Utilisation of High CO2-Content Flare Gas for Steam and Electricity Generation

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December 2008

"UTILISATION OF HIGH CO2-CONTENT FLARE GAS FOR STEAM AND ELECTRICITY GENERATION"

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PETROBRAS - ECUADOR
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PETROBRAS
1. Palo Azul Power Plant Project
2. B18 Field - CDM PROJECT: Incorporate Additional Gas Supply
1.- Palo Azul Power Plant Project
Topics

1. Location
2. Background
3. Technology and Operation
4. Environmental Issues
5. Location
6. Economic Issues
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1. Location
Petrobras operates the Pata and Palo Azul fields in Block 18, located 300 Km. from Quito, the capital of Ecuador.

Concession area: approximately 110,000 hectares.

Location: Northeast section of the Ecuadorian Amazon Region, in the Province of Orellana.
Location...

Panoramic View of the Palo Azul CPF
2. Background
In 2006, the Central Processing Facilities (CPF) were built with a capacity to process 40,000 BOPD (28° API), 75,000 BWPD and 12 MMSCF with 77% CO2.

A power generation demand of 12 MW, with a 17.38 MW installed capacity, powered by provisional, portable diesel-fuelled reciprocal engines at a high fuel cost. Ecuador imports its diesel.
Background ...

GOR wells = 400; 12 MMSCFD (77% CO2)

Technological alternatives were analyzed for the use and disposal of the gas from flares for generating electricity and optimizing operating costs.
Background...

- Analyzed alternatives:
  - Combustible gas in Internal Combustion Engines.
  - Gas in Gas Turbines.
  - Flare Gas and/or crude oil in electricity generation with steam cycle.
Technical-economic analyses determined that the combined steam cycle system is the best option for achieving:

- Reduction of environmental emissions and noise pollution
- Better use of flare gases
- Minimum gas treatment
- Substantial reduction of operating costs
Limited operating window when gas quality decreases

With full Load: 100%

- Maximum gas utilization: 30%
- Requires other fuel (diesel or crude oil): 70%

More environmental emissions, particularly CO2
Poor gas operational window: Dual combustion engine

<table>
<thead>
<tr>
<th>Diesel share %</th>
<th>Gas share %</th>
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<tbody>
<tr>
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<td>100</td>
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<tr>
<td>10</td>
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<tr>
<td>100</td>
<td>0</td>
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</tbody>
</table>

Engine load%:
- P = 68%
  - Fuel share 40%
  - CRO 60%, GAS 40%
  - No estimate on heat rate.
- P = 100%
  - Fuel share 27%
  - CRO 73%, GAS 27%
  - No estimate on heat rate
- P = 100%
  - CRO mode
  - CRO 100%, GAS 0%
  - Guaranteed heat rate 8539 kJ/kWhr at 35°C
The project was developed using SGPMP-PRODEP (Petrobras) methodology.
Background...

APPLIED LAWS AND REGULATIONS:

- Ecuadorian Hydrocarbons Law, articles 11 and 24.


- Ecuadorian Water Act, article 82.

- General Rules for Applying the Water Act, articles: 13, 14 y 15.
Background...

APPLIED LAWS AND REGULATIONS:

- Environmental Management Law, articles: 19 and 20.
- Environmental Regulation for the Electricity Industry, article 10.
- Electrical Sector Regime Law, articles: 2, 3, 30 and 40.
- Regulation of Concessions, Permits and Licenses for the Provision of Electrical Power Services, articles: 5, 11, 12, 54, 55 and 95.
GOVERNMENTAL APPROVALS:


- Authorization to use crude oil: DNH resolution #74 of 8/Feb/2008
GOVERNMENTAL APPROVALS:


3. Technology and Operation
Technology and Operation

- System: 2 steam 6 MW turbogenerators and 1-5.38 MW motor generator.

- 12 MW net generation with gas, 17.38 MW installed capacity.

- Back up motor generator fuelled by crude oil or diesel for start up and auxiliary system.

- Hybrid System using all high CO2-content gas with no prior treatment, depending on required demand.
Technology and Operation

- Boilers with cutting-edge gas-crude oil dual burners.

- All available gas calorific energy is used. (470 BTU/CF)

- Additional contaminant of gas emissions (CO2, among others) are avoided by not burning fossil fuels, such as crude oil, diesel or bunker.
Power Generation Plant Layout

GAS FWKO + SRU

TO BOILERS

CRUDE OIL

TO MOTOR

CRUDE OIL TREATMENT

MOTO-GENERATOR

BOILERS

STEAM TURBINES

Gen1

Gen2

6 MW c/u

COOLING TOWER

Make up

5.38 MW

Technology and Operation
Technology and Operation

Water-Steam Cycle (Rankine Cycle)
3-D View of Plant

Turbogeneradores

Motogenerador
Panoramic View of Boilers Area
Boiler Unit
Crude Oil Generator Unit
4. Environmental Issues
Environmental Issues...

EMISSIONS OF THE BOILERS vs REQUIREMENTS DINAPA®

DINAPA: GOVERNMENT ENVIRONMENTAL OFFICE

UNITs [mg/Nm³]

- 31 -
5. Economic Issues
Economic Issues

- Project allows the use of 100% of flare gas for the steam cycle as thermal energy.

- The achieved results consist of a 90% reduction in equivalent energy expenses, 37% savings (OPEX).
Economic Issues

Year 2007: Power Generation with Diesel # 2

![Graph showing energy consumption and unit cost for the year 2007.](image)

YEAR 2007

- Energy Kw-hr
- Diesel Gall/day
- Unit Cost
Economic Issues

Year 2008: Power Generation with Flare Gas

YEAR 2008

- 35 -
6. VIDEO
Existing Plant

[Video]
7. Conclusions
Conclusions

- Flexible system, poor gas options, poor and rich gas or crude oil blends.
- Use of flare gas, no prior treatment required, only removal of liquids.
- Reduction of 60 MTCDE/year.
- Possibility to use 100% of available gas (12 MMSCFD). Current use is 50%.
- Flexibility for adapting to future field requirements, depending on oil and formation water production.
Conclusions

- Reduction of emissions compared to those of previous plant

<table>
<thead>
<tr>
<th>EQUIP.</th>
<th>SO2 (mg/m³)</th>
<th>NOx (mg/m³)</th>
<th>CO (mg/m³)</th>
<th>MP (mg/m³)</th>
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<td>Diesel Gen.</td>
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<td>24</td>
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<tr>
<td>Gas Boiler</td>
<td>&lt; 5</td>
<td>17</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
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</table>

- Reduction of noise from 115 to 88dB in turbines area.
- Immediate effects consisting of a 90% of energy savings and 37% of OPEX, approximately
2.- B18 Field - CDM PROJECT: Incorporate Additional Gas Supply
Gas availability vs Power Demand

- Gas projection indicates continuing decrease in quantity:
  - Current 12 MMSCF vs. 0.1 MMSCF (2022)

- Power demand increasing, expected peak of 23 MW in 2011

- Future flare gas deficit in power demand peak: 3 MMSCFPD
Crude oil required = 1.6 MMBBLs
Crude oil equivalent = 0.3 MMBBLs
Total crude oil = 1.9 MMBBLs
Gas consumption

![Gas Consumption Graph]

- AVAILABLE NET GAS
- REQUIRED GAS FROM OTHER FIELDS
- TOTAL NET GAS REQUIRED
Objectives…

- Gas purchase from nearby oil fields.

- Near future: Replace crude oil burning with gas burning.

- Expected savings aprox. 1.6 million barrels of crude oil in 14 years for the Block 18 oil field.

- Project development, currently status at Identification & Evaluation phase.
Objectives…

- Expected total savings of aprox. of 1.3 MMTCDE (not burning crude oil) during 14 years.
- Project meets CDM requirements
- Bonuses CER’s are expected
- Project could be part of the Programatic CDM activities of Petrobras-PESA
Thank You