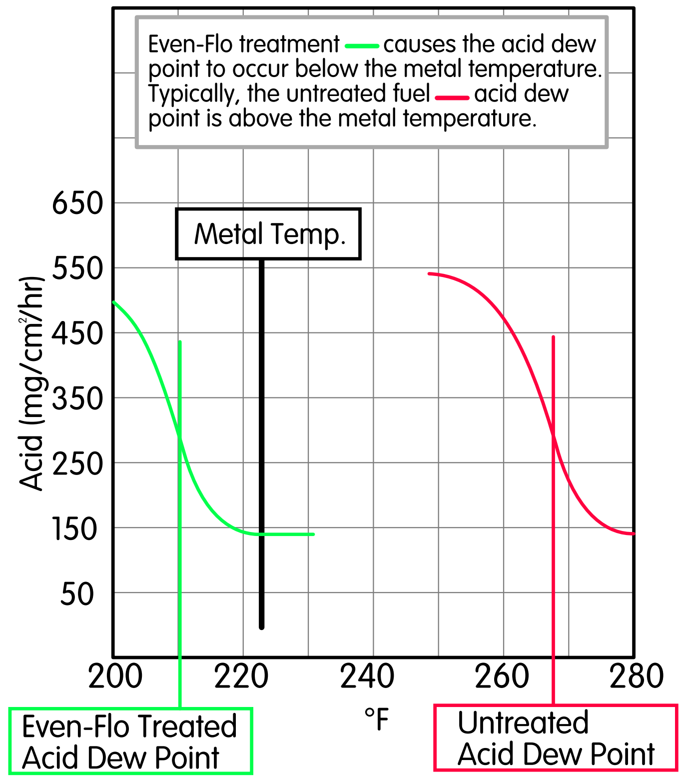
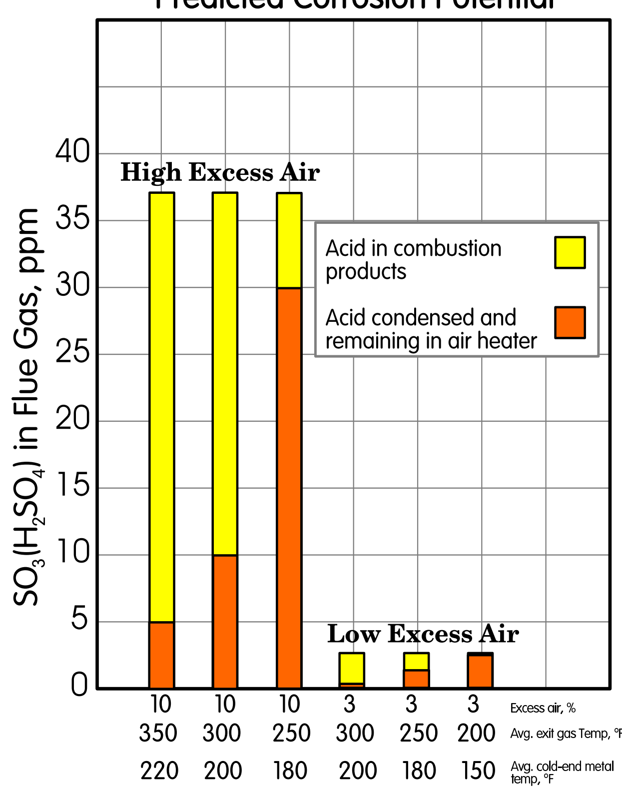
FUEL OIL COMBUSTION PROBLEMS

Sulfur, sodium and vanadium are present in residual fuels in concentrations that depend on the source of the crude feedstock and methods of refining, contamination in handling, and the degree and type of blending. Blends of hydrodesulfurized fuel tend to contain relatively less sodium and vanadium unless contaminated by salt water. **Concentrations of *sulfur* in residuals varies from 0.3% to 0.5% in hydrodesulfurized blends; up to 2% to 3.5% for Venezuelan, Persian Gulf, Texas, etc., fuels**. Vanadium and sulfur vary from 20 ppm to 30 ppm in some hydrodesulfurized fuels to as much as 900 ppm (occasionally more) in the cut back still-bottom residues from the hydrodesulfurization process. Sulfur burns to sulfur dioxide and sulfur trioxide. The **amount of sulfur dioxide formed is approximately 98% of the total sulfur** present. Although sulfur dioxide is not generally detrimental to the boiler and passes harmlessly up the stack, it is an undesirable air pollutant. The **remaining 2% of the sulfur is converted to sulfur trioxide,** depending on the amount of excess air used in combustion and the catalytic effect of coke formed at the burner and throughout the unit. The reaction of sulfur trioxide with sodium results in the formation of acid sulfate deposits. Sulfur trioxide raises the **acid dew point** of the flue gas and if the metal temperatures of economizers, air heaters or last pass tubes are below the dewpoint, condensation occurs with the formation of sulfuric acid and/or acid sulfate salts which corrode the metal surfaces. **Low excess oxygen (below 2%) helps to minimize sulfur trioxide formation** and thereby keeps the dewpoint at a more normal level (see graphs).

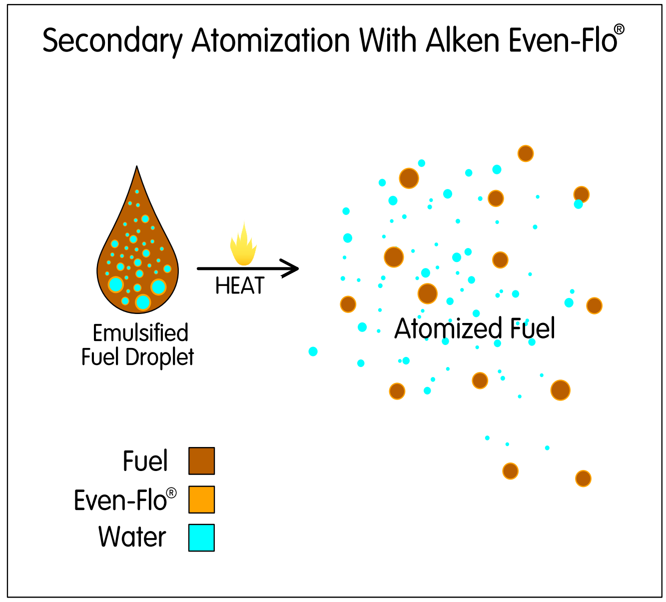
Vanadium is burned to one or more of its oxide forms depending largely on the amount of excess air. Vanadium pentoxide (V_2O_5), the highest oxidation state, is a relatively



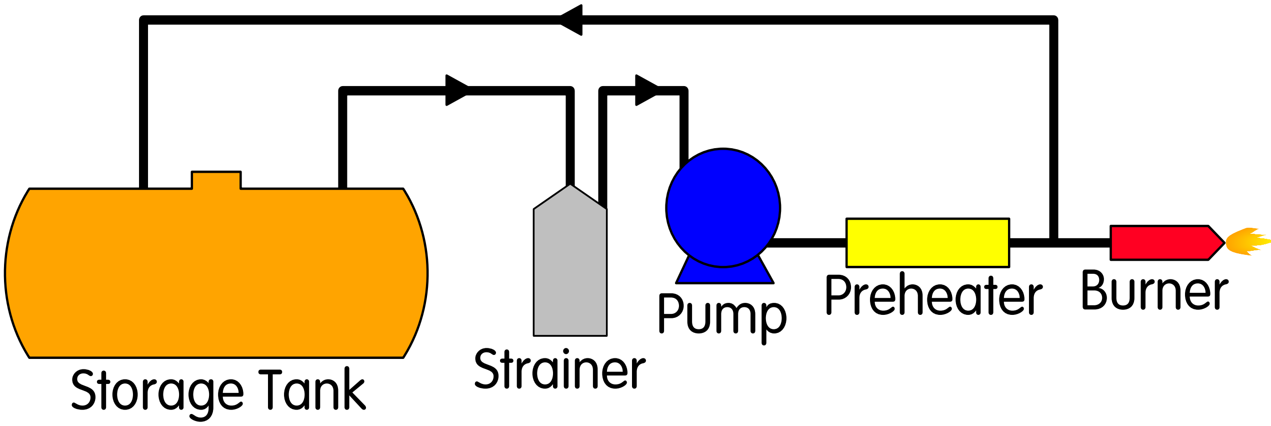
Predicted Corrosion Potential



low-melting-point form which is adsorbed on refractories causing spalling. It also builds up on superheater tubes causing corrosion and forming rock-hard deposits that are extremely difficult to remove. Fluxing of the deposit will occur as sodium gradually reacts with it to convert it to sodium vanadyl vanadate ($Na_2O \cdot V_2O_4 \text{-} 5V_2O_5$), which results in a high corrosion rate on the superheater tubes. Another corrosion causing daughter product of vanadium pentoxide is orthovanadate ($3NiO \cdot V_2O_5$). Deposits in the superheater area can build up to a point where they bridge the screen and superheater tubes and substantially cut down on boiler draft. If excess air can be kept to a minimum through improved atomization (provided boiler design does not require 15% or more excess air), vanadium oxidation can be kept to the tetraoxide (V_2O_4) and trioxide (V_2O_3) forms. These two forms have melting points of 3570°-3580°F. They will not fuse and adhere to boiler metal even in the combustion zone because temperatures there are below the melting point.



Sodium in the fuel reacts with sulfur trioxide and the vanadium oxides to form relatively low melting point salts such as sodium vanadyl vanadate, etc. These can cause corrosion in superheat areas and at the cold end (sodium acid sulfates). Sodium can be removed from the fuel oil to a large extent by **water washing** with approximately 5% of water followed by **centrifuging** to remove the water. The cost of such a procedure makes it uneconomical except for marine installations, although it is common practice in gas turbine operations using high sodium-vanadium fuel.



Typical preburner system flow diagram

HOW ALKEN EVEN-FLO® FORMULAS SOLVE THE PROBLEMS

Pre-treatment is essential to maintaining fuel system cleanliness and providing an even flow of homogeneous fuel to the burners for maximum combustion efficiency. Different **Alken Even-Flo®** formulas either emulsify and disperse water or demulsify and separate water depending on the requirements of the fuel system and the fireside problems experienced. **Demulsification is practical only in above-ground storage** where there is an acceptable means of disposing of the water, which may contain 20 ppm to 40 ppm of oil. If the oil concentration is above 25 ppm, it may be bioremediated with a suitable Alken Clear-Flo® formula. Water separation is desirable where sodium is the major factor in fireside deposits. A major portion of sodium present in the oil as **sodium chloride can be removed** in this manner, very much like water washing of fuel oil. Sodium acid sulfate deposits may be reduced in this manner, depending upon the amount of water in the fuel.

Bacteria grow at the interface between oil and water. Both water and oil are necessary for their growth and survival. Whether the water is separated and removed from the oil or is emulsified and uniformly dispersed, the **interfaces at which bacteria can grow into slime masses are eliminated**.

Surfactants present in **Alken Even-Flo® formulas form protective films on submerged tank surfaces** and help to **control corrosion caused by water and acid compounds** in the oil.

Dispersing agents help to **stabilize the heavy hydrocarbons so that they do not settle in the tank**, but pass through the system with the fuel as it is used. Existing accumulations will be gradually removed. The rate of removal and dosage required depend on the amount of accumulation present, the tolerance of the strainers and burners for the presence of dispersed sludge components, and the rate of oil turnover (the frequency with which the tank is filled and emptied).

Stratification and oxidation **are inhibited by Alken Even-Flo®**, helping to maintain the even flow of homogeneous fuel to the burner. This means that **preheat temperatures, based on viscosity, can be maintained at a constant level for good atomization.** The physical action of the treatment on the surface tension of the fuel promotes good **atomization into the desired particle size of 100 to 150 microns.** Particles of that size gasify with sufficient speed to **minimize coke formation** by thermal cracking of the oil. The reduction in coke allows fewer sticky residues to build up on the fireside where they might act as accumulators for other oil-ash constituents or as catalysts for converting sulfur dioxide to the trioxide. **Higher dew points** are thus maintained and **cold end corrosion is minimized**. The **lower excess air levels** that can be maintained also reduce formation of sulfur trioxide and vanadium pentoxide; vanadium trioxide and tetroxide are formed at the lower excess air level, and **hard vanadium pentoxide slag is minimized**.

Summary of Alken Even-Flo®'s Benefits

- Prevents buildup of sludge and water in tanks and lines.
- Controls corrosion in tanks and lines.
- Eliminates preheater clogging.
- Burner and strainer cleaning are greatly reduced.
- Homogenizes fuel for best atomization and combustion.
- Corrosive sulfur trioxide is reduced.
- Keeps deposits dry and powdery for easy removal by blowing.
- Reduces particulate emission.
- Reduces slagging.
- Reduces plumes and acid smut.
- Maximizes utilization of total fuel heat content.
- Saves fuel oil.

ESTABLISHING AN ALKEN EVEN-FLO® TREATMENT PROGRAM

A complete engineering survey of the fuel oil system and boiler operations should be made with respect to fuel handling and use, fireside conditions and flue gas emissions. Boiler firesides should be inspected, if possible, and the extent of any accumulations noted. Oil tanks should be checked using a Bacon Bomb Sampler to determine existing accumulations, if any, of sludge and water. Samples should be taken at the tank bottom, at 8" to 12" off the tank bottom and at 36" to 48" off the tank bottom. Drainage facilities for possible use of demulsifying formulations should be noted. Analyses of deposits occurring in unit should be obtained, if available, or collect samples of deposits for analysis. Carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) determinations should be run or values should be obtained from recorded data at typical load conditions. Averages for a period of three months prior to the use of treatment should be obtained. Also, if seasonal variations affect operating conditions, an average should be obtained for the same three month period the preceding year. If plant charts are available, the following data should be averaged out for the same period as above:

High Load

Pounds per hour . . . . ______

Hours per day . . . . ______

Air or O_2 . . . . ______%

CO_2 . . . . ______%

Air temp. at preheater inlet . . . . ______°F

Air temp. at preheater outlet . . . . ______°F

Flue gas temp. at preheater outlet . . ______°F

Stack temperature . . . . ______°F

Superheater temperature . . . . ______°F

Blowdown volume . . . . ______

Low Load

Pounds per hour . . . . ______

Hours per day . . . . ______

Air or O_2 . . . . ______%

CO_2 . . . . ______%

Air temp. at preheater inlet . . . . ______°F

Air temp. at preheater outlet . . . . ______°F

Flue gas temp. at preheater outlet . . ______°F

Stack temperature . . . . ______°F

Superheater temperature . . . . ______°F

Blowdown volume . . . . ______

The information collected in this survey of the plant forms the basis for selection of the appropriate formulation of **Alken Even-Flo®**.

HOW TO APPLY ALKEN EVEN-FLO®

Alken Even-Flo® formulas should be added to the system either prior to each fuel delivery on a shot basis, or continuously to the fuel by means of a chemical proportioning pump during the fuel delivery. The pump should be actuated by means of a sensor placed in the fill line to the storage tank.

Alken® oil-soluble metallics (such as **Alken® 935 and 944**) can be added as above or, preferably, metered into the fuel oil line ahead of the burners by means of a chemical proportioning pump.

The dosages indicated in the Product Information Bulletins are for normal usage. Other dosages may be necessary. Low rates of oil turnover, high water contamination, extremely unstable blends, etc., require higher than normal dosages. Double the normal dosage is recommended initially, with adjustments based on results obtained.

EVALUATION OF RESULTS

A complete heat balance on the boilers is not necessary. Steam produced per pound, ton, or barrel of oil used (making allowance for oil gravity and taking into consideration the difference in operating efficiency at various loads as indicated by the information requested above, as well as allowing for the relatively small effect of blowdown), with and without treatment, will provide a fairly accurate measure of fuel savings. However, operation at low load for long periods or any major changes in operating conditions can affect the results obtained, substantially. Such changes, therefore, should be recorded for consideration in treatment evaluation.

In furnace operations, etc., where a product other than steam is produced by direct or indirect firing, the quantity of product produced (such as in a cement plant) should be used as the measure of treatment effectiveness. All factors affecting the operations must, of course, be considered.