AEROSOLS IN RESIDUE GAS AND ORIFICE PLATE METERS

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ABSTRACT

Metering systems are a critical part of the commercial and technical infrastructure undergirding the natural gas industry in the world. Errors in measurement can have commercial, legal and engineering consequences. Often metering errors are related to contamination in the process stream.

A gas plant in North America was experiencing challenges with its orifice plate metering system. Troubleshooting indicated that the orifice plate flow meter was being coated by a viscous oil, likely from the residue gas compressor. Oil fouling of orifice plates is known to cause measurement inaccuracy resulting in potential revenue loss. The residue gas was compressed through a reciprocating compressor and had a discharge coalescer that was expected to capture and remove the compressor lubricating oil. A study of the discharge coalescer downstream of the reciprocating compressor indicated design flaws both in the coalescing elements, and in the housing design. An improved design for coalescing elements was developed, along with an adaptation intended to address housing design deficiencies.

Following implementation of this design, no issues have been observed with the metering system. An estimate of the economic cost of oil loss is provided. The larger commercial impact is related to the metering challenges - and an indicative analysis of the commercial impact of oil carryover on metering highlights the tremendous cost associated with metering challenges.

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INTRODUCTION

A gas processing facility with a name plate capacity of 100 MMscfd was faced with lubricating oil carryover from their residue gas coalescer. The lubricating oil was affecting the downstream metering equipment. Transcend's Innovation, Engineering, Design and Analysis (IDEA) Laboratories' Field Services team conducted a multipronged evaluation of the residue coalescer housing and developed a suitable upgrade. Following the upgrade, the oil carryover to the orifice plate was determined to have stopped. The impact of contamination on orifice plate metering is also provided.

BACKGROUND

The process conditions were reported as follows:

- Flow Rate: 100 MMscfd
- Operating Pressure: 800 psig
- Operating Temperature: 80 - 120 °F
- MW: 16.13
- The oil was a Chevron HDAX low ash ISO 40 oil.
- The oil rate was estimated at approximately 32 gal/day at 55 MMscfd

The primary issue reported by the plant related to the oil contamination of the orifice plates downstream of the residue coalescer. The presence of oil is a practical representation of oil loss from the compressor system. In addition, the coating of the orifice plate meter introduces systematic errors in measurement that can have very real commercial implications in terms of amount of gas metered, and compliance with custody transfer agreements.

Figure 1. Orifice Plate Contaminated with Oil

RESIDUE COALESCER

VESSEL DESIGN

Figure 2 illustrates the vessel used for liquid aerosol removal from the residue gas stream. The vessel comprised, a 42-in ID coalescing vessel, with 14-in I/O nozzles. The general arrangement drawing of the vessel is provided in Figure 2. The relative location of the top of the element to the plane of the outlet nozzle is illustrated in Figure 3. A key item to note is that the tops of the elements were close to the plane of the bottom of the outlet nozzle. This is critical, because the flow streamlines exiting the elements, will have a velocity vector that is perpendicular to the element, rather than parallel and upward to the element.

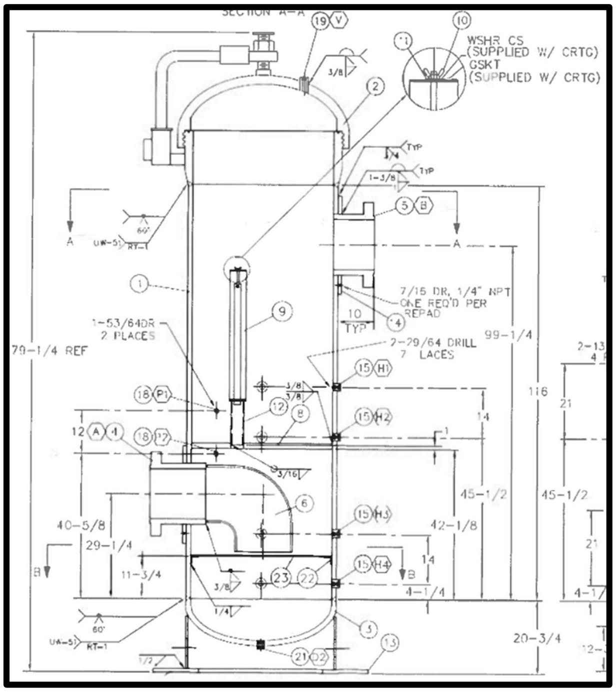

Figure 2. Residue Gas Coalescer

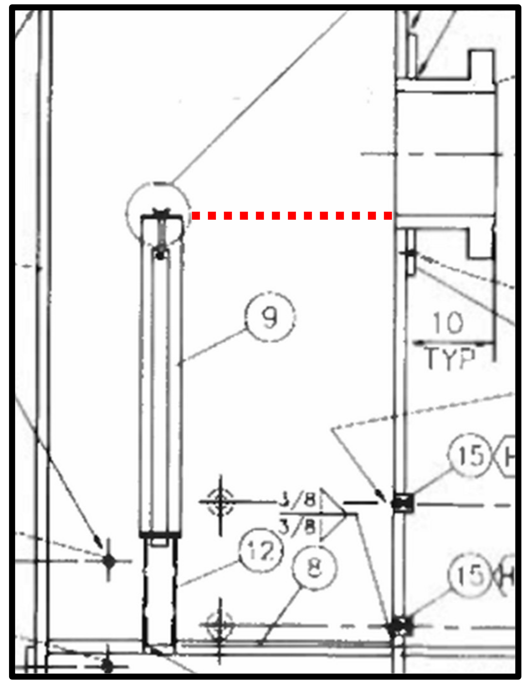

Figure 3. Schematic Showing Top of Element and Outlet Nozzle

COALESCING ELEMENTS

The upper chamber had forty (40) coalescing elements that were nominally 4.5-in OD x 36-in long. The elements were a conventional spiral wound depth style polyester element with claimed efficiencies of 99.99% at 0.3-micron and greater. The polyester fibers themselves were claimed to comprise multi-lobed and cylindrical fibers in an “engineered” depth configuration. The flow through the elements was inside-to-out. The elements had an open end with a flat seal against the riser pipe, and a closed end with a bolt hole that fit over a threaded rod that was retained in place by means of a nut.

SIMULATIONS

The gas flow through the elements was modeled assuming the use of the Ensur™ extended surface area element configuration. The proprietary model evaluates a number of critical flow velocities, fluid properties, and operational parameters to verify sizing is suitable and critical flow velocities are below key threshold values to achieve the desired separation efficiency. The modelling indicated that the housing, with the 40 elements of appropriate design could flow at a higher rate than the plant needed, and was therefore theoretically capable of working effectively. This model evaluated velocities through the media, through the circumferential drainage layer, and the gas velocity in the free space between elements. The model further assumed that the element was actually capable of capturing and growing the liquid aerosols.

HYPOTHESIS

There were three elements to the hypothesis of the failure of the coalescer to effectively remove oil from the residue gas stream:

1. Inefficient Elements. This inefficiency can often be deduced by manufacturers specification of efficiency in terms of 0.3-micron *and larger*. The "and larger" terminology often allows manufacturers to include 3-micron and 30-micron droplets in the efficiency calculation. A simple exercise shows that a 30-micron droplet has one million times the volume of a 0.3-micron droplet, so including "and larger" allows manufacturers to claim efficiencies in the sub-micron range even if their elements were inefficient at the sub-micron aerosol removal.

2. Flow dynamics. The location of the outlet nozzle in the plane of the coalescing elements allows perpendicular flows from the element surface, thereby allowing liquid droplets to be stripped out of the element. By comparison, if the outlet nozzle were located above the element, the velocity streamlines would be vertical, and parallel to the elements, allowing droplets to gravitationally settle either within or outside the element.

3. High Surface Area media. The use of an "extended surface area configuration" compared to the tubular depth configuration, enables utilizing a shorter element, while still meeting the media velocity, drain velocity and free area velocity requirements. The use of a shorter element, in turn allows us to address item #2 above.

IMPLEMENTATION

A shorter element was developed that would fit on the existing risers without any modifications. The element comprised a 9-in blank section that was bonded to a 27-in Ensur high efficiency aerosol removal section. The blank section was oriented such that it would be located at the top of the element (Figure 4), thereby allowing a more uniform flow configuration.

Figure 2. Blank Top Section of the element.

Once installed in the housing, the elements can be seen against the outlet nozzle, in Figure 5 and 6. Although the closed ends are in the same plane as the bottom of the 14-in nozzle, the media where gas exits the elements is nominally 9-in below the plane of the outlet nozzle.

The size of the blank section is the result of a tradeoff. A longer blank section at the top of the element increases the distance between the separation media and the outlet nozzle. This increased distance from the outlet nozzle results in more uniform upward velocity streamlines and minimizes the potential for stripping liquids directly from the media at the outlet nozzle. However, the longer the blank section, the shorter the separation media section. If the media section is decreased too much, the potential exists to exceed design practice on media velocity and drain velocity or the coalescing media.

The location of the top of the elements relative to the plane of the closure necessitates vessel entry to change out elements. The plant opted to not invest in elements that could be designed to be removed from outside the vessel, and for elements that are to be bolted in place. Elements are available with an interface at the closed end of the coalescing element to accept a placement tool. The use of the placement tool and appropriate elements allows placement and removal of the coalescing elements and placement and removal of the retention nuts without the need for vessel entry, even when vessel design requires elements to be recessed well below the closure.

Figure 3. Location of the Elements Relative to the Outlet Nozzle.

RESULTS

The plant started up the residue compressor discharge separator without incident. After the start-up, the plant checked the orifice plate meter. Inspection of the orifice plate by plant personnel after start-up indicated no visible oil residue on the orifice plate.

Figure 6. Spent Element, showing a Brown Band of Oil Seepage at the Bottom

Figure 6 shows a spent element retrieved for evaluation, with a band of brown oil seepage at the right, which would be the bottom of the element. This is consistent with appropriately sized elements, where the liquid drainage within the element is effective and only the lower few inches of the element experiences saturation and free liquid collection at the exterior of the element. The top section appears clean, because only gas exits at this point, with liquid gravitationally settling and seeping out at the bottom. The spent element further indicates that lateral flow of oil carryover was not seen at the top of the element. Most critically, the clean outer surface over the top 80% of the element indicate that the oil was being captured and grown within the element.

IMPLICATIONS

Every custody transfer point in the midstream gas transmission and processing space has a metering device of some kind. Generally, there is compression upstream of this custody transfer point. Usually, that compression is an oil lubricated reciprocating compressor. The carryover from an oil compressor is widely recognized have a significant sub-micron component. For the discharge compressor separator to work effectively and prevent oil carryover, it is essential that the vessel and element system accomplish the following, in concert:

(a) Capture liquid aerosols across the droplet size spectrum [Media technology]
(b) Effectively grow the droplets [Element technology]
(c) Remove the droplets from the gas stream without re-entrainment [Housing design]

Failure to effectively achieve any of these will result in a system evidencing oil carryover. Accomplishing these items requires:

(a) High efficiency media technology that can effectively capture sub-micron aerosols
(b) Element seals that force the gas through the media, and prevent oil contaminated gas from bypassing the element
(c) Media technology that is compatible with the gas and liquid

(d) Media bed and housing design that allows the growth and drainage of the liquids without re-introduction to the gas stream
(e) Removal of liquid from the vessel

Measurement Accuracy

The consequences of oil carryover to the orifice plate can be quite dramatic in terms of measurement accuracy. The thin film of oil coating the orifice effectively reduces its diameter, which in turn affects the pressure drop for a given flow. This introduces error in the measured flow rate, which is based on a conversion of differential pressure. While obstruction of the orifice through contamination exhibits the greatest impact on measured flow readings, deposition of oil at the plate face results in significant decrease in flow measurement accuracy as well. Contamination induced orifice plate metering errors from oil or grease deposition can vary from 0.1% to 4% or greater[2].

An error of 0.1% on a gas flow of 100 MMscfd is equivalent to a “error” of 0.1 MMscfd. At a (nominal) gas price of $3 / Mscf, this is equivalent to 0.1 MMscfd x 1000 x 365 days x $3 /Mscf = $109,500.

Oil Loss

The typical oil injection rates reported by reciprocating compressor manufacturers is in the 5-20 ppmw range. This corresponds to an oil injection rate of approximately 3 – 10 gal / 100 MMscf. Assuming a compressor oil cost of $20 / gal, we can obtain an estimate of the cost of oil loss. The amount of oil carryover as a function of efficiency is shown in the table below

Element Efficiency	Oil Lost (gal / year)	Cost of Oil Loss ($ / year)
99.99%	0	$0
90%	100 – 180	$2,000 - $3,600
50%	500 – 900	$10,000 - $18,000
0%	1,000 – 1,800	$20,000 - $36,000

Note that some horizontal filter coalescers have been shown to have 0% efficiency in residue gas service[1], and therefore, the last row is a very real and industry relevant example to consider.

Beyond the implication of the measurement inaccuracy and oil loss is the possibility of contractual violation with the takeaway pipeline. Failure to meet the contractual obligation of delivering gas “commercially free” of oil or liquids to the pipeline can result in shut-in of the plant from the distribution network which carries orders of magnitude greater commercial impact.

SUMMARY

A North American gas plant was experiencing oil carryover from its residue gas compressor discharge coalescer. A technical review of the discharge coalescer revealed that the element technology being used was incapable of removing the oil aerosol due to a combination of factors including the high velocity through the element, element efficiency, and housing design. An innovative approach to upgrade the elements was undertaken, to avoid any vessel modifications. This upgrade resulted in an element using high efficiency media, in an extended surface area configuration, with a blank section on the top that addressed the flow dynamics associated with nozzle placement. The results indicated a clean downstream orifice plate and a successful upgrade of conventional vertical coalescer vessel.

In addition, the commercial impact of poor residue compressor discharge coalescers is also discussed. The impact of oil loss was estimated at $36,000 / 100 MMscfd or less, and the impact on metering error was estimated at $100,000 / 100 MMscfd as a lower bound. The impact of contractual violations with the takeaway pipeline was not estimated.

References:

[1] Hahn, C. W., “The impact of aerosol contamination on RSV efficiency”, Laurance Reid Gas Conditioning Conference, February 20-23, 2023.

[2] Pritchard, M., Marshall, D., Wilson, J., “An assessment of the impact of contamination on orifice plate metering accuracy”, Paper 2.2, North Sea Flow Measurement Workshop, 26-29 October, 2004.

ACKNOWLEDGEMENT

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