GTEN 2019 Symposium
October 21-23, 2010 | Banff, Alberta

19-GTEN 208 Dawn Hub and Compressor Utilization

Paul Medd – Enbridge Gas Inc.

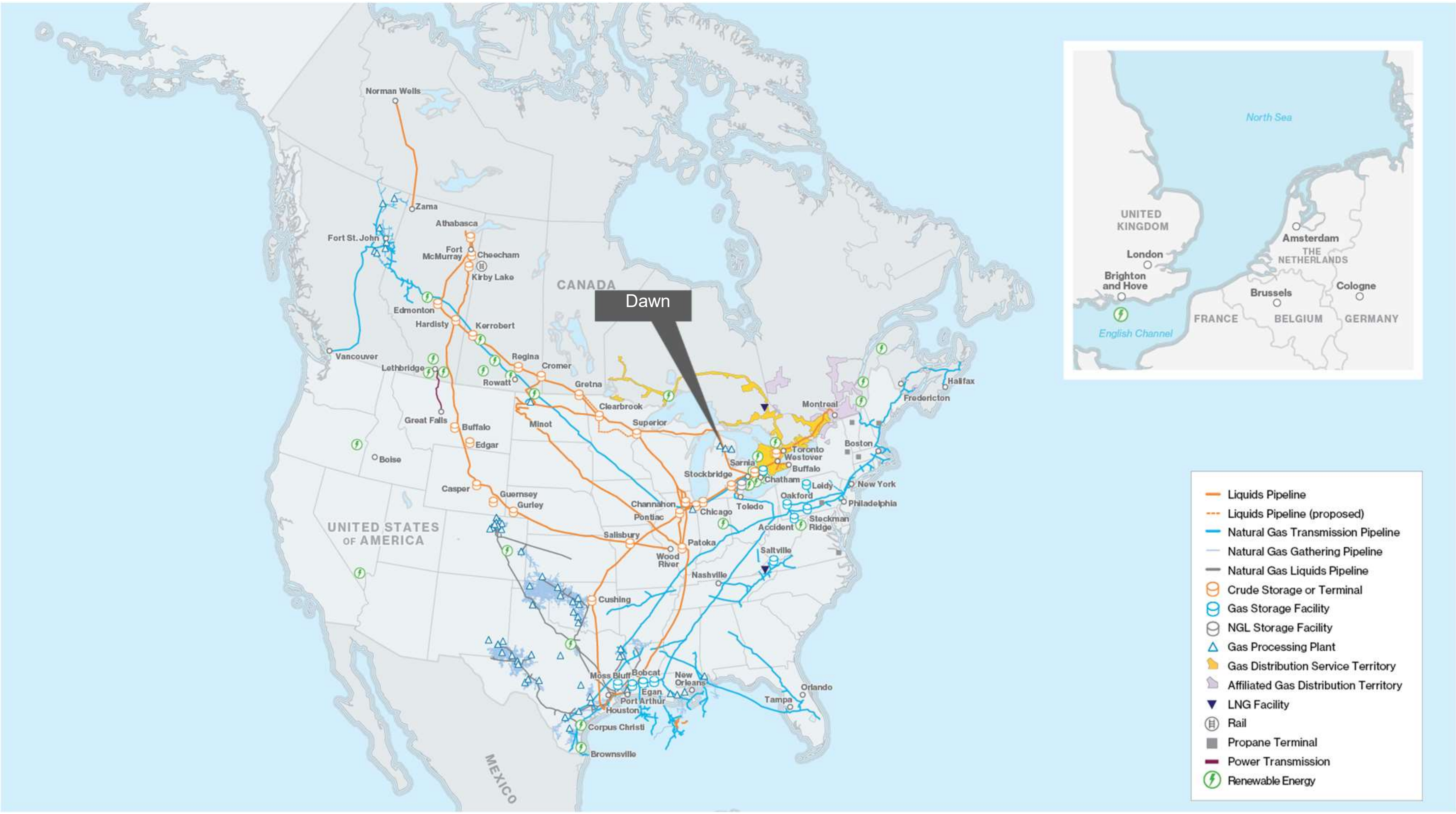
Presented at the GTEN 2019 Symposium, Banff, Alberta, Canada - October 2019

Dawn's Strategic Location

- Dawn is located about 20 miles south of Sarnia Ontario.
- Geographically, the 34 formations that are operated through the Dawn Hub are located in a position that brings gas close to heavily populated areas.
- Gas from the Texas Panhandle, Western and Eastern Canada, as well as the newly discovered shale gas formations are central to the Dawn Hub.
- Prior to the shale gas extraction in the U.S., the Dawn Hub supplied gas to the eastern US on a daily basis at a rate of 1 bcf /d or morevia the interconnect at Kirkwall.
- The production of shale gas in the eastern states such as New York and Pennsylvania has now turned this gas flow into an import into the Dawn - Parkway pipeline system for transportation to the heavily populated areas.
- Dawn sits in an area between Sarnia and Windsor that have many co-gen facilities that burn natural gas to provide electricity to the grid.

Major Pipeline Connections Throughout North America

The Dawn Hub and Enbridge Storage is a seasonal warehouse for natural gas being produced in the west and in the shale formations during off peak times. Withdrawals during peak winter season support residential and industrial load in eastern Canada and the United States.



Introduction to Dawn Storage

- Oil production in Lambton County dates back to the mid 1800’s when `gum beds` were recognized as a form of asphalt. Oil Springs, near the Dawn hub, was the site of Canada’s first commercial oil well in 1858.
- Gas reserves were identified in the surrounding area as part of the oil exploration activities in the late 1800’s and early 1900’s.
- Union Gas was established in 1911. Energy shortages were a major concern during the cold winter of 1918. The provincial government was forced to restrict industrial customers in favor of residential customers.
- During WWII, oil imports and reserves were also insufficient to meet the demands of winter.
- At the time, small imports of natural gas were delivered to Ontario on the Panhandle Eastern Pipeline Company, but were not sufficient to meet the heating needs of the area. Local production was also falling off year after year.
- In 1938, Dr. Charles S. Evans, Union Gas’s first full time geologist suggested that these tapped formations be used to store compressed gas through the summer months when demand was low, and withdraw to the customer during winter. In 1942, this vision became a reality with injections to Dawn 4749 pool.
- Once this new practice of injection / withdrawal was perfected and more storage was developed, it was evident that more gas had to be delivered to Dawn for storage. Dawn now had the ability to store 3.4 bcf of working inventory each year.
- In 1951 a 63 mile section of 16” was constructed from Windsor to Dawn to deliver more gas from the Panhandle Eastern system to Dawn.
- Through the late 1950’s the first 26” transmission line from Dawn to the Toronto area was built, followed by the 34”, 42”, and 48” through the next 40 plus years to keep pace with the energy needs of eastern Canada and the United States.

Dawn Plant Circa 1950 – 7 Reciprocating Engines Totalling 2500 HP

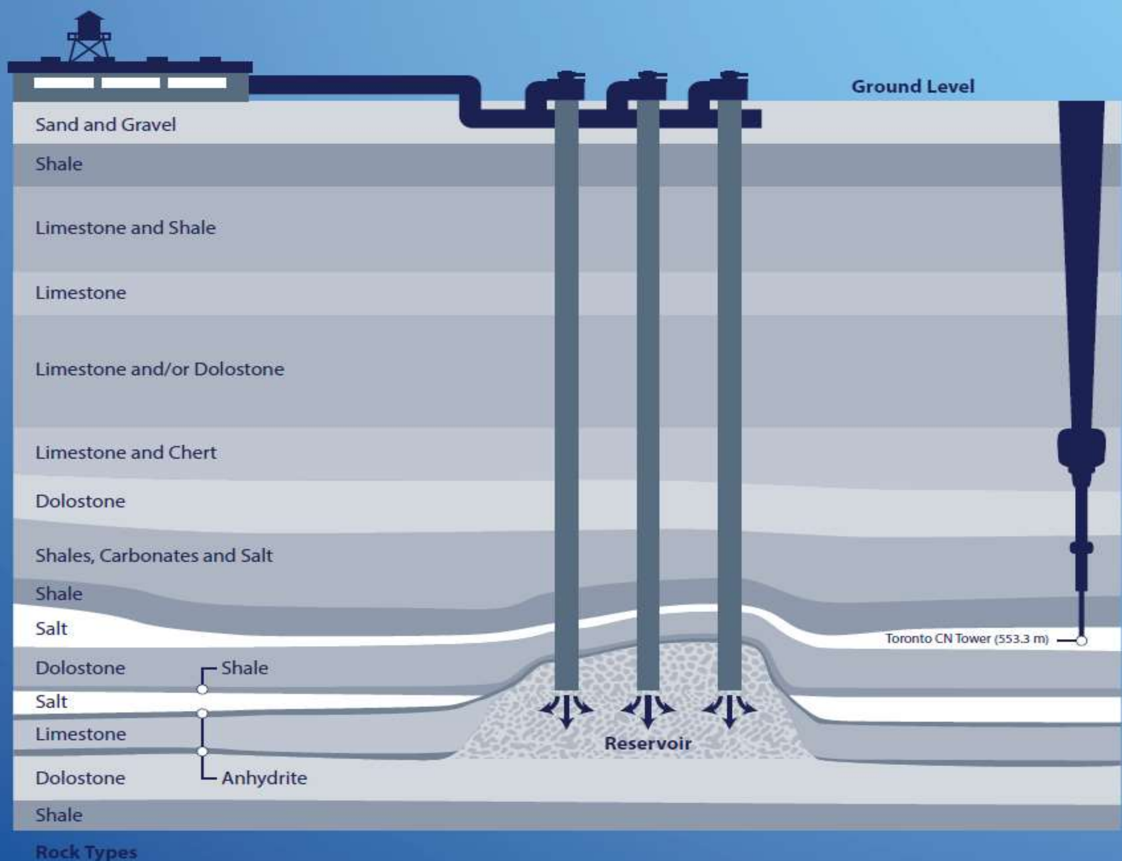
Current Dawn Plant

Area of the original Dawn Plant

GTEN 2019 Symposium

Naturally Occurring Storage Formations

Dawn Storage:
Naturally Occurring Underground Reservoirs



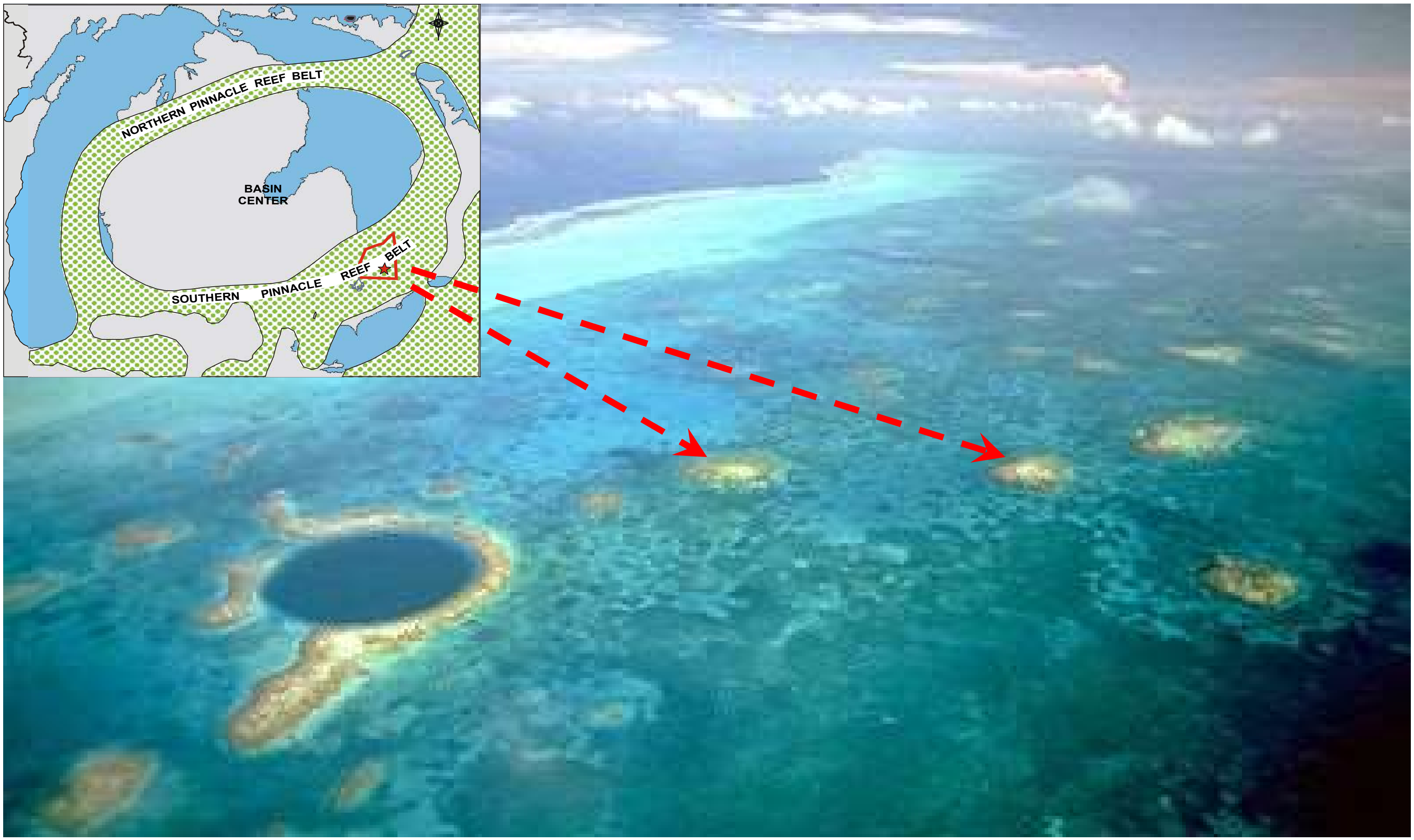
Dawn Storage allows Union Gas to purchase gas in the summer when it is less expensive, for use on cold winter days when it is needed most. Natural gas is injected into porous rock formations with billions of tiny holes for gas molecules to squeeze into.

Like customers use a bank account to deposit and withdraw money, customers from across North America use our Dawn storage system to save energy until they need it.

uniongas
An Enbridge Company

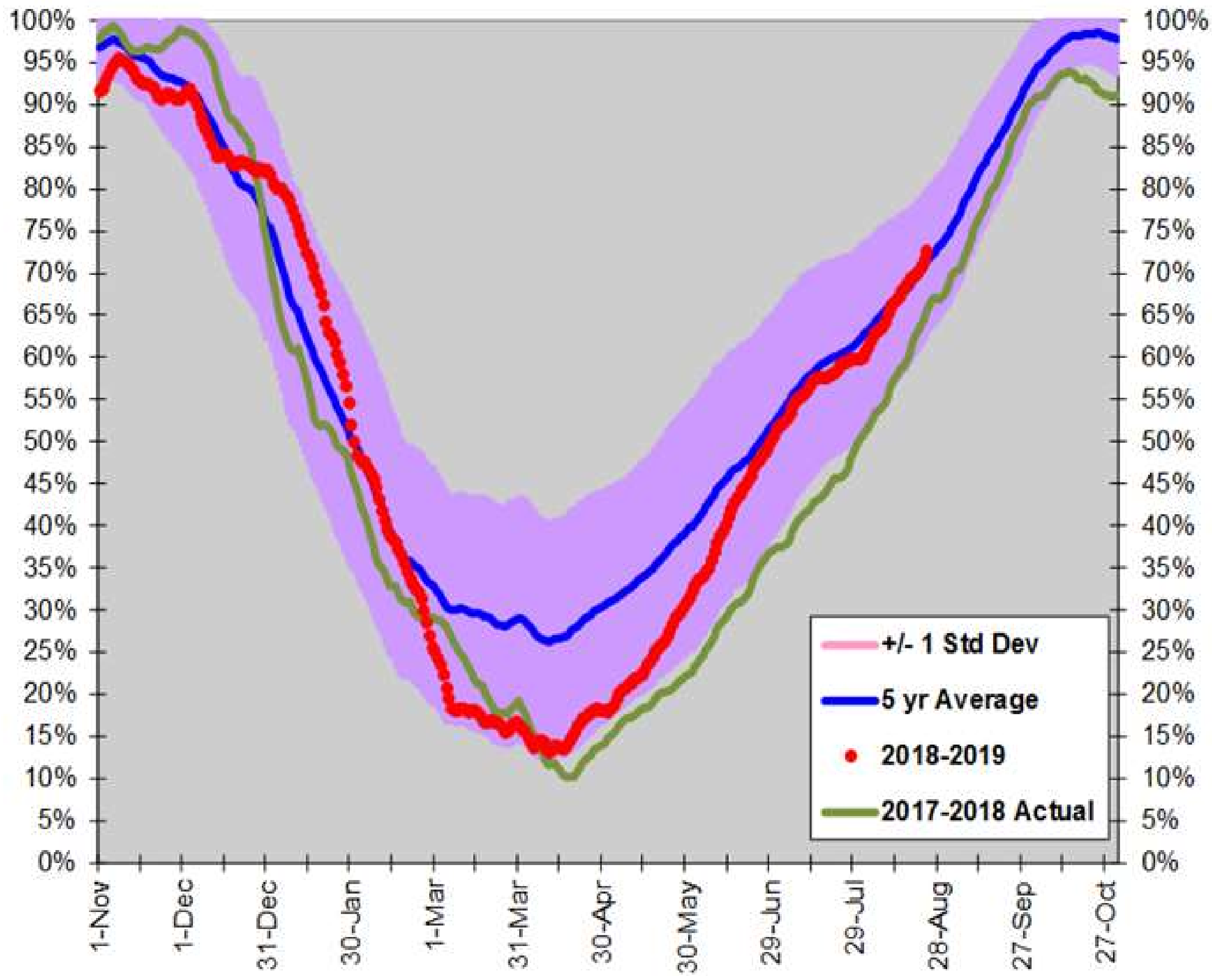
DAWN STORAGE CELEBRATING 75 YEARS EST. 1942

Natural Underground Pinnacle Reef Formations Millions of Years Old



GTEN 2019 Symposium

Storage Volume Increases 1942 - 2017

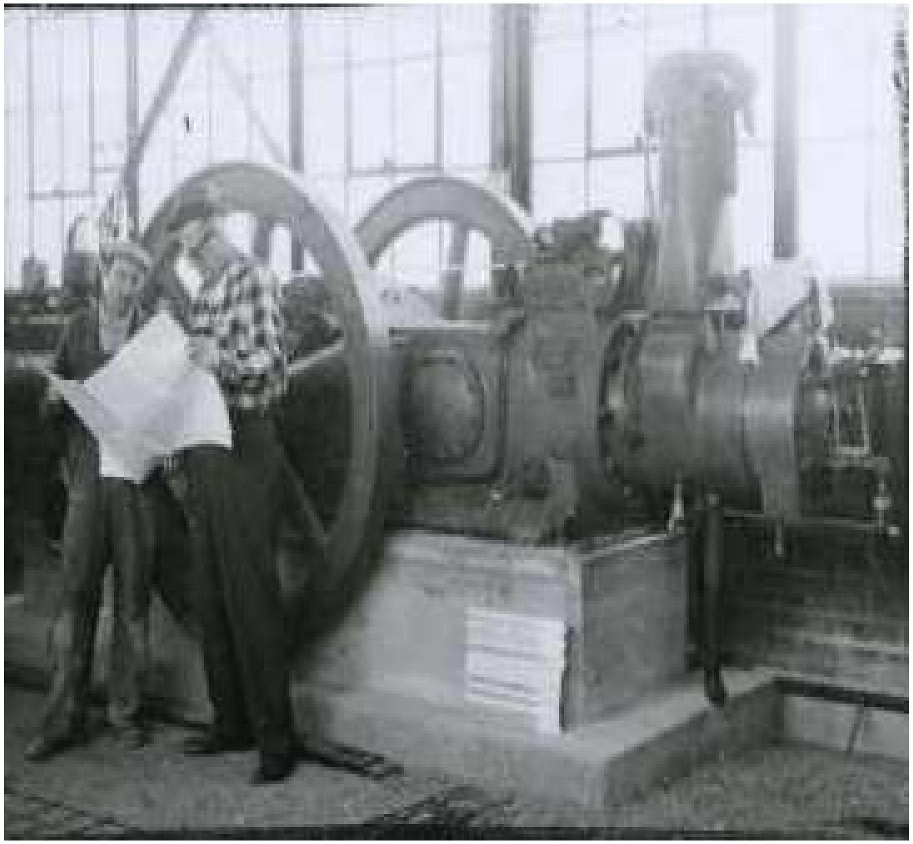


- Injection / withdrawal inventory curve
- Compares averages with the past 2 years

Compression Technology From 70 hp to 35,000 HP

Compression at Dawn has evolved from a 70 HP single cylinder compression to 300 – 3400 HP multi cylinder compression to the latest turbine units ranging from 13,000 to 44,500 hp.

70 HP single cylinder compressor used for production circa 1930



35,000 HP Plant G – RB211-24C driving 3 compressor cases 1993

The Move to Turbine Driven Compression

- The first turbine driven compressor unit was constructed at Dawn in 1978. This plant was known as `Plant B`, and it was impressive for that era. The package included a Rolls Royce RB211-22, driving two compressor cases that could be operated in a series or parallel mode. At 26,700 HP, this package almost doubled the existing power available in the entire reciprocating plant. At the time, this power was something that was hard to manage given the infrastructure of the existing plant piping and overall system. It was ahead of its time. The series and parallel modes, made it flexible to perform storage injection and withdrawals, and the parallel mode was used primarily for transmission applications.
- Plant B was used sparingly at first until the Dawn yard modifications and the transmission system expanded to fit this level of horsepower. The addition of a hydraulic coupling after the original build allowed the use of only the inboard compressor, which then allowed for more flexibility with smaller gas flows.
- As the storage activity increased and the need for high volume withdrawals during peak times became common, `Plant C` was built at Dawn in 1982. The package included a Rolls Royce RB211-24A, also driving two RRBB36 compressor wheels that could be operated in a single or series mode. At 30,270 HP, this package was ideal as a storage withdrawal unit to meet the demands of the system during cold weather.
- Plant C was able to pump 500 mmcfd from low pressure storage pools at pressures down to 200 psi. Reciprocating compression at the time could not achieve these low pressures and flows. With reciprocating compression to reach this performance, we would have to build 10-15 units. Both Plant B and Plant C had maximum discharge pressures of 1000 psi
- As the storage withdrawal activity accelerated, the need for dehydration was realized in 1985. The summer of 1985 saw the construction of an additional 42” header and modifications to the Enbridge (Tecumseh) storage piping into Dawn. Storage gas from both Union and Enbridge could now be dried to meet the gas quality requirements of the transmission system. The dehydration facility today is one of the largest natural gas drying facilities in North America. The 4 contactor towers can handle up to 5.17 bcf of total flow and reduce the moisture content from as high as 20 lbs / mmcf to less than 4 lbs / mmcfd, which meets the current tariff standards of pipeline quality.

Dawn Dehydration Towers and Glycol Regeneration Boilers

Reciprocating Compression at Dawn

Operational and instrumental for summer injection phases of the operation.- 1957 through till approximately 2008

- 3 – 2000 HP Units
- 2 – 3400 HP units.

- Combined turbocharged units totalled 12,800 HP

- Plant F in 2006 was built with 2 Solar Taurus 70 units that far exceeded the power output and flexibility of this reciprocating plant, making it obsolete.

The twin Solar Taurus 70 units allowed the Dawn Plant to decommission the remaining reciprocating compressors after they were built in 2006.

Expansion of Gas Turbine Power at Dawn

- Between 1989 and 1993, three RB211 – 24C units were installed at Dawn. Plant D was designed primarily for low pressure withdrawals, Plant E was designed for high volume transmission and Plant G was a one of a kind 3 compressor unit with the flexibility to do both transmission and storage operations.
- During these 4 years of rapid horsepower expansion at Dawn, the transmission system piping and line horsepower at Lobo and Bright were also expanding. Markets for natural gas east of the Parkway Station were growing quickly.
- Reciprocating compression was still critical to the injection phase at Dawn until 2006 until Plant F was built. Large RB211 units were simply too much power for day to day storage injections.
- Two years later in 2008, another 44,500 HP unit was installed for the purposes of withdrawing large volumes in the spring on a \`design day\`. Plant I was designed with twin 5 stage compressor cases and can be operated in single case or parallel mode.
- In 2011, another Solar Taurus 70 was constructed at Dawn to increase our injection flexibility and also to help fine tune our power requirements day to day.
- The latest and largest expansion at Dawn saw a new 44,500 unit constructed for transmission purposes. Dawn Plant H was in service in the fall of 2017, and saw over 1000 hrs of operating time in its first winter season. As part of this expansion, the original RB211-22 (Plant B) from 1978 was decommissioned and demolished.

GTEN 2019 Symposium

- The Dawn yard becomes increasingly complex as gas balances from plant to plant are managed. Process control within the compressor plant and also points of control within the yard headers is critical to the balance each plant needs to perform its function.
- The Dawn yard is made up of 8 major headers, most of which are 42” and 48” in size.
- The headers are strategically designed to meet not only the high volumes from storage during peak winter demand, but also to compress gas back into these same formations throughout the summer. There are many `typical` yard configurations that need to be in place as the storage pools collectively come down in pressure.
- The Operations group at Dawn, along with the Gas Control and Capacity Planning group will forecast expected Dawn send out volumes in advance and move to the necessary header and horsepower configuration before the markets pick up. Making yard configuration changes and horsepower changes during periods of high send out is not recommended, as it may be difficult or impossible to recover from any unexpected outage during heavy system loads.
- One of the major challenges with gas to the market lines and also to the transmission line is the moisture content. In order to maintain acceptable levels of moisture without the cost of running the large Dawn dehydration plant, Operations will blend dry transmission gas that is received from GLGT and Vector with storage gas to create an acceptable mixture.

Slide 17

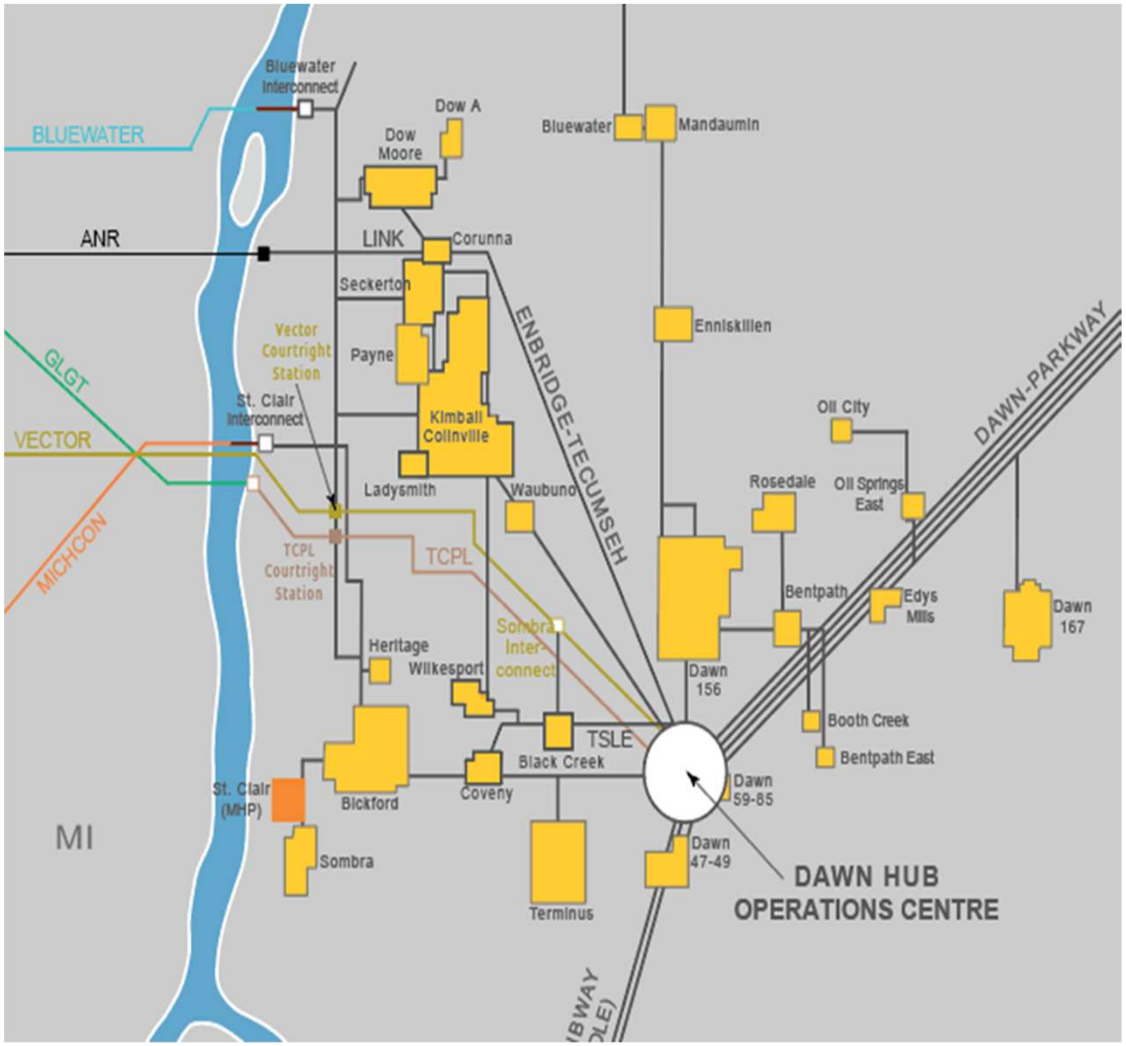
BW13 see previous comments

Bob Wellington, 2019-06-28

BW12

GTEN 2019 Symposium

Dawn Hub Peak Day Withdrawal Capabilities



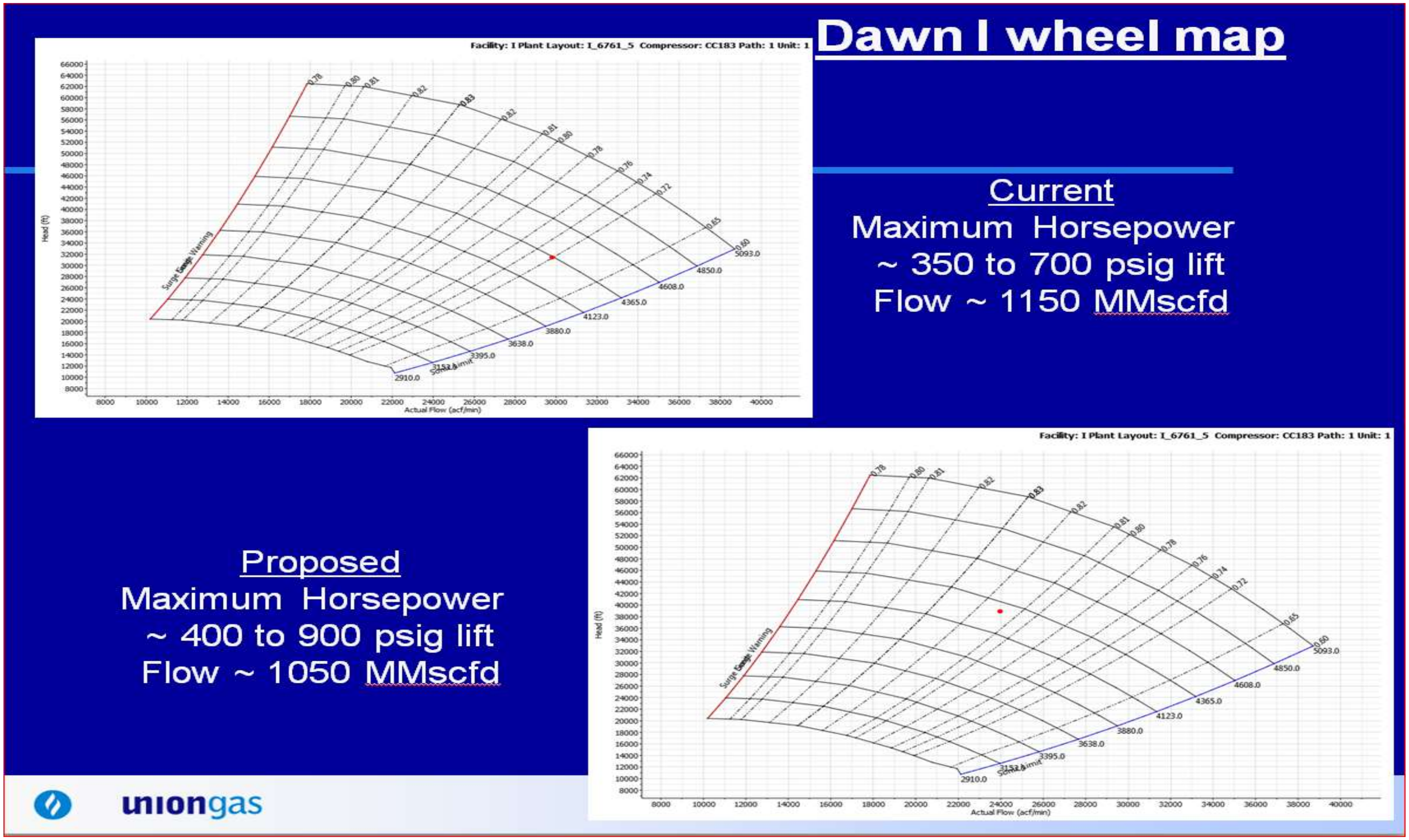
- During the last winter cold period between Jan 30 – Feb 2, `Legacy Union` storage withdrawals peaked at 5100 / km3 / hr (4.35 bcfd), and `Legacy Enbridge` peaked at 2150 km3 / hr (1.85 bcfd)
- On Jan 30th 2019 gas day, we surpassed the previous storage withdrawal record by 19%.
- The Dawn and Corunna (Tecumseh) compression was critical in the delivery of clean, dry storage gas to the eastern markets of both Canada and the U.S. during the Jan 30 – Feb 2 timeframe last winter season.
- During the peak withdrawal season, expected dry transmission volumes from TCPL (from Great Lakes Gas Transmission at Dawn and the Kirkwall Interconnect east of Bright), and Vector Pipelines can be reduced considerably as the demand for gas increases.
- Horsepower reliability and timely starts are critical as the system reaches it capacity. Any outage can be very difficult to recover from when the system is under heavy load.

Slide 18

BW12 All good info to use in speaker notes and in your paper. For the presentaiton, I would just leave this slide out and speak to the Dawn Hub drawing I've pasted in slide 12.

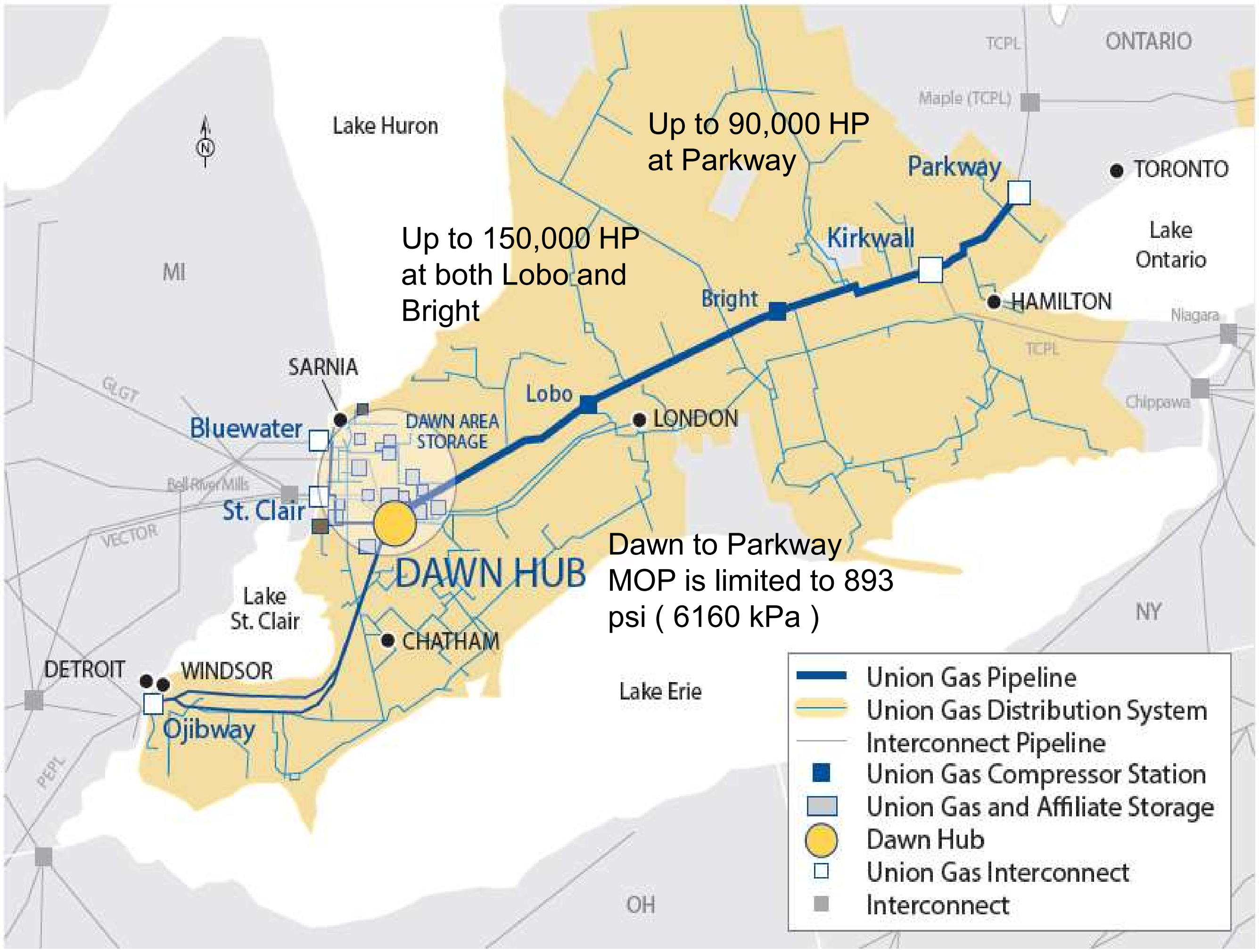
Bob Wellington, 2019-06-28

Dawn Plant `I` Wheel Map – Design Day Withdrawal Capabilities
Compression can be set up based on the health of the storage formations when high withdrawals are required. Higher suction pressure at 400 psi allows for a direct lift to the mainline piping.



GTEN 2019 Symposium

Transmission Lines Leaving the Dawn Hub



- 225 km Dawn to Parkway corridor made up of 26”, 34”, 42” and 48” transmission lines. On peak winter days, over 75% of the gas leaving Dawn exits the system at Parkway.
- The GTA, and markets in Eastern Canada and the U.S. are supported with this export.
- Many times, 90% of the gas leaving Dawn is storage gas withdrawn from available storage.
- 80 km Dawn to Windsor Panhandle Transmission made up of 36”, 20” and 16” lines to power generation and greenhouse loads

Seasonal Complexity of the Storage System

- The Dawn facility is also a complex storage hub during the summer months.
- Storage injections are managed through the Dawn facility, Legacy Spectra remote compression, and Legacy Enbridge compression at the Tecumseh Plants. The gas injected to the Legacy Enbridge storage pools is delivered to them through the Dawn Plant.
- Storage formation maximum pressures range from just over 6900 kPa to as high as 11,500 kPa.
- The dedicated pressures to fill high pressure storage sometimes require multiple stages of compression at different plants to achieve the final pressure required to get the formation to the official MOP before shutting in for it stabilizing period.
- The entire system includes more that 1900 valves and approximately 105 MOP separation points.
- The Dawn MCR and the Legacy Enbridge Control Room at Tecumseh have specific injection strategies to combine these pools with the appropriate horsepower to ensure they are full in a timely manner, then stabilized and made available for withdrawal.

Dawn Hub Summary

- Largest gas compressor facility in North America.
- Largest integrated storage facility in Canada.
- One of North America's most liquid natural gas trading hubs, Dawn provides direct access to North America's major supply basins.
- We have 34 storage pools – all having different characteristics that must be managed year round
- 280 Bcf/d – Total Storage Working Inventory, cycled seasonally
- 5.8 Bcf/d of combined Design Day Deliverability from the combined storage
- Without this seasonal supply in the area of Southwestern Ontario, the landscape of industry, population, and energy possibilities would be vastely different than they are today

The Human Element in Operations

- The Master Control Room at Dawn (MCR) controls the balance between storage requirements and transmission requirements to meet the needs of the pipeline system around the clock. SCADA systems and a local DCS system provide the MCR with the necessary information and control to maintain supply nominations and pipeline system requirements.
- The Dawn MCR controls the balance of the entire pipeline from Dawn to Parkway by instructing the plants at Lobo, Bright and Parkway on their operation. With each section of the four pipeline system being roughly 45 miles, and each plant equipped with over 150,000 HP, there is a delicate balance of line pack, compressor efficiencies and compressor pressures across the system. These requirements are managed through the Dawn MCR to the various stations.
- With increasing nomination windows within the gas day, supplies can be unpredictable. During peak times, the MCR will use line pack as a defense against compressor failures, supply decreases or unpredictable load increases. During times of high throughput, other gas utilities are also under operational stress to manage demand. The Dawn Plant and storage system can be a backstop at times for other utility outages during peak times.
- Many of the decisions on the system operation are done by experience, instinct and a collective discussion between the System Operator, the Shift Manager, and the Advisor of System Operations. Experience plays a key role in anticipating system loads and reacting to unexpected outages. Recovery time is a key factor when outages occur. The MCR plans as best they can for compressor recovery with spare units.
- System Operator roles are key to the system management. Since this role is seasonal in nature, a System Operator may have to experience several winter seasons to develop instinctive pipeline strategies and setups to meet the needs of the system.
- As well, the flexibility complexity of the Dawn yard itself, and the key points of balanced control may take several years of experience to truly feel comfortable with.
- As seasons change, the characteristics of the pipeline system and compression change with added pipelines, added blocks of compression or the change in compressor wheels. Each modification to the system will require the MCR to again become comfortable with the overall system performance.

Questions ?


HIGH
MEDIUM
LOW
GROWTH
CUSTOMER SERVICE


CustomerExperience
CustomizedService
Competitive
Growth
Transparent
Diversity
Options
Security
Flexible
DAWN
Liquid
CustomizedServices
Economic
Diversity
Options
Liquid
CustomerFocus
Competitive
Transparent
Growth
Liquid
DAWN
CustomizedService
TransportationServices
Options
Growth
CustomerFocus
Competitive
Liquid
Transparent
CustomerFocus
Economic
Storage
Transparent
CustomizedServices
Economic
Flexible
CustomerExperience
Storage
SecurityOfSupply
Diversity
THANK YOU

Dawn Plant D Gas Turbine at Work Withdrawing Gas From Storage