect for MOC #1. RI-362 section 5.1 states, *“Changes that impact existing Process Safety Information will trigger the Management of Change Process (MOC). This is done to ensure that modified PSI remains current and is available.”* RI-362 Appendix I should be amended to include both “active” and “archived” MOC documentation. Additional criteria (guidance) is needed to address how redlined P&IDs and other MOC-modified PSI are archived, and readily available site-wide while a temporary MOC is in effect. RBPS provides related examples in Sections 15.3.3 and 15.4.3.

Recommendation 2

To avoid losing track of temporary changes, improve the redlining process for the Master P&IDs used in the field. Further, improve RI-362 “Process Safety Information” to include criteria for handling all in-process (active) and archived (closed) MOC-modified PSI (i.e., P&ID originals) while a temporary MOC is in effect. RI-370 “Management of Change” may need parallel changes.

4.1.4 Process Hazard Analysis

A process hazard analysis (PHA) is one of the most important, fundamental elements of the process-safety management program. (OSHA 3133 PSM Guidelines for Compliance)⁵² When used effectively, the information developed in a PHA (potential process deviations, failure scenarios, consequences, and safeguards) provides a solid basis for decisions that affect all other elements of the process-safety management system.

The PHA team analyzes potential causes that can lead to severe consequences such as fires, explosions, releases of toxic or flammable chemicals and major spills of hazardous chemicals. The PHA focuses on equipment, instrumentation, utilities, human actions (routine and non-routine), and external factors that might affect the process. The information is necessary to ensure that good decisions are made to improve process safety and minimize potential failures. A systematic and detailed review of the potential causes of deviations and the necessary safeguards helps to identify process and mechanical weaknesses. Understanding these potential failure modes helps build effective inspection test and preventative maintenance (ITPM) plans to enhance mechanical integrity and reliability. The team should review operating

procedures and troubleshooting guides for potential human errors and discuss appropriate response measures, including an evaluation of the process safety time available for operator intervention. This leads to improved operating procedures and additional measures designed to improve human performance and minimize failures.

PII staff reviewed 14 documented PHAs at CUSA Richmond and conducted a horizontal review of nine PHAs. A vertical review evaluates the quality and completeness of the PHA (and determines if recommendations have been closed or resolved). A horizontal review, in contrast, uses the PHA as a starting point to see if the critical features in the process (as identified in the PHA report) are being maintained appropriately to achieve acceptable safety and reliability factors. In this case, the horizontal review identified a sampling of critical (related to avoiding a high consequence) component features and human response features (these features included both causes and safeguards) to determine if these are being properly maintained.

PII determined that there is an effort to perform a thorough PHA of existing plants in a timely manner. An expert PHA Team Leader position was recently added to the PSM team to manage all aspects of Existing Facility and Project PHAs. The PHA Team Leader is responsible for facilitators, scribes, management of documents, and contractors that are hired as team leaders and scribes. The PHA Team Leader is the liaison for the refinery. This position is also responsible for scheduling PHAs and managing the PHA recommendations.

The PHA team member qualifications specified and observed in CUSA PHA Instruction RI-363 are consistent with best practices.⁵³ PHA Team requirements include:

- Facilitator must have 10 years operational experience and corporate training course completion (these are also requirements for contractors).
- Scribe (no technical requirements) using PHA Pro for recording PHA.
- Operator must have 10 years of experience and be both board- and field-qualified. If the operator is unavailable then the meetings are delayed or cancelled.
- Engineering representatives must have 5 years of experience and be either Process or Design Engineers.
- A Business Improvement Network (BIN) Leader, who participates in a portion of each PHA team meeting⁵⁴.

The following Process Hazard Analysis program concerns were identified:

- The PHAs conducted before September 2013 focus on the continuous mode of operation. According to CUSA management, Subject Matter Experts (SMEs) from Technical and Operations take part in hazard analysis discussions regarding startups and shutdowns and share significant incidents that occurred. The deviations of startup and shutdown are discussed as a hazard and operability (HAZOP) deviation within an equipment node, but data shows this will not adequately address the hazards for these modes of operation. Online maintenance modes of operation have not been considered. Industry data indicates that 70% of process safety accidents occur during these non-routine modes of operation. U.S.OSHA, state, and industry entities (since 1989 and onward) have cited lack of PHA of procedures (for these non-continuous modes of operation) in their investigations of accidents in the process industry (including accidents at Phillips [TX], Ashland Oil [KY], Bayer Crop Sciences [WV], and BP offshore). Simply considering the deviations of “startup, shutdown, and maintenance” during a node-by-node HAZOP of parameters has, in PII’s experience, been shown to catch less than 10% of the accident scenarios during these operating modes. These factors and data are why the CCPS added a new Chapter 9 in the 3rd

edition of *Guidelines for Hazard Evaluation Procedures* (2008), which is the key standard for PHAs.⁵⁵ Richmond Refinery should update their Process Hazard Analysis Procedure to include complete hazard review of the step-by-step procedures for startup, shutdown and online maintenance modes of operations. Refinery management reports that Procedural PHAs for loading and unloading operations have been conducted.

PII noted that an action item from the Richmond Refinery Chevron Corporate internal RISO Audit Report (2013) stated that screening criteria had not been established and implemented to determine which procedures may be appropriate for a Procedural PHA. Rather than screening procedures to limit the PHA to only the higher-risk tasks, PII data and best industry practice prescribe a PHA of all procedures.

However, the procedures with lower risk (which is likely 70% of procedures at a refinery) can be reviewed using the What-If methodology. The procedures for higher-risk tasks (about 30%) can be reviewed with the 2-Guideword HAZOP approach, applied to each step that changes the state of the process.⁵⁶

For PHAs reviewed by PII, it appears that loss of containment causes, such as corrosion, erosion, external impact, improper maintenance, material defect, pump seal failures, gasket/packing failure, and drains/vents left open were not discussed during each HAZOP node. One exception at the refinery was loss of containment resulting from pump seal damage, which is evaluated as part of (within) standard HAZOP deviations, such as “low flow” or “high pressure.”

- As reported by CUSA management, during the HAZOP, the operator is asked to identify issues related to drains/vents, sample connections and valves that can be opened to the atmosphere. This should foster a loss of containment discussion. Identified concerns for these types of loss of containment scenarios are noted in the PHA documentation. Recent PHAs included a BIN Leader who participates in a portion of each PHA team meeting.⁵⁷

However, since specific/individual damage mechanisms from API 571 “Damage Mechanisms Affecting Fixed Equipment in the Refining Industry” are not considered at each process section (node) within the process, it is likely that unique hazardous scenarios have been missed. (Best practice, as stated in *Guidelines for Hazard Evaluation Procedures*, 2008,⁶⁰ is to consider damage mechanisms within each equipment node.) It is also likely that some necessary safeguards such as remote isolations, leak detection, etc., for pipe sections, pumps, vessels, and columns have been missed.

- PII found minimal evidence in PHAs conducted before 2013 that mechanical integrity data such as deficiency reports, damage mechanisms, number of piping repairs (clamps), and location of specification breaks were used in PHA process node analysis in the deviation for loss of containment (see 4.1.5 Mechanical Integrity). As a result, PHAs conducted before 2013 probably have covered less than 30% of the potential equipment damage causes (mechanisms). The same may also apply to the PHAs conducted since 2013, if the procedures for conducting PHAs have not been corrected for this weakness.

CUSA management reports that the Design Engineering Group piloted a specification-break review in 2013. (Specification “spec” breaks are where the materials of construction or pipe thickness change.) Also, each PHA is intended to identify any potential spec break concerns within the unit (as is typical for PHAs that follow industry best practice). It is understood that a policy and procedures to codify spec-break

reviews will be implemented. This approach to damage mechanisms related to materials specification is considered a best practice. Most competent PHA teams in the industry ensure a discussion of each spec break during a PHA.

- PHAs at CUSA do use a latent conditions checklist, and most of the PHA/HAZOP tables list very few (essentially no) human factors in the causes or safeguards.

According to CUSA management, the PHA Team completes a walk-through of the plant before conducting the human factors/latent conditions review. The team reviews the latent condition checklist in the PHA meeting, with plant observations documented as needed during the meeting. "Human Factors" is also considered with each node and any items of concern are documented by exception. This type/level of human factor review has been proven insufficient to fully analyze and document potential causes for many loss of containment scenarios. The refinery should implement Human Factors analysis techniques that address RISO requirements and go beyond these to follow well-established, industry best practices for review of Human Factors, especially during PHAs.

- Safeguards and causes or scenarios with outcomes below Consequence Level I and II are not included in the ITPM program and follow-up on ITPM reviews is not forwarded back to the PHA leader. This can result in the risk of the scenarios increasing due to lack of periodic validation.
- At the time of this Safety Evaluation, the Richmond Refinery did not consistently follow CCPS Hazard Evaluation Procedure 3rd Edition (and OSHA) guidance^{58,59} for justifiably declining a PHA recommendation. The revised policy and procedure for managing recommendations should include instructions for declining recommendations, in writing, based upon adequate evidence that one or more of the following conditions is true:
 - The analysis upon which the recommendation is based contains material factual errors;
 - The recommendation is not necessary to protect the health and safety of the employer's own employees or the employees of contractors;
 - An alternative measure would provide a sufficient level of protection; or
 - The recommendation is infeasible.

Recommendation 3

To avoid missing causes and necessary safeguards against loss of containment, be sure hazardous scenarios starting from pertinent damage mechanisms are reviewed during each unit's PHA. (Pertinent damage mechanisms include corrosion, erosion, seal failure, pump failure, external impact, external fire, material defect, improper maintenance, drains/vents left open, etc.) In particular, review external impact as a damage mechanism for each node.

A review of such loss of containment scenarios in each node is recommended, as described in the *Guidelines for Hazard Evaluation Procedures*, 3rd Edition, 2008, CCPS/AIChE. Adding a loss of containment deviation would double-check against missing standard damage mechanisms (such as corrosion and erosion) during unit-wide reviews. It would also improve the current PHAs by providing a review at each node for external impacts and control of drains/vents. Review and incorporate mechanical integrity data during this analysis.

Recommendation 4

For PHAs, improve Human Factors' incorporation in brainstorming accident scenarios. Also, improve documentation of how human factors are accounted for in causes and safeguards listed in the PHAs, per industry best practices. (Also, see 4.1.5 Mechanical Integrity and 4.1.7 Operating Procedures for ensuring these safeguards remain reliable.)

- Human safeguards (protection layers) include operator actions (alarm response, problem identification, troubleshooting).
- Human causes include operating errors related to issues such as inaccuracies and lack of clarity in procedures and misidentification of process equipment (because of inadequate labeling, numbering, and nomenclature).

Recommendation 5

Continue, and expand, the current Procedural PHA program implementation so that all modes of operation are evaluated. Include a PHA of startup, shutdown, and online maintenance procedures, as described in Chapter 9 of the *Guidelines for Hazard Evaluation Procedures*, 3rd edition, CCPS/AIChE, 2008.⁶⁰ This will entail using a 2-guideword HAZOP approach on each step for critical procedures and a What-if (no guideword) approach for less-critical procedures. No procedures should be excluded.⁶¹

Recommendation 6

Implement a policy and procedures for documenting, in writing, the justification for declining PHA recommendations (per *Guidelines for Hazard Evaluation Procedures*, 3rd Edition 2008).⁶² Base justifications upon adequate evidence that one or more of the following conditions is true:

- The analysis upon which the recommendation is based contains material factual errors;
- The recommendation is not necessary to protect the health and safety of the employer's employees or contractors' employees;
- An alternative measure would provide a sufficient level of protection; or
- The recommendation is infeasible.

At the time of this evaluation, all Safety Instrumented Functions (SIF) at CUSA are required to have LOPA (since the SIFs were already installed, for the most part, before the company decided to comply with ANSI/ISA 84 requirements for SIS). CUSA is developing a new decision process (expected to be released April 2014) for determination of when a LOPA is necessary. Safety Objectives Analysis (CUSA term for LOPA) started in 2007 but was ended in 2008. This process was considered to be too conservative as it did not use conditional modifiers resulting in much higher SIL requirements than expected. The new methodology will include appropriate conditional modifiers resulting in a lower number of high SIL safeguards. CUSA is currently in the process of setting up mechanisms for inspection, maintenance, and analysis of SIS and they are reviewing the installations to ensure that they meet the ANSI/ISA standards.

Recommendation 7

Follow through on the existing plans to implement a process for determining when a LOPA is necessary.

Recommendation 8

Follow through on the existing plans to establish ITPMs for SIS. Also, ensure they meet CCPS and ANSI/ISA requirements for SIS.

At the time of this evaluation, the asset integrity (AI) program includes safeguards associated with Consequence Level I (50-100 fatalities) and II (5-50 fatalities), as outlined in “RI-368 Mechanical Integrity” and “RI-371 Near Loss, Event Reporting, and Incident Investigation.” Safeguards associated with Consequence Level III (1-4 fatalities) are not currently included. The PHA manager provides the OOA with a list to ensure that all safeguards are included in regular testing and verification. However, criticality is not consistently assigned, ITPMs are not consistently created, and findings are not fed back to the PHA team. RI-368 is being revised and reviewed, but crucial gaps remain in the newest version.

Recommendation 9

Update policies and procedures to define clearly the process, roles, and responsibilities for managing and maintaining equipment and human actions identified as safeguards and causes (as identified in PHAs). The safeguard management system(s) of the asset integrity program should include safeguards and causes identified in PHAs for Consequence Levels I and II. In addition, expand them to include Consequence Level III events. Criticality should be identified, such as by labeling as independent protection layers (IPLs) in the PHA report. This rating should be maintained in the CMMS. Appropriate ITPMs should be developed, performed, and documented for each of these items. Further, until the ITPM plans are established and active for a safeguard, no credit should be taken for it (e.g., it should not be considered an IPL). *NOTE: The IPL management system that the refinery has begun may address the concerns of this recommendation. However, control of the frequency of causes is just as important as the control of the probability of failure on demand of an IPL.*

4.1.5 Mechanical Integrity (MI)

All equipment used to process, store, or handle highly hazardous chemicals needs to be designed, constructed, installed and maintained to minimize the loss-of-containment risk. This requires that a mechanical integrity program be in place to ensure the continued integrity of process equipment. Key elements of an effective mechanical integrity program include:

- Identification and categorization of equipment and instrumentation,
- Inspections and tests,
- Testing and inspection frequencies,
- Development of maintenance procedures,
- Training of maintenance personnel,
- The establishment of criteria for acceptable test results,
- Documentation of test and inspection results, and
- Documentation of manufacturer recommendations as to mean time to failure for equipment and instrumentation. (OSHA PSM 1910.119)⁶²

Richmond Refinery has a concentrated effort to update and upgrade maintenance procedures and practices. Procedure writers have recently been added to the maintenance organization.

Maintenance procedures are being developed with guidance from the L&D team and migrated into the site's electronic manual management system (EMMS). However, this is a system in transition – many maintenance procedures remain to be developed or upgraded. Chevron-general and refinery-specific mechanic training and certification are reported to be similar to other refineries in the area. Training documentation and control remains within the department or craft of the Richmond Refinery. Maintenance personnel training procedures and practices need to be formalized to meet future staffing needs.

PII reviewed the past three to five years' history for preventive maintenance (PM) compliance, Break-ins (unplanned turn around work not including discovery work resulting from planned inspections), and Due Date compliance. "Metrics monthly meetings" and Routine Work Control Program are providing necessary focus to improve in all areas. PM compliance is 100% and Break-ins are consistently at less than 5%. All trends show improvement. As listed on a public access website maintained by CUSA (<http://chevronmodernization.com>), the refinery tracks the following 26 process safety indicators in the OERI database:⁶³

- PHA Recommendation Implementation Overdue
- Safety Instrumented Systems (SIS) Functions Disabled
- SIS Functional Test Overdue
- Open Safety Work Requests
- Overdue Preventative Maintenance
- Inspections Overdue
- Overdue Training
- Training Due in 30 days
- Permanent MOCs Overdue
- Temporary MOCs Overdue
- Mechanical Availability
- Incident Solutions Overdue
- Investigations
- Audit Action Items
- Pre-Startup Safety Review Exceptions
- Overdue Testing of Over Speed Trips
- Overdue PRDs (Pressure relief valves) Testing
- Days Exceeding Alarm Limit
- Critical Process Variable Deviations
- Routine Duties Not Completed
- Work Order Schedule Adherence
- Open Temporary Leak Repairs
- Utilization (Mechanical Utilization)
- Reliability Clock (Mechanical Reliability)
- Industrial Safety Ordinance Recommendation Implementation Overdue
- Overdue Compliance Assurance Program tasks

All show significant improvement over the last 4 years. (This list is similar to indicators tracked by other refineries and chemical plants.)

CUSA Richmond's MI objective is to identify and prevent hazardous material releases caused by equipment failures. Since 2009, the refinery has averaged 500 total temporary leak repairs (TLR), of which an average of 11 TLR/yr are in hydrocarbon and chemical service; the rest are essentially for water, steam, or condensate service. This number of TLRs per year (for hazardous chemicals) is low compared to CUSA peers. These TLRs should be replaced during major shutdowns, but currently there are 83 TLR in hydrocarbon service. A review of safety

work orders shows their closure remained steady at ~86% over the same 4-year period. Because of the significant number of temporary leak repairs (83) for hydrocarbon (HC) service that were reported to PII as “open,” refinery management should investigate these further. CCPS Mechanical Integrity guidelines provide extensive guidance concerning definitions of a “deficiency,” and it provides some typical corrective action methods to address these mechanical integrity needs.⁶⁴

Recommendation 10

Follow through on the current refinery initiatives to reduce the number of TLRs and improve the closure speed on safety work orders.

During a live navigation of the Maximo computerized maintenance management system (CMMS) system, PII staff searched for ITPM plans and records for instrumentation and equipment identified in a recent (<3 years old) PHA as either a cause or a safeguard for a risk level 3 (Major) incident. These included pressure vessels and tanks, piping systems, critical process control loops and alarms, rotating equipment, and emergency block valves. Opportunities for improvement were found in varying degrees:

- Many tag numbers for instruments listed as causes or safeguards in PHAs could not be found (according to CUSA staff, only about 50% of the instrument tags were brought over during migration to Maximo from an older CMMS system). The tagging and labeling of instrumentation within CMMS should match the labels on the P&IDs and other documents (such as cause and effect diagrams and loop diagrams), so field operators and maintenance technicians can verify the status of ITPM inspections.
- CUSA reports that a naming convention is established and used for updating and adding new plant information within Maximo. When applying the naming convention, instrumentation is generally set up as a loop associated within or connected to a larger asset or as a “virtual point.” Richmond Refinery should upgrade and formalize this naming convention process to clearly identify, test, and monitor safety critical equipment and individual instrument components within the MI program.
- Individual equipment is sometimes associated with a vessel or with larger pieces of equipment such as a furnace or compressor. See discussion above for instrumentation.
- The reliability department is responsible for criticality assessment. Most instrument items did not have the criticality associated with the equipment. Those that did were set as “low.” Criticality is reviewed for safety, environment and production. The sRCM (reliability centered maintenance) project was started in 2007. Process safety instrumentation will be ranked and have an ITPM specified, and will be included on the Maximo maintenance process (targeted for 2014).
- Per CUSA management, since 2000, a guideline has been in place for the information handed over to the “Add, Change, Delete” coordinator (ACD). The ACD coordinator manages the input and updating of the equipment, piping and instrumentation inventory and naming nomenclature. Observed inconsistency in this process indicates that revalidation of the policy and procedures is warranted. Include guidance for the add, delete, change process so that causes and safeguards identified in the PHA reports are included in the formal MI program, as stated earlier in this report.
- SIS sheets contain the specifications for each piece of equipment, size, metallurgy, etc. The Reliability group is currently responsible for entering and retaining this information.

Since the above issues make it difficult to track mechanical integrity history, identify potential equipment failures, review maintenance performed, or create effective ITPMs, the refinery initiated the sRCM process in 2007 to address these gaps. However, written ITPM plans, procedures, and records could not be located for all process safety critical equipment during this evaluation (2013). The MI task and frequency selection process for process safety critical equipment should include manufacturer's ITPM recommendations, applicable codes and standards, Chevron's operating experience, other recognized and generally accepted good engineering practices (RAGAGEP), and best practices (which may differ greatly from RAGAGEP).

Work is underway to close part of this gap with resources assigned to write and manage procedures in the electronic maintenance manuals (EMM) database. However, data is missing and/or incomplete in both maintenance and reliability databases (Maximo and Meridium). A numbering system and data structure must be established to provide the granularity required to manage ITPMs at the component level. While the sRCM project initiated in 2007 should address these MI gaps, the refinery should evaluate the project schedule and resourcing, considering the critical nature of this MI gap.

Recommendation 11

Finish identifying MI-critical assets to add to the ITPM program. The criteria should consider the asset function (control, safeguard, containment, etc.) and the consequence of failure (which is also listed in sRCM documentation). As stated in Recommendation 9, until the ITPM plans are established and active for a safeguard, no credit should be taken for it (e.g., IPL).

An organizational change has been implemented in the maintenance and reliability (M&R) departments to ensure that the proper personnel are assigned to newly established roles for MI. Creation of a lead person and technical support for data input shows there is a focus to ensure that data entered into the system has better integrity than in the past. Roles and responsibilities are being better defined, personnel are being hired, and asset integrity in the field is a focus.

Inspection Supervisors (IS)/Analysts assigned to the area business unit (ABU) are tasked to ensure the accuracy and consistency of information being entered into the Meridium database. The IS reviews and approves all inspection(s) and recommendations. The IS provides oversight to data entry for inspection recommendations and history briefs entered into Meridium. A Fixed Equipment Integrity Manager was a newly established position at the time of review.^{65, 66} This additional layer of management is being put in place to upgrade and improve the quality of the MI program. An MI SME for fixed equipment is developing ITPM procedures and job aids for all ITPM tasks including selection of equipment for the MI program, selection of ITPM methodology (including consideration of Damage Mechanisms), and who/what/how to perform ITPM tasks. The MI SME is also preparing ITPM reports, and developing how ITPM results will be tracked.

As of October 2013, many good programs are being put into place; and Richmond Refinery management is attempting to understand where it needs to concentrate its efforts and priorities and is taking steps to close most gaps.

Recommendation 12

Continue the current emphasis on the MI procedures and processes. Follow regulatory guidelines, and implement best industry practices, such as those described in the CCPS *Guidelines for Mechanical Integrity Systems*.⁶⁷ Continue developing maintenance work instructions for ITPM. Provide resources and systems to effectively manage ITPMs at the component level for all process safety equipment. In addition to the general improvements above (toward which the

refinery is already working), consider implementing the following specific improvements:

- a) Review/update the policy and procedures that define how instrumentation is entered into the Maximo system and verify implementation. Ensure that instruments are maintained (and tracked and documented) per ISA requirements.**
- b) Review/update the policy and procedures that define the “Add, Change Delete” equipment-information management system and that direct how information is entered into the Maximo and Meridium systems.**
- c) Train the ACD Coordinator on the updated policy and procedures (see Recommendation 12.b, above.) so that ITPM entry, tracking, and historical data are associated with the proper equipment.**

During live navigation of the Meridium database, PII and CCHMP staff identified issues regarding information availability and retrievability that affect the ability to quickly identify operating and maintenance history associated with each piece of equipment. Live navigation of Meridium with SME operation demonstrated that ITPM data was mishandled and not available to support the refinery mechanical integrity program. Current maintenance methods fail to input ITPM data so that the data could be used to manage ITPM tasks for refinery mechanical integrity. Per the Meridium live demonstration, PII could not determine if the ITPM inspections were complete or if the ITPM reports were complete. MI information was not sufficient to determine that critical components identified in the PHAs are being maintained.

For example, the Safety Evaluation team selected various piping circuits flagged on the P&IDs as covered by the PSM program to see if these piping circuits are included in the MI management program demonstrated through Meridium performance. The MI SME had difficulty finding MI data for specific sections of pipe requested. The evaluation team interviewed the MI fixed equipment management team. The Richmond Refinery fixed equipment MI management team recognized several deficiencies with the MI program for piping systems based on difficulty in locating and analyzing such data. (As discussed later in this section, the piping data for all 10 of the selected piping was eventually located and reviewed.)

CUSA (as of late 2013) has a program to close the gaps in the ITPM program for piping systems containing highly hazardous materials by completing additional thickness measurements, inspection and testing for piping circuits based on damage mechanisms, critical reliability variables, and determination of erosion and/or corrosion rates. Based on interviews with MI staff, MI procedures for inspection of piping systems that contain hydrocarbons and chemicals are being prepared. These will provide guidelines on how to manage the reliability of piping sections including identifying critical reliability variables, material of construction, damage mechanisms and corrosion rates.

Per the inspection manager, about 80 percent of the units in the refinery have specific PFDs indicating possible corrosion or damage mechanisms that are not currently on the P&IDs. The PFDs are unit specific, but not the same drawings that are in API 571. CCHMP reviewed a drawing, D-308226-6, revision 4, dated 10/21/04, originally created and approved 2/27/90, Plant Equipment Reliability Flow Diagram, which describes all of the different damage or corrosion mechanisms with corresponding numbers. These, in turn, are used to indicate the type of unit specific mechanisms on the unit specific PFDs. Per the inspection manager, the numbers used do not match API-571, so part of the ongoing project is to use the same numbers as API-571. A draft corporate standard guides this effort.

A summary of the MI improvements (per the public access website maintained by CUSA (<http://chevronmodernization.com>), being implemented at the time of the Safety Evaluation is as follows.^{68, 69}

- To ensure that mechanical-integrity related recommendations (e.g., for a design change recommendation from incidents that occur at peer companies) are appropriately reviewed, prioritized, and acted upon, the refinery has developed and implemented processes for additional oversight of such recommendations. These include recommendations from Chevron's Energy Technology Company and other subject matter experts, as well as from general industry alerts. A review of mechanical-integrity standards has been undertaken and these standards will be compared to existing Chevron standards to identify any discrepancies and establish a plan to reconcile those discrepancies on a go-forward basis.
- A Fixed Equipment Integrity Manager (FEIM) has been added, who is responsible for developing, implementing, and stewarding the refinery's Fixed Equipment Integrity program. The goal is to achieve zero process-safety incidents and improve mechanical availability.
- Refinery MI staff were developing an Integrity Threat Process, which has been deployed to address inspection recommendations for equipment and piping that could significantly impact safety, or environmental or plant operations. The refinery Operations group is notified of all integrity-threat inspection recommendations and takes action to develop a planned resolution by the target completion date. The integrity-threat inspection recommendation is tracked through the refinery's MERIDIUM and OERI databases until it is resolved.
- The refinery has also updated its internal work instructions to address inspection results that indicate that equipment or piping will reach "flag" or "alert" thickness prior to the next scheduled turnaround. The refinery's on-stream inspection work instruction was updated in 2013 to include immediate notification to Chevron of any field measurements that indicate a remaining life of one year or less. An API-certified inspector assesses the results of the inspection and expands the inspection program for the equipment or piping as appropriate. In such a situation, an integrity-threat inspection recommendation is issued to the refinery's Operations group and tracked to completion.
- MI threat MOCs are tracked by ABU inspectors working with ABU staff to review recommendations with design engineering to develop a repair plan (including ISO, CML plan, reviewing design issues such as dead leg, and mitigation) Present MI planning is to make permanent repairs to all temporary leak repairs during turnarounds or other opportunities.
- The refinery has also developed a new process to review all damage mechanisms that may affect a given plant at the process level. This Damage Mechanism Review (DMR) process, which is consistent with API 571, requires a team of SMEs to review, analyze, and make recommendations concerning damage mechanisms and how to mitigate the effects of damage mechanisms on each process unit. The results of these reviews are then provided to the PHA team for their consideration and review as that team formulates its recommendations. The DMR process was piloted at Richmond in 2013 and has since been made a required element in the PSM process at the refinery for selected process units, on an ongoing basis.

- The refinery has also modified its Reliability Opportunity Identification/Intensive Process Review (ROI/IPR) process and, as discussed above, its PHA procedure, to ensure that damage mechanisms are appropriately considered.
- In addition, the Fixed Equipment Integrity Group was developing asset strategy plans for each process unit at the piping circuit level. The refinery was developing an asset strategy plan based on Integrity Operating Windows (IOW) consistent with draft *API RP 584 – Integrity Operating Windows*, and planned to address damage mechanisms and recommendations for mitigation of risks.⁷⁰ (These operating limits are currently identified at the refinery as Critical Reliability Variables [CRVs]). Operation within the preset limits of IOW (or CRVs) should result in predictable and reasonably low rates of degradation, unless unanticipated variances are uncovered. These asset integrity plans include consideration of, among other things, process conditions, inspections techniques and frequency, mixing and injection points, and corrosion monitoring locations (CML). These plans will be integrated with the DMR process. A pilot of the asset-strategy plan process has been performed for the crude unit, and asset strategy plans will be implemented for all processing units on an ongoing basis.⁷¹
- The MOC process is followed including PSSR and tracked in MAXIMO and/or Meridium databases. TLRs can be tracked by assigned due date.

The MI SME has a fundamental understanding of the CRVs (IOWs) for the refinery's various process units and good knowledge of the potential damage mechanisms. This understanding is required to establish and maintain an inspection program that yields the highest probability of detecting potential damage. In the past, Chevron's Reliability Department developed corrosion-profile analysis documents for the refinery's process units that included CRVs, specification breaks, material of construction, and corrosion mechanisms for the various processes (these were documented on process flow diagrams). The corrosion analysis profiles were not maintained as PSI, and, in the past, these profiles have not been updated as a critical PSM document. The new initiatives should correct this situation. In addition, the MI department is adding more staff to conduct the accelerated ITPM inspections and documentations.

Chevron Richmond Manufacturing has a Shaping Plan that lists many objectives around inspections, damage mechanisms, leak repairs and organizational capability.

The Refinery Fixed Equipment management team should continue their program to upgrade their MI programs. Based on employee interviews as part of this evaluation, CUSA is (1) adding more inspectors and resources to perform identified ITPM task activities; (2) reorganizing the MI management organization to improve management of MI data; and (3) implementing the appropriate ITPM tasks for refinery piping process including appropriate damage mechanisms for the specific process and conditions. CUSA is obtaining the resources to bring the present program up to industry best practices.

ITPM plans in use for the refinery were found to be incomplete for some process operating conditions. As listed on a public access website maintained by CUSA (<http://chevronmodernization.com>), prior to and during this safety evaluation, the refinery also undertook a component-by-component inspection of all individual carbon steel piping components exposed to high-temperature sulfidation conditions. The inspection followed newly implemented inspection guidelines consistent with API 939-C – *Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries* and *Updated Inspection Strategies for Preventing Sulfidation Corrosion Failures in Chevron Refineries* (Sept. 30, 2009). The inspection program has been divided into two primary phases: Phase one calls for the inspection of piping components in service with temperatures above 500° F, and phase two calls for inspection of piping components in service with temperatures between 450° and 500° F.

As of March 2014, the refinery had inspected nearly 19,000 individual piping components, including all high-priority piping components operating at or above 500° F. The inspection program is scheduled to be complete by August 2014. Pursuant to the inspection program, components are replaced as needed, and additional corrosion monitoring locations (CMLs) are being added where the inspections indicate higher corrosion rates.⁷²

A pilot program for DMRs was underway also. The refinery is addressing items identified during this pilot study; the refinery needs to update the MI procedures to complete implementation of this project. For example:

- Per the City of Richmond website for the Richmond refinery “Chevron Modernization Project Environmental Impact Report”⁷³, Appendix 4.13-REL_r2:⁷⁴

“Chevron has a best practice for managing sulfidation corrosion, Inspection Strategies for Preventing Sulfidation Corrosion Failures in Chevron Refineries, (Chevron, 2009). It is based on the guidelines in API-939-C, Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion in Oil Refineries (API-939, 2009), supplemented by Chevron’s personal experience with this damage mechanism. Therefore, based on several considerations, including the past sulfidation failure incidents and their sulfidation best practice, which stipulates specification of 9CR piping at sulfidation temperatures greater than 525 °F, Chevron is planning on replacing 17 piping circuits currently either carbon steel or 5Cr-1Mo with 9Cr-1Mo at the next scheduled turnaround in 2017, plus four partial circuit replacements (Table A4.13-REL-5 and Table A4.13-REL-6). This Reviewer agrees that this decision is an appropriate one to mitigate risk uncertainty associated with future sulfidation failures.”

Prior to this DMR pilot program, the Richmond refinery MI program identified and addressed specific corrosion mechanisms in the MI program but did not uniformly consider damage mechanisms consistent with the refinery operating conditions, as identified by the Chevron corporate best practices. As a result, some of the Richmond refinery processing unit process piping that Chevron corporate recognized as subject to high-temperature sulfidation corrosion is not constructed from Chevron specified materials of construction. Further, affected portions of these piping circuits were not inspected frequently enough or completely enough to address the original/mixed specification piping, considering current operating conditions. Best practices MI programs integrate DMR program results into MI and PHA procedures.

- ITPM plans were not developed for all process piping sections. ITPM plans did not always consider damage mechanisms, design data, CRV, guidelines, etc. when developing the plans. MI data in Meridium could not easily be correlated to P&IDs and PFDs, making it more difficult to share MI data with employees, such as PHA team members.

At the time of this evaluation, Richmond CUSA was implementing inspection of each carbon steel component exposed to sulfidation conditions.

The Refinery MI programs should be based on positive material identification (PMI), understanding of possible damage mechanisms, CRV, best practices in piping design (material of construction determination, sizing, corrosion allowance, fabrication, etc.). The programs must also account for changes in process conditions.^{75,76} Piping systems installed in the 1960s that are subject to high-temperature sulfidation corrosion should be inspected at every component (because the exact material of construction is not known and cannot be determined with non-destructive testing methods) to ensure their integrity. Piping system failures can be catastrophic. To address this need, the refinery is transitioning to a circuit-based ITPM plan for piping.

The Richmond Refinery uses their MOC tracking system to address process safety-related online temporary repairs, which include communication and tracking of open TLRs. As part of the MOC process, when process safety temporary repairs have been executed, the area operators are notified to ensure awareness and monitoring of the repaired piece of equipment. Awareness of this information is critical during unit upsets, possible leak identification and emergency response.

Recommendation 13

Revise the TLR policy/program to require operators to check more often for leaks while a TLR is in place.

As described above, at the time of the Safety Evaluation of the Richmond Refinery, refinery management was making improvements in their reliability organization to provide more mechanical integrity oversight and to improve process safety work processes. For piping systems containing highly hazardous materials, these improvements were being based on API RP 584 and appropriate API codes and standards such as API RP 571, API 580, and API 939-C and refinery operating experience.

PII (with the assistance of CCHMP staff) selected 10 critical process lines and reviewed the ITPM data for these piping systems. All of the lines had external inspections and thickness measures within the 5 years before the Safety Evaluation. Two (2) of the ten (10) piping systems were 6 months past the 5-year “typical” external inspection frequency. Data for one of the pipe systems made no mention of the calculated remaining life (which can be derived from the measured thickness, based on the rate of corrosion observed). All other piping systems had remaining life of 6 to 60 years. None of the piping records referenced API RP 584. The ITPM for these piping systems also did not reference API RP 584.

Chevron currently plans to:

- Accelerate inspections of process piping system based on criteria in API 571 and API 584.
- Develop and implement improved MI procedures on how to ensure the mechanical integrity of process piping, vessels, and storage tanks using guidance from API 584 and API 571. (As mentioned earlier, the refinery is transitioning to circuit-based approach for ITPM of piping.)

Chevron should follow through on plans to improve piping ITPM by using appropriate API codes and standards and Chevron’s operating experience to develop MI procedures and practices to guide MI inspectors. Guidance should include:

- *API RP 571 Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*
- *API RP 574 Inspection Practices for Piping System Components*
- *API RP 939-C Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries*
- *API RP 584 Integrity Operating Windows* – This RP explains the importance of IOWs for process safety management and guides users in how to establish and implement an IOW program for refining and petrochemical process facilities for the express purpose of avoiding unexpected equipment degradation leading to loss of containment. It is not the intent of this document to provide a list of specific IOWs for the numerous types of hydrocarbon process units in the industry (though some generic examples are provided in the text and in Appendix A). Rather, it provides the user with information and guidance on the work process for development and implementation of IOWs.

- Chevron's operating experience and guidance from Chevron MI SME.

Recommendation 14

Follow through on plans to improve piping ITPM by using appropriate API codes, standards, and Chevron's operating experience, to develop MI procedures and practices to guide MI inspectors. Complete the current plans to determine which piping systems are most susceptible to corrosion issues, especially sulfidation and high-temperature hydrogen attack. To achieve the highest probability of detecting potential damage in process piping, audit and as necessary, complete the development and implementation of DMR and ITPM for process piping sections. This should be based on an understanding of process/operating conditions and resulting damage mechanisms. Use damage mechanisms appropriate for the units and operating conditions, such as high-temperature sulfidation, high-temperature hydrogen attack, and hydrochloric acid (HCl) corrosion.

Currently, when an integrity threat is detected by the Asset Integrity (AI) inspection department, the ABU team is required to develop a mitigation plan. A form is submitted and approved by the ABU, the Fixed Equipment Integrity Manager (FEIM), and the inspector. Integrity threats are grouped together and managed separately (from other equipment deficiencies) to ensure that they are given top priority (to prevent loss of containment) relative to other reliability issues. At the time of this evaluation, the integrity threat form and a flowchart developed for training were the only documents that define ABU responsibility for the Integrity Threat process. A formal document refinery instruction (RI), procedure or guideline defining the integrity threat process is needed.

Per input from refinery management, the Chevron Manufacturing Fixed Equipment Integrity-Threat Work Process (with Richmond additions) was updated September 14, 2013. The equipment integrity-threat work process describes tracking threats, inspector testing and analysis responsibilities, and the OOA and Business Unit manager responsibilities. The ABU is responsible to ensure equipment is safe to operate or to take appropriate action while a mitigation plan is developed. The Fixed Equipment Inspector is responsible for advising management of any immediate threat to loss of containment and notifying the FEI Lead Person of the situation status. The FEI and FEI Lead Person are also responsible for issuing integrity threat forms to document what mitigation is taken. They are also charged to follow the work process for identification and resolution of fixed equipment integrity threats to identify, document and implement the resolution. The Fixed Equipment Inspector manages equipment status in Meridium (MI database). MI documentation includes the following information:

- Line description and line size
- Service (hydrocarbon, steam, etc.)
- Suspected damage mechanism
- Target completion date (date when work should be completed in field)
- Description of the corrosion
 - Internal/external
 - Size and location of the corroded area (e.g., uniform wall loss, circumferential, or isolated pitting)
 - Corrosion rate if known or state that it is not known or not linear
 - Mark up P&ID or isometric drawing to show location

- Any pictures as appropriate
- Fixed equipment area lead, team lead, or FEIM are responsible to review and approve integrity threat by completing the following:
 - Ensure inspection recommendation information is complete (per job aide) including (1) damage mechanism and (2) basis for initial target completion date
 - Select name in the final approver name field
 - Change the status from created to approved (if the team approves the actions)
 - Notify Reliability Administrator to issue Inspection Recommendation (IREC) on integrity threat form

Also, according to management, the new initiative ensures that after the appropriate communication of the integrity threat to the Business Unit and stakeholders for approvals, the OOA develops a resolution plan with team resources. The RBM consults with the FEIM if additional time is required to develop the resolution plan or when the target completion date for the recommended action will not be met. The technical SME conducts the initial engineering evaluation to identify if equipment is at/below flag thickness, and the SME notifies the ABU of the findings and consults with the Fixed Equipment Inspector as needed for additional information. The RBM approves the integrity threat resolution plan and due date by signing the integrity threat form. He then returns the form with the documented resolution plan and due date to the FEIM for approval. The OOA issues a maintenance work request if needed and assigns responsibilities to other groups as needed to execute the plan. The OOA meets periodically with the team to track status of resolution until implementations are complete. Also, the RBM proactively monitors the ABU resolution plan implementation to help ensure completion by the due date. The OOA works with the area team to determine if the integrity threat requires mitigation until the resolution can be implemented. The Fixed Equipment Integrity Manager approves integrity threat resolution plans, assigns the due date and mitigation plan with due date (if mitigation is required) by signing the integrity threat form.

Then per this new plan, the Fixed Equipment Inspector updates integrity threat target completion dates in Meridium to reflect the agreed upon resolution and/or mitigation due date. If mitigation is required, the Meridium target completion date will be the agreed upon mitigation completion date until mitigation is complete. The FEI verifies that resolution and/or mitigation of the integrity threat is complete. The approved resolution documentation must be approved by the FEI Lead or FEIM.

Recommendation 15

Follow through on the current initiative to develop a policy and procedures (refinery instruction [RI], procedure, or guideline) that describes the process, roles, and responsibilities for the integrity threat process.

Currently, whenever it is necessary to bypass or disable a safety instrumented function (SIF) within the safety-instrumented system (SIS), the shift team leader (STL) initiates the bypass process. A "Safety Device Bypass Waiver" is submitted requiring final approval/authorization by the Operations Manager. SIF bypass is included as a topic in the daily turnover to ensure that personnel are aware in the field. At the time of this evaluation, these bypasses had no time limitations. Best practice is to have an instruction that identifies time limits for different integrity levels, acceptable replacement or mitigation options when it appears that prompt repair (within the expected Mean Time to Repair for the SIF) is not possible, and the roles and responsibilities for making these decisions.

Recommendation 16

Develop and implement a formal procedure and process to ensure that SIFs are not bypassed for an indeterminate amount of time. Have an instruction that identifies (1) time limits for different integrity levels, (2) acceptable replacement or mitigation options when it appears that prompt repair (within the expected Mean Time to Repair) is not possible, and (3) the roles and responsibilities for making these decisions. These should be consistent with industry guidelines, such as those found in ANSI/ISA 84 or the *Guidelines for Safe Automation of Chemical Processes*, second edition, from CCPS/AICHE.

PII staff are concerned with the current ITPM practice used at the refinery for individual “smart” transmitter installations in process safety critical service. Note that the reliability of “smart” transmitters is a factor when considering the frequency of initiating events and the PFD of SIFs, if a smart transmitter is used in a SIF.

According to management, the refinery follows the manufacturer’s recommendation to replace “smart” transmitters upon failure. “Smart” installations are configured so that the transmitter element is part of the transmitter body. They do not receive any PM; they are pre-calibrated and limited in the factory, and if there is ever a problem, the whole assembly requires replacement. Management states that the practice at the refinery is to replace the transmitter completely, which they assert is consistent with recommended practices. Critical equipment in the refinery has redundant instrumentation loops attached. The process indicators using smart transmitters feed back to the control system and can alarm when inconsistent readings are identified at the control board to indicate to operations that one of the transmitters has failed.

Several process safety issues are associated with “run to failure” (RTF) operation for safety-critical equipment, most importantly how any SIF evaluation is impacted by an intentional failure probability of 1. As an example, with CUSA process safety critical smart transmitter installations, effective ITPM should track transmitter operating hours and replace transmitters before manufacturer’s mean time to equipment failure has elapsed to prevent an instrument failure probability of 1 (unity). In addition, CUSA would need to track service life and actual time to failure for each process safety smart transmitter. Additionally, CUSA would have to analyze this data to validate that design, construction, maintenance and operating methods do not shorten manufacturer’s recommended replacement schedules. “Run to failure” is an unacceptable process safety mechanical integrity philosophy, it is only acceptable if the loss does not increase the risk of a process safety incident or if the loss (failure) is well announced. CUSA has determined that their smart transmitters provide “well announced failures.”

CUSA Richmond should develop a detailed list for each process safety smart transmitter installed in the refinery and reevaluate the process safety implications for “run to failure” operations. For example, a work order should be documented for each process safety smart transmitter replacement in Maximo. Yet, many are not documented this way, since these instruments are associated within the records of parent equipment such as a pump, compressor, vessel, furnace, etc. The process safety instrumentation that is not smart and shows no completed PMs in Maximo may be in a “station fill” work order, grouped collectively under one work order per unit or per area.

Recommendation 17

Periodically test process safety “Smart” transmitter installations as part of the ITPM. Otherwise, process safety Smart transmitters that are run to failure should have notes to that effect in the inspection, test, and PM database. If the transmitter is run to failure, then each failure and replacement should be documented. The refinery should track the failure rate of process safety Smart

transmitters to determine whether to change the ITPM practices (e.g., decide not to run to failure). The refinery should develop a procedure and analysis for how different “criticality level” (process safety) instruments are maintained and tested to deliver consistent equipment and instrument availability. These safeguards and SIS require a proper management system.

Safe, fast, efficient, and effective maintenance turnarounds are critical across the refining industry. CUSA uses a process originally developed in 1996 called the Initiative for Managing Pacesetter Turnarounds (IMPACT). The seven-step IMPACT process provides structure for planning and executing turnarounds, with a focus on achieving the four major goals of successful turnarounds: Safety & Environmental, Reliability (Mechanical Availability), Schedule and Cost.

Turnaround work orders are managed in the IMPACT database. The ABUs review these in advance, and dates are set going into a turnaround. The ABU is responsible to ensure that resolving temporary repairs, PMs that need to be executed during shutdown mode, and SIS testing (in the future, when SIS are implemented at the Richmond Refinery) are all included on the work scope. The Impact Team Lead (ITL) controls Break-ins (unplanned work not including discovery work resulting from planned inspections). Occasionally they are elevated to the Decision Review Board, which is comprised of the RBM and other refinery departmental managers.

The Maintenance Turnaround Teams (and associated managers) have primary responsibility for:

- Safe work,
- Reliable completion of all Engineering work orders and maintenance,
- Schedule adherence, and
- Cost to ensure a reliable start up and continued reliable operations.

They define the scope of work during the turnaround window to limit schedule changes, shorten the turnaround where possible, and manage the cost (cost of repair and production revenue). These competing priorities could result in delaying (or deleting from a turnaround plan) some repairs, including work that affects the risk at the refinery. Such changes to the plan are currently carefully scrutinized by senior management and technical staff, to ensure the risk is not increased beyond tolerable limits. (See related data and comments found in the US CSB investigation report.)

The PMI program for new components made of alloys appears to be thorough from as-received to as-welded/installed. This will provide good control of accelerated corrosion that would otherwise occur if the wrong materials are used. Based on document reviews and interviews conducted during this evaluation, it does not appear that a baseline PMI has been conducted across the refinery. (However, several staff mentioned that a baseline PMI was in progress, with first priority going to the units with higher inherent risk of corrosion.) Some refineries in the USA and many in other countries completed a 100% baseline PMI inspection of alloys more than 10 years ago.

Recommendation 18

CUSA should address the following gaps in the MI quality assurance (QA) programs, which create significant potential for loss of containment incidents:

- **Develop a positive material identification policy, procedure and practice for all process areas where the wrong material of construction can cause loss of containment of a hazardous material. This would include areas where alloys are used, high-silicon steel is used, and killed steel is used.**
- **Complete the 100% baseline PMI for alloys in the refinery as quickly as possible to identify refinery equipment and piping locations with high risk for loss of containment incidents. (Completion within 2 to 3 years is possible with proper priority and resources.)**

In addition, verify projected remaining life of any equipment and/or piping systems that contain hydrocarbons and/or process chemicals identified as Integrity Threats during refinery turnarounds. The Integrity Threat Assessment should be completed and temporary/permanent repairs implemented before startup. Also, include appropriate upper management approval of prescribed temporary repairs.

While reviewing MI records on more than 30 vessels, drums and columns, the review team discovered integrity issues with one vessel (V-421) (condensate pot built in 1950s) in the Cracking Alkylation Plant. In a 2005 inspection, the inspector noted that the vessel was constructed in-house. California codes specify that the refinery would have to supply engineering calculations and verify that material and construction techniques meet code requirements. There was no evidence that this deficiency had been addressed. Note that this is a small vessel; too small for humans to enter.

One of the issues that we observed is that some vessels were only getting “external” inspections and not internal inspections as per API 510 Section 6. Because the vessels are not accessible (too small of a diameter to allow full access to the bottom of the vessel), a complete internal inspection was not possible. In addition, the points of inspection were not changed to ensure that data was accurate.

Recommendation 19

Upgrade the current visual inspection policy, program and checklist to include locating nameplate information on small vessels/drums/columns. Determine if internal inspections can be performed adequately on these small vessels using boroscopes. Complete engineering calculations and verify materials and construction for vessel/drums/columns without nameplates (see V-421 as one example).

4.1.6 Training

At the time of the on-site portion of this Safety Evaluation, newly hired operators start on-site in the Basic Operator Training (BOT) class, which is part of CUSA’s “Global Fundamental Operator Training Program” (FOTP). Here they receive a combination of web-based and instructor-led training classes designed to establish a strong foundation in operations, process, and safety fundamentals from the beginning. This includes Loss Prevention Safety (behavior-based safety) training and PSM training.

After BOT, they are assigned to individual units and attend a formal job training class (completed each time that a different job is to be learned). New operators must complete a formal written test before joining a crew. Once they complete the test, the operators then are assigned to their crew to follow (piggyback with) a senior operator under the close observation of a Head Operator. The ABU establishes new Job Break-In Checklists (NJBIs) for each role. The operator completes an oral test in the field with their Head Operator and Shift Team Leader to verify Emergency procedures and plant knowledge. This includes safe work practices, such

as Lock-out/Tag-out (LOTO), Hot Work, and Confined Space Entry (CSE), in the area where they will be working. In the Sulfur Recovery Unit (SRU) that we observed in more detail, this OJT appeared best in class, with consistent high levels of competency of the senior operator and lead operator doing the OJT. Operators in some other units commented that the level of competency and level of willingness of the field trainers (senior operator or lead operator they were shadowing) were inconsistent, and in some cases lacking.

Some portions of CUSA's initial and new hire training process could be considered as industry best practices. However, not all of these aspects are listed here, since there were plans to improve the program further, as described below.

During this evaluation, Chevron began updating the Richmond Refinery formal operator training program to include a performance agreement with the represented employees. PII learned that this agreement was dated 3/24/2015 (Follow-up on this action will occur in the next new phase of on-site evaluation). The agreement reportedly outlines performance expectations such as:

- (1) Classroom participation requirements;
- (2) Periodic assessment requirements;
- (3) Schedule for the training (nine weeks); and
- (4) Field activities that require the operator to:
 - a. Identify various pieces of equipment,
 - b. Identify contents of piping and vessels,
 - c. Identify potential safety risks, and
 - d. Describe the process.

Per refinery management, the training includes a comprehensive examination at the midpoint and conclusion, which require a minimum score of 80% correct to pass. After completing the Refinery FOTP, the operator-in-training will be assigned to an operating area. The operator-in-training will participate in an OJT program that focuses on developing the skill, knowledge and competencies required to perform operator responsibilities. The OJT will include job-shadowing, classroom training, and on-the-job training. The operator-in-training is expected to demonstrate growth in skill and knowledge through successful completion of written evaluations, checklists, situational problems, and field tests. The operator-in-training will be required to complete formal classroom training, break-in checklist, solo written and oral tests, and situational and panel oral and written tests.

Details of the training activities can be found in the Richmond Refinery Fundamental Training Guidelines, Volume I, Section 3; Operator Training. Operators-in-training will be trained on three operator jobs within the first three years of employment. After completing the training program, the operator will graduate and be promoted to the role of a Fully Qualified operator.

Recommendation 20

Consider updating the OJT process to include feedback from the trainee operators on how the senior operator trainers (field trainers) performed training activities. Validation of training checklist quality and thoroughness could help the consistency of training given to new operators during OJT.

Upon successful completion of tests and field demonstrations, the new operator is allowed to "Solo" – taking over in the new position but still under close observation by colleagues. During the solo period, the Head Operator evaluates new operator progress through a prescribed series of "situationals," operating scenarios for which the new operator must demonstrate a clear understanding of the process and describe the proper actions and responses. A "situational" is five to ten in-depth equipment and plant questions designed to help the new operator with the learning process.

At the time of this safety evaluation, new operators would return for Phase II of FOTP 1.0. Now that they have some practical experience as operators, they are introduced to a “deeper dive” into additional operations and safety topics such as process equipment and various refinery instructions (RIs).

They will return for Phase III FOTP 2.0, Operator Troubleshooting. Then, they will return for their final new-hire class, Phase IV FOTP 3.0, Advanced Operator Training.

New operators will demonstrate proficiency in the situationals. The Head Operator (HO) then will determine that they are ready for a “Panel” (starting with a written test). Upon operators’ successful completion of the written test, the employees’ supervisor, Head Operator, and area trainer interview them. Passing this “Panel” interview is the final phase of new operator training for the specified job.

Operator refresher training consists primarily of computer based training (CBT) modules combined with a review process with the trainer. The training mostly centers on a review of operating procedures, panel written testing material, and Electronic Operating Manual information. Interview data suggests that the operators do not feel that this is adequate. In particular, they think the CBT mode of training (without workshops or discussion time with an expert) is very weak.

Sometime in the past, annual refresher training was done completely in a classroom setting, where operators in the same jobs could discuss common issues and learn from each other’s experience. Many operators appreciated the value of these refresher-training classes and expressed a strong desire to return to classroom training. CUSA management indicates that CBT facilitates Control Board Operators from multiple plants to complete refresher training using the high-fidelity simulator with smaller classes or one-on-one sessions with their trainers. CBT also allows for practicing Emergency, start up and shutdown procedures. In a compliance interpretation letter on October 11, 1994 (to ICF Kaiser Engineers), related to emergency response refresher training (not to training in general), OSHA stated that using CBT alone for refresher training is not adequate and should be supplemented with discussion with a qualified trainer and, after refresher training, performance audits of the worker in the field.⁷⁷ PII agrees and believes the same applies to refresher training related to any activity performed in the field/unit, especially operations and maintenance activities.

Recommendation 21

Consider incorporating different modes of refresher training. These could include classroom discussion and reviews, field walks, table-top reviews, group/control room training and CBT reviews. For example, if CBT is used for standardized training topics, then use facilitated sessions to discuss troubleshooting methods and review role-specific procedures. To promote “buy-in” (i.e., employee participation) and operators’ retention of skills and knowledge, include operators in the design and delivery of these classes.

Each shift team executes “hypotheticals” monthly to address planning, scheduling, executing, and critique of response to hypothetical emergency situations. Currently, each shift is responsible for creating their hypotheticals. Lessons learned are documented, but these are not consistently shared throughout the units or the refinery. Including PHA scenarios in operations situationals (related to emergency response) and hypotheticals would create excellent learning opportunities.

The “hypothetical emergency drills” are a more intensive level of “hypothetical,” which test the operation and maintenance groups’ emergency response capabilities. These are designed to

improve the unit's ability to respond to actual emergencies. The policy at the time of this evaluation was to:

- (1) Use the emergency shutdown procedure;
- (2) Test the ability of crew personnel to initiate the evacuation plan;
- (3) Demonstrate scene emergency coordination between plant operators and Chevron Fire Department personnel responding to scenarios (such as a gas release);
- (4) Demonstrate the use of emergency response equipment for a tank seal fire; and/or
- (5) Demonstrate the use of emergency notification procedures in response to a large release of a hazardous material.

The drill objectives are to improve response to a documented hypothetical for a realistic emergency scenario.

The hypothetical drill should be realistic and address objectives identified in Richmond Refinery Instruction RI-465 Hypotheticals. Industry best practices are to have an emergency action plan for realistic emergencies where there could be a large release of a highly hazardous material (such as tank seal fire, compressor failure, and/or loss of containment of flammable liquids and/or gases). Normally the PHA is the best source of scenarios to use in selecting a hypothetical drill. The action plan should include the following elements, at a minimum:

- Emergency escape procedures and emergency escape route assignments;
- Procedures to be followed by employees who remain to operate critical plant operations before they evacuate;
- Procedures to account for all employees after emergency evacuation has been completed;
- Rescue and medical duties for those employees who are to perform them;
- The preferred means of reporting fires and other emergencies; and
- Names or regular job titles of persons or departments who can be contacted for further information or explanation of duties under the plan.

The action plan should address, as a minimum, the hazard of the situations, such as:

- How to activate the fire protection systems,
- How to evacuate the area,
- How to set up the response zones,
- How to isolate a loss of containment to minimize the size of the release,
- When to respond and under what conditions, and
- When not to respond to an emergency (potential explosion, flash fire, catastrophic failure of a piping system containing highly hazardous materials, etc.).

It is important that key lessons learned during hypotheticals are documented and shared throughout the refinery where employees could be impacted by an actual scenario.

Recommendation 22

Consider developing appropriate hypotheticals and situationals for use in training operators to handle scenarios that may lead to a catastrophic outcome. These should be taken from critical safety scenarios identified in incidents and in the PHA process (and in other brainstorming activities). Consider providing

additional structure and guidance around the refinery-wide practice of hypotheticals, such as table-top reviews of response to an emergency, performed within an operator's shift.

Process Control Operator (PCO or board operator) training includes time training on the process simulators. These realistic control room settings are designed to look and respond as closely as possible to the way the actual process would respond to inputs and upsets. CUSA also has an initiative underway to identify the essential competencies needed to be a successful PCO. Continued efforts in this area are expected to enhance situational awareness, troubleshooting, and response capabilities for operators assigned to these critical positions.

At least one PHA team recommended that operators receive additional PCO simulator training to increase operator understanding of how to react to process deviations. However, the additional training was declined during the ABU PHA recommendation review meeting. Following the on-site Safety Evaluation, CUSA management indicates simulator training was added to refresher training, with consideration given to operator concerns.

Training for engineers at Chevron combines OJT and formal classroom training. New engineers attend six weeks of Chevron Technical University (CTU) to help them develop:

- Knowledge of the refinery industry,
- Equipment and technologies,
- Fundamental engineering calculations,
- Engineering design,
- Corrosion mechanisms and mechanical integrity, and
- Instrumentation and safety systems.

The manufacturing fundamentals segment of the training covers:

- Process Safety Management (PSM),
- Project Evaluation Planning,
- Environmental Health Screening,
- Safety in Design (tread widths, design of valves, location of equipment for access, plot plan development),
- Job Hazard Analysis,
- Hazard Awareness, and
- Field Safety Manual training.

Engineers also train on the Chevron Project Development and Execution Process (CPDEP) to ensure the successful development and execution of projects. Project Management Boot Camp is provided for less experienced Project Managers. Chevron subject matter experts teach courses in a classroom setting. Furthermore, competency development is ongoing, using a combination of online courses through the refinery Learning Management System (LMS) and classroom training, to continue to build technical, safety and soft skill competencies. Engineers often rotate through other workgroups or facilities to give them broader exposure and to further their development. Finally, engineers often rotate through units to get broader exposure and to learn more about operators and shift-work.

4.1.7 Operating Procedures

Type of Required Written Instructions for Richmond Refinery	Approximate Number
Operating Procedures	1293

The Richmond Refinery has approximately 2,482 Written Instructions for Operations and Maintenance.

Maintenance Procedures	450
Emergency Procedures	739
Total (approx.)	2482

RI-124 describes the “Requirements for Operations Work Instructions,” with assigned responsibilities for RBM, SH, RSL, OOA, STL, HO, CO, FO, Section Trainer, M&P specialist and operators. The Pre-Use Review portion of RI-124 directs the following (abridged):

- STL and HO (both for critical; HO only otherwise) sign and date Work Instructions (WI) for suitability, and confirm affected crewmembers have reviewed the applicable WI.
- For identified discrepancies, HO makes necessary changes and conducts HSE with STL and crew prior to execution as needed.

RI-124 directs WI users to apply appropriate Sign-Offs, addresses multiple person operating instructions, Multiple-Shift Execution and WI retention.

RI-124 section 4.4 addresses “Changes to Work Instruction.” This section and the Pre-Use Review and Appropriate Sign-Offs sections provide the prescribed methods to ensure Operations Work Instructions are ready for operator use and completed accordingly.

The Head Operator (and Shift Team Leader for critical WIs) review and sign off on Work Instructions as accurate and complete before each use. Per RI-124, operators should review and confirm with HO that Work Instruction is ready for use, or redlined (with MOC) if necessary. RSL, STL, HO and operators share responsibility to ensure Work Instructions are reviewed, approved for use, and used/completed/signed as directed. It is not apparent RI-124 procedures are used to correct deficiencies. Evidence suggests that some procedures are updated routinely (several times per year), while others have not been revised since their original issue (>10 years ago), perhaps meaning no changes were needed in the past 10 years or so for that procedure. The Safety Evaluation team did not make a direct comparison of the procedure review/revision history and the relative percent accuracy of the procedures (discussed later), but some procedures had a significant number of errors (as discussed later).

RI-124 section 4.6 “Certification of Electronic Operating Manuals” specifies Work Instruction validation processes and schedules. Per section 4.6, all operating procedures are formally reviewed on a 3-year EMMS triennial review cycle. However, this review process does not require that they are walked down by SMEs and revalidated in the field. Section 4.6 also references Field Verification Pre- and Post-use review (probably operator and HO) as a WI validation process.

Per the 2012 Chevron Corporate Major Incident Survey (MIS), “*Procedures or Safe Work Practices*” were cited more frequently than any other root cause category. For 128 of the 167 events studied (77%), one or more root causes fell into the Procedures or Safe Work Practices category.” Furthermore, “approximately 65% of these events involved issues with Operating and Maintenance (O&M) procedures and various work instructions, compared to Managing Safe Work (MSW) standards themselves.” Procedures were also listed as the second most frequent root cause of incidents in the 2008 MIS. Only Risk Awareness ranked higher.

PII has found similar data from review of more than 2000 process safety incidents around the world. Of these, when a proper root cause analysis is performed, about 90% of accidents have “procedure deficiency” as one of the root causes.^{78,79}

To independently evaluate the accuracy (correctness, completeness, and clarity for comprehension) of procedures at Chevron Richmond, PII staff and select CCHMP staff walked down 38 operating procedures in the field (~2.9% of the total estimate of operating procedures). PII scored 34 of these operating procedures for content accuracy. PII based scoring on comments from the operators in the field on whether the steps written are what they actual do.⁸⁰

The approach for the procedure walk-down began with the refinery providing the operating procedure title list to PII. Then, PII would choose a refinery unit and a procedure title from within the unit. The refinery then arranged for the walk-down in the unit by scheduling the operator (sometimes the walk-down was rescheduled one day later to allow a relief operator to be arranged for the operator who was performing the walk-down). The procedure was printed and signed out to PII staff an hour or two before the walk-down. One (or sometimes two) PII staff (with the proper PPE and with a management-appointed safety escort) would meet a senior unit operator in the control room and sign into the unit. The group would then check with unit staff to confirm there were no safety issues in the unit. Thereafter, the senior operator, PII auditor, and the escort would proceed to mimic execution of the procedure in the field (without changing the state of the process/unit), including climbing ladders and standing and viewing exactly what the operator would see and where they had to reach to accomplish each step. The procedure used by the operator was marked up as discrepancies were noted.

The operator's statements of how to perform the task were taken as the basis for judging the accuracy of the steps. This decision was based on two factors: (1) PII's experience performing many such audits at other refineries, petrochemical plants, and similar chemical process sites has shown that what the operator says is generally accurate. (2) Operators author the operating procedures.

For the first 18 procedure walk-downs, several (sometimes many) other personnel followed the trio mentioned above. In several cases, some of the others (especially third-party PSM consultants hired by CUSA) would encroach into the discussion of how to do these steps. Since most areas of a refinery are relatively noisy, this made a tight squeeze in some areas of the units.

Despite initial crowded conditions and the distractions by managers and lawyers who also accompanied some of these walk-downs, operators appeared to be very candid and forthcoming about where the documented operating procedure steps were wrong or missing. The operators also pointed out many human factor engineering or work environment issues. The PII staff member used a procedure-writing checklist and human-factors checklist to record observations on the clarity of the procedures and on human factor issues observed in the units.

Inaccurate content can mean a step is missing, a step is wrong, or a step is out of sequence. Each inaccurate step was counted as one mistake in the procedure. The sum of the number of erroneous steps was divided by the total number of written steps in the procedure section reviewed in the field. The average accuracy of content was 84.4%, with a standard deviation of 12% and a range of 50-100% accuracy.

- Seven of 34 procedures reviewed had 95 to 100% accurate step content.
- Six of 34 procedures reviewed had between 90% and 95% accurate step content.
- Eleven of 34 procedures reviewed had less than 90% but at least 80% accurate step content.
- Six of 34 procedures had between 80% and 70% accurate step content.
- Four of 34 procedures were below 70% accurate step content.

Note that accuracy varied widely between procedures from different operating unit. Some were in very good shape while others have higher rates of inaccuracies. For example, the SRU operating procedures that were walked down were in the upper range of accuracy: 95-100% accuracy for steps. This corresponds with the excellent OJT we observed in that same unit.

From PII data previously collected by interviews across more than 100 operating sites (not including Richmond Refinery).⁸¹

- Nearly all workers will ignore a procedure that is 70% accurate or worse.
- Greater than 50% will ignore a procedure that is about 80% accurate.
- More than 80% of the staff will follow good procedures, which are about 95% accurate.
- Excellent procedures are 98% accurate or better; nearly all staff respect such procedures.

Note that the 84% accuracy of content at the Richmond Refinery is better than the roughly 75% average of the facilities measured by PII. Despite this favorable comparison to peers, significant improvement in procedures in some units is possible. From the results above, PII estimates (interpolating from the refinery sample data above) that about 40% of the operating procedures at the refinery may not be used by operators due to inaccuracy of content. (At most refineries where similar walk-downs were performed, it was estimated that more than 60% of the procedures are not being used by operators.) In addition, erroneous steps in the procedure could lead directly to a cause of an accident, if the erroneous step is performed. Therefore, human error rates are very likely higher than they should be, in the units with poor operating procedure content accuracy. These conclusions appear to be consistent with observations from the internal *Chevron Corporate Major Incident Study* in 2008 and 2012 that listed procedure inaccuracy as a major concern.

Note though, that the sample size, though large compared to other audits, is still small compared to the number of procedures at the refinery. After a larger sample is collected, it should be possible to determine why the procedures are inaccurate in some units and not in others. However, PII believes (based on results from helping many companies develop operating and maintenance procedures) that requiring the written procedures to be walked down (validated) in the field by operators from multiple shifts will help ensure that procedures are 95% or higher accurate.

These procedures were also scored for clarity of the content (in addition to accuracy), using a scoring scheme developed by PII⁸² that is in turn based on scoring schemes developed by Swain⁸³ and U.S.NRC.⁸⁴ The results on procedure clarity are discussed in the Human Factors portion of this Safety Evaluation (see Section 4.2).

All operating procedures are formally reviewed on a 3-year cycle. However, the review process does not require SMEs to walk down procedures to validate their accuracy. Industry peers have found it necessary to periodically walk down a small sample of procedures to assure procedures stay accurate.

Recommendation 23

Implement management systems at the refinery so that procedures are accurate, complete, clear, and consistent with best practices for reducing human error. For example:

- **Develop procedure walk-down instructions for SMEs (i.e., operators) to use when checking a procedure for accuracy and completeness. Provide guidance on addressing (including) human factors/latent conditions for simultaneously evaluating procedure clarity.**
- **Walk down enough procedures in the refinery to determine which units fall below 95% accuracy. Rewrite and revalidate as quickly as possible the procedures in the units with accuracy scores lower than 95%. Develop a procedure-updating matrix to focus resources on most critical procedures.**

- Have SMEs (i.e., operators for operating procedures, maintenance craft-persons for maintenance procedures) walk down all new procedures in the refinery before they are issued, to ensure accuracy is 95% or above.
- Complete the upgrade of procedures to follow the best practices for page format and step format.
- Expand SME expertise in Human Factors using a best practices human-factors checklist during procedure walk-downs so that they can quickly implement control of other human factors.
- Continue to upgrade the Criticality Index for written instructions to make clear to operators which instructions are procedures, checklists (required for use), or job aids (instructional basic assistance).
- Because of operating procedures' significance to process safety, measure OE Leadership and Refinery Safety Culture for Written Instructions (all departments) by implementing KPIs that reflect management commitment and operator buy-in for accurate and useful procedures. Emphasize procedure updates, improved procedure composition to address human factors, walk-down of procedures by a second and perhaps third operator (other than the author), etc.
- Ensure that a procedural PHA is done on each newly created and/or revised startup, shutdown or emergency procedure before the procedure is released for use.
- Revise RI-363 Process Hazard Analysis to include roles, responsibilities, procedures and documentation for conducting Procedural PHAs.

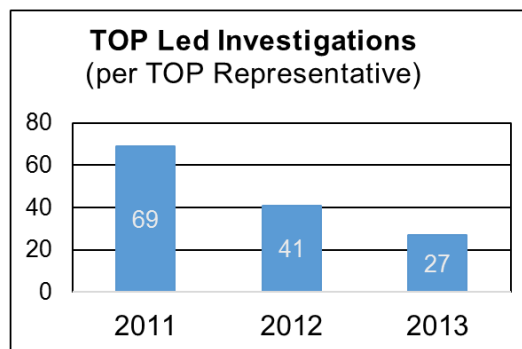
4.1.8 Incident Investigation (Root Cause Analysis)

TOP (Triangle of Prevention – *United Steelworkers*) trained investigators (represented workers trained as incident investigators using the TOP method) have the opportunity to request leading investigations. In 2012, TOP investigators requested 126 investigations and 41 requests were accepted.

Feedback to the safety-evaluation review team indicated half of the requests received no response. CUSA management indicates investigations were declined because management is allowed to choose from other approved methodologies: 5-Why or *TapRoot*™.

Represented employee feedback regarding declined TOP investigation requests indicated that the TOP methodology always blames management, so management does not want to use that method.

Other TOP representatives commented that they were told that management wants to retain the right to discipline employees who may be found at fault. The TOP agreement does include a requirement that no discipline will be given because of the TOP investigation. Chevron management expectations are that discipline is not administered because of incident investigation findings unless there is evidence of neglect or intentional misconduct. Neither the management team nor the union has re-signed the TOP agreement of commitment to safety



(there is not a set frequency for re-signing this agreement). TOP representatives have requested training in other methods, specifically *TapRoot™*. Refinery management has not granted the requests for funding of this training. The refinery does provide training for TOP. *TapRoot™* classroom training is conducted for *TapRoot™* investigation facilitators, identified by CUSA management. Just-in-time training is conducted before each *TapRoot™* investigation and includes all scheduled investigation participants. *TapRoot™* investigations are conducted on all API RP-754 Tier 1 incidents and can be used on other incidents.

API RP-754 Tier 1 Indicator Definition and Consequences⁸⁵

A Tier 1 Process Safety Event (T-1 PSE) is a loss of primary containment (LOPC) with the greatest consequence as defined by API RP-754. A T-1 PSE is an unplanned or uncontrolled release of any material, including non-toxic and non-flammable materials (e.g. steam, hot condensate, nitrogen, compressed CO₂ or compressed air), from a process that results in one or more of the consequences listed below:

Note: Non-toxic and non-flammable materials (e.g., steam, hot water, nitrogen, compressed CO₂ or compressed air) have no threshold quantities and are only included in this definition because of their potential to result in one of the other consequences.

- An employee, contractor or subcontractor “days away from work” injury and/or fatality;
- A hospital admission and/or fatality of a third-party;
- An officially declared community evacuation or community shelter-in-place;
- A fire or explosion resulting in greater than or equal to \$25,000 of direct cost to the company;
- A pressure relief device (PRD) discharge to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences:
 - Liquid carryover;
 - Discharge to a potentially unsafe location;
 - An on-site shelter-in-place;
 - Public protective measures (e.g. road closure); and a PRD discharge quantity greater than the threshold quantities in Table 1 [API RP-754]; or
- A release of material greater than the threshold quantities described in Table 1 [API RP-754] in any one-hour period.

TOP and 5-Why investigations are conducted for API RC-754 Tier 2 or lower incidents.

Tier 2 Indicator Definition and Consequences⁸⁶

A Tier 2 Process Safety Event (T-2 PSE) is a LOPC with lesser consequence. A T-2 PSE is an unplanned or uncontrolled release of any material, including non-toxic and non-flammable materials (e.g. steam, hot condensate, nitrogen, compressed CO₂ or compressed air), from a process that results in one or more of the consequences listed below and is not reported in Tier 1:

Note: Non-toxic and non-flammable materials (e.g. steam, hot water, nitrogen, compressed CO₂ or compressed air) have no threshold quantities and are only included in this definition because of their potential to result in one of the other consequences.

- An employee, contractor or subcontractor recordable injury;
- A fire or explosion resulting in greater than or equal to \$2,500 of direct cost to the company;
- A PRD discharge to atmosphere whether directly or via a downstream destructive device that results in one or more of the following four consequences:
 - Liquid carryover;
 - Discharge to a potentially unsafe location;
 - An on-site shelter-in-place;
 - Public protective measures (e.g. road closure); and a PRD discharge quantity greater than the threshold quantity in Table 2 [API RP-754]; or
- A release of material greater than the threshold quantities described in Table 2 [API RP-754] in any one-hour period.

Results from the Process Safety Culture Written Survey show that 79% of all refinery employees and contractors responded favorably to the following question, “Workers at all levels of my refinery actively participate in Near Loss Incident and Loss Incident investigations.” Responses for hourly operators are 59% and hourly maintenance is 65% favorable for the same questions. This difference in scores between the operator/maintenance level and the engineering/technical levels could be indicative of observed employee involvement vertically within the refinery organization as a whole, but with narrow participation (only a few) within the hourly work group. The difference in opinion is significant from the Safety Culture Interviews, which showed that less than 20% of technical staff and management had a *negative* view of the incident reporting and investigation at the site, while at the opposite end of the opinion scale, only 20% of the hourly staff had a *favorable* view of incident reporting and investigation. Interview Survey results of 20% favorable from represented employees indicate they are not convinced of management’s leadership commitment to Near Loss and Loss Incident investigations. (See Section 4.4 for a discussion of how and why written survey results differ from interview data and direct observations of process safety implementation.)

To address this important process safety-culture factor, management must demonstrate commitment. Best practices observed by PII (across several industries) at sites that have closed this gap are:

- Management provides training for investigators; nearly all investigation leaders are from operations and maintenance workers; typically, 10-15% of the workers are trained to be investigators (root cause analysts).
- All operations and maintenance staff are trained on how to recognize and report near misses and on how to interview peers.

- Selected staff reaches a higher competency to allow them to "quality assure" the results of other investigators (root cause analysts).
- One or two staff is trained to tabulate and query the data for systemic trends.
- Management allows the employees the time necessary to investigate incidents and generate reports.
- Management communicates incidents and lessons learned to all affected employees, and management must forward this information to other sites where the lessons would be important.
- Management shows an interest in the results and enforces follow-through and documentation of the resolution of recommendations.⁸⁷

Richmond Refinery can benefit by following the steps listed above.

Feedback from employee interviews suggests that most investigations (as much as 90%) use the 5-Whys methodology, led by an area leader/supervisor responsible for the area (first line of management). CUSA follows an incident-reporting matrix that provides specific requirements for investigation methodologies and investigation leadership based on severity of incident. More severe incidents apply *TapRoot*™ investigations and include Union Representatives. SMEs are not always involved in investigations and do not always agree with the conclusions. For 5-Whys, root causes are categorized by Loss-Prevention System Factors and Solutions. The available solution categories include:

- Training
- Develop/Amend Procedure
- Implement System/Set Expectation
- Provide/Repair/Replace Tools or Equipment
- Coach/Discuss and Gain Commitment from Employee, and
- Minimize/Limit Impact.

Per interview feedback, several of the above categories (training, set expectations, coach/discuss/gain commitment) seem to be frequently identified (or at least interpreted by the employee) as operator errors or unsafe behaviors (assigning blame). Divergent views for management and represented employees about the effectiveness of incident investigations and the prescribed solutions are the byproduct of not getting to the root cause(s) for the incident. It also is indicative of a culture that focuses on investigations of the "big stuff" and misses the many opportunities to learn from incidents with little or no current consequences (but with high consequence potential, eventually).

Industry of all types recognizes the necessity to investigate incidents and accidents with significant consequences. However, best practices for process safety-incident prevention require leadership initiative and commitment to learn from near misses, i.e., those incidents without actual harm or loss.

Investigating near misses is critical to preventing accidents, because near misses share the causes and root causes of accidents. They are one or two barriers away from the loss/accident. Many apparently unrelated accidents likely are prevented when near miss incidents are investigated with effective recommended actions (solutions) that prevent the others, which are obviously related.

The evaluation team's records review indicates near miss reporting and TOP incident investigations are in decline, possibly for similar reasons.

Industry data indicates that ratios of 50 to 100 near misses reported to loss incidents are possible with the right leadership and systems. The primary industry textbook, *Guidelines for Investigating Chemical Process Incidents*, 2nd Edition, 2003, CCPS/AIChE, cites the same targets.⁸⁸ The barriers to getting near misses reported listed in these references are:^{89,90}

1. Fear of disciplinary action
2. Fear of teasing by peers (embarrassment)
3. Lack of understanding of what constitutes a near miss versus a non-incident
4. Lack of management commitment and lack of follow-through once a near miss is reported
5. An apparently high level of effort is required to report and to investigate near misses compared to low return on this investment
6. There is No Way to investigate the thousands of near misses per month or year!
7. Disincentives for reporting near misses (e.g., reporting near misses hurts the department's safety performance)
8. Not knowing which accident investigation system to use (or confusing reporting system)
9. Company discourages near-miss reporting due to fear of legal liability if these are misused by outsiders

Some represented employees feel that investigation results tend to blame the employee whenever an incident occurs. (Recall the results from the Safety Culture Interviews: Only 20% of the hourly staff interviewed felt good about incident reporting and investigation.) When incident/accident investigations with major consequences are completed and do not seem to address management system failures as the root causes, then results from other companies indicate that near miss (near loss) reporting and investigation will suffer.

It is critical to note that the only definition of a root cause adopted by the chemical-related industries, as stated in the *Guidelines for Investigating Chemical Process Incidents* (2003), is:

*A **root cause** is a fundamental, underlying, system-related reason why an incident occurred that **identifies a correctable failure(s) in management systems**. There is typically more than one root cause for every process safety incident.*⁹¹

The ratio of number of reported near loss incidents (NLI) to loss incidents (LI) is 1.6 in 2013, and 2.2 to 2.3 in the previous two years; up from about 0.7 three years ago, indicating marginal improvement.

CUSA Richmond Incident Report History								
	Level	2007	2008	2009	2010	2011	2012	YTD 2013
LI	3 & 3a	11	8	13	10	12	10	409
LI	2	27	32	40	34	44	56	
LI	1	553	523	678	484	385	403	
NLI		298	283	297	397	976	1068	670
NLI/LI Ratio		0.50	0.50	0.41	0.75	2.21	2.28	1.64

Industry experience as documented in the *Guidelines for Investigating Chemical Process Incidents* (2003), which includes data from refineries, petrochemical plants, and chemical plants, indicate that near miss to accident ratios of 20:1 or higher are achievable with

management leadership (an exceptional organization may achieve 100:1). PII helped to collect much of the data for the research into getting near misses reported. From the data, near miss reporting does not help to reduce the likelihood of losses/accidents until the ratio is greater than about 5, and miss reporting and investigation begin to significantly help drop accidental losses when the ratio is above 10. Most companies initially target a ratio of 15 or 20. Based on Richmond Refinery reported ratios in the 1 to 2 range, most near misses are **not** being reported and investigated.

Each NLI has about 50% of the root causes as an LI⁹², so at a ratio of 2 near loss incidents to 1 loss incident, the refinery may be currently learning an equal amount from each type of incidents (if a good root cause analysis was completed on each type). However, once the refinery achieves a “good” ratio of 20 to 1 and investigates each NLI to root causes, they will find 10 times as many root causes from NLI investigations as they do from LIs. Achieving this level has been instrumental in other facilities reducing losses by 90%. ***Another way to look at the data is that the refinery is currently missing 90% (compared to a ratio of 20:1) to 98% (compared to a ratio of 100:1) of their root cause data.*** This is especially critical, because root cause data can tell the refinery precisely where they are weakest.

The refinery is experiencing low ratios similar to many in the refining industry, apparently for the same nine (or so) reasons listed above. Other sites and industries have been able to change a ratio from as low as 0.5 to (within one year) reaching ratios of 50 or higher, once the barriers to near miss reporting are reduced or eliminated. The typical barriers cited at the refinery during safety culture individual interviews (discussed in detail later) are:

- Fear of being blamed by management for mistakes/errors (this is reinforced by mandatory drug testing)
- Embarrassment
- Lack of follow-through on previously reported NLIs
- Confusion over which system to use (CUSA or TOPs)
- Fear of the extra workload

Refinery management can inadvertently reduce near miss reporting by related actions they take. In a recent refinery management decision, a corporate policy to drug test all employees involved in any incident report (if impairment cannot be ruled out as a possible contributing factor) was re-communicated to all refinery staff. The perception was that drug testing would increase following reporting of LIs or NLIs. Indeed, a review of drug testing data from the refinery shows that in 2012, 1.1% of reported incidents resulted in drug testing, and in 2013, 3.8% of reported incidents resulted in drug testing. So, drug testing increased 3-fold. However, the percentage is still relatively low, indicating that the fear of drug testing is higher than the actual percentage of drug testing occurring. To help improve near miss reporting, it may be best for the refinery to restate their drug testing policy related to incident reporting to something akin to: “The refinery reserves the right to administer drug testing, whenever there is evidence of impairment. But it is not the policy of the refinery to drug test simply because there is an LI or NLI.” Fear of mandatory drug testing following reporting of an incident or near miss has driven near miss report down at other facilities.

CUSA Richmond should explore methods for increasing Near Loss reporting with emphasis on removing barriers to reporting and then implement effective solutions that identify/resolve root causes (management system weaknesses). Examples from industry are provided below.

Industry example: Ashland refinery recognized the need to get more near misses reported, to learn what causal factors existed and how to prevent these, by addressing the root causes of the causal factors. Part of the successful approach was to appoint a represented employee (a maintenance mechanic) as the Chief Investigator for the refinery. Many operations and maintenance staff received training. The Chief Investigator coached new investigators, and he ensured investigations reach root causes (management system weaknesses). Near miss reporting greatly improved at the site and accidental losses dropped dramatically.

Industry example: Amoco Oil's offshore business unit in the Gulf of Mexico recognized the need to get more near misses reported, to learn what causal factors existed and how to prevent these, by addressing the root causes of the causal factors. Part of the successful approach was to turn over all investigation responsibility to operators and mechanics and riggers and roustabouts. About 15% of such staff received investigation leader and root cause analyst training. Refresher training was provided after six months. A simple MS Access database was created to store and track incident investigation results and to trend root causes. Within two months of initiating this change and completing the training of investigators, near miss reporting improved to a ratio of about 80 near misses being report per loss event (accident). The ratio before this initiative was less than 1. Accidental losses dropped dramatically.

Industry example: A recently updated research paper on the gains from near miss reporting provides many examples of companies that have achieved high near misses reporting. Typically, achieving a ratio of 20 near misses reported versus number of accidents will result in a 90 to 95% reduction in losses (and severity of accidents).⁹³

Recommendation 24

Explore methods to minimize known barriers to near loss incident reporting, including establishing a blame-free zone for all incidents, especially near loss incidents. These steps should include:

- Simplify investigation and reporting for NLIs.
- Consider modifying the written drug testing policy and its negative influence when coupled with incident reporting.
- Ensure only peers interview peers during data collection.
- Ensure investigations get to root causes (management system failures).
- Allow hourly staff to take the lead on investigations (as other companies have done).

Establish and achieve a NLI/LI ratio goal of 20 or more.

Recommendation 25

As mentioned in Recommendation 24, use hourly operators and maintenance workforce more as lead investigators. To facilitate this, consider providing broad training (including to operators and maintenance hourly staff) in the best practices of investigation and root cause analysis methodologies. Note that TOP does not have a Root Cause Coding Tree to ensure investigations reach root causes.

Recommendation 26

Consider ways to improve incident investigations. These investigations should be conducted in a balanced, consistent, and timely manner, involve people closest to the work being performed, find root causes, and develop sustainable solutions.

Refinery management should reinforce that investigations focus on fixing the underlying management systems. They also should reiterate that only management system weaknesses (including those that affect design of equipment and design of tasks) can be root causes. Periodically conduct a management-level review of all incident investigations.

The refinery has a Green Card system for reporting unsafe conditions, unsafe acts, or near misses. This system can be anonymous and is one way to capture near misses that might otherwise go unreported. The Green Card system appears to work as intended. Note, though, that anonymous reporting of near misses does not help reduce the likelihood of the related accident: A root cause analysis cannot be performed with the specifics of the incident, because it is not possible to collect the data needed if the incident is reported anonymously.

Chevron tracks and closes recommendations from incidents using IMPACT. PII did not find issues with this closure system, other than it appeared that many operators and maintenance craft-persons did not review the closure system as asked to do many times, to review and learn from the recommendations and the closures.

4.2 HUMAN FACTORS

Section 2.6 “What Are Human Factors” of this report lists key human factors that any endeavor must try to control. Chevron Richmond recognizes the importance of human factors and has programs in place to address many aspects of human factors. Although significant weaknesses are identified in the control of human factors, the refinery is well ahead of most U.S. Refineries. A great many refineries do not have any program on human factors.

General refinery Human Factor program (RI-381) references:

- RI-384 for Latent Conditions
- RI-360 for Process Safety Policy
- RI-363 for addressing human factors in PHAs
- RI-371 for Event Reporting and Incident Investigation
- OEM guidelines for writing operating procedures
- RI-382 for MOC, which includes management of organizational changes (MoOC)
- Site Safety Plan, which provides an overview of what the site does to comply with requirements from CCHMP in RISO

In addition, other corporate standards and refinery instructions (some are mentioned later in this section) cover other categories of human factors control. RI-381 (*Human Factors Program*) requires training of operating and maintenance staff in human factors, with the PSM department responsible for this training. The Operational Excellence & PSM Manager oversees the sustainability of the *Human Factors Program*. The online document for the refinery that describes the Operation Excellence program also describes the functioning of the Human Factors committee.

There is also a refinery Human Factors Committee (as part of the RISO requirements, and so assigned to RISO team) that includes management, workers, union representatives, PHA rep member, incident investigation and reporting representatives, contractors, and L&D representatives.

- This committee meets monthly.
- It focuses mainly on *Latent Condition* as listed in the master checklist by the same name (the Latent Condition Checklist serves as a common ground for discussions of what constitutes human factors).
- It addresses concerns raised related to reviews conducted using this checklist and from other reviews, such as investigations of incidents.

The following summarizes the evaluation team's findings related to human factors. Also, see the CCHMP audit on the RISO requirements for human factors.

4.2.1 Procedure Clarity

Section 4.1.7 describes issues related to procedure content and accuracy. As an additional human factors consideration, the operating procedures do not consistently follow best practices for formatting a page or a step. During the procedure walk-downs, the human factors issues listed below were found with the formatting of the pages and steps of the procedures. Each of these affects the error rate in using the procedure; each factor is independent of the procedure accuracy. Note that the procedure rules that these observations are based upon can be found in papers from PII in *Table 3: Procedure Quality Checklist*, provided in "Human Factors and Their Optimization" (2012), www.piii.com/resources.^{94,95} These, in turn, are based on rules developed by Swain⁹⁶ and further enhanced by JBF Associates, ABS Consulting, and PII (see the training materials on procedure writing from these companies).

- Titles are clear and descriptive, but they are not the largest item on the page. Currently, this will cause minimal impact on human error rates.
- Document control features are not the smallest items on the page. Currently, this will cause minimal impact on human error rates.
- White space is effectively used, numbers are very simple, and overall page format is appropriate. This is good.
- Most steps are written as commands with a single action per step. This is good.
- Acronyms, jargon, and level of detail are appropriate, common words are used. This is good.
- Graphics are infrequently used, and when present they are not effective because of poor quality or confusing details. This aspect should be improved across Chevron.
- Play scripts are used sometimes to coordinate between control board operator and field operators. However, some tasks that require coordination between two or more individuals (such as furnace lighting) in the field are not specified. Further, tasks that require coordination with non-operators (maintenance, process engineering) are not always well defined. This aspect should be improved, especially for the cases where two operators must coordinate activities to accomplish the task.

- Many procedures include redundant information up front (chemical hazards, PPE requirements, etc.). This could be moved to a more general section in the unit operating manual. If these sections remain up front, then make sure any implied actions in these sections are numbered instructions/steps.
- Prerequisites and assumptions included in introductory materials are useful, since knowledge of the “starting point” is often essential in determining which procedure should be followed. However, these starting assumptions and prerequisites should be converted to steps to verify the conditions are met.

PII reviewed several procedures that have been revised to comply with the new Human Factor (HF) requirements and template. However, these were not significantly more accurate, nor did they follow the clarity rules better than those procedures that had not been recently revised. The Human Factor reviewers within Chevron Richmond are not SMEs in operations, and so they are not responsible for procedure content or accuracy.

The writers (SMEs, operators in this case) have a copy of the *Latent Conditions* checklist with them while writing new procedures. They also have a guide from the *Procedure Writing* CBT course as a guide.

Per interviews, the Manuals and Procedures (M&P) group staffing was recently increased. They have responsibility to ensure that all procedures are reviewed in a timely (3-year cycle) manner, apply good human factors, and comply with all HES requirements. Housed within the L&D group, M&P has four full-time members. All procedures are managed in the EOM database. The content and accuracy of all procedures remains the responsibility of the ABU.

According to interviewees, many operations trainers have attended an instructor-led training course (two 4-hour classes) in procedure writing that covers good human factors. All refinery employees have taken the CBT in human factors, although many were unable to recall anything from the CBT course.

Note: Special assignments are generally 3-year assignments, although how these are handled varies across the ABUs and departments. Some rotate every three years while others are able to continue as trainers in these roles beyond the 3-year assignment. Most are SMEs with extensive experience in their areas who are “go-to” people. Management depends heavily on them for accomplishing many “special projects” in addition to their procedure and training responsibilities. In some circumstances, this can and has diluted their focus.

See Recommendation 23 in Section 4.1.7

4.2.2 Verbal Communication

Verbal communication (the controls against miscommunication) is under the responsibility of L&D. Most workers seem to have heard of and previously taken a CBT on the rules for controlling verbal communication. However, there is no enforcement program and no measurement/tracking of implementation. The training did not include some of the best practice rules, such as repeat back. However, some units (such as SRU, Chevron Fire Department, and at the Long Wharf) do use repeat back routinely because “they know it reduces errors.”

Per observations during operating procedure walk-downs, clear communications between the field operators and the CBOs are recognized as essential. Yet, the operations personnel in all areas of the refinery do **not** consistently use some good verbal communication practices, such as repeat-back.

PII reviewed the CBT on radio communication. This generic course does not discuss many of the best verbal communication practices or site-specific requirements. The auditors were not able to find any refinery-specific guidance or procedures for preventing miscommunication.

Note that the *Latent Condition Checklist* used in PHAs only elicits issues such as poor radios for human factors related to verbal communication. The PHA facilitators do not include best practice rules for verbal communication, and the *Latent Condition Checklist* does not include a question on how to practice verbal communication to reduce error.

There is a project to replace the current radio system (the hardware, which was undergoing testing at the time of the on-site data collection.) It was scheduled to begin implementation in June 2014 and to be fully implemented by March 2015.

In a review of more than 2000 incidents across the industry, miscommunication has been a root cause in about 50%. Further, the CCPS guideline, *Risk Based Process Safety* (on page 475 in Chapter 17) requires following such rules as “repeat back” and using common terminology as a way to reduce such miscommunication.

Recommendation 27

Improve the program to control potential miscommunication by radio, phone, and face-to-face (such as in noisy areas). This can be done by adopting industry best practices for ensuring clear and accurate verbal communication. Such a program normally involves training on standardized terminology, repeat-back, and other rules for clear communication. It also includes frequent checking (monitoring of radio channels) and feedback by supervision on the use of proper communication techniques.

Programs are available as models for addressing the concern above. For instance, the U.S.DOE, U.S.NRC, U.S.FAA, and maritime safety organizations all require implementing programs for minimizing verbal miscommunication. Some example documents include:

- DOE-STD-1031-92; Guide to Good Practices for Communications⁹⁷
- Shift Turnover Guide – U.S.DOE 1038-93⁹⁸
- Rules for Effective Verbal Communication (Table 5), provided in “Human Factors and Their Optimization” (2012), www.piii.com/resources⁹⁹
- Guidelines for Conduct of Operations, CCPS/AIChE, 2011¹⁰⁰

4.2.3 Fitness for Duty (FFD)

The Human Resources (HR) Manager is the sponsor and the HR Business Partner is the advisor for the FFD element. Fatigue is recognized on the *Latent Conditions Checklist* used in PHAs and during other activities.

Refinery Instruction RI-395 (updated 3/12/2013) governs *Fatigue Risk Management* on the site. The Instruction was modified to align with API RP 755. This alignment was also agreed to in the latest round of contract negotiations (in 2012), with the understanding that a task team would be created to develop site-specific guidance for handling expected issues such as overtime distribution, call-in procedures, and seniority rights.

Operators work 12-hour shifts: 4 nights on, 3 days off, then rotate to 3 days on, 2 day off, then 3 nights on, 3 days off and then 4 days on, then 7 days off. Such 12-hour shift schedules result in higher intra-shift fatigue. The average error rate during a 12-hour shift tends to be twice as high as within an 8-hour shift. A nap break in the middle of a 12-hour shift will lower the intra-shift fatigue considerably and typically results in fewer errors than an 8-hour shift. A 12-hour shift for

operators is now typical for oil and gas industry, but that does not mean this is optimal for low error rates.

The refinery allows a maximum of six consecutive days of work followed by a mandatory 1 off-day. For turnarounds, the plant follows RI-395 (based on API RP 755), which allows 12 consecutive workdays on, and then two mandatory days off for short-duration tasks (such as turnarounds). As shared in interviews, workers commented that they may have worked 14 days max before a required two days off. CUSA management states that work schedules typically follow six days of work followed by 1 day off during turnarounds.

This number of 12 consecutive days of work allowed by API RP 755 and allowed by exception by CUSA for what they refer to as “short duration tasks” far exceeds the maximum exception of six consecutive days allowed by U.S. Nuclear Regulatory Commission (NRC) standards. It also far exceeds what is followed by the California State Lands Commission (CA SLC) for wharfs regarding fatigue management (these other standards are far superior to API RP 755). The aviation industry has similar rules, but more stringent than even the U.S.NRC standards. Note that the U.S. Chemical Safety Board (CSB) rejected API RP 755 as a poor standard (see the notice in March 2013 from the U.S.CSB).

The exception at Chevron Richmond to the limits above is the wharf. The wharf adheres to CA SLC rule 2376 of no more than 72 hours in six consecutive days, with then a minimum of 36 hours off duty as an upper limit. This is good.

On the other hand, exceptions to exceed the limits stated in RI-395 can be granted by refinery management based on factors such as (1) desire to have a worker put in more hours, (2) consideration of the types of errors they could make, (3) potential consequence of those errors, and (4) control measures to minimize those errors.

The supervisors are trained on fatigue management and performing fitness for duty evaluations to help them in dealing with workers who may not be fit for duty. If a supervisor judges a worker to have a serious impairment or deems him unfit for duty, the supervisor removes the worker from active assignments and sends him to the clinic/EMT for evaluation.

Currently, the functional managers and supervisors perform tracking and compliance with RI-395. There are no high-level metrics, and there appears to be limited oversight. A new work-hour tracking system is being implemented, and the refinery plans to track this type of information in the future.

Recommendation 28

Reduce the probability of human error by following 10 CFR 26 (U.S.NRC) for Fitness for Duty (FFD), which includes management of fatigue. This program outlines maximum hours on-site per day and per week and minimum time away from work per week. It also outlines how to detect symptoms of FFD issues and how to respond to these. Especially limit the maximum number of consecutive days worked to four days of 12-hours shifts and six days of 8-hrs shifts, even during turnarounds. Alternatively, allow five to six days of 12-hour shifts, with a 45-minute nap break midway through the shift. Do NOT follow the 14 consecutive day allowance in API RP 755. Note that other alternatives to work-hour limits are available, such as allowing naps in the middle of a shift (with coverage of the workload). In addition to work hours, other factors that increase fatigue are poor diet, lack of exercise, etc. CUSA should explore all issues to reduce the probability of errors resulting from fatigue.

Chevron has a substance abuse program and enforcement similar to the rest of industry in the USA, with a letter of agreement by the unions for random substance abuse testing. Amended to

the *Drug and Alcohol Letters of Agreement* with the unions are Enclosure 2, *A Supervisors Guide to Post Incident/Accident Testing*, and Enclosure 2.1, *Supplementary Instructions*, dated December 4, 2001. Per interview, the policy of doing drug tests after most near loss and loss incidents has been in place for a long time. However, it has not been consistently followed in the past. Recently, corporate HR issued a directive to reinforce compliance with this policy. Supervisors received training on the expectations and the frequency of testing increased in 2013.

4.2.4 Human-Machine Interface (HMI)

A few corporate and RIs cover HMI.

- SID (*Safety in Design*; corporate standard) covers mostly occupational safety issues. It also gives minimum requirements for egress (related to emergency egress) and access to equipment such as valves and instruments, and it allows for a risk-based approach. This standard only applies to new facilities. Note that during the procedure walk-down in one process area, one of the valves in the main process line for the compressor could not be reached without standing on some process equipment. SID-SU-5106-B, part 1.9 provides specifications for access to process isolation and bypass valves without standing on equipment. PII noted a few other HMI weaknesses in other procedure walk-downs as well. Refinery PHA teams conduct a Latent Conditions Review before PHA meetings to assess escape routes and valve positions. The effectiveness of this type of review should be investigated to determine the root cause resulting in this valve access problem.
- There is an RI for HMI, including design of control screens and alarms. However, the refinery control-screen standard was set before the issuance of the Abnormal Situation Management (ASM) Consortium guidance on using grays and limiting colors to only alarms and equipment condition changes. All of the control room screens PII observed were black backgrounds with bright colors used for the equipment components. This high-contrast, bright-color scheme makes it harder to distinguish alarms and equipment that is changing condition.
- Labeling (see RI-302) is poor throughout half of the units and good in the others. The RI for labeling has not been fully implemented, and interviewees mentioned that the improved labeling is being implemented on a risk-based plan. Yet, based on a walk-through of a number of process areas, there are many instances where the labeling and/or color coding was missing from critical lines and valves. Other high-risk areas also do not have clear labeling yet. The operators said they can identify special areas to get better labeling, but so far, progress has been slow.

RI-302, *Color Identification and Labeling of Equipment and Pipelines*, states that the "Instruction is mandatory for all new facilities and all major facility upgrades. All existing facilities are expected to eventually comply with this Instruction." Per interview and observation, new installations appear to be clearly labeled and in compliance with RI-302. However, very few facilities that existed before RI-302 was issued have been retrofitted with adequate labeling and color-coding, and compliance is inconsistent across the refinery.

For PHAs that PII reviewed, documentation did not indicate that HMI were considered consistently during the HAZOP node analysis.

Best practices would be to include operators as SMEs who are assigned the lead role in identifying where improvements in labeling and color-coding are needed. However, these SMEs likely will need training first on best practices for color identification and labeling.

Recommendation 29

Inspect the refinery units following the corporate standard for human factor engineering: *Safety in Design*. This inspection could be completed within the PHA Latent Conditions Review before PHA meetings. However, this inspection schedule could leave conditions like hard-to-reach valves unidentified (latent) for years. The walk-throughs spotted hard-to-reach valves in several units. This appears to be systemic. The operators should be the SMEs assigned the lead role in identifying possible changes in valve placement. They likely can help prioritize the units for these activities. First, review the Latent Condition Checklist versus human-factors best practices to find any gaps in the checklist.

4.2.5 Control of Dependent Error Rates

The SIS standards have not been implemented at Richmond Refinery as of the on-site data collection. The instruments on redundant channels for Emergency Shut Down (ESD) are NOT being maintained by different technicians on different days. Because this maintenance practice is not being followed, the same person can easily repeat one error on redundant channels on the same day. This maintenance practice is necessary to prevent degrading a system with 1/100 to 1/1000 probability of failure on demand to a system with no better than 1/10 probability of failure on demand.^{101,102,103}

Recommendation 30

For refinery safety systems with multiple, similar devices that serve in a protective function against the same accident scenario, the refinery needs to establish practices/procedures to reduce the chance of repetitive human error. If one person maintains these similar systems daily, he or she could repeat an error across several systems in one day. Therefore, schedule ITPMs activities to be done on different days, preferably by different technicians/staff. These situations include Safety Instrumented Systems (SIS) for Safety Integrity Level 2 and 3, ESDs, multiple check-valves, and multiple relief devices. Otherwise, the probability of failure on demand of such safety systems could be 10 to 100 times higher than expected.

4.2.6 Task Design and Staffing

For human responses that could be counted as IPLs in hazard analyses or LOPA, currently drills are not timed to validate if the human (operator) can indeed perform the actions required within the time available for the response. The control rooms do perform many situational drills (called *situationals* and *hypotheticals* across the refinery) that accomplish the same practicing of the action. However, these are done without validating that the response task can be successfully completed within the required maximum allowable response time (which is typically 1/2 of the process safety time for the accident scenario). (Note: Process safety time is the amount of time from when a process excursion begins until there is no longer any chance of preventing the ultimate consequence. Process safety time can be seconds to hours.)

Per interviews, operators on a daily, weekly, and monthly basis test many alarms listed in the PHAs as either safeguards or potential causes. Individual operating areas maintain the routes and frequencies of these responses in handheld devices. The results are not captured in a central database for review.

However, PII evaluated a selection of 16 high-consequence alarms drawn from PHA reports that require human response. PII found only one (6%) of these alarms on any of the area *routine duty lists*. Initial job training and *situationals* covered nine (56%) of these high-

consequence alarm responses, but only four (25%) were reviewed as *hypotheticals*. Note that *hypotheticals* are table-top scenario reviews, which the Head Operator of each shift selects, leads, and documents. Hypotheticals selected in the past have been related to emergency response actions rather than how to respond to critical process alarms and prevent process upsets. ABUs provide minimal, inconsistent guidance or oversight for hypotheticals, other than inclusion as a numerical performance objective (along with LPO and MOC reading/review objectives) to qualify for a \$100 safety incentive.

Refinery staff frequently mentioned *Hypotheticals* as an excellent learning tool. PII considered these drills of hypotheticals to be best in class (when compared to industry-wide practices).

Control rooms are always occupied, and staffing appears appropriate for all modes of operation. Additional operators can be called in quickly to assist in an emergency.

Recommendation 31

For human response IPLs, ensure that the response action is practiced to mimic the actual response to a critical process excursion. This practice should be timed (such as by the supervisor or a designee). The time and success or failure should be recorded to validate that the humans can respond within the predicted maximum allowable response time. This resolution could be accomplished by formalizing and recording data from the ad hoc *situationals* (and perhaps some *hypotheticals*) already performed by the refinery operators and Head Operators. Note that this recommendation is related to “how to” ensure the reliability of IPLs; following up Recommendations 9 and 11 regarding identifying IPLs and establishing an ITPM for each.

Examples of sources to address this concern include:

- “LOPA and Human Reliability – Human Errors and Human IPLs,” Bridges, W., 6th Global Congress on Process Safety, American Institute of Chemical Engineers (AIChE), 2010.¹⁰⁴
- U.S. NRC 10 CFR 55, which has a section on testing of human response to process deviation alarms.¹⁰⁵

4.2.7 Risk Analysis of Human Factors

At the Richmond Refinery, the risk analyses of human factors is performed before (and independent of) a PHA Revalidation using:

- The *Latent Conditions Checklist*. The PHA revalidation is performed using the Latent Conditions Checklist during the refinery-wide review every 5 years, which was initiated in 2008. It was supposed to be repeated every 5 years. According to data from management, the last refinery-wide Latent Conditions Review was done in 2013/2014. (Note the valve access observation in Section 4.2.4 Human-Machine Interface. Based on the evaluation teams’ limited observations, the completeness/quality of the refinery-wide Latent Conditions Review needs to be evaluated.)
- The *Alarm Objective Analysis* (AOA). This analysis is intended to help evaluate alarm overload. The most recent AOA was done for the CoGen Unit.

Both of these activities are good, although as mentioned early (See recommendation 29) the LC Checklist and Review may need improvement. In addition, there is a unit walk-through with the LCC at the start of a Revalidation to revisit these issues. The current PHA analysis method requires the PHA team to “recall” pertinent latent condition topics during the Revalidation and bring up LC items in specific nodes and for deviations, as needed/remembered. Some PHA

reports document evidence that human factors were identified that could affect causes or safeguards. However, from PII experience, a PHA of a specific unit can and should reveal an extensive list of human factor issues, as shown below.

Example of improper application of the *Latent Condition Checklist* for the Cracking (FCC) PHA Revalidation performed 8/15/2013:

- *Communication section of checklist*
 - Stated Radios were inadequate on unit and mentioned a refinery-wide issue with a project underway to replace the radios. (Note that the SRU PHA states that radios are adequate, with the supplemental use of telephones and Motorola Walkie-Talkies.)
 - As mentioned earlier, there was no discussion of the rules used by the workers to communicate (and we could not find a written program for verbal communication protocols, although there is a CBT (see Communication section of this report).
- *Labeling section of checklist* – The results stated “Yes” (meaning there is labeling) and then stated it was inadequate (from our walk-downs, we agree).
- *Alarms and alarm overload, alarm distinction, displays, information* – this discussion appears good and appears to match interviewee comments as well.
- *Procedures* – States they were written by operators for operators, but there is no evaluation of the accident scenarios that can and do occur during startup, shutdown, and online maintenance as identified during PHAs.
- Only one question addresses the many considerations about *Fitness for Duty*.

The PHAs list an alarm as a safeguard in *many* instances. However, per interviews, there was no discussion of “is there enough time for the operator to respond.” This is a critical concept for the human-error analysis portion of a PHA, since the alarm is useless if the operators cannot respond in time. Also, these alarms are NOT consolidated on a list and then checked versus (1) the control rooms to ensure the alarms can be responded to in time and to ensure they are indeed drilled by each worker once a year and (2) the inspection, test, PM database for instruments, to ensure the instruments are maintained.

In the PHA/Reval (mostly these are Redo method), there is a deviation called Human Factors. This is GOOD. Note, though, that in the PHA for CoGen completed Aug 30, 2012, the entries were almost entirely “No new causes.” Per interviews, there is not a “new discussion of HF” at this deviation (it is not like a recap of the latent conditions checklist). Rather, the HF deviation allows the team members to voice any HF concerns they may have (without prompting) for that part of the process. Several of the 27 recommendations from the CoGen PHA are related to human factor issues, which indicate there were human factor discussions.

A discussion of risk analysis for human factors would not be complete without referencing Section 4.1.4 Process Hazard Analysis and the PHAs’ focus on the continuous mode of operation. PHAs do not adequately consider non-continuous modes of operation when major accidents occur that are driven by individual human error. Simply considering the deviations of “startup, shutdown, and maintenance” during a node-by-node HAZOP of parameters has, in PII’s experience, been shown to catch less than 10% of the accident scenarios during these operating modes.

See Recommendation 5 in Section 4.1.4

4.2.8 Analysis of Human Factors during Investigation of Losses and Near Loss Incidents

Injury and Illness Prevention Plan (IIPP) – The refinery uses the approach named *TapRoot™* (from System Improvement) for accident investigations of major incidents. This approach includes consideration of human factors as, or within, root causes and drives the investigation to root causes. However, it appears the *TapRoot™* investigation results are subsequently sorted into Chevron categories to fit the Refinery's dedicated incident database structure. Using the Refinery database categories could redirect the investigation team's focus to issues other than root causes (i.e., other than management system failures and weaknesses).

For topic-specific discussions on this interlocking aspect of human factors control, see Section 4.1.2 Employee Involvement and Section 4.1.8 Incident Investigation. Per the findings listed in these sections, very few near loss incidents are reported, and almost none of these are investigated to root causes. So, most (perhaps 95% to 98%) of the root cause analysis data that could be captured is currently not available to CUSA Richmond, because of very low near loss incident reporting and very few root cause analyses of near misses.

Root causes are defined by AIChE/CCPS in multiple textbooks as “management system weaknesses,” and management systems in turn control human factors, and ultimately, human error rates.

The Safety Evaluation team noted that an action item from the Richmond Refinery Chevron Corporate internal RISO Audit Report (2013) stated that periodic human factors program evaluation needed better documentation (3-year versus 5-year cycle). The review team also noted that an action item from the Richmond Refinery Chevron Corporate internal RISO Audit Report (2013) stated that qualifications and experience requirements for human factors trainers were not established. Chevron Richmond Refinery staff say they will track these action items to closure.

4.3 PROCESS SAFETY CULTURE

4.3.1 Process Safety Culture — Qualitative Analysis

Some quantitative measures of process safety performance, such as the process safety leading indicators discussed earlier, are also indicators of an organization's process safety culture. Often, these can be compared across different facilities and even across different industries to establish standards and gauge the relative effectiveness of organizations. However, many of the more qualitative elements of process safety culture may be unique to an individual facility or even to a specific work group within the facility. It is very difficult to compare results and establish qualitative standards across different work units. Still, it is possible to establish a baseline and measure progress over time within the same (or similar) work units. (See Process Safety Culture – Making This a Reality for more details)¹⁰⁶

When conducting a culture assessment, data is best collected in a variety of ways designed to encourage complete and accurate disclosure while minimizing any bias imposed by the collection process. Results can then be compared to eliminate (or explain) inconsistencies.

The three methods for determining the process safety at Chevron Richmond (listed in order of relative strength) were:

- **Process Safety Implementation Evidence**
- **Individual Safety Culture Interviews**
- **Written Process Safety Culture Surveys**

4.3.2 Process Safety Culture — Findings/Observations from Process Safety Implementation Evidence

In this report (see Sections 4.1 Process Safety Management and 4.2 Human Factors), the evaluation team presents their summary of observations for process safety implementation evidence at the Richmond Refinery. The team considers these observations the strongest source of data for evaluating Chevron Richmond's Process Safety Culture.

4.3.2.1 Summary of Process Safety Culture Score based upon observed Process Safety Implementation Evidence

The scores in the table below represent a *Delphi approach* to collecting expert opinion, in which four PII experts (each were present for on-site data collection), independently evaluated each factor based on their observations at CUSA and their experience from other sites. The scores were averaged, but extra weighting was given (in rounding up or down) based on the relative experience and expertise of the respondent with respect to each question. This score is related to Process Safety Culture only and not to process safety implementation effectiveness, although the two are connected. This score also excludes consideration of Occupational Safety Culture.

Selected Process Safety Metrics Based on Process Safety Implementation Evidence that Relates Most Directly to Process Safety Culture		Process Safety Culture Score
Mechanical Integrity	Timely completion of ITPMs including documentation/ analysis/ follow-up on “as-found” data	Fair
	Backlog of process safety and process integrity work orders - should be low and/or decreasing	Fair
	Maintenance emergency repairs and break-in work versus planned maintenance - should be low and/or decreasing	Poor
	Temporary leak repairs - should be very low or zero	Poor
	PMI inspections performed - should be 100% for baseline equipment and welds, and for new components and new welds	Poor
	Effective “bad actors” program	Fair
Action Item Follow-up	Timely completion of recommendations and action items (from all sources including PHAs, IIs, PSSRs, MOCs, Compliance Audits)	Fair
	Audit of closure process for completeness and effectiveness	Good
Process Safety Competence	Timely completion of process safety training	Fair
	Evaluation of operator response during drills for each critical alarm (one drill per alarm per operator per year)	Fair
	Field verification and validation of operating and maintenance procedures (95% and higher accuracy of the content and 90% score on following human factors rules for clarity)	Poor
Learning from Near Losses	Work or process is stopped when workers/staff suspect serious problems	Poor
	Reporting ratio of near loss incidents to loss incidents - below 5 is poor and greater than 25 is good and greater than 50 is excellent ⁹	Poor
	Timely completion of incident investigations	Fair
	Analysis (trends) and follow-up on incident investigation results	Poor
Human Factors Control	Good control of fatigue (overtime hours, consecutive days worked)	Poor
	Observations performed of pre-job planning activities, shift turnovers	Good
	Observations performed and enforcement of rules for radio communications	Poor
	Evaluation and control of Human Machine Interfaces (HMI)	Fair
	Staffing, vacancies, absenteeism	Fair
	Job experience, certifications, and training levels	Fair
	Effective use of “Management of Organizational Change” processes	Fair
COMPOSITE SCORE ON PROCESS SAFETY CULTURE:		Fair

4.3.2.2 Selected Findings and Recommendations related to Process Safety Culture from Process Safety Implementation Evidence

Near Loss Reporting: One of the clearest indicators of (Process) Safety Culture is the number of near loss incidents being reported. This is best expressed as the ratio of the “number of near loss incidents reported” divided by the “number of actual loss incidents.” As mentioned in Section 4.1.8 Incident Investigation, this ratio should be 20 or higher to be considered good. Less than 5 is considered poor (less than 1 is considered very poor). The ratio at CUSA Richmond has gradually increased from 0.5 to 2 in a 6-year period.

Companies with strong safety culture make near loss reporting one of their top 3 priorities, since near losses can effectively predict what actual losses are about to occur. Sites of equal size have been able to propel near loss reporting ratio from the 1 range to the 50+ range in a matter of months by virtue of management emphasis and employee trust. What makes this possible is

a shift in the site leadership. Another factor may be the company's willingness to assume full responsibility and take swift corrective action of the root causes of near loss and actual loss incidents and create a blame-free environment for reporting of near loss incidents. So, Richmond Refinery's low reporting ratio of near loss incidents is a direct indicator of mistrust between represented workers and management, which indicates weak process safety culture. (See similar evidence of the poor near miss reporting environment in the related portion of Section 4.3.3 Safety Culture Interviews.)

See Recommendation 24, 25, and 26 in Section 4.1.8 Incident Investigation

The refinery has a Human Resources Department (HRD), which handles employee records, coordinates hiring, facilitates retirements and terminations, and tracks data such as hours worked, medical issues, fitness for duty issues, etc. Although this department does not have a direct role in controlling process safety, many other companies/sites have benefited from HRD becoming knowledgeable and eventually expert in human factors and the limits on human error rates. In a few companies, HRD has eventually taken a leadership role in tracking and implementing human reliability.

Recommendation 32

Increase the Human Resources Department's Process Safety Culture competencies in human factors. Also, enlarge their role in optimizing certain human factors to strengthen development of refinery work processes and staffing.

Willingness to stop work when undue risk is perceived: Another of the clearest indicators of process safety culture is how management acts to control risk when production rates are affected. The Chevron "Stop Work Authority" process normally addresses stop, notify, correct and resume approach for a resolution of potentially unsafe conditions. SMEs and represented workers verbally provided numerous instances where the SWA was used effectively for tasks that involved personal (occupational) safety concerns. Written examples show examples of such SWAs as well. They gave no examples (verbally or in writing) of SWAs used for process safety considerations (such as for preventing a process from starting back up or to shut down a process). Some process incidents have occurred that would have required a shutdown and/or delay in startup where SWA was not effectively used in improving the decision-making process.

CUSA uses an "Alert and Bulletin" process to share instances of positive use of Stop Work Authority for process and personal/occupational safety concerns, good catches from near loss reporting, and in-depth follow-up after incident investigations are complete. Often, Operations uses the non-MOC HSEs to assess process safety concerns with the appropriate subject matter experts. This is a checklist of topics for the team to reference as thought-provokers.

Chevron employees (both management and hourly) would benefit from additional training on how to apply the SWA for process safety issues. This should include:

- A description of the decision-making process in an emergency,
- The importance of basing decisions on potential process hazards of the situation, and
- An informed analysis by people that understand the hazards of the process unit and understand the risk of continuing to operate.

Chevron should conduct NLI (or LI) investigations when a SWA has been implemented for process safety reasons, including determining why the troubleshooting guides or emergency response/operating procedures may not have provided the proper guidance on handling the process upset or incident.

Continue to celebrate, communicate, investigate, and share process safety SWA successes across departments (such as potential incidents averted or minimized because of appropriate SWA intervention, resulting in a process shutdown or delayed restart). Use motivational techniques learned while implementing occupational/personal safety SWA to develop and expand process safety SWA application.

Recommendation 33

Develop methods to increase management and employee expertise in applying SWA to process safety issues (situation identification and decision-making).

4.3.3 Process Safety Culture — Findings/Observations from Individual Safety Culture Interviews

Individual interviews often provide candid and concrete examples of behaviors, actions, events, and stories that support individual perceptions and feelings. So the data tends to be much more relevant to the question area because the interviewee is able to get clarification on the questions and focus areas. The interviewer must be able to establish rapport, assure confidentiality, ask open-ended questions, and avoid judgmental or leading responses. A sufficient number of interviews are necessary to ensure that the findings are representative of the workgroup being studied and to help protect the identity of individuals. The confidence levels of the results are presented later in the section. The presence of management representatives, attorneys, union representatives or other third parties generally will negatively influence the openness of the discussion and is likely to increase a bias in the results in favor of “good culture here.”

When conducting safety culture interviews, it is useful to provide the interviewer with a guide to help keep the conversation flowing on relevant topics. For the purposes of individual interviews, PII grouped process safety-culture interview responses into the following categories:

- *Accountability (responsibilities well defined, challenges for meeting them)*
- *Learning (competence, time allocated to training, too much, too little, cancellations)*
- *Corrective action program (issues are addressed, timely, appropriate)*
- *Commitment (management support, importance of safety, personal involvement)*
- *Reporting and environment for raising concerns (near misses, willingness, practices, hesitation, and retaliation)*
- *Change Management (reorganization, organizational changes preparedness, effectiveness)*
- *Work control, work practices (empowerment, being able to stop processes, direct instructions, procedure quality)*

4.3.3.1 Summary of Interview Data

The graphs on the following pages of this section summarize responses collected during interviews of Chevron employees by the evaluation team. The findings and recommendations from the results are discussed after the graphs. Note that the color codes represent the overall opinion of the interviewee.

- Dark Green (to the far left) means Very Favorable
- Light Green means Favorable
- Gray means no opinion or uncertain it applies

- Light Red means Unfavorable
- Dark Red means Very Unfavorable

	Number interviews	% of total employees interviewed	Approx. % sampling, job category	Approx. % total refinery workforce
Technical and Management	36	37%	13%	27%
Hourly	60	63%	8%	73%
Total interviewed	96	100%		

96 Chevron Richmond Refinery employees were interviewed. The above table summarizes distribution for employees interviewed.

See the previous discussion (see Section 3.4.2 Individual Interviews) related to the random selection process and employee responses to interview invitations. The sample size was large enough for meaningful interpretation of the interview results, with an 85% confidence level in the results, at a 90% confidence interval (10% error range).

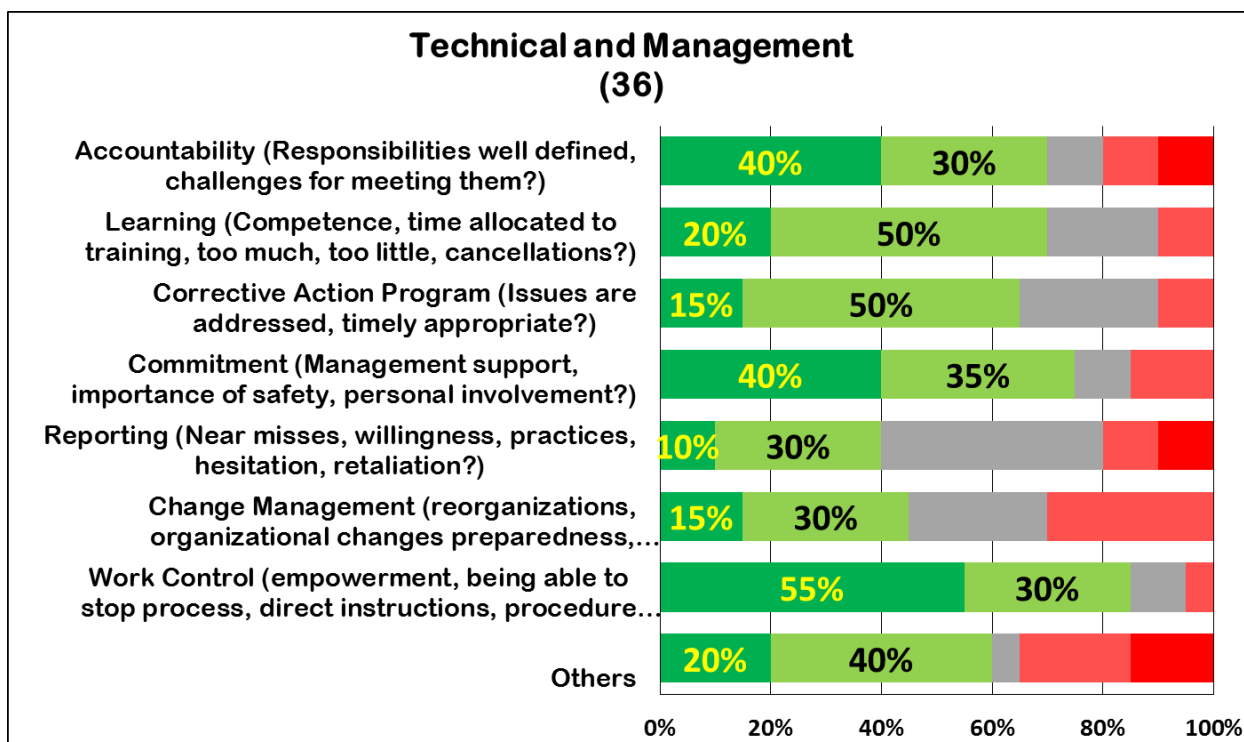
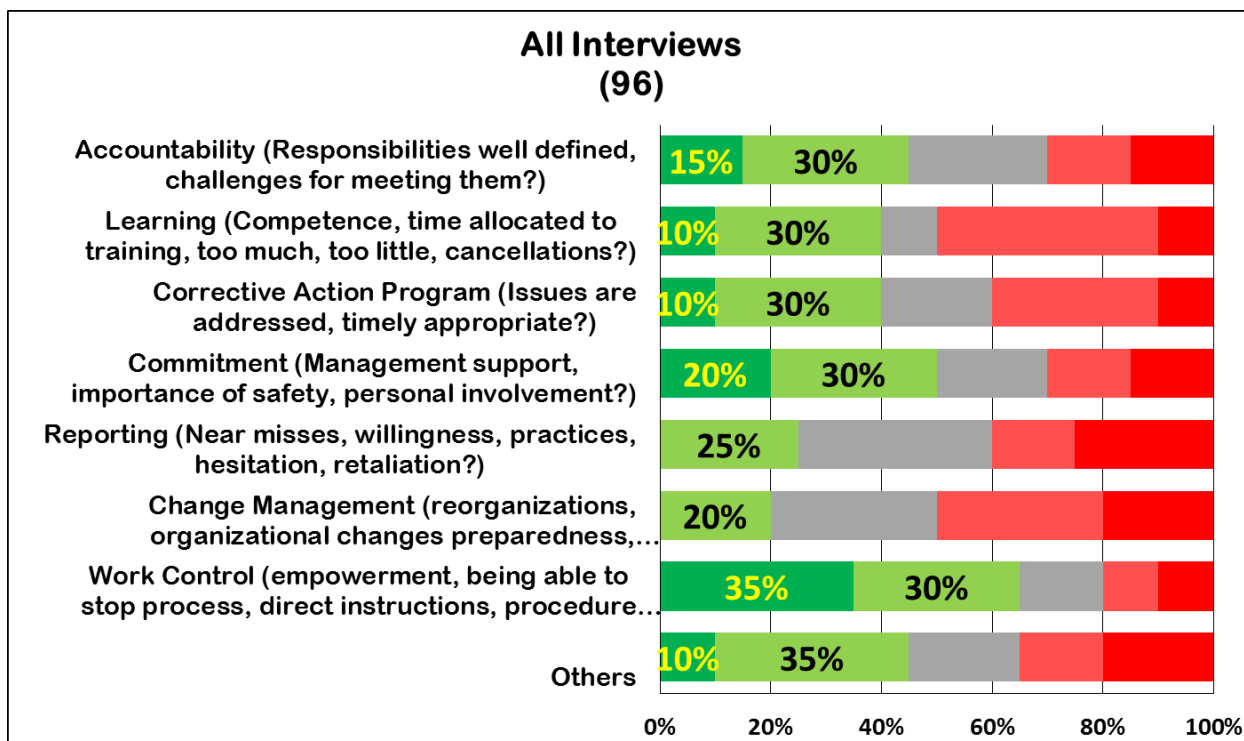
4.3.3.2 Selected Findings and Recommendations:

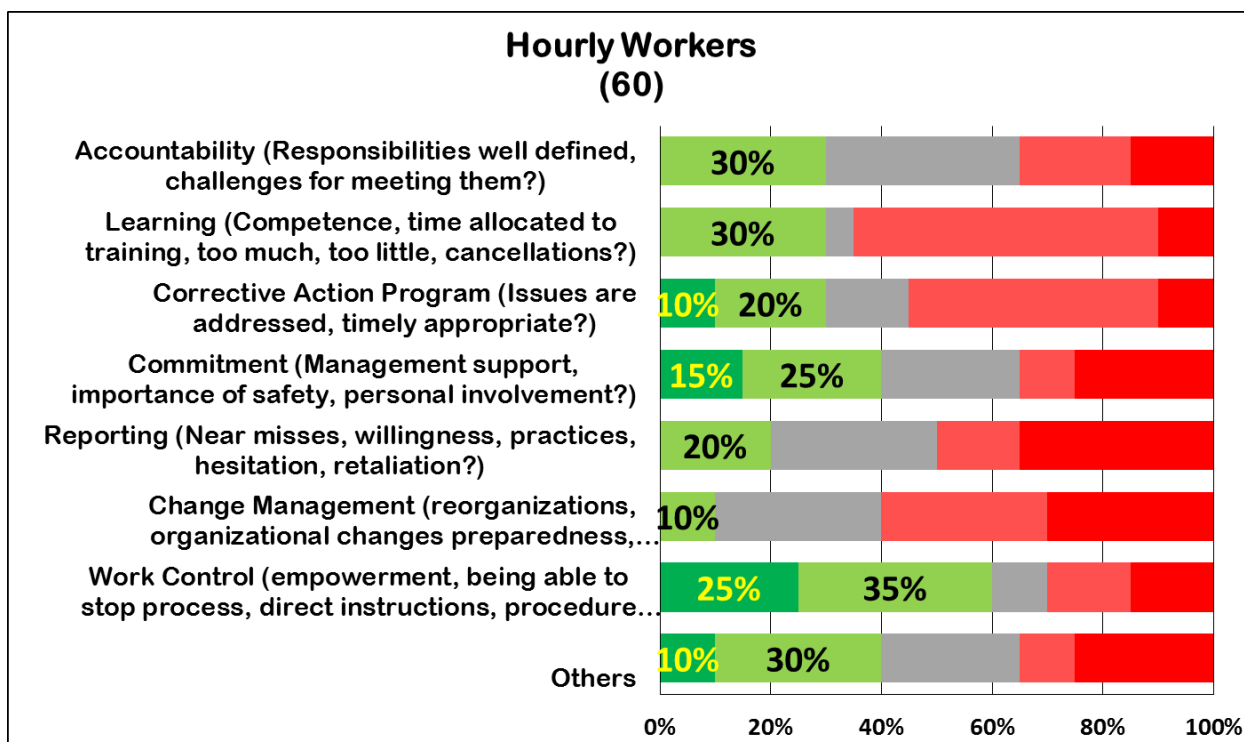
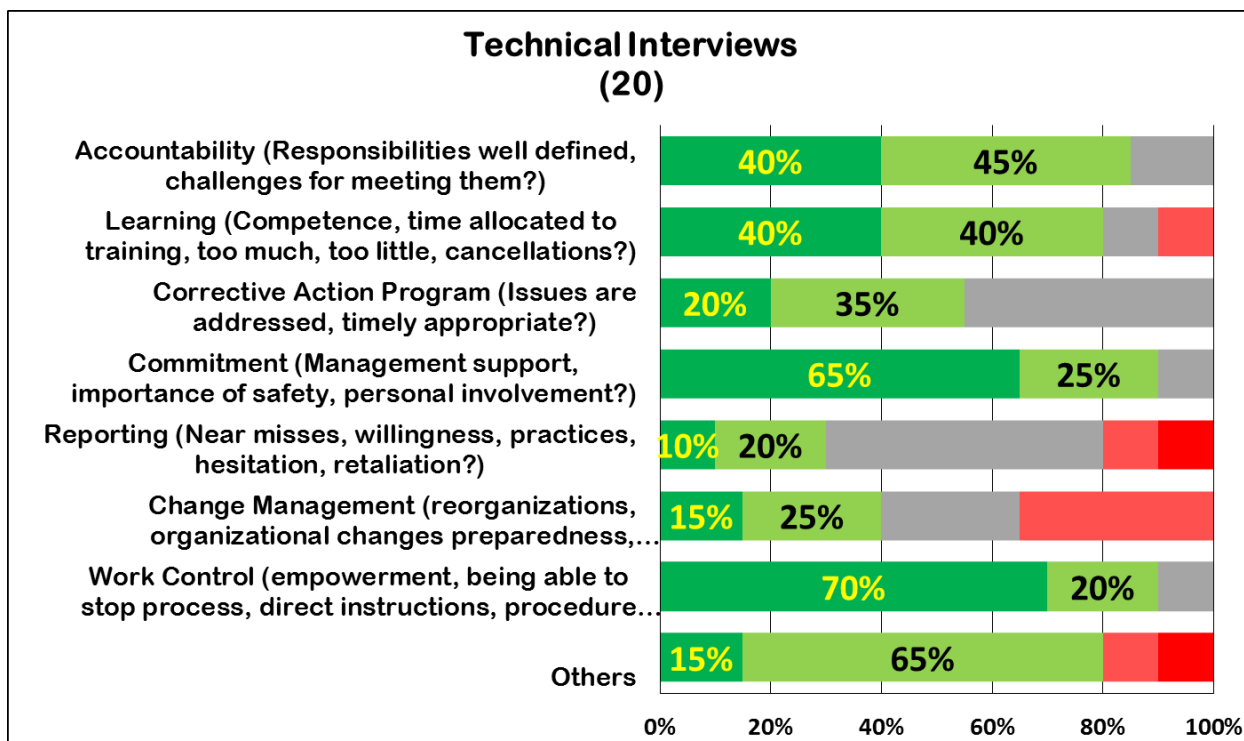
Collective Interviews for Chevron Richmond Refinery employees:

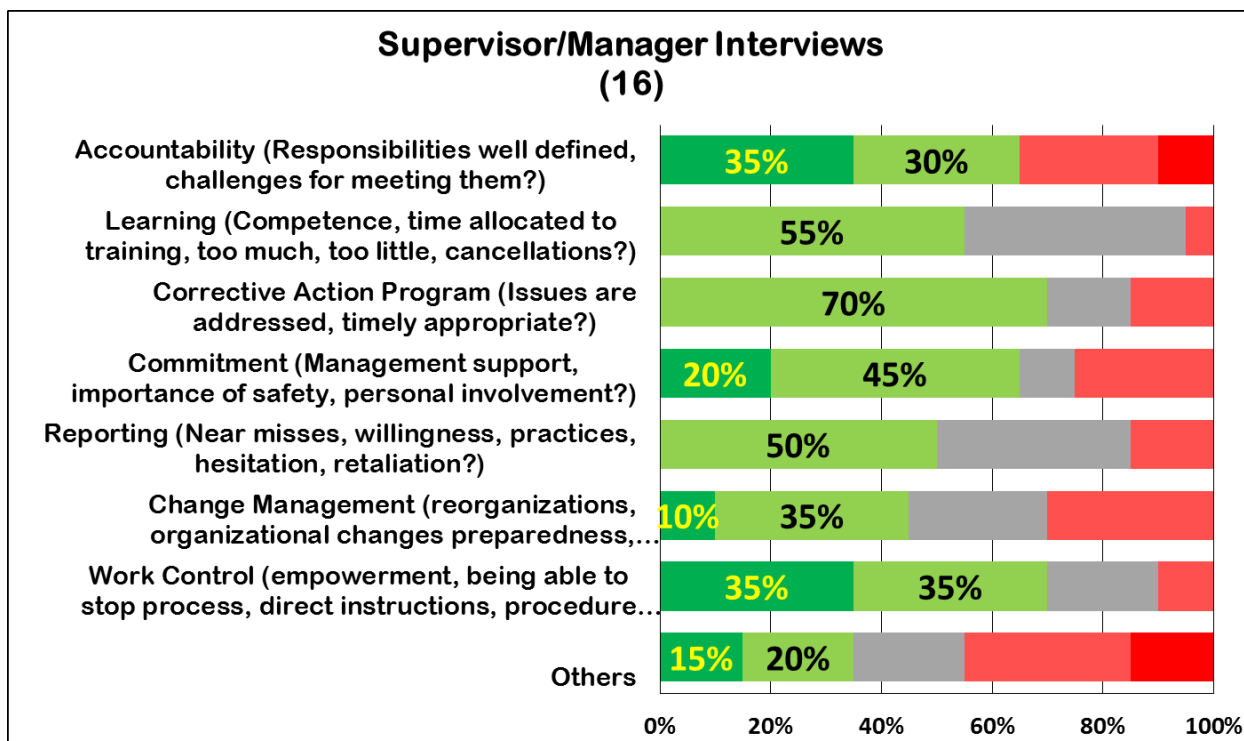
- *Accountability for process safety at the refinery (% of favorable and very favorable responses):*
 - All employees (~40%)
 - Non-represented employees (management, supervisors, technical staff) (~70%)
 - Represented employees (operators and maintenance) (~30%)

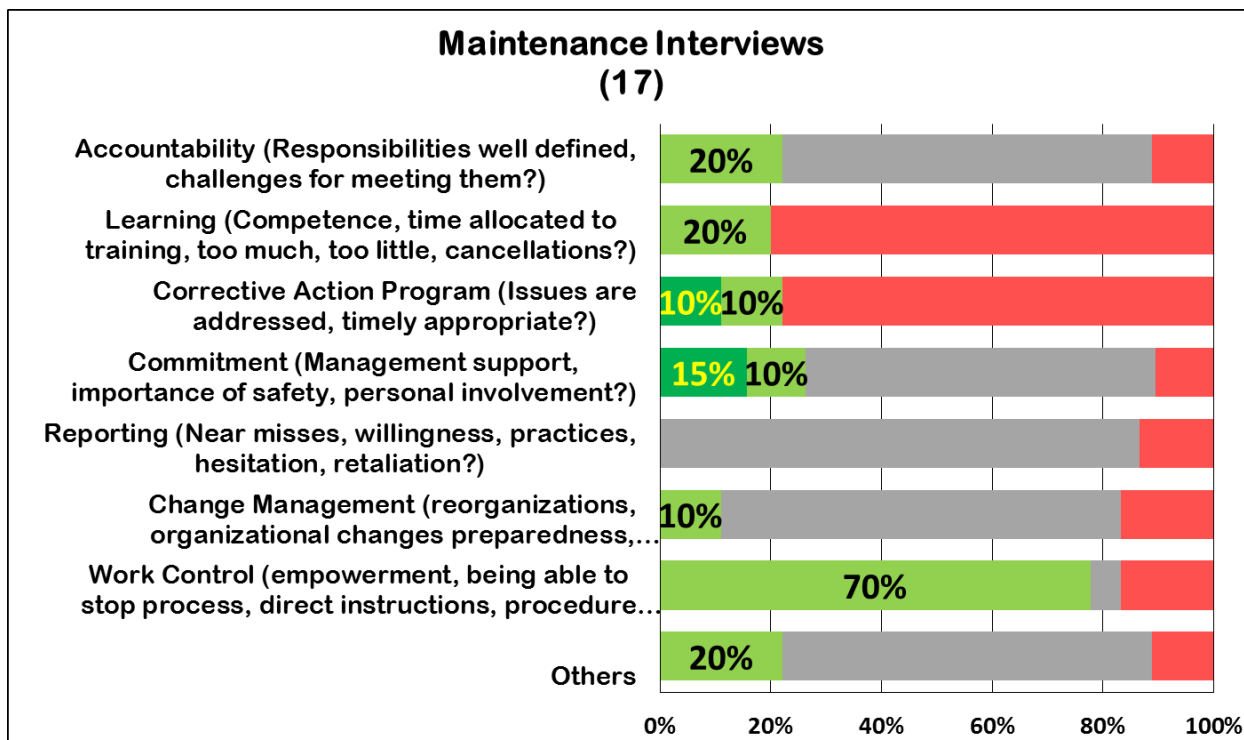
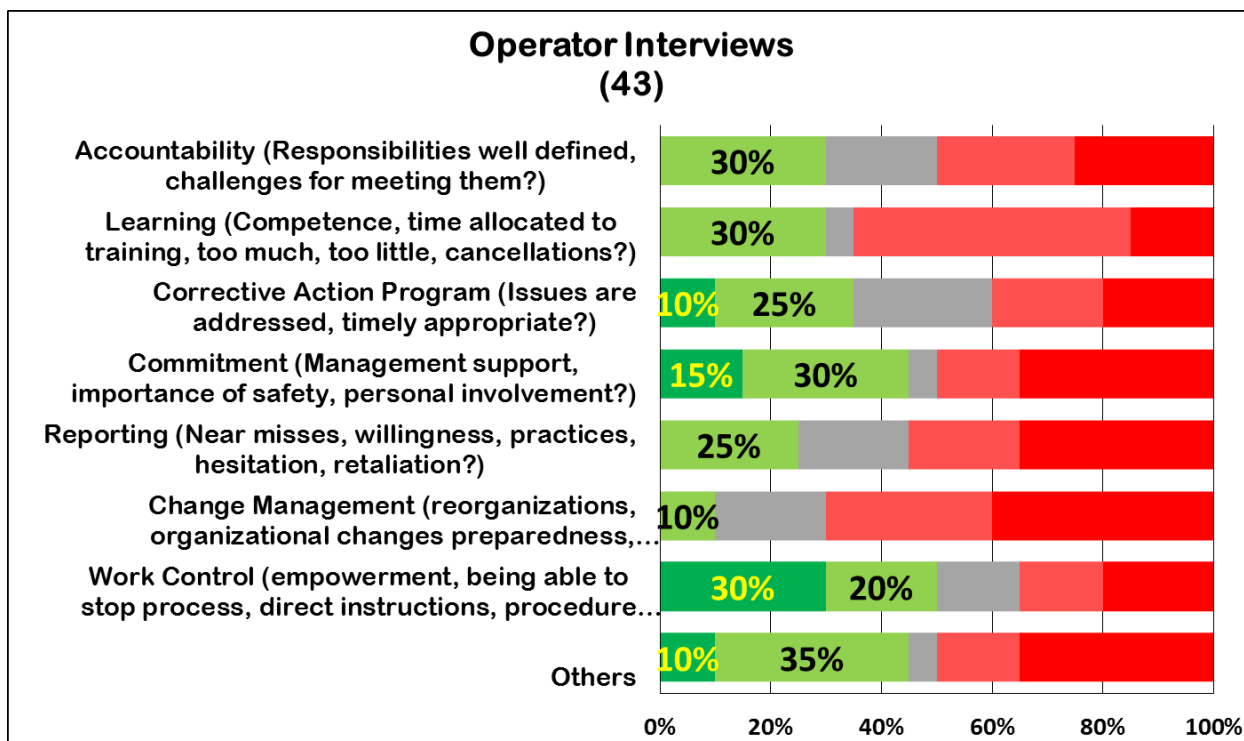
Employees said that roles and processes are clear and well defined. Employees and contractors alike are held accountable to meeting high performance standards. Most supervisors and managers are knowledgeable and most are supportive of their staff. Some responses from represented employees indicate the employees feel that some managers use employee/worker accountability as a way to direct blame to the employees when things go poorly.

A second area of concern expressed during interviews is that employees feel they are overloaded because of a shortage of qualified workers and increased paperwork (document review, email communications, incident investigations, checklists and permits for example). This indicates (in the workers' view) less than adequate accountability of management as reflected in the shortage of staffing. By contrast, according to the results of the written survey (described in section 4.3.4), about 60 to 75% of the represented workers have a favorable or very favorable opinion of management's commitment to process safety.









Recommendation 34

Ensure that an adequate number of staff have high competencies in process safety-critical roles. The goal is to ensure adequate numbers of the various competencies for day-to-day process safety implementation (related to Recommendation 1). For each process role/activity, establish the following:

- **How to reach competency for an activity?**
- **Who is the competency judge?**
- **How to identify competencies that may be leaving?**

Collectively, 40% of all CUSA employees interviewed have a favorable perception of the status of **Learning** at the Refinery.

- *Learning pertaining to process safety at the refinery (favorable or very favorable responses):*
 - All employees (~40%)
 - Non-represented employees (management, supervisors, technical staff) (~70%)
 - Represented employees (operators and maintenance) (~30%)

Represented employees voiced the least support with roughly 70% expressing either negative or very negative responses (and only 25% favorable or very favorable). The initial training that new hires receive and much of the ongoing training that all employees receive is generally considered good and effective. The use of simulators for control board operator training is very highly regarded. However, using computer based training (CBT) instead of interactive, instructor-led classes for initial and refresher training has not been well received. Many employees believe that workshops, discussion, and information sharing with peers provide valuable learning and share relevant information that CBT cannot duplicate. Represented employees stated that they want to see improvement in consistency of the competency and level of engagement of (on-the-job) trainers. Concerns were also expressed about management's perceived inconsistent support of the training process. Examples include pressure to complete training quickly, the threat of discipline if all required training is not completed in a timely manner, and training communication shortcuts such as emails instead of face-to-face review.

See Recommendation 21 (in Section 4.1.6)

Concerning **Closure of Corrective Action Items from loss, near loss, PHA, and process safety audits**, all employees' comments were roughly 40% favorable.

- *Corrective Action (favorable or very favorable responses):*
 - All employees (~40%)
 - Non-represented employees (management, supervisors, technical staff) (~65%)
 - Represented employees (operators and maintenance) (~30%)

Tracking systems such as the OERI dashboard are in place to ensure that corrective actions are completed in a timely manner. These are considered effective in defining responsibility and maintaining management focus. In addition, consensus is that the performance has improved significantly over the last few years. However, concerns were expressed that this

may be a numbers game. It is perceived that some corrective actions are closed without effective resolution and employee feedback/review, and that management priorities are still apparently driven by production and cost impacts. The action-tracking database indicates that recommendations are “closed” and documented. Sometimes, these are labeled “declined.” The refinery has a system to review rejections and declines with the PHA team. However, the evaluation team believes improvements are necessary with respect to reviewing declined actions with the PHA team and affected employees.

Recommendation 35

Ensure that the action-item closure process for PHAs, MOC risk reviews, and incident investigations includes:

- **Documented evidence of why a corrective action is declined;**
- **Improved action-item closure visibility; and**
- **Feedback/review by the appropriate people involved, especially the originator(s) of the request and people affected by the corrective action.**

Roughly 50% of all of the refinery employees interviewed have a favorable perception of the level of **Commitment** to process safety.

- *Commitment (favorable or very favorable responses)-*
 - All employees (~50%)
 - Non-represented employees (management, supervisors, technical staff) (~75%)
 - Represented employees (operators and maintenance) (~40%)

Represented employees responded roughly 40% favorable and 35% unfavorable, with ~25% expressing no observed opinion. Favorable responses include an appreciation of management's presence and accessibility in the field. People are generally confident that recent changes in management are heading in a better direction. However, comments from some represented employees indicate concern about leadership inconsistency in support and commitment at different levels of the organization. Employee responses indicate that some managers say the right words, but then push back when process safety concerns are raised and continue to make short-term decisions based on cost. From comments from those with an unfavorable opinion, high turnover in some higher-level management positions remains a concern as well, with the perception that short-term decisions can be made without regard to the long-term consequences.

Chevron should:

- Ensure that key site leaders have sufficient assignment time in their roles to demonstrate commitment and develop expertise, knowledge, and understanding of their process safety responsibilities.
- Establish, track, and broadly communicate effective and measurable organizational goals and objectives for process safety so that the refinery develops a culture (habit) of discussing process safety at all levels of the organization.
- Ensure that there remains adequate and consistent funding for process safety engineering (e.g., capital improvements) and process-safety management job positions and activities.

- Ensure that appropriate mid-level and senior management review and control mechanisms are in place to protect both the short- and long-term interests of the site.
- Ensure effective feedback mechanisms communicate alignment between management's statements (vision, goals, and objectives) and management's decisions and actions.
- Engage and involve workers at all levels in process safety activities (as discussed in other recommendations), and ensure alignment of goals across all work groups. Use these activities to also develop mutual credibility and reestablish trust between management, non-represented staff, represented staff, contractors, and the community.
- Continue to invest in classroom training and mentoring of key operations staff, maintenance staff, and process engineers to develop a full understanding of both process hazards (including damage mechanisms) and human factors, to allow effective, ongoing minimization of process risk.

Recommendation 36

CUSA Richmond should implement a policy and procedures to sustain process safety competency in key organizational roles, including refinery leadership. Steps could include setting minimum times in place for key leadership roles.

Only 25% of all CUSA employees interviewed have a favorable perception of **Reporting incidents**.

- *Near Miss and Accident Reporting (favorable or very favorable responses)*
 - All employees (~25%)
 - Non-represented employees (management, supervisors, technical staff) (~40%)
 - Represented employees (operators and maintenance) (~20%)

This is the second-lowest rating for any process safety-culture measurement from the interviews. The results correlate to the evidence of low numbers of near misses reported at the refinery and declining number of investigations by represented employees. (See discussion in Section 4.1.8) Based on PII staff experience helping implement process safety across about 100 sites, a low score in this category is the most reliable indication of poor process safety culture. During the interviews, 55% of the represented workers indicated that learning from incidents and near miss reporting in particular, was poor to very poor. Employees mentioned many barriers to reporting incidents and especially for the reporting of near loss incidents. Barriers included

- That investigations are perceived to blame the employee (rather than find the root causes)
- The perception (based on employee feedback) that little gets done
- The system is difficult to use
- The focus appears to be on small, unimportant things
- The perceived lack of resources to document and investigate every incident

However, the operators' and maintenance staff's most overwhelming negative response is related to a recently re-communicated refinery policy (perceived as a change), which the represented employees believe requires drug testing of anyone involved in an incident (even a

near miss) unless employee impairment can be eliminated. This perceived change in policy is considered punitive and unfair, and it seems to further discourage reporting of near loss incidents.

Sites that follow industry best practices achieve a ratio of more than 25 near misses reported per accident loss. A ratio of less than 5 (such as at Richmond) is considered poor. It leaves the refinery to learn about weaknesses mainly from actual losses instead of from near misses. Further, this low reporting of near loss incidents is a direct indicator of mistrust between represented workers and management, which again indicates weak process safety culture.

See Recommendations 24, 25, and 26 in Section 4.1.8.

Collectively, only 20% of all CUSA employees interviewed have a favorable perception of **Change Management** (the lowest of any category).

- *Commitment (favorable or very favorable responses)*
 - All employees (~20%)
 - Non-represented employees (management, supervisors, technical staff) (~45%)
 - Represented employees (operators and maintenance) (~10%)

Represented employees provided unfavorable responses 60% of the time while discussing Change Management. Employees shared concerns that the MOC paperwork process is too cumbersome. This affects the MOC process effectiveness, and it is therefore subject to being bypassed (Note: Compare this with Written Survey Question # 39). Some affected employees said they are not adequately involved (or consulted) when evaluating the changes being considered and training shortcuts are perceived to be taken, i.e., employing email notification instead of face-to-face MOC training. A concern was also raised regarding frequent turnover at the ABU supervisor level, where inexperience and short-term thinking could contribute to poor decision-making. Recent changes in operations staffing (addition of an OOA) and maintenance (reliability) staffing were perceived as positive steps for the organization.

Recommendation 37

Consider streamlining the MOC review and documentation procedures for low-risk changes. Continue to ensure that appropriate risk assessment is performed and documented before significant changes are implemented. Implement an improved MOC process that covers changes requested to operating and maintenance procedures and include (or consult) the affected personnel on best ways to approach these requested changes. All impacted employees (including represented employees) should be appropriately involved in Management of Organizational Change (MoOC) reviews (see related CCHMP finding). Chevron should audit MOCs frequently enough to better define the MOC situations that require face-to-face training (see related CCHMP finding).

Collectively, roughly 65% of all CUSA employees interviewed have a favorable perception of **Work Control**.

- *Work Control (favorable or very favorable responses)*
 - All employees (~65%)
 - Non-represented employees (management, supervisors, technical staff) (~85%)
 - Represented employees (operators and maintenance) (~60%)

The represented employees gave 60% favorable responses in this category. Stop Work Authority (SWA) is well understood, broadly used, and widely accepted as one of the primary cornerstones of personal safety at the refinery. However, some (particularly operators) commented that for process safety, a better name could be “*Pause Work*” (rather than Stop Work) since they perceive significant pushback from management whenever SWA conflicts with continued operations (most of these referenced instances are process safety issues). Work often proceeds after meeting with management with few or no changes to the original plan.

Examples of SWA usage most often mentioned involved personal safety concerns, and they usually involved outside groups (maintenance or contractors) working in an unfamiliar area. Process safety examples were mentioned less frequently, and these usually involved transitional operating modes (startup, shutdown, online maintenance) and not process safety that would halt normal operation. Per refinery management, there are many examples of SWA having been used for process safety NLI or LI. However, there are currently no data breakouts or key performance indicators for Process Safety-related SWAs. Further, per the plant staff interviewed, and particularly operators, the implementation of SWA for maintenance tasks (typically related to occupational safety impacts) has worked well, while the implementation of SWA for operational issues (typically related to process safety impacts) is not as effective. From most of the represented employees interviewed, management seems to authorize start, restart, or not stopping a process, even if workers can identify additional safeguards for the current situation.

As expressed by represented employees, management's unconditional support of SWA appears to wane as the financial consequences of stopping work (i.e., halting production) increase. So, the SWA program illustrates that the occupational safety culture is strong while the process safety culture is weak.

See Recommendation 33 in Section 4.3.2.2

Other issues discussed during the interviews include a generally positive perception by most that the Richmond Refinery is one of the best and safest refineries in the area (based on benchmarking to peers in the area). Most interviewees believe the site has a safety culture that has been continuously improving over time. However, many represented employees expressed low trust in management, broad reluctance to speak out for fear of retaliation, and the perception of the existence of a punitive, blaming, and “protect yourself” environment. Considering recent events, multiple investigations, potential personal liability, and high public scrutiny of the site, a certain lack of trust, cautiousness, and restraint should be expected. However, management's leadership and their trust relationship with the represented employees remain as a prime opportunity for Process Safety Culture improvement.

4.3.3.3 Comments on the Safety Culture Interview Process and Its Effect on the Results

Interview responses for non-represented staff were significantly more positive than corresponding interview responses for represented employees. The Written Process Safety Survey results showed a difference as well, but to a much smaller magnitude. Is this because of a real difference in process safety observations, differences in perceptions, or is the difference in interview feedback amplified by the way the data was collected (interview atmosphere)? Based on the evidence from process safety implementation, which matches many of the interview results, PII believes the safety-culture interview results are credible and that they reflect the process safety status and process safety culture more accurately than the written survey results.

Having other company representatives present in all of the salaried employee interviews (who could presumably report interview observations to upper management) could cause the

interviewee to refrain from overtly negative statements. The interview team did not maintain demographic data (age, years of service, etc.) but about half of the salaried workers interviewed appeared to be new in their roles (less than 2 years), and some appeared new to the site (less than four years).

It is possible that hourly workers (interviewed without company representatives) would be perceived as more “protected” from immediate outcomes from their statements (if these were negative) since the interview is confidential (only the PII or county interviewer was sitting with the interviewee, and no names were divulged outside of the interview). However, all interviewees might be at risk (if they made negative statements related to the process safety implementation at the refinery) from the longer-term implications at the Richmond Refinery, if such statements resulted in a negative finding in this Safety Evaluation. This latter concern was voiced on several occasions in represented employee private interviews, in interactions in the field, and by union representatives reviewing the interview process.

Based on the number of staff interviewed (96), there is a statistical difference in the data provided by hourly and salaried workers. Below are some key factors to consider when judging the differences in the data between hourly and salaried employees at the refinery. ***Note that these differences apply to both written survey data and to interview data:***

- **Data:** Hourly staff typically have much different data on process safety implementation than the average salaried staff or management because of their exposure to the minute-by-minute operation of the units. The difference in data between hourly (or shift workers of all types) and non-shift workers is much larger if there is low near miss reporting, as is the case at the Richmond Refinery, because the shift workers would be aware of the near misses, but unless they report them, others would not be aware.
- **Communications/Perspective:** Salaried workers are involved in a higher percentage of daily, weekly, and monthly meetings with managers and site leadership as part of their job assignments and daytime work schedules. Hourly worker interactions with higher levels of management are less frequent because of job assignments and shift schedules. Therefore, the messages they receive on vision and changes to match a vision are likely not reinforced to the same degree as for salaried staff. Represented employees may be frustrated as they observe opportunities to make things better within their work scope, but they may be directed to accommodate these shortcomings for now because other projects have a higher priority at this time. When their issue is a significant, substantiated safety or environmental concern, they generally see immediate actions taken. However, if it affects production (increases costs), or if a temporary workaround can be implemented, they may see permanent action items delayed for months or years.
- **Distance/Line of Fire:** On average, salaried worker assignments require less time in the process areas (compared to hourly staff), reducing their interaction with occupational and process risks. They may have a theoretical understanding of those risks. Yet, they may lack operational experience on how those risks must be managed and how operators and maintenance and inspection staff must implement rigorous, detailed operational/maintenance discipline on a routine basis to address these risks. This is particularly true of less experienced salaried staff with limited field experience. Many experienced managers, supervisors, and engineers do have this deeper operational experience and understanding. However, they may have difficulty relating with workers who must deal with limited resources and real time hazards.

Hourly workers' proximity to the process equipment also makes it more likely that they will be held directly responsible for any mistakes they make (since they are the last

ones to touch the equipment before an incident occurs), while the salaried workers (except for management, of course) are somewhat shielded from this level of accountability. Historically in process industries, discipline is more likely (though unfairly) to occur whenever there is an identified breach of protocol, such as:

- Failure to follow the correct procedures,
- Failure to recognize and maintain awareness of the hazards, or
- Failure to respond in a timely manner and take the proper actions. (Even though in 99% of the cases, the root causes of such mistakes are human factor weaknesses and ultimately management system weakness.) (See CCPS *Guideline for Investigating Chemical Process Incidents*, Chapter 5 in particular, for further elaboration.)¹⁰⁷

Salaried workers are generally insulated from this type of potential disciplinary action since their type of errors are further back in the sequence of events leading to an incident and less obvious.

If root cause investigations end at the causal factors (operator and maintenance technician errors or component failures) and fail to dig deeper and identify management system failures (true root causes), then the hourly workers will be blamed for the losses in a high percentage of incidents. Further, the hourly workers may see (or believe) that the refinery is not interested in correcting the real issues. This is one reason for the low near miss reporting rates at the refinery. (Of course, if the investigations do not get to root cause [management system weakness], which includes the systems that control the design of the process equipment, then the likelihood of future accidents related to the same root causes will be unnecessarily high.)

- **Peer Group:** A person's peer group affects their perception to some extent. Regardless of the magnitude of the effect, it is clear that the group of hourly operator peers is different from the hourly maintenance staff, and both of these peer groupings is significantly different from most salaried (or non-shift salaried) employees. This effect is likely not as strong as the other effects listed above.

4.3.4 Process Safety Culture — Findings/Observations from Safety Culture Written Survey

To facilitate confidentiality and encourage participation, a written safety culture survey was conducted using a combination of company-provided iPads, remote web access, and pencil and paper administration. Towers Watson managed the data collection process and provided the raw data to PII for analysis. Towers Watson also prepared a high-level summary of the results and presented it to CUSA management.

The survey instrument used was identical to the survey conducted by the Baker Panel¹⁰⁸, with only minor modifications to account for CUSA- and site-specific terminology. There were 49 primary questions (some with sub-parts), which can be further classified into six primary categories:

- Process Safety Incident Reporting
- Safety Values/Commitment to Process Safety
- Supervisory Involvement and Support
- Procedures and Equipment

- Worker Initiative/Professionalism/Empowerment
- Process Safety Training

CUSA management and the trade unions both encouraged participation in the survey, but it was also made clear that participation was voluntary. Both refinery management and unions sent many appeals for participation. 2,197 survey invitations were extended, with 1,023 invitations to Chevron employees and 1174 invitations to other personnel who work at the Richmond Refinery (contractors). There were 1,195 surveys completed with a response rate of 54%. Chevron employee response was 62% and non-Chevron (contractor) employee response was 48%.

The Chevron employee response rate is acceptable for a written survey. The sample size based on the response rate was large enough for meaningful interpretation of the survey results. There is a 95% confidence level that the results reflect the average opinion of the refinery staff (if all had returned a survey), at a 96% confidential interval (4% error range).

The table on the next page shows a breakdown of the survey numbers.

Chevron Richmond Refinery Written Survey Statistics

	Chevron Employee	Other Company Employees	Chevron Richmond Written Survey Invitation & Response Totals			Chevron Richmond Written Survey Invitation Totals			Chevron Richmond Written Survey All Respondents		Chevron Richmond All Respondents % by Group	CUSA Richmond Employee Response %			
			All Invitees	All Respondents		All Invitees	CUSA Employees								
Operators hourly Maintenance, hourly			Represented	213	18%	437	20%	437	43%	213	18%	213/437	49%	213	34%
				256	21%	244	11%	244	24%	132	11%	132/244	54%	132	21%
Other			Non-represented	726	61%	342	16%	342	33%	289	24%	289/342	85%	289	46%
						1174	53%			561	47%	561/1174	48%		
		Total	2197	100%	1195	100%	2197	100%	1023	100%	1195	100%		634	100%
			Total Survey%/Response→			1195	54%	CUSA Employee % Response→						634	62%
						/2197								/1023	

The non-Chevron employees (contractors) responded at a lower rate (48%). Their responses were generally positive on Richmond Refinery process safety, but the contractors included more “no opinion or uncertain it applies” responses, which is to be expected. Many of the contractors who were invited to participate have little interface with process safety at this refinery because of the nature of their work.

Some questions showed a definite difference between feedback from Chevron and non-Chevron employee surveys.

- Question #34a – Process equipment is not regularly: Tested – non-Chevron employees positive responses were ~10 points lower.
- Question #34b – Process equipment is not regularly: Maintained – non-Chevron employees positive responses were ~10 points lower.
- Question #47d – The following receive the necessary process safety training to do their job safely: Contractors – non-Chevron employees’ positive responses were ~15 points higher.

For the questions listed above, it would appear that non-Chevron employees might need additional training on process safety related to work at the Chevron refinery, to increase their understanding of the Richmond Refinery process safety program. (Alternatively, perhaps the refinery management needs to communicate more effectively the maintenance activities at the refinery.)

Contractors working at the Richmond Refinery recognize that procedures and checklists are important to incorporate process safety into their work assignments (Question #33a ~+9 points).

Most of the following data and analysis relates to direct-hire Chevron employees at the refinery.

Note that the factors such as Data, Peer Group, etc., discussed in Section 4.3.3.3, also apply when judging the differences between average responses to the written Process Safety Survey of hourly and salaried employees at the refinery.

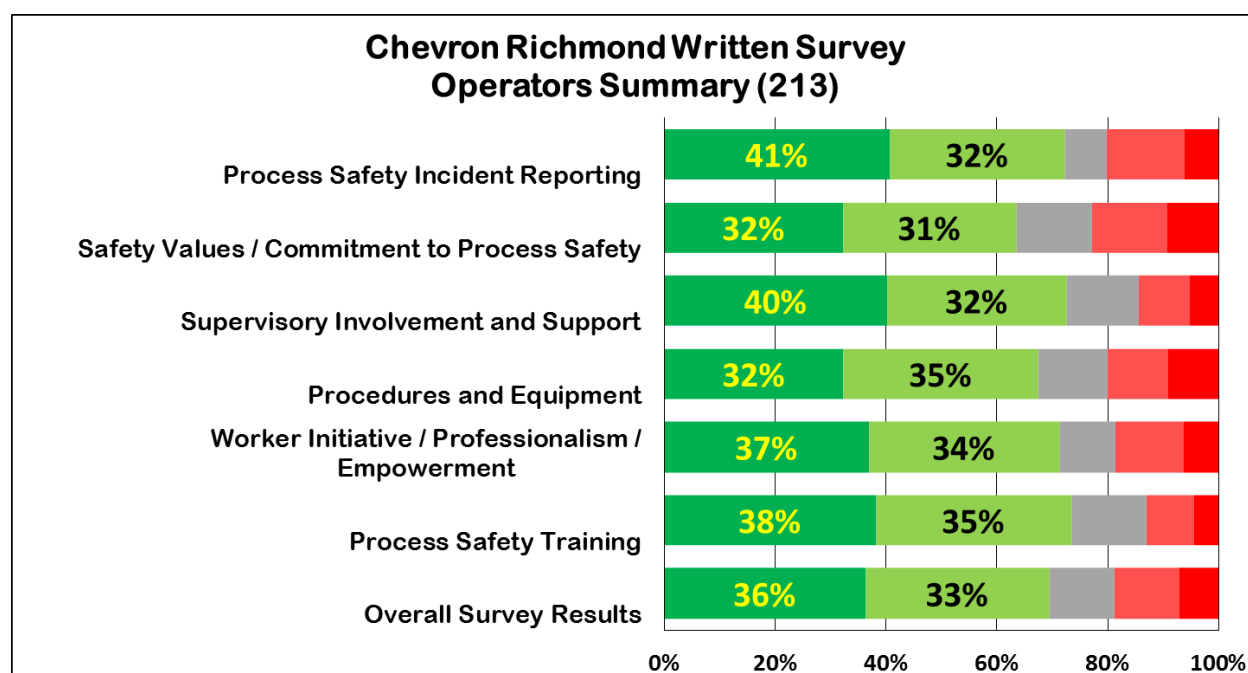
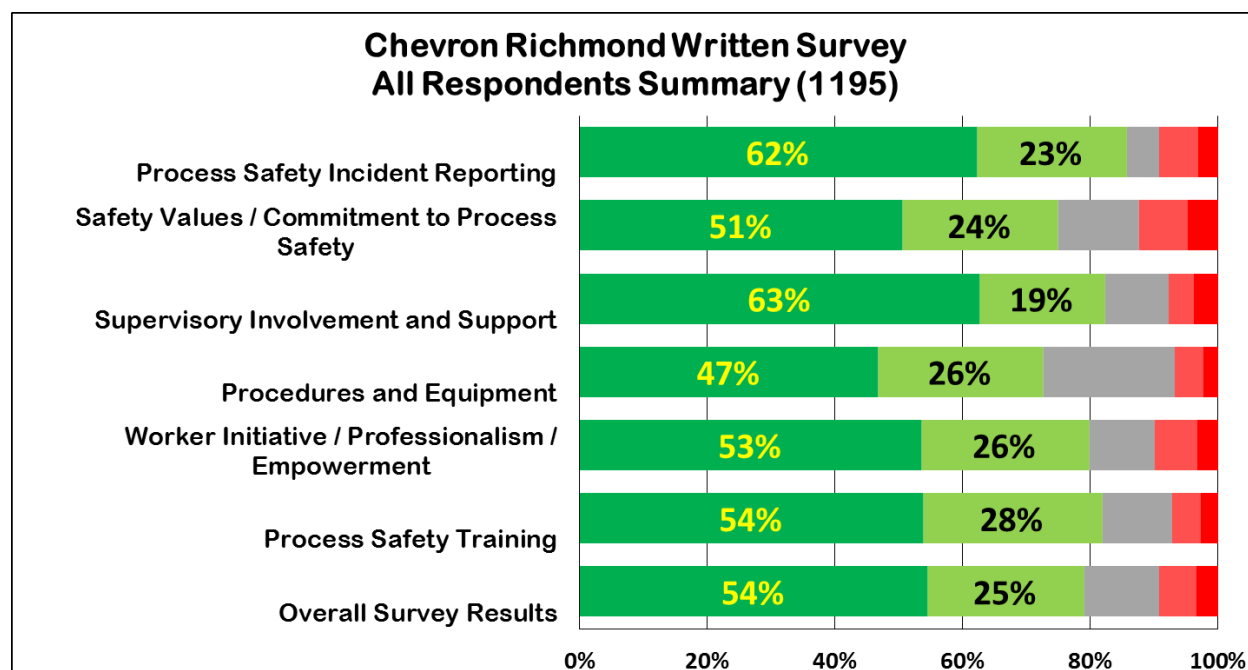
4.3.4.1 Summary of Written Survey Data

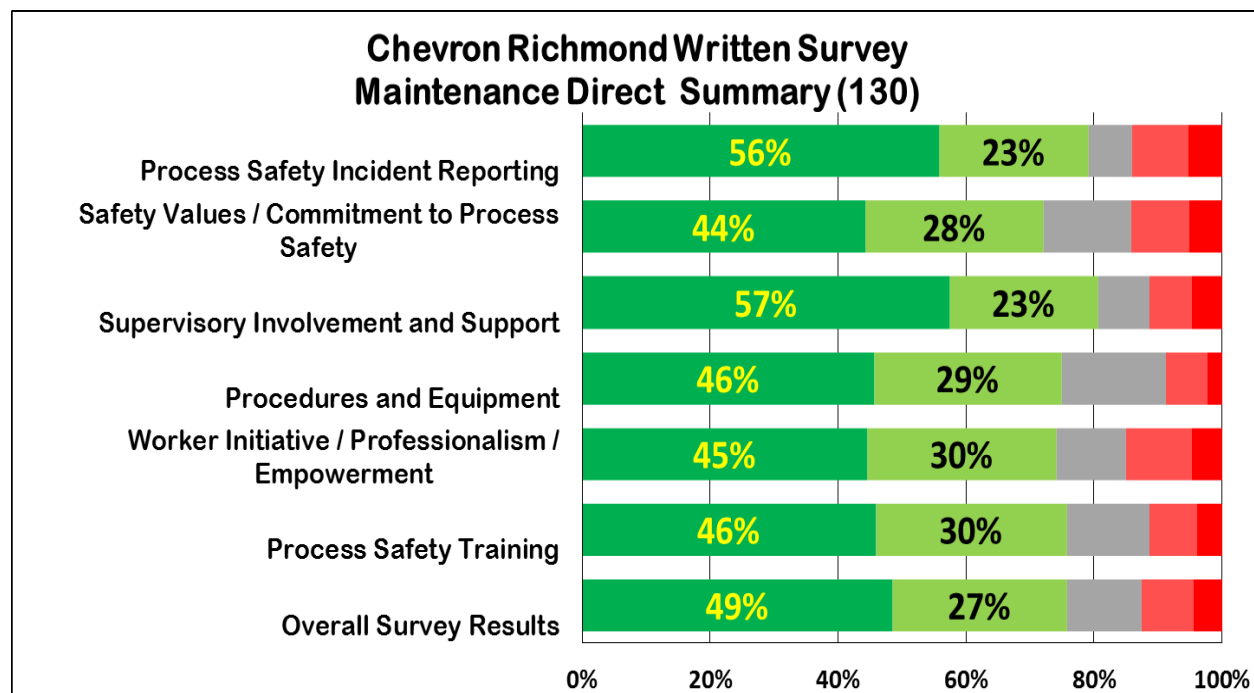
The three following graphs illustrate the average, generalized results of the interviews from each subset of staff interviewed. The findings and recommendations from the results are discussed after the graphs.

The **All Respondents** graphs include Chevron employees (53% of total responses) and non-Chevron employees (47% of total responses).

Note that the color codes are:

- Dark Green (to the far left) means Strongly Agree
- Light Green means Agree
- Gray means no opinion or uncertain it applies
- Light Red means Disagree
- Dark Red means Strongly Disagree





Graphs showing the results of each survey question are presented in the following pages. Some written survey questions may be truncated in the graphs. The full text of each question follows.

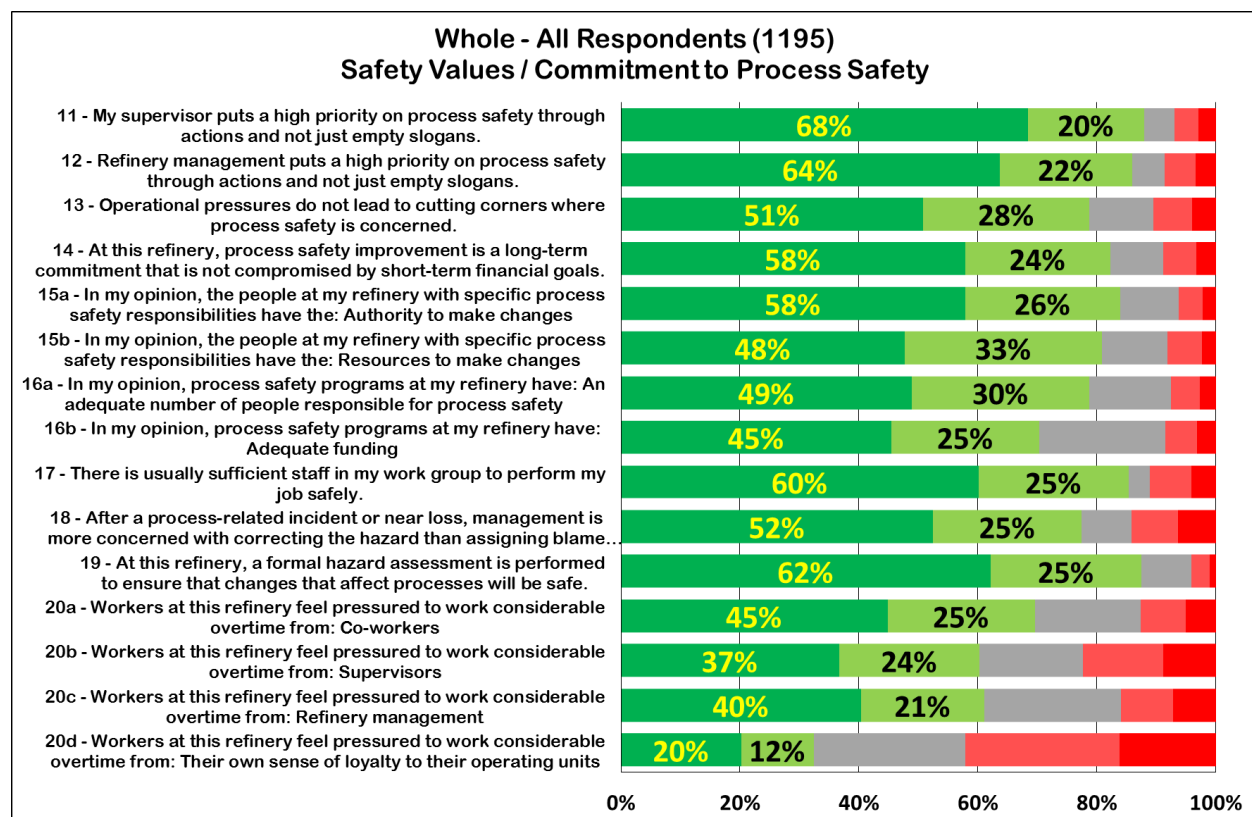
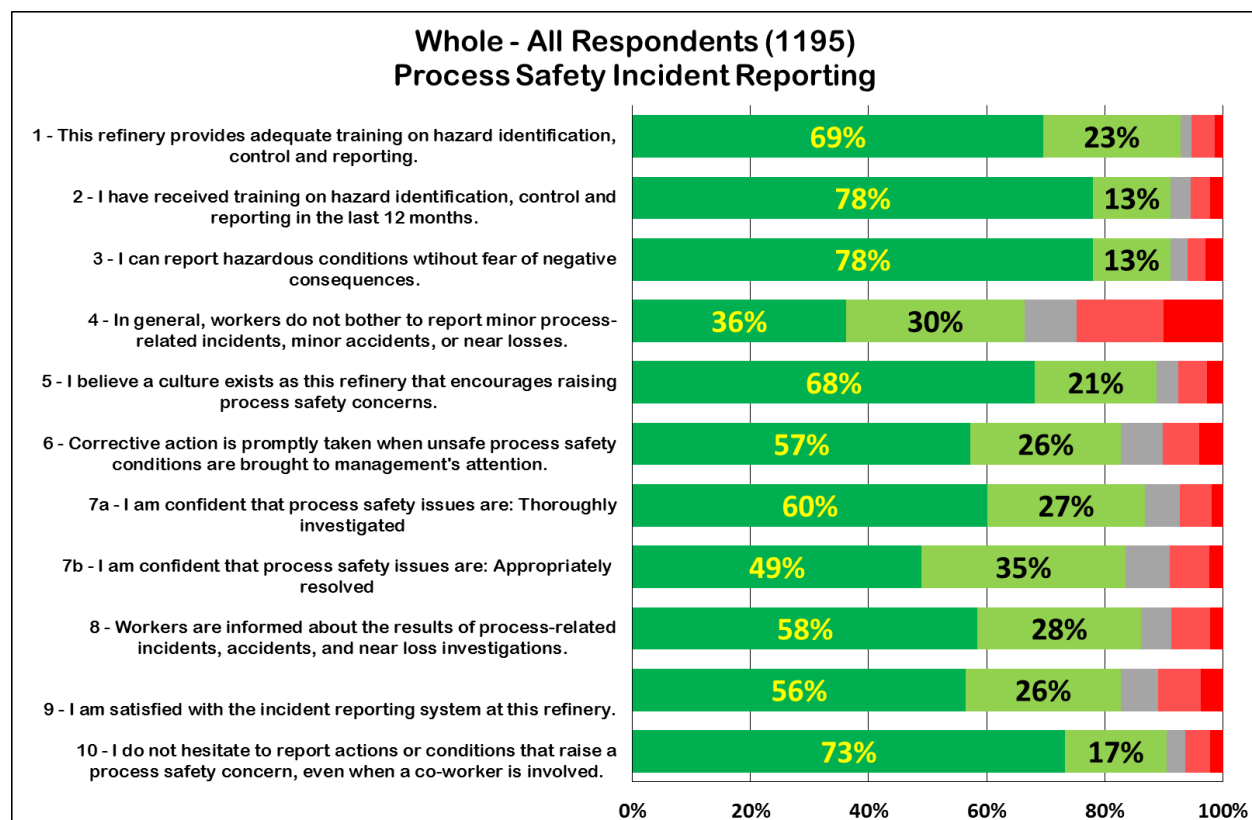
2013 Chevron Process Safety Culture Survey Questions

(based on Baker Panel 2006 Safety Review Report Survey)

1. This refinery provides adequate training on hazard identification, control and reporting.
2. I have received training on hazard identification, control and reporting in the last 12 months.
3. I can report hazardous conditions without fear of negative consequences.
4. In general, workers don't bother to report minor process-related incidents, minor accidents, or near misses.
5. I believe a culture exists at this refinery that encourages raising process safety concerns.
6. Corrective action is promptly taken when unsafe process safety conditions are brought to management's attention.
7. I am confident that process safety issues are:
 - a. Thoroughly investigated
 - b. Appropriately resolved
8. Workers are informed about the results of process-related incident, accident, and near miss investigations.
9. I am satisfied with the process safety reporting system at this refinery.
10. I do not hesitate to report actions or conditions that raise a process safety concern, even when a co-worker is involved.
11. My supervisor puts a high priority on process safety through actions and not just empty slogans.
12. Refinery management puts a high priority on process safety through actions and not just empty slogans.
13. Operational pressures do not lead to cutting corners where process safety is concerned.
14. At this refinery, process safety improvement is a long-term commitment that is not compromised by short-term financial goals.
15. In my opinion, the people at my refinery with specific process safety responsibilities have the:
 - a. Authority to make necessary changes
 - b. Resources to make necessary changes
16. In my opinion, process safety programs at my refinery have:
 - a. An adequate number of people responsible for process safety
 - b. Adequate funding
17. There is usually sufficient staff in my work group to perform my job safely.

18. After a process-related incident, accident, or near miss, management is more concerned with correcting the hazard than assigning blame or issuing discipline.
19. At this refinery, a formal hazard assessment is performed to ensure that changes that affect processes will be safe.
20. Workers at this refinery feel pressured to work considerable overtime from:
 - a. Co-workers
 - b. Supervisors
 - c. Refinery management
 - d. Their own sense of loyalty to their operating units
21. In my work group, process safety concerns are secondary to achieving production goals.
22. My supervisor sometimes asks me or encourages me to operate an unsafe process.
23. My supervisor will support me if I refuse to participate in unsafe work.
24. My supervisor encourages me to identify and report unsafe conditions.
25. My supervisor makes sure that procedures relating to the following activities are safe, accurate and clear before such activities are initiated:
 - a. Operations
 - b. Maintenance
26. Persons with appropriate supervisory authority and expertise participate in hazardous process-related activities, such as startup.
27. My supervisor takes action when a worker engages in a poor process safety practice.
28. My supervisor takes appropriate action in response to my suggestions for process safety improvements.
29. Interlocks, alarms, and other process safety-related devices are regularly:
 - a. Tested
 - b. Maintained
30. Disabled or failed control equipment or process safety devices are restored to service as soon as possible.
31. Written operating procedures, checklists and job aids are:
 - a. Regularly followed
 - b. Kept up to date
32. Procedures exist at this refinery that instruct operators to take action as soon as possible if safety critical interlocks, alarms, or other process safety-related devices fail or become unavailable during operation.
33. Maintenance checklists, job aids and procedures are:
 - a. Easy to understand
 - b. Easy to use
34. Process equipment is not regularly:
 - a. Tested
 - b. Maintained

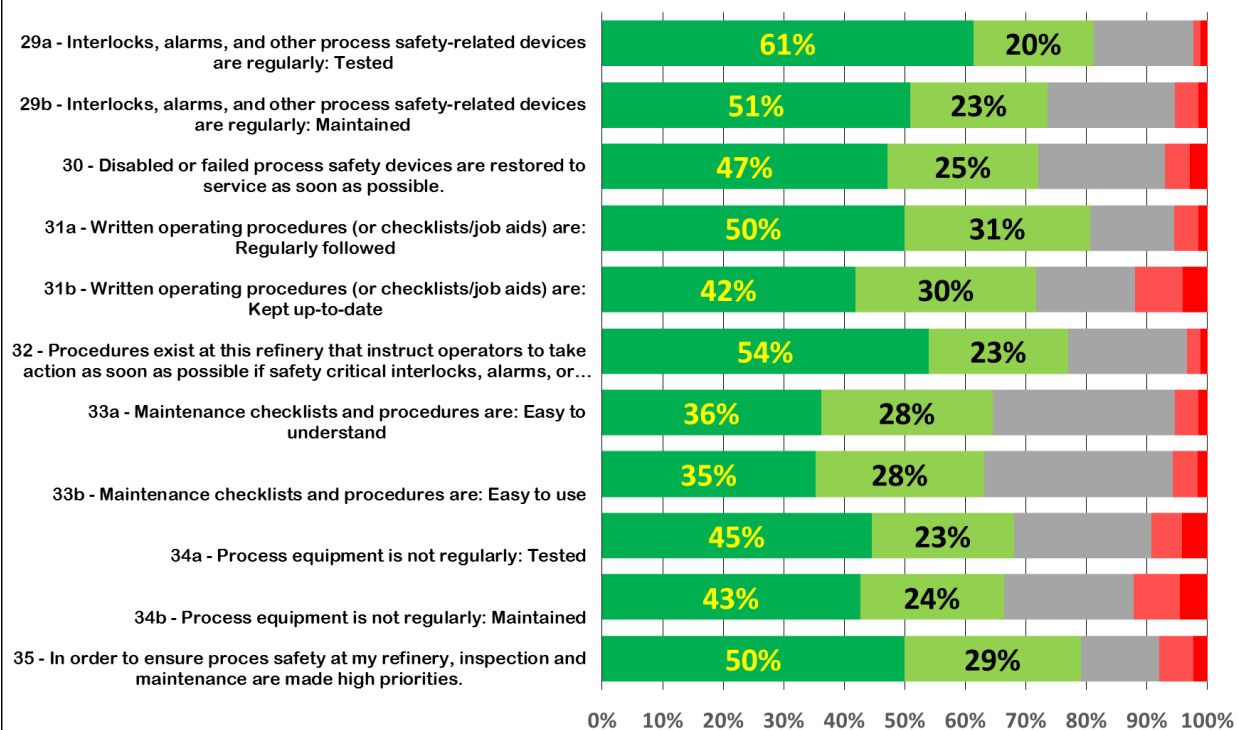
35. In order to ensure process safety at my refinery, inspection and maintenance are made high priorities.
36. I feel that I can influence the process safety policies implemented at this refinery.
37. Workers at all levels of my refinery actively participate in:
 - a. Hazard reviews and assessments
 - b. Near miss incident and accident investigations
38. When a process safety issue is involved, I can challenge decisions made by the following without fear of negative consequence:
 - a. My supervisor
 - b. Refinery management
39. Workers sometimes work around process safety concerns rather than report them.
40. Creating unapproved shortcuts around process safety is not tolerated at my refinery.
41. I am informed when potentially dangerous processes are started.
42. I am responsible for identifying process safety concerns at my refinery.
43. I feel free to refuse to participate in work activities that are unsafe.
44. Operators are empowered to take corrective action as soon as possible (including shutting down when appropriate) if safety critical interlocks, alarms, or other process safety-related devices fail or become unavailable during operation.
45. The training that I have received does not provide me with a clear understanding of the process safety risks at my refinery.
46. I know how to access appropriate process safety resources if I need them.
47. The following receive the necessary process safety training to do their job safely:
 - a. New workers
 - b. Experienced workers
 - c. My supervisor
 - d. Contractors
48. The process safety training that I have received allows me to recognize when a process should be shut down if safety critical interlocks, alarms or other process-safety devices fail or become unavailable during operation.
49. The process safety training that workers receive at my refinery is adequate to prevent process-related incidents, accidents and near misses.

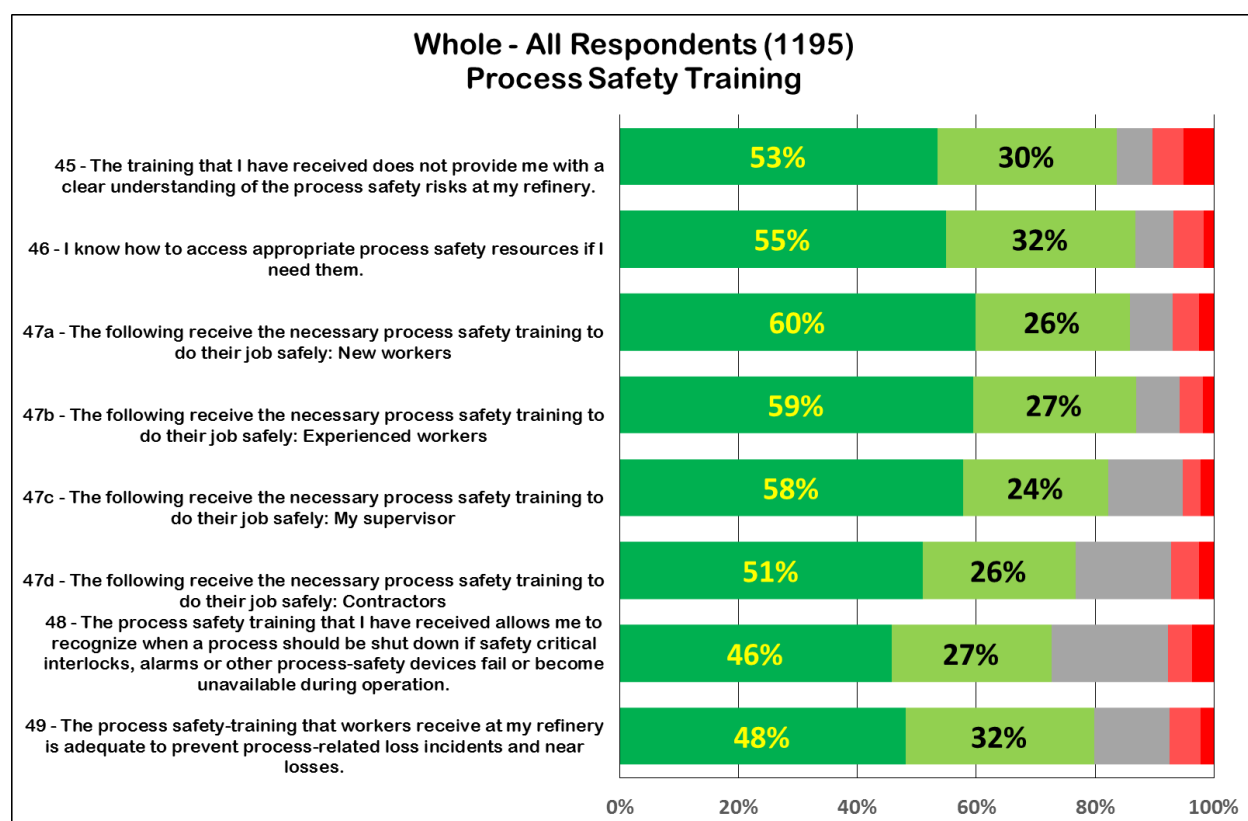
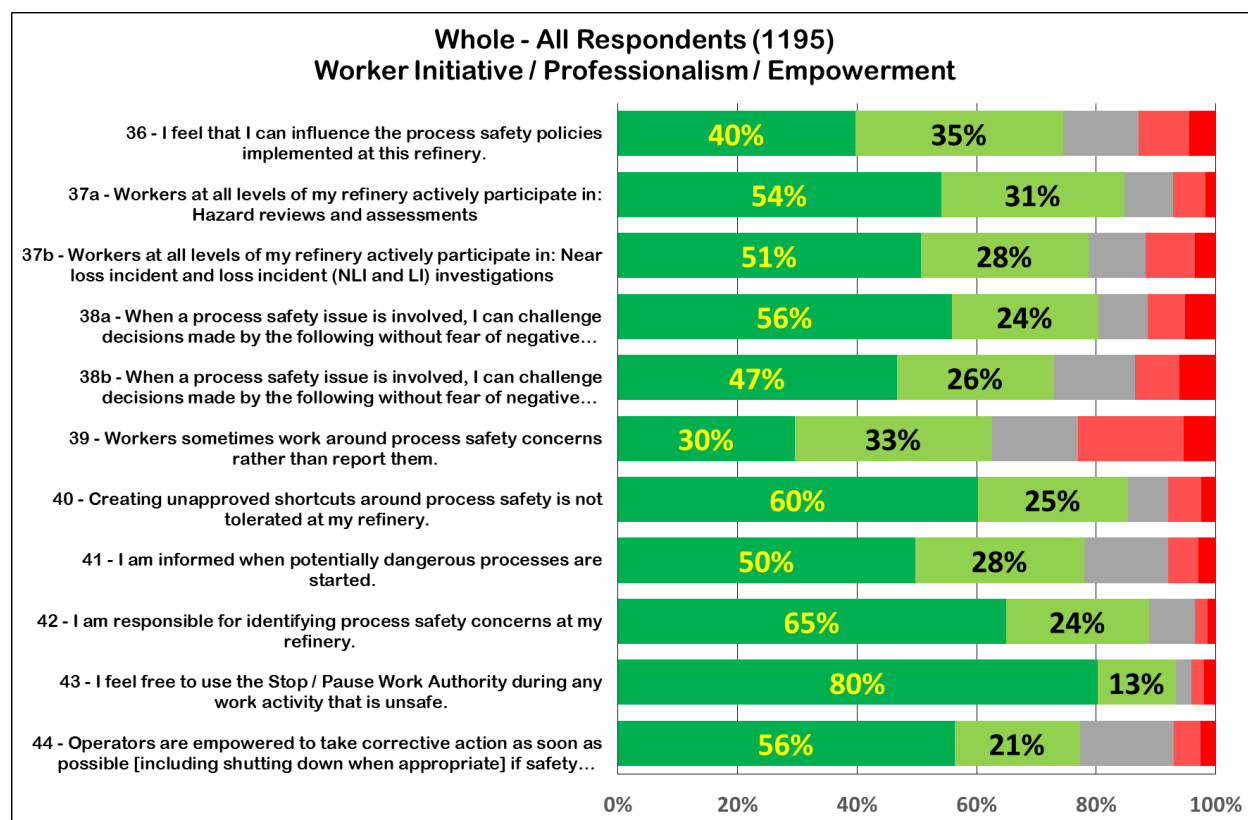


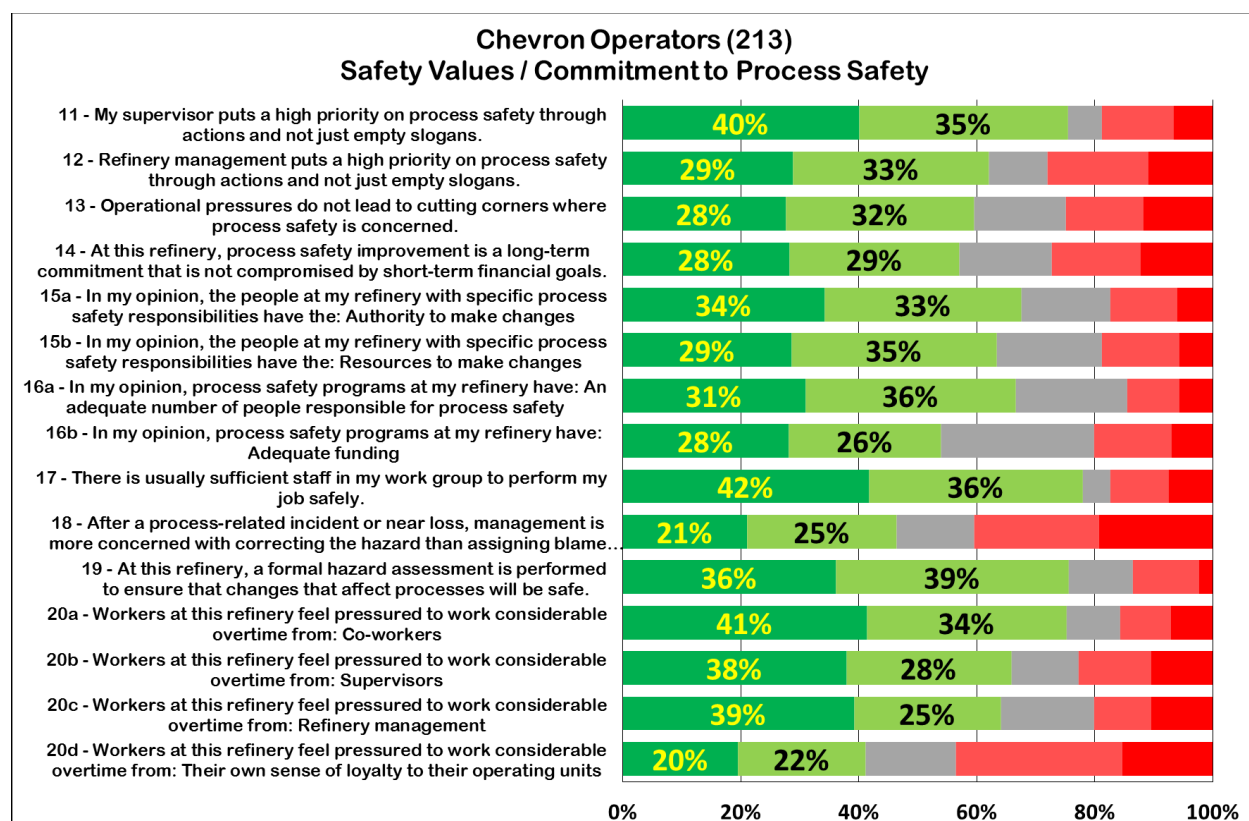
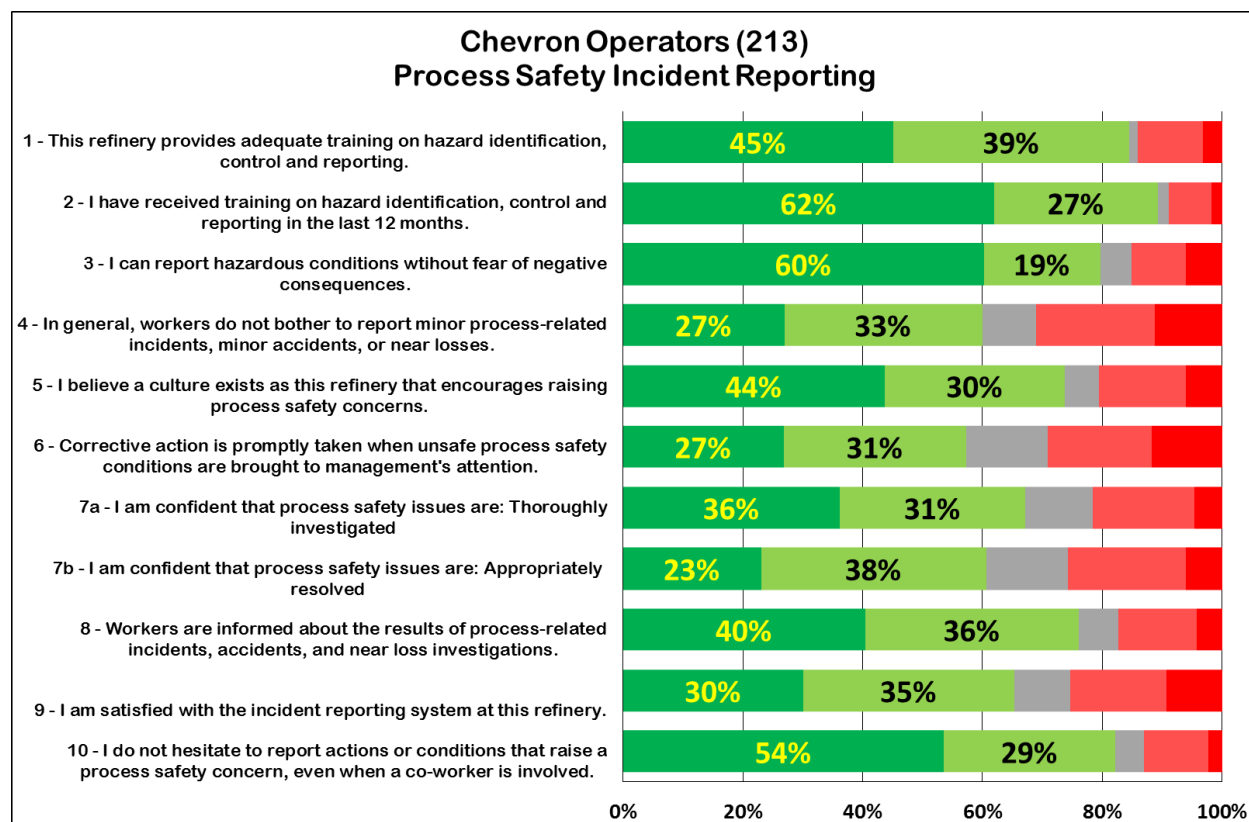
Whole - All Respondents Supervisory Involvement and Support



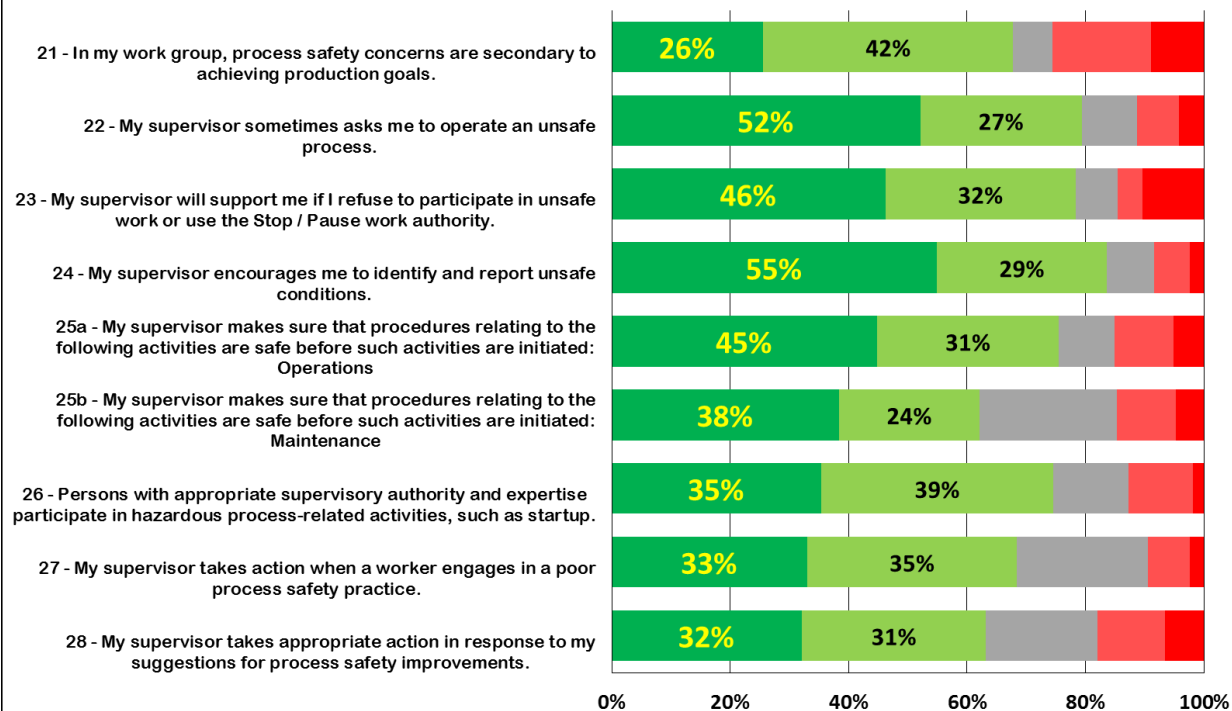
Whole - All Respondents (1195) Procedures and Equipment



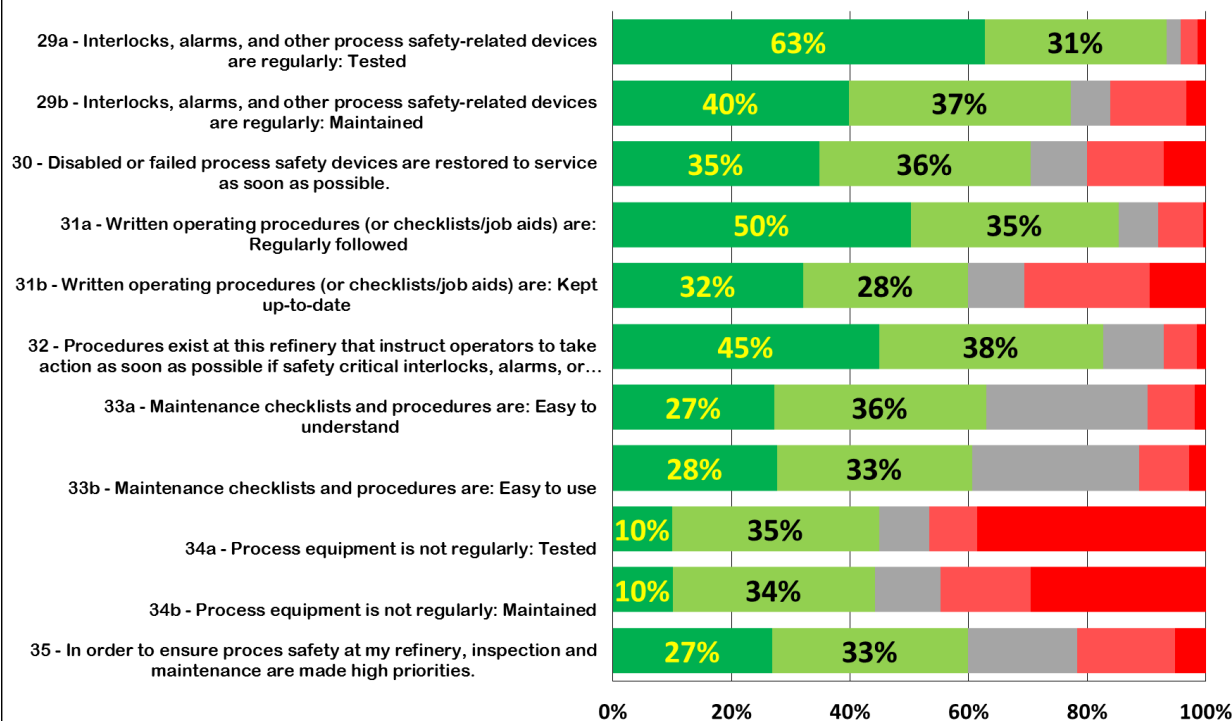


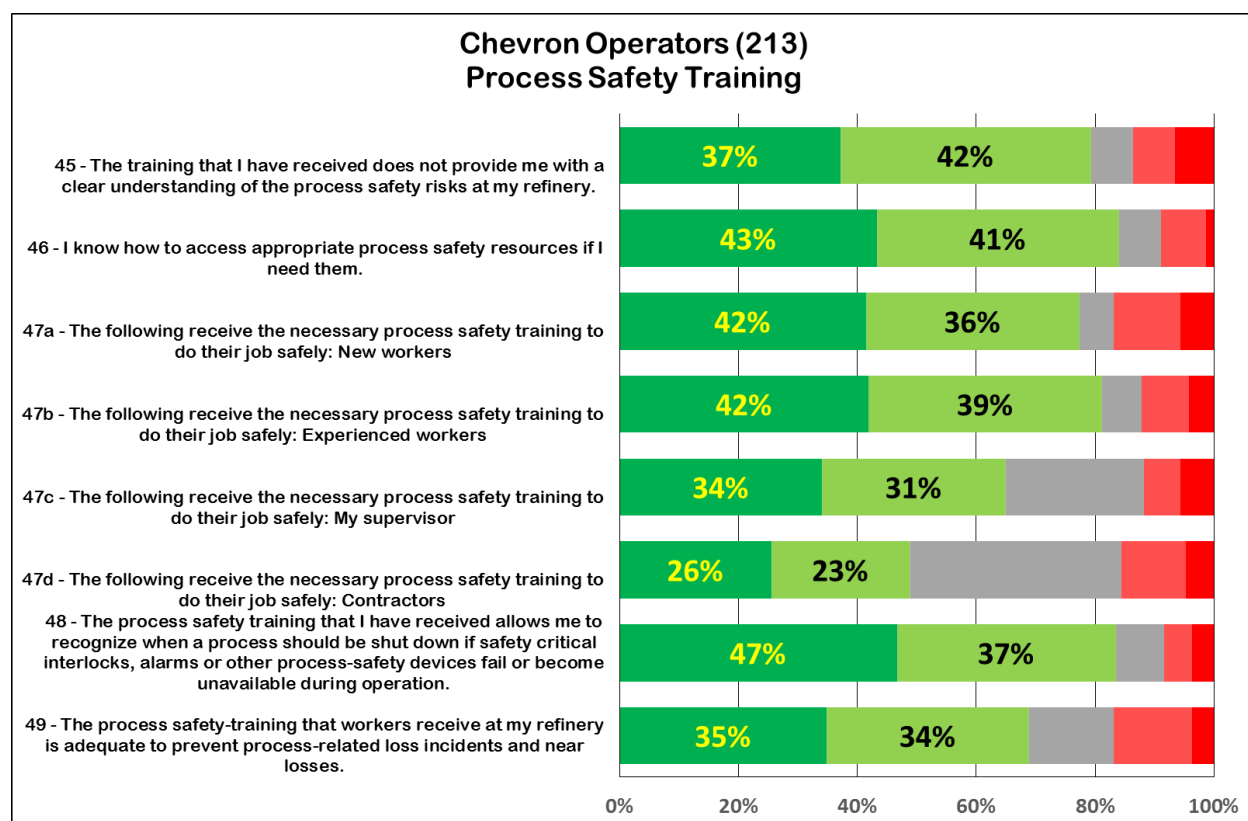
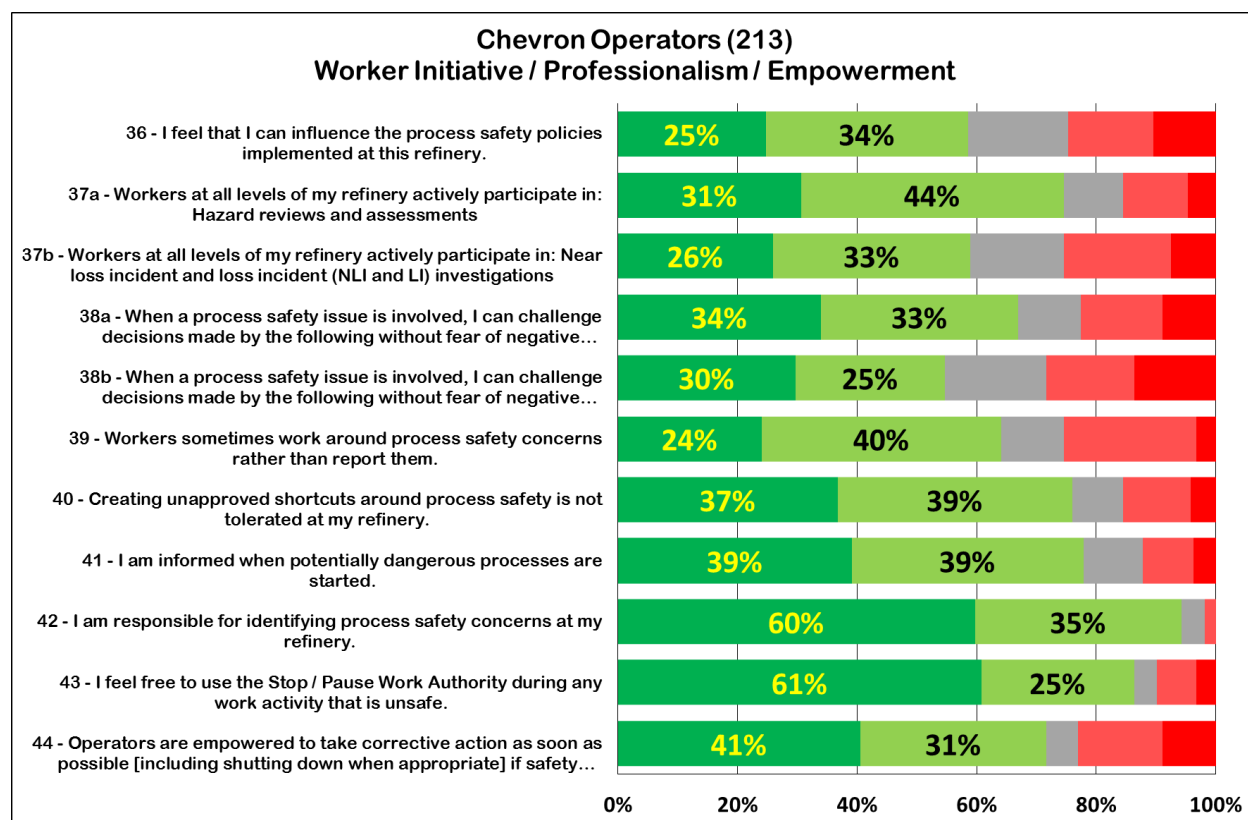


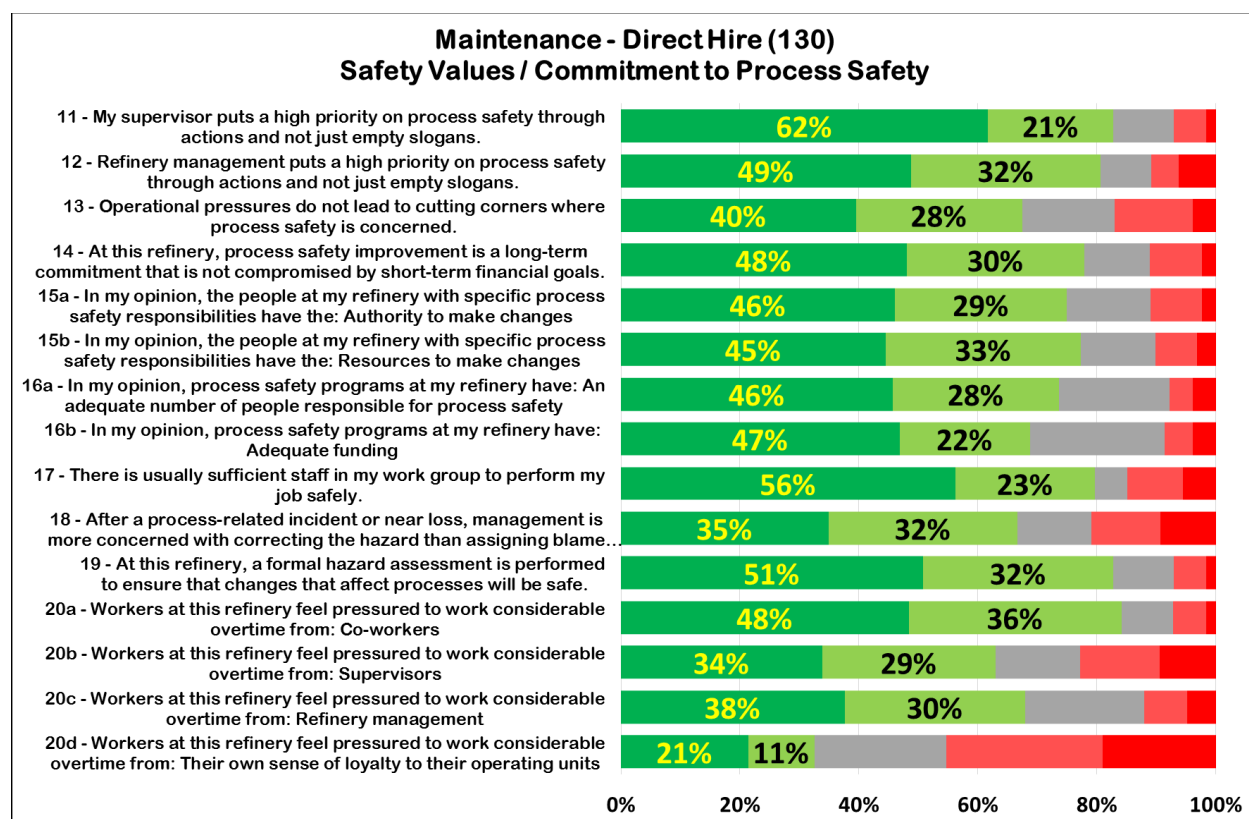
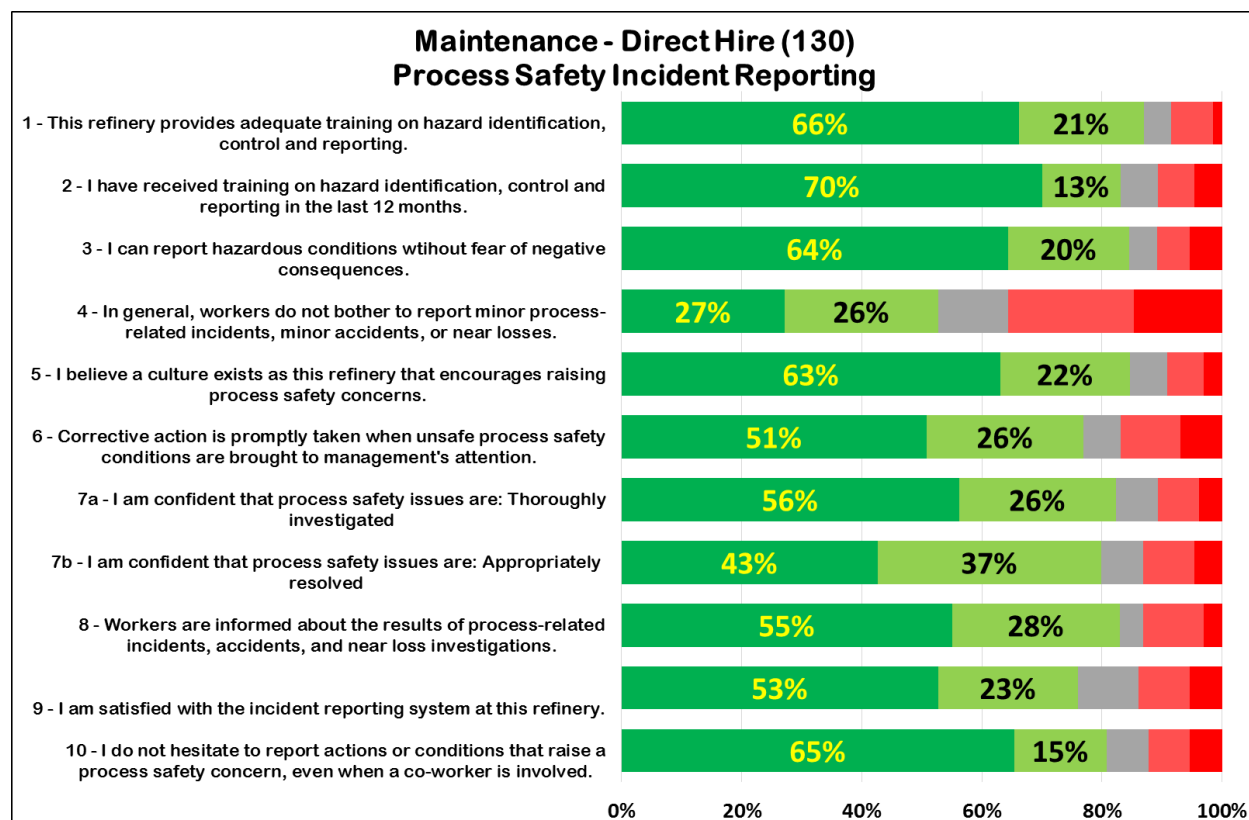
Chevron Operators (213) Supervisory Involvement and Support

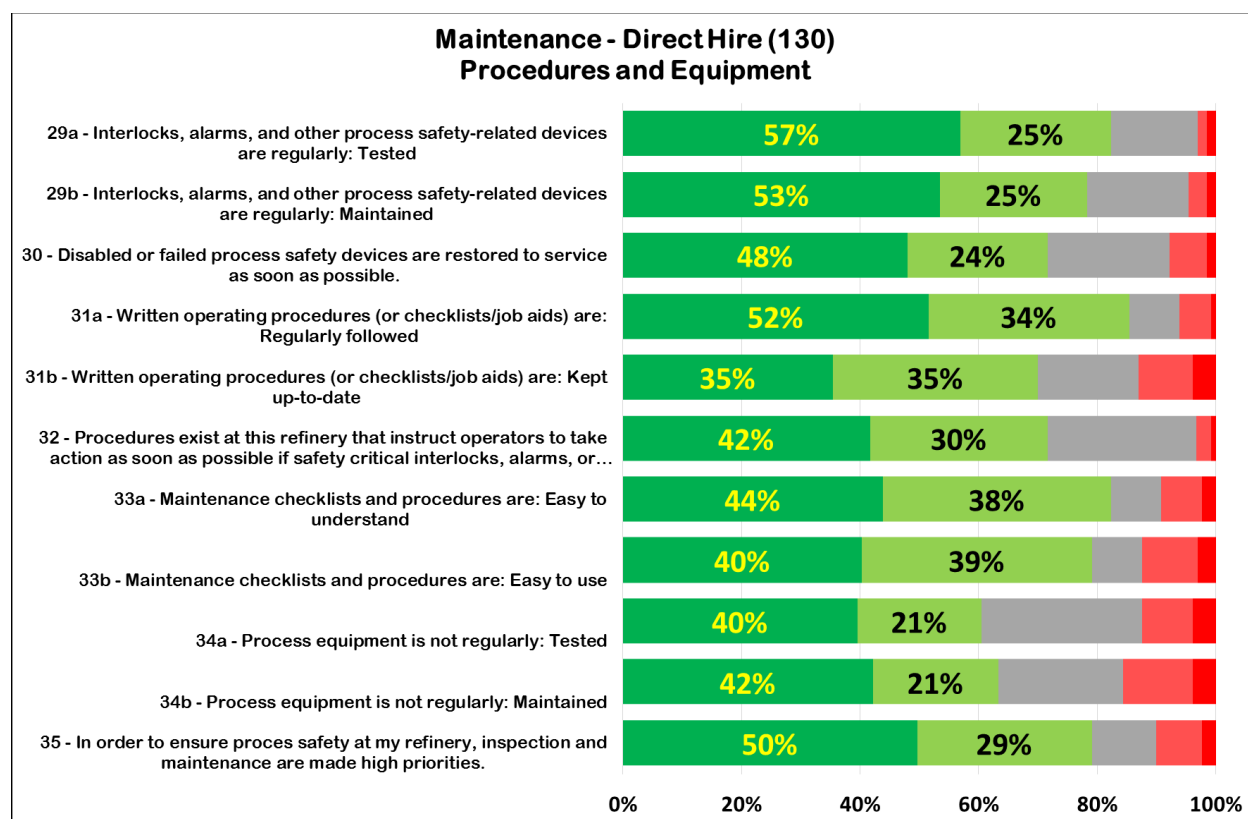
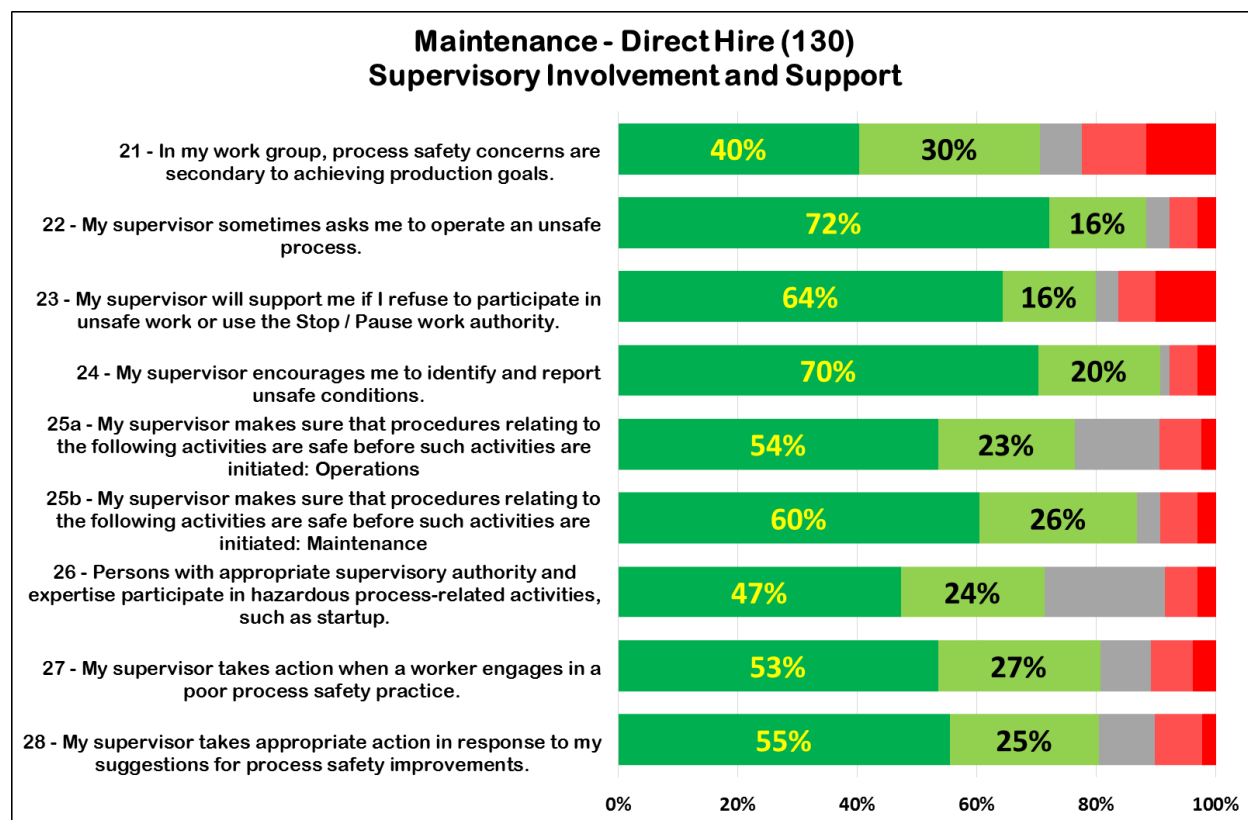


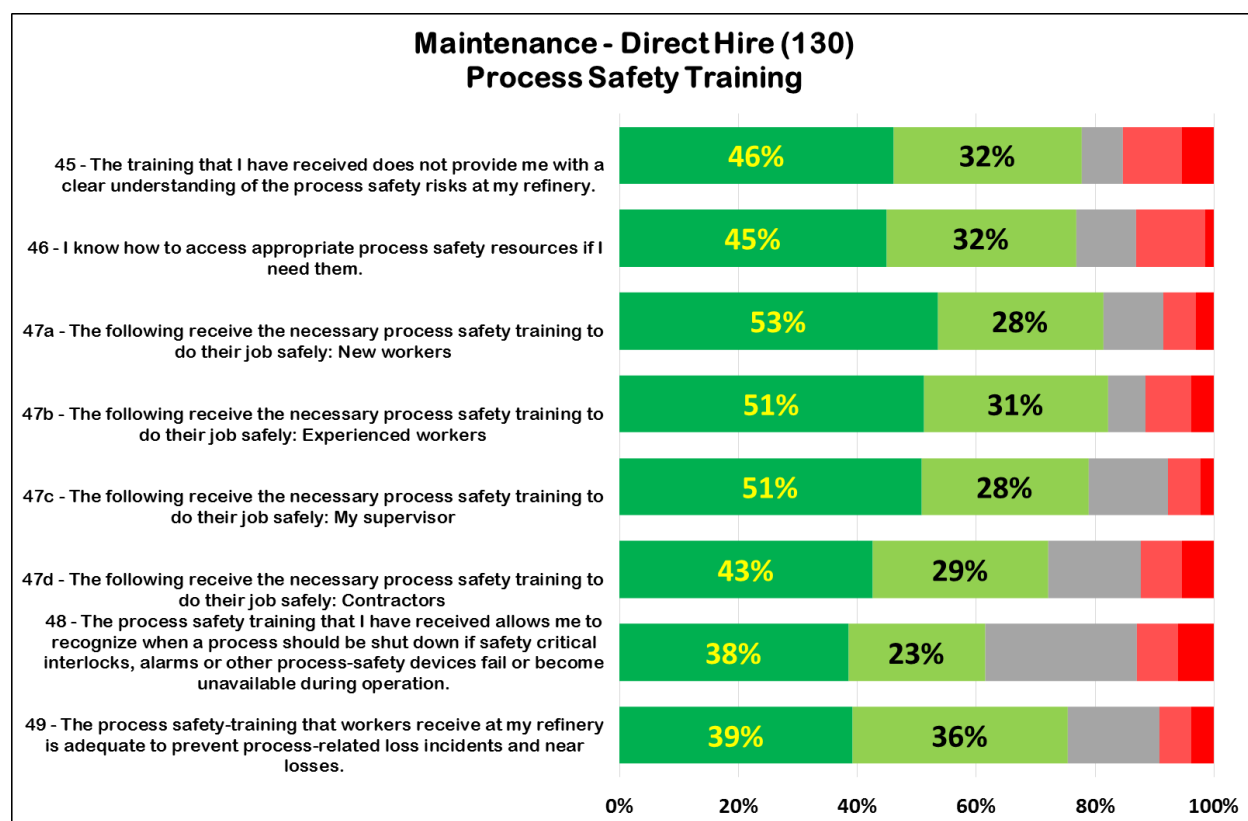
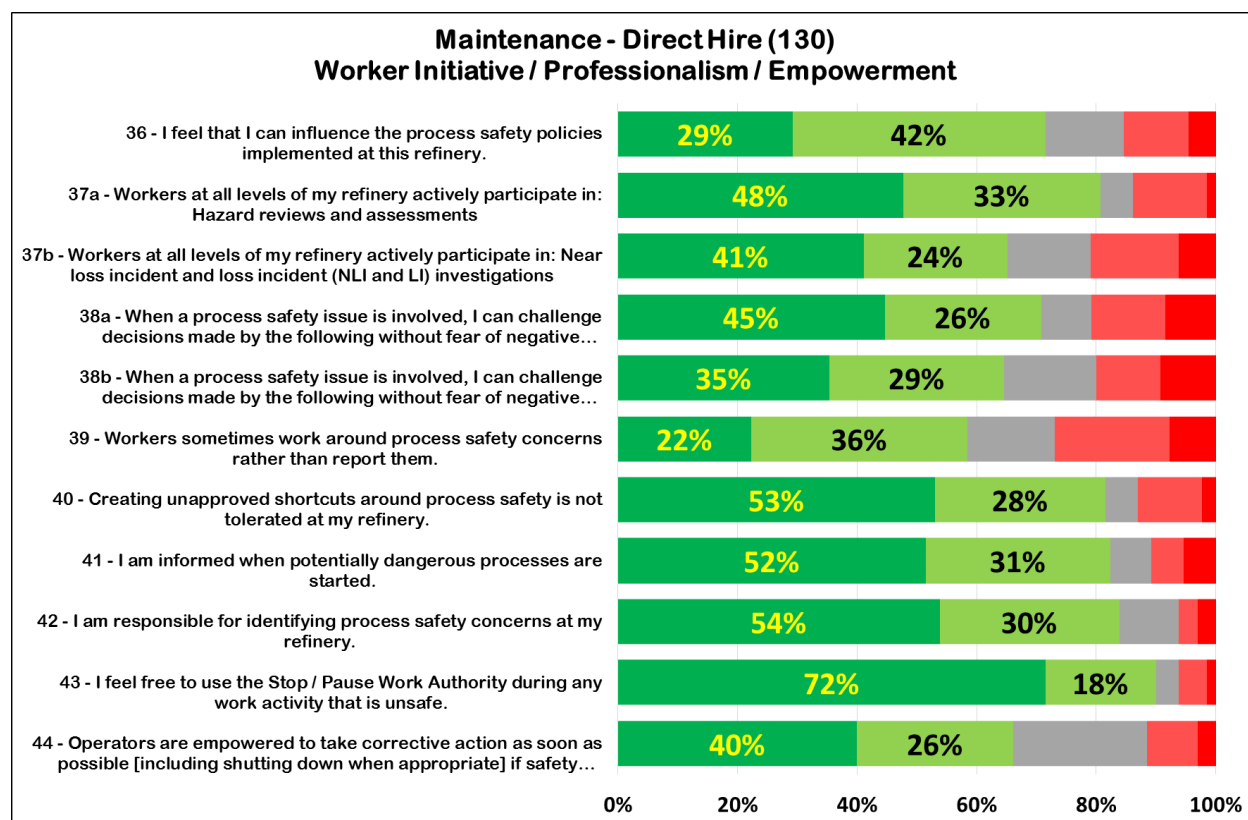
Chevron Operators (213) Procedures and Equipment











4.3.4.2 Selected Findings and Recommendations

Collectively, employees at the Chevron Richmond Refinery responded to the written survey with a very favorable view of safety culture at the site. 80% of all responses for all written survey respondents were favorable (agree or tend to agree) while only 9% were unfavorable. Represented employees gave more unfavorable responses than their non-represented colleagues (18% for operators and 12% for maintenance) did, but there was still a strong favorable response (70% for operators and 76% for maintenance). Generally, the represented respondents' positive responses were roughly 10 points lower than non-represented responses.

Comparing the written survey responses to individual questions for represented and non-represented employees indicates that non-represented employee responses were generally 10 points more favorable than represented employee responses. Several questions deserve special review in each of the survey question sub-groupings:

Process Safety Incident Reporting – Process Safety Incident Reporting was seen as the most favorable category – 86% of all responses were favorable (9% unfavorable). This result starkly contrasts with the evidence of low near miss reporting at the refinery and the safety-culture interview results. That is because this category contains 11 questions, and the responses to the specific questions on near miss reporting are different from the overall category.

For example, 66% of all respondents (60% of operators, 48% of maintenance) responded favorably when considering Question #4 “that workers do not bother reporting minor process related incidents, minor accidents, or near losses.” (Note that the responses were reversed to account for the negative wording of the question, so the higher the score, the better the respondent thought the refinery was doing on getting near misses reported). Represented employee favorable responses were 13 to 21 points lower for 5 of the 11 questions in this question group when compared to non-represented employee responses (including Question #4).

Six of 11 questions indicate that Chevron needs to improve process safety performance for reporting incidents and incident investigations. This reinforces previously discussed evidence of low near miss reporting at the refinery. It also supports the related recommendations regarding the need for improvement in near loss incident reporting and improvements in the overall incident investigation processes.

Process Safety Training – One of the most positive responses (82% positive) was on training provided for hazard identification, control and reporting, and the lack of hesitation to report actions or conditions that raise a process safety concern, even when a coworker is involved. Four of eight questions received roughly 80% favorable responses. The other four questions' favorable responses ranged from 66 to 75%. Richmond Refinery provided field evidence of a very strong training program, with many facets demonstrating world-class capabilities. Still, the responses to training questions from Richmond Refinery frontline employees (operators and maintenance technicians) indicate that these employees are not sure they (or their supervisor or coworkers) are prepared to complete their process safety-related job assignments as well as possible.

Supervisory Involvement and Support – Another favorable category included Supervisory Involvement and Support (82% favorable responses). One potential area of weakness in this category is indicated by Question #21, with favorable responses (77% for the average of all respondents, 68% favorable for operators, 69% favorable for maintenance) “that process safety concerns are secondary to achieving production goals.” Represented employee favorable responses were 13 to 15 points lower for three of nine questions in this question group than non-represented employee responses. As could be expected, represented employees

experience more stress to achieve production goals (Question #21) than most of their non-represented counterparts. Management must continue to demonstrate their commitment to addressing process safety concerns. Questions #27 & 28 (supervisor action) indicate that represented employees desire their supervisors to increase process safety emphasis.

Safety Values/Commitment to Process Safety – Safety values and commitment to process safety received the least favorable statistical response at 75% of all respondents (64% of operators, 72% of maintenance). Represented employee favorable responses were 15 to 27 points lower for five of 15 questions in this question group than non-represented employee responses. Represented employee responses indicate they “feel pressured” to work considerable overtime (by their own sense of loyalty to the unit, their supervisor, and refinery management – Questions #20a, b, c, and d). Operator low favorable responses (27 points lower than non-represented worker responses) to Question #18 (46%) support the interview feedback “that management is overly concerned with assigning blame or issuing discipline following a process-related incident, accident, or near miss.” This reinforces previously discussed recommendations regarding the need for improvement in both fitness-for-duty and incident investigation processes. Also noteworthy is favorable responses to Question #20a (worker pressure to work by coworker) which is 11 points higher for represented employees. Represented employees responses indicate they look for more Leadership by example (rather than assigning blame) and more process safety resourcing.

Procedures and Equipment – Represented employee favorable responses were 14 points lower to Question #35 (inspection, maintenance high priority) than non-represented employee responses. From the evidence collected from procedure walk-downs, the evaluation team also noted that procedures need improvement. The evidence from the field and from interviews also indicated that the refinery needs to follow through on the efforts begun to implement best practices in refinery mechanical integrity. Notably, represented employees responded more favorably (+12 points) to Questions #33 a and b (understanding and using maintenance checklists and procedures).

Worker Initiative/Professionalism/Empowerment – Represented employee favorable responses were 12 to 20 points lower for five of 11 questions in this group than non-represented employee responses. Represented employee responses of 70% favorable or lower to these questions indicate only a slight challenge for Richmond Refinery leadership, whereas the data from safety culture individual interviews indicated that this category is a major issue at the refinery. That Question #37b (incident investigation participation) received only 67% favorable response for represented employees highlights an opportunity for refinery management to increase employee incident investigation participation and collect additional near-loss incidents (as recommended earlier in the report). Of particular concern is the represented employee low favorable response (59%) to Question #39 (work-arounds): Too many operators or maintenance technicians feel they or their coworkers will (need to or must) include work-arounds to address process safety concerns rather than report them or correct them more permanently. Represented employees responded very favorably to Questions #41, 42 and 43, strong positive feedback concerning communication while starting potentially dangerous process, personal responsibility to identify process safety concerns and free to use Stop Work Authority (SWA). However, the interviews clarified this to mean for occupational safety issues only. From the interviews, the majority of operators feel the SWA does not work well for process safety issues when these affect production rates.

4.4 SUMMARY OF RESULTS FROM THE WRITTEN SURVEY

Chevron employee response to the written survey process is encouraging and indicates that employees are willing to engage in dialogue on process safety implementation at the Richmond Refinery. Feedback from Towers Watson (written survey administrator) indicates that Chevron written survey participation and positive responses compare favorably with written survey participation and responses for refining industry and with refiners in the area.

This Safety Evaluation team's assignment was to review the Richmond Refinery process-safety culture, human factors program, and process safety implementation compared to best process safety practices as implemented by industries worldwide processing highly hazardous materials. The written survey findings above are generally much more positive than the results obtained from objective evidence collected from field observations and from records at the refinery. In addition, the data from the 1-hour interviews with 96 employees provide deeper insight than the roughly 10 minutes required to take the written survey.

The written survey does reflect the same relative weaknesses in various facets of process safety culture or implementation at the refinery as the other sources of data. And the magnitude of the difference from "best practice" process safety implementation and the actual process safety implementation at the refinery is not reflected as well in the written survey. Further, PII has observed from surveys on various topics (including process safety culture) at other locations, that even a very weak system will still get many favorable comments. Perhaps this is due to the respondents being reluctant to criticize the company in writing. Or perhaps the respondents do not have sufficient background in best practices in process safety to make such value judgments.

(See the paper co-authored by PII and CCHMP for more discussion on the relative value of data from written surveys, individual interviews, and direct process safety data from the site.¹⁰⁸)

Therefore, PII believes the evidence concerning process safety implementation derived from objective site data is the most trustworthy source on which to base conclusions about process safety culture and comparisons to best practices. PII also believes that the Safety Culture interview data provides more process safety-culture insight than the Safety Culture Written Survey results, since the interviewee can ask and get clarifications to the questions, and since the interviewers requested examples from the interviewees to explain their positive or negative comments. In a survey, there is no way to actively test for respondent's level of comprehension of the question.

- End of Section 4, Evaluation and Findings -

5 CONCLUSIONS

The Richmond Refinery has a robust initiative to improve process safety. This has led to many recent improvements. However, there are still many weaknesses in process safety and control of human factors at the refinery. Some of these are related to technical gaps. Some are related to deficiencies in management practices at the refinery. The refinery management should put the plan, schedule, and budgets in place to improve on all of these areas.

As listed throughout the report, there were 37 specific recommendations from this evaluation at Chevron's Richmond Refinery. Many of these have several subparts, and each of these should be addressed. Below is a summary of the recommendations listed in the report, along with a reference to the related report section:

5.1 SUMMARY OF RECOMMENDATIONS

Rec. No.	Recommendations	Reference Sections
1	CUSA Richmond should expand operators' and maintenance craft-persons' involvement in leading roles in process safety activities. Increase the number of operators and craft-persons involved in these activities, too. For example, involve more operators and maintenance crafts-persons in: • Writing and validating procedures, • Leading process hazard evaluations of small MOCs, • Participating in PHAs (particularly using a broader selection of operators), and • Leading incident investigations.	4.1.2
2	To avoid losing track of temporary changes, improve the redlining process for the Master P&IDs used in the field. Further, improve RI-362 "Process Safety Information" to include criteria for handling all in-process (active) and archived (closed) MOC-modified PSI (i.e., P&ID originals) while a temporary MOC is in effect. RI-370 "Management of Change" may need parallel changes.	4.1.3
3	To avoid missing causes and necessary safeguards against loss of containment, be sure hazardous scenarios starting from pertinent damage mechanisms are reviewed during each unit's PHA. (Pertinent damage mechanisms include corrosion, erosion, seal failure, pump failure, external impact, external fire, material defect, improper maintenance, drains/vents left open, etc.) In particular, review external impact as a damage mechanism for each node. A review of such loss of containment scenarios in each node is recommended, as described in the <i>Guidelines for Hazard Evaluation Procedures</i>, 3rd Edition, 2008, CCPS/AIChE. Adding a loss of containment deviation would double-check against missing standard	4.1.4

Rec. No.	Recommendations	Reference Sections
	damage mechanisms (such as corrosion and erosion) during unit-wide reviews. It would also improve the current PHAs by providing a review at each node for external impacts and control of drains/vents. Review and incorporate mechanical integrity data during this analysis.	
4	For PHAs, improve Human Factors' incorporation in brainstorming accident scenarios. Also, improve documentation of how human factors are accounted for in causes and safeguards listed in the PHAs, per industry best practices. (Also, see 4.1.5 Mechanical Integrity and 4.1.7 Operating Procedures for ensuring these safeguards remain reliable.) - Human safeguards (protection layers) include operator actions (alarm response, problem identification, troubleshooting). - Human causes include operating errors related to issues such as inaccuracies and lack of clarity in procedures and misidentification of process equipment (because of inadequate labeling, numbering, and nomenclature).	4.1.4
5	Continue, and expand, the current Procedural PHA program implementation so that all modes of operation are evaluated. Include a PHA of startup, shutdown, and online maintenance procedures, as described in Chapter 9 of the <i>Guidelines for Hazard Evaluation Procedures</i> , 3rd edition, CCPS/AIChE, 2008. This will entail using a 2-guideword HAZOP approach on each step for critical procedures and a What-if (no guideword) approach for less-critical procedures. No procedures should be excluded.	4.1.4 4.2.7
6	Implement a policy and procedures for documenting, in writing, the justification for declining PHA recommendations (per <i>Guidelines for Hazard Evaluation Procedures</i>, 3rd Edition 2008). Base justifications upon adequate evidence that one or more of the following conditions is true: - The analysis upon which the recommendation is based contains material factual errors; - The recommendation is not necessary to protect the health and safety of the employer's employees or contractors' employees; - An alternative measure would provide a sufficient level of protection; or - The recommendation is infeasible.	4.1.4
7	Follow through on the existing plans to implement a process for determining when a LOPA is necessary.	4.1.4
8	Follow through on the existing plans to establish ITPMs for SIS. Also, ensure they meet CCPS and ANSI/ISA requirements for SIS.	4.1.4

Rec. No.	Recommendations	Reference Sections
9	Update policies and procedures to define clearly the process, roles, and responsibilities for managing and maintaining equipment and human actions identified as safeguards <u>and causes</u> (as identified in PHAs). The safeguard management system(s) of the asset integrity program should include safeguards and causes identified in PHAs for Consequence Levels I and II. In addition, expand them to include Consequence Level III events. Criticality should be identified, such as by labeling as independent protection layers (IPLs) in the PHA report. This rating should be maintained in the CMMS. Appropriate ITPMs should be developed, performed, and documented for each of these items. Further, until the ITPM plans are established and active for a safeguard, no credit should be taken for it (e.g., it should not be considered an IPL). <i>NOTE: The IPL management system that the refinery has begun may address the concerns of this recommendation. However, control of the frequency of causes is just as important as the control of the probability of failure on demand of an IPL.</i>	4.1.4
10	Follow through on the current initiatives at the refinery to reduce the number of TLRs and improve the closure speed on safety work orders.	4.1.5
11	Finish identifying MI-critical assets to add to the ITPM program. The criteria should consider the asset function (control, safeguard, containment, etc.) and the consequence of failure (which is also listed in sRCM documentation). As stated in Recommendation 9, until the ITPM plans are established and active for a safeguard, no credit should be taken for it (e.g., IPL).	4.1.5

Rec. No.	Recommendations	Reference Sections
12	Continue the current emphasis on the MI procedures and processes. Follow regulatory guidelines, and implement best industry practices, such as those described in the CCPS <i>Guidelines for Mechanical Integrity Systems</i>. Continue developing maintenance work instructions for ITPM. Provide resources and systems to effectively manage ITPMs at the component level for all process safety equipment. In addition to the general improvements above (toward which the refinery is already working), consider implementing the following specific improvements: a) Review/update the policy and procedures that define how instrumentation is entered into the Maximo system and verify implementation. Ensure that instruments are maintained (and tracked and documented) per ISA requirements. b) Review/update the policy and procedures that define the “Add, Change, Delete” equipment-information management system that direct how information is entered into the Maximo and Meridium systems. c) Train the ACD Coordinator on the updated policy and procedures (see Recommendation 12.b above) so that ITPM entry, tracking, and historical data are associated with the proper equipment.	4.1.5
13	Revise the TLR to require operators to check more often for any leaks while a TLR is in place.	4.1.5
14	Follow through on plans to improve piping ITPM by using appropriate API codes, standards, and Chevron’s operating experience, to develop MI procedures and practices to guide MI inspectors. Complete the current plans to determine which piping systems are most susceptible to corrosion issues, especially sulfidation and high-temperature hydrogen attack. To achieve the highest probability of detecting potential damage in process piping, audit and as necessary, complete the development and implementation of DMR and ITPM for process piping sections. This should be based on an understanding of process/operating conditions and resulting damage mechanisms. Use damage mechanisms appropriate for the units and operating conditions, such as high-temperature sulfidation, high-temperature hydrogen attack, and hydrochloric acid (HCl) corrosion.	4.1.5
15	Follow through on the current initiative to develop policy and procedures (refinery instruction [RI], procedure, or guideline) describing	4.1.5

Rec. No.	Recommendations	Reference Sections
	the process, roles, and responsibilities for the integrity threat process.	
16	Develop and implement a formal procedure and process to ensure that SIFs are not bypassed for an indeterminate amount of time. Have an instruction that identifies (1) time limits for different integrity levels, (2) acceptable replacement or mitigation options when it appears that prompt repair (within the expected Mean Time to Repair) is not possible, and (3) the roles and responsibilities for making these decisions. These should be consistent with industry guidelines, such as those found in ANSI/ISA 84 or the <i>Guidelines for Safe Automation of Chemical Process</i> , second edition, from CCPS/AIChE).	4.1.5
17	Periodically test process safety “Smart” transmitter installations as part of the ITPM. Otherwise, process safety Smart transmitters that are run to failure should have notes to that effect in the inspection, test, and PM database. If the transmitter is run to failure, then each failure and replacement should be documented. The refinery should track the failure rate of process safety Smart transmitters to determine whether to change the ITPM practices (e.g., decide not to run to failure). The refinery should develop a procedure and analysis for how different “criticality level” (process safety) instruments are maintained and tested to deliver consistent equipment and instrument availability. These safeguards and SIS require a proper management system.	4.1.5
18	CUSA should address the following gaps in the MI quality assurance (QA) programs, which create significant potential for loss of containment incidents: • Develop a positive material identification policy, procedure and practice for all process areas where the wrong material of construction can cause loss of containment of a hazardous material. This would include areas where alloys are used, high-silicon steel is used, and killed steel is used. • Complete the 100% baseline PMI for alloys in the refinery as quickly as possible to identify refinery equipment and piping locations with high risk for loss of containment incidents. (Completion within 2 to 3 years is possible with proper priority and resources.) In addition, verify projected remaining life of any equipment and/or piping systems that contain hydrocarbons and/or process chemicals identified as Integrity Threats that <u>during</u> refinery turnarounds. The Integrity Threat Assessment should be completed and temporary/permanent repairs implemented before startup. Also, include appropriate upper management approval of prescribed temporary repairs.	4.1.5

Rec. No.	Recommendations	Reference Sections
19	Upgrade the current visual inspection policy, program and checklist to include locating nameplate information on small vessels/drums/columns. Determine if internal inspections can be performed adequately on these small vessels using boroscopes. Complete engineering calculations and verify materials and construction for vessel/drums/columns without nameplates (see V-421 as one example).	4.1.5
20	Consider updating the OJT process to include feedback from the trainee operators on how the senior operator trainers (field trainers) performed training activities. Validation of training checklist quality and thoroughness could help the consistency of training given to new operators during OJT.	4.1.6
21	Consider incorporating different modes of refresher training. These could include classroom discussion and reviews, field walks, table-top reviews, group/control room training and CBT reviews. For example, if CBT is used for standardized training topics, then use facilitated sessions to discuss troubleshooting methods and review role-specific procedures. To promote “buy-in” (i.e., employee participation) and operators’ retention of skills and knowledge, include operators in the design and delivery of these classes.	4.1.6
22	Consider developing appropriate hypotheticals and situationals for use in training operators to handle scenarios that may lead to a catastrophic outcome. These should be taken from critical safety scenarios identified in incidents and in the PHA process (and in other brainstorming activities). Consider providing additional structure and guidance around the refinery-wide practice of hypotheticals, such as table-top reviews of response to an emergency, performed within an operator’s shift.	4.1.6
23	Implement management systems at the refinery so that procedures are accurate, complete, clear, and consistent with best practices for reducing human error. For example: • Develop procedure walk-down instructions for SMEs (i.e., operators) to use when checking a procedure for accuracy and completeness. Provide guidance on addressing (including) human factors/latent conditions for simultaneously evaluating procedure clarity. • Walk down enough procedures in the refinery to determine which units fall below 95% accuracy. Rewrite and revalidate as quickly as possible the procedures in the units with accuracy scores lower than 95%. Develop a procedure-updating matrix to focus resources on most critical procedures. • Have SMEs (i.e., operators for operating procedures, maintenance	4.1.7

Rec. No.	Recommendations	Reference Sections
	craft-persons for maintenance procedures) walk down all new procedures in the refinery before they are issued, to ensure accuracy is 95% or above. • Complete the upgrade of procedures to follow the best practices for page format and step format. • Expand SME expertise in Human Factors using a best practices human-factors checklist during procedure walk-downs so that they can quickly implement control of other human factors. • Continue to upgrade the Criticality Index for written instructions to make clear to operators which instructions are procedures, checklists (required for use), or job aids (instructional basic assistance). • Because of operating procedures' significance to process safety, measure OE Leadership and Refinery Safety Culture for Written Instructions (all departments) by implementing KPIs that reflect management commitment and operator buy-in for accurate and useful procedures. Emphasize procedure updates, improved procedure composition to address human factors, walk-down of procedures by a second and perhaps third operator (other than the author), etc. • Ensure that a procedural PHA is done on each newly created and/or revised startup, shutdown or emergency procedure before the procedure is released for use. • Revise RI-363 Process Hazard Analysis to include roles, responsibilities, procedures and documentation for conducting Procedural PHAs.	
24	Explore methods to minimize known barriers to near loss incident reporting, including establishing a blame-free zone for all incidents, especially near loss incidents. These steps should include: • Simplify investigation and reporting for NLIs. • Consider modifying the written drug testing policy and its negative influence when coupled with incident reporting. • Ensure only peers interview peers during data collection. • Ensure investigations get to root causes (management system failures). • Allow hourly staff to take the lead on investigations (as other companies have done). Establish and achieve a NLI/LI ratio goal of 20 or more.	4.1.8 4.3.2 4.3.3.2

Rec. No.	Recommendations	Reference Sections
25	As mentioned in Recommendation 24, use hourly operators and maintenance workforce more as lead investigators. To facilitate this, consider providing broad training (including to operators and maintenance hourly staff) in the best practices of investigation and root cause analysis methodologies. Note that TOP does not have a Root Cause Coding Tree to ensure investigations reach root causes.	4.1.8 4.3.2 4.3.3.2
26	Consider ways to improve incident investigations. These investigations should be conducted in a balanced, consistent, and timely manner, involve people closest to the work being performed, find root causes, and develop sustainable solutions. Refinery management should reinforce that investigations focus on fixing the underlying management systems. They also should reiterate that only management system weaknesses (including those that affect design of equipment and design of tasks) can be root causes. Periodically conduct a management-level review of all incident investigations.	4.1.8
27	Improve the program to control potential miscommunication by radio, phone, and face-to-face (such as in noisy areas). This can be done by adopting industry best practices for ensuring clear and accurate verbal communication. Such a program normally involves training on standardized terminology, repeat-back, and other rules for clear communication. It also includes frequent checking (monitoring of radio channels) and feedback by supervision on the use of proper communication techniques.	4.2.2
28	Reduce the probability of human error by following 10 CFR 26 (U.S.NRC) for Fitness for Duty (FFD), which includes management of fatigue. This program outlines maximum hours on-site per day and per week and minimum time away from work per week. It also outlines how to detect symptoms of FFD issues and how to respond to these. Especially, limit the maximum number of consecutive days worked to four days of 12-hours shifts and six days of 8-hrs shifts, even during turnarounds. Alternatively, allow five to six days of 12-hour shifts, with a 45-minute nap break midway through the shift. Do NOT follow the 14 consecutive day allowance in API RP 755. Note that other alternatives to work-hour limits are available, such as allowing naps in the middle of a shift (with coverage of the workload). In addition to work hours, other factors that increase fatigue are poor diet, lack of exercise, etc. CUSA should explore all issues to reduce the probability of errors resulting from fatigue.	4.2.3
29	Inspect the refinery units following the corporate standard for human factor engineering: <i>Safety in Design</i> . This inspection could be completed within the PHA Latent Conditions Review before PHA meetings. However, this inspection schedule could leave conditions like hard-to-reach valves unidentified (latent) for years. The walk-	4.2.4

Rec. No.	Recommendations	Reference Sections
	throughs spotted hard-to-reach valves in several units. This appears to be systemic. The operators should be the SMEs assigned the lead role in identifying possible changes in valve placement. They likely can help prioritize the units for these activities. First, review the Latent Condition Checklist versus human-factors best practices to find any gaps in the checklist.	
30	For refinery safety systems with multiple, similar devices that serve in a protective function against the same accident scenario, the refinery needs to establish practices/procedures to reduce the chance of repetitive human error. If one person maintains these similar systems daily, he or she could repeat an error across several systems in one day. Therefore, schedule ITPMs activities to be done on different days, preferably by different technicians/staff. These situations include Safety Instrumented Systems (SIS) for Safety Integrity Level 2 and 3, ESDs, multiple check-valves, and multiple relief devices. Otherwise, the probability of failure on demand of such safety systems could be 10 to 100 times higher than expected.	4.2.2
31	For human response IPLs, ensure that the response action is practiced to mimic the actual response to a critical process excursion. This practice should be timed (such as by the supervisor or a designee). The time and success or failure should be recorded to validate that the humans can respond within the predicted maximum allowable response time. This resolution could be accomplished by formalizing and recording data from the ad hoc <i>situationals</i> (and perhaps some <i>hypotheticals</i>) already performed by the refinery operators and Head Operators. <i>Note that this recommendation is related to “how to” ensure the reliability of IPLs; following up Recommendations 9 and 11 regarding identifying IPLs and establishing an ITPM for each.</i>	4.2.6
32	Increase the Human Resources Department's Process Safety Culture competencies in human factors. Also, enlarge their role in optimizing certain human factors to strengthen development of refinery work processes and staffing.	4.3.2
33	Develop methods to increase management and employee expertise in applying SWA to process safety issues (situation identification and decision-making).	4.3.2 4.3.3.2 4.3.3.3
34	Ensure that an adequate number of staff have high competencies in process safety-critical roles. The goal is to ensure adequate numbers of the various competencies for day-to-day process safety implementation (related to Recommendation 1). For each process role/activity, establish the following: • How to reach competency for an activity?	4.3.3.2

Rec. No.	Recommendations	Reference Sections
	- Who is the competency judge? - How to identify competencies that may be leaving?	
35	Ensure that the action-item closure process for PHAs, MOC risk reviews, and incident investigations includes: - Documented evidence of why a corrective action is declined; - Improved action-item closure visibility; and - Feedback/review by the appropriate people involved, especially the originator(s) of the request and people affected by the corrective action.	4.3.3.2
36	CUSA Richmond should implement a policy and procedures to sustain process safety competency in key organizational roles, including refinery leadership. Steps could include setting minimum times in place for key leadership roles.	4.3.3.2
37	Consider streamlining the MOC review and documentation procedures for low-risk changes. Continue to ensure that appropriate risk assessment is performed and documented before significant changes are implemented. Implement an improved MOC process that covers changes requested to operating and maintenance procedures and include (or consult) the affected personnel on best ways to approach these requested changes. All impacted employees (including represented employees) should be appropriately involved in Management of Organizational Change (MoOC) reviews (see related CCHMP finding). Chevron should audit MOCs frequently enough to better define the MOC situations that require face-to-face training (see related CCHMP finding).	4.3.3.2

- End of Section 5, Conclusions -

6 APPENDICES

6.1 RECOMMENDED READING

Individuals with technical backgrounds conducted this Safety Evaluation. The findings and recommendations are addressed to technical staff at the Chevron Richmond Refinery. However, citizens of Contra Costa County, CA, will also read this report. So, the authors attempted to put

the issues discussed in this report into common terms wherever possible. Still, because of the nature of the subject, use of technical terms is unavoidable.

If you want to learn more about main aspects of this evaluation, we recommend you start with the papers below. For more depth, the textbooks listed below are a good follow-on read. Of course, the list of references in Section 6.5 provides even greater depth on specific issues.

Process Safety

Contra Costa County (California) Industrial Safety Ordinance (ISO), online interactive website – <https://cchealth.org/hazmat/iso/> (download also available):

- *Guidelines for Risk Based Process Safety*, 2007, CCPS/AIChE
- “Process Safety Competency,” R. Tew, G. Burch, and W. Bridges, PII; 10th Global Congress on Process Safety, 2014, AIChE; download from www.piii.com/resources
- “Optimizing Qualitative Hazard Evaluations For Maximized Brainstorming,” W. Bridges, and R. Tew, 43rd Loss Prevention Symposium, 2009, AIChE; download from www.piii.com/resources

Human Factors

- “Human Factors and Their Optimization,” W. Bridges, Dr. G. Collazo; 8th Global Congress on Process Safety, 2012, AIChE; download from www.piii.com/resources
- *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications*; NUREG/CR-1278, Swain, A.D. and Guttman, H.E. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983. (downloadable at: <http://pbadupws.nrc.gov/docs/ML0712/ML071210299.pdf>)
- *Guidelines for Preventing Human Error in Process Safety*, 2004, CCPS/AIChE
- Section B: Chapter 2, Contra Costa County (California) Industrial Safety Ordinance (ISO), download from http://cchealth.org/hazmat/pdf/iso/sect_b_ch_2.pdf

Process Safety Culture

- “Process Safety Culture – Making This a Reality,” C. Chung, CCHMP; G. Burch and W. Bridges, PII; 10th Global Congress on Process Safety, 2014, AIChE; download from www.piii.com/resources
- “Gains from Getting Near Misses Reported,” Research paper by W. Bridges, 8th Global Congress on Process Safety, 2012, AIChE; download from www.piii.com/resources
- *Safety Culture and Risk; The Organisational Causes of Disasters*, Hopkins, Andrew, Sydney, New South Wales: CCH Australia Limited, 2005
- U.S. Chemical Safety Board’s Final Investigation Report on the Chevron Richmond Refinery Pipe Rupture and Fire, presented at 11th Global Congress on Process Safety (GCPS) – Case Histories and Lessons Learned, American Institute of Chemical Engineers (AIChE), April 30, 2015

6.2 SCOPE OF WORK FOR THE SAFETY EVALUATION

Chevron Richmond Refinery
Management Systems and Safety Evaluation
Statement of Scope

The evaluation will be conducted at the Chevron Richmond Refinery.

1. Evaluate how the refinery's management systems, safety culture, and human factors are incorporated in the information and expectation sharing and training of operating, maintenance, management personnel, other staff and contractors. Address the management systems in place for: Mechanical Integrity, Operating Procedures, Training, Management of Change (including management of organizational change), Process Safety Information, Pre Start-Up Safety Reviews, Incident Investigation, Hot Work, Contractors, Emergency Response Program, Compliance Audits, Employee Participation, and Process Hazard Analysis. The review of the management systems is to include how Chevron follows up with action items from incident investigations (internal and external), audits (internal and external) and actions to address enforcement citations. This evaluation should include, but not be limited by the list in Appendix A *"Self-evaluation Questionnaire for Managers Considering Ways to Improve Human Performance-Policy Issues,"* Appendix B *Contra Costa County's Safety Program Guidance Document Section B: Human Factors Program,"* Appendix C *Contra Costa County's Safety Program Guidance Document Section F: Safety Culture Assessments,* and the items listed below:
 - a) How is management intent, as expressed in internal policies, carried out at field level?
 - b) How are procedures and policies developed? What do personnel at Chevron Richmond Refinery do when work falls outside of the written procedures or policies?
 - c) How is bottom-up input provided for, and on what range of subject matter? How are disagreements resolved?
 - d) What systems are in place to assure that policies and/or procedures are followed? Do these include audits (scheduled and random)?
 - e) What accountability exists at each level of the organization? Who is accountable for what and to whom?
 - f) Is there stop work authority for all refinery personnel and if there is, does the line and support staff believe that there will no repercussions if the policy is followed?
 - g) Does stop work thoroughly include stopping/shutting down a process, or just maintenance work?

- ### h) Does the frequency in changing the refinery top management affect the overall safety culture of the refinery?
2. Public Participation – This evaluation will include public participation. A committee has been developed that will oversee the work of the evaluation. The Oversight Committee will assist in selecting the successful evaluation team. A meeting with the Oversight Committee will be held prior to the beginning of the on-site evaluation, in which the contractor will explain the approach and plan on how the contractor will perform the evaluation. Interim meetings during the on-site safety evaluation with the Oversight Committee to update the Oversight Committee on the progress of the evaluation and the confirmed findings. This will be at least one meeting but may be additional meetings as needed. A meeting will be held with the Oversight Committee after the draft report is issued to explain the results of the evaluation. The Oversight Committee will have the opportunity during this meeting to ask questions and give comments on the draft report. At this meeting the Oversight Committee will either accept the report or not based on the work of the consultant. If the report is not accepted, the evaluation team will be directed on what changes need to be made so the Oversight Committee will be able to accept the report. When the draft report has been accepted by the Oversight Committee, the draft report will have a 45 day public comment period. During the 45-day public comment period, a public meeting will be held. The public meeting will be an opportunity for the contractor to listen to the public's concerns and consider making changes in the report or doing additional on-site work to complete the evaluation. The contractor working with Contra Costa Health Services shall respond to all written comments and comments that are raised in the public meeting. The contractor should expect to attend and present reports at the following meetings:
- a) An initial meeting with the Oversight Committee before starting the evaluation.
 - b) Interim meetings during the on-site evaluation to update the Oversight Committee on the progress of the evaluation and some of the confirmed findings of the consultant.
 - c) Additional meeting or meetings with the Oversight Committee to discuss the draft findings of the evaluation and to receive acceptance of the draft report.
 - d) A public meeting to present the draft report.
 - e) A public meeting of the Richmond City Council.
 - f) A public meeting of the Contra Costa County Board of Supervisors, to present the final report.
 - g) Review the Chevron Richmond Refinery's action plan to help ensure that the action plan is addressing the recommendations and findings from the safety evaluation.
3. A follow-up evaluation will be done to include the following:
- a) What systems are in place to assure that policies and/or procedures are followed? Do these include audits (scheduled and random)?
 - b) What accountability exists at each level of the organization? Who is accountable for what and to whom?
 - c) Is there stop work authority for all refinery personnel and if there is, does the line and support staff believe that there will no repercussions if the policy is followed?

- d) Does stop work thoroughly include stopping/shutting down a process, or just maintenance work?
- e) Does the frequency in changing the refinery top management affect the overall safety culture of the refinery?

The contractor will prepare a plan for evaluation and will submit this plan to the Project Manager from Contra Costa Health Services for review. The plan shall include interviewing the Union Safety Committee. Included in Appendix A are examples of items to be considered in this evaluation. The contractor should use this list to assist in the evaluation of Chevron Richmond Refinery's current programs for addressing management systems, safety practices, and the safety culture of the Chevron Richmond Refinery.

6.3 COMMENTS AND RESPONSES FROM PUBLIC

Pending receipt of comments from public.

6.4 GLOSSARY OF TERMS, ACRONYMS, AND ABBREVIATIONS

ABU	Area Business Unit (CUSA)
ACD	Add, Delete, Change (CUSA)
ACGIH	American Conference of Governmental Industrial Hygienists
AI	Asset Integrity (CUSA)
AIChE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
AOA	Alarm Objective Analysis
API	American Petroleum Institute
ASM	Abnormal Situation Management Consortium
ASME	American Society of Mechanical Engineers
BIN	Business Improvement Network (CUSA)
BOT	Basic Operator Training
BP	British Petroleum
CA	Compliance Audits
CAIB	Columbia Accident Investigation Board
Cal ARP	California Accidental Release Prevention
CBT	Computer Based Training
CCHMP	Contra Costa Hazardous Materials Program
CCPS	Center for Chemical Process Safety (of AIChE)
CFR	Code of Federal Regulations
CHESM	Contractor Health, Environmental, and Safety Management systems
CML	Condition Monitoring Location
CMMS	Computerized Maintenance Management System
CPDEP	Chevron Project Development and Execution Process
CRV	Critical Reliability Variables
CSB	U.S. Chemical Safety and Hazard Investigation Board
CSE	Confined Space Entry
CTU	Chevron Technical University
CUSA	Chevron U.S.A.
DCS	Distributed Control System
EMMS	Electronic Manual Management System (CUSA)
EOM	Electronic Operating Manuals (CUSA)
EPA	Environmental Protection Agency (USA)
ERP	Emergency Response Plan
ESD	Emergency Shut Down
FEI	Fixed Equipment Integrity
FEIM	Fixed Equipment Integrity Manager
FFD	Fitness for Duty
FOTP	Global Fundamental Operator Training Program (CUSA)
GCPS	Global Congress on Process Safety (of AIChE)
GM	General Manager (CUSA)
HA	Hazards Assessment
HAZOP	Hazard and Operability; as in HAZOP Analysis or HAZOP Study
HF	Human Factors
HMI	Human Machine Interface
HO	Head Operator (CUSA)
HRD	Human Relations Department
HSE	Health, Safety, and Environment

I/O	Input/Output
ISO	Industrial Safety Ordinance
IE	Initiating Event
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers, Inc.
II	Incident Investigation
IIF	incident and Injury Free (CUSA)
IOW	Integrity Operating Window
IPL	Independent Protection Layer
IMPACT	Initiative for Managing Pacesetter Turnarounds
IREC	Inspection Recommendation
IS	Inspection Supervisors (CUSA)
ISA	International Society of Automation
ISF	Instrumented Safety Function
ISS	Instrumented Safety System
ITL	Impact Team Lead
ITPM	Inspection, Testing, and Preventive Maintenance
KPI	Key Performance Indicator
LA	Leadership and Accountability
LCC	Latent Conditions Coordinator
L&D	Learning and Development
LI	Loss Incident (CUSA)
LMS	Learning Management System
LOC	Loss of Containment
LOPA	Layer of Protection Analysis
LOTO	Lockout/Tagout
LPO	Loss Prevention Observations (CUSA)
LPS	Loss Prevention System (CUSA), includes behavior based safety principles
M&R	Maintenance and Reliability (CUSA)
MART	Maximum Allowable Response Time
Maximo	The CMMS used by CUSA
MAWP	Maximum Allowable Working Pressure
MAWT	Maximum Allowable Working Temperature
Meridium	The CUSA database for equipment design, inspection, and repair history
MI	Mechanical Integrity
MIS	Major Incident Survey (CUSA)
MOC	Management of Change
MoOC	Management of Organizational Change
NASA	National Aeronautics and Space Administration
NJBI	New Job Break-In Checklists (CUSA)
NLI	Near Loss Incident (CUSA)
NRC	Nuclear Regulatory Commission
NUREG	U.S. Nuclear Regulatory Commission Regulation
OERI	Operational Excellence Reliability Intelligence (CUSA)
OJT	On-The-Job (Training)
OOA	Optimization Operations Assistant (CUSA) position designed to support the STL
OP	Operating Procedures
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration (USA)
PCO	Process Control Operator (CUSA)

PERD	Process Equipment Reliability Database
PHA	Process Hazard Analysis
PII	Process Improvement Institute, Inc.
P&ID	Piping & Instrumentation Diagram
PMI	Positive Material Identification
PPSS	Plant Process Safety Symposium (of AIChE)
PSI	Process Safety Information
PSM	Process Safety Management (OSHA PSM Standard 29 CFR 1910.119)
PSSR	Pre-Startup Safety Review
PST	Process Safety Time
QA	Quality Assurance
RAGAGEP	Recognized and Generally Accepted Good Engineering Practice
RBPS	Risk Based Process Safety
RCA	Root Cause Analysis
REC	Recommendation
RISO	Richmond Industrial Safety Ordinance
RMP	U.S.EPA Risk Management Plan (40 CFR 68)
RP	Recommended Practice
RTF	Run To Failure
SCA	Safety Culture Assessment
SCI	Safety Culture Interview
SID	Safety In Design (CUSA)
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SME	Subject Matter Experts
sRCM	Reliability Centered Maintenance
SRU	Sulfur Recovery Unit (CUSA)
STL	Shift Team Leader
SWA	Stop Work Authority (SWA)
SWP	Safe Work Permit
TLR	Temporary Leak Repairs (CUSA)
TOP	Triangle of Prevention – United Steelworkers
UL	Underwriters Laboratory
U.S.EPA	United States Environmental Protection Agency
U.S.OSHA	U.S. Department of Labor, Occupational Safety and Health Administration
WPIA	Work Process Improvement Coordinator

6.5 REFERENCES (END NOTES)

- ¹ Oversight Committee. "Final Request for Proposal." *Chevron Richmond Refinery Safety Evaluation*. Contra Costa Health Services Environmental Health and Hazardous Materials Programs, May 23, 2013.
- ² Ibid.
- ³ Cheung, Burch, and Bridges. "Process Safety Culture – Making This a Reality." *10th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2014.
- ⁴ Ibid.
- ⁵ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Investigation Report: Catastrophic Rupture of Heat Exchanger (Seven Fatalities), Tesori Anacortes Refinery, Anacortes, WA, Report No. 2010-08-I-WA, Draft for Public Comment*. U.S. Chemical and Safety Hazard Investigation Board (CSB), January 29, 2014.
- ⁶ Baker, James A., et al. "The Report of the BP U.S. Refineries Independent Safety Review Panel." January 2007.
- ⁷ "Columbia Accident Investigation Board (CAIB) Report." National Aeronautics and Space Agency (NASA), August 2003.
- ⁸ Contra Costa County Hazardous Materials Programs. "Section F Safety Culture Guidance." In *Contra Costa County Industrial Safety Ordinance (ISO)*, by CCHMP. June 15, 2011.
- ⁹ Ibid.
- ¹⁰ Hopkins, Andrew, *Safety Culture and Risk; The Organisational Causes of Disasters*. Sydney, New South Wales: CCH Australia Limited, 2005,
- ¹¹ Contra Costa County Hazardous Materials Programs. "Section F Safety Culture Guidance." In *Contra Costa County Industrial Safety Ordinance (ISO)*, by CCHMP. June 15, 2011.
- ¹² Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ¹³ Learning and Development. "Human Factors for Procedure Writing." *Materials and Procedures – EOM*. Chevron Richmond Refinery, January 2013.
- ¹⁴ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Investigation Report: Refinery Fire and Explosion, BP, Texas City, TX, Report No. 2005-04-I-TX*. U.S. CSB, March 2007.
- ¹⁵ OSHA Directive Number CPL 03-00-004. "Petroleum Refinery Process Safety Management National Emphasis Program, Appendix A, Section I – Human Factors." Occupational Safety and Health Administration (OSHA), June 7, 2007.
- ¹⁶ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.

-
- ¹⁷ OSHA 29 CFR 1910.119. "Process Safety Management of Highly Hazardous Chemicals." Occupational Safety and Health Administration (OSHA), [57 FR 23060, June 1, 1992; 61 FR 9227, March 8, 1996; 77 FR 17776, March 26, 2012; 78 FR 9313, Feb 8, 2013].
- ¹⁸ State of California. "Chapter 4.5 California Accidental Release Prevention (Cal ARP) Program." *California Code of Regulations, Title 19. Public Safety*. California Code of Regulation, June 28, 2004.
- ¹⁹ Contra Costa County Hazardous Materials Programs. "Section B Chapter 2: Human Factors and Human Error." In *Contra Costa County Industrial Safety Ordinance (ISO)*, by CCHMP. June 15, 2011.
- ²⁰ Center for Chemical Process Safety (CCPS). *Guidelines for Risk Based Process Safety*. American Institute of Chemical Engineers (AIChE), 2007.
- ²¹ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ²² Contra Costa County Hazardous Materials Programs. "Section B Chapter 2: Human Factors and Human Error." In *Contra Costa County Industrial Safety Ordinance (ISO)*, by CCHMP. June 15, 2011.
- ²³ Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ²⁴ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications; NUREG/CR-1278*. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ²⁵ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ²⁶ Ibid.
- ²⁷ Bridges, W. "LOPA and Human Reliability – Human Errors and Human IPLs." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ²⁸ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ²⁹ Bridges, W. "LOPA and Human Reliability – Human Errors and Human IPLs." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ³⁰ Ibid.

-
- ³¹ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications; NUREG/CR-1278*. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ³² Bridges, W. "LOPA and Human Reliability – Human Errors and Human IPLs." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ³³ Ibid.
- ³⁴ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications; NUREG/CR-1278*. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ³⁵ Bridges, W. "LOPA and Human Reliability – Human Errors and Human IPLs." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ³⁶ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ³⁷ Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures*. American Institute of Chemical Engineers (AIChE), 1985.
- ³⁸ Center for Chemical Process Safety (CCPS). *Guidelines for Layer of Protection Analysis (LOPA)*, American Institute Of Chemical Engineers (AIChE), 2001.
- ³⁹ Center for Chemical Process Safety (CCPS). *Guidelines for Technical Management of Chemical Process Safety*. American Institute of Chemical Engineers (AIChE), 1989.
- ⁴⁰ Center for Chemical Process Safety (CCPS). *Guidelines for Risk Based Process Safety*. American Institute of Chemical Engineers (AIChE), 2007.
- ⁴¹ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ⁴² Ibid.
- ⁴³ DOE Standard DOE-STD-93. *Guide to Good Practices for Operations Turnover*. U.S. Department of Energy, June 1993.
- ⁴⁴ Center for Chemical Process Safety (CCPS). *Guidelines for Risk Based Process Safety*. American Institute of Chemical Engineers (AIChE), 2007.
- ⁴⁵ Center for Chemical Process Safety (CCPS). *Guidelines for Auditing Process Safety Management Systems, 2nd Edition*. American Institute of Chemical Engineers (AIChE), 2011.
- ⁴⁶ Baker, James A., et al. "The Report of the BP U.S. Refineries Independent Safety Review Panel." January 2007.
- ⁴⁷ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Investigation Report: Refinery Fire and Explosion, BP, Texas City, TX, Report No. 2005-04-I-TX*. U.S. CSB, March 2007.

-
- ⁴⁸ Baker, James A., et al. "The Report of the BP U.S. Refineries Independent Safety Review Panel." January 2007.
- ⁴⁹ OSHA 29 CFR 1910.119. "Process Safety Management of Highly Hazardous Chemicals." Occupational Safety and Health Administration (OSHA), [57 FR 23060, June 1, 1992; 61 FR 9227, March 8, 1996; 77 FR 17776, March 26, 2012; 78 FR 9313, Feb 8, 2013].
- ⁵⁰ Cheung, Burch, and Bridges, W. "Process Safety Culture – Making This a Reality." *10th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2014.
- ⁵¹ Bridges, W. "Gains in Getting Near Misses Reported (Updated)." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁵² OSHA 3133. "Process Safety Management Guidelines for Compliance." Occupational Safety and Health Administration (OSHA), 1994.
- ⁵³ Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures, 3rd Edition*. American Institute of Chemical Engineers (AIChE), 2008.
- ⁵⁴ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Interim Investigation Report: Chevron Richmond Refinery Fire*, U.S. CSB, August 6, 2012.
- ⁵⁵ Ibid.
- ⁵⁶ Bridges, W. and Clark, T. "How to Efficiently Perform the Hazard Evaluation (PHA) Required for Non-Routine Modes of Operation (Startup, Shutdown, Online Maintenance)." *7th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2011.
- ⁵⁷ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Interim Investigation Report: Chevron Richmond Refinery Fire*, U.S. CSB, August 6, 2012.
- ⁵⁸ Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures, 3rd Edition*. American Institute of Chemical Engineers (AIChE), 2008.
- ⁵⁹ OSHA Instruction CPL 2-2.45A. (Revised 9/15/1994) "Process Safety Management of Highly Hazardous Chemicals – Compliance Guidelines and Enforcement Procedures." Directorate of Compliance Programs, Occupational Safety and Health Administration (OSHA), September 28, 1992.
- ⁶⁰ Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures, 3rd Edition*. American Institute of Chemical Engineers (AIChE), 2008.
- ⁶¹ Bridges, W. and Clark, T. "How to Efficiently Perform the Hazard Evaluation (PHA) Required for Non-Routine Modes of Operation (Startup, Shutdown, Online Maintenance)." *7th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2011.
- ⁶² OSHA 29 CFR 1910.119. "Process Safety Management of Highly Hazardous Chemicals." Occupational Safety and Health Administration (OSHA), [57 FR 23060, June 1, 1992; 61 FR 9227, March 8, 1996; 77 FR 17776, March 26, 2012; 78 FR 9313, Feb 8, 2013].

-
- ⁶³ U.S. Chemical Safety and Hazard Investigation Board (CSB). *Interim Investigation Report: Chevron Richmond Refinery Fire*, U.S. CSB, August 6, 2012.
- ⁶⁴ Center for Chemical Process Safety (CCPS). *Guidelines for Mechanical Integrity Systems*. American Institute of Chemical Engineers (AIChE), 2006.
- ⁶⁵ Chevron Data Transmittal #89: Attachment 1 Modernization Project Reliability Program, March 11, 2014, http://chevronmodernization.com/wp-content/uploads/2014/03/Trans_090-Update-Post-Aug-6-Safety-Measures-Email1.pdf.
- ⁶⁶ Chevron Data Transmittal #89: Attachment 1 Modernization Project Reliability Program, March 11, 2014, http://chevronmodernization.com/wp-content/uploads/2014/03/Trans_089-Att-1-Modernization-Project-Reliability-Program1.pdf.
- ⁶⁷ Center for Chemical Process Safety (CCPS). *Guidelines for Mechanical Integrity Systems*. American Institute of Chemical Engineers (AIChE), 2006.
- ⁶⁸ Chevron Data Transmittal #90: Attachment 1 Update Post August 6 Safety Measures, March 11, 2014, http://chevronmodernization.com/wp-content/uploads/2014/03/Trans_090-Update-Post-Aug-6-Safety-Measures-Email1.pdf.
- ⁶⁹ Chevron Data Transmittal #90: Attachment 1 Update Post August 6 Safety Measures, March 11, 2014, http://chevronmodernization.com/wp-content/uploads/2014/03/Trans_090-Att-1-Update-Post-August-6-Safety-Measures.pdf.
- ⁷⁰ Ibid.
- ⁷¹ Ibid.
- ⁷² Ibid.
- ⁷³ City of Richmond California, "Chevron Refinery Modernization Project" website, <http://chevronmodernization.com/project-documents/>
- ⁷⁴ Hendrix, David, Chevron Refinery Modernization Project EIR, "Reliability Analysis of Modernization Project Changes" Appendix 4.13-REL (rev 2), March 7, 2014 (https://s3.amazonaws.com/chevron/Appendix_4.13-REL_r2.pdf)
- ⁷⁵ OSHA Directive Number CPL 03-00-004. "Petroleum Refinery Process Safety Management National Emphasis Program, Appendix A, Section I – Human Factors." Occupational Safety and Health Administration (OSHA), June 7, 2007.
- ⁷⁶ Center for Chemical Process Safety (CCPS). *Guidelines for Mechanical Integrity Systems*. American Institute of Chemical Engineers (AIChE), 2006.
- ⁷⁷ US OSHA letter of interpretation from Ruth E. McCully, Director, Office of Health and Compliance Assistance, to Mr. Gerald Joy, ICF Kaiser Engineers, Pittsburgh, PA, Occupational Safety and Health Administration (OSHA), October 11, 1994.
- ⁷⁸ Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁷⁹ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*.

-
- American Institute of Chemical Engineers (AIChE), 2010.
- ⁸⁰ Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁸¹ Tew, R. and Bridges, W. "Human Factors Elements Missing from Process Safety Management (PSM)." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ⁸² Ibid.
- ⁸³ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications*; NUREG/CR-1278. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ⁸⁴ Gertman, D., Blackman, H., Marble, J., Byers, J., and Smith, C. The SPAR-H Human Reliability Analysis Method; NUREG/CR-6883, INL/EXT-05-00509. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research Washington, DC 20555-0001, Idaho National Laboratory, August 2005.
- ⁸⁵ American Petroleum Institute (API), Process Safety Performance Indicators for the Refining and Petrochemical Industries, ANSI/API Recommended Practice 754, API Publishing Services, 1220 L. Street, NW, Washington, D.C. 20005, April 2010.
- ⁸⁶ Ibid.
- ⁸⁷ Bridges, W. "Gains in Getting Near Misses Reported (Updated)." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁸⁸ Center for Chemical Process Safety (CCPS). *Guidelines for Investigating Chemical Process Incidents, 2nd Edition*. American Institute of Chemical Engineers (AIChE), 2003.
- ⁸⁹ Bridges, W. "Gains in Getting Near Misses Reported (Updated)." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁹⁰ Smith, G, Burch, G.D., Bridges, W.G., and Tew, R. "Proven Approach to Investigating Near Misses." *9th Global Congress on Process Safety (GCPS)*. American Institute of Chemical Engineers (AIChE), 2013.
- ⁹¹ Bridges, W. "Gains in Getting Near Misses Reported (Updated)." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ⁹² Ibid.
- ⁹³ Ibid.
- ⁹⁴ Bridges, W. and Williams, T. "Create Effective Safety Procedures and Operating Manuals," Chemical Engineering Progress, American Institute of Chemical Engineers (AIChE), December 1997.
- ⁹⁵ Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American

Institute of Chemical Engineers (AIChE), 2012.

- ⁹⁶ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications; NUREG/CR-1278*. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ⁹⁷ United States Department of Energy. "Guide To Good Practices For Communications," DOE-STD-1031-92 Washington, D.C. 20585, December 1998.
- ⁹⁸ United States Department of Energy. "Guide To Good Practices For Operations Turnover," DOE-STD-1038-93 Washington, D.C. 20585, December 1998.
- ⁹⁹ Bridges, William G. and Collazo-Ramos, Dr. Ginette. "Human Factors and Their Optimization." *8th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2012.
- ¹⁰⁰ Center for Chemical Process Safety (CCPS). *Conduct of Operations and Operational Discipline*. American Institute of Chemical Engineers (AIChE), 2011.
- ¹⁰¹ Swain, A.D. and Guttman, H.E. *The Human Reliability Handbook – with Emphasis on Nuclear Power Plant Applications; NUREG/CR-1278*. U.S. Nuclear Regulatory Commission, Division of Facility Operations, 1983.
- ¹⁰² Gertman, D., Blackman, H., Marble, J., Byers, J., and Smith, C. The SPAR-H Human Reliability Analysis Method; NUREG/CR-6883, INL/EXT-05-00509. U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research Washington, DC 20555-0001, Idaho National Laboratory, August 2005.
- ¹⁰³ Bridges, W (PII) and Thomas, H. (exida) "Accounting for Human Error Probability in SIL Verification Calculations," 8th Global Conference on Process Safety (GCPS), American Institute of Chemical Engineers (AIChE), April 2012.
- ¹⁰⁴ Bridges, W. "LOPA and Human Reliability – Human Errors and Human IPLs." *6th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2010.
- ¹⁰⁵ U.S. Nuclear Regulatory Commission (NRC), 10 CFR Part 55 Operators Licenses, Subpart E Written Examinations and Operating Tests, Washington D.C., July 2012.
- ¹⁰⁶ Cheung, Burch, and Bridges, W. "Process Safety Culture – Making This a Reality." *10th Global Congress for Process Safety Proceeding (GCPS)*. American Institute of Chemical Engineers (AIChE), 2014.
- ¹⁰⁷ Center for Chemical Process Safety (CCPS). *Guidelines for Investigating Chemical Process Incidents, 2nd Edition*. American Institute of Chemical Engineers (AIChE), 2003.
- ¹⁰⁸ Baker, James A., et al. "The Report of the BP U.S. Refineries Independent Safety Review Panel." January 2007.