HAZOP Study and Design Alternatives for Pfizer's Chlorine System

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The Categories of HAZOP

A hazard and operability (HAZOP) study refers to the critical analysis of a process to identify safety or production risks [1].

INTENTION

- Purpose of equipment

DEVIATION

- Departures from the designer's purpose detected by guidewords

CAUSES

- Reasons for how or why the deviation may have occurred

CONSEQUENCE

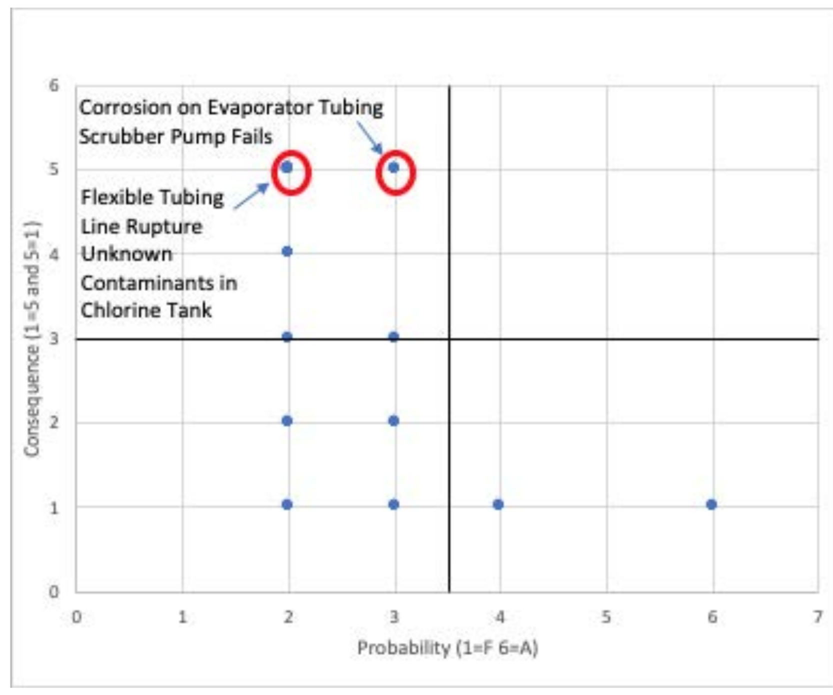
- Result following the deviation occurrence

SAFEGUARDS

- Factor to reduce risk to an acceptable level

HAZOP Findings

Below are the higher risk rated findings discovered:



HAZOP Finding	Risk Ranking
Corrosion on Evaporator Tubing	7
Flexible Tubing Line Rupture	11
Unknown Contaminants in Chlorine Tank	11
Scrubber Pump Fails	11

Figure 1: (Left) A Boston Square of all 50 HAZOP findings from the extensive chlorine handling study, and (Right) an itemized table of the higher risk HAZOP rankings.

Key Recommendations

Material of Construction Change for Evaporator Internals

Carbon Steel Tubes

- Over 15 years, 16.7% corrosion

Tantalum Replacement

- Negligible corrosion
- 0.2'' thickness

New Risk Ranking

- Adjusted from 7 to 16

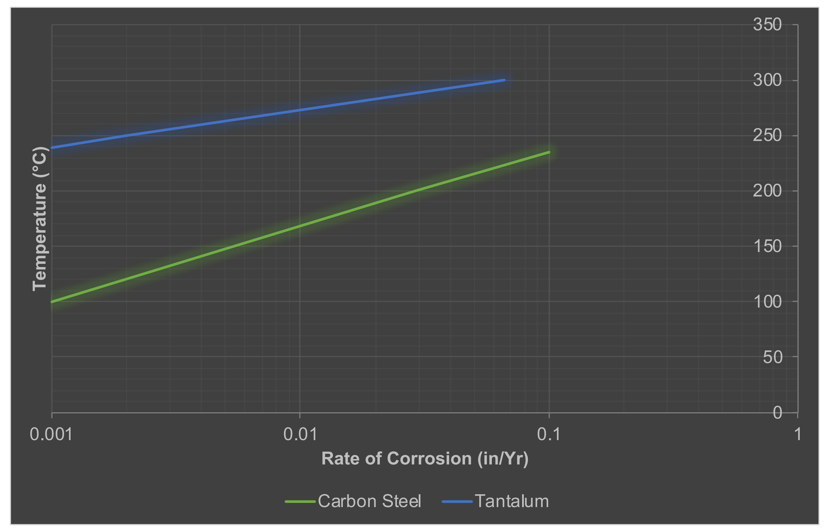


Figure 2: Corrosion rates of carbon steel and tantalum in the presence of liquid chlorine [2]

Spool Piece Design to Replace Flexible Tubing

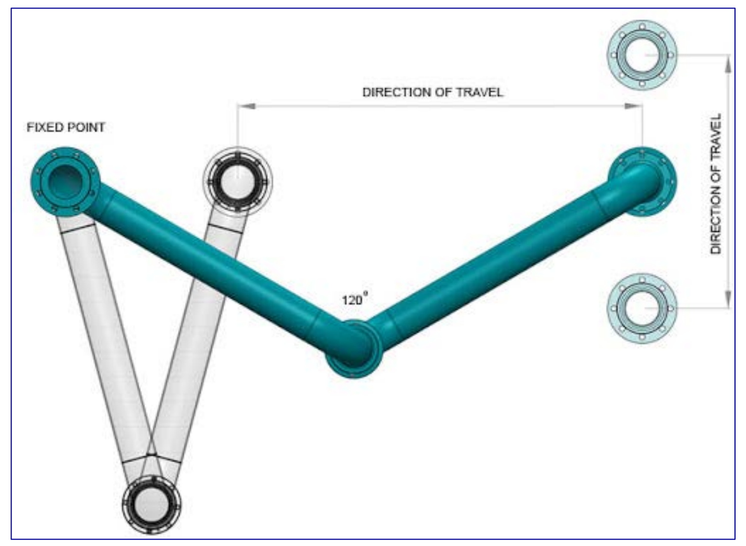


Figure 3: Theoretical spool piece design to replace flexible in-process tubing [3].

Specifications

- Flange class: 300
- Diameter: ½"
- Bolt pattern: 8 bolt

Material of Construction

- Carbon steel

New Risk Ranking

- Adjusted from 11 to 16

Chlorine Tank Composition Analyzer

InPro 7250HT PEEK Conductivity Sensor

- Suitable for hazardous areas and chemicals
- Conductivity for liquid chlorine is 1000 uS/cm and water is 10 uS/cm

New Risk Ranking

- Adjusted from 11 to 16

Figure 4: Chlorine Composition Analyzer from Mettler Toledo [4]

Scrubber Back-Up Pump

Scrubber Recirculation Pump Duplicate

- Requires two three-way valves to be implemented

New Risk Ranking

- Adjusted from 11 to 16

Design Alternatives

Heated Tank Design

Amount of Heat Needed to Create Gaseous Chlorine

- $\Delta T = Q / (U*A)$
- $U = 10$ W/(m^2*K)
- $A = 11$ m^2
- $Q = 250{,}000$ kW
- $\Delta T = 9.2$ °C
- U is the assumed value for convective heat transfer

Risk Ranking Analysis

- Removes risks associated with the evaporator
- Produces a confined space hazard

Making Chlorine Onsite with Salt Water Electrolysis

With salt water electrolysis, for every ton of chlorine generated, 2.25 tons of 50% sodium hydroxide (caustic) and 340 cubic meters of hydrogen will also be produced.

Advantages

- Mitigates evaporator and direct chlorine handling hazards
- Produces usable side products

Disadvantages

- Hydrogen flammability risks
- Caustic handling risks
- High energy costs and safety risks

	Mercury	Diaphragm	Membrane
construction costs	expensive	relatively cheap	cheaper than mercury cell
operation	toxic mercury must be removed from effluent	frequent asbestos diaphragm replacement	low maintenance costs
NaOH product concentration	high purity 50%- as required	less pure 12%- needs concentration	high purity 30%-needs concentration
typical cell energy consumption (kw hours per tonne of chlorine)	3 360	2 720	2 500
steam consumption per caustic evaporation	nil	high	medium
purity of brine	important	important	very important

Figure 5: Electrolysis cell comparison for chlorine production [5]

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