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THE EFFECTS OF ADDITIVES ON METERING IN LIQUID PIPELINES
CT 8160

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Introduction

Today's refined fuels are formulated using a recipe of chemical blending and complex processing. Current blends that make-up fuel & chemicals introduce new problems that challenge product quality and performance. Refined products can be altered or degrade prior use by secondary forces such as environment and handling. A wide range of performance and handling problems are minimized or resolved by use of chemical additives. Additives to fuel products are often included in the refining processes that address these problems. Fuels may require additional blending of additives separate from the refining process. The effect these additives have on liquid metering is variable based on their composition and concentration.

Pipeline and terminal metering systems must adjust to the varying properties the additives introduce to the liquid. This paper highlights the effects some common & not-so-common fuel additives have on liquid metering systems.

Physical Properties Effecting Metering

Additives used in today's fuels are blended to enhance the performance of the fuel as well as the performance of the system using fuel. Additives typically alter one or several physical properties of the fuel. Additives that influence metering in liquid pipeline applications alter the same physical properties of the transported fluid.

Properties altered by additives include density, viscosity, flow, lubricity temperature and pressure. Pipeline metering systems are affected by changes to one or combination of these physical properties. Additives that alter a fuel's physical properties also altered the net effect of metering systems.

To understand an additive's effect on liquid metering, its best to first understand physical properties influencing metering:

Flow:

Flow and/or velocity profile is a major influence on most metering systems. A flow profile established with a fluid having a constant viscosity at a given temperature (Newtonian fluid) typically defines the reference flow condition for most flow meter applications. From these conditions, most corrections are made. Flow characteristics can be divided into laminar and turbulent flow profiles. A fluid having laminar flow characteristics is described as moving in continuous parallel paths. A turbulent flow profile a fluid moves in random paths. A flowing fluid will alter between laminar & turbulent flow based on three conditions, fluid viscosity, flow velocity and fluid-to-pipe boundary conditions. At low flow velocities through smooth pipe, flowing fluid moves in layers and travel parallel with the pipe wall. As flowing velocities increase or pipe wall surfaces become rougher, the layered flow becomes agitated and a turbulent flow profile develops. Additives that influence flow friction can also alter flow profile. Changing flow profiles will influence performance of flow measurement equipment. A turbine meter performs different with changing flow profiles. Flow friction additives include drag reducing additives (DRA's) and often additives that increase lubricity.

Viscosity:

Flow characteristics will change with changes in fluid viscosity. A change in fluid viscosity will alter the liquids flow characteristics between laminar & turbulent flow profiles. With more viscous fluids, flow is restricted to parallel or layered motion. With less viscous fluids, fluid particles move in a turbulent or a random manner. Additives that can alter fluid viscosity (usually in high concentrations) can also influence flow profile. Viscosity altering additives include pour point improvers, additives that alter low temperature flow properties as well as cloud point improvers.

Density:

Fluid density can be affected with selective fuel additives. Density altering additives (in high concentrations) include solutions used to separate water from fuels. These additives include demulsifiers and dehazer additives. Fluid density can also be changed with cold point improvers and anti icing additives.

Additives that alter viscosity or density must be accounted for by volumetric (meter)and physical properties measurement (pressure & temp) devices. An additive having viscosity-altering characteristics will cause shifts in meter factor curves. Measurement or metering systems that assumes a fluid maintains a constant density or viscosity will incorrectly account for volumes when viscosity or density parameters are altered as a result of additives.

Lubricity:

Many additives have a secondary impact on a fluid property aside from the primary function of the additive. Lubricity is a secondary influence with many additives in liquids. Lubricity promotes a fluid's ability to minimize friction between surfaces. With some additives, lubricity increases. With other additives, the lubricity may decrees while performing the primary function of the additive. Additives are often blended into fuel mixtures for the sole purpose to improve lubricity. Additives used for lubricity improve the wear inhibiting properties of low viscosity fuels. If the end purpose of some additives is to improve the wear properties in their final application, they also alter the lubricating effect on the equipment used for its transportation & measurement. Many metering components employ moving parts in close tolerances. A fluid having low lubricity will affect meter performance differently than a fluid with high lubricity. Corrosion inhibitors increase the lubricity of the fluid. Corrosion inhibitors can act as a lubricating film on equipment surfaces and reduce fluid friction similar to DRA's anti friction ability. Lower fluid friction will reduce eddies resulting in changed flow profiles. Lower friction also reduces temperatures of flowing fluids. The fluid friction effect is termed the "C Factor" C factor ratings between 155 & 160 are typical for new pipeline systems that have been effectively treated with a film forming corrosion inhibitor. A low C Factor indicates higher internal friction within a pipeline system, reducing efficiency.

Temperature & Pressure:

Physical properties of temperature and pressure are also altered when fluid additives are introduced into a flowing stream. An additive that reduces the friction between pipe wall and the fluid will maintain a lower temperature of the flowing liquid. With changing temperatures there also exists a change in the operating pressure. Also impacting fluid and equipment temperature is the lubricity an additive has on liquids. Additives that elevate lubricity reduce measurement component friction on moving parts. Additives that reduce fluid lubricity elevate component temperatures and reduce their overall performance and operating life.

Additives and their Effect on Metering

Many additives are used in fuel products today for improving performance, preserving quality or eliminating an undesirable byproduct. Petroleum additives are blended at concentration levels dictated by the desired enhancement the additive provides. Additives can effect meter equipment when blended at normal concentration levels.
Alternatively, additives can have no impact on equipment even at high concentration levels.

Some common additives used in fuels and their impacts on the measurement process include the following:

Drag Reducing Additives:

A relatively new process for increasing throughput on pipeline systems in recent years has been the introduction of Drag Reducing Additives (DRA's). When DRA's are blended/injected into fuels, volume through put on liquid pipelines can be increased up to 20% without the added costs for larger pumps or larger diameter pipe. DRA's reduce eddy currents formed at the pipe wall during fluid flow. The reduction in eddies reduce liquid friction between pipe wall and flowing liquid causing the interface between liquid & pipe surface to appear smoother. This reduction in liquid friction reduces pipe flow restriction. The effect of DRA's on liquid metering can be variable from application to application. DRA's are delivered in the flowing stream in two forms; a gel based and a suspended based solution. The gel form is injected in the liquid stream as a continuous strand dissolving during transport. Should the DRA gel not become dissolved in the liquid, the gel can separate, ball-up and accumulate downstream in filters, meters and other process equipment.

The suspended form of DRA dissolves easier in the liquid and not as likely to separate and accumulate. Eddy currents are known components of meter flow profiles. Suppression of eddy currents and friction forces for which DRA's are intended for reduces these eddies and frictional forces existing in and around metering systems. A meter factor developed based on one profile can be significantly altered when the flow profile has changed due to the presence of DRA. The distance a DRA travels in pipelines may also impact liquid metering. DRA's influence eddies & frictional losses at points closer to their injection. As DRA moves away from its injection point, the higher the potential for breakdown or "sheafing" of the DRA molecule.

This same impact is true for metering systems. The further a metering system is located from DRA injection, the less influence DRA's will have on meter flow profiles. If the metering system is located beyond DRA liquid impact, the impact on metering is small or insignificant. The point at which DRA effect has fully diminished is dependent on the pipeline conditions. Studies have shown that DRA's have fully degraded after traveling just several miles in a pipeline. A secondary effect of DRA on liquid metering is a reduction in frictional energy. Injected DRA's reduce frictional energy in the pipeline segment. Frictional energy is present in the form of temperature. A reduction in liquid temperature will impact temperature compensation. Non-compensated metering systems or volumes that are batch averaged for temperature may not register volume correctly if periods of non-DRA liquids are present in the batch. With all additives, their effect on liquid metering is most impacting based on their delivered concentration levels. Normal use concentration levels of DRA range around 10 to 15 PPM and are only slightly impacting at this concentration level.

Oxygenates:

Prior to the 1970's, lead additives were used to increase octane ratings in gasoline. Leaded gasoline has a relative gravity based on its composition. Aware of its environmental impact on air quality, the EPA mandate a gradual phase-out of the lead content in gasoline in the mid 1970's. Refiners were forced to look for other octane enhancers. Oxygenates such as ethanol, MTBE or TAME were used to replace lead additives and are added to gasoline to improve the octane level and to reduce specific exhaust emission levels in gasoline. The new additives used in reformulated gasoline blends for elevating oxygenates impact fluid density characteristics.

Reformulated gasoline introduces variable changes in the base density of the gasoline. This variability is based on the concentration of oxygenates. A reformulated gasoline mixture with 3% MTBE will have a different density value than a 10% gasohol blend. On-line density devices adjust for changes in density as concentration levels change. However, if hourly density readings use a thermal-hydrometer for correction in place of on-line density devices, density updates will increase measurement uncertainty if changing levels of oxygenates are seen across fungible pipeline batches .

Oxygenates will also influence a measurement by shortening the life span of materials exposed to the oxygenate additive. Seals, coatings, sphere materials and other non-metallic compounds used in pipeline service react to oxygenate additives. Many sealing compounds were in service long before reformulated gasoline began transport on pipeline systems. Premature aging of prover coating causes prover volumes to grow between calibrations. Sealing material not resistive oxygenate additives may impact valve seal integrity and a lower confidence in measurement.

Corrosion Inhibitors:

Corrosion inhibitors are added to fuels during the refining process to delay onset of corrosion activities on exposed metals. In transportation and fuel systems, steel & other metallic components will corrode when both water and air enter the system. Water can become entrained in fuels through refining processes such as water washing or mix with fuels through storage or transportation. Air entrained during pumping and mixing processes will introduce the oxygen needed for continued corrosion.

Corrosion inhibitors used in fuel systems function by absorbing onto exposed metal surfaces to form a protective film layer. The inhibitor layer acts as a barrier to prevent water from contacting the surface of metal components and initiating corrosion. Inhibitors used to protect fuel system components such as storage tanks, pipelines as well as combustion systems are typically dissolved in the fuel and carried to the metal surface by the fuel. The inhibitor is deposited onto exposed metal surfaces as the fuel passes through the system. A corrosion inhibitor additive may impact metering systems several ways: When a corrosion inhibitor is introduced into an existing system that has not already received an inhibitor or into a system having preexisting rust, the inhibitor attaches to a clean metal surface and removes rust on metal surfaces. The rust travels with the fuel and accumulates in filters or other areas of low turbulence downstream.
Rouge is a term used to describe the fine powder-like material that develops on the inside walls of pipelines & storage tanks. When fuel containing corrosion inhibitors is used in systems containing rouge or rust, the inhibitor develops a filming effect on the surface and displaces the rouge. As a result, the rouge is released into the fuel. The free flowing rouge material acts as an abrasive on equipment such as rotor bearing on meters or cams on PD's altering performance and equipment life span. Several meter types have moving components with very close tolerances. Rust particulate may buildup and become lodged in close tolerance areas causing premature shifting in meter & performance factors.

Corrosion inhibitors introduced onto non-coated pipe or calibration apparatus such as a steel prover not receiving inhibitors in the past may grow the prover through rust removal of pipe wall metal. By the same process as metal pipe releasing rusts, the prover volume changes unknown to the operator if calibrations are infrequent.

Proprietary Additives:

Additives applied to products at marketing terminals are typically known as proprietary additive packages. These additives are applied to fuel mixtures to brand fuels for oil companies products. Branding additives are typically detergents and dispersants added to fuels to improve combustion efficiency and reduce deposit buildups within fuel systems.

In gasoline engines, most detergents prevent deposit formations on carburetors, fuel injectors and intake valves and control formation of deposits in engine combustion chambers. Detergents used in diesel fuel limit/control the formation of deposits on fuel injector nozzles as well as prevent deposit and gum formation on high-pressure injectors.

Proprietary additives are blended with fuels in such low concentration levels that liquid metering is seldom effected. However, when these same additives are misused or over added in gasoline & fuels, metering systems may become fouled by gum build-up of the over stated additive.

Conclusion:

Many forms of fuel additives are available for performance enhancement purposes. Additives are blended into fuels to enhance combustion and engine performance. Changes to the physical properties of fuels are often a byproduct of the additive enhancement. As a liquid's physical properties change, the measurement system can be affected. Awareness of an additive's effect on metering systems should always be included in pipeline measurement procedures and oversight programs.

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