BEST PRACTICE IN VAM PROCESSING

Bogota 24 July 2018
Richard Mattus

• Why is VAM an issue?

• Technologies for processing VAM
• Proven technologies so far
• Successful installations
• Guide lines for feasibility
Drainage gas

Low volume
High CH₄
> 30%

Coal Excavation

Main Coal Mine Vent Shaft

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VAM, Ventilation Air Methane

Drainage gas

Low volume
High CH₄
> 30%

Very high volume

Very low CH₄
< 1%

Main Coal Mine Vent Shaft

Coal Excavation
## TECHNOLOGIES FOR PROCESSING VAM

### CONDITIONS:
- **Very large volumes of air** with extremely low CH$_4$ content.
  - $\sim 1\,000,000\, Nm^3/hr$
  - $<1\%$ to $<<1\%$

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**TECHNOLOGIES FOR PROCESSING VAM**

**CONDITIONS:**

Very large volumes of air with extremely low CH₄ content.

~1 000 000 Nm³/hr

<1% to <<1%

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**INDUSTRIAL OXIDIZERS**

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## TECHNOLOGIES FOR PROCESSING VAM

### CONDITIONS:
- Very large volumes of air: \(1\,000\,000\) Nm\(^3\)/hr
- With extremely low CH\(_4\) content: \(<1\%\) to \(<0.1\%\)

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1997 **Kyoto Conference** - Agreement to reduce emissions and to introduce mechanism of Carbon Credits

Official launch of Kyoto related Carbon Credits

**CARBON CREDITS TRADING**

**CARBON CREDITS TRADED**

EU ETS

**Kyoto Period** 2008 - 2012

**LARGE SIZE VAM INSTALLATION**

Power plant, WestVAMP, Australia

1994

VAM PILOT

UK trial at British Coal
A few months

1997

VAM PILOT

A full year

Abatement demo 1½ year
CONSOL, US

2001

2007

2009

2012

2015

2018
1992 **Rio** Conference
- Agreement to establish the UN Framework Convention on Climate Change, UNFCCC

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2009 **Copenhagen** Conference
- Failure to extend Kyoto Protocole

- Official launch of Kyoto related Carbon Credits

**LARGE SIZE VAM INSTALLATION**
*Power plant, WestVAMP, Australia*

- 1994 UK trial at British Coal
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- 1997 Australian trial at BHP
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- 2009 VAM PILOT
- 2015 VAM PILOT
- 2018 Richard Mattus 2018: Best Practice VAM Processing
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2001 EU ETS
- CARBON CREDITS TRADED

2007 LARGE SIZE VAM INSTALLATION
- Power plant, WestVAMP, Australia

2009 Abatement/hot water, China
- JWR, US

2012 LARGE SIZE VAM
- Power plant, GaoHe China

2015 Abatement, JWR, US
- McElroy, US

2018 LARGE SIZE VAM
- Abatement, hot water, SongZao, China

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VAM PROCESSING AND CARBON CREDITS

1992 **Rio Conference**
- Agreement to establish the UN Framework Convention on Climate Change, UNFCCC

1997 **Kyoto Conference**
- Agreement to reduce emissions and to introduce mechanism of Carbon Credits
- Official launch of Kyoto related Carbon Credits

2009 **Copenhagen Conference**
- Failure to extend Kyoto Protocole

2015 **Paris Agreement**
- Various ETS (Emission Trading Schemes)

**CARBON CREDITS TRADING**
- EU ETS
- Carbon Credits Traded

**VAM PROCESSING**
- UK trial at British Coal
  - A few months
- Australian trial at BHP
  - A full year
- Abatement demo 1½ year
  - CONSOL, US

**LARGE SIZE VAM INSTALLATION**
- Power plant, WestVAMP, Australia

2015 **Paris Agreement**
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**LARGE SIZE VAM INSTALLATION**
- Power plant, GaoHe China

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**LARGE SIZE VAM INSTALLATION**
- Abatement, McElroy, US

**LARGE SIZE VAM INSTALLATION**
- Abatement, hot water, SongZao, China

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COMMERCIAL SIZE VAM PROCESSING

BY EXPERIENCED RTO-SUPPLIERS

- VAM Power Plant WestVAMP 250 000 Nm³/h
- DaTong 375 000 Nm³/h
- ZhengZhou 60 000 Nm³/h
- CONSOL Energy 60 000 Nm³/h
- McElroy, 180 000 Nm³/h
- JWR 60 000 Nm³/h
- VAM Power Plant GaoHe 1 080 000 Nm³/h

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COMMERCIAL SIZE VAM PROCESSING
OFFICIALLY STILL IN OPERATION BY JUNE 2018

Closures of others due to:
• Moving of mining activities
• Failing values of carbon credits

VAM Power Plant GaoHe
1,080,000 Nm³/h
Since 2015

McElroy,
180,000 Nm³/h
Since 2012

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RTO technology
- How does it work?
Like all VOC gases, methane oxidize at 850-900°C to form water and CO$_2$.

And release Energy!
VOC Oxidation Rate

Temperature vs. Oxidation Rate

100% oxidation at 1000 °C
Single can RTO

RTO FUNCTION:
1. Heat center cross section of ceramic bed to 1000°C.
2. Pass ventilation air through, heating media, oxidizing all VAM in air passing the hot zone.
3. Change direction of flow, making hot zone remain in center bed section.

No catalyst
operate at natural oxidizing temperature
Single can RTO
Main difference between the single can RTO and 2 can or multiple can RTO’s: Oxidation in a combustion chamber instead of in the ceramic bed.
RTO installations typically consists of multiple modular RTO units.
Min 0.2% CH\textsubscript{4} to keep oxidizing going.

If higher, the excess can be utilized.
CONVERTING ENERGY OF VAM INTO USEFUL ENERGY

.. as heating or cooling, or as electricity.
Indications of VAM project economics

- The project economics of a VAM processing installation will largely depend on;
  - **Total costs** for investment, operation and maintenance.
  - Average **VAM concentration** of the ventilation air being processed.
  - The **value** of reducing the emissions.

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0.2 % methane needed to maintain oxidation.
Energy of concentrations above 0.2 % can be recovered.

Example:

800 000 m$^3$/h
1 % CH$_4$

$\rightarrow$ 72 MW(th) $\rightarrow$ 21 MW(el)
(at 30% efficiency)

Example:

800 000 m$^3$/h
0.6 % CH$_4$

$\rightarrow$ 36 MW(th) $\rightarrow$ 10 MW(el)
(at 30% efficiency)
Cogeneration of electricity and heating – plus cooling

Cooling water from electricity generation drives absorption chiller

Example:

800 000 m³/h
1% methane

72 MW(th) → 21 MW(el) → 19 MW(el) + 38 MW(cool)
Hot water from VAM (thermal energy)

Heat straight from bed. Water at 70 - 150°C

<table>
<thead>
<tr>
<th>%</th>
<th>0.3%</th>
<th>0.6%</th>
<th>0.9%</th>
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<td>3 MW</td>
<td>11 MW</td>
<td>18 MW</td>
<td></td>
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- For each 250 000 Nm/h of ventilation air

Secondary heat-exchanger. Water at 70°C

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<th></th>
<th>1 MW</th>
<th>8 MW</th>
<th>15 MW</th>
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Secondary heat-exchanger. Water at 150°C

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<th>2 MW</th>
<th>10 MW</th>
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**Electricity from VAM** (electrical energy)

For large size plants (min ½ million m³/h of ventilation air), conversion from thermal to electrical energy can be expected to be around 30%, and lower for smaller plants.
Calculations of CO$_2$e from VAM processing

Examples:
250 000 Nm3/h @ 0.9 % VAM comes to 240 000 tonnes of CO$_2$e
125 000 Nm3/h @ 0.9 % VAM comes to 120 000 t CO$_2$e
125 000 Nm3/h @ 0.3 % VAM comes to 40 000 t CO$_2$e

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<th>Nm3/h vent air</th>
<th>VAM conc’n</th>
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<td>40</td>
<td>80</td>
<td>120</td>
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<td>480</td>
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<td>1 000 000</td>
<td>0.0 %</td>
<td>320</td>
<td>640</td>
<td>960</td>
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Annual emission reductions in thousand tons of CO$_2$e
VAM Project Financial Feasibility

VAM project economics indications

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VAM Project Financial Feasibility

VAM project economics indications

Examples:

• An emission reduction value of EUR 16/t CO$_2$e and a 0.8% VAM concentration would yield an IRR of approx 65% - i.e. an expected pay back of less than 2 years.

• A value of EUR 10/t CO2e and a 0.6% VAM concentration would yield an IRR of approx 20% - i.e. an expected pay back of around 5 years.

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CONCLUSIONS for reasonable/good pay back:
- VAM concentrations should be min ½ percent
- Carbon emission reduction value (Carbon Credits/Carbon Tax etc) should be minimum EUR 10/t CO$_2$e
Carbon Credits Trading

The world’s largest trading scheme is the EU ETS

= The EU carbon credits Emissions Trading Scheme
Carbon price overview EU

Kyoto Compliance Period
2008 - 2012
Carbon price overview EU

The initial price level of EUR 20-30 per ton CO2e was interrupted by economic recession and by introductory disturbances.

Lowered value primarily relating to:
• 2012 Kyoto end uncertainty
• Low industrial & energy production creating a major surplus of Carbon Credits flooding the market
Most of the compliance period saw a steady and balanced trend.

Kyoto Compliance Period
2008 - 2012

Carbon price overview EU
Carbon price overview EU

2018 EUA price:
By June above € 15.
Coming back to a balanced market situation?

Kyoto Compliance Period
2008 - 2012
FORECAST PUBLISHED IN FEBRUARY 2018
(- when EUA at €13 EUR)

EU carbon prices forecast to triple by 2030
EUR per metric ton, nominal

Source: Bloomberg New Energy Finance
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Source: Bloomberg New Energy Finance
Overall OPTIMIZATION of CH$_4$
- CMM and VAM emissions

- High CH$_4$ >30%
- Low CH$_4$ < 1%

60-80% of emissions

Very high volumes. Very low concentrations.
Overall OPTIMIZATION of CH$_4$ - CMM and VAM emissions

- Low CH$_4$ < 1%
- 60-80% of emissions
- High CH$_4$ > 30%

Gas Engines

Main Coal Mine Vent Shaft

Coal Excavation
Overall OPTIMIZATION of CH$_4$ - CMM and VAM emissions

- Low CH$_4$ < 1%
- 60-80% of emissions
- Min $\frac{1}{2}$ million m$^3$/h
Overall OPTIMIZATION of CH$_4$
- CMM and VAM emissions

For optimization if motivated by VAM energy utilization.

Min $\frac{1}{2}$ million m$^3$/h

60-80% of emissions

High CH$_4$
>30%

Low CH$_4$
< 1%

VAM processing

Main Coal Mine Vent Shaft

Coal Excavation

Gas Engines
VAM PROCESSING

• Experienced RTO suppliers can provide proven VAM processing solutions
• There will in time be more suppliers and more technical solutions to VAM processing

• For best feasibility of VAM projects, look for:
  o VAM concentrations of $\sim \frac{1}{2}$ % or more
  o Possibility to enrich the ventilation air (into VAM processing) to min $\frac{1}{2}$%
  o Possibilities to utilize thermal energy close to ventilation shaft (Heating? Cooling?)
  o Look for good value of reducing VAM emissions (Carbon Credits or similar)

For very large mines: Optimize your overall emission strategy between processing of drainage gas and processing of VAM for power generation.

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VAM specialist
UN Group of Experts on CMM