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Corrosion of carbon steel caustic header in the presence of chloride ions

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ABSTRACT

Caustic soda produced in caustic cells at a petrochemical plant was loaded into a crude tank by means of a caustic header line made of plain carbon steel. After a fraction of expected service life, the header was severely corroded. Scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS) and X-ray diffraction (XRD) was used to identify the material and the corrosion product. Metallurgical evaluation suggested that the mode of failure was localized attack by chlorine and/or hydrochloric acid at pipe connections (flanges) where concentrated solutions could accumulate. Most evidence pointed out that the failure resulted from corrosion attack due to condensation of hydrochloric acid. Misalignment of the pipe at the flange led to cold work which is also thought to accelerate the corrosion rate. It was recommended to consider a better pipe alignment practice as well as the addition of an inhibitor as a short-term solution. Since the piping system was used close to the critical operating conditions, it was recommended as a long-term solution to replace the caustic header material by one of the higher grades Ni–Cr–Mo alloys.

1. Background

A petrochemical plant produced ~500,000 tons of caustic soda (sodium hydroxide, NaOH) annually. The caustic soda was produced by feeding both salt (NaCl) and water into caustic cells, thereby resulting in the following basic reaction:

$$2NaCl(aq) + 2H_2O \rightarrow Cl_2(gas) + H_2(gas) + 2NaOH(aq)$$

Some of the water fed into the caustic cell was consumed in the above reaction and the remainder left the cell as saturated vapor along with chlorine and hydrogen gases. In this process, it is necessary to prevent reaction of the NaOH with the chlorine which was accomplished by means of an ion selective membrane or porous membrane. Caustic soda was transferred into a crude tank using caustic header line consisting of 10 in. and 16 in. diameter pipes as schematically illustrated in Fig. 1.

After a short period of usage, severe corrosion occurred particularly concentrated at two locations of the 16 in. header. At the top section, corrosion initiated in the flange and extended about 1.5 m into the pipe as illustrated in Fig. 1. However, at the bottom section, corrosion occurred in the flange only. Four sections of the failed pipe/flange were evaluated as described below:

(a) One section of the 16 in. diameter flanged pipe removed from the top section.
(b) One section of the 16 in. diameter pipe removed from the top section.

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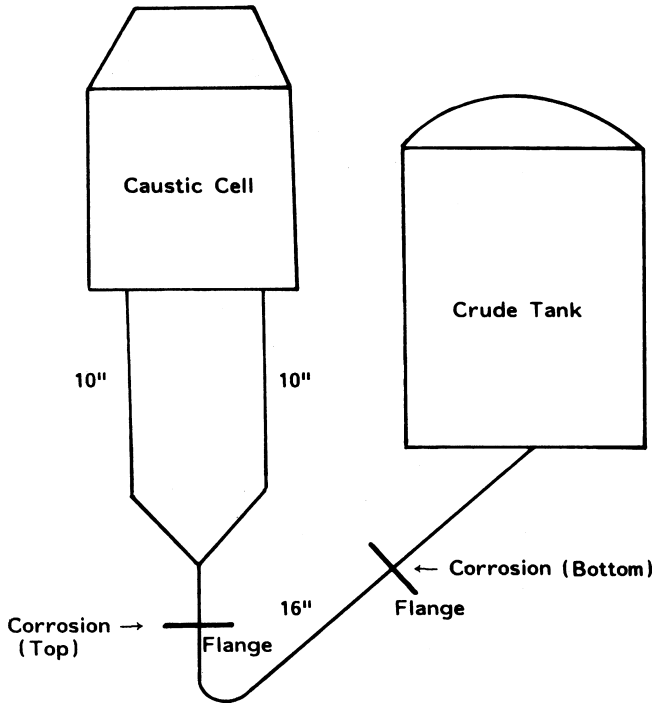

Fig. 1. Schematic illustration of the caustic cell and the locations of corrosion attack.

(c) One section of the l0 in. diameter flanged pipe.
(d) One section of the l0 in. diameter pipe.

Also, corrosion deposit removed from the 16 in. diameter flanged pipe at the top section was characterized. Table 1 summarizes the design specifications of the caustic header. It was the objective of this investigation to metallurgically evaluate the corroded caustic header to identify the mode of failure, determine the cause of failure, and provide proper recommendations to combat the problem.

2. Experimental procedure

Selected specimens were prepared from the as-received sections of the header for metallurgical evaluation. Specimens were examined in the as-received, polished and etched conditions. All specimens were etched in nital solution (2.5% nitric acid). Microstructural features were characterized using scanning electron microscopy (SEM) in the emissive mode. Chemical analysis of the header and flange materials as well as the corrosion deposit was conducted by energy dispersive X-ray spectroscopy (EDS) in the SEM. Phase analysis of the corrosion deposit was carried out by X-ray diffraction (XRD).

3. Results and discussion

3.1. Visual inspection

Visual inspection revealed that the corrosion attack was localized in nature. The 16 in. diameter caustic header lost its structural integrity as a result of an attack by what appeared to be a highly corrosive environment. Metal wastage occurred

Table 1
Design specifications of the caustic header

Size (in.)	16
Pipe material	API 5LB STD
Operating temperature (°C)	110
Design pressure (kPa)	1035
Service	11–13% caustic with 12–15% NaCl, 0.4–0.8% Sodium sulfate and 5–50 ppm sodium hypochlorite
Flow (m^3/d)	2542
Velocity (ft/s)	0.74
Flange material of 10 in. pipe	590 MFF 10 150 B16A105N STD 42238 Italy