Total Solutions Approach to Vapor Recovery
PRESENTATION AGENDA

Introduction to HY-BON
Regulatory Considerations
General Overview of Vapor Recovery
Compressor Selection Criteria
Vapor Recovery Towers
Vapor Combustion Units
Bio-Filters
Vapor Recovery Project Examples
Gas Measurement (HY-BON IQR)
HY-BON Experience and Value Add
What Does HY-BON Do?

We take waste gas emissions and convert them into revenue, while keeping you in Compliance and Safe.
• Wasting resources and most importantly additional revenue!
Actual Measurement

- 530 tons per year VOC Emissions
- 55 MSCFD x $4 / MSCF x 2000 BTU
  = $132,000 revenue per year
- Project Cost: $100,000 (VRU, VRT, VCU and install estimate)
- **PAYOUT 9 Months!!!!!!**
EPA Amends Definition of Storage Vessel Affected Facility

- A single storage vessel located in the oil and natural gas production segment, natural gas processing segment or natural gas transmission and storage segment and has the potential for VOC emissions equal to or greater than 6 tpy MUST reduce the emissions by 95% taking into account requirements under a legally and practically enforceable limit in an operating permit or by other mechanism.
6 tons per year sounds like a lot, but is it ..... 

Threshold based on potential to emit VOCs - 6 tons per year or more

Daily equivalents could be as low as:

- 33 pounds emission
- About 1 mcf emission
- 1 barrel of condensate produced
- 20 barrels of oil produced
- 2000 barrels of water with 1% oil carryover processed
Applicability Date

- Same as current rule = August 23, 2011
- Replacement storage vessel is considered a new source and an affected facility if it has PTE* of 6 tpy or more and is put into service after August 23, 2011
Determination of Affected Facility

- Each storage tank or vessel
- Date of installation, reconstruction, modification
  - Prior to Aug 23, 2011 (not affected)
  - Aug 23, 2011 to April 12, 2013 (Group 1)
  - After April 12, 2013 (Group 2)
Group 1

- Storage vessels constructed or modified between August 23, 2011 and April 12, 2013
- PTE of 6 tpy or greater
- Initial determination by October 15, 2013
- Initial notification by January 15, 2014
- Control required by April 15, 2015
Group 2

• Constructed or modified after April 12, 2013
• PTE of 6 tpy or greater
• Applicability determination and control by April 15, 2014 or 60 days after startup, whichever is later
Emission Limitations

• Proper capture
• 95% control
  – 40 CFR 60.18 (flares)
  – Vapor combustors
  – Vapor recovery units (*Process unit...not a control device*)
Emission Limitations

• The 6 tpy limit is on a per tank basis. Even if the tanks are manifolded together in a series the PTE needs to be looked at on a per tank basis. So if all of the flash is occurring in the first tank of the series, and as a result it’s PTE is 10 tpy and the remaining tanks are only 1 tpy each, then the first tank is an affected source under OOOO and the others are not. Since the flash is occurring in that first tank, those emissions must be accounted for for that tank’s PTE and cannot be averaged out to the other tanks in the series.

• **Oklahoma**
  • Kendal Cody Stegmann
  • Sr. Environmental Manager
  • Compliance and Enforcement Group
  • Air Quality Division
  • (405) 702-4150

• **Texas**
  • Joe Shine
  • Team Leader, Rule Registrations Section
  • Air Permits Division
  • joe.shine@tceq.texas.gov
  • (512) 239-6595
Alternative Compliance

• Sustained **uncontrolled** emissions less than 4 tpy for 12-mo (confirm every month)
• Option to remove controls
• Remain affected facilities (records, monitoring, etc.)
• If increase emissions to 4 tpy or more, must achieve 95% control
  – 30 days or
  – Immediately on handling liquids if re-frac well
We agree that it is better to recover resources than to burn them. (However, by law, if someone meets the 95 percent control requirement, we cannot specify how they must meet it. In other cases, where we cannot set a numerical limit, we can set work practice or equipment standards, but there are specific criteria we must meet in order to do so.)
WHAT GETS SEEN, GETS MEASURED

WHAT GETS MEASURED, GETS CONTROLLED

WHAT GETS CONTROLLED, CAN MAKE YOU MONEY
See greenhouse emissions like never before.

Now anyone can measure and map emissions with CRDS precision and cloud-based algorithms. In seconds.

Methane emissions in Foster City, CA
What is Vapor Recovery?
As the oil resides in the tanks, it gives off vapors, thereby increasing the pressure inside the tank.
Sources of Methane Losses

Flash losses
• occur when crude is transferred from containment at a high pressure to containment at a lower pressure

Working losses
• occur when crude levels change and when crude in the tank is agitated

Standing losses
• occur with daily and seasonal temperature and pressure changes

• Approximately 26.6 BCF/YR of Methane is lost from storage tanks Does not include VOC’s

Source: Natural Gas STAR Partners
GAS COMING OUT OF SOLUTION
Methane has 25X the greenhouse gas effect of CO2 (1 ton CH4 = 25 tons CO2e) – and costs the oil company money.

What money?

Un-captured profits and regulatory risk (*additional liability*)!!

An average tank battery can emit from $500 to $50,000 in natural gas per month!
Hydrocarbon gas venting from a condensate storage tank in a gas field.

Gas is invisible to the naked eye – but the volumes of vent gas off of these tanks are often quite amazing.
PURPOSE

Vapor Recovery units are designed to comply with regulatory standards, provide additional profits to the oil producer and eliminate the emission of stock tank vapors to the atmosphere.

Most vapors contain varying amounts of methane, ethane, propane, butanes and pentanes, etc. and contribute to the gravity of lease crude.

Dissipation of these products to the atmosphere on a conventional tank battery means a reduction in gravity of the liquid in the tank, thereby decreasing its value.
A tank (or tanks manifolded to a common suction line), is piped to the suction scrubber on the vapor recovery unit.

An independent sensing line, generally 1-inch, is run from any one tank to the drip pot on the control panel. This sensing line should be an independent connection to the tanks and as far as practical from the suction line.

The discharge piping from the VRU is connected to the gas gathering line, a meter run, the suction of the field gas compressor, or a combination of all three.

The scrubber drain system is piped either to waste or back to the stock tanks.

The electrical control panel may be mounted remotely, or in an explosion proof (NEMA 7X) enclosure on the skid.
VAPOR RECOVERY SYSTEMS

ONE INCH SENSING LINE
May be flexible PVC, fiberglass or steel, taped or banded to suction line.
CAUTION: Sensing line must be independent of suction line.

PRESSURE / VACUUM RELIEF

SUCTION LINE
Steel or Fiberglass

SCRUBBER DRAIN PUMP

V. R. UNIT SCRUBBER

BUTTERFLY OR GATE VALVE

STOCK TANK →

DRIP POT ON V.R. SENSING PANEL

NOTES
All lines must be horizontal, or sloped down to V.R.U. suction as shown.
Scrubber fluid is piped back to tanks or to waste.
The system must be closed — no air entry.
Maintaining Integrity of the System

Maintaining a “closed” system is imperative to a successful Vapor Recovery system.

Systems are programmed to start automatically at a predetermined set point. As a general rule a 2½” W.C. pressure will start the unit.

As the tank(s) pressure is reduced to approximately 1½” to 2” W.C., a by-pass mode is initiated and a small percentage of the discharge volume is diverted back to the suction scrubber. This allows the tank pressure to increase and, as it reaches the 2” mark, the by-pass closes. If, while in the by-pass mode, that tank pressure continues to diminish, the unit will stop and wait for the start pressure to be attained.

To avoid pulling a vacuum on any tank, shut-down pressure is generally at 1” W.C.
Benefits of Vapor Recovery Units

$ Capture up to 100 percent of hydrocarbon vapors that accumulate in tanks. Up to you to prove.

$ Recovered vapors have much higher BTU content than pipeline quality natural gas

$ Recovered vapors can be more valuable than methane alone

$ Reduce regulatory & liability exposure
Criteria for VRU Locations

• Steady source and sufficient quantity of losses
  – Available gathering system. 15-20 mcf/d profitable

• Outlet for recovered gas
  – Access to pipeline or on-site fuel use

• Tank batteries that are subject to state/federal air regulations. **Flaring restrictions are coming**
Quantify Volume of Losses

• Measure losses using orifice well tester and recording manometer

• Estimate losses from chart based on oil characteristics, pressure, and temperature at each location

• Estimate emissions using the *E&P Tank* Model
Estimated Volume of Tank Vapors

Pressure of Vessel Dumping to Tank (Psig)

Vapor Vented from Tanks - SCF/BBL - GOR

- 40° API and Over
- 30° API to 39° API
- Under 30° API

SPE Web Events

#SPEWEBEVENTS
What is the Recovered Gas Worth?

- Value depends on BTU content of gas
- Value depends on how gas is used
  - On-site fuel - measured in terms of fuel that no longer must be purchased
  - Natural gas pipeline - measured by the higher price for rich (higher BTU) gas (=2.5 X)
  - Gas processing plant - measured by sale of NGLs and methane, which can be separated
VRU Decision Process

1. Identify possible locations for VRUs
2. Quantify the volume of losses (IQR?)
3. Determine the value of recoverable losses
4. Determine the cost of a VRU project
5. Evaluate VRU project economics
VRU Evaluation Checklist

Is the unit on location a vapor recovery unit?

• Does it have a pressure sensing device on the tanks or on the skid?
• Does it have a bypass system to circulate gas between the compressor and the inlet or suction vessel?
• Is the correct type of compressor being utilized? (Rotary vane vs. rotary screw vs. scroll vs. reciprocating compressors)
• Does it have a PLC controlling the unit for extremely low pressures
Is the production system properly configured to capture the vent gas?

- Is the piping from the tanks to the compressor sloped downward with no visible liquid traps (U in the piping)?
- Are the tanks manifolded together properly?
- Is a gas blanket being used?
- Are all Enardo valves and tank hatches secure?
- Is the pressure sensing device sensing pressure off the top of the tanks?
Why do many VRU projects from tanks fail?

• #1 The package purchased or rented IS NOT a vapor recovery unit – that is, a dry gas type wellhead unit used; resulting in personnel safety hazard AND no gas captured (*but it is cheap*).

• Players involved have no true vapor recovery experience - realistically, there is a 3 to 5 year learning curve in understanding the dynamics of low pressure, low volume, wet gas applications

• After failed project, then end user jumps to refinery spec

• After properly designed package is purchased, the overall design system not designed properly or “closed” to air ingress (holes in tank, thief hatches, etc)
“The Division has determined that improperly secured thief hatches, visible emissions from a flare, and audible emissions from a thief hatch or PRV are violations of Regulation No. 7. The Division has determined that the minimum fine for an open thief hatch, visible emissions from a flare or audible emissions from a thief hatch or PRV will be $15,000 per day. The duration of each such violation will be at least one day, unless evidence gathered by the Division and/or provided by the source proves otherwise.” (emphasis in original).
VRU Project Keys to Success

• Carpenters Rule – measure twice, cut once
  – Fully understand your gas volumes, pressures & design options / minimum 24 hours tank tests
  – Ensure the players have experience with the application
  – Ensure the equipment is suitable for capturing extremely low pressure, low volume, wet gas streams

• Involve the field in the overall system design, from piping to tank configurations & requirements

• Ensure a system is in place for ongoing monitoring of gas volumes being captured, and a strong preventive maintenance program

• Review incentive programs to insure goals are aligned with desired outcomes
HOW DO WE CHOOSE THE APPROPRIATE COMPRESSOR?

Natural Gas STAR Program recommends limited compressor types for vapor recovery:
- Rotary vane
- Rotary screw
- Venturi Jet (Eductors)
Rotary Vane Compressors

- Eccentrically mounted rotor
- Centrifugal force causes vanes to slide in or out
- Gas is forced into decreasing space thereby causing compression
- Jacket water cooling system
- RPM range 400 to 1600
Rotary Vanes

Advantages
- Excellent for relatively high volumes and relatively low differential pressures
- Efficient at low pressures
- Can handle wet gas relatively easy
- Comparatively low initial cost and ongoing maintenance

Disadvantages
- Limited as to discharge pressure
- Limited as to suction temperature capabilities
- Free liquid causes blade breakage problems
Applications of Various Compressor Types

**Rotary Vane Compressors**

- Vapor Recovery
- Low Pressure Gas Boosting
- Digester Gas Recovery
- Landfill Gas Recovery
- Casinghead Pressure Reduction

* Where discharge pressure stays below 50 psi
Flooded Screw Compressors

- Twin helical rotors
- Oil is both the cooling medium and the compression medium
- Various configurations of gears, internal porting and loader/unloader valves available
- Gas mixed with oil - must be separated after compression
General Principle - Rotary Screws
Oil Flooded Screw Compressor Typical Operating Parameters

- Differential pressure equal to or less than 300 psig (for single-stage models).
- Volume from approximately 20 MSCFD to 2.5 MMSCFD (for single-compressor units).
- Virtually any temperature (< 180° F)
Oil Flooded Screws

Advantages
• Excellent in a large volume/medium differential pressure range
• Can handle wet gas better than rotary vanes
• Excellent temperature control for controlling condensate fallout

Disadvantages
• More sophisticated system with oil/gas separator
• Higher maintenance
• Higher operational expense (oil, filters, etc.)
Applications of Various Compressor Types

Oil Flooded Screw Compressors

- Vapor Recovery
- Wellhead Compression
- Medium Pressure Gas Boosting
- Casinghead Pressure Reduction

- In wet or dry gas applications
- Up to 300 psig discharge
VENTURI TYPE

- Venturi ejector vapor recovery units (EVRU™) or Vapor Jet
  - Use Venturi jet ejectors in place of rotary compressors
  - Do not contain any moving parts
  - Eductor requires source of water
  - Vapor Jet requires high pressure water motive

*Patented by Hy-Bon Engineering
Venturi Jet (Eductor)

Typical Operating Parameters

- Differential pressures of up to 40psig
- Handle limited volumes (approx 70mscfd)
- Require an available water source (motive fluid)
- No moving parts on compressor but require water pumps

*Patented by Hy-Bon Engineering*
Venturi Jet (Eductor)

Advantages
• No moving parts on “compressor”
• Do not introduce compressor oil into hydrocarbon stream
• Easily handles very wet, heavy gases
• Relatively low maintenance

Disadvantages
• Low differential pressure capability
• Low discharge pressure limit (40psig)
• Low flow rate capability in a single machine
Applications of Various Compressor Types

Venturi Jet (Eductor)

- Vapor Recovery
- Wellhead Compression
- Some low pressure process applications
TYPICAL COMPRESSOR TYPES

Reciprocating Compressors

- Higher pressure services
- Piston/cylinder arrangement
- May be air, water or oil cooled
- Ages old technology
- May be slow speed or high speed
Reciprocating Compressor

Typical Operating Parameters

• Differential pressure in excess of 2000-3000 psig (for multi-stage models).
• Volumes in excess of 20MMSCFD+++ (dependent upon suction pressure).
• Relatively high suction temperatures (< 200° F)
Reciprocating Compressors

Advantages
• High volume/high pressure
• Able to handle spikes in pressure
• Relatively low maintenance

Disadvantages
• Low suction pressure results in large first stage cylinder size
• Inefficient at low pressures
• Rings and valves fail in wet gas applications
• Control is difficult at atmospheric pressures
Applications of Various Compressor Types

Reciprocating

- Wellhead Compression
- Gas Boosting (medium to high pressures)
- CNG
- Casinghead Pressure Reduction
- Gas Gathering
- Process applications

*Best in dry gas applications*
Vapor Recovery Towers (VRT’s)
Vapor Recovery Tower (VRT)

Benefits:

• Captures flash vapors without contaminating the captured gas with air.

• Opportunity to maximize vapor capture, while reducing flash in storage tanks.

• Vapor Recovery Tower could potentially remove storage tanks from regulatory reporting.
Oil is dumped from a separator into the VRT.
Vapor Recovery Unit monitors the pressure of the gas section of the VRT and maintains 1 PSIG or less of pressure.
Pressure is monitored by a pressure transmitter through the sensing line.
Since the oil has entered this low pressure from a higher pressure gas will break out of the oil or (flash)
The VRT is designed so that the oil must travel down and back up so that it has retention time in the low pressure.
Typical design is for 25 – 30 min. retention time. To assure the gas has time to break out before going to the storage tank.
The idea is to have the gas flash, or break out in the VRT, be recovered by the VRU and sent to a sales line.
Instead of breaking out and venting from the storage tanks.
Not always the Answer
IF YOU CAN MAKE MONEY
Benefits:

• 99% DRE (Destruction Removal Efficiency)
• Stainless steel design
• Completely Enclosed Combustion
• Eliminate Pilot Gas operates on Process Gas ONLY
Vapor Combustor Unit (VCU)

- AB-20 rated for 20MCFD (based on a BTU value of 2200)
- AB-100 rated for 100MCFD (based on BTU value of 2200)
- Custom designs for higher flow rates (Emergency Combustors etc.)
- Electric or Solar Powered
- Electronic ignition
- Data logging
When Odor and Visibility are an issue, 99.+% Destruction Removal Efficiency
Bio-Filters for Oil Production Tanks and Waste Water Storage Tanks

The Bio-Filter works on the absorption principle using a dry, glycol based media.

These filters are filled with this media to reduce VOC’s and GHG Emissions.
Bio-Filters for Oil Production Tanks and Waste Water Storage Tanks

SAFETY
The Bio-Filter installed as shown here does not compromise the integrity or safety of the storage tanks.

CONNECTION
The Bio-Filter canister can be a 4 inch thread connection, victaulic or flanged connection. Filter is generally installed by or under the supervision of HY-BON personnel.

Vent gas will follow the least path of resistance and we are using this theory to flow the gas through the Bio-Filter.
Based on the data provided and discussions from the meeting we have agreed to allow tanks in low flow service where conditions are acceptable to the installation and operation of the Tank Gas Conservation Filter a baseline collection of 80%. If a company wishes to authorize a higher collection efficiency then direct measurement of the tank emissions with the filter in place is necessary. The measurement results would need to be submitted with the application registration for any claims over 80%.

Best,

Joe Shine
Team Leader, Rule Registrations Section
Air Permits Division
joe.shine@tceq.texas.gov
(512) 239-6595
Vapor Recovery System (VRU / VRT / VCU)
Well Production

1 to 2 PSIG

Direct Measure or E&P Tanks

Resulting Emissions:

HY-BON VRT

25 to 45 PSIG - GOLD Standard Solution

Sales Line

Gas To Sales

Economic Payback

6.65 Months

Operational Data

<table>
<thead>
<tr>
<th>Qty</th>
<th>Project Installed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Volume MSCFD</td>
<td>100</td>
</tr>
<tr>
<td>Operating Days</td>
<td>350</td>
</tr>
<tr>
<td>BTU of GAS</td>
<td>2100</td>
</tr>
<tr>
<td>Gas Price</td>
<td>$3.57</td>
</tr>
<tr>
<td>Annualized Revenue</td>
<td>$262,395.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UNIT SELECTION</th>
<th>Op Range</th>
<th>PSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB-NK100-40-36D</td>
<td>60-120</td>
<td>200</td>
</tr>
<tr>
<td>HY-BON(VRT)</td>
<td>7-5</td>
<td>1-2</td>
</tr>
<tr>
<td>HY-BON Combustor (SM)</td>
<td>.7MTF</td>
<td>4 oz</td>
</tr>
</tbody>
</table>

Gas Price

$3.57

Install Cost

100% Installation Cost

$71,900
Vapor Recovery Project Examples
Standardized packages – with rotary screw or rotary vane compressors - provide a cost effective, highly reliable and flexible solution to vent gas issues.
Vapor Recovery Projects

Engine drive packages to 75HP – with a controller configuration that emulates the same level of control as an electric motor with a VFD.
Stock tank vapor recovery in West Texas.

Note that the control panel is mounted off-skid outside of the hazardous area classification zone.

Oil / condensate tanks are manifolded together and piped to the Vapor Recovery Unit (VRU) – eliminating the vent gas.
Gas Measurement (HY-BON IQR)
HY-BON’s IQR Service is based on three simple points in the process of defining the needs of a vapor recovery project:

- **IDENTIFY (I)** the emission sources with the best available technology

- **QUANTIFY (Q)** the volumes of gas escaping from the system tanks and define the gas content (gas analysis) of the emissions

- **RECTIFY (R)** emission levels via the best technical alternatives available in the industry for capturing each source and adding to the revenue stream
IDENTIFY

- primarily done by filming the site with FLIR GasFindIR® Infrared Cameras

- these versatile tools provide the ability to see sources of emissions we may not know exist

- many sources of emissions only require simple repairs to address
- using a breadth of different measurement tools, we can develop a full profile of the gas venting from the system.

- profile needs to include high flow and low flow cases to ensure the selected equipment can operate throughout the full range of conditions.

- using tools like turbine meters mounted on the top of a tank to complete a 24 hour (or longer) flow sample of the system.
- Taking pressurized samples of the gas and analyzing the constituents allows us to better collect design information and correctly select the compressor type / trim and package requirements for the application.

- Level of heavier constituents (C2, C3 +) and H2S/CO2 can greatly impact the size of coolers, piping, vessels and can be key in selecting the types of materials for design.
- detailed reports provide a concise way to see what data was measured as compared to the known site data and how much gas loss is taking place

- these types of reports can be used as part of the required submittals to the regulating authorities

![Field Test Information Table]

<table>
<thead>
<tr>
<th>Field Test Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of Oil: 53, 65</td>
</tr>
<tr>
<td>Production of Water: 138, 151</td>
</tr>
<tr>
<td>Production of Gas: 983, 1223</td>
</tr>
</tbody>
</table>

![Tank Volume Measurement Table]

<table>
<thead>
<tr>
<th>Tank Volume Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instant Flow Volume: 500-2000 CFH</td>
</tr>
<tr>
<td>Total Flow Volume: 26.5 MCFD</td>
</tr>
</tbody>
</table>

![FLIR GasFindIR Survey Table]

<table>
<thead>
<tr>
<th>FLIR GasFindIR Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video ID: 0, 1, 2, 3</td>
</tr>
<tr>
<td>Description: Overview Video, Hatch West Tank, Vent Valve, Meter In Place</td>
</tr>
<tr>
<td>Location Overview:</td>
</tr>
<tr>
<td>Description:</td>
</tr>
</tbody>
</table>

![Additional Data Table]
Once the flow is measured, the gas is analyzed and the point to send the gas is identified, you can design and define the solution.

In cases where an equipment solution is warranted, one can select from a purchased unit from a standard equipment line or a project specific engineered solution.

In some cases, a standard rental solution may be suitable.

In some cases (depending on emission levels), simple repairs can be sufficient.
Working with reliable, hard data and experienced providers, you can arrive at solutions to RECTIFY almost any venting situation.
In the past HY-BON has been awarded and built major vapor recovery and flare reduction projects in:

<table>
<thead>
<tr>
<th>Angola</th>
<th>Argentina</th>
<th>Algeria</th>
<th>Bolivia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>China</td>
<td>Colombia</td>
<td>India</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Kuwait</td>
<td>Libya</td>
<td>Malaysia</td>
</tr>
<tr>
<td>Mexico</td>
<td>Russia</td>
<td>Venezuela</td>
<td>Yemen</td>
</tr>
</tbody>
</table>

In the U.S. market, projects installed in:

<table>
<thead>
<tr>
<th>Alabama</th>
<th>Alaska</th>
<th>California</th>
<th>Colorado</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>Kansas</td>
<td>Louisiana</td>
<td>Montana</td>
</tr>
<tr>
<td>New Mexico</td>
<td>N. Dakota</td>
<td>Ohio</td>
<td>Oklahoma</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>Texas</td>
<td>Utah</td>
<td>W. Virginia</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Gulf of Mexico</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The HY-BON Difference

Machine Shop

Worldwide
Field Service

Spare parts inventory
HY-BON ENGINEERING COMPANY, INC.

Setting a New Standard