U.S. Chemical Safety and Hazard Investigation Board

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Hon. Rafael Moure-Eraso
Chairperson

Hon. Mark Griffon
Board Member

November 17, 2012

Via Electronic Mail

Mr. Bill Lindsay
City Manager
City of Richmond
450 Civic Center Plaza, Suite 300
Richmond, CA 94804

Dear Mr. Lindsay:

This letter responds to your request for information concerning the Chevron Richmond Refinery's application for building permits for the replacement of piping involved in the August 6, 2012, fire at the site, which imperiled a number of workers and resulted in more than 15,000 residents seeking medical attention. Specifically, you asked us about Chevron's plan to replace the carbon steel piping that failed with a 9% chromium (9Cr) steel alloy.

It is important to note that the CSB is still investigating the corrosion mechanisms related to the #4 side cut piping failure at the refinery, which precipitated the fire. We anticipate that testing of the failed pipe will be completed in the next several weeks. Although the corrosion mechanism that led to the pipe failure has yet to be identified, sulfidation corrosion is one likely mechanism.[1] Because the CSB's investigative activities are still ongoing we are not currently able to provide any formal recommendations related to the pipe failure or replacement. However, since the parties have asked for guidance and are in the process of making decisions on rebuilding the Chevron #4 Crude Unit, the CSB is providing some preliminary considerations and questions related to these issues.

I would add that Chevron has continued its excellent cooperation with the CSB investigation, and Chevron has further expressed to the CSB its willingness to discuss issues related to piping material selection with the CSB and other parties in the near future.

Traditional arguments for choosing lower-grade or less expensive piping materials have generally suggested that virtually any material can be utilized as long as it is inspected

[1] Chevron has also noted that the observed failure is consistent with sulfidation corrosion; see Chevron's September 26, 2012, "Industry Alert: Richmond Refinery Piping Failure" available at http://richmond.chevron.com/Files/richmond/pdf/IndustryAlertvFinal2.pdf (accessed on November 17, 2012).

often enough to predict and prevent failure.[2] While this argument is perhaps theoretically plausible, the industry continues to experience serious incidents where the inspection program was *not* adequately predicting or preventing piping and equipment failures. At Chevron, the facility had even implemented what could be considered "extraordinary inspection" practices for the 8-inch hydrocarbon line that failed, inspecting it on three separate occasions over the 12 months prior to the fire according to information gathered by the CSB investigative team.

The failure of Chevron's inspection program to avert the failure underscores the importance of using inherently safer materials of construction wherever feasible in the design and construction of highly hazardous chemical processes. In the safety hierarchy of controls, design controls (such as the use of the safest materials) are considered the most robust and reliable, while inspection programs to detect incipient failures – which ultimately rely for success upon an indefinitely sustained series of appropriate human actions – are considered an administrative control and therefore among the least reliable.[3]

Utilizing a more robust material of construction can add a level of inherent safety that would have benefits to the facility, workers, and neighbors. The CSB is currently reviewing the Contra Costa County and Richmond industrial safety ordinance provisions concerning inherently safer systems. We do note, however, that the both the Contra Costa County and the Richmond ordinances have existing language requiring that:

> *For all covered processes, the stationary source shall consider the use of inherently safer systems in the development and analysis of mitigation items resulting from a process hazard analysis and in the design and review of new processes and facilities. The stationary source shall select and implement inherently safer systems to the greatest extent feasible. If a stationary source concludes that an inherently safer system is not feasible, the basis for this conclusion shall be documented in meaningful detail.*[4]

Although the applicability of this language to Chevron's rebuilding of an existing process remains to be clarified, it is the clear intent of this provision to promote use of inherently safer designs and materials to the greatest extent feasible.

A recent serious fire in February 2012 at BP's Cherry Point refinery in Washington State further emphasizes the importance of material selection in refinery piping that is subject to sulfidation corrosion. According to information provided to CSB investigators by the Washington State Department of Labor & Industries, which investigated the fire at BP,

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[2] The CSB has not examined the cost of using 9Cr steel versus other materials for the piping in the Chevron crude unit. Chevron has stated that 9Cr piping does not represent a cost savings compared to stainless steel.

[3] See American National Standard Institute (ANSI), *Occupational Health and Safety Management Systems*, ANSI/AIHA Z10-2005; also Kletz, T., Amyotte, P., *Process Plants: A Handbook for Inherently Safer Design*. CRC Press, 2010.

[4] Richmond Code of Ordinances Chapter 6.43.090 (d)(3); Contra Costa County Ordinance Code, Chapter 450-8.016.

the incident resulted from sulfidation corrosion and the associated catastrophic failure of 9Cr process piping, similar to what Chevron proposes to install in response to the August 2012 crude unit fire, replacing the carbon steel piping that failed. The BP incident occurred in an associated subunit of the refinery's crude unit, and both the process stream and the process conditions were generally similar to those in Chevron's #4 crude unit distillation tower. Photographs of the piping failure at BP, provided by Washington state authorities, show a striking resemblance to the failure at Chevron.

This week the CSB issued a subpoena to Chevron, with a response date of December 7, to obtain more information on the company's decision-making process concerning the replacement of the crude unit piping, including:

- The knowledge Chevron has of the BP Cherry Point sulfidation failure and whether or not that information was used in the proposed selection of 9Cr steel for replacement piping;
- The basis for the proposed plan to utilize 9Cr steel rather than stainless steel piping, which is considered by the American Petroleum Institute's relevant Recommended Practice 939-C to be the most resistant to sulfidation-related failure;
- Any reasons for not utilizing stainless steel to prevent future sulfidation corrosion in piping circuits at the Richmond facility.

In May 2009, the American Petroleum Institute, a prominent industry trade organization which develops widely used safety guidance documents for oil production and refining, published the first edition of its Recommended Practice 939-C, "Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries." Draft versions of the API were previously available to Chevron, and in 2007 Chevron's Energy Technology Company developed an internal document entitled "Guidelines for Preventing Sulfidation Corrosion Failures in Chevron Refining: Comparison of API RP 939-C and Chevron Practice – Rev. 0."[5]

This Chevron document states that the API draft recommended practice was the result of "repeated sulfidation corrosion failures in the refining industry." According to the document, "failures of refinery equipment due to sulfidation can often have severe consequences such as ruptures, blow-outs, and fires." The Chevron document also acknowledges the role of both a high sulfur content and a low silicon content (for carbon steel) in promoting sulfidation corrosion. In a section entitled "Guidelines for New Construction: Materials of construction for high-temperature service," the 2007 document states that 300 series stainless steels are one of the recommended choices because they "virtually eliminate sulfidation corrosion."

The broader industry guidance, as finalized in 2009, contains similar recommendations. API 939-C notes that sulfidation corrosion was first observed in the late 1800s in a crude

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[5] The document was provided to the CSB investigation with Bates numbers CUSA-CSB-0117417 to 0117433.

separation unit, due to the naturally occurring sulfur compounds found in crude oil. When heated for separation, the various fractions in the crude were found to contain sulfur compounds that corroded the steel equipment.[6]

The API notes that the industry relies on graphical curves (the "modified McConomy curves") to predict sulfidation corrosion rates, but due to uncertainties in the data the guidance document acknowledges that the curves can inaccurately forecast the actual corrosion rate by up to a factor of ten. The API states that "despite the industry's best efforts, the accurate prediction of … sulfidation corrosion rate for a specific crude oil and its fractions is an elusive technical challenge" – further supporting the importance of choosing inherently safer materials rather than relying primarily upon inspection and detection of emerging corrosion. The guidance acknowledges that due to global economic factors, refineries may use many different crude stocks in the course of a year, complicating efforts at predicting corrosion rates.

The curves nonetheless highlight the beneficial effect of chromium (a key component of stainless steel[7]) and clearly illustrate that at a given temperature and total sulfur level, steels with decreasing chromium content will experience higher corrosion rates. Thus the predicted sulfidation corrosion rates follow the pattern: 18Cr [stainless] < 9Cr < 5Cr < carbon steel. In fact, the API states that "carbon steels and low-alloy steels up to and including 9Cr-1Mo can be susceptible to H2-free sulfidation corrosion," but 300 series stainless steels "virtually eliminate sulfidation corrosion."[8]

To summarize the main points:

1. Industry consensus standards and guidance as well as the Contra Costa County and Richmond Industrial Safety Ordinances emphasize the importance of using inherently safer designs and materials to the greatest extent feasible to prevent catastrophic chemical incidents.

2. American Petroleum Institute and Chevron guidance documents note that sulfidation corrosion of piping can be prevented by using inherently safe materials of construction i.e. stainless steel that contains 18% chromium. Lower alloy steels containing 9% or less chromium remain susceptible to sulfidation corrosion.

3. The fact that the API Recommended Practice on sulfidation corrosion repeatedly references the use of 300 series stainless steels for piping indicates that the selection and use of the more corrosion resistant alloy is certainly feasible.

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[6] API 939-C is applicable to hydrocarbon process streams containing sulfur compounds, with and without the presence of hydrogen, which operate at temperatures above approximately 450 °F up to about 1,000 °F. Neither the Chevron crude unit nor the BP Cherry Point crude/vacuum unit has added hydrogen and the applicable guidance from API RP 939-C is for non-hydrogen containing service where hydrogen sulfide (H_2S) is present.

[7] 300 series stainless steels typically contain 18% chromium.

[8] American Petroleum Institute, Recommended Practice 939-C, "Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries," First Edition, May 2009, pp. 6, 14.

4. The August 6 fire at the Chevron Richmond Refinery involved a severely thinned section of carbon steel piping in a service where sulfidation corrosion is a known problem.

5. A serious fire in February 2012 at the BP Cherry Point refinery in Washington State involved sulfidation corrosion of 9Cr steel piping that was in similar service conditions as the Chevron pipe.

6. American Petroleum Institute guidance on sulfidation corrosion from 2009 notes that sulfidation corrosion rates are extremely hard to predict, particularly as refineries use differing crude slates in response to market conditions. The difficulty in predicting corrosion rates underscores the need for choosing the safest materials of construction, since inspections based on predicted corrosion rates may not prove to be reliable.

7. Chevron has stated its willingness to discuss the selection of piping materials in the rebuilt crude unit with relevant parties. This letter focuses principally on the issue of preventing sulfidation-related corrosion failures and does not examine other factors or potential failure modes that could influence pipe selection.

Thank you for your ongoing interest in the investigation of the Chevron Richmond Refinery fire and for your concern about chemical safety.

Sincerely,

Rafael Moure-Eraso, Ph.D.
Chairperson

Cc: Mr. Nigel Hearne, Chevron Richmond Refinery
Mr. Mike Smith, United Steelworkers Local 5
Mr. Kim Nibarger, United Steelworkers International Union
Mr. Randy Sawyer, Contra Costa Health Services
Ms. Ellen Widess, CalOSHA
Mr. Jack Broadbent, Bay Area Air Quality Management District
Hon. Jared Blumenfeld, U.S. Environmental Protection Agency