White Paper /
e9 Pro Performance Metal Treatment

SLOW THE BUILDUP OF PARAFFINS, ASPHALTENES AND OTHER OIL-BASED CONTAMINANTS

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Paraffin and asphaltene buildup is a fact of life in many oil and gas production fields. When downhole reservoirs lose pressure or temperature, paraffin precipitates and builds up on everything from pipe to valves to instrumentation to vessel walls. This buildup slows the production process, constricts lines, and clogs instruments.

This paper will show how using e9 Treatments' Pro Performance Metal Treatment to coat the surfaces of sensitive instruments, vessels, meters, and valves—can slow or stop the buildup of these contaminants. By changing the bonding energy of the surface metal, this chemical surface treatment hinders the ability of contaminants to adhere to a surface.

INTRODUCTION

Paraffin and asphaltene buildup are a fact of life in many oil and gas production fields. The deposition of organic solids poses a serious challenge in the oil industry, from production to oil transportation and storage operations. When downhole reservoirs lose pressure or temperature drops, paraffin and asphaltene precipitate out of the fluid and build up on everything from pipe to valves to instrumentation to vessels through the entire production process. This buildup slows the production process, constricts lines, and clogs instruments causing costly downtime.

By most estimates, paraffin/asphaltene remediation and prevention is a multi-billion-dollar industry. By simply looking at a few instances of the cost for remediation, we can see how these dollars can add up quickly. Hot-oiling a LACT (Lease Allocation Custody Transfer) skid can cost up to $1,000/day plus the cost of any downtime to production. Removing, cleaning, servicing and recalibrating a Coriolis or Vortex meter can cost anywhere from $500 to $4500 per instance depending on the size of the device. Add in the cost of travel time for the service company and lost production and the cost of servicing a Coriolis meter can easily approach $10,000. These figures do not begin to factor in the cost of miss-calibrated instruments, reduced production rates due to clogged lines, and other factors.

Traditional methods to address paraffin deposits and other contaminants are widely known, including thermal treatments such as hot-oiling, chemical treatments, mechanical removal, and even the use of specialized coatings. However, these methods are expensive and have their own shortcomings.

This paper explains how e9 Treatments' Pro Performance Metal Treatment works to protect metal surfaces and improve performance of instrumentation. In addition, the paper provides case studies, which show that in addition to treating liquids in the production process, operators should also consider using e9 Treatments' Pro Performance Metal Treatment to treat the surfaces of components in the flow line—including sensitive instruments, vessels, meters, valves, and other devices—to slow or stop the buildup of paraffin, asphaltene and other contaminants.

HOW e9 TREATMENTS' PRO PERFORMANCE METAL TREATMENT WORKS

Surface energy is the measure of the energy present at the surface of a material. It describes the wetting and adhesion properties between materials or surfaces. Metal surfaces in their natural state tend to have high surface energy, which means they attract contaminants allowing strong bonds to occur and making the surface difficult to clean.

When applied to a metal surface, e9's Pro Performance Metal treatment reduces the substrate's surface energy making the surface less attractive to contaminants. Deposits that settle on the surface due to gravity or other means, do not bond to the treated substrate and either slough away in the production process or are easily cleaned.

This paper highlights several case studies that show the benefits of using e9's Pro Performance Metal Treatment to impart anti-fouling properties to metal surfaces. Application of e9's Pro Performance to metal surfaces of instrumentation (both internal and external surfaces) results in significant reduction of wax buildup, paraffin and asphaltene deposition, as well as other types of deposition in critical instruments. With this improvement, there is no longer a need to regularly pull instrumentation and devices out of the production line to clean, re-service or to prove. e9's Pro Performance Metal Treatment can also help in reducing deposition of some corrosion causing contaminants and play a crucial role in surface protection.

Table 1 lists the surface free energy of many common materials that are great candidates for application of e9's Pro Performance Metal Treatment. The last column in the table shows the reduction in the surface free energy of these materials after they are treated, which also creates a surface repellent to oil and water. This change in the surface

energy in turns helps to keep many contaminants from depositing and adhering to the surface of these materials.

Material	Surface Free Energy Untreated (Dyne / cm)	Surface Free Energy Nano Surface Treated (Dyne / cm)
Aluminum	30-50	16
Copper	30-50	15
Glass	65-100	16
Stainless Steel	40-60	13.5
Zinc	30-50	15
Teflon®	18	N/A

*Teflon® is a known non-stick surface and is provided as a reference

Table 1: Surface Free Energy of common materials before and after treatment with Pro Performance Metal Treatment.

CASE STUDIES AND HISTORY OF SUCCESS

In certain geographic markets, instruments can fail due to buildup in a matter of days or weeks, leaving the instrument useless or providing false readings. Over the last few years, e9 's Pro Performance Metal Treatment has been used in many of the oil and gas producing fields in the United States and several in Western Canada. While originally promoted to address paraffin and asphaltene fouling, Pro Performance has provided benefits in repelling other oil- and water-based organic and inorganic materials that build up on instrumentation in oil production processes. This section, details several case studies that showcase the benefits of applying Pro Performance to the surfaces of instrumentation: increased surface repellency, extended maintenance intervals, increased production uptime and capacity, easier to clean surfaces, and savings on service work.

Turbine Meters

Turbine flow meters are rugged devices that perform well under extreme conditions. The meters provide highly accurate and repeatable measurement of oils, water and some chemicals with a low cost of ownership. Turbine flow meters excel at measuring clean, steady and medium-to-high speed flows of low-viscosity fluids, particularly those found in "pump-intensive" oil field environments. They are sensitive to build up in and around the blades of the turbine and in the bearings. Paraffin, polymers, and other contaminants stick to the blades, causing them to change their calibration characteristics[1].

The purpose for meter verification or meter proving is to ensure accurate measurement to minimize losses and maximize profits. These metering systems are the "cash registers" for all petroleum operations and errors in meter factors can and will generate enormous financial errors in a company's invoicing in a short period of time. As per the 43 CFR § 3174.11 Meter-proving requirements; If the difference between meter factors established in two successive proving cycles exceeds ±0.0025, the meter must be immediately removed from service, checked for damage or wear, adjusted or repaired, and reproved before returning the meter to service.

Example: An 8-inch crude line delivering product to a Refinery at a flow rate of 2150 Barrels/Hour (bph). The flow meter used in line is found to be inaccurate by 0.25% and the crude wholesales for $50 per barrel. In one month, the product was incorrectly invoiced in the amount of $193,500 (2150 X 24 hours X 30 days X .0025 error factor X $50). It's very crucial to have metering devices running accurately and within the required meter factor to not lose revenue in the petroleum business.

Application

A 1" NPT Turbine meter was tested at a well site with a history of meters failing proving every month to 6 weeks, requiring maintenance or complete replacement of the meters if the Meter Factor deviation was beyond repair.

The brand new 1" NPT model TM0100 turbine meter was treated with e9's Pro Performance Metal Treatment. The meter was treated using a dip/flush method, where the meter cavity was filled with the treatment solution. The solution contacted all the parts of the meter within the cavity, the shaft, retaining ring, blades, rotors, etc. and allowed to treat the meter components for 3 to 5 minutes. Thereafter, the treatment solution was poured out of the meter and the meter and its parts were left to dry at room temperature. The treatment formed a 5 – 10nm thick layer creating a surface that repelled water (hydrophobic) and oil (oleophobic).

Test

The treated meter was proved by an authorized third-party prover, as is standard practice, prior to it being qualified for field use. After proving, a meter factor (MF) of 1.0000 was assigned to the treated turbine meter. The treated 1" NPT turbine meter was then installed at the same well site where fouling issues were prevalent. The meter was operational at this site for 6 months without any fouling or operational issues. After the 6-month period, the meter was taken out of service for examination; see Figure 1. There was a thin layer of paraffin observed on the walls of the meter's housing. The meter was not cleaned and run through the proving process as is. The meter had recorded a deviation of 0.0004. This result indicated that the turbine meter had a MF change well within the range established as per the 43 CFR § 3174.11 Meter-proving requirements of ±0.0025. It further implies that if the turbine meter had not been taken out for examination, it would have remained within the MF specs required for compliance and accurate flow measurements.

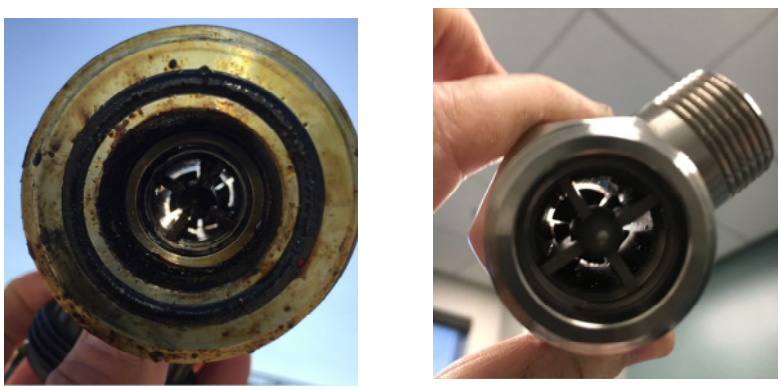

Figure 1: 1" NPT treated Turbine meter (left) while operational in the field; (right) after proving without any cleaning process.

Vortex Meters

A vortex flow meter is a flow measurement device best suited for measurements where the introduction of moving

parts presents problems. Vortex flow meters measure fluid velocity using a principle of operation referred to as the von Kármán effect, which states that when flow passes by a bluff body, a repeating pattern of swirling vortices is generated. The frequency that the vortexes are shed depend on the size and shape of the body. It is ideal for applications where low maintenance costs are important.

Application

An OEM had a customer complaining about paraffin fouling in the vortex meter, causing a frequent need to pull the meter out for cleaning and recalibration. Specifically, the vortex meters were fouling in less than 30 days at the customer's well site. A 2" Vortex Meter installed in the separator oil flowline proved to be good for approximately 50-60 days. After that time erratic data started to be noticed. Upon removal of the meter, it was noticed that large paraffin deposits were packed around the shedder bar as well as caked or packed into the sensing ports or "nostrils" of the meter. Upon inspection it was agreed that the paraffin had affected the accuracy of the meter.

Figure 2 demonstrates a vortex meter caked with paraffin and asphaltene deposition. After a meter failed due to paraffin deposition, the customer typically spent anywhere from $3500 - $4500 per incident to place a replacement meter, and to have the failed meter cleaned, reserviced and recalibrated.

Figure 2: 2" untreated Vortex meter caked with paraffin fouling after 50-60 days of operations.

The OEM decided to treat the Vortex meter with e9's Pro Performance Metal Treatment and have it tested at the customer's well site for improvements. It was critical that the meter remain within spec for more than 30 days and not be pulled out due to fouling issues, in order to keep the customer's business. A 2" Vortex Meter was treated with e9's Pro Performance Metal Treatment via a dip / flush treatment process. The whole housing and all the components inside the meter's cavity were treated.

Test

The treated vortex meter was installed at the customer's site in the same separator oil flowline. The meter had 1% tolerance in measurement. The test was conducted to evaluate if the treated meter would remain within the 1% tolerance for 30 days. The treated Vortex meter continued to remain within specs for 60 + days. After 80 days in service, the treated meter was pulled out for inspection.

Figure 3 shows the state of the meter and amount of deposition. As evident from the following photos, the treated surfaces of the meter handled the fouling agents and kept them from adhering to the meter parts. This ensured the meter could function for an extended period without any maintenance related interruptions. The data output from the meter before and after treatment remained consistent.

Figure 3: e9 Pro Performance treated 2" Vortex meter with minimal deposition after 80 days of operations.

Coriolis Meters

Coriolis meters are used in a wide range of different industries, such as the life sciences, chemicals, petrochemicals, oil and gas, food, and custody transfer. In the past several years, Coriolis Meters have become increasingly popular for liquid and gas measurement in the Oil and Gas Industry. Coriolis mass flow meters work using the inertia caused by fluid or gas flowing through oscillating tubes. That inertia then causes the tube to twist in proportion with the mass flow rate, and this twisting is measured with sensors to generate a linear flow signal. Simultaneous measurement of mass flow, density and temperature provides for process control, quality assurance and safety[2,3].

To be used for Custody Transfer, the rules state that a Coriolis meter must be proven every 30 days. To ensure accurate flow and density rates, if a meter factor has shifted more than 0.25% from the previous month, the meter must be pulled, cleaned, and reproved before it can be used again. e9's Pro Performance Metal Treatments can extend the time between these meter factor failures. The financial benefit of extending this time is significant. If the meter factor is 0.25% off, then the true volume is at least 0.25% off. For a well producing 500 bbl. /day this can mean $2000/month (0.25% x 500/day x 30 days x $52/bbl.). Multiply this by 500 meters or more in a field and these numbers are significant—even without calculating in the liability to other stakeholders in the field (the lease holder, pipeline company, Bureau of Land Management, etc.)

Application

A customer was interested in testing e9's Pro Performance Metal Treatment on Coriolis Meters used in LACT units at two different field sites. They were pulling the meter every month (in some instances within 3 weeks) to clean the meter and have it proved, due to extensive fouling along the walls of the Coriolis meter tubes. The meter sees flows in the range of 500 – 600 BOP / 2" / 90-160 psi at 95 – 110F temperature range. Each time the meter failed or required maintenance, it cost the customer ~ $500 - $2000, not including any losses due to production interruption or loss of revenue.

Test.

A brand new 2" Coriolis meter was treated with e9's Pro Performance Metal Treatment. This treated meter was proved by a proving service which assigned a starting MF of 1.0000 to the treated meter. Thereafter, the meter was installed at the customer's field site in a LACT unit. The treated meter was operational for 1 month after which it was scheduled for proving and scoping with a camera inside the tubes of the meter. At the 1 month proving cycle, the treated Coriolis meter stayed within the 0.25% deviation of the meter factor (MF) and the meter was installed back in the LACT unit.

During the scoping of this meter, it was observed that in the areas of the tube subject to high F_L, there was minimal paraffin attachment observed. F_L is the pressure recovery factor which is the difference between the exit pressure

and pressure at the vena contracta (point of lowest pressure). A high F_L indicates a high pressure drop and thus a favorable section for paraffin attachment. This was another indication that the treatment was preventing paraffin from adhering to the walls of the tube.
The same meter was again pulled out at the two-month cycle for inspection and proving. The MF results after 2 months in the field were MF 1.0020; yet again staying within the 0.25% deviation. Therefore, the treated Coriolis meter passed proving again after being operational for 2 months in the field. See Table 2 for the meter factors recorded on the meter during the duration of the test.

	Meter Factor after Treatment	Meter Factor after 1 month	Meter Factor after 2 months
New 2" Coriolis Meter	1.0000	1.0024	1.0020

Table 2: Meter Factor recorded after treatment and during 2 months operational in a LACT unit.
Note: No cleaning, rinsing or maintenance was performed on this meter during this study, except for proving.

The results observed in this case study confirm the benefits of e9's Pro Performance Metal Treatment in operation of a Coriolis meter. Treatment helped extend the maintenance cycle on these meters by two times if not more, as they passed the proving and maintained the meter factor within the required range acceptable.

Multiphase Meters
For many years, the need for multiphase flow measurements in oil and gas production has been well known and as this technology became available, its users have increased rapidly. Many such meters have been designed and developed over the years. Various combinations of technologies have been tested as prototypes. Multiphase flow measurement technology provides an alternate means to measure unprocessed well streams that are close to the well. Multiphase meters are capable of providing continuous monitoring of well performance and thus helps with better reservoir exploitation and drainage[4].

Roxar Multiphase Flow Meters offered by Emerson, accurately characterize flow regimes and provide critical information on a well's production capabilities. The meters apply advanced signal processing and field electronics to provide sensitive measurements and a comprehensive mapping of flow[5].

Application
Roxar Multiphase Flow Meters were facing fouling issues in shale oil applications, in particular during the cold season, due to contamination on the meters sensing electrodes situated within the meters flow channel. Paraffin / asphaltene in the flow stream would stick along the walls of the cavity, including the electrode surface and required interruption in the functions as the meter had to be cleaned. Figure 4 demonstrates the fouling as one can see paraffin deposited around the walls of the flow cavity of a multiphase flow meter. The team at Emerson had been investigating different techniques and methods to mitigate the fouling and reduce the maintenance cycle on their meters, and detection and compensation by software has been implemented. However, for more directly addressing the core of the issue they were intrigued by surface treatment via nanotechnology, as this provided a possible means to reduce fouling on the electrode surface, and have minimal effect on the functions and sensitivity of the electrode itself.

Figure 4: Image showing paraffin deposition on the walls of the flow cavity of an untreated multiphase flow meter.

This was a very important factor in the Emerson team's consideration of whether to use e9's Pro Performance Metal Treatment on their electrodes. It was imperative that the functionality, sensitivity and operational range of the electrodes remain as expected by design, as that was critical to the core performance of the multiphase flow meters.

Test

In order to confirm that Pro Performance treated electrodes would maintain the expected performance of their meters, the Emerson team decided to carry out a control bench test with a multiphase flow meter, first as is without any treatment and then after being treated with e9's Pro Performance Metal Treatment. They collected the data in both scenarios, measuring any deviation or change to determine if it was within the acceptable tolerance limits for the meter.

The tests were conducted by doing calibration checks, where several simultaneous conductivity measurements were performed. As per this method, the normal acceptable tolerance is ±3%. There are many factors that can influence these readings, like temperature, bubbles stuck on the electrode surface, and reference probe calibration; to name a few.

The main mode of measurement, very similar to a '4-wire resistance measurement' principle was carried out on the 6-electrode plane. Calibration measurements were carried out on the meter before and after treatment with the '4-wire resistance measurement' principle. The results showed that readings on the treated meter were ±1.5%, meaning they were well within the acceptable tolerance range.

The other mode of measurement was used primarily for diagnostic purposes. This was a '2-wire measurement' principle and was carried out on a 2-electrode plane. Measurements conducted by this method can be directly influenced by any changes in electrode surface conductivity or contact area. The '2-wire measurement' principle was carried out on the meter before and after treatment for a 1 – 10S/m conductivity range. The deviation in the conductivity measured on the meters before and after application of Pro Performance Metal Treatment are noted in Table 3.

	Before treatment		After treatment	
Reference range [S/m]	4-wire method [%] deviation	2-wire method [%] deviation	4-wire method [%] deviation	2-wire method [%] deviation
1.06 – 1.07	- 0.2	- 0.1	- 0.7	- 1.4
6.21 – 6.40	+ 2.4	+ 1.9	+ 0.4	- 1.7
9.26 – 9.30	+ 2.7	+ 1.6	0.0	- 2.8

Table 3: % Deviation in conductivity measurements in multiphase meter before and after treatment with Pro Performance Metal Treatment.

The results were found to be within the ±3% tolerance. The measurement series was repeated a couple of times with washing and alcohol rinse in between measurement. In conclusion, the '4-wire measurement' showed no influence of the treatment on the electrode's functions, and on the other hand, the '2-wire measurement' showed a trend in the deviations, but stayed within the tolerance limits of the meter for the tested 1 – 10 S/m conductivity range.

This is an important case study to demonstrate that e9's Pro Performance Metal Treatment does not alter or change the core functionality of a device. To reiterate this fact, Emerson team shared the following statement stating the benefits of e9's Pro Performance Metal Treatment in their multiphase flow meter operations.

"We have used e9's Pro Performance Metal Treatment for a range of our multiphase flow meters operating in US shale oil applications, in wells known for paraffin wax deposition conditions. The meter has powerful tools for detecting and also for correcting for wax deposits, and through the use of these tools we have observed that the electrodes of Pro Performance treated meters remain essentially free from wax."

Other Applications

In addition to the case studies described in this paper, there are many other instruments and measurement devices that have benefitted or can benefit from e9's Pro Performance Metal Treatment's ability to extend periods of uninterrupted instrument performance.

Valves

Valves are a critical and vital part of any piping system and play a crucial role in the oil and gas industry. Valves are used to control flow rates, isolate equipment and direct refining in crude processing. Ball valves control flow in high pressure liquids and gases with minimal pressure drop. They are easy to open and close and provide a tight seal with low torque. A customer was having fouling issues while operating ball valves ranging from 12" diameter to 18" diameter in the line. Iron sulfide was being carried by small oil and water droplets in what was supposed to be a dry gas pipeline. The water would settle on the surface of the ball, then the iron sulfide would drop out and stick to the ball preventing it from sitting cleanly in the ball valve seat. Maintenance and cleaning of these valves was a very time consuming and challenging task. Contamination settled in the seat of the valve, causing the valve to not work properly. The customer had two new ball valves treated with e9's Pro Performance Metal Treatment and installed the treated ball valves during a change out. After 9 – 12 months of the treated valves being in service, the operator no longer faced issues due to contamination in the seat of the valve. The treated valve showed a reduction in accumulated contamination and extended performance. These valves have been running over four years with no build up related service as of this writing.

Tuning Forks
A similar situation often occurs with tuning forks. Scale and or calcium carbonate is transported by mist or water droplets in a tank. The water wets the surface of the fork and the calcium carbonate precipitates out and builds up on the surface. When treated with e9's Pro Performance Metal Treatment, the fork becomes hydrophobic allowing the water to drip off the fork continuously and preventing the calcium carbonate from precipitating out and adhering.

Level Gauges
In the Oil and Gas industry, the use of fluid sensing is very critical. Level sensors are widely used for production monitoring, inventory control and leak detection. One OEM was searching for a solution for their magnetic level gauges as their end-user complained about floats sticking. e9's Pro Performance Metal Treatment was offered as a possible solution. The customer compared the effects of the fluid wetting on a treated float vs untreated float. Fluid completely coated the untreated float while the fluid rolled off the float treated with Pro Performance Metal Treatment. This demonstration convinced the customer and end user to move forward treating not only the floats, but the entire interior of the magnetic level gauge sensor cavity, to deter the accumulation of contaminants.

Chemical Reactors and Blenders
Many chemical companies supply various chemicals to the oil and gas industry for chemical injection into wells; these include fracking and anti-bacterial chemicals, as well as others. These companies operate chemical reactors to produce batches and batches of different blends for different customers and fields. They incur huge costs in maintenance and cleaning of their reactors at every blend change out. Maintenance workers use caustic chemicals and power washing to get rid of all the deposited contaminants and to prepare the reactor for the next blend. Even without a blend or formulation change, reactors can become contaminated to the extent that deep cleaning is required every few batches (8-12). Each deep clean event can cost anywhere from $10K - $12K just in cleaning expenses, not including the loss of yield and loss of production due to the interruption.

One company decided to treat the entire internal surface of their chemical reactor to reduce the deposition of residue on the reactor's walls and other parts, and to make the cleaning process easier, quicker and cheaper. The company treated 2 of their chemical reactors with e9's Pro Performance Metal Treatment. They were able to run 35 – 40 batches with no issues of buildup on the reactor. During their study, they also recorded an increase in average yield per batch, which was attributed to the reduction in lost product stuck to the walls of the reactor.
By treating their chemical reactors with e9's Pro Performance Metal Treatment, the company saw savings in the range of $30K / reactor / month just in reduced cleaning intervals and costs.

Similarly, many customers operating in the oil and gas industry have used e9's Pro Performance Metal Treatment to solve critical performance issues stemming from fouling of their instrumentation. Orifice plates, water cut meters, S&W Meters, thermo wells, electrodes and many similar instruments have benefitted from the application of Pro Performance Metal Treatment.

VALUE PROPOSITION

As described in the previous case studies, the cost or remediating not just paraffin, but various types of buildup on oil and gas instrumentation, can add up quickly. Taking a device out of service, cleaning and placing it back into service can easily cost $4,000-$10,000 per incident.

A small amount of e9's Pro Performance Metal Treatment can treat a large surface area, as the thickness of the treatment is generally less than 10 nanometers. One treatment container potentially can treat several devices when using a dip or flush application process, depending on the size of the devices. Treatment applies in minutes and

requires no curing or dry time, so devices can be placed in service quickly after treating. In almost every case study reported in this paper, customers experienced benefits in the form of reduced maintenance, reduced labor and fewer interruptions to operations. Adding the application of Pro Performance Metal Treatment to the end of the cleaning processes, when pulling fouled parts, takes minutes and can allow the device to run well and within tolerance for 2 -5X longer than an untreated part (based on application and environmental variables).

CONCLUSION

In conclusion, e9's Pro Performance Metal Treatment offers a new and novel way to maintain flow through valves, sensitive instruments, and other critical components in a flow line as well as other processes in oil and gas production and refining. This treatment is easily applied, has a permanent effect on the surface energy of the metal, and does not hinder the optical, mechanical, or electrical properties of treated devices. Benefits of these treatments include reduced maintenance downtime and cost, improved performance of critical instrumentation and increased reliability. The treatment can be applied easily to both to new and properly cleaned used equipment.

While this paper mainly discusses treating devices in flow lines, the success of e9's Pro Performance Metal Treatment in remediating the buildup of water- and oil-based organic and inorganic material on metal surfaces can easily be transferred to other applications within the oil and gas and many other industries.

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