

Vapor Recovery Developments in Emission Standards and Applications

Simon Shipley
2nd June 2015

ZEECO



BURNERS



FLARES



INCINERATORS



PARTS & SERVICES

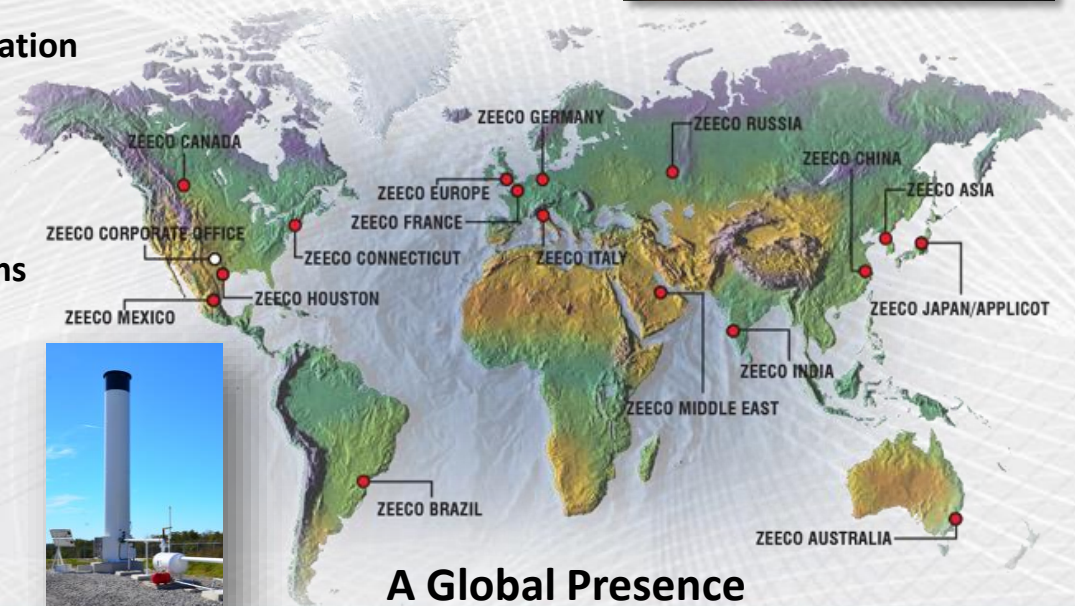
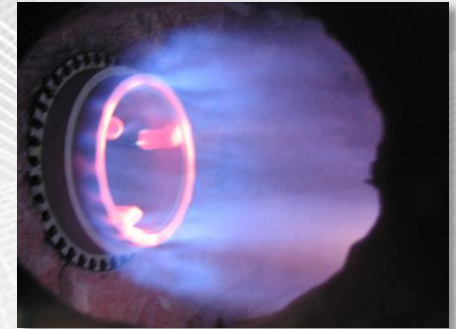
➤ Zeeco Company Profile



- Privately held by a family who has been involved in Process Engineering and Combustion Technology for over 80 years.
- Headquarters in Broken Arrow, near Tulsa, Oklahoma
- More than 20 Worldwide locations.



Process Burners / Burners Power Industry / Duct Burners
BMS Management and Control Systems
Flares and Flare Systems
Thermal Oxidation / Incineration
Vapor Recovery Systems
Vapor Combustion Systems
Flare Gas Recovery Systems
Mechanical Vapor Recovery
Land Fill Combustion Systems



A Global Presence

➤ Environmental Control



Environment Legislation:

reduction of hydrocarbon emissions to the atmosphere, improving air quality and operational safety.

Nearly Always the Key Driver

Economics:

recovery of valuable petroleum products that would otherwise be lost to atmosphere.

Rarely a driver for the implementation of control measures.



■ Vapor – Volatile Organic Compound (VOC).

- Vapor generated through evaporation / hydrocarbon saturation of the air / inert gas above a hydrocarbon liquid.
- Gasoline / Crude Oil / Naphtha / Condensate / Benzene / Xylenes



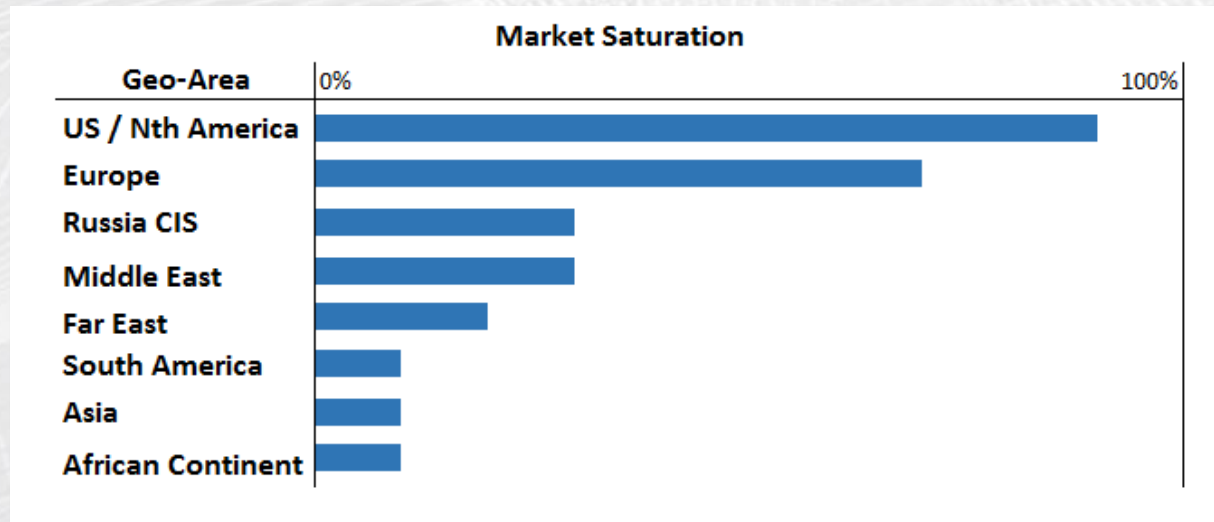
■ Vapors recovered from :

- Road Truck Loading - (Vapor Displaced from the Truck / Rail Car / Vessel during filling).
- Rail Car Loading.
- Ship / Barge Loading.
- Tank Venting. Vapours displaced through filling and or thermal growth / evaporative effects in the tank.



➤ Historical Growth

- Truck Loading Applications in the US : 1970 / 80s
 - Vapour Recovery Systems and Vapour Combustion Systems
- Legislation introduced into Europe In the 1990s
 - Covering Gasoline Loading Operations.
 - ◆ EU Directive 94/EU/63
- Other Countries Followed : Far East / Middle East / Russia
- Environmental legislation driver for other emission controls legislation.
 - Advancing The Legislation in Terms of Applications and Emissions Requirements.



➤ Types Of Vapour Control Technologies

- Activated Carbon Adsorption Vapor Recovery – BAT
- Cold Liquid Absorption Vapor Recovery
- Membrane Vapor Recovery
- Pressurised Absorption Vapor Recovery
- Vapour Combustion Vapor Control Measures

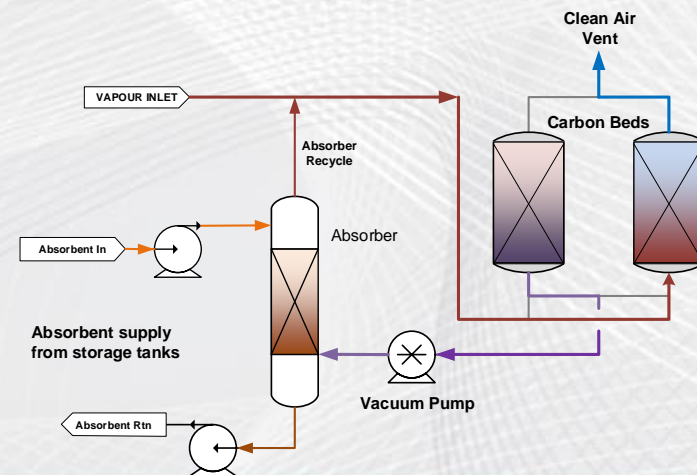
► PROCESS SELECTION

Process		Low HC %	High HC %	Intermittent Loads	Emissions Range	Temp > 140oF	Temp < 140oF	ROI	Capital Cost	Operating Cost
ZCA	Activated Carbon Absorption >>	***	***	***	***	*	***	\$\$\$	\$	\$
CLA	Cold Liquid Absorption >>	*	***	**	*	**	***	\$	\$\$\$	\$\$\$
Mem	Membrane >>	**	***	**	**	**	***	\$\$	\$\$	\$\$
PA	Pressurised Absorption >>	*	***	**	*	*	**	\$	\$	\$\$
VCU	Vapour Combustion >>	**	***	**	***	***	***	-	\$	\$\$

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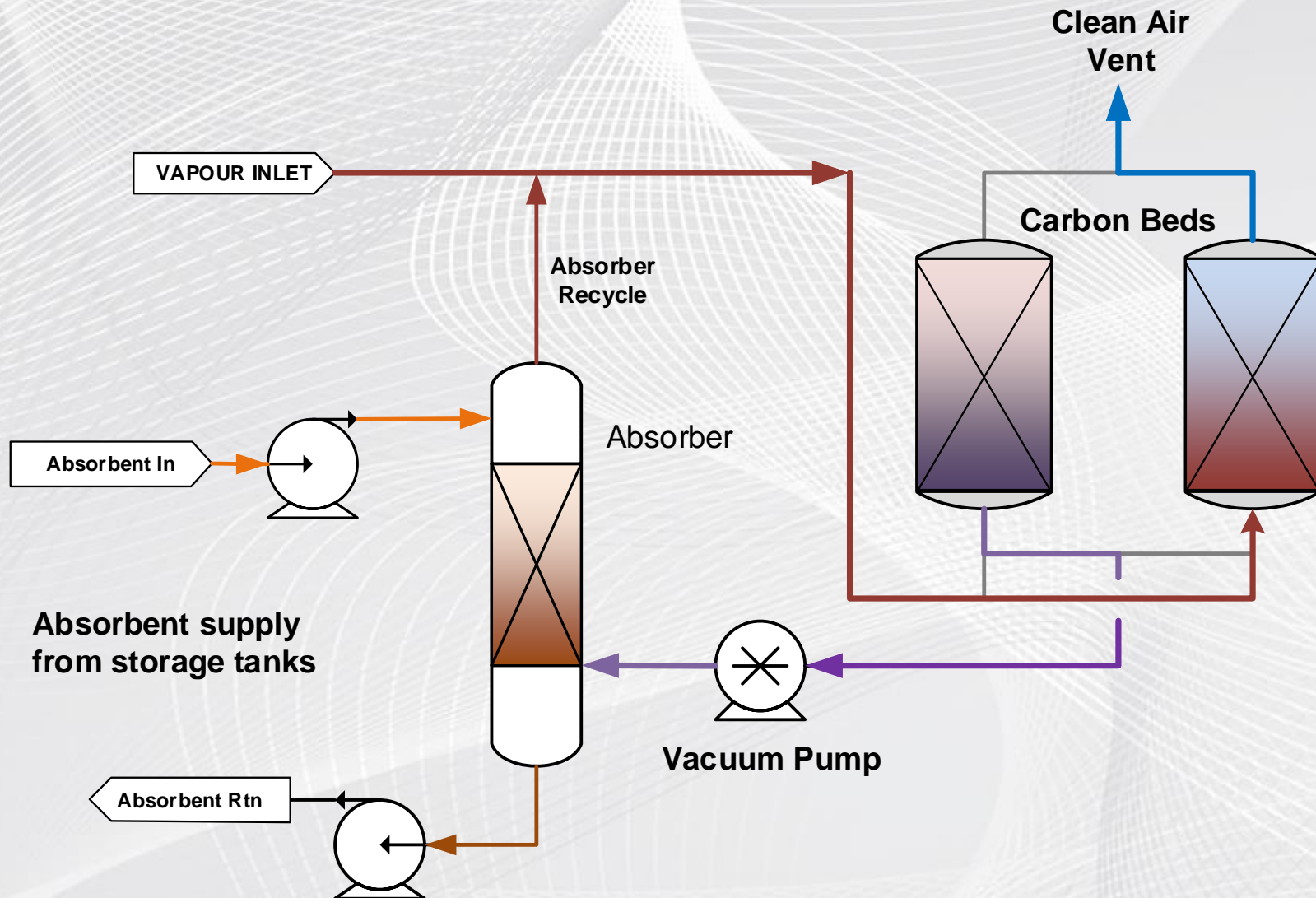
➤ **ZCA - Activated Carbon Vapour Recovery**

Best Available Technology (BAT)



- **Simple Reliable Process**
- **Wide Turn Down Capability : 0 to 100% of Design (Flow and Inlet HC Concentration)**
- **Wide Range of Products.**
- **Wide Range of Applications : Truck Loading Through to Ship Loading.**
- **Good Wide Range of Emissions Capabilities.**
- **Relatively Low Power Requirements.**
- **Good Overall Operating Efficiency – i.e. Recovered Product / kW**
- **Low Maintenance Requirements**
- **Familiar Construction**

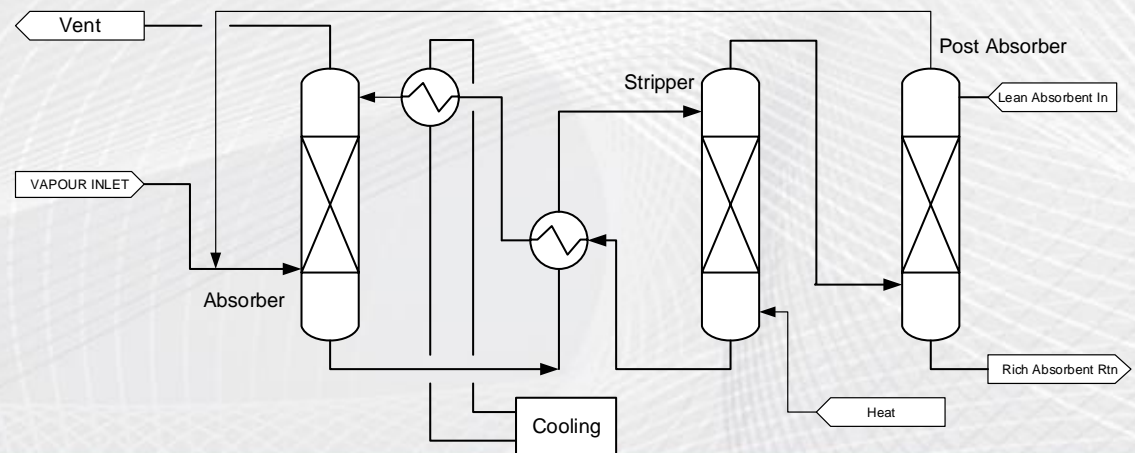
➤ Activated Carbon Vapour Recovery Process



► PROCESS SELECTION

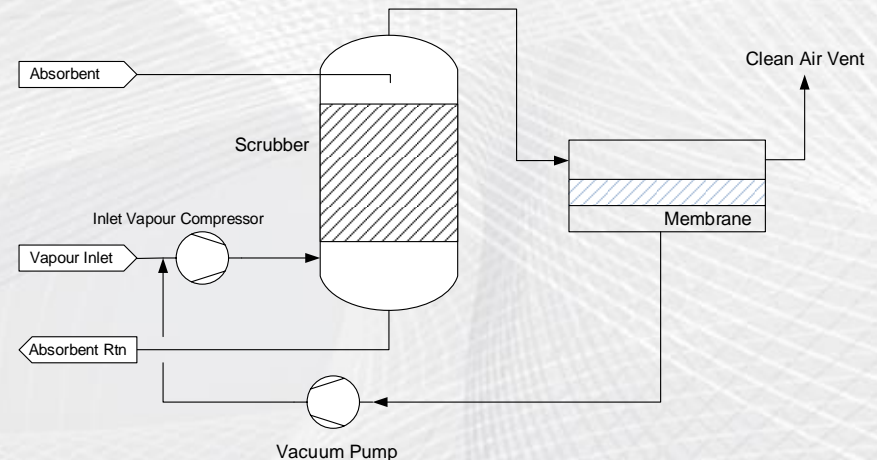
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Cold Liquid Absorption



► PROCESS SELECTION

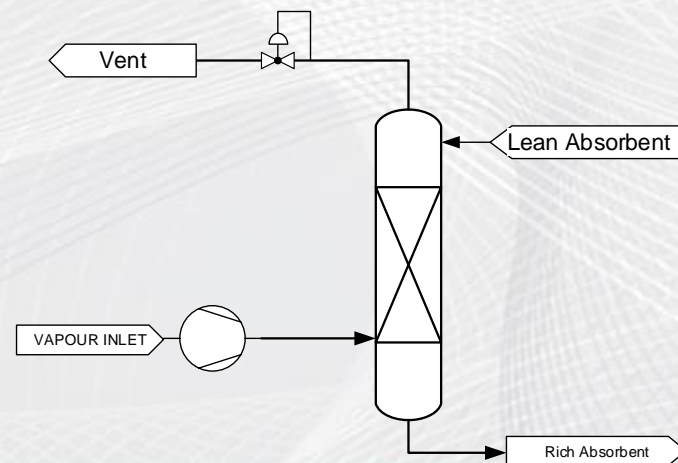
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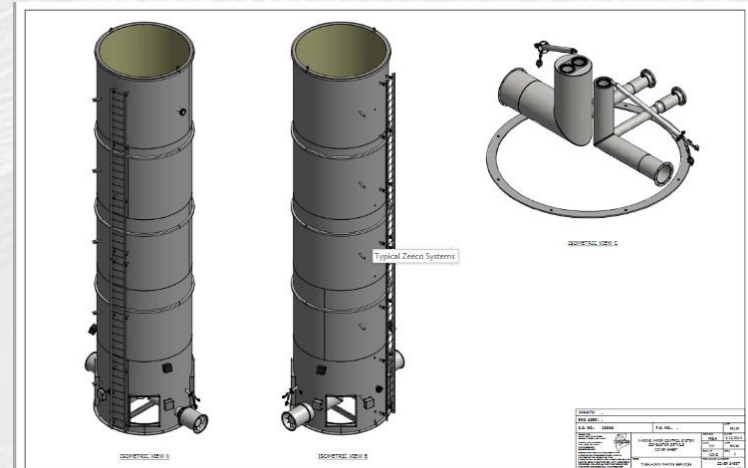
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Pressurised Lean Oil Absorption (PLA)



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➤ Development

- **Products Loaded**
- **Vacuum Pump Technology Developments**
- **Tightening of Emission Requirements**
- **Widening Range of Applications**
- **Increase in the Loading Rates – Size of VRUs**

➤ Development

- **Products Loaded**
- Vacuum Pump Technology developments
- Tightening of Emission Requirements
- Widening Range of Applications
- Increase in the Loading Rates – Size of VRU's

► Products

- Gasoline [Truck / Ship / Rail Car]
- Crude Oil [Ship / Rail Car]
 - Variable Compositions / Physical Properties
 - H₂S Concentrations
- Aromatics – Benzene / Xylenes [Truck / Ship]
- Naphthas / Condensates [Ship / Tanks]
- Ethanol / Methanol [Truck / Tanks / Ship]

➤ Development

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- Increase in the Loading Rates – Size of VRU's

Rotary Vane Vacuum Pump

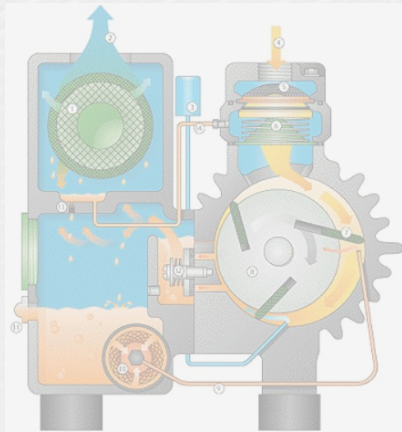
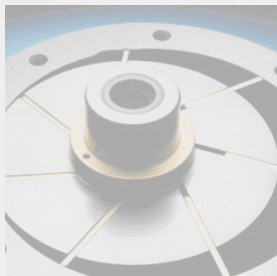
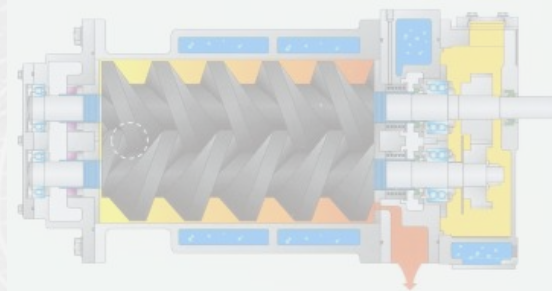


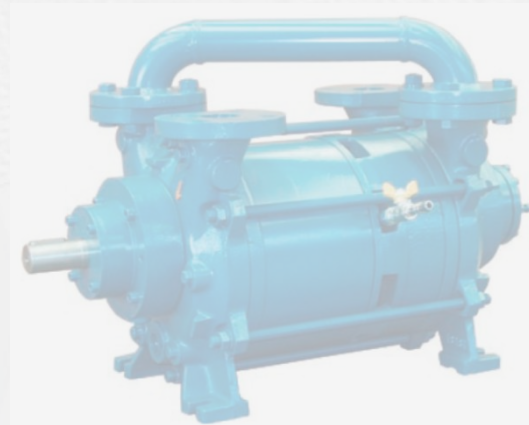
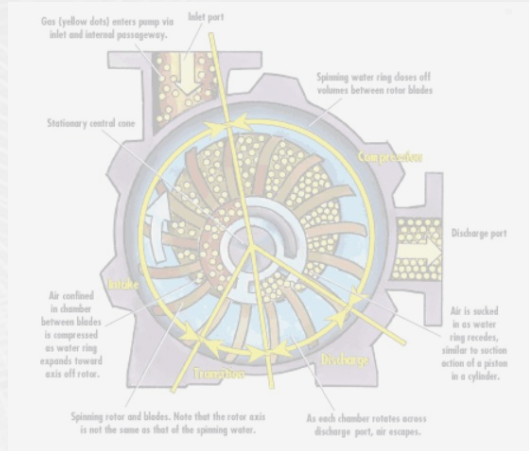
Foto: BUSCH R5 Serie
principle and cutaway



Screw Vacuum Pump



Liquid Ring Vacuum Pump



Rotary Vane Vacuum Pump

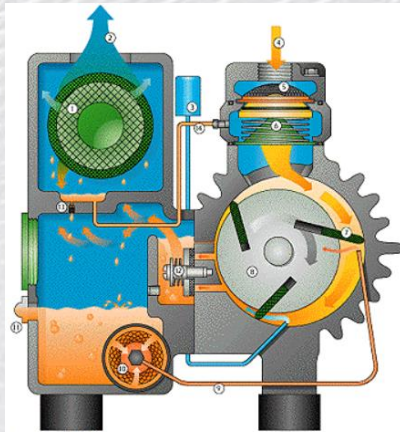
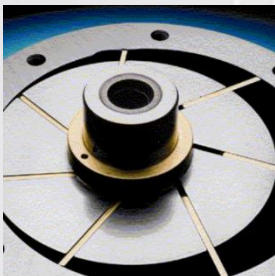
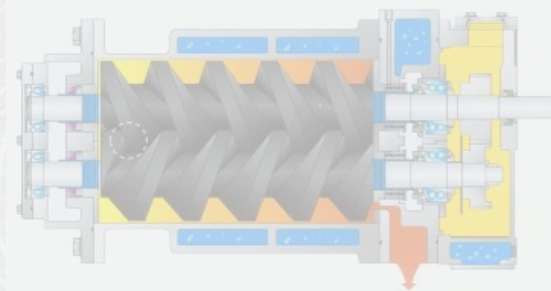


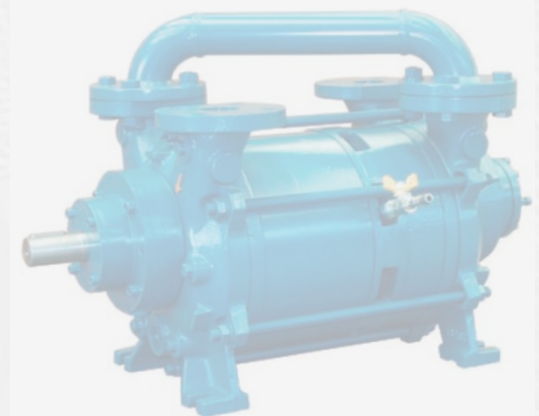
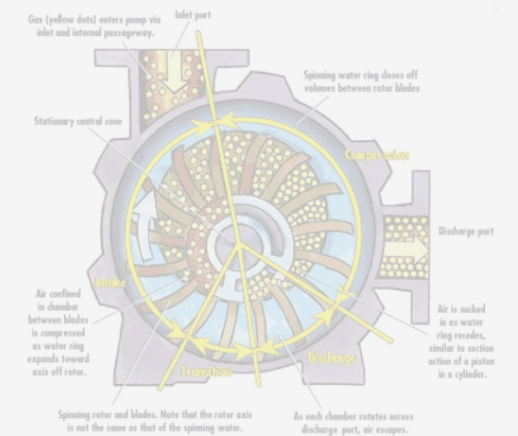
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Screw Vacuum Pump



Liquid Ring Vacuum Pump



Rotary Vane Vacuum Pump

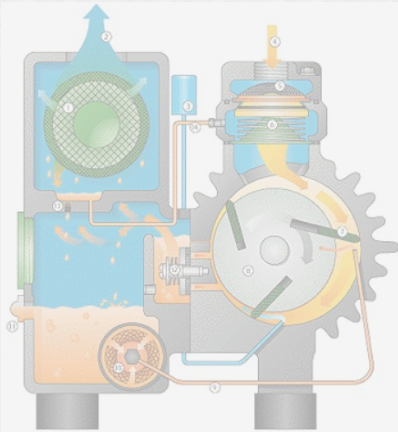
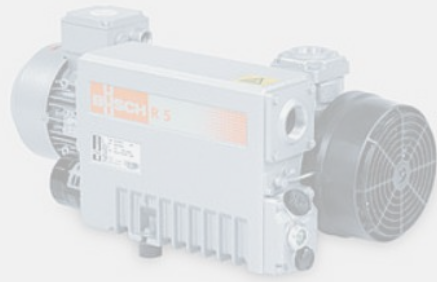
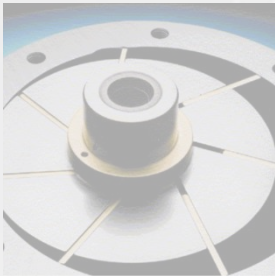
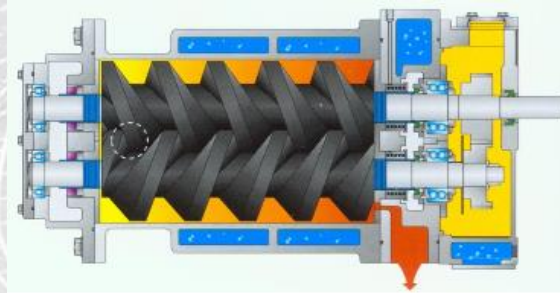


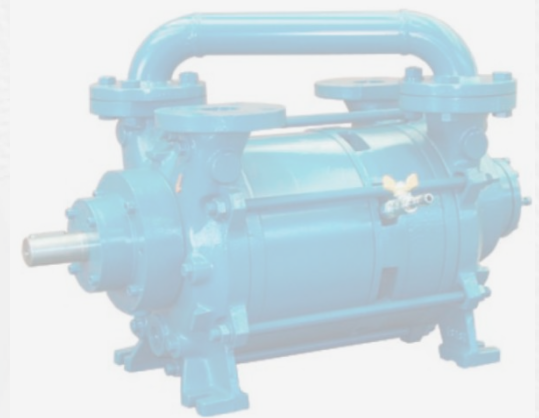
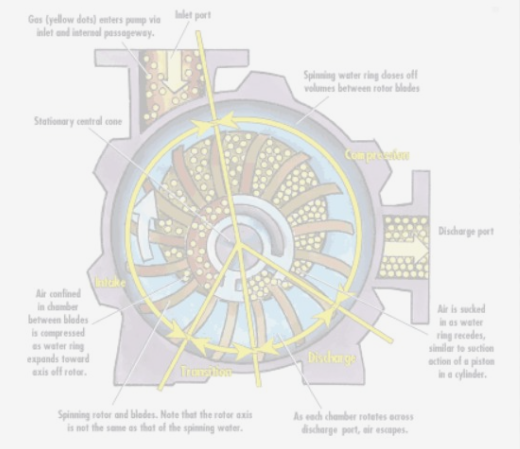
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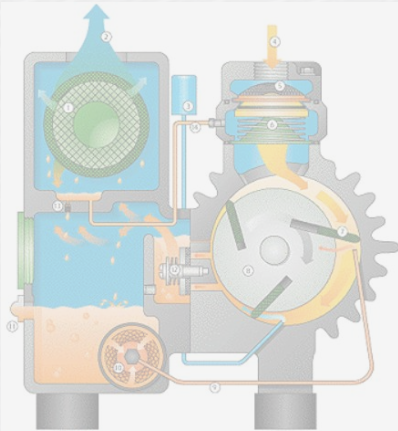
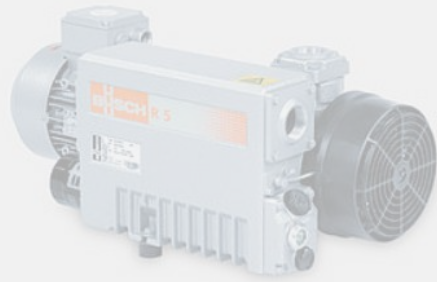
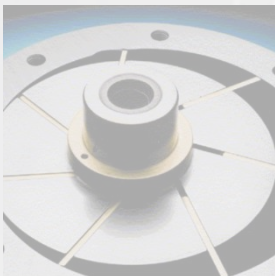
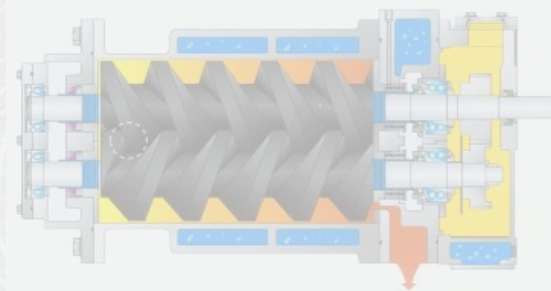


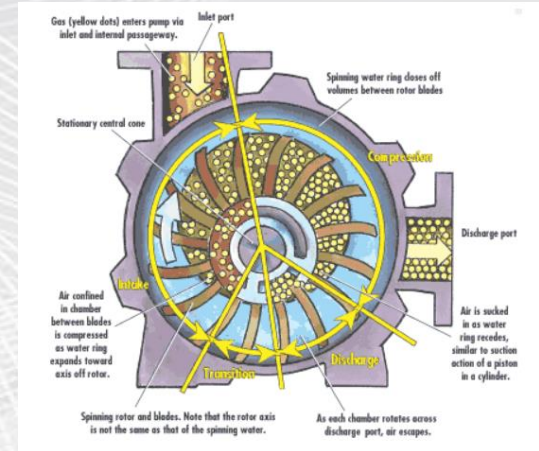
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Screw Vacuum Pump



Liquid Ring Vacuum Pump



➤ Development

- Products Loaded
- Vacuum Pump Technology developments
- **Tightening of Emission Requirements**
- Widening Range of Applications
- Increase in the Loading Rates – Size of VRU's

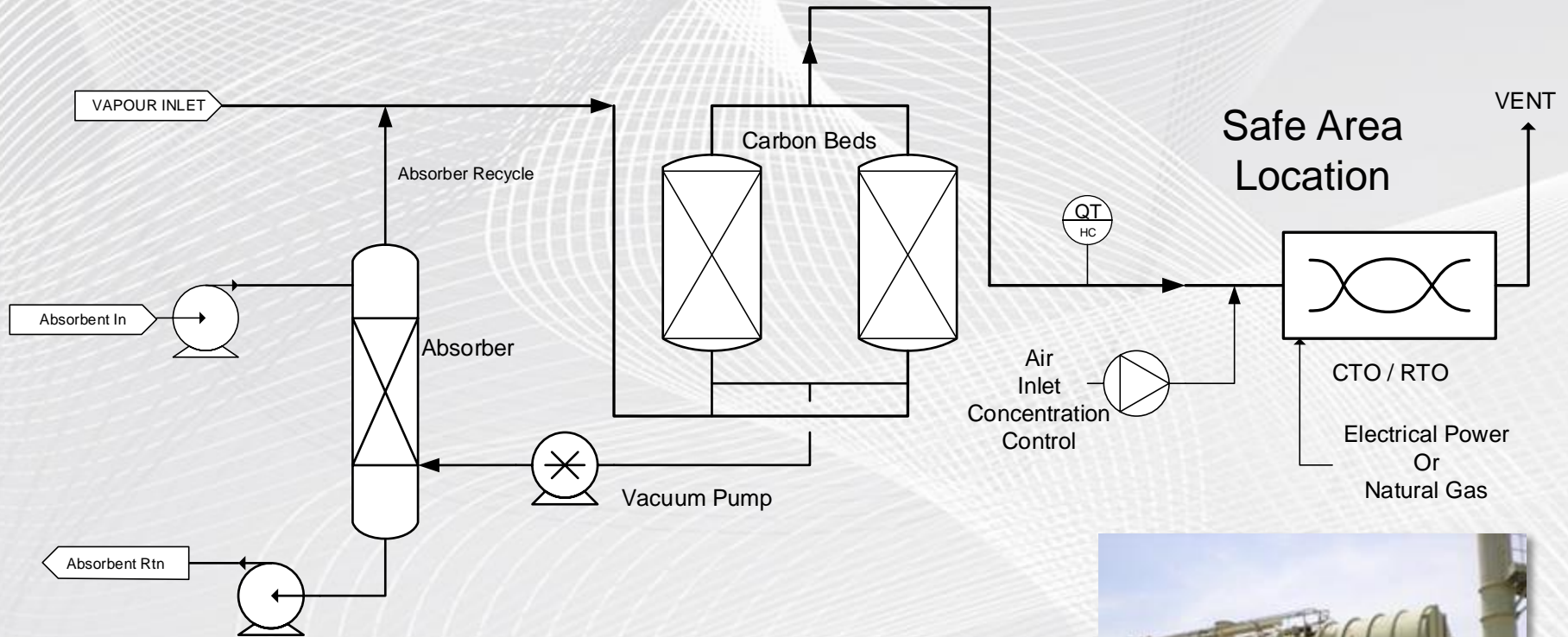
► Emission Regulations

- | ■ Region | Emission Limit |
|---|--|
| ■ EU (gasoline) | 35 g/Nm ³ (Vented) |
| ■ USA | 35 g/Nm ³ (Loaded) |
| ■ India | 5 g/Nm ³ |
| ■ Denmark | 150 mg/Nm ³ |
| ■ Germany / NL | 50 mg/Nm ³ |
| ■ Oman | 35mg/Nm ³ |
| ■ Middle East : | Typically 95% Recovery Efficiency
although depends on the individual application. |
| ■ Recovery Rates : 1 to 2 ltrs per 1000ltrs loaded | |
| ● 10 g/Nm ³ –A common standard adopted by designers and operators | |
| ● Aromatics (Benzene / p-xylene) – 1mg/Nm ³ to 10mg/Nm ³ ; | |
| ● Crude Oil Vapours : | Typically 78% to 95% Recovery Efficiency
Dependent on Crude Oil. |

► Extreme Emission Requirements $<100\text{mg}/\text{Nm}^3$



Zeeco Activated Carbon Adsorption/Absorption (ZVA)



➤ Development

- Products Loaded
- Vacuum Pump Technology developments
- Tightening of Emission Requirements
- **Widening Range of Applications**
- Increase in the Loading Rates – Size of VRU's

➤ Vapour Recovery Applications

- Vapours Recovered Directly from Truck and/or Railcar Loading
- Vapour Balancing
- Tank Filling
- Tank Breathing



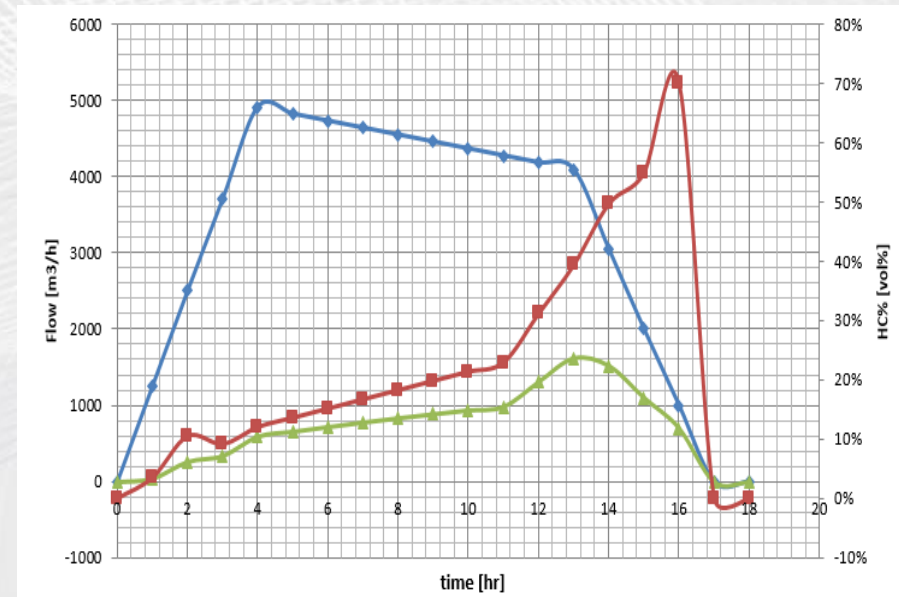
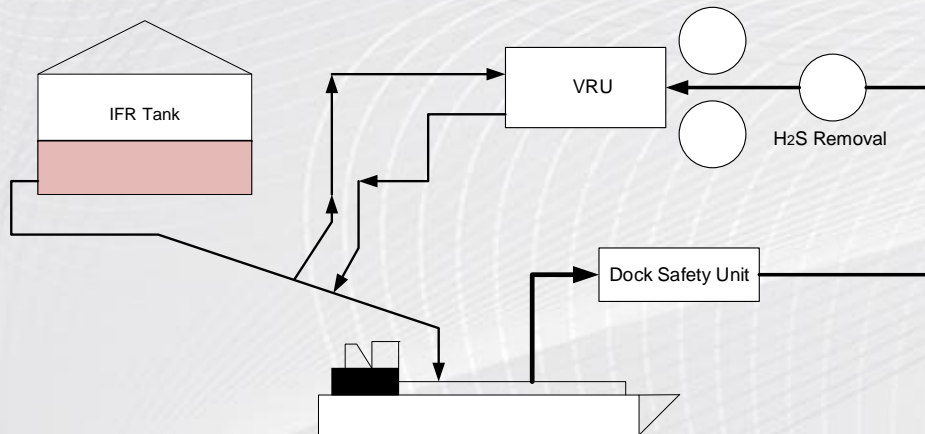
➤ VRU-Applications – Maritime & Crude Oil

- Gasoline
- Crude Oil Loading
- Naphtha & Condensates
- Chemicals - BTX
- On-Shore (Quay Side)
- Off Shore
 - Shuttle Tanker
 - FPSOs



➤ Ship Loading Applications

- Continuous Loading Operations
- Large Flow Rates
 - 2000m³/hr to 67,000m³/hr
- Power Requirements : 500kW up to 5MW (Potentially Higher)
- Wide Range of Products
- Complex Loading Dynamics



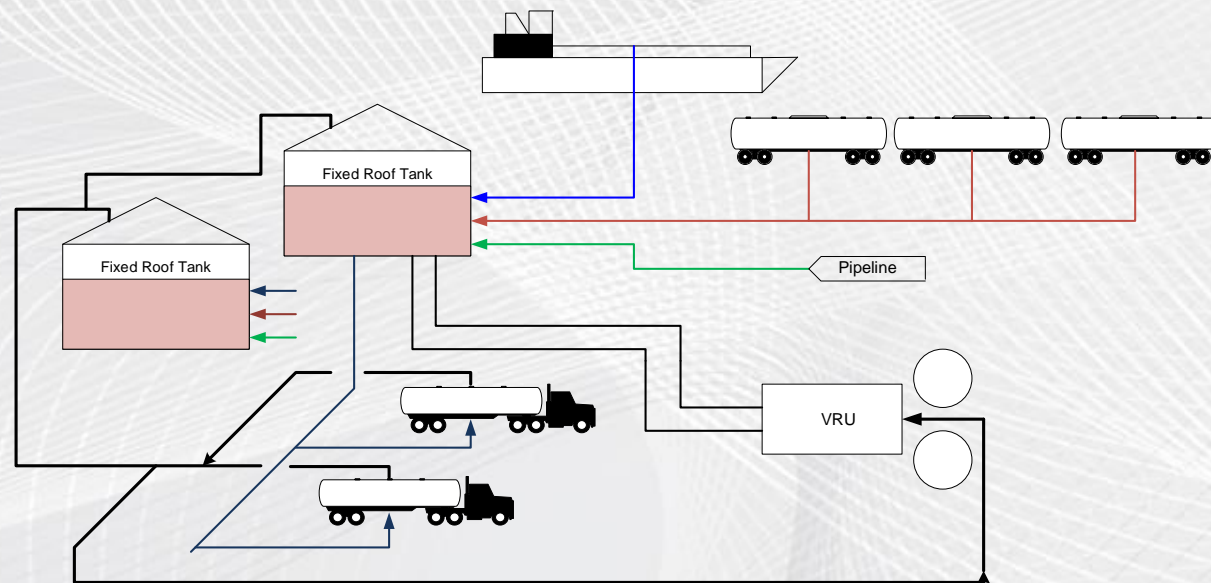
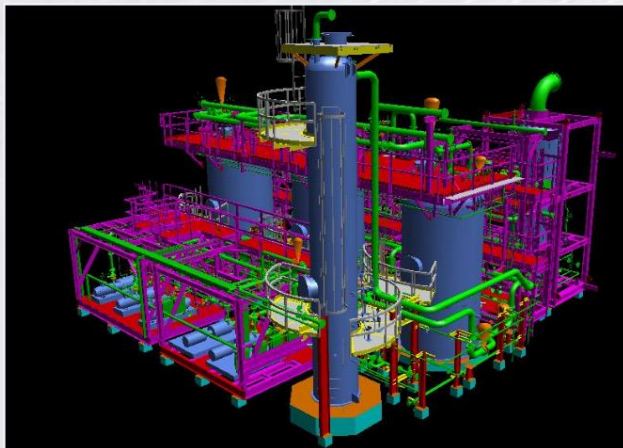
➤ Truck Loading Applications

- Mature Product Development
- Non-Continuous Loading Operation
- Small to Medium Sized Systems
- Power Requirements; Typically 50 to 120kW
- Typical Loading Capacities : 500 to 980m³/hr : 10,000m³/day
- Emissions from 35g/Nm³ to 35mg/Nm³
- Positive Return on Investment



► Tank Venting

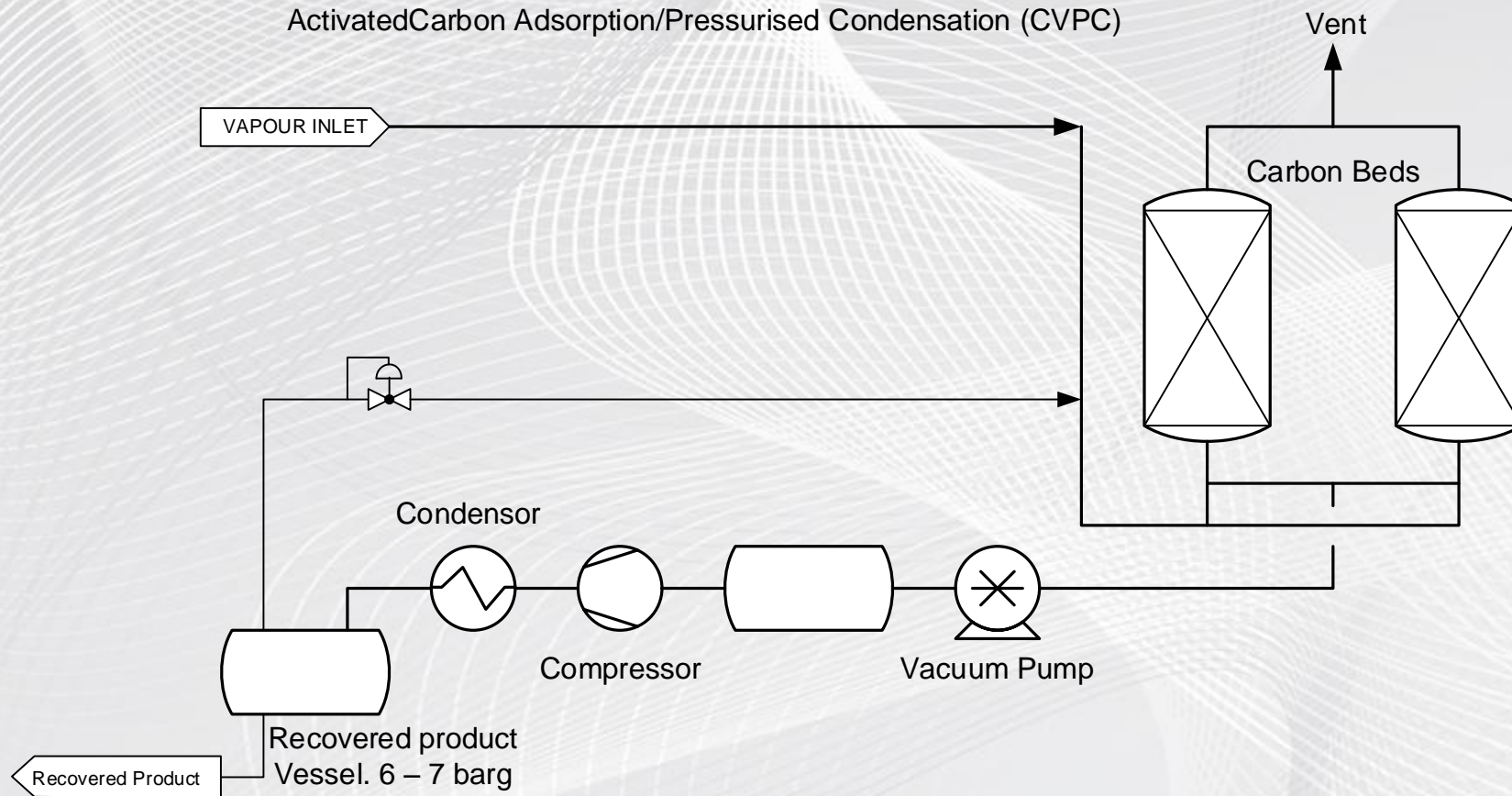
- Continuous Duty Application
- Tanks Vents or Balanced Vapour Systems Combined with Either Truck Loading or Ship Loading.
- Vapour Concentrations : Generally Should Be Considered as Saturated.
- Emissions from :
 - Tank Filling
 - Thermal Growth
 - Draw Out Emissions



► Carbon Vacuum Pressurised Condensation



Activated Carbon Adsorption/Pressurised Condensation (CVPC)



➤ Development

- Products Loaded
- Vacuum Pump Technology developments
- Tightening of Emission Requirements
- Widening Range of Applications
- **Increase in the Loading Rates – Size of VRUs**

➤ Loading Rates

- Truck Loading : Relatively Low Loading Volumes
 - Typically $100\text{m}^3/\text{hr}$ up to $980\text{m}^3/\text{hr}$ (32,000 to 260,000usgph)
- Ship Loading :
 - Low end : 800 to $1000\text{m}^3/\text{hr}$ (5000 – 6300bph)
 - Mid Range : 2000 to $10,000\text{m}^3/\text{hr}$ (12,600 – 63,000bph)
 - High Mid Range : 15000 to $25,000\text{m}^3/\text{hr}$ (94,300 – 157,250bhp)
 - High End : $36,000\text{m}^3/\text{hr}$ – $45,000\text{m}^3/\text{hr}$ (226,500 – 283,000bph)
 - ◆ $50,000\text{m}^3/\text{hr}$ to $65,000\text{m}^3/\text{hr}$ (314,500 – 408,800bph)
 - Vapour Flows : $80,000\text{m}^3/\text{hr}$ (352,000gpm)

➤ OPEX / ROI

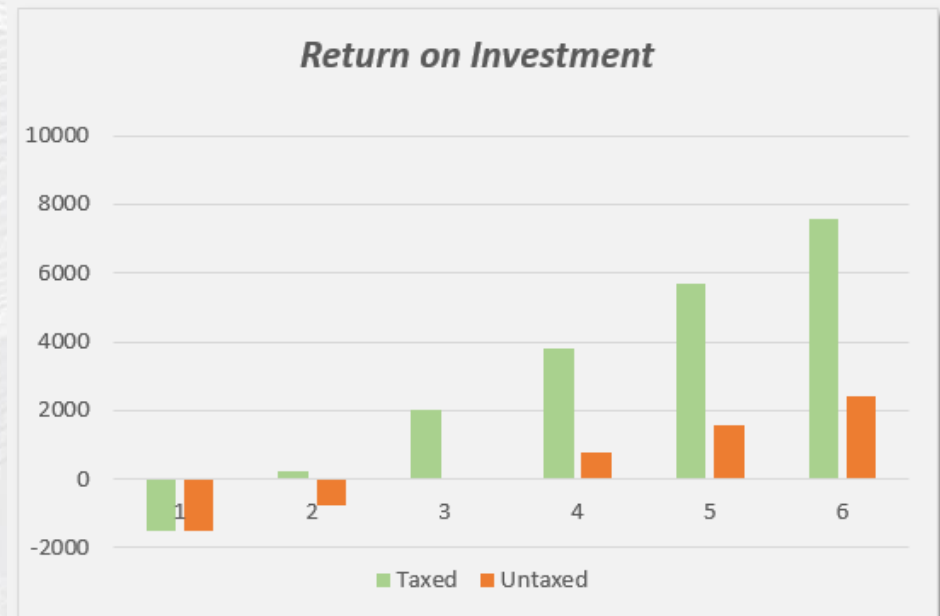
- The through-put of the terminal
- The gasoline / diesel split
- Vapour pressure of the product
- The efficiency of the VRU
 - How well is it maintained
 - Are energy saving operations incorporated into the design
 - Utility prices, i.e. electrical power
- The value of the product itself (can vary significantly)
- Where is the product taxed
 - (At the refinery or at the loading racks?)
- Whether Stage II recovery has been implemented

► Typical Product Recovery Rates



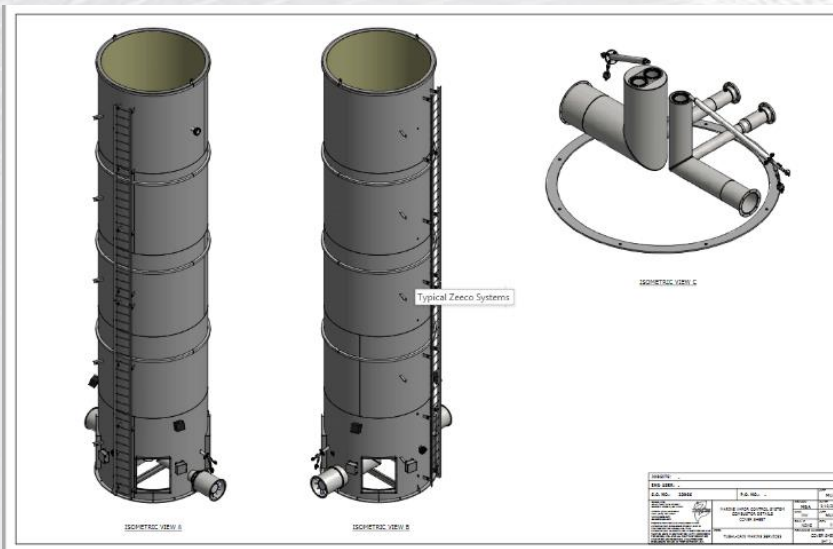
- Empirical data based on over 200 VRU's in operation:
 - Recovered product qty between 1 and 1.5 ltrs/1000 ltrs loaded
 - These figures are based on average hydrocarbon concentrations in vapour, typically varying from 25 to 40%.
- At a 5,000,000 ltr/day terminal:
 - Product recovered : 5,450 ltrs to 10,000 ltrs
 - Value of recovered product: EUR 2,500 to 4,600/day

- Medium sized terminal – 1,500,000 m³/yr throughput.
- Typical VRU purchase price : Euro 500,000
- Typical installation cost : Euro 1,000,000
 - Typically 2 – 3 times the cost of the VRU
- Total est. installation cost : Euro 1,500,000
- Annual electrical costs : Euro 10,500
 - Based on electrical cost of Euro 0.065/kWh
- Annual maintenance costs : Euro 8,300
 - Assumes reasonable spares & utility usage
- Typical annual operating cost : Euro 18,800



➤ Vapor Combustors

- **Primary Customers**
 - Loading Terminals
 - Tank Batteries
- **Often used in place of VRU or as backup to VRU**



➤ Portable Vapour Combustors





➤ Aftermarket and Service



► Aftermarket and Service: Service Capabilities



We can provide our own Field Service Engineers who are fully trained on all of Zeeco's equipment.

Our engineers are trained in:

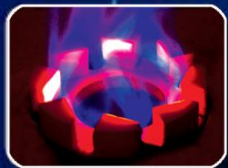
- **Health and Safety of the operation of combustion equipment.**
- **Supervision of installation and erections.**
- **Pre-commissioning activities.**
- **Commissioning activities.**
- **Start-up of equipment.**
- **Pre-inspection of equipment for retrofitting.**



Zeeco engineers are also offshore trained



► **THANK YOU!!**
Please visit www.zeeco.com



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