In full operation – the world’s first VAM Power Plant

Presented at Methane to Markets Partnership Conference & EXPO in Beijing
30 Oct 07 by Richard Mattus, MEGTEC

OFFICIALLY OPEN 14 SEPT 2007
WestVAMP IN FULL OPERATION

- At the WestCliff Colliery of BHP Billiton in Australia
- Based on (patented) technology from MEGTEC Systems
- VOCSIDIZERs from MEGTEC are made part of the power plant steam cycle
WestVAMP IN FULL OPERATION

- 250 000 Nm³/h (150 000 scfm) of ventilation air with
- 0.9% CH₄ concentration (VAM + drainage gas) generating
- High pressure, superheated steam driving a
- Conventional 6 MWe power plant steam turbine

Fuel contains ~ 99% air
WestVAMP HOOD CONNECTION

- Open connection having no influence on ventilation system
WestVAMP IN FULL OPERATION

- In full operation since April 2007
- Officially opened on 14 September by the honorable Morris Iemma, Premier of NSW, Australia

.. national Australian news of that date
Key Topics covered:

- 4 Coal Mine VAM site demo’s of MEGTEC
- Who is MEGTEC and how did MEGTEC solve the VAM dilemma (utilizing large volumes of extremely lean gas as fuel)?
- Why is reducing VAM emissions of high interest?
- VAM Project economics
REFERENCES OF CONCENTRATION - CMM

- FEED TO NATURAL GAS GRID
  - CONCENTRATION UPGRADING
  - CHEMICAL FEED STOCK
  - BOILER FEED
  - TOWN GAS
  - etc

SPECIAL GAS ENGINES

VAM POWER PLANTS

- Explosive Range
  - ~1% to 1% for energy recovery (as thermal or as electricity)
  - 0.2% for stable process

100% CH4 concentration

Min ~97%

~30%

15%

5%

~1%
CMM EMISSIONS – VAM vs DRAINAGE

Drainage gas

~97 %

100 % CH4 concentration

~30 %

~15 %

5 %

VAM

GLOBAL CONCLUSION: Most CMM is emitted as VAM

Distribution of total methane emissions

- from typical coal mine in China

80 % VAM

- from mine (anywhere) with extensive drainage

20 % drainage

50 % VAM

50 % drainage
US industrial corporation noted on NYSE
USD >2 billion (2006 Sales)

.. belongs to

SEQUA Corporation

USD >0.2 billion in sales
Over 800 employees worldwide
Aerospace
Chromalloy Gas Turbine

Automotive
Arc Automotive
Casco Products

Metal coating
Precoat Metals

Speciality chemicals
Warwick International

Industrial machinery
MEGTEC Systems

Other products
After Six
MEGTEC Locations Worldwide

MEGTEC Systems Worldwide Headquarters
De Pere, WI
Columbus, OH

MEGTEC Systems Regional Offices
Vero Beach, FL
Melbourne, Australia
Singapore
Shanghai, China
Pune, India
Göteborg, Sweden
Amål, Sweden
Maintal (Frankfurt), Germany
Evry (Paris), France
Maidenhead, UK
Ingne, France
Manchester, UK

MEGTEC in China
Globally leading supplier
of emission control equipment

In house competence and experience
of boilers and boiler design.
MEGTEC has delivered over 800 VOCSIDIZERs in many different industrial applications, now including..

- Coal Mine Ventilation Air Methane
Like all VOC gases, methane oxidize at 850-900°C to form mainly water and CO₂.

And release Energy!
VOC Oxidation Rate

Oxidation Rate vs. Temperature

100% VOC Oxidation Rate

1000 °C
The Flameless VOCSIDIZER

Flameless: Oxidation completely in-bed.
No NOx: No flame. Even though temp is high, it is not near where thermal NOx is generated.

No catalyst
operate at natural oxidizing temperature
First coal mine site demonstration
Thorseby Coal Mine, British Coal, UK

1994:
Demonstrated efficient VAM Abatement
Efficient Energy Recovery from VOCSIDIZER bed

VAM FOR **THERMAL** USE
First coal mine site demonstration
Thoreseby Coal Mine, British Coal, UK
1994:
Demonstrated **efficient VAM Abatement**

Second coal mine site demonstration
Appin Colliery, BHP, Australia
2001 - 2002:
Demonstrated, by boiling water during 12 months,
- **Efficient Heat Recovery**
- **Ability to handle variations in VAM concentration**
First coal mine site demonstration
Thoreseby Coal Mine, British Coal, UK

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Second coal mine site demonstration
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2001 - 2002:
Demonstrated, by boiling water during 12 months,
- Efficient Heat Recovery
- Ability to handle variations in VAM concentration

Awarded in April 2005 as ACARP’s best Greenhouse Gas Project

The Appin Project was partly Government funded by ACARP - Australian Coal Association Research Programme
VOCSIDIZER Energy Recovery as Superheated Steam
PRINCIPLE DIAGRAM FOR:
VOCSIDIZER STEAM CYCLE FOR POWER GENERATION
VAM Power Plant
- VAM AS PRIMARY FUEL
FOR THE GENERATION OF ELECTRICITY

Third coal mine site demonstration:
VAM Power Plant in successful operation since April 2007.

- In September 2007, receiving the Excellence in Energy Award by the Australian Institute of Energy

The WestCliff Project was partly Government funded by AGO – Australian Greenhouse Office
**Fourth coal mine site demonstration:**

Windsor mine, CONSOL Energy, USA

- 50,000 m³/h (30,000 scfm) of ventilation air
- 0.1 – 1.2 % methane (abandoned mine gas)
- Unmanned operation since May 2007

**PROJECT DESIGN:**

Injecting high concentration mine gas into a large flow of fresh air in order to simulate various concentrations of VAM, then to evaluate abatement in the VOCSIDIZER.

The Project is partly Government funded by the US EPA and the US DOE.
0.2% methane needed to maintain oxidation. Energy of concentrations above 0.2% can be recovered.

Example: 800 000 m³/h

1% CH₄

→ 72 MW(th) → 21 MW(el)

(at 30% efficiency)

Example: 800 000 m³/h

0.6% CH₄

→ 36 MW(th) → 10 MW(el)

(at 30% efficiency)
Cogeneration of electricity and heating – plus cooling

Cooling water from electricity generation drives absorption chiller.

*Example:*

\[
\begin{align*}
800,000 \text{ m}^3/\text{h} & \quad 72 \text{ MW(th)} \\
1\% \text{ methane} & \quad 21 \text{ MW(el)} \\
\rightarrow & \quad 19 \text{ MW(el)} + 38 \text{ MW(cool)}
\end{align*}
\]
VAM Energy Recovery for District Heating / cooling
THREE OPTIONAL VAM VOCSIDIZER CONCEPTS

A
VAM Abatement Only
A type of "flaring".

B
VAM to Thermal Energy

C
VAM Power Plant (VAM to Electrical Energy)
The technology and concept of oxidizing and utilizing VAM has been presented by MEGTEC at Work Shops and Conferences in China since 2004.
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WHY ALL THIS INTEREST TO REDUCE VAM EMISSIONS?

- What is carbon credits financing?
One bubble of atmosphere
One bubble of atmosphere

Atmosphere thickness to the Earth is like the skin to the apple
One bubble of atmosphere

Some heat radiation is reflected back to Earth by the atmosphere.
One bubble of atmosphere

Human activities are emitting large quantities of gases into atmosphere.

Gases with impact on Global Warming: CO$_2$, CH$_4$, N$_2$O, CFC’s ..
One bubble of atmosphere
One bubble of atmosphere

Gases accumulate and reflect more heat back to Earth
Green House Effect resulting in Global Warming

One bubble of atmosphere
CO$_2$ remains 100 years in the atmosphere, continuously accumulating at *accelerating* rate.
- Governments of the World agree this trend must be broken
- The Kyoto Protocol introduced a *system of emission caps for industrialized countries*, and a *system of trading emission allowances* – promoting investment in emission reductions *where investment is most efficient* in reducing GHG (Green House Gas) emissions. All emissions are into the same thin bubble of atmosphere.

Besides Kyoto, now also local emission reduction schemes
Recent trend is companies and individuals buying Voluntary Emission Reduction credits
CONCLUSIONS:
- Structures of trading schemes of “carbon credits” (CER / ERU / VER / NGAC ..) are now established
- Trading is increasing quickly and becoming globally integrated
- Media attention as well as public awareness and concern are very high and increasing

➢ Carbon credit financing of successful emission reduction projects is here to stay
The aim of all efforts to reduce GHG emissions is now to break the trend of increasing global warming, which is melting the ice of the Arctic.
Greenhouse Gases Contributions

- CO2: 53%
- CH4: 17%
- Trop Ozone: 13%
- N2O: 5%
- CFC's: 12%

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<thead>
<tr>
<th></th>
<th>CO2</th>
<th>CH4</th>
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<tbody>
<tr>
<td>Global Warming Power</td>
<td>1</td>
<td>23</td>
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<tr>
<td>(21 in the first Kyoto Period)</td>
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<tr>
<td>Life time in atmosphere</td>
<td>100</td>
<td>12 ½</td>
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Global Methane Emissions - by source

BIGGEST TOTAL SOURCE:
Cows, sheep etc

PROBLEM:
Each source is very small

50-100 kg per cow 1-2 t CO2e per year
ANNUAL GREENHOUSE EFFECT on Global Warming

Coal mine VAM
800,000 m³/h, 1% (50,000 t CH₄/yr)

1 million t CO₂e
ANNUAL GREENHOUSE EFFECT on Global Warming

Coal fired Power plant 300 MW_th =

Coal mine VAM 800 000 m3/h, 1% (50 000 t CH4/yr)

1 million t CO2e
ANNUAL GREENHOUSE EFFECT on Global Warming

Coal fired Power plant
300 MW$_{th}$ =

½ million cars =

Coal mine VAM
800 000 m$^3$/h, 1%
(50 000 t CH$_4$/yr)

1 million t CO$_2$e
Calculations of CERs

For calculation of amount to CERs, consider:
- Vocsidizer cleaning efficiency and availability
- conversion rate of CH4 into CO2e.

The formula will be:
\[(\text{Cleaning Efficiency}) \times (\text{Hours of availability}) \times (\text{Volume flow of ventilation air}) \times (\text{VAM concentration}) \times ((\text{CH4 weight}) \times \text{Global Warming factor} - (\text{CO2 weight}))\]

which comes to:
\[0.97 \times [8760 \times 0.97] \times \text{Flow of ventilation air} \times \text{VAM concentration} \times [0.71 \times (21 - 2.75)]\]

Examples:
250 000 Nm3/h @ 0.9 % VAM comes to 240 000 tonnes of CO2e
125 000 Nm3/h @ 0.9 % VAM comes to 120 000 t CO2e
125 000 Nm3/h @ 0.3 % VAM comes to 40 000 t CO2e

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<th>0.3</th>
<th>0.6</th>
<th>0.9</th>
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<td>125 000</td>
<td>40</td>
<td>80</td>
<td>120</td>
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<tr>
<td>250 000</td>
<td>80</td>
<td>160</td>
<td>240</td>
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<tr>
<td>500 000</td>
<td>160</td>
<td>320</td>
<td>480</td>
</tr>
<tr>
<td>1 000 000</td>
<td>320</td>
<td>640</td>
<td>960</td>
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Thousand tons of CO2e per year

**IN ADDITION at energy recovery:**
If carbon based energy is replaced, the effect on Global Warming is ~20% better.
VAM Project Economics

- ETS €15 – 20/t CO2e for 2008
- CDM in China $ 10/t CO2e
- VERs 3 – 4 $/t CO2e

- Many parameters – especially for VAM Power Plants
- Each site must be evaluated separately
- The new market for carbon credits is still very volatile

FOLLOWING PAGES:
Indications to estimated levels, trends and critical values.
Please note that these are indicative only.
CONCLUSIONS:
• VAM should be min 0.6 %
• Carbon credits should be min 10 USD/t CO2e

.. then the straight pay back time is only a few years - provided approved
VAM Project Economics - *indications*

**ABATEMENT ONLY**

250 000 Nm/h (150 000 scfm)

*indicative profitability*

at various values of carbon credits

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**ELECTRICITY**

250 000 Nm3/h (150 000 scfm)

*indicative profitability*

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VAM Project Economics - *indications*

- VAM Power Plants have higher CAPEX and higher revenues
4 CONCLUSIONS on VAM (Ventilation Air Methane)

1. VOCSIDIZER can abate VAM
4 CONCLUSIONS on VAM (Ventilation Air Methane)

1. VOCSIDIZER *can abate* VAM

2. VOCSIDIZER *can convert* VAM into useful energy
4 CONCLUSIONS on VAM (Ventilation Air Methane)

1. VOCSIDIZER can abate VAM

2. VOCSIDIZER can convert VAM into useful energy

3. Project WestVAMP in Australia is the World’s first large scale VAM Power Plant - using VAM as primary fuel
1. VOCSIDIZER *can abate* VAM

2. VOCSIDIZER *can convert* VAM into useful energy

3. Project WestVAMP in Australia will be the *World’s first* large scale *VAM Power Plant* - using VAM as primary fuel

4. A full scale VAM Power Plant can reduce annual emissions of 1 million tons CO$_{2e}$ - providing significant positive impact on Global Warming
ADDITIONAL CONCLUSION on VAM

At:

- > ½ percent CH4 and
- > 10 USD/t in value of Carbon Credits,

**VAM projects can have pay back time of a few years only!**
The World’s first VAM Power Plant is
IN FULL OPERATION