IGTC Gas Turbine Conference

Brüssel October 2018

Reliable power when and where you need it.
Clean and simple.

Capstone Turbine

- Founded 1988 − Commercial launch in 1998
- Public Corporation 2000 (NASDAQ: CPST)
- World leader in Microturbines
- Headquartered in Chatsworth, California
- More than 9,000 units shipped worldwide
- Over 50,000,000 operating hours
- Over 95 distribution partners and 787 dedicated distributor employees
- Installations in 73 countries worldwide
- Not heavily dependent on government subsidies
- Tremendous business leverage

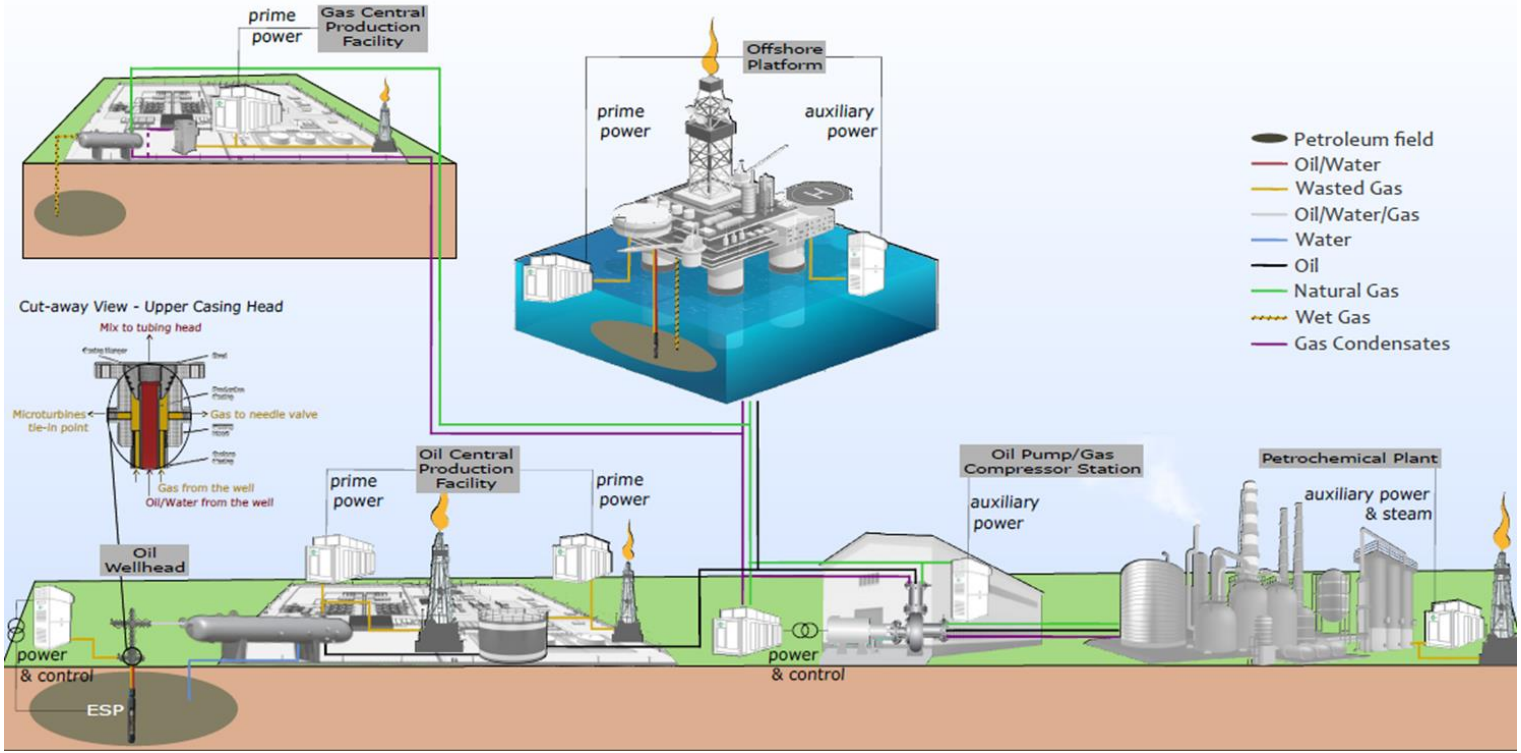
Global energy transition: a path forward

- Shift away from fossil-based energy generation
  1. Reduce and stop wasting extracted fossil energy – gas flaring: 158 GW average 2015
  2. Optimize usage of produced commercial fuels: butane CHP/CCHP, synthetic fuels, smart grid, hydrogen

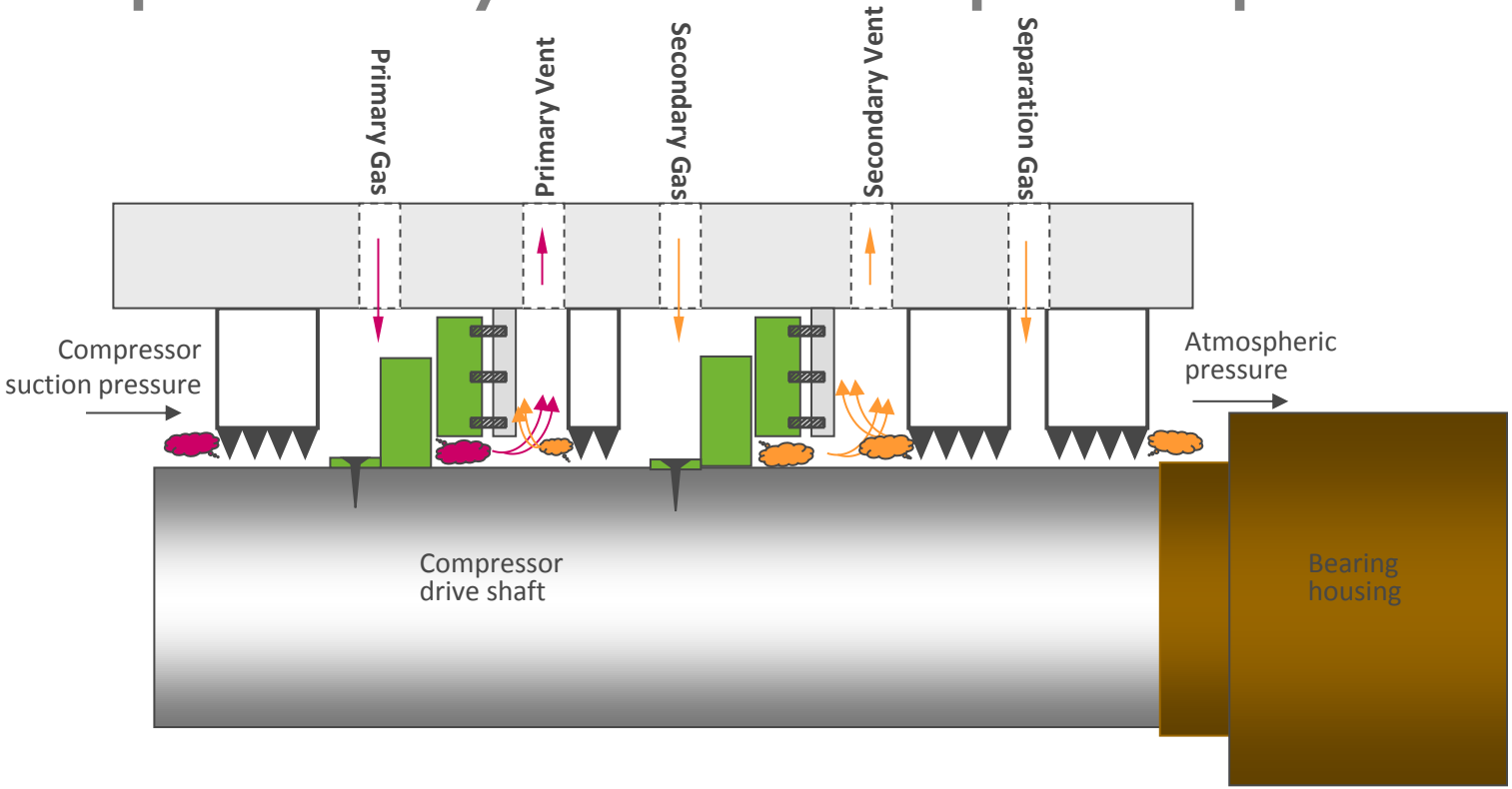
- Implement effective environmental regulation
  - Greenhouse gases emissions monitoring: CO_2, CH_4, N_2O
  - Public health: PM, CO, NOx, SOx

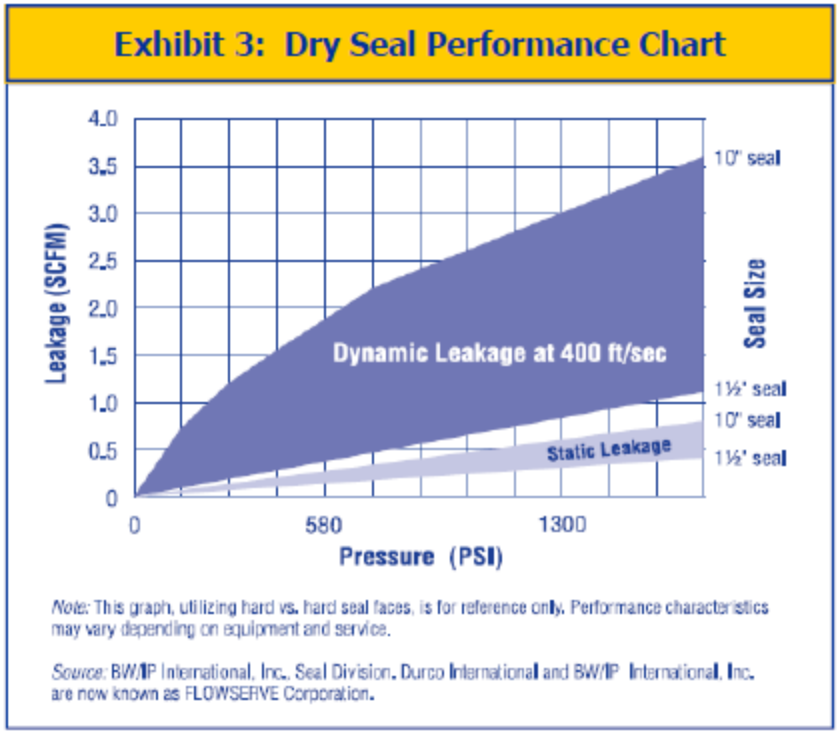
Gas storage application – Compressors dry seal

UPSTREAM MIDSTREAM DOWNSTREAM



Compressor dry seals – Principle of operation



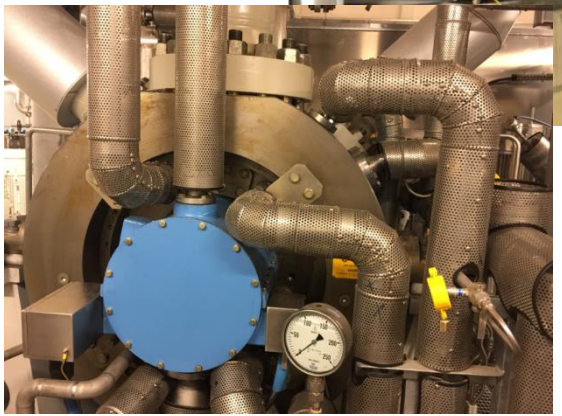


Source: BW/IP International, Inc., Seal Division. Durco International and BW/IP International, Known as Flowserve Corp.

- Separation gas Nitrogen
- On the flare NG 95%, Nitrogen <5%
- Oil seals are being replaced by dry seals
- Compression in this case from 50 bar to 200 bar
- Flare 20 m3/h, at a pressure of 2.5 bar
- Storage/buffer of 3 cubic meters

Gas storage application – Site description

- Underground gas storage facility connected to utility
- 50/50 cyclic operations:
  - Compressors are running during gas injection phase – **gas leakage**
  - Compressors are shutdown during gas selling phase – **no gas leakage**
- Dry seals leakage gas was captured and vented outside the building before Capstone installation
- Compressors are electrical-driven, no turbine/engine prime movers



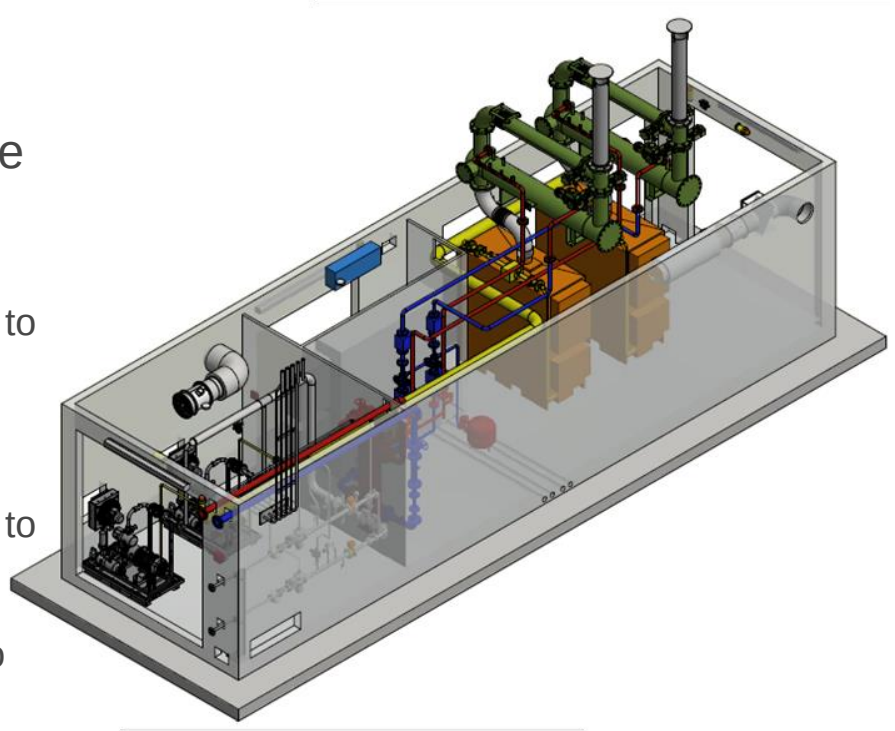
Primary seal gas leakage – conventional solutions

Solutions	Benefits	Constraints
No capture, vented through the package	No investment	Methane regulations, outdoor only
Capture and venting	**Very low investment**	**Methane regulations**
Capture and flaring	Low investment	No energy recovery, high gas flow
Capture and injection into gas turbines air inlet stream	Low investment, efficient, reliable, no maintenance	Conventional gas turbines on site
Capture, compression and injection into transportation/storage system line	100% gas recovery in the system	High investment, high gas commercial value
Capture and electrical valorization	**No wasted energy**	**High investment , high spark spread**

- **C30 Requires 433,000 BTU/hr (457 MJ/hr)**
  - 12.1 m3/hr of natural gas
  - 4.36 m3/hr or 17.4 l/hr of LPG (60/40 mix)
  - 12.8 l/hr of diesel fuel
- **C65 Requires 842,000 BTU/hr (888 MJ/hr)**
  - 23.6 m3/hr of natural gas
  - 8.47 m3/hr or 33.9 l/hr of LPG (60/40 mix)
  - 24.8 l/hr of diesel fuel
- **C200 Requires 2,280,000 BTU/hr (2,400 MJ/hr)**
  - 63.8 m3/hr of natural gas
  - 22.9 m3/hr or 91.6 l/hr of LPG (60/40 mix)
  - 66.9 l/hr of diesel fuel

Gas storage application – Solution description

- (x2) C65 CHP units, 130 kW nominal power and ~760 kBtu/hr hot water
- 2 gas compressors on dry seals leakage gas line, 5 bar MT inlet pressure
- Summer season:
  - During injection phase, the MTs export power to the grid, fueled by dry seals leakage gas
  - During selling phase, the MTs are shutdown
- Winter season:
  - During injection phase, the MTs export power to the grid and produce hot water, fueled by dry seals leakage gas
  - During selling phase, the MTs export power to the grid and produce hot water, fuel line switched to natural gas from facility



Gas storage application – Technology differentiation

- Flexibility – the MTs run w/o any deterioration
  - at partial load (1-100%): gas flow variations due to compressors operation
  - frequent start/stop cycles: multiple gas injection/selling cycles per day

- Emissions Comparison – mg/Nm^3 at ISO conditions, full power, 3% O_2

Component	C65 NG standard	C65 NG CARB	65 kW gas engine
NOx	57	24	100
CO	150	26	300
VOC (CH_4)	15	2	30

Gas storage application – Solution performances

- Economics
  - Satisfying in high spark spread areas
  - Environmental regulation is a key lever – emissions penalties, carbon incentives
- Greenhouse
  - 7 MMcf of methane emissions avoided per year
  - Greenhouse impact is equivalent to 3,585 metric tons of CO2 or 768 passenger cars
- Public Health
  - Ultra-low emissions

Capstone® Turbine Corporation

Thank you

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