Vapor Recovery Unit (VRU)

April 2014
What is VRU?

Recovery of vapors (mainly volatile hydrocarbons) in form of liquid, during loading/unloading process to/from road, rail or marine tankers
Why VRU?! 

The cost of:

✓ Safety in the terminal

✓ Environmental impacts of hydrocarbon and chemical components, on both human health and pollution of troposphere

✓ Venting of unrecovered product during loading/unloading processes (Simply, money!)
HC Emission Norms

**US EPA:** 35 mg of HC vapor emitted per liter of liquid loaded

**European norms (European Directive EC94/63):** 35 mg of HC vapor emitted per liter of vapor at VRU outlet

**Some European Countries (like France and Russia):** 10 mg of HC vapor emitted per liter of vapor at VRU outlet

**Germany (TA-Luft 01), Switzerland (LRV) and Netherlands (NER):** 0.15 mg of HC vapor emitted per liter of vapor at VRU outlet

**Sultanate of Oman:** 0.035 mg of HC vapor emitted per liter of vapor at VRU outlet (!)

**Iran:** N/A

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Various Technologies

- Carbon Adsorption
- Lean Oil Absorption
- Membranes
- Refrigeration

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Lean Oil Absorption

The incoming vapors are absorbed into a liquid of low vapor pressure, e.g. chilled kerosene. The mixture is distilled and separated into concentrated gasoline vapors and the absorbing medium. The absorbing medium is chilled and recycled to a buffer capacity. The gasoline vapors are recovered by passing them counter current to a gasoline stream in a re-absorber column. To prevent icing an anti-icing additive, e.g. methanol, has to be injected. This additive will end up in the wastewater, which can pose environmental problems. This technology has been used extensively in Europe. This technology has a high peak handling capacity, as the absorbing medium can be stored. It could be considered for recovery of chemical vapors and crude vapors.
Lean Oil Absorption

“650kW” electric heater

Water cooled
Main Advantages

• No need for blower, compressor or vacuum pump,

• No external absorbent is required (the lean oil is distilled and reused, although make-up might be required),

• Not affected by high humidity.
Main Disadvantages

- The process works slightly above freezing point (need for a refrigerant),

- Stripper re-boiler is required (at temperature of appx. 180 °C), which requires much more electricity to run,

- Cooling water is required (might be alternated with refrigerant cooling which may have its own disadvantages).
Hydrocarbon-selective membranes are used to separate the incoming vapors from the air. The necessary pressure differential across the membranes is created by compressing the incoming vapors with a compressor and/or pulling a vacuum at the other side with a vacuum pump. The concentrated gasoline vapors are recovered by passing them counter current to a gasoline stream from storage in a re-absorber column. This technology has extensively been used in Europe. As the process cannot cope with large variations in throughput, a vapor holder tank (gasometer) upstream of the VRU is normally needed. Special consideration shall be given to the safety aspects of having rotating equipment within the vapor collection system.
Membrane Process

Feed → High Pressure → Retentate
Low Pressure
Permeate enriched with hydrocarbons

- Hydrocarbon
- Inertgas, e.g. nitrogen

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Main Advantages

• Membranes never get saturated,
• The least number of equipment among all other technologies
Main Disadvantages

• Use of both vacuum pumps and a liquid ring compressor,

• Compression of air/HC mixture increases risk of explosion,

• Relatively high operating pressure (2 ~ 3 barg),

• The nature of membrane technology is sensitive to varying throughputs (need for vapor holder).
Why Carbon Adsorption?

- Well-proven in practice
- Relatively easy to operate and maintain
- The only required utility is electricity
- Relatively low energy consumption
- Low vapor concentration at VRU outlet with a single stage unit
- Near ambient pressure and temperature, no vapor holder, no refrigeration
Principals

✓ The mass transfer zone removes the bulk of the HCs
✓ The transition zone provides a buffer for variations in flow rate and concentration
✓ The emission level depends on level of vacuum:
  - 100 mbar for 1000-5000 mg/m³
  - 30 mbar for 50-100 mg/m³
Why Us?

✓ Simple process, yet reliable and fully automated
✓ Low energy consumption (up to 0.08 kWh/m³)
✓ Stand-alone operation
✓ Use of dry screw vacuum pump (DVP)
✓ Less space occupied
✓ Dual PLC control / safety system to increase reliability (safety)

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Dry Vacuum Pump (DVP)

- Small size compared to LRVPs
- Less complexity
- Reduced power consumption (up to 40%), due to use of VFD
- No ethylene glycol and associated equipment, no chance of corrosion and abrasion
- Less maintenance requirements (no need to change glycol)

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Dry Vacuum Pump (DVP)

- No product contamination
- No internal touching (metal) parts, no wear
- Can handle liquid slugs
- Overhaul required after 40,000 hours of operation
Dry Vacuum Pump (DVP) 
Swiss Made

1. Inlet
2. Exhaust
3. Water Jacket
4. Screw
5. Oil
6. Gas Path
7. Timing Gears
8. Bearings
9. Shaft Seals
10. Oil Seal

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Dry Vacuum Pump (DVP)
Swiss Made
Based on 1200 g/m³ HC in the vapor inlet to the VRU:

<table>
<thead>
<tr>
<th>Emission (g/m³)</th>
<th>35 EU / US</th>
<th>20</th>
<th>10</th>
<th>2 (Optimum)</th>
<th>0.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Required (kWh/m³ inlet vapor)</td>
<td>0.08</td>
<td>0.09</td>
<td>0.09</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>g/m³ recovered</td>
<td>1179</td>
<td>1188</td>
<td>1194</td>
<td>1199.4</td>
<td>1199.92</td>
</tr>
</tbody>
</table>

Extra 0.5 g recovered costs 0.1 kWh or 200 kWh per kg. To make this energy we need to burn 15 x the equivalent as fuel.

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Four vendors, similar conditions of flow rate and emission:

<table>
<thead>
<tr>
<th>Mfc’s Name</th>
<th>Technology</th>
<th>Emission Design</th>
<th>Req. power (kW) Max / largest eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Zink</td>
<td>Carbon Adsorption</td>
<td>150 mg/m³ (ex. C1)</td>
<td>220 / 132</td>
</tr>
<tr>
<td>Carbo Vac</td>
<td>Carbon Adsorption</td>
<td>35 mg/m³ (ex. C1)</td>
<td>185 / 30</td>
</tr>
<tr>
<td>Petrogas</td>
<td>Lean Oil Absorption</td>
<td>35 mg/m³</td>
<td>840 / 650</td>
</tr>
<tr>
<td>Borsig</td>
<td>Membrane</td>
<td>35 mg/m³</td>
<td>290 / 200</td>
</tr>
</tbody>
</table>
Activated Carbon

Wood based:  
- 1200~1800 m²/g of surface  
- Low density  
- Even distribution of micro, meso and macro pores  
- Activated by phosphoric acid  
- More sensitive to hot spot formation

CECA Arkema X:  
- Reactivity is tempered by a special resin, which gives the carbon a hygroscopic property and reduces the heat of adsorption  
- Expected life is more than 15 years in combination with DVS

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Activated Carbon

Coal based:
- 1200~1800 m²/g of surface
- Many more mini pores
- More sensitive to aging (formation of oily heel)
- Less sensitive to hot spot formation

VS50:
- Mini pores are super-activated
- Expected life is more than 15 years in combination with DVS

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Safety Features

- All valves in the system are automatic and pneumatically operated. This will eliminate system failures due to malfunctioning of the electrically operated sequential valves and limit switches.

- All the sequential valves are of double eccentric butterfly type with S.S disk and PTFE seal rings.

- In case of lack of instrument air in site, a small standard ATLAS COPCO twin piston compressor with air buffer is supplied.

- All instruments within the package are ATEX certified.

- The unit resists the pressure of an eventual internal explosion.

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Safety Features

- Precise monitoring of the explosion prone locations in the unit:
  - Inlet vapor line (flame arrestor equipped with TAHH)
  - Carbon Adsorbers (TAHH)
- Monitoring of discharge temperature of DVPs
- Monitoring of operational parameters of DVPs
- Monitoring of sequential valve positions
- Independent high and low level switches on the re-absorber
- Double fail closing valves on each absorbent line
- Level switch on the condensate drain pot at the inlet to the VRU
- ...

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As soon as the loading is finished and the activated carbon has been properly desorbed, the unit automatically switches to standby mode. All the pumps will be stopped and all the valves are closed.

Three levels of shut-down:
- ESD push button acting on main switch
- Normal shut-down by main PLC
- Independent second level shut-down by the second PLC (watch dog)

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Control and ESD

PLC outputs power shut down

Shut down signal

Inputs
Level, Pressure, Position, ...

Outputs
Valves, Pumps

Inputs
High Levels, Temperatures
Required Design Inputs

- Required Emission
- Instantaneous Flow rate: \( Q_{(i)} \) >> ID of carbon adsorbers
- Cycle throughput: \( Q_{(c)} \) >> Pressure drop calcs.
- 4-hr throughput: \( Q_{(4h)} \) >> Volume of activated carbon
- Daily throughput: \( Q_{(d)} \) >> Vacuum capacity adjust.
- Physical properties of product >> Type of activated carbon
  >> Design of absorption sec.
  Composition, liquid / vapor densities, max RVP in summer/winter,
  max. ambient temperature in summer/winter
- Geometry of terminal:
  min./max. level in storage tank, distances from loading rack and
  storages, availability of utility (electricity and voltage, cooling water,
  instrument air)

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Oman Raysut Revamp

- **PROJECT:** EPC of Raysut Terminal Revamp
- **CLIENT:** Sultanate of Oman, Ministry of Oil and Gas (MOG)
- **CLIENT REPRESENTATIVE:** Oman Oil Refineries and Petroleum Industries Company (ORPIC)
- **PMC:** Mott MacDonald & Company LLC (MMC)
- **CONTRACTOR:** Rampco International Technical Services (RITS)
- **ENGINEERING:** Hampa Energy Engineering and Design Company (HEDCO)
- **LOCATION:** Raysut, Salalah, Dhofar, Sultanate of Oman

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Raysut Terminal is an onshore terminal operated by ORPIC. The terminal has Gas Oil, MOGAS and II Jet A-1 storage tanks and a tanker loading area with loading pumps and gantries to supply the products to the Salalah and Dhofar region of South. Products are delivered to the terminal by means of ship from port of Salalah. Two pipelines deliver products from ship to the terminal and store them inside nine storage tanks.

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<table>
<thead>
<tr>
<th>Bay No.</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>Diesel</td>
</tr>
<tr>
<td>No. 2</td>
<td>Gasoline</td>
</tr>
<tr>
<td>No. 3</td>
<td>II Jet A-1 (no vapor arm)</td>
</tr>
<tr>
<td>No. 4</td>
<td>Gasoline</td>
</tr>
<tr>
<td>No. 5</td>
<td>Diesel</td>
</tr>
</tbody>
</table>
**VRU Design Inputs**

**Emission value:** 35 mg/m³ of vented vapor  
**Gasoline:** max. VP 0.7 / 06 (winter / summer)  
**Design Ambient (Absorbent) Temperature:** 40 °C  

4 bays in simultaneous operation: 4 x 137 = 548 m³/h  
T-4 max. filling rate: 600 m³/h  

**Instantaneous Flow rate** \( (Q_i) \): \( 548 + 600 \) = 1148 m³/h  
**Cycle Throughput** \( (Q_c) \): 0.25 \( (4 \times 137 + 600) \) = 287 m³/h  
**4 Hour Throughput** \( (Q_{4h}) \): 4 \( (8 \times 36.4 + 600) \) = 3565 m³/h  
**Daily Throughput** \( (Q_d) \): 96 \( 36.4 + 3880 \) = 7375 m³/h  

**Electricity:** 415 VAC, 3PH, 50Hz  
No other utility available
VRU Design Outputs

Size of Vapor line to VRU: 10”
Max. absorbent flow rate required: 70 m³/h
Size of Absorbent lines: 4”
VRU Skid Size: 8 x 10 x 10 (m)
Weight of Skid: 80 tons
Electrical Consumption: (5x30 + 2x15 + 5) 185 kW
VRU Design Outputs

Size of El. Panels (incl. VFDs):
3 x (1000 x 2000 x 500) (mm)

Size of Control Panel (incl. PLC):
1000 x 2000 x 500 (mm)

Supervision PC:
Conventional Desktop Size

Safety

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Our Sub-vendors

<table>
<thead>
<tr>
<th>ITEM DESCRIPTIONS</th>
<th>VENDOR</th>
<th>COUNTRY</th>
<th>ALTERNATIVE</th>
<th>REMARK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Pump</td>
<td>BUSCH</td>
<td>Switzerland</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absorbent Pump</td>
<td>Hermetic</td>
<td>Germany</td>
<td>KSB</td>
<td>or equivalent</td>
</tr>
<tr>
<td>Absorbent Pump</td>
<td>Hermetic</td>
<td>Germany</td>
<td>KSB</td>
<td>Approved</td>
</tr>
<tr>
<td>Blower</td>
<td>FIMA</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
</tr>
<tr>
<td>Detonation Arrestor</td>
<td>PROTEGO</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>Motors</td>
<td>ABB</td>
<td>Finland</td>
<td>SIEMENS</td>
<td>Approved</td>
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<tr>
<td>Butterfly valves</td>
<td>KSB S.A.S. AMRI DIVISION</td>
<td>France</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>Angle Globe Valve</td>
<td>DRESSER PRODUITS INDUSTRIELS</td>
<td>France</td>
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<td>or equivalent</td>
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<tr>
<td>Thermal Expansion Valve</td>
<td>LESER GMBH AND CO KG</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
</tr>
<tr>
<td>Pressure Safety Valve</td>
<td>LESER GMBH AND CO KG</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>Level Indicator</td>
<td>KROHNE</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
</tr>
<tr>
<td>Level Switch</td>
<td>MAGNETROL</td>
<td>Belgium</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>Level Transmitter</td>
<td>MASONEILAN</td>
<td>Italy</td>
<td>SPIRAX SARCO</td>
<td>or equivalent</td>
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<tr>
<td>Temperature Indicator</td>
<td>WIKA ALEXANDER WIEGAND GMBH AND CO</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>Temperature Transmitter</td>
<td>WIKA ALEXANDER WIEGAND GMBH AND CO</td>
<td>Germany</td>
<td>E&amp;H</td>
<td>or equivalent</td>
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<tr>
<td>RTD</td>
<td>WIKA ALEXANDER WIEGAND GMBH AND CO</td>
<td>Germany</td>
<td>E&amp;H</td>
<td>or equivalent</td>
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<tr>
<td>Pressure Switch</td>
<td>WIKA ALEXANDER WIEGAND GMBH AND CO</td>
<td>Germany</td>
<td>CELLA</td>
<td>or equivalent</td>
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<tr>
<td>Pressure Transmitter</td>
<td>VEGA GRIESHABER KG</td>
<td>Germany</td>
<td>E&amp;H, YOKOGAWA</td>
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<tr>
<td>Solenoid Valve</td>
<td>HERION</td>
<td>Germany</td>
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<td>or equivalent</td>
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<tr>
<td>IR online concentration</td>
<td>BOPP &amp; REUTHER</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
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<tr>
<td>LV Motor</td>
<td>ABB OY ELECTRICAL MACHINES</td>
<td>Finland</td>
<td></td>
<td>or equivalent</td>
</tr>
<tr>
<td>PLC</td>
<td>SIEMENS AG A AND D AS EWK</td>
<td>Germany</td>
<td></td>
<td>or equivalent</td>
</tr>
</tbody>
</table>
Thank You for your attention

Any Questions?!