JTF-RH's Response to DOH's April 14, 2023 Electronic Correspondence

1. INTRODUCTION

DOH and EPA RFI's to Navy requested clarification on pipeline pressures, pipeline and structural repairs, and operational parameters required to defuel Red Hill Bulk Fuel Storage Facility (RHBFSF). SGH provided a memorandum addressing these concerns on January 17, 2023 (Ref (a)). JTF-RH responded to DOH and EPA RFI's in a February 2023 letter (Ref (b)).

The information below answers RFI's contained in DOH's April 14, 2023 electronic correspondence (Ref(c)).

2. BACKGROUND

For Red Hill defuel, unsteady flow events characterized as surge that were considered as realistic are identified in two initiator categories.

A. Those caused by a sudden change in valve position (closure)
B. Those caused by the sudden collapse of a cavity of low pressure

2.1. Category B

2.1.1. Assessment Basis

JTF-RH, EEI, and SGH evaluated piping repairs and modifications to ensure safe operation. SGH performed finite element analysis and identified locations of peak stress due to a surge. The analysis used a magnitude [redacted] psi event, which was an estimated pressure the system experienced on 06 May 2021. SGH made recommendations for system repairs based on this analysis and assuming a hypothetical recurrence of the low pressure cavity collapse event. EEI designed pipeline modifications to mitigate a recurrence of a low pressure cavity collapse event.

2.1.2. Risk Mitigation

A low-pressure cavity collapse was the initiator event on 06 May 2021. The basis to mitigate this type of event is to reduce the likelihood of recurrence using a combination of measures. The measures include analog pressure gauges, pressure-indicating transmitters, equalization piping around valves, new high point vent capabilities, and improved operational procedures.

These measures provide redundant pressure indication at the Red Hill Facility. At the start of every defueling operation where the Red Hill pipeline will be introduced to tank head pressure, an equalization procedure to include independent validation will be executed regardless of vacuum condition. Operational procedures will be developed and written to deploy the new capabilities.

New instrumentation, equalization piping, improved operational procedures, and mechanical repairs mitigate the likelihood of a damaging surge initiated by a Category B event.

2.1.3. Approach to Increase Resiliency

JTF-RH concurs with SGH and EEI recommendations. Since the Category B event is mitigated, repairs based on a hypothetical recurrence were not necessary. However, in an abundance of caution and to increase resiliency of the system, JTF-RH implemented SGH and EEI recommendations. Contracts were awarded to execute recommended repairs. The work included new u-bolt restraints, new and improved bracing on pipe supports, new pipe supports, axial restraint on the F-24 and JP-5 mainlines, and new code-compliant blind and flange set on the F-24 mainline. The repairs build additional structural resiliency into the system and do not conflict with mitigation measures. Work to install and execute the mitigation and repair measures is in progress.

2.2. Category A

2.2.1. Assessment Basis

In accordance with industry standards, DoD uses ASME B31.3 Process Piping as the code used to establish design pressure. This is coincident with what API 570 §3.1.58 Piping Inspection Code refers to as maximum allowable working pressure. Based on components of the system, UFC 3-460-01 Table 9-1 limits the maximum allowable working pressure to [redacted] psig. However, ASME B31.3 §302.2.4 allows occasional pressure excursions up to 33% above the system design pressure. For purposes of this document, the pressure excursion allowance contains both basic and occasional load components and is named maximum surge pressure. Most of the Red Hill pipeline systems are consistent with the UFC pressure limitation of [redacted] psig. There is an exception in the pipeline system segment between [redacted]. It was built with stronger materials and has a maximum allowable working pressure of [redacted] psig.

In 2010, EEI modeled steady-state hydraulic and dynamic transient surge conditions and reported safe operating pressure guidelines based on analysis, piping configuration, and operational characteristics. In 2022 EEI performed stress analysis which considered the suitability of pipelines and laterals in the tank farm area for ASME B31.3 load conditions.

In 2023 SGH issued memoranda reporting maximum transient surge loads that can be safely resisted by the Red Hill pipelines during defueling. The bases of the analyses were a previous SGH report from April 2022, the DoD Defueling Plan, and ASME B31.3.

2.3. 2010 Surge Analysis Report

The 2010 EEI report *Hydraulic Analysis and Dynamic Transient Surge Evaluation,* modeled 300 cases of potential events based on many different transfer scenarios, surge initiators, and valve lineups. For each initiator case studied, the model calculated surge pressure at eight piping segments from Red Hill to [redacted] using maximum theoretical flow rates stated in the report. Many model cases report on transfer scenarios or lineups which will not be used for defuel, and initiators which have been eliminated or mitigated.

2.3.1. Findings

A significant finding of the report was butterfly valves (BFV) [redacted] must be used as the primary means of throttling and stopping flow during all issue and transfer operations from Red Hill. Per the extensive hydraulic modeling conducted as part of the study, closure of the BFVs did not induce harmful surge pressures for any operation assessed. Table 1 summarizes the 2010 report findings for Transfer Scenarios 4 (F-24) and 7 (JP-5) which are relevant for defuel. Enclosure 5 (F24) and Enclosure 6 (JP5) are excerpts of the 2010 report.

Table 1 2010 EEI Report Summary

Transfer Scenario	Model Case	Product	Location of Maximum Pressure	Maximum Theoretical Flow Rate (gpm / bph)
4	4e4	F24	[redacted]	[redacted]
7	7e4	JP5	[redacted]	[redacted]

2.3.2. Risk Mitigation

Numerous recommendations from the 2010 report have been implemented into operations or are in the development stage. Examples of recommendations from the report that are in-place or planned by Risktec and FLCPH are below.

A. BFVs have been used to throttle and stop flow for more than ten years

B. Locking motor operated fire valves into open position or hand operation mitigates the risk of rapid closure.

C. Using both inner and outer pipeline loops reduces maximum surge pressure

D. Operations order to include throttle valve stepping amounts for cushioning and shutdown rates

E. Operations order to include using both BFVs prevent single-valve surge and reduce maximum surge pressure

F. Closure speed of the [redacted] inner loop manual ball valve is much longer than modeled

G. Commercial tankers have robust operational procedures and most have pressure relief systems onboard

3. ANALYSIS

3.1. EEI 2022

Stress analysis performed in 2022 found that certain pipeline components in the Red Hill tunnel near [redacted] were overstressed at [redacted] psig. The report recommended not loading the system more than [redacted] psig (basic + occasional loads) near the tank gallery to eliminate the overstress condition. This results in a derated limit to the allowable JP5 working pressure of [redacted] psig (basic load, consistent with UFC 3-460-01). The recommendation was adopted and the JP5 system pressure limitation is identified in Table 2.

In addition the analysis found overstress conditions in several existing pipe supports and at locations which required new pipe supports. Report recommendations were adopted and work to brace and install new pipe supports are in progress.

3.2. SGH

The SGH April 2022 report used a postulated repeat of the 06 May 2021 event as the basis for suggesting a number of repairs to harden the system. Since that time, there have been a number of operational and structural improvements made. SGH analyzed pipeline stress based on the improvements. In a Jan 2023 memorandum SGH reported an intensification of stress in the F24 mainline [redacted]. SGH recommended limiting maximum allowable surge pressure to [redacted] psi (basic + occasional loads). The January 2023 memorandum (Ref(a)) contains more information.

After the January memorandum was issued, further operational and structural improvements were made to the pipeline systems. In May 2023, SGH again analyzed F24 pipeline stress based on system improvements. SGH found the F24 pipeline system can be safely operated with a maximum surge pressure of [redacted] psi (basic + occasional loads). The May 2023 memorandum (Ref(d)) contains more information. This results in a derated limit to the allowable F24 working pressure of [redacted] psig (basic load, consistent with UFC 3-460-01). The recommendation was adopted and the F24 system pressure limitation is identified in Table 2.

Table 2 Facility Allowable Pressure Limitations

Product	Facility Limitation on Allowable Working Pressures		
	Maximum Allowable Working Pressure (Basic, psig)	Maximum Allowable Surge Pressure (Basic + Occasional, psig)	Location of Maximum Allowable Pressure Limitation
JP5	[redacted]	[redacted]	[redacted]
F24	[redacted]	[redacted]	[redacted]

3.3. Brice Risktec

Brice Risktec reviewed the 2010 report model output as part of planning defuel operations for JP-5 and F-24. The defuel plan is to load commercial tankers at [redacted] via gravity flow from Red Hill. Both inner and outer loops from [redacted] will be used. The planned operations correspond to report Transfer Scenarios 4 (F-24) and 7 (JP-5). Numerous operational improvements and mitigations are planned to minimize surge pressures. The Risktec memo updated 16 May 2023 (Ref (e)) contains more information.

3.3.1. Maximum Flow Rates and Operating Pressures

Brice Risktec established maximum defuel flow rates. The basis for the rates is Transfer Scenarios 4 and 7 from the 2010 EEI report, constraints of the facility limitation on allowable pressures, and considering uncertainty in flow measurement. Table 3 identifies the planned maximum flow rates for defuel.

Table 3 Planned Defuel Maximum Flow Rates and Operating Pressures

EEI Model Case	Product	Maximum Defuel Flow Rate (gpm/bph)	Maximum Tank Head Pressure (psig)	Location of Maximum Tank Head Pressure	Maximum Surge Pressure (Basic + Occasional, psig)
7e4	JP5	[redacted]	[redacted]	[redacted]	[redacted]
4e4	F24	[redacted]	[redacted]	[redacted]	[redacted]

4. CONCLUSION

A. SGH has evaluated the structural improvements made to the system and recommends the F24 system allowable pressure be derated near [redacted]

B. EEI has evaluated the structural improvements to the system and recommends the JP5 system allowable pressure be derated near [redacted].

C. Risktec has evaluated the 2010 surge analysis report and the facility limitation on allowable pressures, and reported maximum defuel flow rates which result in operating pressures below allowable.

D. Upon completion of the recommended structural, piping, and operational improvements, JTF-RH believes the system is adequate for defuel based on internal analysis as well as those provided by SGH, EEI and Risktec.

E. JTF-RH revised the Release Event Tree Analysis on May 8, 2023 (Ref(f)).

Memorandum

Date: 17 January 2023

To: Capt. Steve Stasick, US Navy, NAVFAC Joint Task Force, Red Hill

From: [redacted]

CC: [redacted]

Project 221162 – Red Hill Defueling Support, Joint Base Pearl Harbor-Hickam, Honolulu, HI

Subject: Red Hill Fuel Pipelines – Surge Assessment

1. INTRODUCTION

The objective of this memorandum is to present the maximum F-24 pipeline transient surge loads that can be safely resisted by Red Hill pipelines during defueling. Since the JP-5 and F-24 pipelines share common branches, the axial surge loads can be transferred from the F-24 to the JP-5 pipeline. In this study, we investigated how the combined pipeline system responds to transient surge events that may form as a result of sudden valve closures. We used SGH's April 2022 report and the US Navy's defueling plan to determine the key inputs and assumptions for our assessment. We performed pipe stress analysis using TRIFLEX software and also performed a refined finite element analysis using ABAQUS software. We followed ASME B31.3 for our pipe stress analysis.

The outcomes of this study should help the US Navy (Navy) establish operational limits for defueling as well as help prioritize repairs. In this memorandum, we discuss surge loads, present results from our independent surge analysis, and provide recommendations on the limiting surge pressure the pipe system can safely withstand. We also summarize how various pipeline design codes that may be applicable to Red Hill address surge loads and past studies that have evaluated possible surge loads at Red Hill.

We recommend that the Navy determine the maximum flow rates using the maximum surge loads that can be resisted by the pipelines to mitigate potential surge damage. If the flow rates can be kept below these thresholds (to be calculated by others), the axial restraints recommended in our April 2022 report would not be required under the assumption that vacuum formation and related surge events will be mitigated through operational measures. The presentation that we gave the defueling team on 12 January 2023 is provided in the appendix to this memorandum.

2. LITERATURE

Transient surge loads are discussed in several pipeline design and analysis codes and standards. In this section, we provide a summary of surge load provisions in applicable industry standards and guidelines. Although these consensus standards and guideline documents have different provisions for the assessment of piping systems, they all require some type of surge assessment to qualify piping and supports against transient surge loads.

2.1 UFC 3-460-01 Change 2 (January 2022)

The Unified Facilities Criteria (UFC 3-460-01) for the design of petroleum fuel facilities stipulates that “all installation pipelines must be designed in accordance with ASME B31.3.” This code also stipulates that “interstate interterminal pipelines must be designed in accordance with ASME B31.4.”

Installation pipelines are defined as “pipelines which connect POL facilities within an installation such as a barge pier to a bulk facility and a bulk facility to an operating (ready-issue) tank. These pipelines do not cross property lines…”

Interterminal pipelines are defined as “pipelines which connect two government installations such as a Defense Energy Supply Center depot to a military installation. These pipelines cross property lines and cross public and/or private properties, streets, highways, railroads, and utility rights-of-way.”

2.2 ASME B31.3

Analysis of process piping is based on ASME B31.3, per UFC 3-460-01 (Revision Date 01-12-2022). We used the 2016 version of ASME B31.3 for our analyses. Section 302.3.6 states that for load combinations that include occasional loads, such as wind, earthquake, or transient surge loads, the sum of the longitudinal stresses is allowed to be as much as 1.33 times the Basic Allowable Stress given in Table A-1 of Appendix A. For ASTM A53 Grade B pipe, at 100°C, the Basic Allowable Stress is [redacted] ksi. Therefore, for load combinations, including surge conditions, the code allows the sum of the longitudinal stresses to be [redacted] ksi.

We note that ASME responded to a user question on accommodating loads due to pressure surges and published their response on the ASME website. They specifically direct users to Section 302.3.6 for increasing the allowable stress due to occasional loads (*Figure 1*). It is critical to note that this interpretation detail is related to longitudinal pipe stresses due to unbalanced loads from pressure surges, such as that can be experienced at a pipe termination (blind flange location) that is subject to pressure and movement in the axial direction.

Interpretation Detail

Standard Designation: B31.3
Edition/Addenda:
Para./Fig./Table No:
Subject Description: Loads Due to Pressure Surges
Date Issued: 09/08/1981
Record Nu ber:
Interpretation Nu ber : 1-50
Question(s) and Reply(ies): Question: How shall longitudinal piping stresses due to unbalanced loads from pressure surges which result in anchor displacements be evaluated in B31.3?

Reply: Loads due to pressure surges are considered as primary loads, and longitudinal stress limits must comply with 302.3.3(c) for sustained loads or 302.3.6 for occasional loads. Pressure temperature limits of 302.2 must also be met.

Figure 1 – ASME's Interpretation Detail Related to Accounting for Surge Pressure Loads as Occasional Loads

We further note that ASME provided clarification that surges are considered occasional loads and should be considered in the assessment of longitudinal stresses (Figure 2). They direct the user to Section 302.2.4. This states in Subsection (f)(a) that it is permissible to exceed the pressure rating or allowable stress by 33% for pressure design, provided the owner approves, and the duration is no more than 10 hrs at any one time and no more than 100 hrs/yr.

Interpretation Detail

Standard Designation: B31.3

Edition/Addenda:

Para./Fig./Table No:

Subject Description: B31.3 1999 Edition (2001 Addenda), Paragraph 302.3.6, Limits of Calculated Stress Due to Occasional Loads

Date Issued: 07/01/2002

Record Number:

Interpretation Number : 19-18

Question(s) and Reply(ies): Question: Does paragraph 302.3.6(a) include occasional internal pressure loads, (e. g. surges, spikes, peaks, and water hammer) in the summation of longitudinal stresses due to sustained and occasional loads?

Reply: Yes. In addition, all pressure variations) must also meet the requirements of paragraph 302.2.4.

Figure 2 – ASME's Interpretation Detail Related to Surge Loads Classified as Occasional Loads

2.3 ASME B31.4

Analyses of fuel transfer pipelines were based on the 2012 version of ASME B31.4 in our April 2022 report. We understand that the Navy considers ASME B31.3 as the applicable code for Red Hill pipelines, but it is worthwhile to note that surge loads are discussed in several sections of this widely-used code.

- Section 401.1.5 lists surge loads as one of the transient load cases that may occur during the operation of the pipeline.
- Section 401.2.2.2 notes that "pressure rise above maximum steady state operating pressure due to surges and other variations from normal operations is allowed in accordance with paragraph 403.3.4."
- Section 401.3 states that the most critical combination of applicable load cases, including "transient loads that can be expected to occur, shall be considered."
- Section 403.3.4 provides the criteria for transient overpressure: "Transient overpressure includes pressure rise due to surge. Surge pressures in a liquid pipeline are produced by a change in the velocity of the moving fluid that results from shutting down a pump station or pumping unit, closing a valve, or blockage of the moving fluid.

> Surge calculations should be made, and adequate controls and protective equipment shall be provided so that the pressure rise due to surges and other variations from normal operations shall not exceed the internal design pressure at any point in the piping system and equipment by more than 10%."

ASME B31.4 provides allowable stresses and load combinations for pipelines but does not provide guidelines on the calculation of transient surge loads. Although the allowable stresses in ASME B31.4 are different from those in ASME 31.3, the general requirements are similar.

2.4 Energy Institue Guidelines for the Avoidance of Vibration-Induced Fatigue Failure in Process Pipework

The Energy Institute (EI) is an industry organization based in the UK. They developed this document as part of a Joint Industry Project (JIP) in collaboration with the regulatory agency in the UK. Several major oil and gas companies, certification agencies, and service providers participated in this JIP. The guidance document covers new design, assessment of existing plants, and addressing potential problems that have been identified in an operating system using a staged approach. Both qualitative and quantitative risk assessment methods are provided for a range of excitation mechanisms, including flow-induced vibration and transient surge events. The following are direct quotes that are of interest:

- "Surge (or water hammer, as it is commonly known) is a pressure wave caused by the kinetic energy of a fluid in motion when it is forced to stop or change direction suddenly. If the pipe is suddenly closed at the outlet (downstream), a pressure wave is generated, which travels back upstream at the speed of sound in the liquid. This can give rise to high levels of transient pressure and associated forces acting on the pipework.

  High transient forces can also be generated by the rapid change in fluid momentum caused by the sudden opening or closing of a valve, e.g., fast operating of a relief valve."

- "Predictive techniques can provide a further level of quantification of excitation and response levels and can be used to explore potential modifications. Examples include structural and acoustic finite element analysis, pulsation and surge simulation, and computational fluid dynamics (CFD)."

- "Fast closure of a valve on a liquid system may generate excessive surge pressures which can generate high levels of transient vibration and/or exceed the flange rating of the pipe."

Section T2.8 of the EI guidelines provides the steps for the assessment of surge/momentum changes due to valve operation. The equation to calculate peak forces due to valve closure and the equation to get the likelihood of failure are provided in this section. The peak force is proportional to the flow rate and correlated to valve closure time and fluid density.

Section T10.8 provides guidelines to mitigate surge loads. For mainline excitation, change in operation is stated as an effective option. It is also noted that "the resulting forces on the pipework caused by the pressure wave (or surge) traveling back upstream from the closing valve can be reduced by either reducing the mean fluid velocity or slowing down the time taken to close the valve." Furthermore, "the effect of rapid changes in fluid momentum caused by a transient flow can be reduced by minimizing the number of bends in a system and the use of long radius bends. This will result in less energy being transmitted from the fluid to the pipework."

EI guidelines recommend using advanced predictor techniques (i.e., finite element and CFD analyses) for the calculation of surge loads in complex and long pipeline segments. The empirical equations are not applicable for pipelines longer than 328 ft (100 m).

3. PREVIOUS STUDIES

The Red Hill facility has a history of transient surge loads. Several studies have been performed by contractors to estimate the surge pressures and their effects on the integrity of the pipelines.

3.1 2000 DESP Pearl Harbor Hydraulic Surge Analysis Study 32 in. DFM

We reviewed the October 2000 "DESP Pearl Harbor Hydraulic Surge Analysis Study 32" DFM" report by Enterprise Engineering Inc. (EEI) and observed that they established the maximum allowable working pressure (MAWP) for the three pipelines using an analytical approach.

- [redacted] F-76 Pipeline: [redacted] psi
- [redacted] JP-5 Pipeline: [redacted] psi
- [redacted] JP-8 Pipeline: [redacted] psi

Gravity fuel issue from Red Hill to Hotel Pier was noted to be limited by the capacity of the [redacted], not the [redacted] system constraints or resistances. The maximum capacity of the [redacted] is approximately [redacted] gal per minute (gpm) or approximately [redacted] barrels per hour (bph).

According to this report, the most severe surge is not caused by the double block and bleed (DBB) valves (fire valves) but by the non-DBB valves such as gate, ball, and butterfly valves.

The 2000 surge analysis included the following recommendations:

1. Establish a maximum fuel flow rate for fuel Issues to [redacted].

2. Adjust valve travel time to accommodate the piping MAWP and fuel flow rate.

3. Review the facility's operational procedures to minimize piping surges due to hydraulic shock.

4. Install ASME-certified relief valves on the piping system with pressure settings that correspond to the MAWP.

3.2 2010 Hydraulic Analysis and Dynamic Transient Surge Evaluation

We reviewed the September 2010 Hydraulic Analysis and Dynamic Transient Surge Evaluation report by EEI and conclude that this report provides valuable information for the worst-case operational scenario. The report indicates that if the Red Hill defueling operation is conducted at a lower flow rate than the maximum flow rate possible, the potential for the transient surge is reduced to levels that are within the design margin of the current piping system.

The intent of the EEI surge evaluation report was to provide a hydraulic analysis and dynamic transient surge evaluation of Pearl Harbor's fuel handling infrastructure and determine the potential risks of damage to the piping due to hydraulic surge. In addition, EEI was asked to provide a Maximum Allowable Operating Pressure (MAOP) evaluation based on the hydraulic and surge evaluation and provide recommendations for future pressure testing. This additional evaluation highlighted that at each tank, the double block and bleed valves are [redacted], which governs the MAOP within Red Hill. For testing, they recommended strength testing the Red Hill pipelines to [redacted] psi and leak testing to [redacted] psi.

The key points noted in this 2010 surge analysis report are summarized below.

1. The hydraulic analysis and dynamic transient surge evaluation assume that each fuel tank is full (highest fuel head) and that the gravity flow rate is at a maximum value (i.e., all valves are 100% open).

2. If the fuel system is permitted to operate at its full flow potential, there is a substantial risk of very high surge pressures, which could potentially damage the system to the point of failure. The pressures modeled at these high flow rates have a moderate risk of causing piping failure either in the Red Hill or Lower Yard Tunnels or on the piers.

3. Facility personnel is currently limiting the flow rate while issuing to the piers (generally governed by the pressure/receipt rate dictated by the receiving vessel). This reduction

in flow rate (below maximum potential) often (though not always) reduces the associated surge potential to within allowable limits, making the associated risk of piping failure much lower.

3.2.1 Worst Case Analysis versus Typical Operational Recommendations

EEI observed that the pier riser valves were being used to throttle the fuel flow, and if these valves were to be closed, there was a high risk of a transient high-pressure surge occurring. EEI stated that for nearly all issue/transfer operations from the Red Hill tanks, the valves with the least potential to cause surges are the motor-operated butterfly valves (T-Valves) in the UGPH, and therefore, EEI recommended that these T-Valves should be used for all flow-control throttling. They also recommended that these T-Valves should be used for stopping the flow at the end of each operation from Red Hill.

3.2.2 JP-5 Pipeline

EEI provided specific analysis for the JP-5 piping system and concluded the following regarding transient surges:

1. During full-flow issue operations, [redacted], closure of the [redacted] has the potential to generate high surge pressures when flowing through [redacted]. One of the [redacted] closes significantly faster than the rest, creating a high potential for the surge.

2. The [redacted], where both [redacted] close in a little over 3 min., has no concerns with respect to surge pressures.

3. Full closure of the [redacted] generally appears to create the lowest surge pressure of any potential initiator and, therefore, should be used as the primary means of throttling and stopping flow during operations.

4. Closure of the [redacted], and closure of [redacted], during full flow from Red Hill [redacted] can create high surge pressures throughout the piping system [redacted].

EEI recommended the following operational control options that support the safe defueling of the JP-5 pipeline:

1. Limit issue rates to [redacted] bph (this is the current normal issue rate per field observations).

2. Use the [redacted] to throttle the fuel flow.

3. Use the [redacted] JP-5 piping system for defueling.

Reducing the flow rate to between [redacted] bph for JP-5 issues at [redacted] from Red Hill (today's normal issue rate per field observations) reduces the potential surge pressures to within acceptable limits. (Note: the recommended reduced flow rate of [redacted] bph to [redacted] is approximately 62% to 68% of the analyzed JP-5 flow rate of [redacted] bph from the 2010 EEI surge analysis on P. 328 of 444 in Appendix D of the report.)

3.2.3 F-24 Pipeline

EEI provided specific analysis for the F-24 pipeline system (called JP-8 in the report) and concluded the following regarding transient surge:

1. During full-flow issue operations, [redacted] to [redacted], closure of the [redacted] has the potential to generate surge pressures as high as [redacted] psi.

2. Closure of the [redacted], even at full flow, does not generate surge pressures above the allowable pressure for a fully qualified [redacted] line. This valve should be used as the primary throttling and/or operation-stopping valve.

3. Closure of the [redacted], [redacted], and [redacted] during full-flow issue operations [redacted] to [redacted] has the potential to create damaging levels of pressure throughout the piping system.

EEI recommended the following options that support the safe defueling of the F-24 Pipeline:

1. Limit fuel issue rates (recommended flow rate was not provided).

2. Use the [redacted] to throttle the fuel flow.

EEI did not calculate a recommended flow rate that would result in transient surge events within acceptable limits. However, based on the EEI recommended reduced flow rates for the F-76 and JP-5 lines, the F-24 defueling rate should not exceed 50% of the analyzed flow rate of [redacted] bph on P. 346 of 444 in Appendix D.

3.3 April 2022 SGH Analysis

SGH performed an independent assessment of the Red Hill fuel pipelines using the surge pressure estimated in the root cause analysis (RCA) report for the 6 May 2021 event (Root

Cause Analysis of the JP-5 Pipeline Damage – 7 September 2021). To the best of our knowledge, SGH's previous study may have been the only documented study where the response of the pipelines and supports to axial transient surge loads was checked. In our study, we used a transient surge pressure of [redacted] psi, assuming a surge event similar to that discussed in the RCA report. This pressure was the result of the collapse of a vacuum and exceeded the MAOP of the pipelines, but it was lower than many of the surge pressures estimated in EEI's surge analysis reports from 2000 and 2010. Our analysis indicated that the pipelines and supports might be overstressed and fail if they are again subjected to surge pressures similar to the 6 May 2021 event. Therefore, we recommended several axial and lateral restraints to transfer the surge loads from the pipelines to supports and foundation elements. We showed that the addition of restraints can reduce the pipeline stresses to within acceptable limits.

4. SURGE RESPONSE ASSESSMENT

We understand that operational improvements and some design changes were made at the facility. These changes are expected to reduce the risk of vacuum-related transient surge pressures. However, the pipelines can still be exposed to surge loads due to valve closures, as highlighted in the 2010 EEI surge analysis report. Although surge pressures due to valve closure can be mitigated or reduced through operational controls, we believe that the maximum surge pressures that can be resisted by the pipelines and supports can be established quantitatively. Our further assessment considers the effect of surge pressures on hoop stresses and axial stresses due to the reflection of a surge pressure wave at the blocked end of pipelines (i.e., at a blind flange).

4.1 Pipe Stress Analysis and Code Check Methodology

For our further analysis to consider the effect of surge pressures, we developed several pipeline stress analysis models for the F-24 and JP-5 fuel lines, as outlined in our memorandum of 7 December 2022. The following general defueling assumptions were provided by the fuels group:

1. The F-76 line will be abandoned in place (i.e., no repairs will be completed) down to the fire valves, and the F-76 product will be rerouted to the JP-5 line.

2. [redacted] (containing F-76) will be defueled using the JP-5 line.

3. The skillets between [redacted] will be removed, and the F-24 trunkline will be filled with product to the blind flange near [redacted]

4. The F-24 line will be cut above the lower skillet [redacted] and a pressure-rated blind flange will be installed. The F-24 trunkline will be reconnected immediately upstream of the new blind flange.

5. JP-5 tanks ([redacted]) will be defueled via the JP-5 line.

6. F-24 tanks ([redacted]) will be defueled via the F-24 line.

7. Defects will be addressed as per the Consolidated Repair List to increase the MAOP of the JP-5 and F-24 lines.

Note that only one of Assumptions 3 and 4 in the above list will be performed, and these assumptions (3 and 4) are under final consideration by the Navy. Therefore, we assessed different pipeline configurations in our models based on whether Assumption 3 or Assumption 4 will be in effect.

Our analyses aim to ascertain the pressure limits of the F-24 and JP-5 fuel lines when subject to transient loads. We represent a potential transient load as a force applied at discrete blind flanges in the pipeline system and back-calculate the corresponding pressure that results in a demand-to-capacity (DCR) ratio of 1.0 anywhere in the analyzed fuel pipelines. A DCR of 1.0 indicates that the maximum stress induced in the pipeline system by the applied loading (due to the operating loads of gravity, temperature, and pressure) equals the code allowable stress. It does not represent pipeline failure.

At all pipeline segments where the F-24 and the JP-5 pipelines run parallel, they are tied together at each tank lateral via double tee risers, the exception being at [redacted], which only have F-24 and F-76 pipeline connectivity. We analyzed the pipeline system in the tank gallery specifically because of the 2021 spill history and the propensity for pressure surges to occur.

We used the TRIFLEX and ABAQUS software packages for our pipe stress analysis, which are discussed in more detail in the following sections. Our models represent discrete sections of the fuel system, defined at specific tanks, between tanks and concrete anchor block supports, and represent variations in potential fuel line packing scenarios. We developed the following three pipe stress analysis models:

1. Model 1: Pipeline segments from the concrete anchor downstream of [redacted] to the concrete anchor upstream of [redacted], including the trunklines and laterals at [redacted].

2. Model 2: Pipeline segments at [redacted], modeled between the concrete anchor downstream of [redacted] and the concrete anchor upstream of [redacted]

3. Models 3 and 4: Pipeline segments between [redacted] and [redacted] (the end of the F-24 line), modeled between the concrete anchor downstream of [redacted] and the concrete wall upstream of [redacted].

In our first model (Figure 3), we assess whether a transient surge pressure may impact the pipeline laterals in the [redacted] galleries. In our April 2022 report, we found that a [redacted] psi surge load occurring at the closed ball valve at the [redacted] lateral overstressed the pipeline due to the piping bends. The pipe stress analysis presented in this memo estimates the maximum allowable surge force if a surge occurred at this closed ball valve at the [redacted] lateral.

[redacted]

Figure 3 – Stress Analysis Model of Pipelines by [redacted]

Our second model (Figure 4) evaluates the pipeline performance for the representative tank laterals at [redacted], where the smaller and larger pipelines are tied together. Although the F-76 pipeline will not be used for defueling, at some laterals, it is tied into the F-24 and JP-5 lateral lines and is part of the load path for the other two fuel lines. We have two variations for this second model, each representing an alternative location of impact for the transient load on either the closed ball valve on the small diameter pipe at [redacted]

[redacted]

Figure 4 – Stress Analysis Models of Pipelines by [redacted]

Our final model (Figure 5) evaluates the response of the entire F-24 fuel line between [redacted] and [redacted], considering whether Assumptions 3 or 4 described previously are in effect. In this case, the transient load is either applied to the new blind flange upstream of [redacted] or applied at the blind flange at [redacted]

We used a friction coefficient of 0.3 in the pipe stress analysis models.

[redacted]

Figure 5 – Entire F-24 Pipeline Stress Analysis Model

We used TRIFLEX for our pipe stress analyses and ASME B31.3 code checks. Additionally, we performed detailed analyses using ABAQUS to corroborate our TRIFLEX results. We developed local models in ABAQUS, which required axial spring stiffnesses of the entire F-24 line from the TRIFLEX model to simulate the boundary conditions of the local models. Three-dimensional (3D) modeling and analysis capabilities of ABAQUS are better able to capture local stress concentrations in the pipe joints and can more accurately predict local stresses compared to pipe stress analysis software with one-dimensional pipe elements.

4.1.1 Detailed Finite Element Analysis

The objective of this analysis is to develop a detailed finite element (FE) model that can capture the stress intensification effects and pipeline nonlinearity to determine more accurate allowable surge pressures at the header of the F-24 line at [redacted] or at the new pressure rated blind flange at [redacted].

ABAQUS is a general-purpose, nonlinear FE analysis software developed by Dassault Systems. It contains a wide range of one-dimensional, planar (two-dimensional), and solid (three-dimensional) elements with the capability to incorporate nonlinear geometric and material properties to simulate structural responses under various loading scenarios. ABAQUS is widely used to perform complex analyses of civil, structural, and mechanical systems in critical applications, including in the aerospace, nuclear, and petroleum industries.

4.1.1.1 Analysis Model for the F-24 Pipeline at [redacted]

Figure 6 shows the ABAQUS FE model used to simulate the structural response under a surge load at the header of the F-24 line at the new pressure-rated blind flange, which would be installed at the present location of the downstream skillet near [redacted]. This analysis model is based on Assumption 4 in Section 4.1 being implemented, i.e., that the skillet near [redacted] will be replaced with a pressure-rated blind flange, and the F-24 trunkline will be reconnected immediately upstream of the new blind flange.

The two axial spring stiffnesses of [redacted] kips/in. and [redacted] kips/in., as shown in Figure 6, were obtained from our TRIFLEX global pipe stress analysis model and are used as boundary conditions (BC) in our models. These springs represent the segments of the F-24 line not explicitly modeled.

Shell elements were used in the tee connection region (to capture the stress intensification effects), and beam/pipe elements were used beyond the highly stressed tee connection region.

Gravity loads, a temperature gradient, and internal pressure were applied prior to the application of the surge pressure.

[redacted]

Figure 6 – ABAQUS FE Model for the F-24 Pipeline at [redacted] (with Lower Skillet Replaced by a Pressure-Rated Blind Flange and the F-24 Line Reconnected Immediately Upstream)

4.1.1.2 Analysis Model for the F-24 Pipeline at [redacted]

Figure 7 shows the ABAQUS FE model used to simulate the structural response under surge load at the header of the F-24 line at [redacted]. This analysis model is based on the assumptions that 1) the skillet near [redacted] will be removed but will not be replaced with a pressure-rated blind flange, and 2) additional axial restraint will not be provided. In this case, only one spring boundary condition is needed to simulate the presence of the F-24 line downstream of the pipe anchor on the JP-5 line.

[redacted]

Figure 7 – ABAQUS FE Model for the F-24 Pipeline at [redacted]

The pipe anchor of the JP-5 pipeline was modeled as a “pinned” boundary condition. An axial spring stiffness of [redacted] kips/in was used for the F-24 line near the pipe anchor location to represent the F-24 line not explicitly modeled downstream of this location. The axial spring stiffness was obtained from our TRIFLEX pipe stress analysis model. The lateral connections to [redacted] were modeled with “fixed” boundary conditions.

4.2 Load Cases and Combinations

The pipeline load cases include dead, thermal, operating, and transient loads based on ASME B31.3 (Process Piping) and ASME B31.4 (Transfer Pipelines). Dead loads consider the weight of the pipe and the weight of the contents. Thermal loads consider a [redacted] F delta (see SGH Memorandum dated 30 November 2022), and operating pressures consider an [redacted] psi pressure representing the pressure from a full head in the tanks. Transient loads are iteratively determined to back-calculate a DCR of 1.0 in the analyzed pipelines.

4.3 Material Properties

In May 2000, Pond C/M engaged Finaly Testing Laboratories, Inc., to conduct tensile testing of coupon samples from the Red Hill fuel pipelines ([redacted]). This testing was part of addressing emergent repairs highlighted in a Thermal Engineering Corporation (TEC) November 1999 report (PRL 93-9 and 93-10 Repair Red Hill Tunnel Pipelines FISC Peral

Harbor, Hawaii, Amendment No. 16). Finaly tested ten coupons per pipeline size, with yield strength averages of [redacted] psi, [redacted] psi, and [redacted] psi for the [redacted]. fuel pipelines, respectively. In August 2000, Engineering Design Group, Inc., and Dmitrijev & Associates issued a Final Inspection and Construction Report (SPAWAR Contract No. 65236-01-D-7827 DO No. 001) for the emergent repairs. In this report, minimum yield strengths for the pipelines are specified as the Finaly test averages modified according to ASME B31.4 437.6.7 (using a 0.8 factor) [redacted]

In 2019, EEI clarified assumptions in the Engineering Design Group, Inc., and Dmitrijev & Associates' August 2000 report, updating minimum yield strengths for the [redacted]. pipelines. Through destructive testing, EEI determined that ASTM A53 Grade B piping was a reasonable approximation for future analytical assessments.

In EEI's subsequent analyses (Pipeline Stress Analysis and Structural Evaluation Report – Red Hill Lower Access Tunnel 2022), they used ASTM A53 Grade B material properties for all pipelines in the Red Hill tunnels. The analysis presented in this memorandum uses material properties consistent with EEI's material type determination.

We note that the ASTM A53 Grade B material characteristics are slightly less conservative than using the ASME B31.4 modified Finaly test data as the yield strength for the [redacted] pipeline (F-76 fuel line). However, in our April 2022 Report, we compared the analysis results for the [redacted] pipeline using the two different material characteristics described above and found that the performance of the pipeline was not altered. Although the [redacted] pipeline will not be used for defueling the F-76 fuel, it is tied into the F-24 and the JP-5 fuel lines at some locations, and therefore, for the analysis presented in this memorandum, we find that the use of ASTM A53 Grade B is acceptable.

We take the F-24 specific gravity as 0.84 in the TRIFLEX and ABAQUS models. For the ABAQUS model, we used elastic, perfectly plastic material models for ASTM A53 Grade B steel, typical for the nonlinear analysis of carbon steel pipes.

4.4 Maximum Allowable Pressure Rating

EEI April 2016 Inspection and Repair of Red Hill Pipelines Report notes the locations of both ANSI Class 150 and Class 300 carbon steel flanges in the Red Hill tunnels. ASME B16.5 for Pipe Flanges and Flanged Fittings lists ANSI Class 150 carbon steel pipe (ASTM A105 steel with a yield strength of [redacted] ksi) as having a pressure rating of [redacted] psi for temperatures under 100°F. This is in accordance with UFC-3-460 Table 9-1 "Allowable Pressure Table – ANSI Class 150 Flanged Joints." The pressure rating of flanges may exceed the pressure rating of pipelines due to section loss and other factors. We understand that the pressure rating of pipelines will be increased through the implementation of consolidated repairs.

4.5 Geometry

Analysis inputs related to the layout of the Red Hill pipelines were determined from reviewed documents and our measurements at the site.

4.6 Corrosion and Defect Allowance

We did not consider defects affecting the capacity of the pipelines and supports. Instead, we assumed that any deficient parts of the system would be repaired prior to defueling the Red Hill tanks, as per our April recommendations and the consolidated repair/enhancement list compiled on 24 October 2022 by the Navy's Red Hill Joint Task Force.

4.7 Flexibility and Stress Intensification Factors

We considered flexibility and stress intensification factors (SIFs) where necessary in our pipe stress analysis. The software TRIFLEX applied code-specific flexibility and SIF values to bends and branch connections in accordance with ASME B31.3. The branch connections at the tees consist of unreinforced fabricated tees at the header pipe riser and welded tees at the lateral pipe branch. The unreinforced tees have high SIF values calculated up to a factor of [redacted] Our analysis results, as discussed in Section 5, indicate the SIF values contribute to high stress at the unreinforced tee locations (pipeline riser at the base of the tee connection).

SIF values are dependent on the fabrication method for the pipe bends and branch connections. SIFs are used for the analysis of piping components and assemblies under service loads and fatigue conditions.

5. PIPE STRESS ANALYSIS RESULTS

5.1 TRIFLEX Analysis Results

In the following sections, we present our pipe stress analysis results from TRIFLEX for the three models described in Section 4.1.

5.1.1 [redacted] Piping Laterals

Our April 2022 report highlighted the pipe lateral at [redacted] that was overstressed by about 30% from a [redacted] psi surge pressure due to the presence of the piping bend. We re-evaluated this piping segment to determine the maximum allowable transient surge force it could withstand during defueling. Figure 8 below shows the model geometry of the piping laterals at [redacted].

[redacted]

Figure 8 – [redacted] JP-5 Pipeline Stress Analysis Model

We found that applying a surge force of [redacted] lb (corresponding to a surge pressure of [redacted] psi) based on the lateral pipe diameter of [redacted] together with concurrent service loads, results in stresses approximately equal to the [redacted] for occasional loads (Section 2.2). Figure 9 below shows the maximum stress located in the piping bend.

[redacted]

Figure 9 – JP-5 Pipeline Stress Contours for Tanks [redacted] – Surge Load at [redacted]

5.1.2 [redacted] Piping Laterals

The current piping configuration at the [redacted] laterals (Figure 10) could be overstressed due to the bends in the laterals. We evaluated this configuration for surge loads acting separately at the [redacted] laterals.

[redacted]

Figure 10 – [redacted] Pipeline Stress Analysis Model

We found that a [redacted] lb surge load (corresponding to a surge pressure of [redacted] psi) acting on the small diameter pipe ball valve towards [redacted], together with concurrent operating loads, results in stresses approximately equal to the [redacted]. Figure 11 below shows the location of maximum stress at the location [redacted]

[redacted]

Figure 11 – [redacted] Pipeline Model – [redacted] Side Stress Contours

The second model, where the surge force acts on the small diameter pipe ball valve towards the [redacted] side, has similar results. Applying a surge load of [redacted] lb ([redacted] psi), together with concurrent operational loads, results in stresses approximately equal to the [redacted] Figure 12 below shows the location of maximum stress at the location where [redacted]

[redacted]

Figure 12 – [redacted] Pipeline Model – [redacted] Side Stress Contours

5.1.3 F-24 Pipeline [redacted]

Our April 2022 analysis indicated that a high surge load acting along the F-24 header subjects the F-24 pipeline riser at the base of the tee connection to overstress. We modeled the entire F-24 line to account for the additional stiffness from the laterals (Figure 5). The following sections discuss the two analyses we performed to determine the maximum allowable surge forces in the F-24 pipeline: 1) a blind flange is installed near [redacted] with the upstream portion of the F-24 line reconnected, and 2) a blind flange is not installed near [redacted], and the F-24 line is filled with the product up to [redacted].

5.1.3.1 Updated Results Based on Defueling Assumptions

Based on the defueling assumptions for the F-24 lines as listed in Section 4.1 (Assumptions 3 or 4), we performed a confirmatory analysis to evaluate the response due to transient surge pressure in the longitudinal direction if additional axial restraints are not installed. Figure 13 below shows the geometry of the F-24 pipeline model near [redacted].

[redacted]

Figure 13 – F-24 Pipeline with Blind Flange Installed Near [redacted]
(and F-24 Line Reconnected Immediately Upstream)

We found that a surge load of [redacted] lb ([redacted] psi surge pressure) applied at the new pressure-rated blind flange just upstream of [redacted], together with concurrent operational loads, results in stresses approximately equal to [redacted] for occasional loads. Our results indicate that the pipeline joint at [redacted] experiences the maximum stress. Figure 14 below shows a line rendering of the JP-5 [redacted] where maximum stress occurs.

[redacted]

Figure 14 – Stress Contours for the F-24 Pipeline with Blind Flange Installed Near [redacted]

5.1.3.2 Updated Results in the Event the Blind Flange on the F-24 Header Near [redacted] Is Not Installed Prior to Defueling

If the blind flange near [redacted] will not be installed prior to defueling, we assumed that the non-pressure resisting skillets will be removed, and the F-24 line will be filled with fuel up to the end of the F-24 header near [redacted]. We analyzed the maximum allowable transient surge force for the F-24 line for the case without any additional axial restraints.

[redacted]

Figure 15 – F-24 Line End of Header ([redacted]) if the Blind Flange Is Not Installed Near [redacted]

We found that a surge load of [redacted] lb ([redacted] psi surge pressure) applied at the header of the F-24 line at [redacted], together with concurrent operational loads, results in stress approximately equal to [redacted] for occasional loads. Similar to the analysis with a blind flange installed near [redacted], our results indicate that the [redacted] experiences the maximum stress. Figure 16 below shows a line rendering of the JP-5 [redacted] where the maximum stress occurs.

[redacted]

Figure 16 – F-24 Line Near [redacted] with the Blind Flange not Installed Near [redacted] Stress Contours

5.2 Detailed FE Analysis Results using ABAQUS

5.2.1.1 Analysis Results for the F-24 Pipeline at [redacted] When a New Blind Flange is Installed at the Lower Skillet Location at [redacted]

With an applied surge load at the header of the F-24 line at [redacted], the maximum stress occurs at the [redacted] due to stress intensification effects. The analysis results can be summarized as follows:

- To limit the stress in the model within the allowable stress of [redacted] ksi, the maximum allowable surge pressure at the header of the F-24 line at [redacted] is approximately [redacted] psi (Figure 17).

- To limit the stress in the model within the elastic range (less than [redacted] ksi), the maximum allowable surge pressure at the header of the F-24 line at [redacted] is approximately [redacted] psi (Figure 18). The pipeline system would still maintain its integrity during the defueling process if the surge pressure at the header of the F-24 line at [redacted] is kept to less than [redacted] psi.

- Therefore, it appears that additional axial restraint is not required at this location of the F-24 line if the lower skillet near [redacted] is replaced with a pressure-rated blind flange and the pipeline is reconnected immediately upstream of the new blind flange.

[redacted]

Figure 17 – Stress Contours at Surge Pressure of [redacted] psi (Blind Flange Installed at [redacted])

[redacted]

Figure 18 – Stress Contours for a Surge Pressure of [redacted] psi Just Before First Yield (Blind Flange Installed at [redacted])

5.2.1.2 Analysis Results for the F-24 Pipeline at [redacted] If a New Blind Flange is not Installed at the Lower Skillet Location at [redacted]

In this case, the product will be allowed to pack the F-24 line up to the header at [redacted] With an applied surge load at the header of the F-24 line at [redacted], the maximum stress occurs at [redacted] due to stress intensification effects. The analysis results can be summarized as follows:

- To limit the stress in the model within the allowable stress of [redacted] ksi, the maximum allowable surge pressure at the header of the F-24 line at [redacted] is approximately [redacted] psi (Figure 19).

- To limit the stress in the model to the elastic range (with maximum stress less than [redacted] ksi), the maximum allowable surge pressure at the header of the F-24 line at [redacted] is approximately [redacted] psi (Figure 20). The pipeline system would still maintain its integrity during the defueling process if the surge pressure at the header of the F-24 line at [redacted] is kept to less than [redacted] psi.

[redacted]

Figure 19 – Stress Contours for a Surge Pressure of [redacted] psi in the F-24 Pipeline at [redacted] (Blind Flange Not Installed at [redacted])

[redacted]

Figure 20 – Stress Contours for Surge Pressures of [redacted] psi (just before the first yield) and [redacted] psi (at first yield) in the F-24 Line at [redacted] (Blind Flange Not Installed at [redacted])

6. DISCUSSION

The maximum allowable forces we determine from our analyses are the results of axial unbalanced loads due to postulated surge events from valve closures. The maximum allowable surge pressure depends on the distance between the rapidly closed valve and the location where we apply the load. At the initiation point (the valve), a maximum pressure wave is generated that travels through the product and pipelines and is influenced by the geometry, pipeline flow rate, tank heads, pipeline branches, reducers, and other valves. Because of these influences and the complex nature of transient surge events, our analysis results should be reviewed in conjunction with a follow-up hydraulic surge analysis. Such a hydraulic surge analysis should calculate the pressure wave degradation between valves and the Red Hill pipeline dead ends (blind flanges) based on the new operational constraints that will be enforced during defueling.

Our analysis results show that the controlling forces and pressures relate to the F-24 pipeline and are sensitive to the location of the last pressure-rated blind flange. We recommend implementing Assumption 4 in Section 4.1 (new blind flange installed at the lower skillet location near [redacted], followed by reconnection of the F-24 header) such that the maximum allowable pressure surge at the F-24 blind flange would be approximately [redacted] psi to meet ASME B31.3 allowable stress criteria, and up to [redacted] psi to not exceed the nominal yield stress. If these assumed pipeline configuration changes are not implemented, the maximum surge pressure at the end of the F-24 line [redacted] reduces to approximately [redacted] psi to meet ASME B31.3 allowable stress criteria and up to [redacted] psi to not exceed the nominal yield stress. All the above pressures are in addition to the operating pressure imposed by the fill height of the tanks (i.e., [redacted] psi).

7. CONCLUSIONS AND RECOMMENDATIONS

We recommend a follow-up surge analysis be conducted considering the operational constraints that will be enforced during defueling. This surge analysis should, at a minimum, highlight the regions of the Red Hill system we have analyzed to understand if any valve closure events could result in forces greater than the maximum allowable forces we calculate.

We recommend that the lower skillet in the F-24 line near [redacted] be replaced with a pressure-rated blind flange and that the upstream portion of the F-24 pipeline be reconnected. In this case, a maximum allowable surge pressure of [redacted] psi (or [redacted] psi if the pipe is allowed to yield) can be achieved as per our detailed FE analysis.

However, if the F-24 skillet is removed but not replaced with a pressure-rated blind flange and valve closure can impose forces on the F-24 header at [redacted] greater than the maximum allowable forces we calculate (maximum allowable surge pressure of [redacted] psi or [redacted] psi if the pipe is allowed to yield), the following mitigation methods can be considered:

1. Provide axial restraint for the F-24 pipeline at the JP-5 pipe anchor location near [redacted] to increase the maximum allowable surge pressure at the header of the F-24 line ([redacted]) to [redacted] psi (or [redacted] psi if allowed to yield) (Figure 21), or

2. Use the JP-5 line to defuel the F-24 pipeline, or

3. Provide axial restraint on the F-24 pipeline per our April 2022 recommendations. (Note: this is also consistent with the repair employed by EEI/Aptim in their emergent repairs of the JP-5 header at [redacted], where the JP-5 header has been longitudinally restrained at the end of the tunnel.)

[redacted]

Figure 21 – Stress Contours for Surge Pressures of [redacted] psi (at allowable stress) and [redacted] psi (at first yield) in the F-24 Line at [redacted] (F-24 Pipeline Restrained at the JP-5 Anchor Near [redacted] and a Blind Flange Not Installed at [redacted])

We note that tight control of valve closure times at [redacted], the underground pumphouse, the harbor tunnel, and the lower access tunnel will need to be maintained during the defueling process, especially as each tanker approaches capacity. This way, emergency closure to avoid spills at [redacted] can be avoided and reflected pressure waves can be limited.

[redacted]

APPENDIX
PowerPoint Presentation, 12 January 2023

[redacted]

RED HILL DEFUELING SUPPORT

SURGE RESPONSE ANALYSIS

SIMPSON GUMPERTZ & HEGER

[redacted]

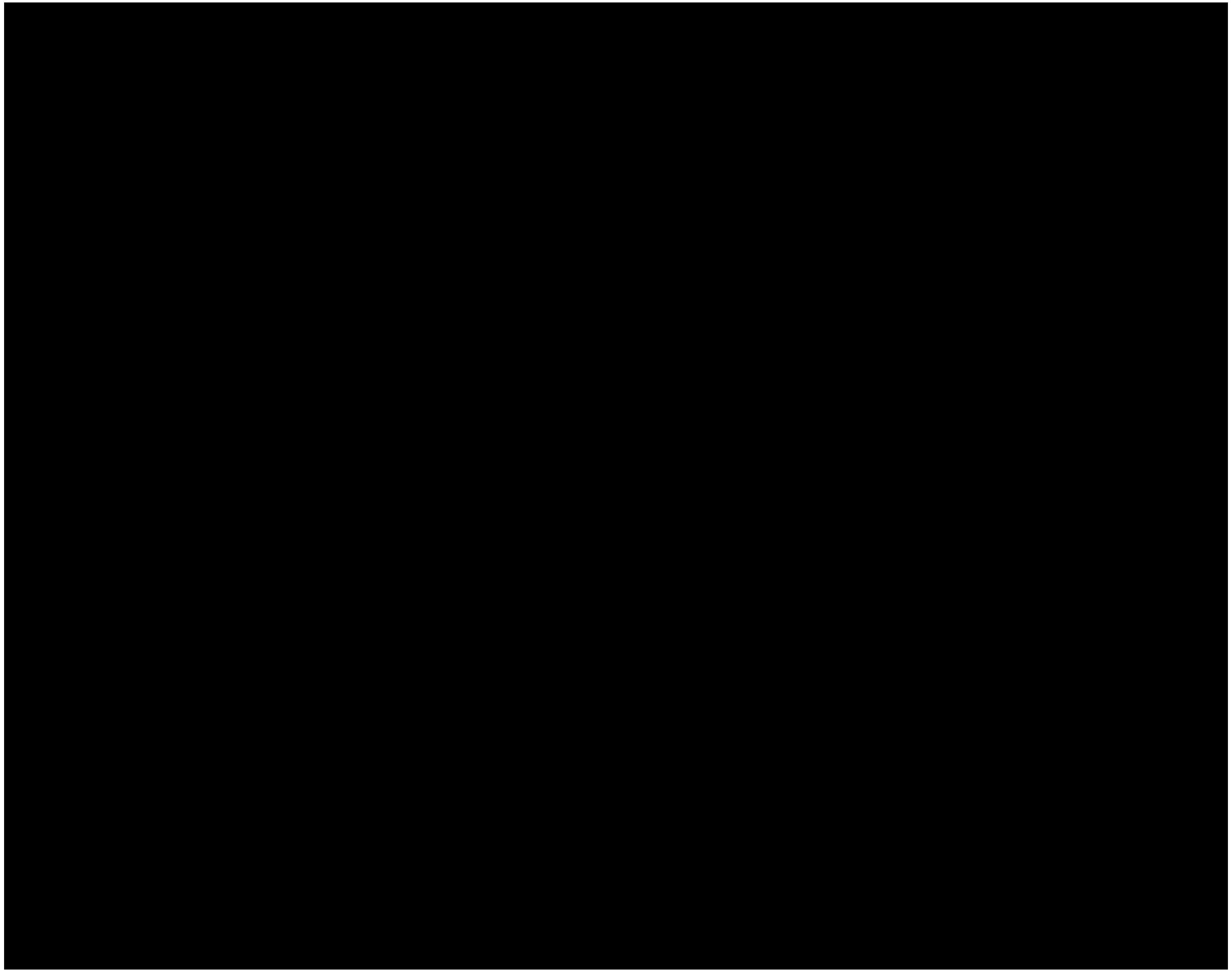
12 January 2023

[redacted]

Agenda

- Introduction
- Background
- Surge Response Analysis
    - Assumptions
    - Pipe Stress Analysis Cases
    - Stress Analysis using TRIFLEX Software
    - Detailed FE Analysis using ABAQUS Software
- Conclusions
- Recommendations

TRANSIENT SURGE MECHANISM



Event Sequence

1. Pressure surge initiates at a valve.
2. Relative to a tank there is product flowing downhill from the tank, and product that is not in motion upstream of the tank.
3. Product in pipeline upstream of tank is at tank hydrostatic pressure (with some degradation due to slope).
4. Tank hydrostatic pressure considered as a boundary condition at the pipeline junction.
5. Pressure wave that is greater than hydrostatic head travels through product toward tank.
6. At the tank pipeline junction, the pressure wave can be reflected downstream, as well as continuing upstream and into the tank.
7. The transmitted wave can induce axial movement in the pipeline depending on the pipeline configuration.

CODES AND STANDARDS

UFC 3-460-01 Change 2 (Jan 2022)

- "All installation pipelines must be designed in accordance with ASME B31.3"
  - Installation pipelines: "pipelines which connect POL facilities within an installation such as a barge pier to a bulk facility and a bulk facility to an operating (ready-issue) tank. These pipelines do not cross property lines…"

ASME B31.3 2022

- Section 302.3.6: For load combinations that include occasional loads, such as wind, earthquake, or transient surge loads, the sum of the longitudinal stresses is allowed to be as much as 1.33 times the Basic Allowable Stress given in Appendix A Table A-1.
- For ASTM A53 Grade B pipe, at 100°C, the Basic Allowable Stress is [redacted] ksi.
  - For lo[redacted]ombinations including surge conditions the code allows the sum of the longitudinal stresses to be [redacted] ksi.

ASME B31.3 INTERPRETATION – SURGE LOADS

Interpretation Detail

Standard Designation:	B31.3
Edition/Addenda:	
Para./Fig./Table No:	
Subject Description:	Loads Due to Pressure Surges
Date Issued:	09/08/1981
Record Nu ber:	
Interpretation Nu ber :	1-50
Question(s) and Reply(ies):	Question: How shall longitudinal piping stresses due to unbalanced loads from pressure surges which result in anchor displacements be evaluated in B31.3? Reply: Loads due to pressure surges are considered as primary loads, and longitudinal stress limits must comply with 302.3.3(c) for sustained loads or 302.3.6 for occasional loads. Pressure temperature limits of 302.2 must also be met.

ASME B31.3 INTERPRETATION – STRESS LIMITS

SGH

Interpretation Detail

Standard Designation:	B31.3
Edition/Addenda:	
Para./Fig./Table No:	
Subject Description:	B31.3 1999 Edition (2001 Addenda), Paragraph 302.3.6, Limits of Calculated Stress Due to Occasional Loads
Date Issued:	07/01/2002
Record Number:	
Interpretation Number :	19-18
Question(s) and Reply(ies):	Question: Does paragraph 302.3.6(a) include occasional internal pressure loads, (e. g. surges, spikes, peaks, and water hammer) in the summation of longitudinal stresses due to sustained and occasional loads? Reply: Yes. In addition, all pressure variations) must also meet the requirements of paragraph 302.2.4.

Note: Section 302.2.4 (f)(a) of ASME B31.3 states it is permissible to exceed the pressure rating or allowable stress by 33% for pressure design, provided the owner approves, and the duration is no more than 10hrs at any one time and no more than 100hrs/year.

Liquid Valve Closure Assessment

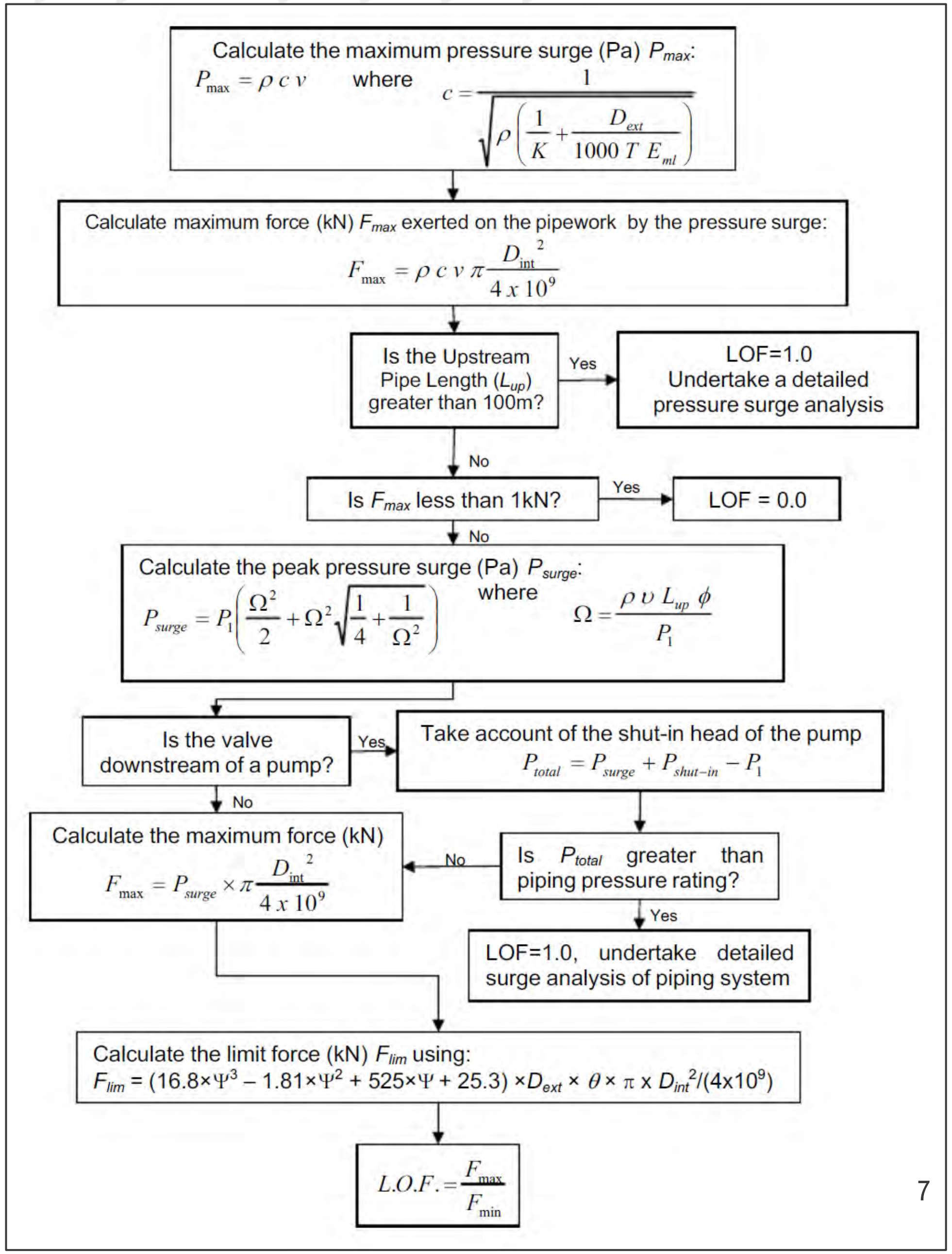
T10.8 SURGE/MOMENTUM CHANGES ASSOCIATED WITH VALVES

T10.8.1 Main Line Excitation

T10.8.1.1 Change in operation

Rapid changes in fluid velocity occur when valves are opened/closed. The resulting forces on the pipework caused by the pressure wave (or surge) travelling back upstream from the closing valve can be reduced by either reducing the mean fluid velocity or slowing down the time taken to close the valve.

Pump start-up and shut-down can also induce rapid changes in fluid velocity resulting in surge problems. The use of a 'soft start' pump can help reduce the resulting surge pressures in the system.



Ref.: Energy Institute, "Guidelines for the Avoidance of Vibration Induced Fatigue Failure in Process Pipework," 2nd Edition, 2008.

SGH

General Defueling Assumptions (Provided by Fuels Group)

- The F-76 pipeline will be abandoned in place (i.e., no repairs will be completed) down to the fire valves, and the F-76 product will be rerouted to the JP-5 line.
- Tanks [redacted] (containing F-76) will be defueled using the JP-5 pipeline.
- [redacted] line w[redacted]d above the lower skillet blind upstream of the T-connection between [redacted] and [redacted].
- The F-24 pipeline will be cut above the lower skillet ([redacted]), and a pressure-rated blind flange will be installed. The F-24 trunkline will be rec[redacted]ely upstream of the new blind flange.
- JP-5 tanks ([redacted]) will be defueled via the JP-5 pipeline.
- F-24 tanks ([redacted]) will be defueled via the F-24 pipeline.
- Defects will be addressed as per the Consolidated Repair List to increase the MAOP of JP-5 and F-24 pipelines.

Pipe Stress Analysis Cases

- Case 1. Pipeline seg concrete wall downstream of [redacted] anchor upstream of [redacted], including the trunklines and [redacted].
- [redacted] 2. Pipeline segments at [redacted] ween the concrete wall downstream of [redacted] and the concrete ancho [redacted].
- Cases 3 & 4. Pipeline segments between [redacted] (the end of the F-24 line), n the concrete anchor do [redacted] concrete wall upstream of [redacted]
    - 24 trunkline with blind flange near [redacted] (the en ine)
    - Case 4. F-24 trunkline with skillet replacemen ge near [redacted]
    - Sensitivity cases with varying load combinations and pipeline configur
    - More than 100 pipe stress analysis cases
    - Gained insights into the affects of various factors on the surge response

SURGE RESPONSE – MODEL 1
PIPING LATERALS AT [redacted]

Load Corresponding to [redacted] psig Surge Pressure at Tank 20 Ball Valve

[redacted]

SURGE RESPONSE – MODEL 2
PIPING LATERALS AT [redacted]

Loads Corresponding to [redacted] psig Surge Pressure at F-24/JP-5 Ball Valves

[redacted]

F-24 and JP-5 Trunklines Modeled to Evaluate Surge Pressure on F-24 Blind Flange(s)

- Modeled laterals to account for additional stiffness
- [redacted] disconnected
- F-24 line is modeled with bends around the concrete anchors
- F-24 and [redacted]
- [redacted]d upstream of [redacted] also [redacted] at the [redacted]

[redacted]

F-24 and JP-5 Trunklines – F-24 Blind Flange not Installed near [redacted]

[redacted]

Load Corresponding to [redacted] psig Surge Pressure at F-24 [redacted]

[redacted]

Case 3 – Axial Load Applied at F-24 Blind [redacted]

[redacted]

CASE 3 ANALYSIS RESULTS – VON MISES STRESSES (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

CASE 3 ANALYSIS RESULTS – VON MISES STRESSES (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

- To limit the stress in the [redacted]el to an allowable stress of [redacted] ksi, the maximum allowa[redacted] surge pressure [redacted] r [redacted] F-24 line at [redacted] should be a [redacted]
- To generate [redacted]n axial surge pressure of [redacted] psig at [redacted] F- [redacted] line at [redacted], a much hig[redacted] to [redacted]

CASE 3 ANALYSIS RESULTS – DISPLACEMENT CONTOURS (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

CASE 3 ANALYSIS RESULTS – VON MISES STRESSES (WITH SURGE PRESSURE OF [redacted] PSIG TO REACH YIELD STRESS)

[redacted]

- At [redacted] surge pressure of [redacted] psig, the first yie[redacted] occu[redacted]ed (yield stress of [redacted] ksi has [redacted] intensification effects
- The system would remain elastic if the s[redacted] psig

CASE 3 ANALYSIS RESULTS – DISPLACEMENT CONTOURS (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

F-24 and JP-5 Trunklines – F-24 Blind Flange Installed Instead of Skillet Near [redacted]

[redacted]

SURGE RESPONSE ANALYSIS – MODEL 4

Lo[redacted]ge Pressure at F-24 Pipeline Blind Flange Upstream of [redacted]

[redacted]

Model 4 – Axial Load Applied at F-24 Blind Flange [redacted]

[redacted]

CASE 4 ANALYSIS RESULTS – VON MISES STRESSES (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

[redacted]

CASE 4 ANALYSIS RESULTS – DISPLACEMENT CONTOURS (WITH SURGE PRESSURE OF [redacted] PSIG)

[redacted]

CASE 4 ANALYSIS RESULTS – VON MISES STRESSES (FIRST YIELD OCCURRED AT SURGE PRESSURE OF [redacted] PSIG)

[redacted]

- For a surge pressure of [redacted] psig, the first yi[redacted]d occur (yield stress of [redacted] ksi has [redacted]n effects
- The system would remain elastic if the surge pressure at [redacted]F-24 line at [redacted] can be kept [redacted] psig

Conclusions

- Pipe Stress and Detailed FE Analyses
  - The ben[redacted]n the laterals at [redacted] and [redacted] can sustain surge pressures on the order of [redacted] psi
  - Tee-joint n the JP-5 and the F-24 lines can be highly stressed due to load path and stress intensification factors.
  - If the skillet is removed on the F-24 line (but not r[redacted]lange), resulting in a surge load impact a[redacted]he end of the F-24 pipeline [redacted], the[redacted]rge pressure would be limited to [redacted] psig to meet ASME B31.3 s (or [redacted] psi if allowed to yield) .
  - If the skillet on the F-24 pipeline at [redacted] is replaced with a pressure rated blind fla[redacted], <u>and</u> the upstream portion connected, a maximum surge pressure rating of [redacted] psig can be achieved (or [redacted] psi if allowed to yield).

Recommendations

- Surge Loads
  - We recommend review of key parameters contributing to the formation of surge loads to establish operational constraints that will be enforced during defueling.
  - This surge load evaluation should at a minimum highlight the regions of the Red Hill system we have analyzed to understand if any valve closure events could result in forces greater than the maximum allowable forces that we calculate.
- Operational Controls
  - Flow rates and valve closure times should be checked to confirm that surge pressures would be within the limits established by our analyses.
  - [redacted] alve closure times at [redacted] l may need to be ma[redacted]
  - In this manner emergency closure to avoid spills at [redacted] can be avoided and reflecting surge pressure waves can be limited.

Recommendations

- Pipeline Surge Response Improvement
  - Replace the F-24 skillet with a blind flange and re[redacted]nnect the [redacted]stream portion of the F-24 pipeline to achieve a maximum allowable surge pressure of [redacted] psig (or [redacted] psi if allowed to yield) as per our detailed FE analysis.
  - If the F-24 skillet is removed but n[redacted] a pressure-rated blind flange and valve closure can impose forces on F-24 header at [redacted] greater than the maximum allowable forces we calculate, the following mitigation [redacted] considered:
    - Provide axial restraint for the F-24 pipeline at the pipe anchor locat[redacted] to increa[redacted] the maximum allowable surge pressure at the header of F-24 line ([redacted] psi (or [redacted] psi if allowed to yield), or
    - Use the JP-5 line to defuel the F-24 line, or
    - Provide axial restraint of the F-24 line per our April 2022 recommendations. [Note that this is al[redacted]ent with the repair employed by EEI/Aptim in their eme[redacted]5 header [redacted] where the JP-5 header was longitudinally restrained [redacted]

Additional EPA Comments on the Red Hill Bulk Fuel Storage Facility (RHBFSF) Consolidated Repair/Enhancement List (October 24, 2022)

1. EPA seeks clarity on the characteristics of a ***realistic*** worst case surge event while defueling assuming the proposed repairs/enhancements and operational enhancements and implemented. By, "realistic worst-case surge" we mean the strongest damaging impulse that could occur within a realistic probability. This information will be evaluated against the design pressure of the system (comment 5). If risk of inducing a surge event is negligible, state as such and support this claim with evidence from the proposed repairs/enhancements and operational enhancements.

Response: For Red Hill defuel, unsteady flow events characterized as surge that are considered a realistic worst-case surge events are identified in two initiator categories:

A. *Those caused by a sudden change in valve position (closure)*
B. *Those caused by the sudden collapse of a cavity of low pressure*

Of these categories, surges associated with two phase flow were not determined to be realistic because the Red Hill system does not operate under those conditions and thus were not considered (see Reference (b)).

Category A
Of the two categories, surges due to sudden changes in valve position are accommodated within the system design pressure. UFC 3-460-01 §9-2.1 requires ASME B31.3 Process Piping as the code used to establish design pressure. This is coincident with what API 570 §3.1.58 Piping Inspection Code refers to as maximum allowable working pressure. Based on components of the system, UFC 3-460-01 Table 9-1 limits the maximum allowable working pressure to [redacted] psig. However, ASME B31.3 §302.2.4 permits occasional pressure excursions up to 33% above the system design pressure ([redacted] psig).

EEI's Hydraulic Analysis and Dynamic Transient Surge Evaluation, FISC Pearl Harbor Fuel System (dated 2010) found that butterfly valves (BFV) in the underground pumphouse must be used as the primary means of throttling and stopping flow during all transfer operations from Red Hill. Per the hydraulic modeling conducted as part of the study, closure of the BFVs in the underground pumphouse did not induce significant surge pressures for any operation assessed. Thus proper operational procedures (which use BFVs to start and stop flow) mitigate the likelihood of a damaging surge event initiated by sudden valve closure.

In the EEI Pipeline Stress Analysis and Structural Evaluation Report – Red Hill Lower Access Tunnel (dated September 2022), it was found that certain pipeline miter joints were overstressed at [redacted] psig. The report recommended derating the system to [redacted] psig to eliminate the overstress condition. Since the system near the miter joints is operated at [redacted] psig for defuel, the recommendation to derate to [redacted] psig accommodates both ordinary conditions and occasional pressure excursions.

ASME B31.3 does not have criteria for defect assessment or evaluation of non-standard components. We are applying algorithms and formulas in ASME B31G, ASME B31.4, API 579, and API RP 1183 to assess defects and determine fitness for defuel service. The details of which *code was used by defect type is in the basis of design table developed by NAVFAC EXWC and included as an attachment in our JTF-RH response on 06 Dec 2022. The stress analysis evaluated non-standard components under ASME B31.3 design pressure conditions.*

Category B

Low pressure cavity collapse or vacuum-related surge events are those which can be mitigated by a combination of new capabilities and revised operational procedures. New analog pressure gauges, new pressure indicating transmitters, and new small bore piping and valves around the tank ball valves are being installed. These capabilities will provide redundant pressure measurement at the location of a tank nozzle. Should a low pressure condition exist, the operator will be able to relieve the condition to atmospheric with a vent and then slowly equalize line pressure across the tank ball valves using the small bore piping. Operational procedures will be developed and written to deploy the new capabilities. Thus new instrumentation, equalization piping, and operational procedures mitigate the likelihood of a damaging surge event initiated by the collapse of a low pressure cavity.

2. The EEI Stress Analysis stated that, "[p]ressure surges can create damaging impulses that cannot be mitigated by structural or piping modifications." Does the Navy agree or disagree with EEI's statement? If Navy believes SGH or EEI may need to amend their report, please provide written correspondence and include it in the documentation files.

Response: The EEI Pipeline Stress Analysis and Structural Evaluation Report – Red Hill Lower Access Tunnel (dated September 2022) was intended to address pressures related to ASME B31.3 code compliance. The magnitude of an extraordinary overpressure event such as the collapse of a large vacuum cavity is extremely unlikely and was excluded from consideration. Designing a piping system to resist an unquantifiable large magnitude pressure event resulting from an operational error is infeasible. As noted in the response to Question 1, measures to mitigate the likelihood of a Category B surge event are in progress for implementation.

EEI provided a clarification memo on 30 Jan 2023 (see Reference (c)) that clarifies the following:

A. *The effects of pressure surges on piping stress and support loads were not specifically evaluated.*
B. *The ASME B31.3 piping code to which the evaluation was performed accounts for occasional overpressure as noted in the response to Question 1.*
C. *Proper operational procedures will prevent any abnormal surge pressures in the tank gallery piping.*

SGH also provided additional information on surge (dated January 2023)(see Reference (d)). The sole recommendation from the assessment to replace the F-24 skillet with a blind flange is currently on contract to execute.

3. Please provide an estimated delivery of the PVC FOR pipeline replacement re-assessment from SGH.

Response: JTF-RH has obligated funds for a contract through DLA on February 2023 to EST to perform an inspection of the Hotel Pier PVC FOR/drain line, repair any discrepancies in the *pipe and pipe supports as necessary, and perform a hydrostatic test based on the SGH memo (see Reference(a)) and DOH's conditional alternate approval (see Reference (e)). This repair project will begin as early as 27 Feb 2023. Documentation will be provided to EPA and DOH upon successful completion of the hydrostatic test.*

4. What code has or will be used to evaluate the design pressure of the piping? Has or will the design pressure be re-established and documented based on the current condition of the system. If not, please explain why.

Response: UFC 3-460-01 §9-2.1 requires ASME B31.3 Process Piping as the code used to establish design pressure. This is coincident with what API 570 §3.1.58 Piping Inspection Code refers to as maximum allowable working pressure. Based on components of the system, UFC 3-460-01 Table 9-1 limits the maximum allowable working pressure to [redacted] *psig. The piping stress analysis report recommended derating the system to* [redacted] *psig. All evaluations of defects and non-standard components were performed using a maximum allowable working pressure of* [redacted] *psig to generate the repair list, likely resulting in a repair list that was overly conservative for the operation of a* [redacted] *psig system. ASME B31G, ASME B31.4, API 579, and API RP 1183 were used to assess defects and determine fitness for defuel service.*

From: Ichinotsubo, Lene K <lene.ichinotsubo@doh.hawaii.gov>
Sent: Friday, April 14, 2023 10:25 AM
To: [redacted] Stasick, Steven James CAPT USN INDOPACOM JTF RED HILL (USA); [redacted] Triggs, Shawn M CAPT USN NAVSUP FLCPH (USA); Obeirne, Michael K CAPT USN DCNO N4 (USA)
Cc: Delhomme, Stephen; Myers, Hugh; Lee, KellyAnn; Kwan, Roxanne S; Osborne, Evan
Subject: [URL Verdict: Neutral][Non-DoD Source] FW: Issues concerning consistency within Defueling Supplement 1.

Hi [redacted],
As requested by [redacted] during our meeting yesterday, the following is a list prepared by our consultant. Let us know if there are any questions. We look forward to another meeting discuss this further.
Thanks,
lene

Here is a list of apparent issues regarding the pressures for Defueling Supplement 1.

- Initially during a meeting the Navy, SGH and DOH agreed that [redacted] psi, based on SGH's calculations of the surge pressure required to move the JP-5 pipeline during the May 2021 event, was a reasonable surge pressure upon which to evaluate the system and design pipe supports (restraints) that would prevent pipe failure during as similar surge event if the by-pass lines and operational procedures failed. This would act as a passive tertiary mitigation measure behind the by-pass lines and new operational procedures. This passive mitigation was thought to have value because human operational failures were blamed on for the release in May 2021. After this meeting, the Navy prepared a repair list based on SGH's design and recommendations and a "probability of release" analysis that takes a risk reduction credit for this passive mitigation.
- It was noted that a subsequent EEI report (September 2022) stated, "*Pressure surges can create damaging impulses that **cannot be mitigated by structural or piping modifications** and must be prevented by operational procedures or mitigated by pressure control and relief systems*." At this point, DOH pointed out the apparent discrepancy between the previously agreed plan to use the structural supports designed for a **reasonable** surge pressure of [redacted] psi and the statement in the EEI report. While EEI's statement is generally true that **some** pressure surges could create pressure high enough to damage a pipe, EEI seemed to disregard SGH's contention is that the system could be designed, through structural or piping modification, to withstand a surge pressure of [redacted] psi.
- Defueling Supplement 1 attempted to reconcile this discrepancy, but the same inconsistency appears to remain between EEI and SGH based on the statements from EEI's report and SGH's initial report (analyzing the surge) and the subsequent January 17, 2023 stress analysis report (analyzing valve closure surge):
    - EEI –"*If a tank shell valve is opened, the rapid introduction of pressure due to the tank head will collapse the vapor cavity causing pressure spikes that are potentially orders-of-magnitude above the ratings of the piping system (**surge modeling of this condition at Red Hill has not been performed**, however based on EEI's experience with modeling surge caused by similar slack-line vapor cavity collapses, pressure spikes of well above* [redacted] *psig are common).*" This is a general statement and was not based on any evaluation of the vacuum surge that occurred at the site. SGH based their analysis on the actual surge that occurred, which indicated a surge pressure of [redacted] psig. The SGH design was not intended to mitigate a [redacted] psi or an indeterminate surge pressure, but one that appeared reasonable to the DOH, Navy and SGH based on their evaluation of the actual May 2021 surge event. So, it is unclear what basis EEI is using, other than general knowledge, to discount SGH's design or the Navy's current approach.
    - EEI says, "*In nearly all cases throughout the petroleum industry and DoD POL, surge risks are mitigated primarily by prevention or surge pressure relief, and not by the design of the piping and supports. Only*

surges (hammering) that are normal to a process and cannot be mitigated by these other means must be addressed through the design of the piping system." Again, while this may be a true general statement, this is not the path recommended by SGH and chosen by the Navy, as previously presented. Certainly, SGH recommended and the Navy is implementing the by-pass lines and operation procedures to prevent surges before they happen. But it appears that the Navy is continuing to implement the structural changes recommended by SGH's original design as well.

- EEI says, "*The intent of the statements made in the Pipeline Stress Analysis and Structural Evaluation Report is to communicate* ***that modifying the piping and structural supports*** *(likely requiring full replacement of all lower access tunnel piping and installation of massive pipe supports)* ***is not a viable*** *or practical approach to address surge at Red Hill, given that operational/procedural mitigation can be effective. Therefore, evaluation and reporting of the piping stress for such surge events would be academic and* ***would not ultimately serve the goal of emptying the Red Hill complex in a safe*** *and timely manner*." This statement appears to directly conflict with SGH's recommendations, the Navy's chosen path and the on-going structural repairs included on the repair list. The statement that using the Navy's chosen method of tertiary mitigation is not viable or safe is troubling. This is especially troubling given that EEI has done no surge evaluation.
- SGH's January memo states, "*To the best of our knowledge, SGH's previous study may have been the only documented study where the response of the pipelines and supports to axial transient surge loads was checked. In our study, we used a transient surge pressure of* [redacted] *psi, assuming a surge event similar to that discussed in the RCA report." and "Our analysis indicated that the pipelines and supports might be overstressed and fail if they are again subjected to surge pressures similar to the 6 May 2021 event. Therefore, we recommended several axial and lateral restraints to transfer the surge loads from the pipelines to supports and foundation elements. We showed that the addition of restraints can reduce the pipeline stresses to within acceptable limits." and "Although surge pressures due to valve closure can be mitigated or reduced through operational controls, we believe that the maximum surge pressures that can be resisted by the pipelines and supports can be established quantitatively.*"
- SGH's January memo also states, "*Since the JP-5 and F-24 pipelines share common branches, the axial surge loads can be transferred from the F-24 to the JP-5 pipeline*" and "*We recommend that the Navy determine the maximum flow rates using the maximum surge loads that can be resisted by the pipelines to mitigate potential surge damage. If the flow rates can be kept below these thresholds (to be calculated by others), the axial restraints recommended in our April 2022 report would not be required under the assumption that vacuum formation and related surge events will be mitigated through operational measures."* This statement appears to indicate several things: 1) If the surges are transferable between pipelines, the lowest flow rate based on the allowable surge pressure in either line should control the operation (or a method to isolate the lines should be included); 2) SGH still believes that surge, and not just operating pressure, should be evaluated for defueling; 3) The structural supports would not be required IF the assumptions is made that the vacuum-related surge is mitigated by operational procedures. Using solely operational procedures is not the assumption agreed to by DOH previously and it is not clear, based on this evaluation, if the Navy is considering changing this assumption to preclude the structural supports. The Navy has consistently stated the intent to perform the complete list of repairs, so we assume that the Navy is still following SGH's original recommendations.

- SGH's summary of the EEI report from 2010 says:
  - *"If the fuel system is permitted to operate at its full flow potential, there is a substantial risk of very high surge pressures, which could potentially damage the system to the point of failure."*
  - *"Facility personnel is currently limiting the flow rate while issuing to the piers (generally governed by the pressure/receipt rate dictated by the receiving vessel). This reduction in flow rate (below maximum potential) often (though not always) reduces the associated surge potential to within allowable limits, making the associated risk of piping failure much lower."*
  - *Full closure of the* [redacted] *generally appears to create the lowest surge pressure of any potential initiator and, therefore, should be used as the primary means of throttling and stopping flow during operations.*
  - *Closure of the* [redacted]*, and closure of* [redacted]*, during full flow from Red Hill (*[redacted] *bph) can create high surge pressures throughout the piping system (over* [redacted] *psi at the pier and over* [redacted] *psi in Red Hill tunnel).*

- *EEI recommended the following operational control options that support the safe defueling of the JP-5 pipeline:*
  - *1. Limit issue rates to* [redacted] *bph (this is the current normal issue rate per field observations).*
  - *2. Use the* [redacted] *to throttle the fuel flow.*
  - *3. Use the* [redacted] *JP-5 piping system for defueling.*
- For the F-24 line: *EEI did not calculate a recommended flow rate that would result in transient surge events within acceptable limits. However, based on the EEI recommended reduced flow rates for the F-76 and JP-5 lines, the F-24 defueling rate should not exceed 50% of the analyzed flow rate of* [redacted] *bph…*

- The EEI January Memo says, *"The stress analysis accounted for an internal pressure of* [redacted] *psig, which is the maximum normal operating pressure during gravity-issue operations due to full tank head. The analysis found that the limiting component is a miter joint with a maximum allowable working pressure (MAWP) of* [redacted] *psig, giving a safety margin of over* [redacted] *psig to accommodate typical minor pressure excursions such as the butterfly valve closure under proper operational procedures."* EEI did not state if this was the JP-5 or F-24 line, but if this is the JP-5 line, then this [redacted] psi is less than the [redacted] psi that SHG says is safe with the structural supports. It does not appear hat EEI's evaluation took the Navy's planned structural improvements into their evaluation or if those structural improvement would affect these mitered joints, so it unclear if this limitation is a conflict between EEI and SGH or just a difference because EEI did not consider the additional structural changes. So, it is not clear what the allowable operating or surge pressures should be.
- DOH agrees that maximum allowable surge pressure to prevent pipe failure is important and agrees with SGH's recommendation that an evaluation should be performed to determine the flow rates that would generate the maximum allowable surge pressure to prevent a release for the F-24 and JP-5 lines, based on the piping configuration and operations plan for defueling. The defueling should then proceed at those flow rates.

Thanks,
[redacted]

[redacted]

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Memorandum

Date: 10 May 2023
(Revised 16 May 2023)

To: Capt. Steve Stasick, US Navy, NAVFAC Joint Task Force, Red Hill

From: [redacted]

CC: [redacted]

Project 221162 – Red Hill Defueling Support, Joint Base Pearl Harbor-Hickam, Honolulu, HI

Subject: Red Hill Fuel Pipelines – Updated Surge Response Analysis

In this memorandum, we present the results of supplemental analyses for a potential transient pressure surge in the Red Hill pipelines that have been undertaken since the completion of our memorandum of 17 January 2023. The January memorandum presented analyses for the maximum F-24 pipeline transient surge loads that Red Hill pipelines can safely accommodate during defueling. Since the release of the January memorandum, several operational and structural improvements have been made that are captured in the analysis presented herein.

1. UPDATED SURGE RESPONSE ANALYSIS

We have performed supplemental pipe stress analyses in addition to the analyses presented in the memorandum of 17 January 2023. Our new analyses follow the same general defueling assumptions and methodology as our analyses discussed in the January 2023 memorandum, assuming that the pressure-rated blind flange is installed along the F-24 pipeline [redacted] Please refer to the January 2023 memorandum for more details on the analysis approach and code check methodology.

The surge response analysis has been updated based on recent repairs. During SGH's site visit in early April 2023, we observed a new axial restraint installed near pipe support [redacted] along the F-24 pipeline, shown in Figure 1.

[redacted]

Figure 1 – New Axial Restraint on F-24 Pipeline [redacted]

Our analysis aims to check whether a maximum surge pressure of [redacted] psi in the F-24 pipeline can be resisted while maintaining stresses induced in the pipeline system within allowable values. We note that others have confirmed that the F-24 pipeline could experience a surge pressure as high as [redacted] psi in the Red Hill tunnel.

To account for the modified stiffness in the F-24 pipeline due to the new axial restraint at [redacted], we updated the TRIFLEX global model by adding the new support to obtain an equivalent axial spring stiffness upstream of the blind flange at [redacted]. Figure 2 shows the response of the F-24 pipeline to a unit load to calculate the equivalent axial stiffness ([redacted].). We note that the addition of the axial restraint at [redacted] has a minimal effect on the axial spring stiffness immediately upstream of the new blind flange due to the long distance from [redacted] and the presence of bends in the pipeline.

[redacted]

Figure 2 – F-24 Axial Load Response Upstream of New Blind Flange [redacted] for Stiffness Calculation

In addition to updating the TRIFLEX model based on recent repairs, we also more accurately modeled the stress concentrations at the JP-5 pipeline by replacing an axial restraint upstream of the new blind flange [redacted] with an axial spring in the finite element (FE) model developed using ABAQUS. Figure 3 shows the unit load response to calculate the JP-5 pipeline axial stiffness [redacted]).

[redacted]

Figure 3 – JP-5 Axial Load Response Upstream of New Blind Flange [redacted] **for Stiffness Calculation**

We updated the boundary conditions in the detailed FE model based on these revisions. The axial spring stiffness of the F-24 pipeline downstream of the blind flange was not changed from our previous analysis. Figure 4 shows an overview and boundary conditions applied in the ABAQUS model.

[redacted]

Figure 4 – ABAQUS FE Model Overview and Boundary Conditions

Similar to the analysis presented in our January 2023 memorandum, with an applied surge load at the header of the F-24 pipeline [redacted], the maximum stress occurs at [redacted] due to stress intensification effects. The ABAQUS finite element (FE) analysis program can more accurately capture the stress concentrations at [redacted] compared to the generalized pipe stress analysis software TRIFLEX. Thus, we used the ABAQUS model to determine the maximum principal stress due to the application of axial load on the blind flange arising from a surge pressure of [redacted] psi in the F-24 pipeline, as shown in Figure 5. The ABAQUS FE model only includes the axial load due to the surge pressure and is not used to capture the effects of self-weight, temperature, and internal pressure. For the present surge analyses in the F-24 pipeline, we assumed that the JP-5 pipeline is not subjected to any internal operating pressure beyond the atmospheric pressure, but we conservatively assumed that the JP-5 pipeline is full to account for fuel weight when there is fuel movement through the F-24 pipeline.

[redacted]

Figure 5 – Maximum Principal Tensile Stress Contours Due to Application of Axial Load Arising from [redacted] psi Surge Pressure in F-24 Pipeline

We used the TRIFLEX model to estimate the stresses due to the loads not considered in the ABAQUS model (self-weight, including fuel, temperature, and internal pressure). Specifically, the internal pressure includes a nominal operating pressure of [redacted] psi and a surge pressure of [redacted] psi in the F-24 pipeline. The [redacted] psi operating pressure was provided by Risktec in the Joint Task Force (JTF) team meeting on 12 May 2023 as the upper-bound operating pressure in the F-24 pipeline due to the maximum liquid head based on the present fuel level in [redacted]

An axial force due to the pressure surge is not included in the TRIFLEX model as it is included in the ABAQUS model. Figure 6 shows the sustained stresses in the JP-5 and F-24 pipelines due to the operating loads and surge pressure described above. As noted previously, the JP-5 pipeline was not subjected to any internal operating pressure.

[redacted]

Figure 6 – TRIFLEX Model Stress Contours due to Internal Pressure of [redacted] psi ([redacted] psi Operating + [redacted] psi Surge), Self-Weight, and Temperature

We linearly added the maximum principal tensile stress from ABAQUS ([redacted] ksi) and the stresses from TRIFLEX ([redacted] ksi) under a [redacted]-psi pressure surge to combine the effects of axial load due to surge, internal pressure due to surge, internal pressure due to nominal operating pressure, self-weight, and temperature. This resulted in a total combined stress of [redacted] ksi at the critical location [redacted]. The total stress of [redacted] ksi is less than the allowable stress of [redacted] ksi. Per Section 302.3.6 (a) (1) of ASME B31.3, the sum of the stresses due to sustained loads and the stresses due to occasional loads (such as surge loads) should be limited to 1.33 times the basic allowable stress provided in Table A-1 of ASME B31.3 and the basic allowable stress for A53 Gr. B steel is [redacted] ksi.

2. CONCLUSIONS

We updated our pipe stress analysis models based on recent repairs and refined the surge response assessment by determining stresses in the pipelines following ASME B31.3 requirements. Our assessment indicates that the F-24 pipeline can safely accommodate surge pressures up to [redacted] psi while maintaining stresses within allowable values. The axial load due to the surge pressure wave impacting the blind flange and the stress intensification effects at the tee joint govern the surge response. The combination of operational, piping system, and structural improvements is expected to maintain pipe stresses below the code permissible values for a surge pressure of up to [redacted] in the F-24 pipeline. Further details of the analysis are presented in the PowerPoint attachment to this memorandum.

[redacted]

APPENDIX A
Updated Surge Response Analysis

RED HILL DEFUELING SUPPORT

SURGE RESPONSE ANALYSIS UPDATE

SIMPSON GUMPERTZ & HEGER

[redacted] [redacted]

16 May 2023

Objectives and Methodology

- Refine the pipe stress analyses presented in SGH's January 2023 memorandum
- Update the previously developed TRIFLEX global and ABAQUS local models based on recent repairs
- Obtain axial stiffnesses of the F-24 and JP-5 pipelines from the TRIFLEX model with updated geometry and update the restraining spring stiffnesses in the ABAQUS finite element (FE) model
- Consider a surge pressure of [redacted] psi in addition to [redacted] psi nominal operating pressure ([redacted] psi was provided by Risktec in the Joint Task Forc[redacted]TF) team meeting[redacted]n 12 May 2023 as the [redacted]boun[redacted] operating pressure in the F-24 pipeline due to the maximum head based on the present fuel level in [redacted]
- Calculate stresses due to combination of surge pressure, operating pressure, thermal expansion and gravity loads
- Determine principal tensile stresses from the detailed FE analysis using the ABAQUS model
- Combine stresses from ABAQUS and TRIFLEX analyses
- Establish the allowable surge pressure that would limit the stresses in the critical piping components to acceptable values

Pipe Stress Analysis Updates

- [redacted]d axial restraint at [redacted]
- Reconnected [redacted] laterals
- Replaced axial restraint with an axial spring [redacted]pstream of new blind flange at [redacted]

[redacted]

F-24 AXIAL SPRING STIFFNESS UPSTREAM OF NEW BLIND FLANGE AT [redacted]

[redacted]

F-24 Line Axial Stiffness

- Stiffness, k = [redacted]
- The additio[redacted]e axial restraint at [redacted] has a minimal eff[redacted]the axial spring stiffness immediately upstream of the new blind flange due to t[redacted]ds in the pipeline.

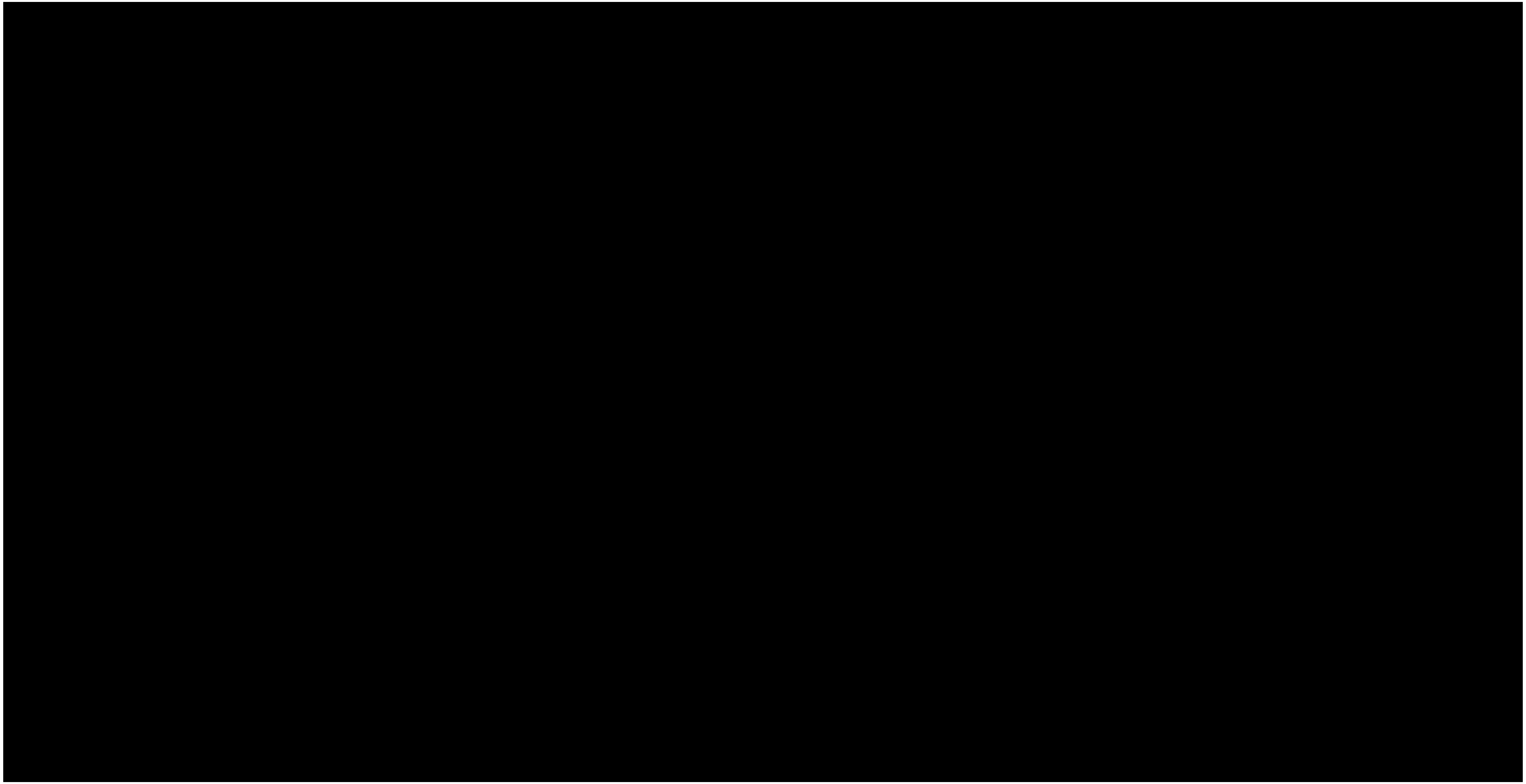
JP-5 AXIAL SPRING STIFFNESS UPSTREAM OF NEW BLIND FLANGE AT [redacted]

[redacted]

JP-5 Line Axial Stiffness

- Stiffness k = [redacted]

DETAILED FE MODEL OVERVIEW AND BOUNDARY CONDITIONS (BC)



MAXIMUM PRINCIPAL STRESS DUE TO APPLICATION OF AXIAL LOAD ARISING FROM [redacted] PSI SURGE PRESSURE

[redacted]

PIPE STRESSES DUE TO [redacted] PSI INTERNAL PRESSURE ([redacted] PSI OPERATING + [redacted] PSI SURGE), SELF-WEIGHT, AND TEMPERATURE

[redacted]

COMBINATION OF STRESSES

- Total combined stress at critical location [redacted]

[redacted] ksi + [redacted] ksi = [redacted] ksi

TRIFLEX Results

Gravity + internal pressure + temperature

ABAQUS Results

Axial load (due to surge pressure)

- Allowable stress for occasional loads (per ASME B31.3) = [redacted] ksi
- The total stress of [redacted] ksi is less than the allowable stress

ASME B31.3-2020 STRESS CALCULATION

(20) **320.2 Stress Due to Sustained Loads**

The equation for the stress due to sustained loads, such as pressure and weight, S_L, is provided in eq. (23a). Equations for the stress due to sustained bending moments, S_b, are presented in eq. (23b).

$$S_L = \sqrt{(|S_a| + S_b)^2 + (2S_t)^2} \quad (23a)$$

$$S_b = \frac{\sqrt{(I_i M_i)^2 + (I_o M_o)^2}}{Z} \quad (23b)$$

where

I_i = sustained in-plane moment index. In the absence of more-applicable data,[9] I_i is taken as the greater of $0.75i_i$ or 1.00.

I_o = sustained out-plane moment index. In the absence of more-applicable data,[9] I_o is taken as the greater of $0.75i_o$ or 1.00.

M_i = in-plane moment due to sustained loads, e.g., pressure and weight

M_o = out-plane moment due to sustained loads, e.g., pressure and weight

Z = sustained section modulus. Z in eqs. (23b) and (23c), is described in para. 319.4.4 but is computed in this paragraph using nominal pipe dimensions less allowances; see para. 320.1.

The equation for the stress due to sustained torsional moment, S_t, is

$$S_t = \frac{I_t M_t}{2Z} \quad (23c)$$

where

I_t = sustained torsional moment index. In the absence of more-applicable data,[9] I_t is taken as 1.00.

M_t = torsional moment due to sustained loads, e.g., pressure and weight

The equation for the stress due to sustained longitudinal force, S_a, is

$$S_a = \frac{I_a F_a}{A_p} \quad (23d)$$

where

A_p = cross-sectional area of the pipe, considering nominal pipe dimensions less allowances; see para. 320.1

F_a = longitudinal force due to sustained loads, e.g., pressure and weight

I_a = sustained longitudinal force index. In the absence of more-applicable data,[9] I_a is taken as 1.00.

ASME B31.4–2012 ACCEPTANCE CRITERIA

SGH

Table 403.3.1-1 Allowable Values for Pipeline System Stresses

Location	Internal and External Pressure Stress, S_H	Allowable Expansion Stress, S_E	Additive Longitudinal Stress, S_L	Sum of Longitudinal Stresses from Sustained and Occasional Loads	Equivalent Combined Stress, S_{eq}	Effective Stress for Casing or Uncased Pipe at Road or Railroad Crossings
Restrained pipeline	$0.72(E)S_Y$	$0.90S_Y$	$0.90S_Y$ [Note (1)]	$0.90S_Y$	$0.90S_Y$	$0.90S_Y$ [Note (2)]
Unrestrained pipeline	$0.72(E)S_Y$	S_A [Note (3)]	$0.75S_Y$ [Note (1)]	$0.80S_Y$	n/a	$0.90S_Y$ [Note (2)]
Riser and platform piping on inland navigable waters	$0.60(E)S_Y$	$0.80S_Y$	$0.80S_Y$	$0.90S_Y$	n/a	n/a
Slurry pipelines	$0.80(E)S_Y$	n/a	n/a	n/a	n/a	n/a

GENERAL NOTES:

(a) S_y = specified minimum yield strength of pipe material, psi (MPa)

(b) E = weld joint factor (see Table 403.2.1-1)

(c) In the setting of design factors, due consideration has been given to and allowance has been made for the underthickness tolerance and maximum allowable depth of imperfections provided for in the specifications approved by the Code.

(d) S_L in the table above is the maximum allowable value for unrestrained piping calculated in accordance with para. 402.6.2. The maximum value of S_L for restrained pipe is calculated in accordance with para. 402.6.1.

(e) See para. 403.10 for allowable stresses of used pipe.

NOTES:

(1) Beam-bending stresses shall be included in the longitudinal stress for those portions of the restrained or unrestrained line that are supported above ground.

(2) Effective stress is the sum of the stress caused by temperature change and from circumferential, longitudinal, and radial stresses from internal design pressure and external loads in pipe installed under railroads or highways.

(3) See para. 403.3.2.

ASME B31.4–2012 STRESS CALCULATION

402.3 Stress From Internal Pressure

For both restrained and unrestrained pipelines, the circumferential (hoop) stress due to internal pressure is calculated as

(U.S. Customary Units)

$$S_H = \frac{P_i D}{2t}$$

402.5 Stress From Thermal Expansion

402.5.1 Restrained Pipe. Thermal expansion stress in restrained pipe is calculated as

$$S_E = E\alpha(T_1 - T_2)$$

402.6 Longitudinal Stress

402.6.1 Restrained Pipe. Longitudinal stress in restrained pipe is calculated as

$$S_L = S_E + \nu S_H + \frac{M}{Z} + F_a/A$$

ASME B31.4–2012 STRESS CALCULATION

402.7 Combining of Stresses

In restrained pipe, the longitudinal and circumferential stresses are combined in accordance with the maximum shear stress theory as follows:

$$S_{eq} = 2\sqrt{[(S_L - S_H)/2]^2 + S_t^2}$$

where

S_{eq} = equivalent combined stress

When S_t can be disregarded, the combined stress calculation can be reduced to the following:

$$|S_L - S_H|$$

such that when $S_L < 0$, $|S_L| \le (S_x - S_H)$, and when $S_L > 0$, $S_L \le (S_x + S_H)$

where

S_x = axial stress, psi (MPa)

Alternatively, the stresses may be combined in accordance with the maximum distortion energy theory as follows:

$$S_{eq} = \sqrt{S_H^2 - S_H S_L + S_L^2 + 3S_t^2}$$

where

S_t = torsional stress, psi (MPa)

ASME B31.4–2012 ACCEPTANCE CRITERIA

403.3.3 Strain Criteria for Pipelines. When a pipeline may experience a noncyclic displacement of its support (such as fault movement along the pipeline route or differential support settlement or subsidence along the pipeline), the longitudinal and combined stress limits may be replaced with an allowable strain limit, so long as the consequences of yielding do not impair the serviceability of the installed pipeline. The permissible maximum longitudinal strain depends upon the ductility of the material, any previously experienced plastic strain, and the buckling behavior of the pipe. Where plastic strains are anticipated, the pipe eccentricity, pipe out-of-roundness, and the ability of the weld to undergo such strains without detrimental effect should be considered. Maximum strain shall be limited to 2%.

COVERSHEET

DATE: May 16, 2023

FROM: [redacted]

This Risktec Memo dated February 6, 2023 identifies an outdated January 17, 2023 SGH Memo.

The SGH recommendation at the time was to operate the F24 system at [redacted] psi and JP5 at [redacted] psi.

Updated recommendations are as follows:

1) F24: [redacted] psi. The SGH May 16, 2023 Memo further analyzed F24 pipeline stress based on improvements which have been made and recommended derating to [redacted] psi (basic + occasional loads).
2) JP5: [redacted] psi. EEI recommended derating the JP5 system to [redacted] psig (basic + occasional loads) near [redacted] to eliminate the overstress condition at the miter joints.

These new pressure limits are still above calculated surge levels and do not change the analysis and conclusions of the Memo.

MEMORANDUM

DATE: February 6, 2023

TO:

FROM: [redacted]

RE: Defueling Flowrate Surge Limitations

Introduction

This memo serves to quantify acceptable flowrates with surge mitigation for both the F-24 and JP-5 Red Hill pipelines during the 2023 defueling event.

This memo is based on information and recommendations provided in the 2023 Defueling Plan CONOP, EEI 2010 Hydraulic and Surge Evaluation, SGH April 2022 Report, and SGH 17 Jan 2023 Memo.

The 2022 and 2023 SGH reports detail recommended repairs on the Red Hill Pipeline and provide Maximum acceptable surge pressures based on various levels of repair.

The 2010 Hydraulic and Surge Evaluation provides maximum unrestricted flowrates and resulting surge pressures from gravity flow for over 300 surge cases.

The Defueling Plan directs the loading of commercial tankers at [redacted] from Red Hill through [redacted] via gravity flow. [redacted]

F-24 Pipeline

SGH 2023 – [redacted] **psi** Maximum surge rating for currently scheduled repairs.

Exceedance Surge Potential – at [redacted] GPM – EEI 2010

[redacted]

Mitigations

4b/b1 – This case requires [redacted] or [redacted] or [redacted] to close. The current condition of the fire valves has very slowed operation often requiring manual valve operation. **1)** Locking [redacted] OPEN or manual mode would prevent this surge case. **2)** Utilizing both the [redacted] starting at the [redacted] would allow for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

4c – This case requires throttle valve [redacted] to be fully actuated from 100% to 0%. **3)** Operations order to include throttle valve stepping amounts for cushioning and shutdown rates. **4)** Operations order to include both [redacted] for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

4d2 – This case requires closing [redacted] **2)** Utilizing both the [redacted] starting at the [redacted] would allow for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

4e – Due to gearing, this manual valve's closure speed is a minimum of [redacted]. Additionally, the closure of 2 manual valves at the maximum closure speed at the same time is unlikely.

4f/g – This will depend on the ship. A commercial tanker with [redacted] would have to close [redacted] valves at their max closure rate to potentially cause a surge. The robust commercial procedures mitigate this, along with the relief system on most commercial tankers. Additionally, the closure of [redacted] valves at the maximum closure speed at the same time is unlikely.

JP-5 Pipeline

SGH 2023 – [redacted] **psi** Maximum surge rating for currently scheduled repairs.

Exceedance Surge Potential – at [redacted] GPM – EEI 2010

[redacted]

[redacted]

<u>Mitigations</u>

7b/b1 – This case requires [redacted] to close. The current condition of the fire valves has very slowed operation often requiring manual valve operation. **1)** Locking [redacted] OPEN or manual mode would prevent this surge case. **2)** Utilizing both [redacted] starting at the [redacted] would allow for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

7c – This case requires throttle valve [redacted] to be fully actuated from 100% to 0%. **3)** Operations order to include throttle valve stepping amounts for cushioning and shutdown rates. **4)** Operations order to include both [redacted] for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

7d2 – This case requires closing [redacted]. **2)** Utilizing both the [redacted] starting at the [redacted] would allow for alternate flow, prevent single-valve surge, and reduce maximum surge pressure.

7e2/5 – Due to gearing, this manual valve's closure speed is a minimum of [redacted]. Additionally, the closure of [redacted] valves at the maximum closure speed at the same time is unlikely.

7f/f1 – This will depend on the ship. A commercial tanker with [redacted] would have to close [redacted] valves at their max closure rate to potentially cause a surge. The robust commercial procedures mitigate this, along with the relief system on most commercial tankers. Additionally, the closure of [redacted] valves at the maximum closure speed at the same time is unlikely.

Conclusions

Implementing the following recommendations will mitigate the requirement to throttle gravity flowrate by keeping potential surge pressures within the current pipeline rating.

Recommendations to prevent surge outside of pipeline rating		
Recommendation	**Priority**	**Difficulty**
1) Lock [redacted] OPEN or in manual mode.	**High**	**Low**
2) Utilize both the [redacted] starting at the [redacted]	***Medium***	***Medium***
3) Operations order to include throttle valve stepping amounts for cushioning and shutdown rates.	**Medium**	**Low**
4) Operations order to include both [redacted]	**Medium**	**Low**
***Recommendation **2** for JP-5 will require a flush of the inside loop if a JP-5 truck load is needed when [redacted] are defueled ***Recommendation **1** to lock open fire and ball valves can be substituted for recommendation **2**		

Appendix

-These mitigations align with the 2010 EEI report pg. 25.

F-24

2. During full-flow issue operations ([redacted] BPH) to [redacted], closure of the [redacted] has the potential to generate surge pressures as high as [redacted] psig. This exceeds the surge limit of even a fully qualified [redacted] system. The actual closure speeds on these valves is relatively long ([redacted]), though none of them have matching closure speeds. Based on observations made from the other products, surge pressures are lowest when the valves finish closing at the same time. EEI recommends that the motor operators on these valves be serviced or replaced such that they all close slowly ([redacted]) and all close at the same rate. Limiting flow rate may also assist in reducing the surge potential.

3. Closure of the butterfly valve in the [redacted], even at full flow, does not generate surge pressures above the allowable pressure for a fully-qualified [redacted] line. This valve should be used as the primary throttling and/or operation-stopping valve.

4. Closure of the manual ball valve at the [redacted] during full-flow issue operations ([redacted] BPH) to [redacted], has the potential to create damaging levels of pressure throughout the piping system. Recommended options are:

- a. Accept the risk (do nothing)
- b. Limit issue rates (recommended flow rate not determined)
- a. Re-qualify [redacted] piping to [redacted] pressure ranges ([redacted] is currently not qualified to pressures over that of a [redacted] pound system.)
- c. Install hard-piped loading arms.
- d. Install a surge mitigation system on or near the pier.
- e. Establish operating procedure to issue through both the [redacted] once MILCON P-200 piping upgrades are complete (will reduce pressures in [redacted] piping to within acceptable limits).

5. Following completion of the P-200 piping replacement, overpressure will still occur in nearly all existing piping due to closure of valves in [redacted] when issuing to [redacted] at full flow through [redacted]. The only segment of pipe that is not over-pressurized is the [redacted].

6. Using [redacted] following completion of the P-200 changes will significantly reduce surge potential for many initiators. Closure of valves which have all of the flow passing through them (such as a [redacted]) still create high surge pressures.

JP-5

2. During full-flow issue operations ([redacted] BPH) to [redacted], closure of the [redacted]) has the potential to generate high surge pressures when flowing through the [redacted]. One of the [redacted] valves closes significantly faster than the rest, creating a high potential for surge. The outer loop, where both [redacted], has no concerns with surge pressures. EEI recommends that the motor operators on these valves be serviced or replaced such that they all close slowly ([redacted] or full closure) and all close at the same rate.

3. Full closure of the butterfly valve in the [redacted] generally appears to create the lowest surge pressure of any potential initiator, and therefore should be used as the primary means of throttling and stopping flow during operations.

4. Closure of the [redacted], during full flow from Red Hill (7[redacted] BPH) can create high surge pressures throughout the piping system (over [redacted] psig at the pier and over [redacted] psig in Red Hill tunnel). Recommended options are:

a. Accept the risk (do nothing)

a. Re-qualify [redacted]

b. Limit issue rates to [redacted] BPH (today's normal issue rate per field observations)

c. Install hard-piped loading arms (does not help Red Hill if implemented alone).

d. Install a surge mitigation system on or near the pier (further analysis required to determine the effectiveness and feasibility)

-These mitigations align with the 2023 SGH memo pg. 32.

We recommend that the lower skillet in the F-24 line near [redacted] be replaced with a pressure-rated blind flange and that the upstream portion of the F-24 pipeline be reconnected. In this case, a maximum allowable surge pressure of [redacted] psi (or [redacted] psi if the pipe is allowed to yield) can be achieved as per our detailed FE analysis.

-Additional repairs from 2022 SGH report pg. 392 may increase surge pressure rating for F-24.

[redacted]

Pearl Harbor JP-8 Surge Analysis

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]