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# FINAL REPORT

## Determining the Effects of Ethanol on Pump Station Facilities

PRCI Project CPS-9-2 Report – Phase 1
**Contract PR-186-09204**
DNV Columbus, Inc. Project EP001681

Prepared for the

Compressor and Pump Station Technical Committee of

**Pipeline Research Council International, Inc.**


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## RESEARCH SUMMARY

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| **Title:** | Determining the Effects of Ethanol on Pump Station Facilities |
| **Contractor:** | DNV Columbus, Inc. (formerly CC Technologies, Inc.) |
| **Principal Investigators:** | Gregory T. Quickel, M.S. and John A. Beavers, FNACE, Ph.D. |
| **Objectives:** | The objective of this project was to investigate ethanol – materials compatibility issues for components involved in pump station facilities. |
| **Scope:** | The project is divided into three phases; Survey of Knowledge and Gaps (Phase 1), Detailed Study to Close Gaps Identified in Phase 1 (Phase 2), and Development of Guidelines (Phase 3). This report summarizes the results of Phase 1. This phase consisted of three Tasks, Industry Survey (Task 1), Literature Search (Task 2), and Report (Task 3). |
| **Technical Perspective:** | Ethanol has been used for the last several years as an environmentally friendly alternative to methyl tertbutyl ether (MTBE), which is an oxygenate additive to gasoline, to increase octane levels, and to facilitate the combustion process. However, the need to find alternatives to imported oil and gas has spurred the increased use of ethanol as an alternative fuel source. Further, ethanol is being promoted as a potential trade-off for $CO_2$ emissions from the burning of fossil fuels since $CO_2$ is consumed by the plants used as the ethanol source. Legislation mandates a significant increase in ethanol usage as fuel over the next twenty years. The widespread use of ethanol will require efficient and reliable transportation from diverse ethanol producers to distribution terminals. Pipelines are, by far, the most cost-effective means of transporting large quantities of liquid hydrocarbons over long distances. For transporting ethanol, both existing pipeline infrastructure and new pipeline construction are being contemplated.<br><br>In companion PRCI projects, the stress corrosion cracking (SCC) of pipeline steels and the performance of elastomer seals/gaskets are being studied. The SCC study not only includes piping grade steel, but also a cast steel that could be used in pumps. Many of the issues related to corrosion are being resolved in these projects. However, to completely address the effect of ethanol and |

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| **Technical Perspective:** (continued) | ethanol-gasoline blends in pipeline systems, investigation of the effects of ethanol on other components, such as pumps, valves, screens, springs, and metering devices should be investigated. These components may have different materials (e.g., non-ferrous alloys), different types of loading, and different exposure conditions. |
| **Technical Approach:** | The first task in Phase 1 of this project involved sending out an industry survey regarding materials in pump stations. This task was performed to determine what components are important from a facilities point of view and what materials are used in these components. The information from the survey was organized into a table that is attached as an appendix to this report. Additionally, manufacturers of the components were contacted in order to determine the materials present in the components in the pump stations. The requests for bill of materials or materials for specific part numbers were performed by email and/or phone calls.<br><br>The second task involved performing a literature search. The survey focused on data from the literature on the ethanol exposure effects of materials involved in various pump station components. The open literature, as well as company reports, was considered. Previous literature surveys conducted for PRCI SCC 4-1 and 4-4, and API, were utilized. The open literature search was performed using two search engines; Engineering Village and Science Direct. The keywords in the search included ethanol, corrosion, failure, various non-ferrous metals, stainless steels, and elastomers/plastics. |
| **Results:** | A number of different materials were found to be present in the components in pump stations. Metals included carbon and low alloy steels, stainless steels, pure nickel, bronzes, and aluminum alloys. There was a variety of stainless steels in pump station components including 300 series (austenitic, high nickel), 400 series (ferritic/martensitic, low nickel) and precipitation hardened alloys. Zinc and titanium were included in the literature search results; although they were not identified in pump station equipment. Non-metallic materials in pump station components include ceramics, fiberglass, Buna N and butadiene rubbers, polyurethane, Teflon, PEEK, Viton®, and nylon.<br><br>No information was found on the performance of ceramic materials in ethanol and the literature on the performance of metallic materials in ethanol is relatively limited. More information was found on elastomer compatibility in ethanol. Information on compatibility in actual FGE was generally more limited than that in other ethanolic solutions. |

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| **Results:** **(**continue) | The materials compatibility data were divided into four different categorizations. *Not Compatible* indicates that sufficient information was found to establish that the class of materials is not compatible. *Probably Not Compatible* indicates that information was limited but the available information suggests that the class of materials is not compatible. *Probably Compatible* indicates that information was limited but the available information suggests that the class of materials is compatible. *Compatible* indicates that sufficient information was found to establish that the class of materials is compatible.<br><br>Zinc and aluminum are not compatible metallic materials in ethanol. Aluminum has exhibited pitting and SCC in ethanol, while zinc has exhibited high rates of general corrosion, pitting, and intergranular attack in ethanol. Titanium is probably not compatible, as it has been reported to be susceptible to SCC in ethanol. With the exception of brasses and other copper alloys that contain significant concentrations of zinc, copper base alloys, nickel base alloys, and stainless steels are probably compatible in ethanol, but more testing is needed on SCC behavior given the limited information on this failure mode and the SCC experience with carbon steels. There was insufficient information in the literature to confirm the compatibility of any metallic materials.<br><br>With respect to elastomers, all available information indicates that Teflon, PEEK, and Viton® are compatible with FGE. Nylon (limited information) and Nitrile (Buna N) probably are compatible with FGE. There may be some issues with swelling in the gasoline – ethanol blends in the case of PEEK (limited information) and Nylon (limited information), some Viton® elastomers (swelling in gasoline), and Nitrile (swelling significantly in 0% ethanol to E-85). Polyurethane is not compatible. |
| **Project Implications:** | • There was insufficient information in the literature to confirm the compatibility of any of the metallic materials.<br>• Additional research is necessary, primarily in the area of SCC, to confirm the compatibility of the metallic materials in ethanol. These materials include copper base alloys (excluding brasses), nickel base alloys, and stainless steels.<br>• Aluminum alloys, which are found in some pump station components, should not be used in ethanol service. Brasses, which contain zinc, are likely to exhibit corrosion problems. |

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| **Project Implications:** (continued) | • A number of elastomeric materials are compatible in ethanol, including Teflon, PEEK, and Viton®. Other elastomers, nitrile rubber, and nylon probably are compatible in ethanol but might exhibit swelling problems in gasoline or ethanol-gasoline blends. One Viton®, Viton® A, also exhibits swelling problems in gasoline and ethanol - gasoline blends containing high gasoline concentrations.<br>• Polyurethane is not compatible with ethanol. |
| **Project Manager:** | John Beavers |

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13. ABSTRACT

There is interest within the pipeline industry in transporting fuel grade ethanol in petroleum pipelines. A significant issue is compatibility of the pipeline materials with ethanol. Other research programs are addressing compatibility issues with elastomers and pipeline steel construction materials. The objective of this project is to investigate ethanol - materials compatibility issues for components involved in pump station facilities. The project is divided into three phases; Survey of Knowledge and Gaps (Phase 1), Detailed Study to Close Gaps Identified in Phase 1 (Phase 2), and Development of Guidelines (Phase 3).

This report summarizes the results of Phase 1. This phase consisted of three Tasks; Industry Survey (Task 1), Literature Search (Task 2), and Report (Task 3). There was insufficient information in the literature to confirm the compatibility of any of the metallic materials, primarily because of the absence of information on the stress corrosion cracking behavior. Never the less, several of these metallic materials are probably compatible; these include copper base alloys (excluding brasses), nickel base alloys, and stainless steels. A number of elastomeric materials are compatible in ethanol, including Teflon, PEEK, and Viton®. Other elastomers, nitrile rubber, and nylon probably are compatible in ethanol but might exhibit swelling problems in gasoline or gasoline ethanol blends. One Viton®, Viton® A, also exhibits swelling problems in gasoline and ethanol-gasoline blends containing high gasoline concentrations. Polyurethane is not compatible with ethanol.

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## 1.0 BACKGROUND

Ethanol has been used for the last several years as an environmentally friendly alternative to methyl tertbutyl ether (MTBE), which is an oxygenate additive to gasoline, to increase octane levels, and to facilitate the combustion process. However, the need to find alternatives to imported oil and gas has spurred the increased use of ethanol as an alternative fuel source. Further, ethanol is being promoted as a potential trade-off for $CO_2$ emissions from the burning of fossil fuels since $CO_2$ is consumed by the plants used as the ethanol source. Legislation mandates a significant increase in ethanol usage as fuel over the next twenty years. The widespread use of ethanol will require efficient and reliable transportation from diverse ethanol producers to distribution terminals. Pipelines are, by far, the most cost-effective means of transporting large quantities of liquid hydrocarbons over long distances. For transporting ethanol, both existing pipeline infrastructure and new pipeline construction are being contemplated.

In companion PRCI projects, the stress corrosion cracking (SCC) of pipeline steels and the performance of elastomer seals/gaskets are being studied. The SCC study not only includes piping grade steel, but also a cast steel that could be used in pumps. Many of the issues related to corrosion are being resolved in these projects. However, to completely address the effect of ethanol and gasoline-ethanol blends in pipeline systems, investigation of the effects of ethanol on other components, such as pumps, valves, screens, springs, and metering devices should be investigated. These components may have different materials (e.g., non-ferrous alloys), different types of loading, and different exposure conditions.

The objective of this project is to investigate ethanol - materials compatibility issues for components involved in pump station facilities. Materials investigated included non-ferrous alloys, stainless steels, and elastomers/plastics.

This project is divided into three phases; Survey of Knowledge and Gaps (Phase 1), Detailed Study to Close Gaps Identified in Phase 1 (Phase 2), and Development of Guidelines (Phase 3). This report summarizes the results of Phase 1. This phase consisted of three tasks; Industry Survey (Task 1), Literature Search (Task 2), and Report (Task 3).

## 2.0 TECHNICAL APPROACH

The first task of this project involved sending out an industry survey regarding materials in pump stations. This task was performed to determine what components are important from a facilities point of view and what materials are used in these components. The experiences of companies involved in PRCI/API projects, Petrobras, Kinder Morgan, and European Companies as relevant were included in this survey. The survey letter is shown in Appendix A. The following information was requested in the survey: Component #, Component Type, Component Manufacture, Component Information, Application, Probable Material, Environment, and Experience. Examples of Applications are pump station components and loading racks in a blending facility. Examples of Environments are fuel grade ethanol (FGE), ethanol-gasoline blends, or a specific blend (e.g., E-85 [85 volume % ethanol – 15 volume % gasoline]). Examples of Component Types are pumps, valves, and metering devices. Examples of Component Information are diameters and construction materials. The information from the survey was organized into a table. Additionally, manufacturers of the components were contacted in order to determine the materials present in the components at the pump stations. The requests for bill of materials or materials for specific part numbers was performed by email and/or phone calls.

The second task involved performing a literature search. The survey focused on putting together data from the literature on the ethanol exposure effects of materials involved in various pump station components. The open literature, as well as company reports, were considered. Previous literature surveys conducted for PRCI SCC 4-1 and 4-4, and API, were utilized. The open literature search was performed using the search engines Engineering Village and Science Direct. The keywords in the search included ethanol, corrosion, failure, various non-ferrous metals, stainless steels, and elastomers/plastics.

## 3.0 RESULTS AND DISCUSSION

The table constructed from the industry survey is shown in Appendix B. The information from the survey was organized with the following headers: Component, Application, Materials, Manufacturer, Model #, and Additional Information. The table is sorted by Application and then by Component. Although it was not possible to identify all of the materials, it appears (based on the repeating of materials for different applications) that the various widely used non-ferrous metals, stainless steels, and elastomers/plastics were identified. Additionally, the material information provided is from vintage components, and some from newer components. All of the information supplied by one component manufacturer (Smith) is for newer components.

Table 1 is a summary of the ceramics identified in the pump stations. Table 2 is a summary of the elastomers/plastics identified in the pump stations. Table 3 is a summary of the non-ferrous metals identified in the pump stations. Table 4 is a summary of the stainless steels identified in the pump stations. Column 1 lists the materials, Column 2 provides a description of the materials, and Column 3 provides the application and/or component that the material is associated.

Information regarding ethanol compatibility was identified in the literature for the following elastmors/plastics: Buna N (nitrile), polyurethane, TFE (Teflon), PEEK, Viton®, and nylon. Information regarding ethanol compatibility was identified in the literature for the following non-ferous metals: 7075 Al, aluminum bronze, bronze, Ni 200, and Ni-Cr-Fe-Mo alloy. Information regarding ethanol compatibility was identified in the literature for the following stainless steels: 302SS, 303SS, 304SS, 316SS, 317SS, 17-4 PH, and 440C. Performance information for these materials in FGE, ethanol-gasoline blends and related environments is provided below.

## 3.1 Non Ferrous Metals

Table 5 and Table 6 list corrosion rates from tables in the literature. Table 5 is a summary of the non-ferrous metals and stainless steels specifically identified in the pump stations along with corrosion rate information. Table 6 is a summary of the non-ferrous metals and stainless steels identified in the literature search that could be present in the pump stations (along with corrosion rate information). Column 1 lists the materials and Column 2 provides a description of the corrosion rates at various temperatures and concentrations of ethanol. Because differing rates, concentrations, and temperatures are given for different references, reference numbers are listed at the end of each description.

### 3.1.1 Aluminum/Aluminum Alloys

Aluminum samples tested in ethanol have experienced low corrosion (less than 2 mils per year) at low temperatures and higher corrosion rates (less than 20 mils per year) at higher temperatures (~200°F).[1, 2, 3] Aluminum alloys are reportedly compatible with E-10 (10 volume % ethanol – 90 volume % gasoline) and not compatible with E-85.[4, 5, 6] Aluminum alloys are known to degrade in ethanol/gasoline blends containing high percentages of ethanol. Active metals, such as aluminum, have a higher probability of being galvanically attacked in E-85 than E-10. E-85 is capable of absorbing more water and contaminants, and the increased water content allows E-85 to be more conductive than E-10. Aluminum nozzles for dispensing fuel have corroded in M-85 (85 volume % methanol – 15 volume % gasoline), and although FGE may not be as aggressive as fuel grade methanol (FGM), similar corrosion of aluminum may occur in FGE. All the references (in this report, unless otherwise stated) regarding the compatibility of metals with E-85 appear to be determined based on the location of the material in the galvanic series; see Table 7 for the galvanic series. References to the compatibility of metals to E-10 are based on very few occurrences of reported failures of metals in contact with E-10 in the U.S.

#### 3.1.1.1 Information from the Literature

Wolynec and others[8] discussed how the automotive industry has experienced pitting and intergranular corrosion of aluminum alloy carburetors in hydrated ethanol (HEA). Note that the ethanol was hydrated, and FGE in the U.S. is intended to be anhydrous. Likely due to the limited use of aluminum alloys carburetors in service at the time of publication, no other information was available. However, more modern fuel injection systems may contain aluminum components.

Pathania and others[9] observed SCC of aluminum alloys in various ethanol solutions. SCC was observed for the following combinations: 1) Al-21.5Zn, Al-8.6Mg, and Al-2.6Mg-6.3Zn in anhydrous ethanol (0.1% $H_2O$) and 2) Al-21.5Zn in hydrous ethanol (5% $H_2O$). The time for the crack initiation decreased with increasing initial stress intensity.

Proctor and others[10,11] documented SCC of aluminum alloys (7075-T6 and T651) in ethanol with U-bend testing (T6), cantilever beam (CB) testing (T651), and double cantilever beam (DCB) testing (T651). For the U-bend testing, the samples were stressed and immediately immersed in the ethanol. In dry ethanol, pitting corrosion was observed after 210 days and cracking was observed after approximately 300+ days of U-bend testing. The presence of intergranular cracks was documented.

For the CB and DCB testing, the samples were fatigue pre-cracked. The CB samples were loaded to 60% to 90% of the critical stress intensity factor for failure in air ($K_{IC}$) and the DCB samples were loaded at 70% to 90% of $K_{IC}$. The DCB samples were tested in methanol, ethanol, isopropanol, acetone, heptane, benzene, and carbon tetrachloride. Ethanol and carbon tetrachloride were the most aggressive environments. Cracking was identified in the ethanol environment. Additionally a critical stress intensity factor for SCC growth ($K_{ISCC}$) for T651 (from DCB testing) in ethanol was estimated as 7 to 9 ksi$\sqrt{\text{in}}$, which is very low, indicating a high susceptibility to SCC.

Samples of ethanol were analyzed for the following cases: 1) before testing, 2) after 210 days of U-bend testing of T6 in ethanol and 3) after 210 days of T651 testing of unstressed in ethanol. The samples were analyzed for the presence of aluminum using aluminon as an indicator. Aluminum was not identified for Case 1 and 3 above but was identified in the ethanol after U-bend testing for 210 days (Case 2). The identification of aluminum indicated that corrosion was occurring.

For the U-bend, CB, and DCB tests, the stress corrosion cracks mainly propagated intergranularly, and the morphology of the fracture surfaces were similar to that of aluminum alloys exposed to aqueous cracking environments.

#### 3.1.1.2 Recommendations

Aluminum alloys are not compatible with FGE. No other work is needed.

### 3.1.2 Copper/ Copper Base Alloys

Copper and copper base alloy (brass, bronze, copper-nickel) samples tested in ethanol have experienced low corrosion rates (less than 2 mils per year) at low temperatures and higher corrosion rates (less than 20 mils per year) at higher temperatures (60-400°F). Copper is reportedly not compatible with E-85 (supporting reasons could not be found in literature). Bronze is reportedly compatible with E-85 and E-10. Brass is reportedly compatible with E-10 but not compatible with E-85. Brass is composed mainly of Cu and Zn and there is little to no Zn in bronze (mainly Cu). As is shown below, zinc does not appear to be compatible with E-85 and this is likely why brass is not compatible with E-85.

#### 3.1.2.1 Information from the Literature

Wolynec and others[8] discussed how the automotive industry has experienced severe corrosion of a bronze screen in the fuel tank intake of cars using HEA. The corrosion product on the screen was black in appearance and consisted mainly of copper sulfide. Interestingly, in a fuel filter made of a bronze screen encapsulated in a zinc plated and chromated steel cage, no corrosion of the bronze screen was observed; the zinc coating was severely corroded. It is likely that the brass was cathodically protected, which is consistent with the galvanic series.

Lechner-Knoblauch and others[12] conducted a weight loss study involving copper (99.99%), among other materials, in denatured anhydrous ethanol (<0.03% $H_2O$). Contaminates, such as acetic acid, sodium acetate, sodium formate, and formic acid, were introduced into the ethanol at varying amounts. The ethanol solutions were saturated with air, nitrogen, and oxygen. Weight loss measurements were recorded after 24, 48, 72, and 100 hours of soaking. No weight loss for the three materials was measured in ethanol or ethanol with 50 ppm of chlorides. The presence of contaminants and gases in the ethanol resulted in weight loss. Corrosion rates for copper in ethanol in 1.0, 0.5, 0.1, 0.005, and 0.001 mol/L of formic acid and the presence of oxygen were 2.22 mm/year (87.4 mils/year), 1.72 mm/year (67.7 mils/year), 0.58 mm/year (23 mils/year), 0.28 mm/year (11 mils/year), and 0.05 mm/year (1.9 mils/year), respectively. The weight loss of copper was greatest in the presence of formic acid in the ethanol. Overall, the corrosion rate of zinc (see below) was greater than that of copper when the contaminants were present.

Uller and others[13] presented an electrochemical and immersion testing study. The electrochemical testing study was conducted using brass (SAE 72), among other materials. The materials were tested in Solutions 1 – 4 shown in Table 8. Overall, the corrosion resistance decreased with increasing water and contaminate (acid and sulfate) concentration. The rate of dissolution was lower in ethanol than in the other solutions. The small amount of sulfate had a significant detrimental effect on the corrosion resistance.

The immersion testing study (78 day test) was also conducted using brass (SAE 72), among other materials. The materials were tested in Solutions 3 – 8 shown in Table 8. Corrosion occurred in brass for the solutions containing sulfuric acid in days (oxidized surface), as no corrosion was visually observed in the presence of HEA in the first days of testing. At the end of the test, the morphology of the samples in the presence of sulfuric acid consisted of generalized corrosion and pitting. The corrosion rate increased as the sulfuric acid concentration in the ethanol increased.

No information from the literature was identified regarding SCC or pitting (although severe corrosion of bronze was noted) of copper base alloys in the presence of ethanol.

#### 3.1.2.2 Recommendations

Bronze and the higher Cu base alloys are probably compatible with FGE. Brass is probably not compatible with FGE. Additional work is needed in the following areas: SCC and pitting resistance studies.

### 3.1.3 Nickel/Nickel Base Alloys

In general, nickel and nickel base alloy samples tested in ethanol have experienced low corrosion rates (less than 2 mils per year) at low temperatures and higher corrosion rates (less than 20 mils per year) at higher temperatures (~60 to 200°F). Some of the higher corrosion resistant nickel base alloys (e.g., Hastelloy) experienced low corrosion rates (less than 2 mils per year) at higher temperatures (~200°F). These alloys are commonly used in high temperature environments, have a high associated cost, and are not likely to be used in pump stations.

#### 3.1.3.1 Information from the Literature

The only information in the literature found regarding nickel compatibility was connected to plating in a report prepared for the DOE[5]. Nickel plating of some incompatible metals (aluminum and brass) have been recommended for nozzles, fittings, and/or connectors (used in dispensing fuel ethanol).

No information from the literature was identified regarding SCC or pitting of nickel base alloys in the presence of ethanol.

#### 3.1.3.2 Recommendations

Nickel base alloys are probably compatible with FGE. Additional work is needed in the following areas: SCC and pitting resistance studies. The fact that nickel plating is recommended, and the location of nickel in the galvanic series, would suggest that nickel base alloys could be used in FGE.

### 3.1.4 Titanium

Titanium samples tested in ethanol have experienced low corrosion rates (less than 2 mils per year) at low and high (~200°F) temperatures.

#### 3.1.4.1 Information from the Literature

Jiang and others[14] documented cracking of titanium in ethanol. Slow strain rate (SSR) testing of TC4 titanium samples was conducted in air, water free ethanol, and ethanol + 1% acetic acid; the fracture times were 46 hours, 40 hours, and 29 hours, respectively. The results of gas chromatography (GC) and infrared spectroscopy (IRS) testing of the electrolyte after the testing of TC4 titanium in the water free ethanol indicated that acetic acid was present. It is believed that the acetic acid forms from the anodic dissolution of titanium in ethanol. Thus, it appears that acetic acid can form in ethanol/titanium systems and the acetic acid can drive SCC when a stress is present. Additionally, increasing the acetic acid concentration decreases the time to fracture; note that 1% acetic acid is above the minimum levels for acetic acid in FGE.

Additionally, an earlier study showed that stress corrosion cracks can propagate from a fatigue pre-crack in the Ti-8-Al-1Mo-1V alloy exposed to ethanol. Details regarding the test conditions could not found in literature.

No information from the literature was identified regarding pitting of titanium alloys in the presence of ethanol. SCC and cracking was documented for titanium alloys in the presence of ethanol.

#### 3.1.4.2 Recommendations

Titanium is probably not compatible with FGE. Additional work is needed in the following areas: pitting resistance studies.

### 3.1.5 Zinc

#### 3.1.5.1 Information from the Literature

Regarding the weight loss study by Lechner-Knoblauch and others[12] discussed above, corrosion rates for zinc (99.99%) in ethanol in 1.0, 0.5, 0.1, 0.005, and 0.001 mol/L of acetic acid and the presence of oxygen were 2.73 mm/year (107 mils/year), 2.73 mm/year (107 mils/year), 0.61 mm/year (24 mils/year), 0.28 mm/year (11 mils/year), and 0.02 mm/year (0.77 mils/year), respectively. As was shown in the study with copper, the weight loss of zinc was greatest with higher concentrations of acetic acid. Overall, the corrosion rate of zinc was greater than that of copper when the contaminants were present.

Regarding the electrochemical testing study by Uller and others[13], a study was also conducted involving Zamak (SAE 925), among other materials. Zamak is an alloy used in carburetors and contains 94% Zn. Overall, the corrosion resistance decreased with increasing water and contaminates (acid and sulfate) concentration. The small amount of sulfate had a significant detrimental effect on the corrosion. Of importance, Zamak was the least resistant to the ethanol solutions and corroded severely, even in the 99.5% ethanol solution.

Regarding the immersion testing study by Uller and others[13], a study was also conducted using Zamak, among other materials. At the end of the test, the morphology of the Zamak samples in all solutions consisted of generalized corrosion and pitting. The corrosion rate increased as the sulfuric acid concentration in the ethanol increased.

Wolynec and others[8] discussed an in-service investigation of a Zamak carburetor (in HEA) that experienced pitting and intergranular corrosion. Considerable amounts of sulfur containing compounds (sulfates) were identified in the corrosion deposits. The corrosion reduces the performance of the carburetor.

No information from the literature was identified regarding SCC of zinc in the presence of ethanol. Pitting and intergranular corrosion were documented for zinc in the presence of ethanol.

#### 3.1.5.2 Recommendations

Zinc is not compatible with FGE. No other work is needed.

### 3.1.6 Stainless Steel

In general, stainless steel samples tested in ethanol have experienced low corrosion rates (less than 2 mils per year) at low temperatures and higher corrosion rates (less than 20 mils per year) at higher temperatures (~200 to 400°F). Additionally, stainless steel alloys are reportedly compatible with E-85 and E-10.

#### 3.1.6.1 Information from the Literature

Of the information found in literature involving stainless steel corrosion and ethanol, many dealt with aqueous ethanol with the addition of high concentrations of acids, such as HCl or $H_2SO_4$. As the acid concentrations increased, the corrosion rate increased.

No information from the literature was identified regarding SCC or pitting of stainless steels in the presence of ethanol.

### Recommendations

Stainless steels are probably compatible with FGE. Additional work is needed in the following areas: SCC and pitting resistance studies.

## 3.2 Elastomers and Plastics

Table 9 is a summary of the corrosion resistance of the elastomers/plastics identified in the pump stations. Column 1 lists the materials identified in the pump stations. Column 2 provides 1) the range of temperatures that the materials are resistant to and 2) information regarding swell and tensile strength loss (for Teflon and nylon). Table 10 is a summary of the volume change data for elastomers and plastics (discussed below) and recommendations for use in FGE. Additional compatibility information is given below.

### 3.2.1 Viton®

Viton® is a DuPont trade name for several fluoroelastomers that have different compositions and performance characteristics. In general, the Viton® elastomers having lower alphabetical names have poorer performance characteristics in a variety of environments. For example, Viton® A is much less resistant to swelling in gasoline than Viton® B. In general, Vitons as a class have been successfully used with FGE and are reportedly compatible with E-85. The corrosion resistant tables from the literature indicate that Viton® A is resistant in ethanol from 60°F to 350°F.

#### 3.2.1.1 Information from the Literature

Abu-Isa[15] evaluated the tensile and swell (volume change) properties in a study involving Viton® A (fluorocarbon elastomer), among other materials and alcohols. Tensile samples and volume change samples were soaked in various ethanol/simulated gasoline blends for 72 hours at room temperature. The simulated gasoline was Indolene HO-III (spiked), which was composed of 46.32% paraffin, 49.95% aromatics (40.21 toluene), and 3.73% olefins. The ethanol/simulated gasoline blends ranged from 0 to 100% ethanol. The variation in the tensile properties and volume change, from low to high ethanol concentrations, was not significant. The volume change at 0% and 100% ethanol was less than 5%. The volume change in E-85 and E-10 was <5% and 6%, respectively, with a maximum swell of 7% in E-15 (15 volume % ethanol – 85 volume % gasoline). The elongation in E-85 was less than that in E-10 and the ultimate tensile strength (UTS) in E-10 was less than in E-85, indicating better material properties in E-85.

In a follow up study by the same author,[16] spiked and unspiked gasoline simulates (Indolene HO-III were tested. Of interest, improved volume change and tensile results were found in the

Indolene HO-III/ethanol blends. The Indolene HO-III had a lower aromatic content (30% compared to 50% in the spiked).

Work done by Micallef and others[17] involved various fluorelastomers containing vinylidene fluoride as a monomer (FKM)s. The most common trade name for FKM is Viton®. FKM compounds were tested in E-22 and E-85, among other solutions. E-22 consisted of 22 volume % ethanol with a standard test fluid used to replicate gasoline. E-85 consisted of 85 volume % ethanol with the standard test fluid. The standard test fluid was composed of 50% toluene and 50% isooctane. Tensile samples and volume change samples were soaked in the solutions for 168 hours at 140°F. The volume change and change in UTS were greater in this study than in the work done by Abu-Isa, which is likely from the increase in temperature, differences in the gasoline stimulant, or in the compositions of the Viton® elastomers. Of importance, less volume change, UTS change, and elongation change occurred in the E-85 compared to the E-22, regardless of the elastomer compound tested. This is consistent with the findings in the study above.

In another study by Ertekin and others[18], Viton® A, Viton® GF, and Viton ®GFLT (among other elastomers) were immersed in neat gasoline, E-20, and E-95 for 28 days at room temperature. The 20 and 95 represented the volume % of ethanol. The neat gasoline was 100% gasoline (reformulated gasoline blendstock for oxygen blending (RBOB)). The Viton® elastomers varied in monomer and fluorine content. The swelling in the E-95 and E-20 were less than 5% and 10%, respectively, for the Viton® elastomers. Of interest, Viton® A's volume change in neat gasoline was approximately 75% compared to less than 10% for the other Viton's. Testing was also undertaken to simulate fuel transitions. The Viton® samples were soaked in E-95 for 28 days, neat gasoline for 28 days, and E-95 for 28 days. For Viton® A, large volume changes occurred in the neat gasoline and not in the E-95, and minimal volume changes occurred in the other Viton® elastomers. Additionally, Viton® GF and GFLT swelled less than 10% at any one time, in a test to simulate fuel transitions. The test consisted of soaking in E-20 for 28 days, neat gasoline for 28 days, and E-20 for 28 days.

#### 3.2.1.2 Recommendations

Viton® is compatible with FGE. No other work is needed in FGE. If a Viton® elastomer is to be used in ethanol blends, then testing in ethanol blends is recommended.

### 3.2.2 Nylon

The corrosion resistant tables from the literature indicated that Nylon 11 and Nylon 66 are resistant in ethanol from 60°F to 210°F and Nylon 6 is resistant in ethanol from 60°F to 250°F. According to a report prepared for the DOE[5], nylon has been successfully used with FGE.

#### 3.2.2.1 Information from the Literature

In a study by Yeager and others[19], nylon (among other materials) was soaked in unleaded gasoline and E-15, among other fluids. The nylon samples were soaked 1) at room temperature for 60 days, 2) at 180°F for 30 days, 3) at 250°F for 28 days, and 4) at 302°F for 7 days. Weight gain was recorded and tensile tests were performed on the samples. A 30% long fiber (Verton RF-7006) Nylon 6/6 composite and 30% standard short glass fiber (RF-1006) reinforced Nylon 6/6 were tested. Individual results for the nylon elastomer samples were not provided but all samples (except for one) had excellent to fair chemical resistance in unleaded gas. The long fiber nylon had superior tensile strength retention relative to the short fiber nylon in both unleaded gas and the ethanol blend. The tensile strength retention of the nylon composite in the ethanol blend was greater than in the methanol blends. Additionally, the reduction in retained tensile strength was greater in the ethanol blend compared to the unleaded gasoline for the Nylon 6/6 composites tested.

#### 3.2.2.2 Recommendations

Nylon is probably compatible with FGE. Additional work is needed in the following areas: volume change testing, at the least, in FGE should be conducted.

### 3.2.3 PEEK

The corrosion resistant tables from the literature indicated that polyetheretherketone (PEEK) is resistant in ethanol from 60°F to 80°F. According to the manufacturers of PEEK (Victrex), there is no attack and little or no absorption when PEEK is in contact with acetic acid, ethanol, and gasoline from 73°F to 212°F[20].

#### 3.2.3.1 Information from the Literature

In a study by Yeager and others[19] above, PEEK demonstrated excellent chemical resistance, temperature resistance, dimensional stability in all fluids tested, including unleaded gasoline and E-15.

#### 3.2.3.2 Recommendations

PEEK is compatible with FGE. No other work is needed in FGE. If PEEK is to be used in ethanol blends, then testing in ethanol blends is recommended.

### 3.2.4 Polyurethane

Polyurethane (UA) was listed as unsatisfactory in one of the corrosion resistance tables from the literature. Polyurethane is reportedly not compatible with E-10 or E-85. According to a report prepared for the DOE[5], UA has been known to degrade in FGE.

#### 3.2.4.1 Information from the Literature

In a study by Abu-Isa[15] (details regarding testing conditions are discussed above), tensile and swell properties were obtained in a study involving UA, among other materials in alcohols. The volume change at 0% and 100% ethanol was approximately 20%. Of interest is that the volume change in E-85 and E-10 was approximately 28% and 51%, respectively, with a maximum swell of 56% in E-20. The elongation in E-85 was greater than that in E-10 and the UTS of the UA in E-10 was slightly less than in E-85.

In a follow up study by the same author[16], similar volume change and tensile results were found in the Indolene HO-III spiked/ethanol blends. Of interest, better swell and tensile results were found in the Indolene HO-III/ethanol blends.

#### 3.2.4.2 Recommendations

Polyurethane is not compatible with FGE. No other work is needed.

### 3.2.5 Teflon

The corrosion resistant tables from the literature indicated that swelling and tensile strength loss of Teflon (FEP, PFA,TFE) in ethanol up to high temperatures (~400°F) is low; thus, Teflon (FEP, PFA, TFE) is resistant in ethanol at high temperatures. TFE is reportedly compatible with E-10 and E-85. According to a report prepared for the DOE, TFE has been successfully used with FGE.

#### 3.2.5.1 Information from the Literature

In the study by Ertekin and others[18] involving various compounds above, the volume change in the neat gasoline, E-20, E-95 was less than 1%. Testing to simulate fuel transitions showed that Teflon (TFE) swelled less than 1%, at any one time, in the various stages described above.

#### 3.2.5.2 Recommendations

Teflon (TFE) is compatible with FGE. No other work is needed.

### 3.2.6 Nitrile

The corrosion resistant tables from the literature indicated that nitrile is resistant in ethanol from 60°F to 180°F. Additionally, nitrile has been successfully used with FGE and is reportedly compatible with E-85.

### Information from the Literature

In a study by Abu-Isa[15] (details regarding testing conditions were discussed above), tensile and swell properties were obtained in a study involving nitrile, among other materials in alcohols. The volume change in E-10 and 100% ethanol was approximately 68% and 11%, with a maximum swell of 99% in E-25.

In a follow up study by the same author,[16] similar swell and tensile results were found in the Indolene HO-III spiked/ethanol blends. Of interest, better swell and tensile results were found in the Indolene HO-III/ethanol blends. Additionally, information regarding nitrile in various ethanol concentrations was documented in this study. The volume change at 0% and 100% ethanol was approximately 35% and 5%, respectively. The volume change in 85% ethanol/Indolene HO-III (spiked) was approximately 28%.

In the study by Ertekin and others[18] involving various compounds above, the swelling of Buna N (nitrile) in neat gasoline, E-20, and E-95 were approximately 20%, 25%, and 7%, respectively. The swelling of Low Swell Buna N in the neat gasoline and E-95, was approximately 125% and <1%, respectively. Testing to simulate fuel transitions showed that Low Swell Buna N swelled greatly (~120%) in neat gasoline, that both Buna N's had low swelling (less than 15%) in E-95, and that Buna N swelled greater than 20% in E-20. The high swelling in blends containing low percentages of ethanol and low swelling in blends containing high percentages of ethanol is consistent with the studies conducted for nitrile in standard testing fluids.

### 3.2.6.1 Recommendations

Nitrile is probably compatible with FGE. Volume change testing, at the least, in FGE containing the lowest possible percentage of ethanol should be conducted since significant swelling occurred in E-85.

## 4.0 SUMMARY AND CONCLUSIONS

The objective of this project was to investigate ethanol - materials compatibility issues for components involved in pump station facilities. The project is divided into three phases; Survey of Knowledge and Gaps (Phase 1), Detailed Study to Close Gaps Identified in Phase 1 (Phase 2), and Development of Guidelines (Phase 3). This report summarizes the results of Phase 1. This phase consisted of three Tasks, Industry Survey (Task 1), Literature Search (Task 2), and Report (Task 3).

The first task in Phase 1 of this project involved sending out an industry survey regarding materials in pump stations. This task was performed to determine what components are important from a facilities point of view and what materials are used in these components. The information from the survey was organized into a table that is attached as an appendix to this report. Additionally, manufacturers of the components were contacted in order to determine the materials present in the components in the pump stations. The requests for bill of materials or materials for specific part numbers were performed by email and/or phone calls.

The second task involved performing a literature search. The survey focused on data from the literature on the ethanol exposure effects of materials involved in various pump station components. The open literature, as well as company reports, were considered. Previous literature surveys conducted for PRCI SCC 4-1 and 4-4, and API, were utilized. The open literature search was performed using two search engines; Engineering Village and Science Direct. The keywords in the search included ethanol, corrosion, failure, various non-ferrous metals, stainless steels, elastomers/plastics, and ceramics.

A number of different materials were found to be present in the components in pump stations. Metals included carbon and low alloy steels, stainless steels, pure nickel and nickel alloys, bronzes, and aluminum alloys. There were a variety of stainless steels including 300 series (austenitic, high nickel), 400 series (ferritic/martensitic, low nickel) and precipitation hardened alloys. Non metallic materials included ceramics, fiberglass, Buna N and butadiene rubbers, polyurethane, Teflon, PEEK, Viton®, and nylon.

No information was found on the performance of ceramic materials in ethanol and the literature on the performance of metallic materials in ethanol is relatively limited. More information was found on elastomer compatibility in ethanol. Information on compatibility in actual FGE was generally more limited than that in other ethanolic solutions.

Table 11 summarizes the results of the Task 2 literature search on the performance of metallic materials in ethanol. In Table 11, the first column lists common nonferrous metals and stainless steels. All but zinc and titanium were confirmed to be present in pump station components. The second column is titled *Compatibility*. For this column, there are four possible categories. *Not Compatible* indicates that sufficient information was found to establish that the class of materials is not compatible. Metallic materials in this category include aluminum alloys and zinc. Aluminum has exhibited pitting and SCC in ethanol, while zinc has exhibited high rates of general corrosion, pitting, and intergranular attack in ethanol. *Probably Not Compatible* indicates that information was limited but the available information suggests that the category of materials is not compatible. Titanium is in this category because one reference indicated that it is susceptible to SCC in ethanolic solutions. *Probably Compatible* indicates that information was limited but the available information suggests that the category of materials is compatible. Materials in this category include copper base alloys (excluding brasses), nickel base alloys, and stainless steels. In the case of copper base alloys, brass is probably not compatible but other copper base alloys, which do not contain high concentrations of zinc, probably are compatible. For all of the materials in this category, additional information is needed on the SCC behavior given the limited information on this failure mode and the SCC experience with carbon steels. *Compatible* indicates that sufficient information was found to establish that the class of materials is compatible. No metallic materials were in this category.

Table 12 summarizes the results of the Task 2 literature search on the performance of elastomeric materials in ethanol. The format for this table is the same as Table 11. All available information indicates that Teflon, PEEK, and Viton® are compatible with FGE. Nylon (limited information) and Nitrile (Buna N) probably are compatible with FGE. There may be some issues with swelling in the gasoline – ethanol blends in the case of PEEK (limited information) and Nylon (limited information), some Viton® elastomers (swelling in gasoline), and Nitrile (swelling significantly in 0% ethanol to E-85). Polyurethane is not compatible.

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Table 1. Summary of the ceramics identified in the pump stations.

| Material | Material Description | Components and Applications in Pump Stations |
|---|---|---|
| **Tungsten Carbide** | Ceramic and metal. Ceramic particles and metallic binder. | Journal, rotor, washer, and bearing in meters (TUR). Mechanical seal and seal face in pump. Sleeve and journal bearing in meter (PT). |
| **Silicon Carbide** | Ceramic | Mechanical seal in pump. |
| **Heanium** | High purity aluminum oxide (ceramic) | Cyclone separator in pump. |

Table 2. Summary of the elastomers/plastics identified in the pump stations.

| MATERIAL | MATERIAL DESCRIPTION | COMPONENTS AND APPLICATIONS IN PUMP STATIONS |
|---|---|---|
| **Fiberglass** | Fine fibers of glass used as a reinforcing agent for polymers | Sump tank. |
| **Buna N (nitrile)** | Copolymer of butadiene and acrylonitrile. | O'ring in meter. |
| **Polyurethane** | Can be categorized as a polymer or elastomer. | Sphere in prover. |
| **TFE (Teflon)** | A synthetic fluoropolymer of tetrafluoroethylene, | Body seal and stem packing in ball valve. |
| **Polyether ether ketone (PEEK)** | A high performance thermoplastic generally used with fiber reinforcements such as glass, carbon, or Kevlar. | Retainer for bearing in meter. Wear ring/bushing in pump (centrigal). Casing ring. |
| **Viton®** | An FKM fluoroelastomer. There are various grades of Viton®. | Diaphragm in flow control valve. Seat for flow check and o'ring for PD meter in truck loading terminal. Valve stem seal packing in valve stem seal. Cyclone separator in pump. O'ring in check valve, differential pressure switch, drain valve, gate valve, pressure switch, pressure transmitter, relief valve, and sump pump. Seal in M/L pump. Mechanical seal. Mainline pump seal in pump. |
| **Viton® B** | A specific grade of Viton®. | Mechanical seal and seal in pump. |
| **Nylon** | Generic designation for a family of synthetic polymers known generically as polyamides | O'ring in surge relief flow valve. |
| **Armstrong TN 9004** | A heavy-duty, high density material with fully cured nitrile butadiene rubber binder. | Casing gasket in pump bearing housing. Flange gasket in mainline pump. |

Table 3. Summary of the non-ferrous metals identified in the pump stations.

| MATERIAL | MATERIAL DESCRIPTION | COMPONENTS AND APPLICATIONS IN PUMP STATIONS |
|---|---|---|
| **7075 Al** | An Al-Zn-Mg-Cu precipitation hardenable alloy (where the primary alloying agent is Zn. The 7xxx series are the strongest aluminum alloys. | Rotor hub in meter (PT). |
| **Aluminum bronze** | Type of bronze which aluminum (2 to 15%) is the main alloying metal added to copper. | Impeller in pump. |
| **Bronze** | A metal alloy consisting primarily of copper, usually with tin as the main additive, but sometimes with other elements such as phosphorus, manganese, aluminum, or silicon. | Case/impeller wear ring and impeller in pump. Impeller for pump in loading rack. |
| **Bronze B584-903, 932, 936, 905, 958** | 903 and 905 are tin bronzes, 932 and 936 are high lead bronzes, and 958 is an aluminum bronze. | Case and impeller ring, throat and throttle bushing, and impeller in pump. |
| **Ni 200** | 99% pure nickel alloy. | Rotor blade in meter (PT). |
| **Hi mu 80** | Information found for HyMu 80 alloy: 80% nickel-iron-molybdenum alloy. | Rim button in meter (PT). |

Table 4. Summary of the stainless steels identified in the pump stations.

| MATERIAL | MATERIAL DESCRIPTION | COMPONENTS AND APPLICATIONS IN PUMP STATIONS |
|---|---|---|
| **CA6NM** | A hardenable Fe-Cr-Ni-Mo alloy (cast stainless steel). | Case/impeller wear ring and impeller in pump. Impeller in pump rotating element. Impeller. |
| **302SS** | Chromium nickel austenitic stainless steel. | Nut, spring, and washer in flow control valve. Spring for gland in meter. Pin for stator in meter (TUR). Ring in meter (TUR). Clamp, lug, spacer, and washer for mechanism in meter. |
| **303SS** | Chromium nickel austenitic stainless steel designed for improved machinability. | Stem in flow control valve. Gland in meter. Pin for shaft in meter. Shaft in meter. Pin for mechanism in meter. |
| **304SS** | Chromium nickel austenitic stainless steel with lower carbon content than 302SS. | Bearing, seat, and washer in flow control valve. Housing in meter. Nut in meter. Pin, clamp, lug, and spacer for mechanism in meter. Cone, flange, rotor hub, and shaft in meter (PT). |
| **316SS** | Chromium nickel austenitic stainless steel with 2 to 3 % molybdenum for increased resistance to pitting/crevice corrosion than 304SS. | Cone, stator, shaft, pin, screw, housing, key, flange, rotor hub, and shaft in meters (TUR). Rim, blade, and hub for rotor in meters (TUR). Lug, spacer, and screw for mechanism in meter. Case/impeller wear rings, diffuser, seal sleeve, shaft, pipe, elbow, nipple, and orifice plate in pump. Square key in pump kit shaft pump. Stud and washer in pump mechanical seal. Connector and cooling tube in pump radial. Casing wear rings, impeller wear ring, set screw, and split ring in pump rotating element. Seat trim is surge relief flow valve. Casing ring. Impeller ring. Throttle bushing. Throat bushing. Throttle sleeve. Throat sleeve. Mechanical seal. |
| **317SS** | Chromium nickel austenitic stainless steel with increased chromium, nickel, and molybdenum compared to 316SS. | Stud in pump. |
| **18-8** | 3xx series stainless steels having approximately 18% chromium and 8% nickel. | Screw and nut in meter (TUR). Screw for stator in meter. Shaft in meter. Shim in pump baseplate and coupling. Spring in surge relief flow valve. |
| **17-7 PH** | A chromium-nickel-aluminum precipitation hardening stainless steel used for applications requiring high strength and a moderate level of corrosion resistance | Spring in flow control valve. Spring for mechanism in meter. |
| **416** | A martensitic free-machining stainless steel which can be hardened by heat treatment to higher strength and hardness levels. | Screw and shaft for mechanism in meter. Shaft in pump. |
| **420** | Hardenable, straight-chromium stainless steel which combines superior wear resistance with excellent corrosion resistance. | Rotor in meter (TUR). Rotor hub in meter (PT). Casing ring. Impeller ring. Throttle bushing. Throat bushing. Throttle sleeve. Throat sleeve. |
| **430F** | A low carbon ferritic stainless steel that contains additionally molybdenum compared to 430. | Screw for rotor in meter (TUR). |
| **440C** | A martensitic stainless steel hardenable to high hardness levels for wear resistance applications and corrosion resistance above carbon steel. | Bearing and plate in meter. Pin, bearing, dowel, and roller for mechanism in meter. |
| **630/17-4 PH** | 630 is also known as 17-4 PH, a martensitic stainless steel that is capable of precipitation hardening. It has very high strength and hardness. | Gear and dowel for mechanism in meter. Shaft for cover in meter. Retainer in surge relief flow valve. Rotor shaft for PD meter in truck loading terminal. |

Table 5. Summary of corrosion rates from tables [1, 2, 3] of nonferrous metal and stainless steels. These metals were specifically identified in pump stations.

| MATERIAL | CORROSION RATES FROM TABLES IN LITERATURE |
|---|---|
| **Copper Base Alloys** | |
| **Bronze** | – average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>– corrosion rate from 60°F to 400°F in ethanol is less than 20 mils per year[3] |
| **Aluminum Bronze** | – the corrosion rate in ethanol from 60°F to 70°F is less than 20 mils per year[3] |
| **Nickel Base Alloys** | |
| **200/200L (99-Ni)** | – the average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>– the corrosion rate in ethanol from 60°F to 200°F is less than 20 mils per year[3] |
| **Ni-Cr-Fe-Mo Alloy** | – the average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **Stainless Steels** | |
| **Type 302** | – the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **Type 303** | – the corrosion rate in ethanol, at any temperature up to 212°F in any concentration to 100% is less than 20 mils per year[2] |
| **Type 304/304L** | – the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>– the corrosion rate in ethanol, at any temperature up to 212°F in any concentration to 100% is less than 20 mils per year[2]<br>– the corrosion rate in ethanol from 60°F to 200°F is less than 20 mils per year[3] |
| **Type 316/316L** | – the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>– the corrosion rate of ethanol, at any temperature up to 200°F in any concentration to 100% is less than 20 mils per year[2]<br>– the corrosion rate in ethanol from 60°F to 400°F is less than 20 mils per year[3] |
| **Type 317/317L** | – the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **17-4 PH** | – the corrosion rate in ethanol from 60°F to 170°F is less than 20 mils per year[3] |

Table 6. Summary of corrosion rates from tables [1, 2, 3] of nonferrous metals and stainless steels. These metals were not specifically identified in pump stations.

| MATERIAL | CORROSION RATES FROM TABLES IN LITERATURE |
|---|---|
| | **Aluminum/Aluminum Alloys** |
| **Aluminum** | - the average corrosion rate in aluminum, at 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol is less than 2 mils per year from 60°F to 180°F and less than 20 mils per year from 180°F to 210°F[3] |
| **Al3003** | - the corrosion rate in ethanol, at any temperature up to 200°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2] |
| | **Copper/Copper Base Alloys** |
| **Copper** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2]<br>- the corrosion rate in ethanol from 60°F to 100°F is less than 20 mils per year[3] |
| **70Cu-30Ni** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2] |
| **90Cu-10Ni** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2] |
| **Admiralty Brass** | - the corrosion rate in ethanol, up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2] |
| **Naval Bronze** | - corrosion rate in ethanol up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 2 mils per year[2] |
| **Silicon Bronze** | - the corrosion rate in ethanol, up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 20 mils per year[2]<br>- the corrosion rate in ethanol from 60°F to 70°F is less than 20 mils per year[3] |
| **Yellow Brass** | - corrosion rate in ethanol up to 70°F in 100% concentration, or saturated, or concentrated solution is less than 2 mils per year[2] |
| **Brass** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol from 60°F to 210°F is less than 20 mils per year[3] |
| | **Nickel/Nickel Base Alloys** |
| **Nickel** | - the corrosion rate in ethanol, at any temperature up to boiling in any concentration to 100% is less than 20 mils per year, and in some instances, is less than 2 mils per year[2] |
| **Ni201** | - the corrosion rate in ethanol from 60°F to 200°F is less than 20 mils per year[3] |
| **Monel 400 (66Ni-32Cu)** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, at any temperature up to 200°F in any concentration to 100% is less than 2 mils per year[2]<br>- the corrosion rate in ethanol from 60°F to 210°F is less than 20 mils per year[3] |
| **Inconel 600 (76Ni-16Cr-7Fe)** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate from 60°F to 80°F is less than 20 mils per year[3] |
| **Inconel** | - the corrosion rate in ethanol, at any temperature up to boiling in any concentration to 100% is less than 20 mils per year, and in some instances, is less than 2 mils per year[2] |
| **Inconel 625** | - the corrosion rate from 60°F to 80°F is less than 20 mils per year[3] |
| **Incoloy 825** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>-the corrosion rate in ethanol at 167°F, between concentrations of 42% to 56%, from 70°F to 221°F, at a concentration of 45%, and from 70°F to 105°F, between concentrations of 0% to 20% is less than 2 mils per year[2] |
| **Hastelloy G/G3** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **Hastelloy B** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, at any temperature up to 200°F in any concentration to 100% is less than 2 mils per year[2]<br>- the corrosion rate from 60°F to 200°F is less than 2 mils per year[3] |
| **Hastelloy B2** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate from 60°F to 200°F is less than 2 mils per year[3] |
| **Hastelloy C** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, at any temperature up to 200°F in any concentration to 100% is less than 2 mils per year[2]<br>- the corrosion rate from 60°F to 210°F is less than 2 mils per year |
| **Hastelloy C-276** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate from 60°F to 210°F is less than 2 mils per year[3] |
| **Hastelloy D** | - the corrosion rate in ethanol from 60°F to 210°F is less than 20 mils per year[3] |
| **Alloy 20** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |

| MATERIAL | CORROSION RATES FROM TABLES IN LITERATURE |
|---|---|
| **CN 20** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **Stainless Steels** | |
| **Type 405, 17Cr, 26Cr-1Mo, 321, 904L** | - the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1] |
| **20 Cb-3** | - average corrosion rate from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol, at any temperature up to 200°F in any concentration to 100% is less than 2 mils per year[2]<br>- the corrosion rate in ethanol from 60°F to 210°F is less than 20 mils per year[3] |
| **Type 410** | - the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol from 60°F to 210°F is less than 20 mils per year[3] |
| **Type 347** | - the average corrosion in ethanol from 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate in ethanol from 60°F to 200°F is less than 20 mils per year[3] |
| **Type 430F** | - the corrosion rate in ethanol, from 70°F to 212°F, at 100% concentration is less than 20 mils per year[2] |
| **Titanium** | |
| **Titanium** | - the average corrosion rate of ethanol, at 0 to 200°F in low to high concentrations of ethanol is less than 2 mils per year[1]<br>- the corrosion rate of titanium in ethanol from 60°F to 210°F is less than 2 mils per year[3] |

Table 7. The galvanic series in seawater.[7]

| |
|---|
| Cathodic (noble) |
| ↑ |
| platinum |
| gold |
| graphite |
| titanium |
| silver |
| zirconium |
| Type 316, 317 SS (passive) |
| Type 304 SS (passive) |
| Type 430 SS (passive) |
| nickel passive |
| copper-nickel (70-30) |
| bronzes |
| copper |
| brasses |
| nickel (active) |
| naval brass |
| tin |
| lead |
| Type 316, 317 SS (active) |
| Type 304 SS (active) |
| cast iron |
| steel or iron |
| aluminum alloy 2024 |
| cadmium |
| aluminum alloy 1100 |
| zinc |
| magnesium and magnesium alloys |
| ↑ |
| Anodic (active) |

Table 8. Ethanol solutions used in immersion and electrochemical tests.[13]

| Solution № | Ethanol Solutions | Alcohol Grade (° INPM) | Acidity (mg/100ml) |
|---|---|---|---|
| 1 | Ethanol | 99.5 | 0.23 |
| 2 | Hydrated ethanol (HEA) | 92.7 | 0.60 |
| 3 | HEA + acetic acid | 92.7 | 1.67 |
| 4 | HEA + acetic acid + $H_2SO_4$ (2 ppm $SO_4$) | 92.7 | 1.86 |
| 5 | HEA + acetic acid + $H_2SO_4$ (4 ppm $SO_4$) | 92.7 | 2.08 |
| 6 | HEA + acetic acid + $H_2SO_4$ (6 ppm $SO_4$) | 92.7 | 2.28 |
| 7 | HEA + acetic acid+ ethyl aldehyde (10mg/100mL) | 92.7 | 1.67 |
| 8 | HEA + acetic acid+ ethyl acetate (10mg/100mL) | 92.7 | 1.67 |

Table 9. Summary of the resistance of elastomers and plastics from tables. [1, 2, 3] These materials were specifically identified in pump stations.

| MATERIAL | CORROSION RESISTANCE FROM TABLES IN LITERATURE |
|---|---|
| | **Elastomers and Plastics** |
| **(Viton® A)** | - is resistant in ethanol from 60°F to 350°F; Viton® (grade not identified) and Viton® B identified in pump stations |
| **Nylon** | - the swelling and tensile strength loss percentages of polyamide nylon in ethanol at any temperature up to 200°F at 100% concentration, or concentrated, or saturated solution are less than 10% to greater than 20% and less than 15% to 50%, respectively; varying or variable rates were reported by multiple sources[2].<br>- Nylon 11 and 66 are resistant in ethanol from 60°F to 210°. Nylon 6 is resistant in ethanol from 60°F to 250°F [3] |
| **PEEK** | - is resistant in ethanol from 60°F to 80°F[3] |
| **Teflon** | - the swelling and tensile strength loss percentages of Teflon (FEP, PFA,TFE) in ethanol at any temperature up to 392°F in any concentration to 100% are less than 10% and 15%, respectively, with little or no chemical attack[2].<br>- FEP is resistant in ethanol from 60°F to 400°F[3]<br>- PFA is resistant in ethanol from 60°F to 390°F[3]<br>- TFE is resistant in ethanol from 60°F to 470°F[3] |
| **Polyurethane** | - is unsatisfactory[3] |
| **Nitrile** | - is resistance in ethanol from 60°F to 180°F[3] |

Table 10. Summary of the volume change (%) data for elastomers from papers in literature, and recommendations for use in FGE. [Note; 0% ethanol is 100% gasoline (neat gasoline or simulated)].

| Ethanol % | Viton® A[15] * | Viton® A, GF, and GFLT[18] ** | UA[15] * | TFE[18] ** | Nitrile (Buna N) [15] * | Buna N[18] ** | Low Swell Buna N[18] ** | Nylon | PEEK |
|---|---|---|---|---|---|---|---|---|---|
| **VOLUME CHANGE** | | | | | | | | | |
| **0** | <5 | 75 (Viton® A), <10 (Viton® GF) and (Viton® GFLT) | 20 | <1 | 58 | 20 | 125 | – | – |
| **10** | 6 | – | 51 | – | 68 | – | – | – | – |
| **20** | – | <10 | – | <1 | - | 25 | – | – | – |
| **85** | 6 | – | 28 | – | 28 | – | – | – | – |
| **95** | – | <5 | – | <1 | - | 7 | <1 | – | – |
| **100** | <5 | – | 20 | – | 5 | – | – | – | – |
| **RECOMMENDATIONS** | | | | | | | | | |
| **Comments** | Viton® is compatible with FGE. No other work is needed in FGE. The choice of which Viton® to be used in blends containing low concentrations of ethanol might be critical | | Polyurethane Is not compatible with FGE. No other work is needed. The volume change was too high if the material is intended for sealing, even in FGE. | Teflon (TFE) compatible with FGE. No other work is needed. Teflon appears to be compatible with various ethanol blends. | Nitrile is probably compatible with FGE. Volume change testing, at the least, in FGE containing the lowest possible percentage of ethanol should be conducted since significant swelling occurred in E-85 .Contact with ethanol concentrations less than 95 or 90% may cause sealing issues. The choice of which nitrile to be used in blends containing low concentrations of ethanol might be critical | | | Nylon is probably compatible with FGE. Additional work is needed in the following areas: volume change testing, at the least, in FGE should be conducted. According to a report prepared for the DOE, nylon has been successfully used with FGE. | PEEK is compatible with FGE. No other work is needed in FGE. If PEEK is to be used in ethanol blends, then testing in ethanol blends is recommended. PEEK demonstrated excellent results in various fluids (including M-85 fuel), and excellent resistance to gasoline and ethanol. |

* Simulated gasoline
** RBOB (reformulated gasoline blendstock for oxygen blending)

Table 11. Summary of the non-ferrous metals and stainless steel compatibility in FGE.

| MATERIALS | COMPATIBILITY | COMMENTS |
|---|---|---|
| Aluminum Alloys | Not compatible. | Pitting and SCC in ethanol. |
| Zinc | Not compatible. | Pitting and IG cracking documented in HEA. Severe corrosion in ethanol. |
| Titanium | Probably not compatible. | SCC documented in ethanol. |
| Copper Base Alloys | Bronze and the higher Cu base alloys are probably compatible. Brass is probably not compatible. | Severe corrosion of brass in HEA. Additional work is needed in SCC and pitting resistance. |
| Nickel Base Alloys | Probably compatible. | Nickel plating recommended for use in FGE. Additional work is needed in SCC and pitting resistance. |
| Stainless Steels | Probably compatible. | Stainless steels recommended for dispensing FGE. Additional work is needed in SCC and pitting resistance. |

Table 12. Summary of the elastomers/plastics compatibility in FGE.

| MATERIALS | COMPATIBILITY | COMMENTS |
|---|---|---|
| Polyurethane | Not compatible | Known to degrade in FGE. High volume change in ethanol. |
| Nitrile (Buna N) | Probably compatible | Minimal volume change in FGE.* |
| Nylon | Probably compatible | Successfully used in FGE.* |
| Teflon | Compatible | Minimal volume change in ethanol. |
| PEEK | Compatible | Excellent resistance to ethanol and M-85.* |
| Viton® | Compatible | Minimal volume change in FGE.* |

* Testing in ethanol/gasoline blends is recommended.

# APPENDIX A

## INDUSTRY SURVEY LETTER

DNV COLUMBUS, INC.
***Materials and Corrosion Technology Center***

5777 Frantz Road
Dublin, OH 43017-1386

Tel: (614) 761-1214
Fax: (614) 761-1633
www.dnv.com
www.dnvcolumbus.com

May 21, 2009

Re: *Determining the Effects of Ethanol on Pump Station Facilities (EP001681)*

Dear PRCI Member:

DNV Columbus was recently awarded the above referenced PRCI project. The objective of the project is to investigate ethanol – materials compatibility issues for components in pump stations and other facilities in which ethanol is handled. There are several tasks in the project and one task consists of an industry survey. This survey is being performed to determine what components are important from a facilities point of view and what materials (that will be in contact with ethanol or ethanol-gasoline blends) are present in these components.

Please take a few moments to fill out the attached tables if you are contemplating getting involved with ethanol transportation or blending and or have experience with transporting or handling ethanol or ethanol blends. You can print out the tables, fill them out in ink and fax them to me at the fax number listed below, or enter the information in the word document and return by e-mail at the e-mail address listed below. If you send the response electronically, please rename the file to avoid confusion. The results of the survey will be provided to all participants with the responders name and company affiliations removed.

Thank you in advance for your input and support on this project. If you have any questions or comments, please contact me at; (direct) 614-761-6909, (cell) 614-570-4607, (fax) 614-761-1633, or e-mail John.Beavers@dnv.com.

Sincerely,

for DNV Columbus, Inc. (formerly CC Technologies)

John A. Beavers, Ph.D., FNACE
Chief Scientist
Materials and Corrosion Technology Center
DNV Columbus, Inc. (formerly CC Technologies)

Table A-1. Wetted components in pump stations and other pipeline facilities.

| Component No. [a] | Component Type [b] | Component Manufacturer | Component Model No. | Component Information [c] |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 11 | | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |

a. Where you have more than one manufacturer of the same component type, enter in individual rows.
b. Pump, valve, metering device, etc.
c. Diameter, construction material, etc.

Table A-2. Experience with wetted components in pump stations and other pipeline facilities.

| Component No. (from Table 1) | Application [a] | Probable Material | Environment [b] | Experience |
|---|---|---|---|---|
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a. Pump station component, loading rack in blending facility, etc.
b. FGE, ethanol-gasoline blends, a specific blend (e.g., E-85), etc.

# APPENDIX B

## A TABLE OF PUMP STATION COMPONENTS IDENTIFIED FROM AN INDUSTRY SURVEY

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Ball | Ball Valve | A108-CS chrome plated | Apollo | 73-108-04 | 2" carbon steel |
| Body | Ball Valve | A105 | Apollo | 73-108-05 | 2" carbon steel |
| Body Seal | Ball Valve | RPTFE | Apollo | 73-108-03 | 2" carbon steel |
| Gland Nut | Ball Valve | A108-CS | Apollo | 73-108-01 | 2" carbon steel |
| Stem Packing | Ball Valve | MPTFE | Apollo | 73-108-02 | 2" carbon steel |
| Rack Control Valve | Ethanol blending system | | Smith | 210 Valve | |
| Rack Meter | Ethanol blending system | | | | Turbine Meter |
| Ethanol Control Valve | Ethanol line for loading rack | Steel | Bray | Series 92/93 | |
| Bearing | Flow Control Valve | Ms3002201 - Astm A 479 Type 304 Cold Finished | Smith | 529531001 | 4" 150 CS |
| Body | Flow Control Valve | Ms1008003 - Asme Sa216 Grade Wcb, .25% Max. Carbon | Smith | 528666001 | 4" 150 CS |
| Cover | Flow Control Valve | Ms1008001 - Asme Sa216 Grade Wcb | Smith | 528760001 | 4" 150 CS |
| Diaphragm | Flow Control Valve | Ms7001601 - Viton® Diaphragm Material, Compound Number Vx-0303 | Smith | 507399002 | 4" 150 CS |
| Diaphragm | Flow Control Valve | Ms7001601 - Viton® Diaphragm Material, Compound Number Vx-0303 | Smith | 507571003 | 4" 150 CS |
| Nut | Flow Control Valve | Low Carbon Steel | Smith | 002752400 | 4" 150 CS |
| Nut | Flow Control Valve | 302 Stainless Steel | Smith | 643756402 | 4" 150 CS |
| O-Ring | Flow Control Valve | Ms7000601 - Astm D2000 M6Hk810 A1-10 B38 Ef31 E078 E088 Z1 Z1= 75 +/- 5 | Smith | 640798416 | 4" 150 CS |
| O-Ring | Flow Control Valve | Ms7000601 - Astm D2000 M6Hk810 A1-10 B38 Ef31 E078 E088 Z1 Z1= 75 +/- 5 | Smith | 640798434 | 4" 150 CS |
| O-Ring | Flow Control Valve | Ms7000601 - Astm D2000 M6Hk810 A1-10 B38 Ef31 E078 E088 Z1 Z1= 75 +/- 5 | Smith | 641276405 | 4" 150 CS |
| Plate | Flow Control Valve | Ms4004801 - Sae J 463 Sep81 Uns C26000 Cold Rolled | Smith | 508553001 | 4" 150 CS |
| Plate | Flow Control Valve | Ms1000101 - Sae J403 May92 Aisi 1010 Cold Rolled | Smith | 528659001 | 4" 150 CS |
| Plug | Flow Control Valve | Ms1007504 - Astm A 105 | Smith | 006505002 | 4" 150 CS |
| Plug | Flow Control Valve | Steel, High Grade Alloy Astm-A105 M-87A | Smith | 644522401 | 4" 150 CS |
| Retainer | Flow Control Valve | Ms1007602 - Astm A 536-84 Gr. 60-40-18 | Smith | 507705004 | 4" 150 CS |
| Screw D | Flow Control Valve | Steel, Zinc Plate | Smith | 640813001 | 4" 150 CS |
| Seat | Flow Control Valve | Ms3004701 - Astm A 351 Grade Cf8 (Type 304) | Smith | 528406002 | 4" 150 CS |
| Spacer | Flow Control Valve | Ms1002801 - Astm A 519-90 Grade 1015-1020 Cold Finished | Smith | 524198004 | 4" 150 CS |
| Spring | Flow Control Valve | Ms3006701 - Sae J 217 Dec88 17-7 Ph Stainless Steel | Smith | 525351003 | 4" 150 CS |
| Spring | Flow Control Valve | Ms3005601 - Sae J 230 Dec88 302 Stainless Steel | Smith | 529464001 | 4" 150 CS |
| Stem | Flow Control Valve | Ms3000301 - Sae J 405 Jan89 Aisi Type 303 | Smith | 528658001 | 4" 150 CS |
| Stud De | Flow Control Valve | Ms1008901 - Asme Sa193 Grade B7 | Smith | 642362407 | 4" 150 CS |
| Washer | Flow Control Valve | Ms1007602 - Astm A 536-84 Gr. 60-40-18 | Smith | 508038003 | 4" 150 CS |
| Washer | Flow Control Valve | Ms3000404 - Sae J405 Jan89 Aisi Type 304 Cold Rolled Annealed | Smith | 528660007 | 4" 150 CS |
| Washer | Flow Control Valve | 302 Stainless Steel | Smith | 643164406 | 4" 150 CS |
| Controller | Instrumentation | | Scully | ST-15-115-E(Part #07748) | Controller for Component No. 19 |
| Densitometer | Instrumentation | | Solartron | 7828ADACAALDBAA | Insertion Type |
| Differential Pressure Gauge | Instrumentation | | Orange Research | 1516DG-1C-4.5B-0-30psid, 1, 6 (20-30) | |
| Flow Switch | Instrumentation | | Flowtec | V6EPB-S-S-2-S | |
| Flow Switch | Instrumentation | | Fluid Components | FLT93S-1A1A104C1B00000 | |
| Haze Tracker | Instrumentation | | APII | HT2 | |
| Level Switch | Instrumentation | | Magnetrol | B15-1E2E-HMN | For tanks without floating roof. |
| Level Switch | Instrumentation | | Magnetrol | B15-1EE2L-HMN | Lead displacer for floating roof. |
| Oil-on-Water Detector | Instrumentation | | InterOcean Systems, Inc. | SS 200 ADS | Slick Sleuth |
| Optical Interface Detector | Instrumentation | | Optical Solutions | 42015FV-F20T-DSXH-5-N | |
| Pig-Sig | Instrumentation | | T.D. Williamson | 04-7778-2013-51 | Pig detector for 6” or larger pipe. |
| Pressure Gauge | Instrumentation | | Perma-Cal | 111NIB07A23 | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Pressure Transmitter | Instrumentation | | Rosemount | 3051CG5A52A1AB4E5M5 | |
| Probe | Instrumentation | | Scully | SP-MU (Part #07996) | |
| Rapid Flasher | Instrumentation | | APII | FR2 | |
| RTD, 100 ohm Pt, for Temperature Transmitter | Instrumentation | | Rosemount | 0068R21C30A30T36E5V1 | 3" Immersion Length, 1" NPT |
| Sampler, 12-can | Instrumentation | | APII | ASI-112 | |
| Sampler, 2-can | Instrumentation | | APII | ASI-102 | |
| Tank Level Transmitter | Instrumentation | | Ohmart Vega | PS62.UXCAM2HKNAX | |
| Temperature Transmitter | Instrumentation | | Rosemount | 3144PD1A1E5B4M5C2 | For use with Component No. 1 |
| Cone | Meter (TUR) Guardsmen | Ms3002401 - Stainless Steel Astm A 479 Type 316 Cold Finished | Smith | 543339201 | 3" Guardsmen |
| Cone | Meter (TUR) Guardsmen | Ms3002401 - Stainless Steel Astm A 479 Type 316 Cold Finished | Smith | 543340210 | 3" Guardsmen |
| Housing (150#) | Meter (TUR) Guardsmen | 544553224 (Pipe) - Ms3002004 - Stainless Steel Astm A 312 Grade Tp304 Seamless<br>641921409 (Flange) - Ms3006601 - Stainless Steel Astm A 182 Grade F 304 | Smith | 544553123 | 3" Guardsmen |
| Housing (300#) | Meter (TUR) Guardsmen | 544553224 (Pipe) - Ms3002004 - Stainless Steel Astm A 312 Grade Tp304 Seamless<br>641613403 (Flange) - Ms3006601 - Stainless Steel Astm A 182 Grade F 304 | Smith | 544553124 | 3" Guardsmen |
| Housing (600#) | Meter (TUR) Guardsmen | 544553224 (Pipe) - Ms3002004 - Stainless Steel Astm A 312 Grade Tp304 Seamless<br>003770403 (Flange) - Ms1013102 - Carbon Steel Asme Sa-105 Or Astm A-105 | Smith | 544553131 | 3" Guardsmen |
| Journal | Meter (TUR) Guardsmen | Ms1007901 - Tungsten Carbide | Smith | 540305208 | 3" Guardsmen |
| Nut | Meter (TUR) Guardsmen | Astm A-194 Gr. 8A 304 Stainless Steel | Smith | 640704001 | 3" Guardsmen |
| Ring | Meter (TUR) Guardsmen | 302 Stainless Steel | Smith | 644420401 | 3" Guardsmen |
| Rotor | Meter (TUR) Guardsmen | 540293203 (Rotor) - Ms3017600 - Stainless Steel Astm A 176 Type 420<br>540296201 (Bearing) - Ms1007901 - Tungsten Carbide | Smith | 540292100 | 3" Guardsmen |
| Screw C | Meter (TUR) Guardsmen | Ms3011901 - 300 Series Stainless Steel (18-8 Ss) | Smith | 646630401 | 3" Guardsmen |
| Stator | Meter (TUR) Guardsmen | 543341203 (Shaft) - Ms3002401 - Stainless Steel Astm A 479 Type 316 Cold Finished<br>543958201 (Stator) - Ms3004103 - Stainless Steel Astm A 743 Grade Cf-8M (Type 316)<br>644417402 (Pin) - 302 Stainless Steel<br>644541401 (Pin) - 316 Stainless Steel<br>645416401 (Screw) - 316 Stainless Steel<br>646630401 (Screw) - Ms3011901 - 300 Series Stainless Steel (18-8 Ss) | Smith | 543856103 | 3" Guardsmen |
| Washer | Meter (TUR) Guardsmen | Ms1007901 - Tungsten Carbide | Smith | 543643202 | 3" Guardsmen |
| Bearing | Meter (TUR) Sentry | Ms1007901 - Tungsten Carbide | Smith | 541454212 | 6" Sentry |
| Bearing | Meter (TUR) Sentry | Ms1007901 - Tungsten Carbide | Smith | 541455212 | 6" Sentry |
| Cone | Meter (TUR) Sentry | Ms3004103 - Stainless Steel Astm A 743 Grade Cf-8M (Type 316) | Smith | 542363211 | 6" Sentry |
| Cone | Meter (TUR) Sentry | Ms3004103 - Stainless Steel Astm A 743 Grade Cf-8M (Type 316) | Smith | 542364211 | 6" Sentry |
| Housing (150#) | Meter (TUR) Sentry | 544506201 (Tube) - Ms3004202 - Stainless Steel Asme Sa-351 Cf8M (Type 316)<br>645053416 (Flange) - Ms1013102 - Carbon Steel Asme Sa-105 Or Astm A-105 | Smith | 544506101 | 6" Sentry |
| Housing (300#) | Meter (TUR) Sentry | 544506211 (Tube) - 544506201 (Tube) - Ms3004202 - Stainless Steel Asme Sa-351 Cf8M (Type 316)<br>645170406 (Flange) - Ms1013001 - Carbon Steel Astm A 350 Grade Lf2 Class 1 | Smith | 544506810 | 6" Sentry |
| Housing (600#) | Meter (TUR) Sentry | 544506221 (Tube) - Ms3004202 - Stainless Steel Asme Sa-351 Cf8M (Type 316)<br>645814406 (Flange) - Ms3011601 - Stainless Steel Astm A 182 Grade F 316 | Smith | 544506827 | 6" Sentry |
| Key | Meter (TUR) Sentry | 645473401 - No. 807, 316 Stainless Steel | Smith | 544115202 | 6" Sentry |
| Nut | Meter (TUR) Sentry | Ms3009901 - 300 Series Stainless Steel (18-8 Ss) | Smith | 643729401 | 6" Sentry |
| Pin | Meter (TUR) Sentry | Astm A-479 Type 316 Stainless Steel | Smith | 645457402 | 6" Sentry |
| Ring | Meter (TUR) Sentry | Ms3007301 - Stainless Steel Castings Astm A 743 Grade Cf-8M (Type 316) | Smith | 541685212 | 6" Sentry |
| Rotor | Meter (TUR) Sentry | 541455212 (Bearing) - Ms1007901 - Tungsten Carbide<br>542238200 (Screw) - Ms3001701 - Stainless Steel Sae J 405 Jan89 Aisi Type 430F<br>543093212 (Rim) - Ms3007301 - Stainless Steel Astm A 743 Grade Cf-8M (Type 316)<br>544425201 (Blade) - Ms3001501 - Stainless Steel Astm A 240 Type 316<br>544435201 (Hub) - Ms3002401 - Stainless Steel Astm A 479 Type 316 Cold Finished | Smith | 544440103 | 6" Sentry |
| Screw | Meter (TUR) Sentry | Ms3009901 - 300 Series Stainless Steel (18-8 Ss) | Smith | 645690401 | 6" Sentry |
| Shaft | Meter (TUR) Sentry | Ms3002401 - Stainless Steel Astm A 479 Type 316 Cold Finished | Smith | 544114201 | 6" Sentry |
| Washer | Meter (TUR) Sentry | Ms1007901 - Tungsten Carbide | Smith | 543851212 | 6" Sentry |
| Ethanol Meter | Meter for loading rack | | Titan Industries | 2" over Gear Pulse Meter | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Bearing | Meter, F4 A1 | Retainer - Lnp Type 3 Peek<br>Balls - 440C Stainless Steel<br>003775001 - Shaft - Ms3002801 - Astm A 564 Type 630 Condition A<br>512077001 - Shaft - Ms3002801 - Astm A 564 Type 630 Condition A<br>512583001 Cover (Sub Assy) - 511999001 (Weldment) - 511973001 - Boss - Ms1001101 - Sae J 403 May 94 Aisi 1215 Cold Finished<br>512001001 - Plate - Ms1007803 - Astm A 516 Grade 70<br>512008001 - Block - Ms1002302 - Astm A 29<br>512011001 - Cover - Ms1002001 - Asme Sa516 Grade 70<br>512123001 - Boss - Ms1001101 - Sae J 403 May 94 Aisi 1215 Cold Finished | Smith | 070360002 | |
| Cover | Meter, F4 A1 | 519882002 - Bushing - Ms5000302 - Powder Metal, Iron & Carbon Steel Mpif Std. 35 F-0008-20<br>641007401 - Pin - Steel, Chrome Vanadium, Sae 6150, Zinc Plate | Smith | 512125001<br>518630001 | |
| Gland | Meter, F4 A1 | 003138011 - Ring - Buna "N", Compound 228-70<br>003141001 - Spring - Ms3005601 - Sae J 230 Dec88 302 Stainless Steel<br>013117001 - Shaft - Ms6000201 - Astm D4181<br>518631001 - Follower - Ms3003001 - Sae J 405 Jan89 Aisi Type 303<br>512581002 (Mach) - 512597002 - 504064002 - Pad - Ms1001201 - Sae J 403 May 94 Aisi 12L14 Cold Finished<br>511948002 - Nozzle - Ms1008001 - Asme Sa216 Grade Wcb<br>511974001 - Foot - Ms1002403 - Astm A 36<br>512072001 - Fitting - Ms1008007 - Asme Sa216 Grade Wcb<br>515863002 - Ring - Ms1002104 - Asme Sa 53 Gr B Type S Or Type E Or Asme Sa106 Gr B Type S<br>517416001 - Ring - Ms1002001 - Asme Sa516 Grade 70<br>518544003 - Shell - Ms1002001 - Asme Sa516 Grade 70<br>518545003 - Strip - Ms1002001 - Asme Sa516 Grade 70<br>641609412 - Head - Ms1002001 - Asme Sa516 Grade 70 | Smith | 511982001 | |
| Housing | Meter, F4 A1 | 553704001 - Flange - Ms1013102 - Asme Sa-105 Or Astm A-105 | Smith | | |
| O-Ring | Meter, F4 A1 | Ms7000303 - Nitrile (Buna N), 70 Durometer | Smith | 512140001 | |
| Plate | Meter, F4 A1 | Ms3001201 - Sae J 405 Jan89 Aisi Type 440C | Smith | 001111001 | |
| Plug | Meter, F4 A1 | 1010-1018 Steel, Zinc Plated | Smith | 006073002 | |
| Plug | Meter, F4 A1 | Ms1007504 - Astm A 105 | Smith | 006505002 | |
| Plug | Meter, F4 A1 | Ms1007504 - Astm A 105 | Smith | 006878002 | |
| Ring | Meter, F4 A1 | Ms3005601 - Sae J 230 Dec88 302 Stainless Steel | Smith | 512066001 | |
| Screw C | Meter, F4 A1 | Steel, Medium Carbon, S.A.E. Grade 5 | Smith | 006169002 | |
| Shaft | Meter, F4 A1 | 065217402 - Pin - Stainless Steel, 18-8 Type 303<br>512068002 - Shaft - Ms3000301 - Sae J 405 Jan89 Aisi Type 303 | Smith | 512069001 | |
| Shaft | Meter, F4 A1 | 512065001 - Coupling - Ms1001201 - Sae J 403 May 94 Aisi 12L14 Cold Finished<br>512134001 - Shaft - Ms3002801 - Astm A 564 Type 630 Condition A | Smith | 512116001 | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| | | 001634001 - Pin - Ms3001201 - Sae J 405 Jan89 Aisi Type 440C | | 517153001 | |
| | | 001723400 - Nut - Ms1009801 - Low Carbon Steel (Less Than .30% Carbon) Cold Finished | | | |
| | | 002198002 - Spring - Ms3006701 - Sae J 217 Dec88 17-7 Ph Stainless Steel | | | |
| | | 003526002 - Screw - Ms3001001 - Sae J 405 Jan89 Aisi Type 416 | | | |
| | | 003527001 - Nut - Ms1008601 - Sae J 995 Jun79 Grade 2 | | | |
| | | 005535800 - Sae 2330, Heat Treated To Rockwell C Scale 40-50, Zinc Plated | | | |
| | | 006100002 - Screw M - Low Carbon, Zinc Plate | | | |
| | | 006140002 - Screw C - S.A.E. Grade 5, Zinc Plate | | | |
| | | 006325002 - Screw C - Steel, Low Carbon, Zinc Plate | | | |
| | | 006519001 - Bearing - 440C Stnl Stl Races | | | |
| | | 440C Stnl Stl Balls | | | |
| | | Stnl Stl Retainer | | | |
| | | 007900400 - Pin - Ms1015001 - Sae J 403 May 94 Aisi 1213 - 1215 Cold Finished | | | |
| | | 008251001 - Pin - Ms3000401 - Sae J 405 Jan89 Aisi Type 304 | | | |
| | | 008253002 - Rotor - 008253002 Rotor (Sub Assy) - 001636001 - Dowel - Ms3001201 - Sae J 405 Jan89 Aisi Type 440C | | | |
| | | 003791001 - Rotor - Ms1007201 - Astm A 48 Class 25 | | | |
| | | 003792001 - Cover - Ms1007201 - Astm A 48 Class 25 | | | |
| | | 006100002 - Screw M - Low Carbon, Zinc Plate | | | |
| | | 008900001 - Blade - Ms4005401 - Astm B 108 Aisi 355.0 T71 Temper | | | |
| | | 008901001 - Blade - Ms4005401 - Astm B 108 Aisi 355.0 T71 Temper | | | |
| | | 009552400 - Nut - Steel, Cadmium Plated | | | |
| | | 009593400 - Pin - Steel, Chrome Vanadium Sae 6150, Zinc Plated | | | |
| | | 009606400 - Screw M - Ms1000202 - Sae J 403 May 94 Aisi 1008 - 1020 Cold Finished | | | |
| | | 010525400 - Screw C - Ms1008302 - Sae J 429 Aug83 Grade 5 | | | |
| | | 011226001 - Clamp - Ms3003502 - Type 301, 302 Or 304 | | | |
| | | 011681001 - Roller - Ms3001201 - Sae J 405 Jan89 Aisi Type 440C | | | |
| | | 064150001 - Ring - Spring Carbon Steel Sae 1065-1090 | | | |
| | | 072186001 - Pitot - Ms1003501 - Astm A 1008 | | | |
| | | 511875001 - Cover - Ms1007201 - Astm A 48 Any Year Of Revision Class 25 | | | |
| | | 511876001 - Shaft - Ms3001001 - Sae J 405 Jan89 Aisi Type 416 | | | |
| | | 511945001 - Arm - Ms1007602 - Astm A 536-84 Gr. 60-40-18 | | | |
| | | 006505002 - Plug - Ms1007504 - Astm A 105 | | | |
| | | 511997010 - Body - Ms1007201 - Astm A 48 Any Year Of Revision Class 25 | | | |
| | | 512002001 - Lug - Ms3000201 - Stainless Steel Sheet & Plate Type 302, 304 Or 316 | | | |
| | | 512062001 - Gear - 512061001 - 512014001 - Ms1001101 - Sae J 403 May 94 Aisi 1215 Cold Finished | | | |
| | | 512015001 - Ms3002801 - Astm A 564 Type 630 Condition A | | | |
| | | 513202001 - Ms1015001 - Sae J 403 May 94 Aisi 1213 - 1215 Cold Finished | | | |
| | | 512064002 - Coupling - Ms1001101 - Sae J 403 May 94 Aisi 1215 Cold Finished | | | |
| | | 512073001 - Pin - Ms3000301 - Sae J 405 Jan89 Aisi Type 303 | | | |
| | | 512074001 - Collar - Ms1001101 - Sae J 403 May 94 Aisi 1215 Cold Finished | | | |
| | | 512075001 - Spacer - Ms3000201 - Stainless Steel Sheet & Plate Type 302, 304 Or 316 | | | |
| | | 512112001 - Plate - 003795001 - Ms1002301 - Astm A 29 Grade 1018 Cold Finished | | | |
| | | 011684001 - Ms1000701 - Sae J 403 May 94 Aisi 1045 Cold Finished | | | |
| | | 512115001 - Dowel - Ms3002801 - Astm A 564 Type 630 Condition A | | | |
| | | 512714001 - Plate - Ms1002403 - Astm A 36 Hot Rolled | | | |
| | | 512715001 - Key - Ms1000301 - Sae J 403 May 94 Aisi 1018 Cold Finished | | | |
| | | 512719001 - Cover - Ms1002501 - Astm A 1008 Commercial Steel Type B | | | |
| | | 065309002 - Washer - Ms1013501 - Astm F 436 | | | |
| | | 516109001 - Bearing & Clamp - 006523001 - Bearing - 440C Stn. Steel | | | |
| | | 512076001 - Clamp - Ms3003801 - Astm A 240 Type 304 Cold Rolled Annealed & Pickled | | | |
| | | 517019001 - Cam - Ms1007401 - Sae J 404 Apr 94 Aisi 4150 Hot Rolled | | | |
| | | 517085001 - Block - Ms1007201 - Astm A 48 Class 25 | | | |
| | | 519882001 - Bushing - Ms5000302 - Powder Metal, Iron & Carbon Steel Mpif Std. 35 F-0008-20 | | | |
| | | 641044401 - Screw M - Steel (Sae Grade 5), Zinc Plate | | | |
| | | 642482406 - Washer - Spring Steel, Zinc Plated | | | |
| | | 643249401 - Washer - 302 Stainless Steel, Full Hard, Cold Rolled | | | |
| Mechanism | Meter, F4 A11 | 643764402 - Screw C - Stainless Steel Type 316 Elc. | Smith | | |
| Automatic Tank Gauge | Pipeline storage & truck terminal | | MTS | | |
| Back Pressure control Valves | Pipeline storage & truck terminal | | Daniel | | |
| Block Valves | Pipeline storage & truck terminal | | Foster | | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Block Valves | Pipeline storage & truck terminal | | OFM | | |
| Block Valves | Pipeline storage & truck terminal | | Orbit | | |
| Block Valves | Pipeline storage & truck terminal | | True Seal | | |
| Block Valves | Pipeline storage & truck terminal | | WKM | | |
| Gate Valves | Pipeline storage & truck terminal | | Velan | | |
| Gravitometers | Pipeline storage & truck terminal | | Densitrack | | |
| Gravitometers | Pipeline storage & truck terminal | | Solatron | | |
| Meters (PD) | | | Brodie | | |
| Injection Pump | Pipeline storage & truck terminal | | Roper | | |
| Injection pumps | Pipeline storage & truck terminal | | FMC | | |
| Mainline Pump | Pipeline storage & truck terminal | | United | 7 stage 6x6x11 | |
| Pressure Relief Valves | Pipeline storage & truck terminal | | Daniel | | |
| Prover ball | Pipeline storage & truck terminal | | Drinkwater | | |
| Prover ball | Pipeline storage & truck terminal | | Enduro | | |
| Sampler pumps | Pipeline storage & truck terminal | | Micropump | | |
| Side line Tank Gauge | Pipeline storage & truck terminal | | Varec | | |
| Tank seals | Pipeline storage & truck terminal | | | | |
| Temp. & Pres. Transmitters | Pipeline storage & truck terminal | | Rosemont | | |
| Twin Seal Valves | Pipeline storage & truck terminal | | General | | |
| Plunger | Prover | Stainless Steel | | | |
| Sphere | Prover | Polyurethane | | | |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Case and impellar rings, throat and throttle bushings | Pump | Bronze B584-903, B584-932, B584-936 | United | | |
| Impeller | Pump | Bronze B584-905, B584-958 | United | | |
| Mechanical Seal | Pump | Tungsten Carbide / Silicon Carbide, Carbon (various grades), AISI 313, Viton® B | John Crane | 8B | |
| Wear rings/bushings | Pump | Graphalloy | Graphite Metallizing Corp | | |
| Case | Pump | Meeh | Byron Jackson | Byron Jackson 20 HQH-VTP | |
| Case | Pump | carbon steel | Flowserve | | |
| Case | Pump | A 120 GR B | Goulds | Goulds 12 x 11 DC-VIC | |
| Case | Pump | A 216 | Goulds | Goulds 12 x 11 DC-VIC | |
| Case | Pump | Steel | Goulds | Goulds 20 x 36 TMC | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Case | Pump | Steel | Johnston | Johnston 20 DHC-24 DC | |
| Case | Pump | Steel | Johnston | Johnston 24 EC-20 QHC | |
| Case | Pump | Steel | Johnston | Johnston 24 EC-24 QLC-2-2 | |
| Case | Pump | A 216 | Sulzer | - Bingham 14 x 14 x 12.5 HSB | |
| Case | Pump | A 216 WCB | Sulzer | Bingham 20 x 24 x 34 HSB | |
| Case | Pump | A 216 | United | United 8 x 13 WMSN-4 | |
| Case | Pump | A 216 | United | United 10 x 12 x 15.5 BFH | |
| Case | Pump | A 216 | United | United L – 8 x 13 WMSNL | |
| Case | Pump | A 216 WCB | United | United 20 x 20 x 28 DVS | |
| Case | Pump | A 216 WCB | United | United 24 x 24 x 24 DVS | |
| Case | Pump | A 216 WCB | United | United 24 x 24 x 33 DVS | |
| Case | Pump | A 216 WCB | United | United V – 8 x 13 WMSN-M | |
| Case | Pump | Cast Steel | United | United U 6 x 11 WMSNDH | |
| Case | Pump | Steel | United | United 14 x 28 DVS | |
| Case | Pump | Steel | United | United 16 x 25 DVS | |
| Case | Pump | | United | United 8 BFH-C | |
| Case/Impeller wear rings | Pump | 316 SS | Byron Jackson | Byron Jackson 20 HQH-VTP | |
| Case/Impeller wear rings | Pump | Bronze | Goulds | Goulds 12 x 11 DC-VIC | |
| Case/Impeller wear rings | Pump | Bronze | Goulds | Goulds 20 x 36 TMC | |
| Case/Impeller wear rings | Pump | Ni Resist | Goulds | Goulds 12 x 11 DC-VIC | |
| Case/Impeller wear rings | Pump | Bronze | Johnston | Johnston 20 DHC-24 DC | |
| Case/Impeller wear rings | Pump | Bronze | Johnston | Johnston 24 EC-20 QHC | |
| Case/Impeller wear rings | Pump | Bronze | Johnston | Johnston 24 EC-24 QLC-2-4 | |
| Case/Impeller wear rings | Pump | Cast Iron-inco Ni Resist I/13% Cr Steel | Sulzer | - Bingham 14 x 14 x 12.5 HSB | |
| Case/Impeller wear rings | Pump | Ni-Resist I/ CA6NM | Sulzer | Bingham 20 x 24 x 34 HSB | |
| Case/Impeller wear rings | Pump | A 436 Ni Resist/A 216 | United | United V – 8 x 13 WMSN-M | |
| Case/Impeller wear rings | Pump | Cast Iron-inco Ni Resist I/13% Cr Steel | United | United 10 x 12 x 15.5 BFH | |
| Case/Impeller wear rings | Pump | Ni Resist I | United | United 8 x 13 WMSN-6 | |
| Case/Impeller wear rings | Pump | Ni Resist I | United | United L – 8 x 13 WMSNL | |
| Case/Impeller wear rings | Pump | Ni Resist/440 HT | United | United 20 x 20 x 28 DVS | |
| Case/Impeller wear rings | Pump | Ni Resist/440 HT | United | United 24 x 24 x 24 DVS | |
| Case/Impeller wear rings | Pump | Ni Resist/440 HT | United | United 24 x 24 x 33 DVS | |
| Case/Impeller wear rings | Pump | Ni-Resist I | United | United 16 x 25 DVS | |
| Case/Impeller wear rings | Pump | Steel | United | United U 6 x 11 WMSNDH | |
| Case/Impeller wear rings | Pump | | United | United 8 BFH-C | |
| Case/Impeller wear rings | Pump | | United | United 14 x 28 DVS | |
| Cyclone Separator | Pump | Heanium (Ceramic), Viton®, 1018 Steel | | | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Diffuser | Pump | Cast Iron | Johnston | Johnston 24 EC-20 QHC | |
| Diffuser | Pump | Cast Iron | Johnston | Johnston 24 EC-24 QLC-2-6 | |
| Diffusers | Pump | 316 SS | Goulds | Goulds 12 x 11 DC-VIC | |
| Diffusers | Pump | Cast Iron | Goulds | Goulds 20 x 36 TMC | |
| Diffusers | Pump | (1) Cast Iron/VIT; (6) Cast Iron/Scothkote | Johnston | Johnston 20 DHC-24 DC | |
| Impeller | Pump | Meeh | Byron Jackson | Byron Jackson 20 HQH-VTP | |
| Impeller | Pump | Bronze | Flowserve | | |
| Impeller | Pump | carbon steel | Flowserve | | |
| Impeller | Pump | cast iron | Flowserve | | |
| Impeller | Pump | Aluminum Bronze | Goulds | Goulds 20 x 36 TMC | |
| Impeller | Pump | Bronze | Goulds | Goulds 12 x 11 DC-VIC | |
| Impeller | Pump | Steel | Goulds | Goulds 12 x 11 DC-VIC | |
| Impeller | Pump | Bronze | Johnston | Johnston 20 DHC-24 DC | |
| Impeller | Pump | Bronze | Johnston | Johnston 24 EC-20 QHC | |
| Impeller | Pump | Bronze | Johnston | Johnston 24 EC-24 QLC-2-3 | |
| Impeller | Pump | CA6NM | Sulzer | Bingham 20 x 24 x 34 HSB | |
| Impeller | Pump | Cast Steel | Sulzer | - Bingham 14 x 14 x 12.5 HSB | |
| Impeller | Pump | A 216 WCB | United | United 20 x 20 x 28 DVS | |
| Impeller | Pump | A 216 WCB | United | United 24 x 24 x 24 DVS | |
| Impeller | Pump | A 216 WCB | United | United 24 x 24 x 33 DVS | |
| Impeller | Pump | A 216 WCB | United | United V – 8 x 13 WMSN-M | |
| Impeller | Pump | Cast Steel | United | United 8 x 13 WMSN-5 | |
| Impeller | Pump | Cast Steel | United | United 10 x 12 x 15.5 BFH | |
| Impeller | Pump | Cast Steel | United | United 16 x 25 DVS | |
| Impeller | Pump | Cast Steel | United | United L – 8 x 13 WMSNL | |
| Impeller | Pump | Cast Steel | United | United U 6 x 11 WMSNDH | |
| Impeller | Pump | | United | United 8 BFH-C | |
| Impeller | Pump | | United | United 14 x 28 DVS | |
| Seal | Pump | Viton® B | Flowserve | | Use Dupont for FI |
| Seal Face | Pump | Carbon | Flowserve | | |
| Seal Face | Pump | Silcar | Flowserve | | |
| Seal Face | Pump | Tungsten Carbide | Flowserve | | |
| Seal Sleeve | Pump | 316 SS | Johnston | Johnston 24 EC-24 QLC-2-5 | |
| Seal Sleeve | Pump | 316 SS | Sulzer | - Bingham 14 x 14 x 12.5 HSB | |
| Seal Sleeve | Pump | 316 SS | Sulzer | Bingham 20 x 24 x 34 HSB | |
| Seal Sleeve | Pump | 316 SS | United | United 8 x 13 WMSN-7 | |
| Seal Sleeve | Pump | 316 SS | United | United 10 x 12 x 15.5 BFH | |
| Seal Sleeve | Pump | 316 SS | United | United 14 x 28 DVS | |
| Seal Sleeve | Pump | 316 SS | United | United 16 x 25 DVS | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Seal Sleeve | Pump | 316 SS | United | United 20 x 20 x 28 DVS | |
| Seal Sleeve | Pump | 316 SS | United | United 24 x 24 x 24 DVS | |
| Seal Sleeve | Pump | 316 SS | United | United 24 x 24 x 33 DVS | |
| Seal Sleeve | Pump | 316 SS | United | United L – 8 x 13 WMSNL | |
| Seal Sleeve | Pump | 316 SS | United | United U 6 x 11 WMSNDH | |
| Seal Sleeve | Pump | 316 SS | United | United V – 8 x 13 WMSN-M | |
| Seal Sleeve | Pump | Cast Iron | United | Johnston 20 DHC-24 DC | |
| Seal Sleeve | Pump | | | United 8 BFH-C | |
| Shaft | Pump | 416 SS | Byron Jackson | Byron Jackson 20 HQH-VTP | |
| Shaft | Pump | 4140 | Goulds | Goulds 12 x 11 DC-VIC | |
| Shaft | Pump | 316 SS | Goulds | Goulds 20 x 36 TMC | |
| Shaft | Pump | 416 SS | Goulds | Goulds 12 x 11 DC-VIC | |
| Shaft | Pump | A 322/4140 | Sulzer | - Bingham 14 x 14 x 12.5 HSB | |
| Shaft | Pump | A 434/4140 | Sulzer | Bingham 20 x 24 x 34 HSB | |
| Shaft | Pump | A 322/4140 | United | United 8 x 13 WMSN-3 | |
| Shaft | Pump | A 322/4140 | United | United L – 8 x 13 WMSNL | |
| Shaft | Pump | A 434/4140 | United | United 20 x 20 x 28 DVS | |
| Shaft | Pump | A 434/4140 | United | United 24 x 24 x 24 DVS | |
| Shaft | Pump | A 434/4140 | United | United 24 x 24 x 33 DVS | |
| Shaft | Pump | A322/4140 | United | United 10 x 12 x 15.5 BFH | |
| Shaft | Pump | A322/4140 Ni Plated | United | United 16 x 25 DVS | |
| Shaft | Pump | Steel | United | United 14 x 28 DVS | |
| Shaft | Pump | Steel | United | United U 6 x 11 WMSNDH | |
| Shaft | Pump | | United | United 8 BFH-C | |
| Shaft | Pump | 316 SS | | Johnston 20 DHC-24 DC | |
| Shaft | Pump | 316 SS | | Johnston 24 EC-24 QLC-2-1 | |
| Shaft | Pump | 4140 Ni Plated | | United V – 8 x 13 WMSN-M | |
| Shaft | Pump | Steel | | Johnston 24 EC-20 QHC | |
| Wear rings/bushings | Pump (Centrigal) | PEEK (polyetheretherketone) | Victrex | | |
| 3/4" Pipe | Pump API 11 SW SS Cano 3/4" #1500 RF | A312 316L | Flowserve | 1 CANRE0066 | |
| Cross | Pump API 11 SW SS Cano 3/4" #1500 RF | A182-92 Gr F | Flowserve | 1 ACCCR0010 | |
| Elbow | Pump API 11 SW SS Cano 3/4" #1500 RF | AISI 316 | Flowserve | 1 ACCNV0023 | |
| Flange | Pump API 11 SW SS Cano 3/4" #1500 RF | A182-92 Gr F | Flowserve | 1 ACCBR0033 | |
| Flexitallic Gasket | Pump API 11 SW SS Cano 3/4" #1500 RF | AISI 316+Flexicarb | Flowserve | 1 027985 | |
| Nipple | Pump API 11 SW SS Cano 3/4" #1500 RF | A312 316L | Flowserve | 1 BW007520160NC | |
| Orifice Plate | Pump API 11 SW SS Cano 3/4" #1500 RF | AISI 316 | Flowserve | 1 A102495DB | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Stud | Pump API 11 SW SS Cano 3/4" #1500 RF | AISI 317 | Flowserve | 1 A07512DB | |
| Baseplate | Pump Baseplate and Coupling | AISI 1010-25 | Flowserve | 1 11151339 | |
| Coupling Guard | Pump Baseplate and Coupling | AISI 1010-25 | Flowserve | 1 11151397 | |
| Hex Head Screws | Pump Baseplate and Coupling | AISI J429 Gr | Flowserve | 1 4R351734 | |
| Shim | Pump Baseplate and Coupling | AISI 18-8 | Flowserve | 1 A101887CK | |
| Casing Gasket | Pump Bearing Housing | Armstrong TN 9004 | Flowserve | 1 11151698 | 6x11 DMX |
| Flange Cover | Pump Bearing Housing | | Flowserve | 1 608211 | 6x11 DMX |
| Mechanized Casing | Pump Bearing Housing | A215 Gr WCB | Flowserve | 1 11151697 | 6x11 DMX |
| Pump | Pump for loading rack | Cast steel case, bronze impeller | Flowserve | 2K4x3-13RV M3 ST FPD - DCI | |
| Shaft Pump | Pump Kit Shaft Pump | D3114=A434 CL BC TP | Flowserve | 1 11151700 | 6x11 DMX-7 |
| Square Key | Pump Kit Shaft Pump | D9051=AISI 316 | Flowserve | 1 C02514DB | 6x11 DMX-7 |
| Hex Nut | Pump Mechanical Seal | A194 CL 2H | Flowserve | 1 4R4821EM | |
| Stud | Pump Mechanical Seal | AISI 316 | Flowserve | 1 A07511DB | |
| Washer | Pump Mechanical Seal | AISI 316 | Flowserve | 1 4R3455DB | |
| 1" Pipe | Pump Mechanized Casing | ASTM A53 | Flowserve | 1 CANRE0029 | 6x11 DMX-7 |
| 3/4" Pipe | Pump Mechanized Casing | A53 Gr B | Flowserve | 1 CANRE0028 | 6x11 DMX-7 |
| Blind Nut | Pump Mechanized Casing | A194 Grd 7 | Flowserve | 1 10132835 | 6x11 DMX-7 |
| Flange | Pump Mechanized Casing | A105 | Flowserve | 1 ACCBR0080 | 6x11 DMX-7 |
| Foundary Casing Lower Half | Pump Mechanized Casing | A216 GR WCB | Flowserve | 1 11151290 | 6x11 DMX-7 |
| Hex Nut | Pump Mechanized Casing | A194 CL 2H | Flowserve | 1 4R4821EM | 6x11 DMX-7 |
| Pin | Pump Mechanized Casing | AISI 1038/45 | Flowserve | 1 AA642511EK | 6x11 DMX-7 |
| Square Head Screws | Pump Mechanized Casing | AISI J429 Gr | Flowserve | 1 TOCAC003334 | 6x11 DMX-7 |
| Stud | Pump Mechanized Casing | A193 GR B7 | Flowserve | 1 A17508AC | 6x11 DMX-7 |
| Washer | Pump Mechanized Casing | D9053 = AISI 1010-25 | Flowserve | 1 62282108 | 6x11 DMX-7 |
| Allen Screw | Pump Radial BRG HSG | AISI J429 Gr 5HT | Flowserve | 1 4N0303534 | Sleeve Refrigeration |
| Babbitt Bearing | Pump Radial BRG HSG | AISI 40+BABBI | Flowserve | 1 62572946 | Sleeve Refrigeration |
| Breather Plug | Pump Radial BRG HSG | AISI 1010-25 | Flowserve | 1 A 100648EH | Sleeve Refrigeration |
| Connector | Pump Radial BRG HSG | AISI 316 | Flowserve | 1 ACTNV0002 | Sleeve Refrigeration |
| Cooling Tube | Pump Radial BRG HSG | AISI 316 | Flowserve | 1 62110051 | Sleeve Refrigeration |
| Dowel Pin | Pump Radial BRG HSG | AISI 1010-25 | Flowserve | 1 AA757409EH | Sleeve Refrigeration |
| Hex Head Screws | Pump Radial BRG HSG | AISI J429 | Flowserve | 1 4R385434 | Sleeve Refrigeration |
| Hex Nut | Pump Radial BRG HSG | SAEJ429GR5HT | Flowserve | 1 4R659734 | Sleeve Refrigeration |
| Nipple | Pump Radial BRG HSG | A53 Gr B | Flowserve | 1 N02515080PB | Sleeve Refrigeration |
| Oiler Ring | Pump Radial BRG HSG | AISI 621 | Flowserve | 1 62571609 | Sleeve Refrigeration |
| Plug | Pump Radial BRG HSG | AISI 1010-25 | Flowserve | 1 4R2999EH | Sleeve Refrigeration |
| Radial BRG. HSG.DMX Serie 350 Ball/SLV | Pump Radial BRG HSG | A216 GR WCB | Flowserve | 1 0625373 | Sleeve Refrigeration |
| Union Double | Pump Radial BRG HSG | A105 | Flowserve | 1 ACCUD0031 | Sleeve Refrigeration |
| Casing Wear Ring | Pump Rotating Element | A479 TP 316L+ST.6 | Flowserve | 1 11151337 | 6x11 DMX |
| Casing Wear Ring Back | Pump Rotating Element | A351 GR CF3M +ST6 | Flowserve | 1 11151341 | 6x11 DMX |
| Center Bushing | Pump Rotating Element | C4016=IR 913 | Flowserve | 1 62790530 | 6x11 DMX |
| Center Sleeve | Pump Rotating Element | D4011=IR 655 | Flowserve | 1 62446794 | 6x11 DMX |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Coupling Nut | Pump Rotating Element | AISI 1213-15 | Flowserve | 1 07328685 | 6x11 DMX |
| Impeller | Pump Rotating Element | A487 Gr CA6NM | Flowserve | 1 10164514 | 6x11 DMX |
| Impeller Wear Ring | Pump Rotating Element | A479 TP 316L+ST.1 | Flowserve | 1 11151328 | 6x11 DMX |
| Set Screw | Pump Rotating Element | AISI 316 | Flowserve | 1 4R1043DB | 6x11 DMX |
| Split Ring | Pump Rotating Element | AISI 316 | Flowserve | 1 62040373 | 6x11 DMX |
| Stuffing Box Bushing | Pump Rotating Element | D4021=A479 TP 410 | Flowserve | 1 62394473 | 6x11 DMX |
| Throat Bushing | Pump Rotating Element | D4011=IR 655 | Flowserve | 1 11151527 | 6x11 DMX |
| Throttling Bushing | Pump Rotating Element | D4011=IR 655 | Flowserve | 1 62723432 | 6x11 DMX |
| Lock Nut | Pump Thrust BRG HSG | AISI 1010-25 | Flowserve | 1 AB1068N12EH | Ball/Sleeve Refrigeration |
| Oil Baffle Plate | Pump Thrust BRG HSG | AISI 1010-25 | Flowserve | 1 62110317 | Ball/Sleeve Refrigeration |
| Shim | Pump Thrust BRG HSG | AISI 1010-25 | Flowserve | 1 A 102381EH | Ball/Sleeve Refrigeration |
| Thrust Sleeve BRG. 7312 | Pump Thrust BRG HSG | AISI 1213-15 | Flowserve | 1 62119037 | Ball/Sleeve Refrigeration |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Washer Lock | Pump Thrust BRG HSG | AISI 1010-25 | Flowserve | 1 AB1068W12EH | Ball/Sleeve Refrigeration |
| Body Suspension | Surge Relief Flow Valves | ASTM A216, A352 | Danflow | | |
| O=ring | Surge Relief Flow Valves | Nylon | Danflow | | |
| Retainer | Surge Relief Flow Valves | ASTM A216, 17-4 PH SS | Danflow | | |
| Seat Trim | Surge Relief Flow Valves | 316SS | Danflow | | |
| Spring | Surge Relief Flow Valves | Cr-V (Alloy Steel), 18-8 SS | Danflow | | |
| Air Eliminator | Truck Loading Terminal | | Smith | QFII | 4” |
| Butterfly Valves | Truck Loading Terminal | | Watts Regulator | 781E791 | CS |
| Check Valve | Truck Loading Terminal | | Sharpe | 12” – 25 -1 – 1 – 4 | 12” 150 # CS |
| Check Valve | Truck Loading Terminal | | Sharpe | 6” – 25 -1 – 1 – 4 | 6” 150 # CS |
| Check Valve | Truck Loading Terminal | | Wheatley | 22531C | 6” CS |
| Dry Break Coupler | Truck Loading Terminal | | Gardner Denver | J0451 - 051 | |
| Flow Check | Truck Loading Terminal | Viton® | Young Oil Tools | Style WC | 4” CS (Viton Seats (o-rings)) |
| Flow Checks | Truck Loading Terminal | Viton® | Davis | 1260 | 4” CS (Viton® Seats) |
| Flow Control Valve | Truck Loading Terminal | | Smith | 210 | 4” CS |
| Flow Control Valve | Truck Loading Terminal | | Smith | 210 | 4” 150# |
| Gate Valve | Truck Loading Terminal | | Crane | N2 1801 | 6” CS |
| Gate Valve | Truck Loading Terminal | | Crane | N2231B | 4” CS |
| Gate Valve | Truck Loading Terminal | | TVI | | 6” CS |
| Gate Valve | Truck Loading Terminal | | TVI | 1053 | 2” CS |
| Gate Valve | Truck Loading Terminal | | TVI | 125 | 8” CS |
| Gate Valve | Truck Loading Terminal | | TVI | 967 | 6” CS |
| Gate Valve | Truck Loading Terminal | | TVI | | 4” CS |
| Meters | Truck Loading Terminal | | Smith | F4 – A1 | 4” CS |
| PD Meter | Truck Loading Terminal | Housing = Carbon Steel, End Plates = Cast Aluminum, Rotors, Cast Aluminum, Hard Anodized, Rotor Shafts = 17-4 ph SS, Rotor Bearings = SS Ball Bearings, O'rings = Viton Standard | Brodie | model 8281 | Birotor plus |
| Pressure relief | Truck Loading Terminal | | Ful Flo | VJ4RSP | 1” CS |
| Pump | Truck Loading Terminal | | Goulds Pump | 776D771 | 4 x 6 – 13 CS Body (S.S. Seal) |
| Pump | Truck Loading Terminal | | Goulds Pump | | 3 x 4 – 13 CS Body (S.S. Seal) |
| Pump | Truck Loading Terminal | Ductile Iron | Ruhrpumpen | H50 12x10x15 | Ductile Iron |
| Thermal Relief Valve | Truck Loading Terminal | | Stra-Val | 1” RV05 – IDT | 1” |
| Turbine Meter | Truck Loading Terminal | | Smith | K2GDA003C00 | 3”, Guardsman LSJ-H Series |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Vane Pump | Truck Loading Terminal | | Blackmer | #GX4B | Sliding vane pump, ductile iron, 300 gpm @ 147' HD |
| Valve Stem Seal Packing | Valve Stem Seal | Viton | Parker | EC Pak and Poly Pak | Most common matl is Viton |
| Ball Valve | | | Apollo | Ball Valve | Small diameter |
| Ball Valve | | | WKM | Ball Valve | Small diameter |
| Casing | | | Flowserve, Sulzer | Various | ASMT A216 Grade WCB |
| Casing Ring | | PEEK | Flowserve | Various | Poly Ether Ether Ketone |
| Casing Ring, Impeller Ring | | | Flowserve, Sulzer | Various | Stellite 6, Stellite 1 |
| Casing Ring, Impeller Ring, Throat Bushing, Throttle Bushing, Throttle Sleeve, Throat Sleeve | | AISI 420, Laser Hardened | Flowserve | Various | AISI 420, Laser Hardened |
| Casing Ring, Impeller Ring, Throat Bushing, Throttle Bushing, Throttle Sleeve, Throat Sleeve | | AISI 316L or ASTM A351 Grade CF3 | Flowserve, Sulzer | Various | AISI 316L or ASTM A351 Grade CF3 |
| Casing Stud | | ASTM A193 Grade B7 | Flowserve, Sulzer | N/A | ASTM A193 Grade B7 |
| Check Valve | | | M & J Valve | Swing Check Valve | Various sizes |
| Check valve | | Viton | Wheatley | | Mainline and station ( O-Ring ) Viton |
| Control Valve 16" line | | | Fisher | | Packing unknown |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Control valve 20" line | | | Mason Neilson | | Packing unknown |
| Differential pressure switch | | Viton | Orange research | | O-ring viton |
| Drain Valves | | Viton | Grove | 4000 D-seal | O-Rings Viton |
| Drain Valves | | | Orbit | | Packing |
| Gasket | | | Advanced Products | Flange Kit, FNDW | Insulating gasket used around meters to insulate from cathodic protection system. |
| Gasket | | | Armstrong | TN-9004 | Main Line Pump parting flange gaskets |
| Gasket | | | Flexitallic | CG, CGI | Various Sizes. CG used in terminals, CGI used in mainline. |
| Gasket | | | Garlock | RW, RWI | Limited uses |
| Gate Valve | | | M & J Valve | 303A | Gate Valve, various sizes |
| Gate Valve | | | M & J Valve | Expanding Gate Valve | Various sizes |
| Gate Valve | | | M & J Valve | Compact Expanding Gate Valve | Various sizes, limited use |
| Gate valve 16" line | | | Grove | | Mainline valve ( O-Ring ) Viton |
| Gate valve 20" line | | | WKM | | Mainline valve ( Packing ) |
| Gate Valves | | Viton | Foster - Ingram Cactus | | O-Rings Viton |
| Impeller | | ASTM A487 Grade CA6NM | Flowserve, Sulzer | Various | ASTM A487 Grade CA6NM |
| Impellers | | Cast Bronze | Flowserve, Sulzer | Various | Cast Bronze |
| Keys, Various Components | | AISI 316 | Flowserve, Sulzer | Various | AISI 316 |
| M/L Pump | | Viton | BWIP | 8x10x13 M MSN 3-stage | Seals have Viton o-rings |
| Mechanical Seal | | AISI 316SS, Silicon Carbide / Carbon, Viton | Flowserve | QB – 5U4X | AISI 316SS, Silicon Carbide / Carbon, Viton |
| Meters (PD) | | | A. O. SMITH | D-200 | |
| Meters (PD) | | | A. O. SMITH | D-75 | |
| Meters (PD) | | | A. O. SMITH | JA-10S7 | |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Meters (PD) | | | Brodie/rockwel | B-95 | |
| Meters (PD) | | | Brooks | B071ACAAAA-CCAA | |
| Meters (PD) | | | Smith | D-200 | |
| Meters (PD) | | | Smith | F4-S1 | |
| Meters (PD) | | | Smith | M-75 | |
| Meters (PD) | | | Smith | S-100 | |
| Meters (PD) | | | Smith | S-75 | |
| Meters (PD) | | | Smith | W-75 | |
| Meters (PT) | | Body, Suspension, Rotor Blades, Rotor Rim, Cones = 304 or 316SS, Flanges = Carbon steel, 304, or 316SS, Rotor Blades = 430SS or Ni 200, Sleeve and Journal Bearings = Cemented Tungsten Carbide, Rotor Hub, 420SS, 7075 Al, 304SS, and 316SS, Rim Buttons = Hi Mu 80, Shaft = 304SS (Chrome Plated) or 316SS | Daniel | 3 through 24 inch liquid tubrine meters | |
| Meters (S) | | | Caldon | 240C | |
| Meters (S) | | | Caldon | 240CT640SS300GP | |
| Meters (S) | | | Caldon | LEFM 240C | |
| Meters (S) | | A216 | Faure Herman | FH8500 | |
| Meters (S) | | | Krohne | 3 beam beta uni | |
| Meters (S) | | | Krohne | Altosonic V | |
| Meters (S) | | | Krohne | AltoV | |
| Meters (S) | | | Krohne | UFM 3030 | |
| Meters (S) | | | Krohne | UFM 3030 K | |
| Meters (S) | | | Krohne | UFM 3030 K-DIV1 | |
| Meters (S) | | | Krohne | UFM Alto 5 | |
| Meters (S) | | | Krohne | UFM3030 3-beam | |
| Meters (S) | | | Panametrics | DF 868 | |
| Meters (S) | | | Smith | W-90 | |
| Meters (TUR) | | | A. O. SMITH | 6CA2-1 | |
| Meters (TUR) | | | A. O. SMITH | 6CS4-6 | |
| Meters (TUR) | | | A. O. SMITH | K2DFA00310 | |
| Meters (TUR) | | | A. O. SMITH | LF (Low Flow) | |
| Meters (TUR) | | | A. O. SMITH | 1-6-CA-27 | |
| Meters (TUR) | | | A. O. SMITH | 5C51-7 | |
| Meters (TUR) | | | A. O. SMITH | 6 CA 17 | |
| Meters (TUR) | | | A. O. SMITH | 6SS4C7S | |
| Meters (TUR) | | | A. O. SMITH | K2DGAOA1100 | |
| Meters (TUR) | | | A. O. SMITH | LF6CA1-1 | |
| Meters (TUR) | | | A. O. SMITH | 6CS21 | |
| Meters (TUR) | | | A. O. SMITH | 6-S-S-B-1C-7-S | |
| Meters (TUR) | | | A. O. SMITH | 8CA2-1 | |
| Meters (TUR) | | | A. O. SMITH | Serial #DM 2210 | |
| Meters (TUR) | | | Brooks | 7402-439054-ML | |
| Meters (TUR) | | | Brooks | PARITY | |
| Meters (TUR) | | | Brooks | SN 9003-22813-1 | |
| Meters (TUR) | | | Brooks | T04BBD1GAAAAB | |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Meters (TUR) | | | Brooks | T06ABF1PA1AAAAA | |
| Meters (TUR) | | | Daniels | 1403-3P | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Meters (TUR) | | | Daniels | 1403-3PX | |
| Meters (TUR) | | | Daniels | 14301-3P | |
| Meters (TUR) | | | Daniels | 3401-3P | |
| Meters (TUR) | | | Daniels | 3403-#P | |
| Meters (TUR) | | | Daniels | 3403-1P | |
| Meters (TUR) | | | Daniels | 3403-3P | |
| Meters (TUR) | | | Daniels | 3404-3P | |
| Meters (TUR) | | | Daniels | 3404IP | |
| Meters (TUR) | | | Daniels | gmpa-h-24 | |
| Meters (TUR) | | | Faure Herman | TLM4-300 | |
| Meters (TUR) | | | Faure Herman | 4040164 | |
| Meters (TUR) | | | Faure Herman | FH 710 | |
| Meters (TUR) | | | FMC | T644645592 | |
| Meters (TUR) | | | Smith | 3401-3P | |
| Meters (TUR) | | | Smith | 4" GLSJ-H TM | |
| Meters (TUR) | | | Smith | 66T2-02 | |
| Meters (TUR) | | | Smith | 6CA-1 | |
| Meters (TUR) | | | Smith | 6CA1-2 | |
| Meters (TUR) | | | Smith | 6-CA-1-2 | |
| Meters (TUR) | | | Smith | 6-CAY-6 | |
| Meters (TUR) | | | Smith | 6CS-1-7 | |
| Meters (TUR) | | | Smith | 6CS1C-7 | |
| Meters (TUR) | | | Smith | 6CS2C1 | |
| Meters (TUR) | | | Smith | 6-CSI-71M | |
| Meters (TUR) | | | Smith | 6-S-S-1C-7-S | |
| Meters (TUR) | | | Smith | 8CSIC2S | |
| Meters (TUR) | | | Smith | A181G12 | |
| Meters (TUR) | | | Smith | K23000 | |
| Meters (TUR) | | | Smith | K2BEA00320 | |
| Meters (TUR) | | | Smith | K2BEA0A200 | |
| Meters (TUR) | | | Smith | K2BEA0A300 | |
| Meters (TUR) | | | Smith | K2BEAOA200 | |
| Meters (TUR) | | | Smith | K2BEB0A400 | |
| Meters (TUR) | | | Smith | K2BED0A310 | |
| Meters (TUR) | | | Smith | K2DEA00310 | |
| Meters (TUR) | | | Smith | K2DGA00200 | |
| Meters (TUR) | | | Smith | K2DGA0A320X | |
| Meters (TUR) | | | Smith | K2DGB0A1000 | |
| Meters (TUR) | | | Smith | K2DGD0A3100 | |
| Meters (TUR) | | | Smith | K-2DHA01320 | |
| Meters (TUR) | | | Smith | K2DHB0B300 Rev. | |
| Meters (TUR) | | | Smith | K2DHBOAT20 | |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Meters (TUR) | | | Smith | K2DHBOB300 Forw | |
| Meters (TUR) | | | Smith | K2DHD0A320X | |
| Meters (TUR) | | | Smith | K-2DJA01320 | |

| COMPONENT | APPLICATION | MATERIALS | MANUFACTURER | MODEL № | ADDITIONAL INFO |
|---|---|---|---|---|---|
| Meters (TUR) | | | Smith | K2DRA | |
| Meters (TUR) | | | Smith | K2PGBOA310 | |
| Meters (TUR) | | | Smith | K-DHA00320 | |
| Meters (TUR) | | | Smith | KKK2DHB0B300 | |
| Meters (TUR) | | | Smith | PJ201495G | |
| Meters (TUR) | | | Smith | SENTRY | |
| Meters (TUR) | | | Smith | Serial DC 21329 | |
| Meters (TUR) | | | Smith | Serial-EH 22523 | |
| Meters (TUR) | | | Smith | Serial-EJ 22916 | |
| Meters (TUR) | | | Smith | WH1934 | |
| Meters (TUR) | | | Smith cc20528 | Smith Sentry | |
| Meters (TUR) | | | Smith Meter | K2DFB00400 | |
| Meters (TUR) | | | Smith/ #FE14343 | Sentry Series | |
| Meters (TUR) | | | Smith/#KC6469 | 8-S-S-2C-2 | |
| Meters (TUR) | | | Turbine | 6CA2C6 | |
| Pipe Plugs | | | Various | Various | Pipe Sealant |
| Pressure Switch | | Viton | Custom control sensor | | Wetted parts stainless steel and ( O-ring ) Viton |
| Pressure Switch | | | Dwyer Instrument Inc. | | Wetted parts ( unknown ) |
| Pressure Transmitter | | Viton | Rosemount | 1151 | O- Ring Viton |
| Prover | | Stainless Steel | Brooks | S/N: 8404-23846 | |
| Prover | | Stainless Steel | Brooks | S/N: 8404-2384 | |
| Pump | | Viton | United | | Mainline pump seals have ( O-Rings ) Viton |
| Pump Shaft | | AISI 4140 | Flowserve, Sulzer | Various | AISI 4140 |
| Relief Valve | | Viton | Anderson Greewood | | O-Rings Viton |
| Sphere Detector | | | WeamcoMetric | Mag-TEK | |
| Strainer | | | WeamcoMetric | FV | Various sizes |
| Sump injection pump | | | Kerr | | Packing |
| Sump Pump | | Vition | Red Jacket | | O-Rings Viton |
| Sump Tank | | Fiberglass | Fluid Containment | 2500 gallon | Fiberglass |
| **Component** | **Application** | **Materials** | **Manufacturer** | **Model #** | **Add. Info** |
| Twin Seal Valve | | | Camron | General Twin Seal | Various sizes. Various models (200, 8800, 800, 400, 900) |

# DNV Energy

DNV Energy is a leading professional service provider in safeguarding and improving business performance, assisting energy companies along the entire value chain from concept selection through exploration, production, transportation, refining, and distribution. Our broad expertise covers Asset Risk & Operations Management, Enterprise Risk Management; IT Risk Management; Offshore Classification; Safety, Health and Environmental Risk Management; Technology Qualification; and Verification.

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