CONSIDERATIONS FOR INCREASED EFFECTIVENESS OF TANK VAPOR COMBUSTION SYSTEMS AT PRODUCTION FACILITIES

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ABSTRACT

With the recent proliferation of federal and state regulation in regards to allowable emissions limits from oil and gas production facilities, sound emissions control methods and their utilization have become increasingly more important. Operator environmental compliance has been frequently emphasized by regulatory agencies, and using vapor combustion units (VCU's) to limit the atmospheric exposure of volatile organic compounds (VOC's) from on-site storage tanks is a practice that is seen with increasing regularity. The installation of VCU's can be time sensitive to ensure regulatory compliance and, because of this, it is not uncommon for the importance of key variables to be underestimated or overlooked in the design and construction process. Throughout this paper, considerations are provided to bring several of these factors to the operators' attention to ensure that the unit and associated piping is installed with maximum effectiveness.

INTRODUCTION

In August of 2011, the EPA passed NSPS Part 60 Subpart OOOO "Quad O" under the Clean Air Act. Part of this regulation requires reducing emissions by at least 95% from tanks with a potential to emit (PTE) 6 tons per year (TPY) or more of volatile organic compounds (VOC's). A tank's VOC PTE can be calculated using any generally accepted calculation methodology (e.g. Vasquez Beggs, Promax, AP-42, etc.). Typically, this calculation is performed by an operator's environmental team to determine whether a tank is subject to NSPS Quad O. If a tank's VOC PTE is 6 tpy or more and the tank was manufactured after August 2011, the project is typically passed on to another group within the company to engineer a solution to effectively reduce the released amount by at least 95%. To meet this criteria, the gas is generally compressed back into the gas sales line or combusted by a vapor combustion unit (VCU). Note that significant fines can be associated with under sizing this equipment and failing to reduce emissions by 95% on tanks subject to OOOO. For engineers, construction specialists, and production technicians responsible for the installation and maintenance of VCU's, this paper aims to be a resource highlighting some technical aspects to consider throughout the VCU implementation process.

EARLY CONSIDERATIONS

This section of the paper will illustrate a few things to consider when gathering data to determine if a VRU or VCU will be used and what size of either needs to be chosen. Before the two options can be evaluated against each other economically, each one must be sized. Once it is established that tank vapors must be reduced, the single, most important factor when sizing a compressor or VCU is the actual emissions rate. Even with the approved methods of calculating emissions, it is not uncommon to incorrectly estimate the amount of gas that actually vaporizes off of the oil in the tanks. Figures 1 and 2 illustrate the potential for differences in a calculated emissions rate and a measured emissions rate for an example facility. In this example, the measured emissions rate off of the oil stock tanks at the example facility averaged 160 macfd over an 18-hr test. The calculated rate for this facility was 96 macfd (67 acfm) which was only 60% of what actually needed to be compressed or combusted. This demonstration is in no way intended to insinuate that process models are typically incorrect, but rather, that any tool can yield inaccurate results when input data does not accurately match or does not take into consideration critical field variables. Variables that are often used to calculate emissions from tanks are: average oil flow rate, assumed oil properties (density, viscosity, etc), assumed pressure at each stage of separation prior to tank storage, assumed heater treater operating temperature, and oil tank pressure. Variables that are often not included in models but still affect emissions rate are: actual oil chemical analysis, true operating temperature and pressure at each stage of separation upstream of tanks, residence time in upstream separation as well as in tanks, ambient temperature fluxuations, sunlight, oil agitation, use of blanket gas regulators, routing of heater treater gas, and anything else that will affect the vaporization of lighter ends in the oil stock tanks. It is not uncommon for ratios such as 0.05-0.1 mscf/barrel of oil (35-40° API crude oil, two stage separation with inlet facility pressure under 100 psig and heater treater operating at 120°F) to be expected but this is just an initial approximation that needs to be backed by field data before using to size equipment.

In general, it is recommended to size the emissions control device for at least 1.1-1.3 times the average expected emissions rate of the battery to account for upset conditions or inaccuracy in rate estimation. It is important to note when sizing the unit that the orifice for the main burner in the VCU needs to be the proper size for the rate and pressure of the application. This orifice size is often overlooked and can limit the throughput of the unit significantly if incorrectly specified.

Other than the economic factors, a few other considerations before choosing a VCU are

- Operators' ability to operate either a VRU or VCU reliably. Significant training may be required.
- Power infrastructure. VCU's are often solar powered and can be a great solution when power isn't readily available.
- Proximity to public receptors. VCU's can be confused with high pressure flares and seen as a safety hazard by the community.
- Gas composition. If there is a significant amount of H_2S, the conversion to SO_2 may not be desireable.

<u>VCU DESIGN</u>

Process design for an effective VCU system begins with two unit inputs as indicated in Figure 3: the main gas line from the oil stock tanks and a pilot gas line from a reliable, dry, gas source. The input for the main gas stream is tied to the vapor space of the oil tanks on site and the pilot gas is taken from the driest, most reliable gas source possible. Good candidates for a pilot gas source are off of the heater treater pilot gas knockout vessel or a gas stream coming off of a production separator or gas scrubber. It is advisable to slope the main gas stream towards a liquid knockout pot to try and salvage any liquids and to allow the combustor to burn cleanly. The knockout pot can be equipped with any assortment of instrumentation but a level switch, sight glass, and pressure transmitter are common. In a knock-out vessel set-up with these instruments, the level switch will shut-down both electrically operated ball valves to prevent liquids from entering either pilot or main burner and the pressure transmitter is used to operate the electricaly actuated ball valves to execute the lighting sequence below.

Common VCU lighting sequence

1. Ignitor rod starts sparking right by the end of the pilot gas line
2. The electrically actuated ball valve on the pilot gas line opens and sends gas to pilot burner
3. Sparks from ignitor rod ignite the pilot gas
4. If a temperature from the pilot is registered, the burner management system (BMS) checks the pressure transmitter on the knockout pot and checks if it is above the value that was set for the main burner to come on at
5. If the knockout pot pressure is greater than set-point, the electrically actuated ball valve on the main gas line (tied to the vapor space in the oil tanks) opens and sends tank vapors to an already lit pilot.
6. The already lit pilot ignites the tank vapors inside the VCU
7. The electrically actuated ball valve on the main tank gas line shuts when pressure transmitter on the KO pot reads the set pressure to turn the unit off at

Liquids salvaged from the knock out pot are generally directed back to a place that can appropriately accommodate volatile liquids. Directly downstream of the knockout pot, the main gas stream often runs through a flame arrestor to prevent flame propagation upstream in the system. As described above, there may be electrically actuated valves on both pilot and main gas lines to control the lighting sequence. The pilot gas line contains a regulator so that the ignition system on the unit is fed by a steady gas stream at the appropriate pressure for the pilot flame. It is important to note that this regulator often gets plugged and causes the unit to go down on low pilot gas temperature (no pilot flame). Certain units may be equipped with a variety of computers that record variables measured by the instruments described above such as knock-out vessel pressure, main burner temperature, combustion rate, and pilot temperature. Installations where this information is displayed to the operator via a HMI screen can be particularly helpful during maintenance and troubleshooting.

HYDRAULICS

The hydraulic design of the piping from the vapor space of the tanks to the VCU is often over-simplified, resulting in installations that still have emissions leaking from the tank hatches while the VCU is running. It is critical to have an accurate hydraulic piping model of the system before determining pipe sizes to ensure that all of the vapors actually get to the VCU. The pressure rating of the oil tanks and the set pressures of the theif hatches, emergency hatches, and end-of-line valves are important variables in determining required piping size. It is not uncommon that many of these theif hatches and emergency hatches actually begin to leak vapors at pressures as low as 60% of their set pressure. This is especially true for the hinged hatches that do not have a spring or locking mechanism. As with all piping systems, larger allowable pressure differentials between the source and sink enable the use of smaller diameter piping. When the set pressure for the VCU to turn on is very close to the maximum pressure your tanks can hold without hatches leaking, the larger your piping from the tanks to the VCU will need to be. This is especially significant when dealing with high emissions rates and VCU’s that are far away from the tanks. The VCU manufacturer can recommend lower end set pressures for the VCU to turn on and off based on orifice size and the specific unit’s measured combustion properties. When the VCU burns at too low of a pressure for a given orifice size it may begin to generate a black smoke. It is important to keep in mind that although emergency type hatches may not seal as well, they may still be critical for gas-blowby situations to the tanks from upstream vessels. VCU or VRU technicians may suggest set pressures or valve types without knowledge of how to size or set these valves to protect the tanks from gas blowby. It is suggested to route the main gas line from the tanks to the VCU as straight as possible to minimize pressure drop from the tanks to the unit. Where possible, 45° bends are often used rather than 90° bends to help reduce pressure drops. It is recommended to gradually slope this piping from the tanks to the VCU. The gradual slope will ensure all liquids drain into the VCU knockout pot, which is suggested to be placed as close to the unit as possible. Installing the knockout pot close to the VCU will reduce possibility of a liquid slug hitting the main burner and generating maintenance problems. Due to the common lower pressure ratings of fiberglass tanks (ex. 4 oz. vs. 8 oz.), the system will generally leak less if the VCU draws vapors from the oil tanks only. Note that this is only applicable if fiberglass tanks are not subject to OOOO.

VCU PLACEMENT

Placement and construction play an important role in the operational reliability of the VCU. Depending on company spacing guidelines, different factors such as supply line location, relation to other equipment, and fall radius must be taken into consideration before completion of the construction phase.

The first thing that should be taken into consideration should be the main gas supply line from the tanks to VCU. The routing of this piping, if not done correctly, could limit access and egress across facility and obstruct vehicle driveways. The supply piping should allow for simultaneous operations throughout the facility. One should ask the questions, “can this unit be accessed for service and maintenance” and “can all of the surrounding equipment be easily access for service and maintenance”.

The potential for generating fires is the second consideration that needs to be made when deciding where to set a VCU. With this being fired production equipment, placement near storage tanks, vents, or any potential hydrocarbon source is strongly discouraged. Awareness of fall radius in proximity of dry brush and power lines should also be considered. Note that the VCU should be properly anchored to the ground so that it is less prone to being blown over during high wind speeds. Note that it is reasonable to assume that the VCU can fall and sever piping (if within the fall radius) containing hydrocarbons, causing a loss of containment and potentially a fire.

SAFETY

As with all equipment, VCU's introduce new hazards and risks to the facility. Before any work is performed on this unit it is imperative that proper energy isolation practices have been discussed and performed. Depending on the type of VCU, confined space entry may be required to access internal combustor components. Clearing the confined space with a Quad-monitor is a recommended practice before entering the potential confined space to perform maintenance as there is the potential for lack of oxygen, a combustable atmosphere, and H_2S. Other common hazards include electrical shock and burns. Before maintenance is performed on the equipment, time must be allotted to allow the unit to properly cool down to minimize burn potential. It is recommended that certified electricians should perform electrical maintenance on the VCU to minimize shock potential. Lastly, safety hazards around the VCU's as well as all production equipment are trips hazards, and poisonous creatures such as snakes and spiders.

SURVEILLANCE

Once the VCU is in service, regular surveillance and maintenance will be required by the lease operator to ensure the unit is running smoothly. An effective surveillance program begins with education and awareness for everyone associated with the installations. If the affected people are taught the fundamentals of why VCUs are required, how they work, regulatory reporting, and proper preventative maintenance, the overall effectiveness of the emissons control program will be increased.

A method of reporting combusted volumes and unit run times will be required to some extent in the event of an internal or external compliance audit. Generally, the reporting requirements are generated by the operators' environmental group and are passed on to operations for execution. Assuming there is a HMI on the VCU to display critical variables, the simplest form of reporting would require the operator to manually record the daily combustion volumes on a log sheet. To minimize this effort, several VCU's offer electronic recording which can be as simple as a removable memory card that can be routinely pulled to check combustion volume history. If the operating facility has access to an established SCADA system, a continuous stream of data from the VCU can be recorded in a variety of ways. Another method of ensuring emissions compliance is by executing routine infrared inspections (IR). IR inspections would ensure tank thief hatches are not leaking and VCU is combusting all emitted VOCs. These inspections can be conducted by anyone using an IR camera approved for this test.

As with reporting, proper preventative maintenance will be required by the operator to ensure the VCU is operating correctly. Routine inspections would include making sure that the VCU has fuel gas at the desired pressure, the pilot is lit, the pilot gas does not have an obstructed flow path, and draining liquids out of knock out as well as the fuel gas supply line. Preventative maintenance would also include tank thief hatch inspections. As mentioned in the hydraulics section, not being able to hold the required pressure to get all VOC's to the VCU is the most common cause that emissions may be seen in an IR camera.

TROUBLESHOOTING

Like with any mechanical device there is the possibility of startup and operating issues that may require operator interaction or troubleshooting. Below are a few tips for common start-up issues.

1. If the burner pilot will not light or stay lit. First, check to make sure all air and liquids are bled out of fuel gas line providing a constant gas stream to regulator. Verify pilot gas regulator is not choked or clogged. Once pilot gas is indeed flowing, block pilot gas and check ignitor (this may require confined space entry). Ignitor spark should arc across pilot gas stream ensuring reliable fuel ignition.
2. If the main burner is not lighting. Verify that pilot is lit. Verify all tank thief hatches holding the correct pressure on the system (keeping in mind that it is not uncommon for tank theif hatches to leak at pressures as low as 60% of set value). Verify pressure transmitter is reading a correct value and that it is not installed incorrectly.
3. If the combustor unit is signaling high liquid level in KO but KO is empty. Check to make sure liquid switch is wired correctly. If wired correctly, unbolt liquid switch to verify the float is not stuck.

<u>CONCLUSION</u>

In summary, correctly estimating the amount of emissions actually being released by the stock oil tanks is the most critical step in VCU sizing and ensuring compliance with NSPS Part 60 Subpart OOOO "Quad O". Once that is established, several of the VCU design, hydraulics, placement, safety, surveillance, and troubleshooting considerations that were presented may be thought through to increase the overall effectiveness of the installation.

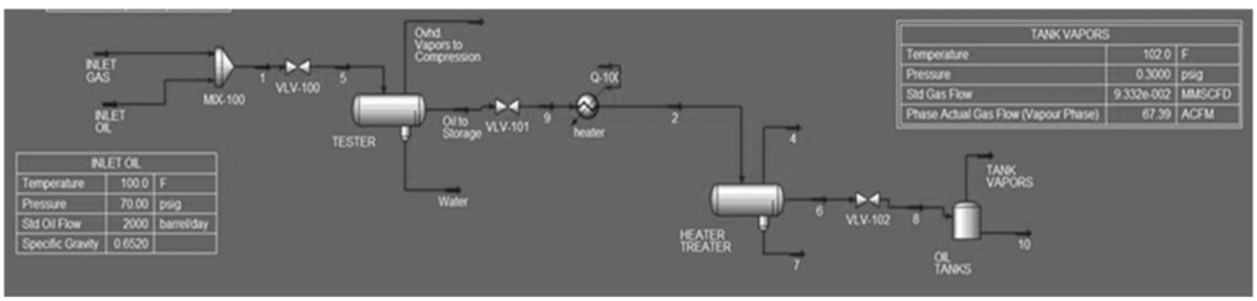

Figure 1 - Calculated emissions rate of example facility

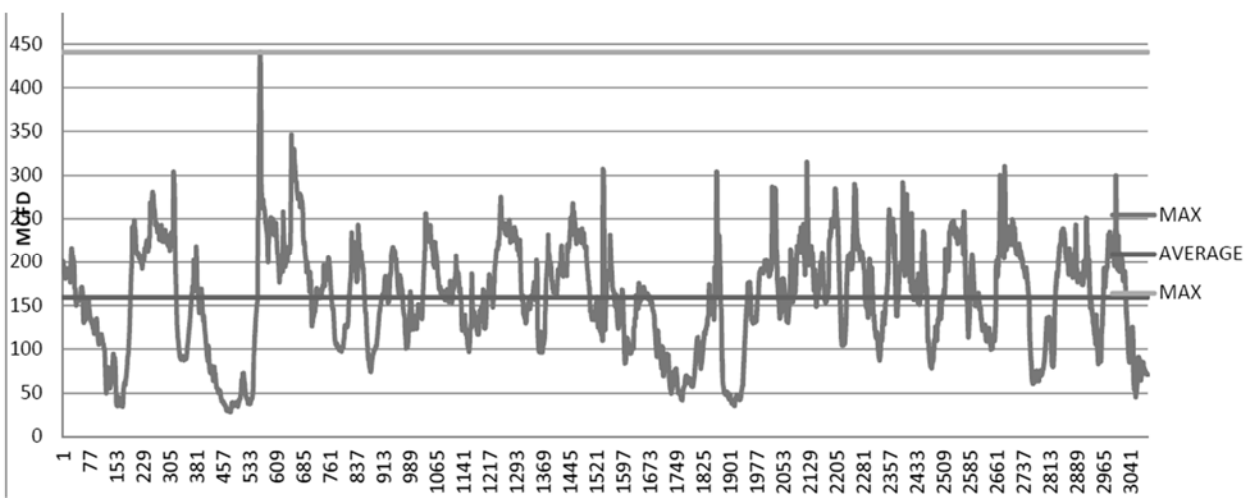

Figure 2 - Measured emissions rate from same example facility

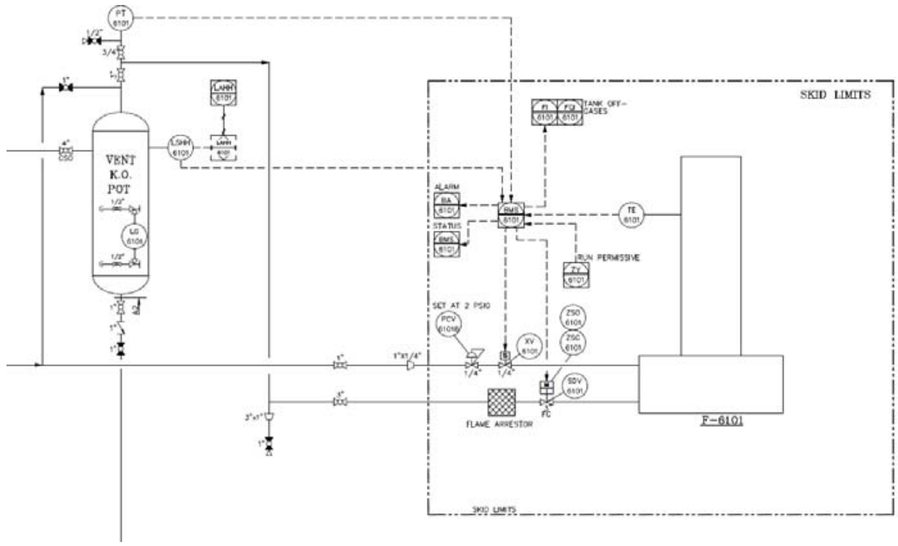

Figure 3 - Example P&ID of VCU installation