

Nickel Based Alloy Casting Failure in Potash Production Mill

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ABSTRACT

A nickel-based alloy knife gate valve exposed to hot potash brine failed in less than two years in service. Failure was realized when the valve was unable to stop the flow. Visual examination of the valve internal body parts revealed heavy scaling and corrosion damage, although the center body part and the two knife gates were intact. Corrosion scale samples were subjected to chemical analysis by X-ray diffraction (XRD) augmented by energy dispersive X-ray spectroscopy (EDS). The XRD technique was unable to identify approximately 85% of the components in the scale due to lack of crystallinity. The crystalline portion of the scale was found to contain a mixture of molybdenum, chromium, nickel and tungsten oxides, and trace amounts of tungsten carbide and nickel sulphate. EDS analysis revealed high concentrations of oxygen, molybdenum and tungsten. Metallographic examination of the corroded surface revealed preferential attack of the inter-dendritic secondary phases in the cast microstructure. The results of the examinations show, the higher carbon content in the cast alloy had consumed a portion of the corrosion resisting alloying elements by forming carbide precipitates. This resulted in the depletion of corrosion resisting alloying elements in localized areas. These depleted localized areas were therefore susceptible to corrosion attack upon exposure to corrosive process fluids.

Key words: Potash, knife gate valve, cast Ni-Cr-Mo alloy, inter-dendritic secondary phases, corrosion.

INTRODUCTION

Potash is mined from deep underground deposits left by ancient inland seas or extracted from saltwater bodies. The typical composition of potash is 40% potassium chloride (KCl), 55% sodium chloride

(NaCl) and 5% clay. About 95% of potash is used for fertilizer in agriculture; the remaining 5% is used in commercial and industrial products such as soap, water softeners, de-icers, drilling muds etc.

Corrosion is one of the major problems in the potash production industry which can affect the stable and continuous operation of the plant. Metallic materials are susceptible to corrosion due to the high concentration of dissolved chlorides in the potash brine. Corrosion resistant nickel-based alloys are often used for process piping, fittings, valves and equipment to prolong their service life.

This paper investigates the failure of an NPS 10-inch, Class 150 dual knife gate valve after less than two years in service.¹ The upstream and downstream segments of the valve body was a cast UNS ⁽¹⁾ N30002 nickel-based alloy,² while the gates and center body part were manufactured from UNS N10276 nickel-based alloy wrought plate.³ This valve was part of a process piping system containing hot saturated KCl and NaCl potash brine which had been operated at 100 °C and 170 kPa with a maximum flow rate of 8500 L/min. It was understood that this piping was also regularly exposed to an acidic descaling chemical containing hydrochloric acid (HCl). Figure 1 shows the failed valve after it was removed from service.



Figure 1: Knife gate valve

EXPERIMENTAL PROCEDURE

Visual Examination

The name plate attached to the valve body specified the valve body material as “HC”. Reference to the valve manufacture’s product literature indicates “HC” meaning the valve body is ASTM A494 ⁽²⁾, material grade CW12MW UNS N30002 nickel-based alloy casting. Visual examination of the internal surface of the upstream valve body revealed heavy scale buildup and evidence of corrosion damage in the bore of the bottom U-shaped region, while the downstream valve body part exhibited less scale buildup and corrosion damage. The center body part and the two knife gates, specified as UNS N10276 nickel-based alloy wrought plate, did not show any evidence of scale buildup or corrosion damage. Figure 2 shows the valve body parts after being dismantled for examination. Figure 3 shows the ASTM casting grade markings that were present on the upstream and downstream body parts. Figure 4 provides a comparison of scale buildup and corrosion damage between the upstream and downstream valve body parts. Figure 5 shows the valve body center part and Figure 6 shows one of the two knife gates.

⁽¹⁾ Unified Numbering System for Metals and Alloys (UNS). UNS numbers are listed in Metals and Alloys in the Unified Numbering System, 10th ed. Warrendale, PA: SAE International and West Conshohocken, PA: ASTM International, 2003.

⁽²⁾ ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 1942-2959.



Figure 2: Disassembled internal parts



Figure 3: ASTM Casting Grade on valve body



Figure 4: Upstream and downstream valve body



Figure 5: Center valve body no corrosion



Figure 6: Knife gate no corrosion

The inner surfaces of the three separated body parts were sandblasted to remove residual scale deposits. Examination of the sandblasted upstream and downstream body parts revealed areas of severe corrosion damage. Figure 7 shows severe corrosion damage present in the bore at the bottom of the upstream body. Figure 8 shows broad patches of less severe corrosion damage in the upper part of the upstream component. Figure 9 shows corrosion damage on the opposite side of the upstream body part around the bottom bore perimeter.