Figure 1. Braskem's 200k ton/year green ethylene plant at the Triunfo Petrochemical Complex, Brazil.

case story

Monitoring World's Largest Green Ethylene Plant

In operation for over 2 years, this article gives an insight into the machine condition monitoring strategy at the plant and how it was implemented.

End-user

Braskem, the largest petrochemical producer in the Americas and the fifth largest in the world by production capacity, commissioned the green ethylene plant in the Triunfo petrochemical complex in the Rio Grande do Sul state in Brazil in September 2010. "Green" ethylene is derived from ethanol that is produced from a renewable source such as sugarcane, instead of from a fossil oil derivative (see the fact box for more information on the green ethylene process).It is the largest green ethylene plant in the world, producing 200k tons/yr. The Compass system was selected for monitoring this plant. (In fact, Compass has been monitoring machines in the petrochemical complex since 1997).

The machine condition monitoring team at the Braskem Maintenance department in Triunfo, led by Otávio Vescovi for the last 22 years, has significant experience in monitoring and diagnosis of machine faults.

In the early years there was only one steam cracker olefin plant operated by Copesul. The machine uptime was so closely tied to the downstream plants that the original Compass system was extended as a service to the other downstream plants[1]. At that time there were 1910 machines monitored at four different plants. Now there are over 3200 machines monitored at 9 petrochemical plants and one utility (all owned by Braskem).

The team currently consists of six vibration analysts and eight technicians who also utilize the Type 2526 data collector for collecting offline data.

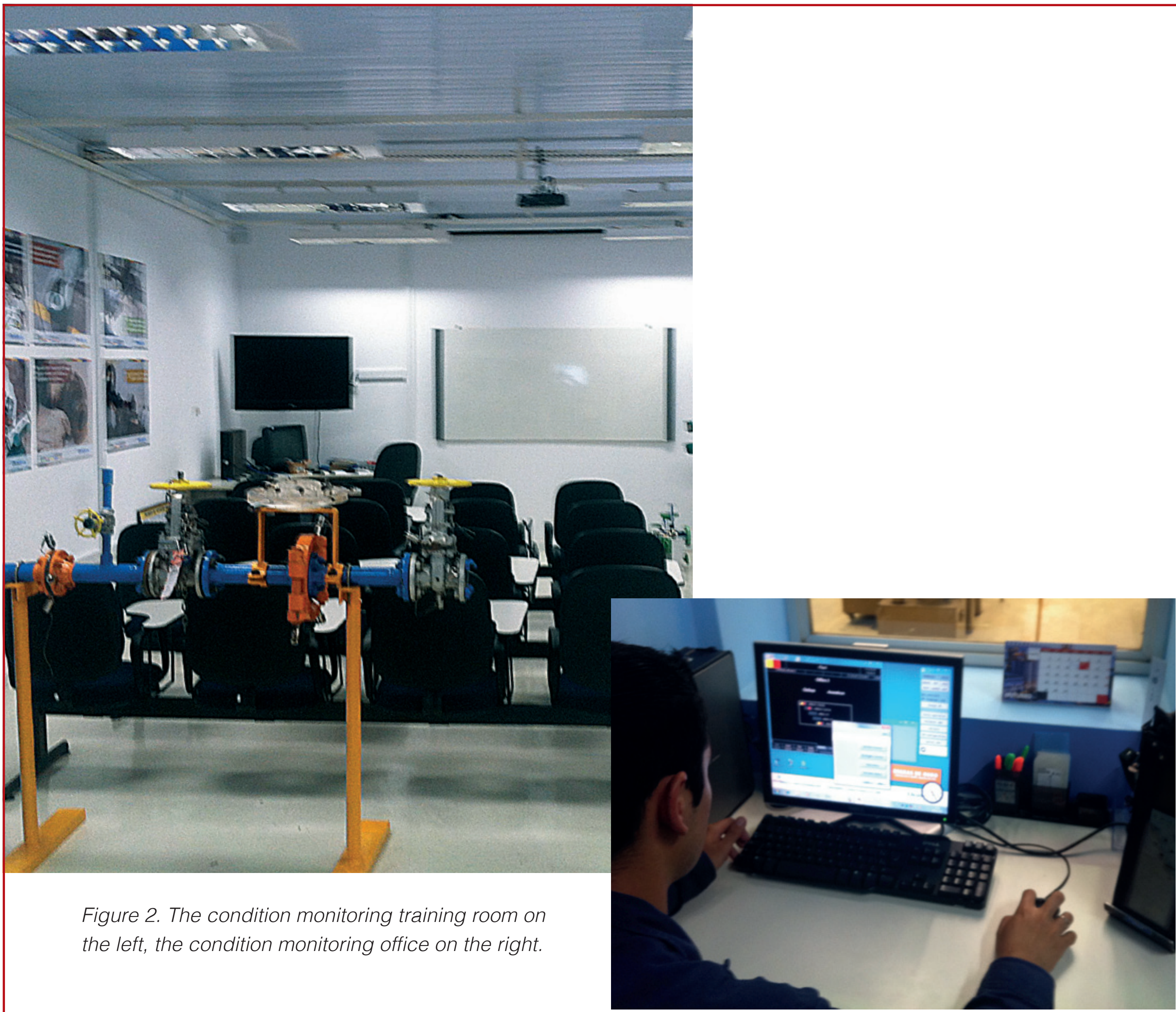


Figure 2. The condition monitoring training room on the left, the condition monitoring office on the right.

Machines

Braskem's proprietary green ethylene process employs the following machines:

- **Charge gas compressor** - Takes the gas effluent from the condensation tower and performs several compression and condensing cycles between the intercooled stages for separating liquefied fractions containing water and oxygenates from the gas. After the last compression stage, the gas stream is sent on to the wash tower to remove water and high oxygenates.
- **Propylene refrigerant compressor** – Compresses the propylene refrigerant gas for the cryogenic distillation part of the process. Gas from the drying columns is cooled to low temperatures so the higher boiling point fractions can be separated to achieve 99.96% pure ethylene
- **Centrifugal pumps** – A number of pumps are used in the entire process; feeding the ethanol to the heat exchanger before the furnace, removing water from the process (approximately 50% of the production), and for transporting the liquid "bottoms" from the various separation phases of the process

An ethylene compressor is not needed in the Braskem green ethylene process as it is for the fossil oil based ethylene plants, because the liquefied ethylene is stored at 17.7 bar pressure in refrigerated spherical tanks.

[1] This is described in the paper "Tele-Monitoramento Utilizado nas Plantas da Copesul e de Empresas de Segunda Geração", presented at the Latin America Power & Gas 2001 Conference, Rio de Janeiro, Brazil, June, 2001

The ethanol-ethylene process

In the Braskem process, ethanol, which is the primary raw material for making green ethylene, comes from fermented sugarcane. The ethanol is catalytically dehydrated in reactors at high temperature and moderate pressure:

$$CH_3CH_2OH \rightarrow CH_2{=}CH_2{+}H_2O$$

Subsequent separation processes remove the water, unreacted ethanol and other impurities.

Green ethylene produced from sugarcane ethanol can save 60 % fossil energy compared to steam cracking of fossil oil (electricity can also be produced from ethanol). The associated greenhouse gas emissions are about 40% less than petro-derived production.

The entire process can be summarized as follows:

- 1 hectare (approximately the area of a soccer pitch) produces 82 tons of sugarcane. The photosynthesis process of the sugarcane captures 7,5 tons of CO^2 from the atmosphere
- This produces 7200 l of ethanol
- This produces 3 tons of ethylene
- This produces 3 tons of polyethylene

The green designation is carried further downstream to the polymer products made from the green ethylene, such as green polyethylene plastic. Green in this case only refers to the process for making the polyethylene (i.e. reduced greenhouse gas emissions during production), not the properties of its composition (i.e. it is not any more biodegradable than ethylene made from fossil oil). In fact, the properties of polyethylene produced by green ethanol are identical to those produced by fossil oil.

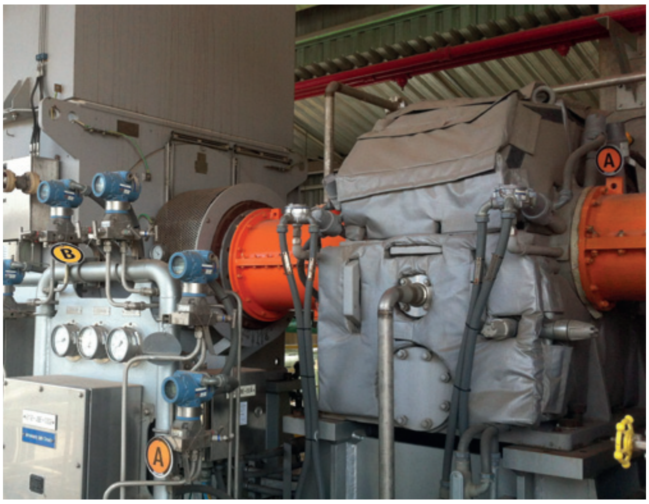


Figure 3. Propylene refrigerant compressor (left), charge gas compressor (right).

Monitoring strategy

The monitoring strategy for the machines at the green ethylene plant is very similar to that used in the two Braskem steam cracker olefin plants in the same petrochemical complex. However, because the process for the charge gas compressor and some of the pumps differs across the two processes, the subsequent potential failure modes may also be different. To date the plant has operated fault free so potential short-term process related faults such as surging and liquid carry-over never appeared and therefore are not considered to be a problem (nor were they ever expected to be). Time will tell if long-term process related faults like:

- Fouling in the compressors
- Corrosion in the compressors and pumps
- Erosion due to long-term minimal quantities of liquid carry-over in the compressors

will occur, but this is not expected.

The monitoring strategy for the bearings, shaft and seals of the compressors and pumps in both the green ethylene and petro derived ethylene plants is identical, as the expected machine loading (pressure, temperature and flow) is similar across both processes.

The economic benefits of condition monitoring of the green ethylene plant are enormous. If a bearing fault, for example, is allowed to fail and this consequently results in a catastrophic failure of the compressor, the costs to repair/replace the machine and lost production due to downtime are in the millions. Just considering lost production, a downtime of 7 days will cost € 3.9 M!

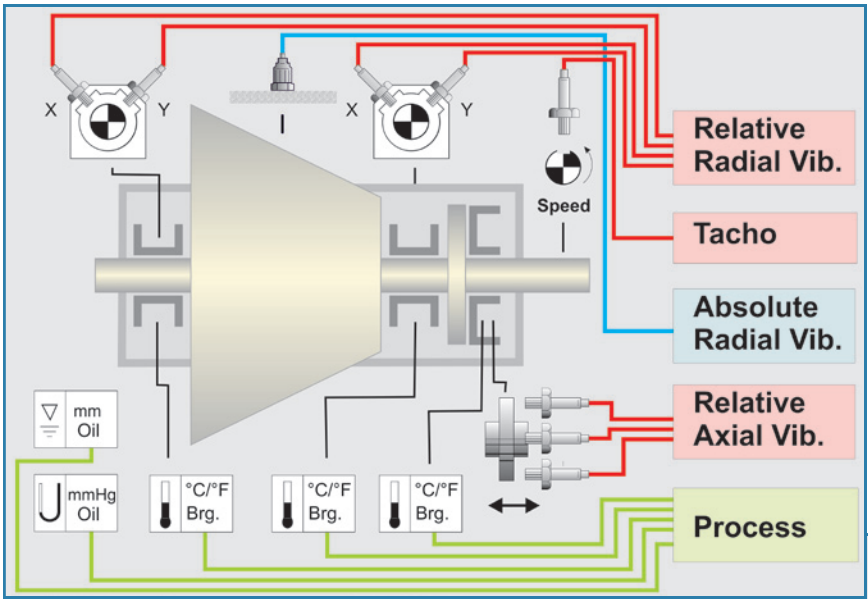


Figure 4. Charge and propylene refrigerant compressor online monitoring inputs: Red: 8x relative vibration sensors (radial, axial and tacho), blue: 1x absolute vibration sensor (casing), green: 5x process sensors (imported or measured).

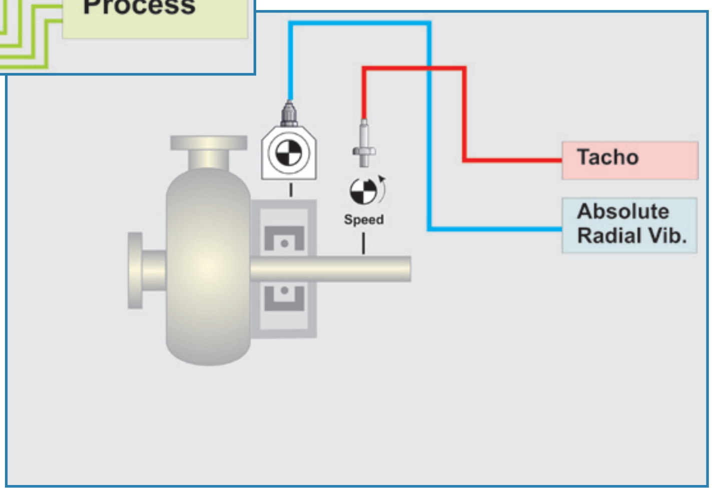


Figure 5. Typical process pump offline monitoring inputs: Red: 1x relative vibration sensor (tacho), blue: 1x absolute vibration sensor (casing).

Sensor (meas. point)	Online Measurements			Plots	Faults that can be detected and diagnosed
	Safety Monitoring	Condition Monitoring			
		Trending	Diagnosis		
Relative radial vibr. (shaft)	▪ **Overall** (ISO:1Hz/10Hz - 1kHz) ▪ S_{max}	▪ **DC** (bearing position)	▪ **Autospectrum** (FFT) ▪ **DC vs. RPM** ▪ **1x, 2x, 3x**	Trend vs. time/ speed, Spectrum, Waterfall, Orbit, Shaft position polar, Transient (Bodé)	Bearing damage, lack of lubrication, overload, wear, misalignment, unbalance
Tacho		▪ **Speed, phase**		Trend vs. time	Phase and triggering used in other measurements
Relative axial displ. (thrust brg)	▪ **DC** (displ.)			Scalar vs. time/ speed	Bearing damage, lack of lubrication, overload, wear
Absolute radial vibr. (casing)	▪ **Overall** (ISO:1Hz/10Hz - 1kHz)	▪ **CPB6%**	▪ **Autospectrum** (FFT)	Trend vs. time/ speed, Spectrum, Waterfall	General faults, flow problems, blade passage
Process (bearing, lube oil)		▪ **DC** (bearing temp. oil level, oil pressure)		Trend vs. time/ speed	Bearing damage, lack of lubrication, overload, wear

Table 1. Charge and propylene refrigerant compressor online monitoring techniques.

Sensor (meas. point)	Offline Measurements		Plots	Faults that can be detected and diagnosed
	Trending SW	Diagnosis SW		
Tacho	▪ **Speed, phase**		Trend vs. time	Phase and triggering used in other measurements
Absolute radial vibr. (casing)	▪ **Overall** (ISO:1Hz/10Hz - 1kHz) ▪ **CPB6%**	▪ **Autospectrum** (FFT) ▪ **Envelope** (bearing)	Trend vs. time/speed, Spectrum, Waterfall	Bearing damage, lack of lubrication, overload, wear, structural looseness, unbalance, misalignment, flow problems, cavitation, blade clearance, rubbing

Table 2. Typical process pump offline monitoring techniques.

Monitoring System Configuration

The Compass system has been monitoring the green ethylene plant since it was commissioned in 2010. Compass was first installed at the petrochemical complex in 1997 and is still being used to monitor the aromatics plant and the two steam cracker olefin plants. The experience gained from monitoring these plants were instrumental in establishing the monitoring strategy used at the green ethylene plant. In general, the Compass system is used for monitoring the critical machines and the Type 2526 Data Collector is used for monitoring the numerous auxiliary and balance-of-plant machines. Due to the large quantity of machines, ADVISOR is also used extensively to automatically scan the database for early detection of symptoms that could indicate a developing fault.

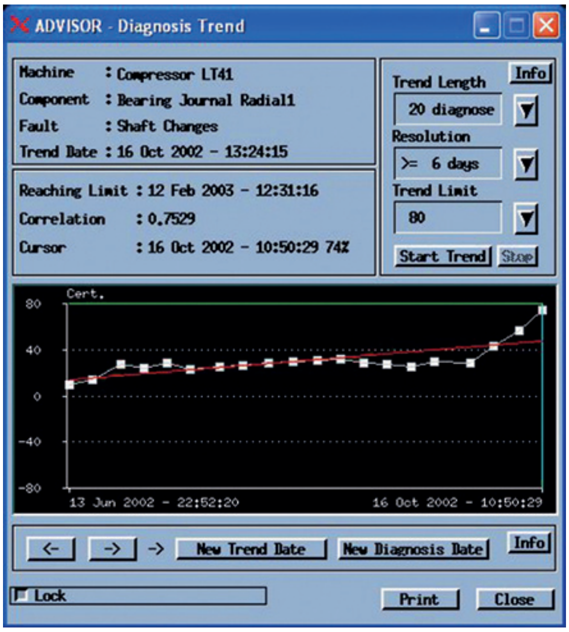
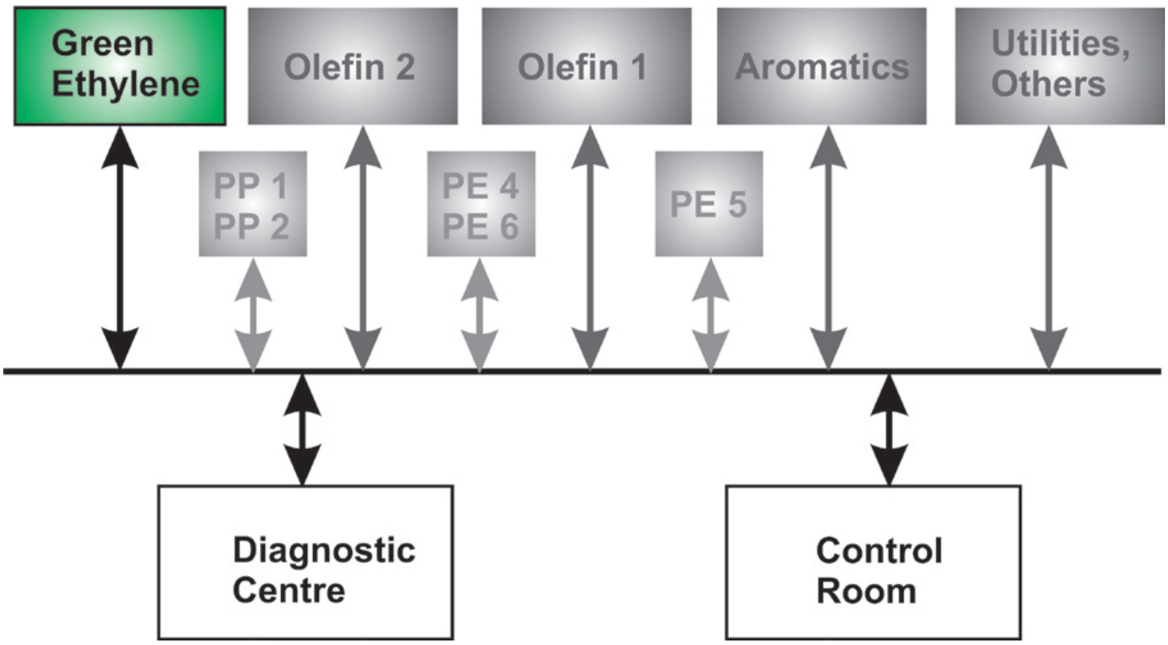


Figure 6. Typical diagnostics trend plot from Advisor for the green ethylene charge compressor.

Figure 7. Monitoring system configuration at the Triunfo Petrochemical Complex. Upstream plants shown on top, downstream plants shown in the middle.



Plant	Machines Monitored	
	Offline	Online
Green ethylene	58	2
Olefin 1	175	8
Olefin 2	150	6

Table 3. Number of machines monitored offline and online at the upstream plants at Braskem. As the green ethylene plant is much smaller than the olefin plants, there are fewer machines in the process. In addition to these upstream plants, there are almost 2000 machines monitored in the downstream polyethylene and polypropylene plants.

Conclusion

The green ethylene plant represents a breakthrough in environmentally friendly industrial processes, but the machines used are actually similar to those used in the petrol-derived ethylene steam cracker plants. Therefore, the monitoring strategy used for the machines is also similar. However, due to the large number of machines monitored, an integrated online/offline monitoring system together with an automatic machine fault diagnosis system is indispensable to economically and effectively track developing faults in such a large fleet of machines. This formula has successfully been used at the steam cracker plants in Triunfo since 1997, and it will continue to be used at the green ethylene plant. There is also a project in the pipeline for producing green propylene in the near future.

Acknowledgement

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