SLB Digital Forum 2022

DEXPro™ & TOp™
"A long awaited team"

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DEXPro
INNOVATIVE DEHYDRATION TECHNOLOGY

Introduction – “the long-awaited dream”

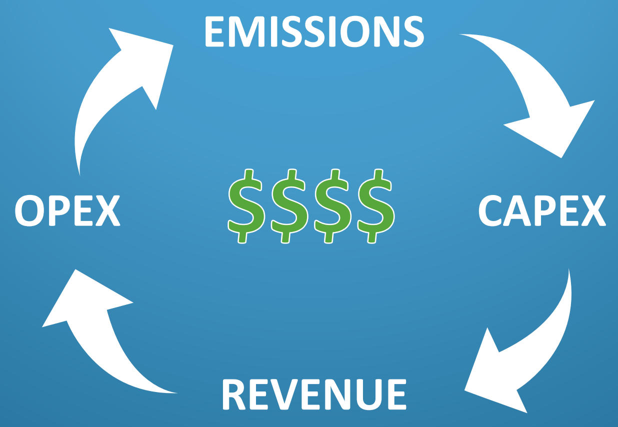
- Started in the heavy oil and thermal operations of Alberta, Canada as a summer student in the infamous 70’s
- Learned drilling, completions, and production engineering in the field over the following several years
- Finally settled into facilities engineering with a producer and eventually as a consultant in the EPCM world
- It was back in 1987 that I got my first exposure to process simulation software (Hysim as it was known at the time), and I was hooked on the power, capability, and magic of it all
- I recall asking the smart guys of the day, “Why can’t we give the software live information and let it manage processes in real time?”
- It has been 35 years, but we finally have the capability!!

Introduction – DEXPro™

- DEXPro™
  - Acid gases, such as CO_2, H_2S, SO_X and NO_X, require dehydration prior to transportation for sequestration or utilization
  - DEXPro™ uses the inherent properties of acid gases to provide a cost-effective, simple, elegant, space saving, emission and chemical free solution to acid gas dehydration
  - In CO_2 EOR applications, DEXPro™ has the potential to provide a significant incremental revenue stream

Introduction – TOp™

- TOp™ - Throughput Optimization
  - A distributed process simulator driven solution that enables real-time dynamic process optimization
    - advanced dynamic control capability
  - Optimization directly impacts the bottom line



2 Key Business Drivers

1. CO_2
   - Migration from hydrocarbon to electricity
   - Significant investment in electric infrastructure will be needed
   - Consumer costs will increase – likely substantially
2. Hydrocarbon
   - Demand <u>should</u> decrease due to,
     - the existing fixed infrastructures and smaller modes of transportation that can transition from hydrocarbon source of enrgy to electric, and
     - the increasing alternative power generation capacity

2 Key Business Drivers

2. **Hydrocarbon (cont'd)**
   - But will likely increase due to,
     - 2nd and 3rd world economies striving to elevate their standard of living, and
     - civil and international unrest…
       - a change in the status quo, such as the global change to an electric economy, creates conflict as people, businesses, and governments try to gain controlling positions in the new environment
       - conflict at the world level consumes big volumes of Hydrocarbon
       - we can see obvious evidence of this playing out nearby as we sit here today

2 Key Business Drivers

2. Hydrocarbon (cont'd)
   - Net increase in demand will result in sustaining or increasing the cost of hydrocarbon fuel going forward
3. Bottom line
   - Beyond the COVID induced inflation cycle we are facing, the evolution of our current path will likely result in a step change increase in both OPEX and CAPEX of oil & gas facilities, as well as similar facilities in other industries (chemical, pulp & paper, mining, etc.)

Optimization

- Equipment and Operations
  - Equipment and operating parameters fixed during design
  - Optimization efforts will likely only produce small incremental gains
- Process
  - New technology (a.k.a. TOp) has enabled a step change in process optimization capability
  - Moving the simulation capability from offline into an onsite, online, real-time dynamic environment, bridges the disconnect between facility design and facility operation.

Optimization

- Process (cont'd)
  - The opportunity to improve efficiency in dynamic real-time translates into an increase in the bottom line
    - Increase throughput (REVENUE), with same CAPEX
    - Reduce CAPEX, with same throughput
    - Reduce OPEX
      - energy demand
      - consumables
      - manpower
    - Reduce EMISSIONS
      - Scope 1 and Scope 2

Case #1 – Compressor Coolers

- Case #1 – Compressor Coolers
  - Current configuration (static)
    - Cooler set 15 °C (27 °F) set back from phase envelope
      - Large safety margin from phase envelope incursions due to daily and seasonal pressure and composition swings
  - Intelligent Optimization (dynamic / real-time)
    - Cooler set 3 °C (5 °F) from phase envelope
  - Results (annual cost of power saving @ $0.10 / kW-hr)
    - Central Alberta, Canada
      - $280k / 100 MMscfd or $146k / 1 MM tonne/yr
    - West Texas, USA
      - $198k / 100 MMscfd or $103k / 1 MM tonne/yr

Case #2 – Hydrate Inhibitor

- Case #2 – Hydrate Inhibitor
  - Current configuration (static)
    - Inhibitor rate set 15 °C (27 °F) set back from phase envelope
      - Large safety margin from predicted hydrate formation temperature that was determined during design
      - Rate is highly variable according to throughput, pressure, temperature, content of former components, and water content
      - Daily and seasonal swings in variables require constant changes to optimum inhibitor rate
  - Intelligent Optimization (dynamic / real-time)
    - Optimum inhibitor rate calculated in real-time
  - Results (varies widely with every application)

Case #2 – Hydrate Inhibitor, cont'd

- Case #2 – Hydrate Inhibitor
  - Pilot test results on a DEXPro™ CO_2 EOR application
    - 52 MMScf/d (1 MM tonne/yr)
    - Operating target was hydrocarbon liquids recovery
    - Temperature below hydrate formation (4 °C / 39 °F)
    - MeOH injection rates
      - Static → 75 kg/hr (approx. 9 °C above HFT)
      - Dynamic → 24 kg/hr (approx. 0 °C above HFT)
    - Annual cost saving → $241,850 US @ $1.64 / gal
  - Results vary widely with every application

Case #3 – Hydrate Control

- Case #3 – Adding process heat to avoid Hydrate
  - Current configuration (static)
    - Process temperature set high
      - Large safety margin from predicted hydrate formation temperature that was determined during design
      - HFT is highly variable according to pressure, temperature, content of former components, and water content
      - Daily and seasonal swings in variables require constant changes to optimum process temperature
  - Intelligent Optimization (dynamic / real-time)
    - Optimum process temperature calculated in real-time
  - Results (varies widely with every application)

Case #4 – Process Target (water content in CO_2 pipeline)

- Case #4 – CO_2 Pipeline Water Content
  - Current configuration (static)
    - Typical N. American CO_2 pipeline water content limit
      - Margin from water dewpoint at buried pipeline temperature and pressure on the coldest night in the last 100(?) years
      - 30 lb/MMscf (appr. 3:1 safety margin @ 40 °F / 4 °C)
        - 631.9 ppm_{MOL} / 211.4 ppm_{STDVOL} / 258.8 ppm_{MASS}
        - Dewpoint → -8 °F (-22 °C) | Hydrate → -1 °F (-18 °C)
      - Actual water content requirement in the summer when the process is working the hardest is much higher
  - Intelligent Optimization (dynamic / real-time)
    - Optimum water content calculated in real-time
  - Results (varies widely with every application)

Case #5+ – Process Targets (real-time)

- Case #5 – NGL Content in Natural Gas
  - Maximize economics of NGL content up to dew point limit
- Case #6 – Dewpoint control
  - Real-time dewpoint control according to process stream composition and flowrate changes
- Case #7 – Product blending
  - Real-time blending to spec according to feed stream composition and flowrate changes
- Case #8 – Distillation column control
  - Real-time operating point control (overhead reflux, reboiler operating point, etc.) according to process stream composition and flowrate changes
- Case #7 – Input your imagination here

DEXPro™ - TOps

Throughput Optimization process solution

World-class technology from parent companies
Rockwell Automation and Schlumberger
+
Process and system integration knowledge from DEXPro™
=
Value through real-time intelligent optimization

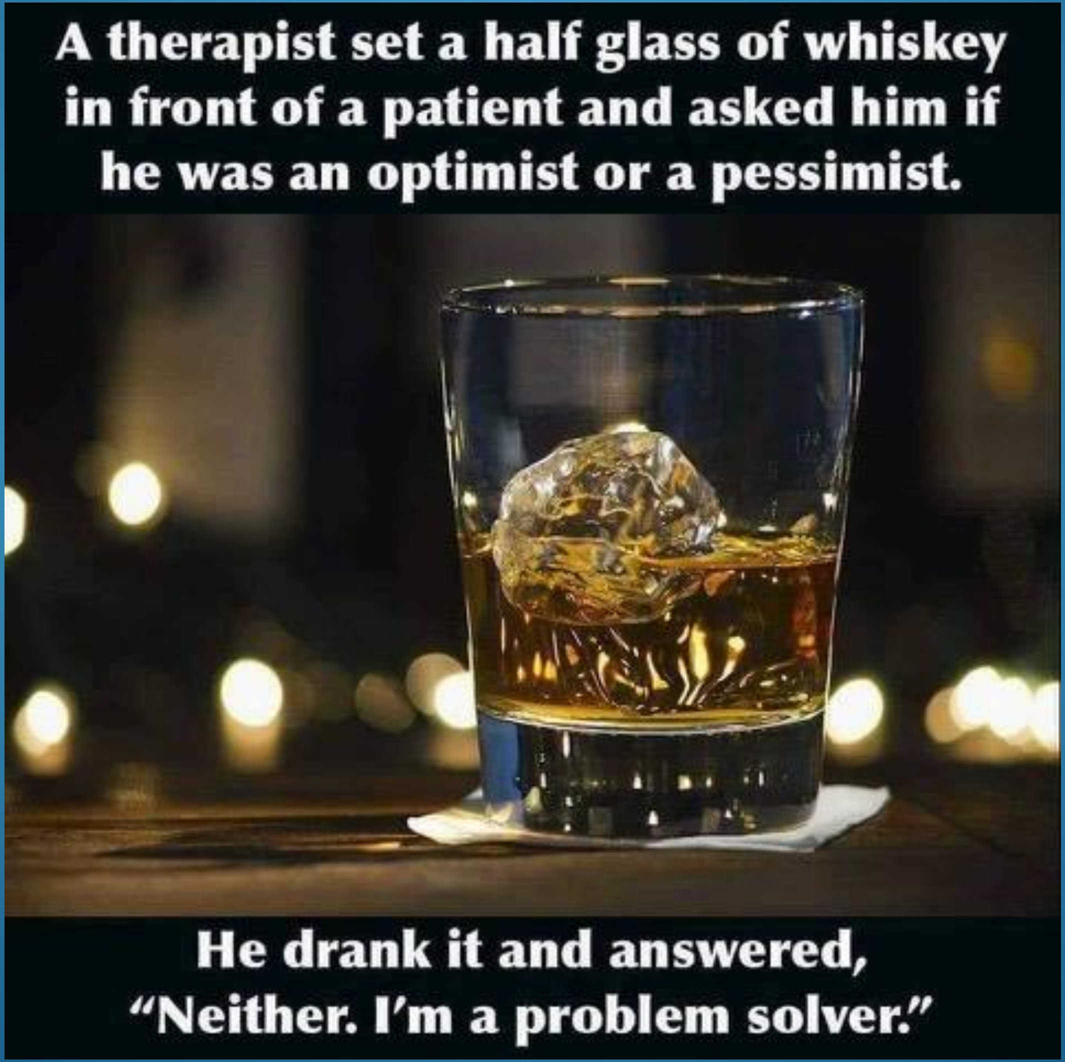
DEXPro
INNOVATIVE DEHYDRATION TECHNOLOGY

sensia
Rockwell Automation + Schlumberger

Rockwell Automation

Schlumberger

Optimist or Pessimist ?



QUESTIONS ?

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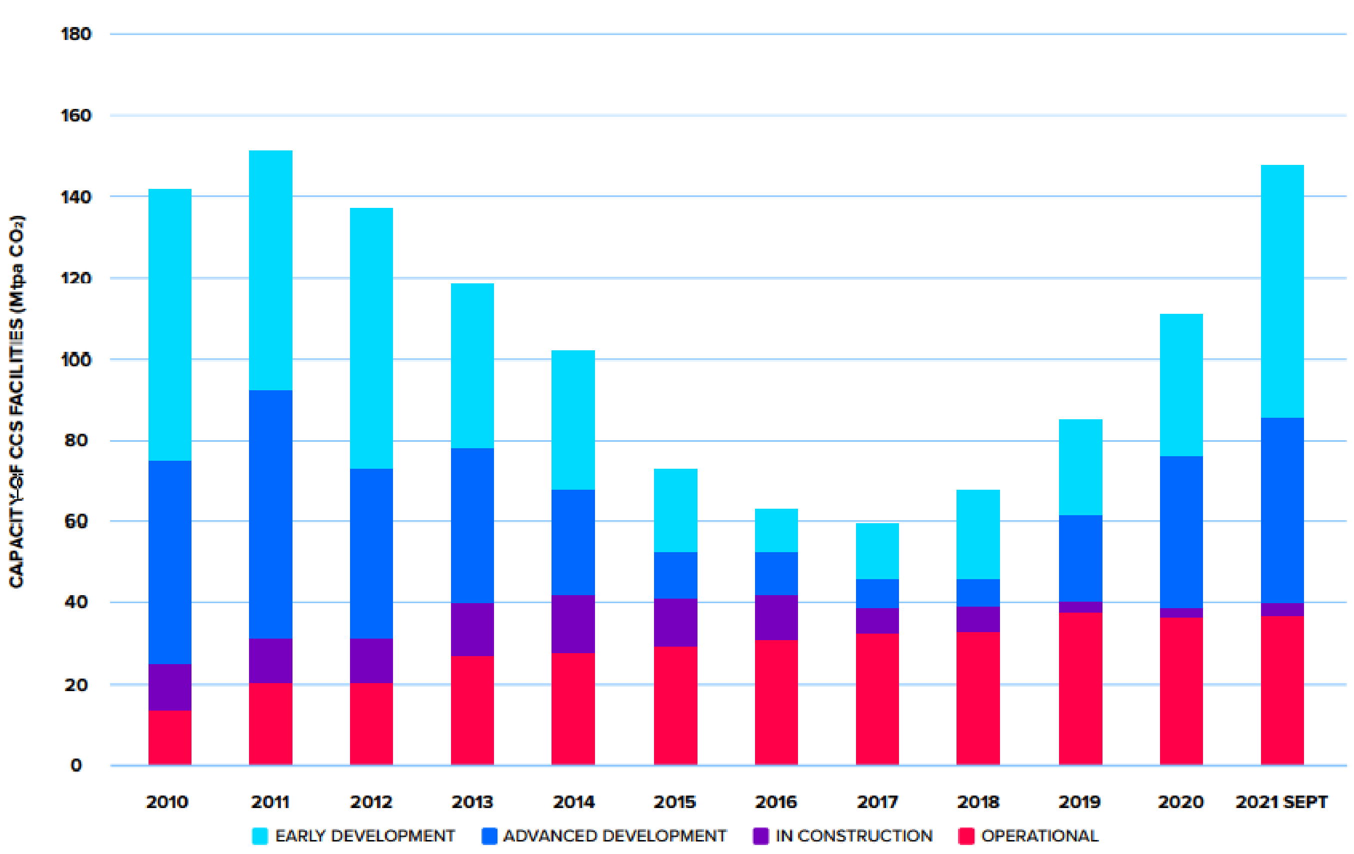
DEXPro™ Markets – CCS/CCUS (World)

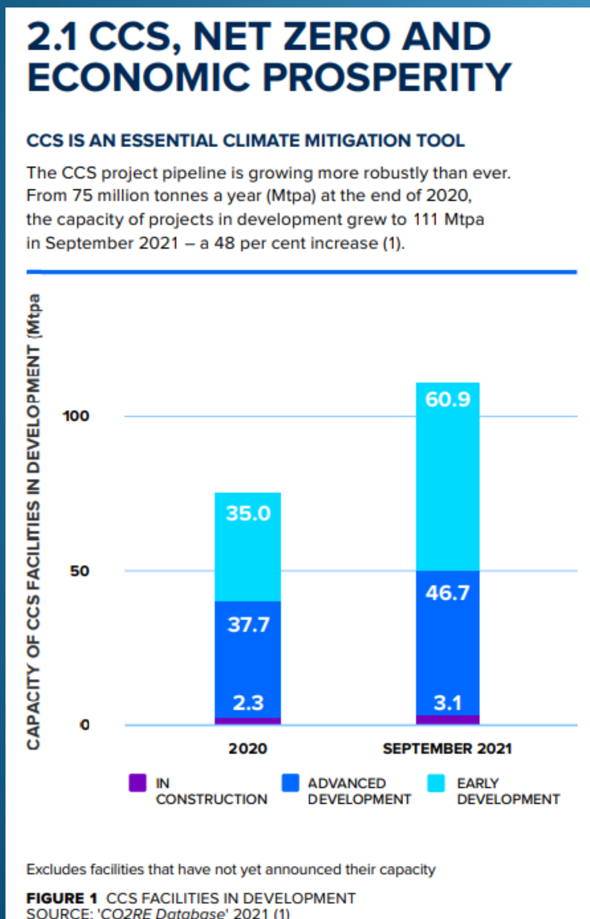
Global Status of CCS 2021 - Global CCS Institute



Facilities that have not announced their capacity are not included in this chart

FIGURE 7 PIPELINE OF COMMERCIAL CCS FACILITIES FROM 2010 TO SEPTEMBER 2021 BY CAPTURE CAPACITY

DEXPro™ Markets – CCS/CCUS (World)



2.1 CCS, NET ZERO AND ECONOMIC PROSPERITY

CCS IS AN ESSENTIAL CLIMATE MITIGATION TOOL

The CCS project pipeline is growing more robustly than ever. From 75 million tonnes a year (Mtpa) at the end of 2020, the capacity of projects in development grew to 111 Mtpa in September 2021 – a 48 per cent increase (1).

Excludes facilities that have not yet announced their capacity

FIGURE 1 CCS FACILITIES IN DEVELOPMENT
SOURCE: '*CO2RE Database*' 2021 (1)

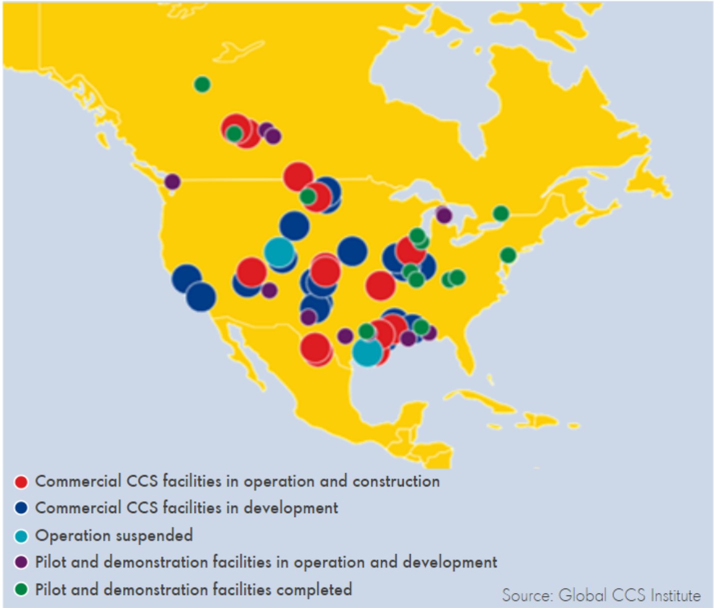
- **CCS – Carbon Capture & Sequestration**
  - Largest segment of our market going forward (inquiries doubling every 4 months for the last year)
  - Under Construction or Advanced Development
    - Dec. 2020 → 40.0 Mtpa (2,085 MMscf/d)
    - Sept. 2021 → 49.8 Mtpa (2,595 MMscf/d)
    - 24.5% increase in 9 months!!
  - Strategic alliance initiatives
    - Major oil & gas carbon ventures divisions
    - Large process equipment suppliers
    - Compressor manufacturers & packagers
    - Sensia
    - SOFC technology developer

DEXPro™ Markets – CCS/CCUS (World)

Standalone CCS projects, more prevalent in the Americas, are also significant

Key drivers for standalone projects include:

- Alberta boom – Opportunistic basis driven by $170/te tax incentive
- US Gulf Coast – Driven by CO_2 network and low gas price
- California Low Carbon Fuel Standard (LCFS) – Continues to provide a significant incentive for CCS deployment



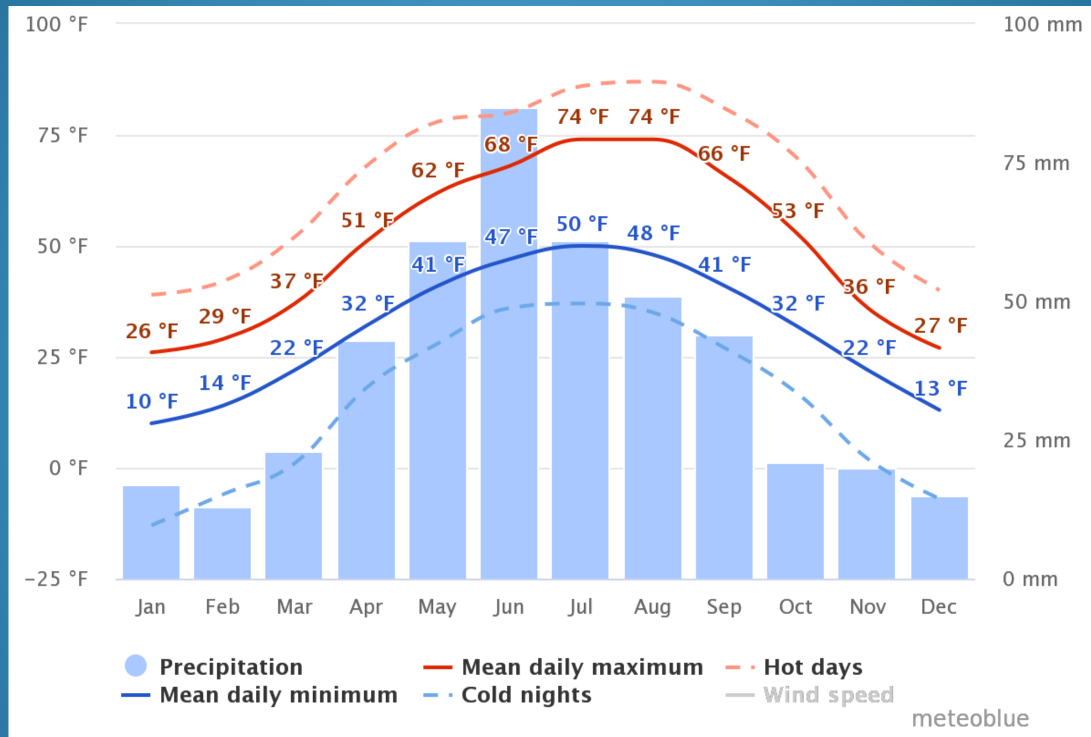
DEXPro™ - Intelligent Optimization

21 MMscf/d CO_2 / 3 stage / 100 - 2,000 psig / Ariel KBZ6 / 4,000 hp VFD											
AC2											
T_{amb}	°F	95.00	85.00	80.00	75.00	65.00	55.00	45.00	35.00	25.00	**H_2O Freeze Limit**
$T_{ICoffset}$	°F	15	15	15	15	15	15	15	15	15	
T_{ICmax}		110.00	100.00	95.00	90.00	80.00	70.00	60.00	50.00	40.00	
15 °C											
T_{DP}	°F	69.66	68.14	67.67	68.07	69.07	70.01	71.05	72.13	73.04	
$T_{PhaseOffset}$	°F (15 °C)	27	27	27	27	27	27	27	27	27	
$T_{PhaseMin}$	°F	96.66	95.14	94.67	95.07	96.07	97.01	98.05	99.13	100.04	
T_{IC}	°F	110.00	100.00	95.00	95.07	96.07	97.01	98.05	99.13	100.04	
P_{in}	psig	833.03	819.09	811.44	815.75	826.63	837.60	849.17	861.22	873.29	
P_{out}	psig	823.03	809.09	801.44	805.75	816.63	827.60	839.17	851.22	863.29	
Speed	rpm	707.0	691.2	683.2	676.3	662.4	648.3	634.1	619.7	605.2	
Power	hp	3,520	3,424	3,375	3,344	3,283	3,220	3,155	3,089	3,021	
3 °C											
T_{DP}	°F	69.66	68.14	67.67	66.91	65.17	63.22	63.43	64.32	65.16	
$T_{PhaseOffset}$	°F	5	5	5	5	5	5	5	5	5	
$T_{PhaseMin}$	°F	74.66	73.14	72.67	71.91	70.17	68.22	68.43	69.32	70.16	
T_{IC}	°F	110.00	100.00	95.00	90.00	80.00	70.00	68.43	69.32	70.16	
P_{in}	psig	833.03	819.09	811.44	803.28	785.38	765.09	767.26	776.7	786.26	
P_{out}	psig	823.03	809.09	801.44	793.28	775.38	755.09	757.26	766.7	776.26	
Speed	rpm	707.0	691.2	683.2	675.2	658.9	642.4	627.6	613.3	598.8	
Power	hp	3,520	3,424	3,375	3,325	3,224	3,120	3,048	2,983	2,919	

DEXPro™ - Intelligent Optimization

21 MMscf/d										
$Power_{DIFF}$	hp	0	0	0	(19)	(59)	(100)	(107)	(106)	(102)
$\%_{Power}$		0.00%	0.00%	0.00%	0.57%	1.83%	3.21%	3.51%	3.55%	3.49%
105 MMscf/d	hp	0	0	0	(95)	(295)	(500)	(535)	(530)	(510)
$0.09	$/kWhr	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09	$0.09
Saving	$/hr	$0.00	$0.00	$0.00	($6.38)	($19.81)	($33.57)	($35.92)	($35.58)	($34.24)

DEXPro™ - Intelligent Optimization



Lacombe, AB												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Average Daily High	39 °F	42 °F	52 °F	68 °F	78 °F	80 °F	86 °F	87 °F	81 °F	70 °F	51 °F	40 °F
Mean Daily Maximum	26 °F	29 °F	37 °F	51 °F	62 °F	68 °F	74 °F	74 °F	66 °F	53 °F	36 °F	27 °F
Mean Daily Minimum	10 °F	14 °F	22 °F	32 °F	41 °F	47 °F	50 °F	48 °F	41 °F	32 °F	22 °F	13 °F
Average Daily Low	-13 °F	-6 °F	1 °F	18 °F	28 °F	36 °F	37 °F	35 °F	27 °F	17 °F	2 °F	-7 °F
Mid Point	13 °F	18 °F	27 °F	43 °F	53 °F	58 °F	62 °F	61 °F	54 °F	44 °F	27 °F	17 °F
Range	52 °F	48 °F	51 °F	50 °F	50 °F	44 °F	49 °F	52 °F	54 °F	53 °F	49 °F	47 °F

DEXPro™ - Intelligent Optimization

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hourly Temp	1	19.7 °F	24.2 °F	33.1 °F	49.5 °F	59.5 °F	63.7 °F	67.8 °F	67.7 °F	61.0 °F	50.4 °F	32.8 °F	22.6 °F
	2	26.0 °F	30.0 °F	39.3 °F	55.5 °F	65.5 °F	69.0 °F	73.8 °F	74.0 °F	67.5 °F	56.8 °F	38.8 °F	28.3 °F
	3	31.4 °F	35.0 °F	44.5 °F	60.7 °F	70.7 °F	73.6 °F	78.8 °F	79.4 °F	73.1 °F	62.2 °F	43.8 °F	33.1 °F
	4	35.5 °F	38.8 °F	48.6 °F	64.7 °F	74.7 °F	77.1 °F	82.7 °F	83.5 °F	77.4 °F	66.4 °F	47.7 °F	36.9 °F
	5	38.1 °F	41.2 °F	51.1 °F	67.1 °F	77.1 °F	79.3 °F	85.2 °F	86.1 °F	80.1 °F	69.1 °F	50.2 °F	39.2 °F
High	6	39.0 °F	42.0 °F	52.0 °F	68.0 °F	78.0 °F	80.0 °F	86.0 °F	87.0 °F	81.0 °F	70.0 °F	51.0 °F	40.0 °F
	7	38.1 °F	41.2 °F	51.1 °F	67.1 °F	77.1 °F	79.3 °F	85.2 °F	86.1 °F	80.1 °F	69.1 °F	50.2 °F	39.2 °F
	8	35.5 °F	38.8 °F	48.6 °F	64.7 °F	74.7 °F	77.1 °F	82.7 °F	83.5 °F	77.4 °F	66.4 °F	47.7 °F	36.9 °F
	9	31.4 °F	35.0 °F	44.5 °F	60.7 °F	70.7 °F	73.6 °F	78.8 °F	79.4 °F	73.1 °F	62.2 °F	43.8 °F	33.1 °F
	10	26.0 °F	30.0 °F	39.3 °F	55.5 °F	65.5 °F	69.0 °F	73.8 °F	74.0 °F	67.5 °F	56.8 °F	38.8 °F	28.3 °F
	11	19.7 °F	24.2 °F	33.1 °F	49.5 °F	59.5 °F	63.7 °F	67.8 °F	67.7 °F	61.0 °F	50.4 °F	32.8 °F	22.6 °F
	12	13.0 °F	18.0 °F	26.5 °F	43.0 °F	53.0 °F	58.0 °F	61.5 °F	61.0 °F	54.0 °F	43.5 °F	26.5 °F	16.5 °F
	13	6.3 °F	11.8 °F	19.9 °F	36.5 °F	46.5 °F	52.3 °F	55.2 °F	54.3 °F	47.0 °F	36.6 °F	20.2 °F	10.4 °F
	14	0.0 °F	6.0 °F	13.8 °F	30.5 °F	40.5 °F	47.0 °F	49.3 °F	48.0 °F	40.5 °F	30.3 °F	14.3 °F	4.8 °F
	15	-5.4 °F	1.0 °F	8.5 °F	25.3 °F	35.3 °F	42.4 °F	44.2 °F	42.6 °F	34.9 °F	24.8 °F	9.2 °F	-0.1 °F
	16	-9.5 °F	-2.8 °F	4.4 °F	21.3 °F	31.3 °F	38.9 °F	40.3 °F	38.5 °F	30.6 °F	20.6 °F	5.3 °F	-3.9 °F
	17	-12.1 °F	-5.2 °F	1.9 °F	18.9 °F	28.9 °F	36.7 °F	37.8 °F	35.9 °F	27.9 °F	17.9 °F	2.8 °F	-6.2 °F
Low	18	-13.0 °F	-6.0 °F	1.0 °F	18.0 °F	28.0 °F	36.0 °F	37.0 °F	35.0 °F	27.0 °F	17.0 °F	2.0 °F	-7.0 °F
	19	-12.1 °F	-5.2 °F	1.9 °F	18.9 °F	28.9 °F	36.7 °F	37.8 °F	35.9 °F	27.9 °F	17.9 °F	2.8 °F	-6.2 °F
	20	-9.5 °F	-2.8 °F	4.4 °F	21.3 °F	31.3 °F	38.9 °F	40.3 °F	38.5 °F	30.6 °F	20.6 °F	5.3 °F	-3.9 °F
	21	-5.4 °F	1.0 °F	8.5 °F	25.3 °F	35.3 °F	42.4 °F	44.2 °F	42.6 °F	34.9 °F	24.8 °F	9.2 °F	-0.1 °F
	22	0.0 °F	6.0 °F	13.8 °F	30.5 °F	40.5 °F	47.0 °F	49.3 °F	48.0 °F	40.5 °F	30.3 °F	14.3 °F	4.7 °F
	23	6.3 °F	11.8 °F	19.9 °F	36.5 °F	46.5 °F	52.3 °F	55.2 °F	54.3 °F	47.0 °F	36.6 °F	20.2 °F	10.4 °F
Mid Point	24	13.0 °F	18.0 °F	26.5 °F	43.0 °F	53.0 °F	58.0 °F	61.5 °F	61.0 °F	54.0 °F	43.5 °F	26.5 °F	16.5 °F

DEXPro™ - Intelligent Optimization

Daily Hours @	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
T_{amb} >= 80 °F	0	0	0	0	0	1	5	5	3	0	0	0	**1.2**
T_{amb} >= 75 °F	0	0	0	0	3	4	2	2	2	0	0	0	**1.1**
T_{amb} >= 65 °F	0	0	0	3	6	4	4	4	4	5	0	0	**2.5**
T_{amb} >= 55 °F	0	0	0	6	2	4	4	2	2	4	0	0	**2.0**
T_{amb} >= 45 °F	0	0	5	2	4	4	2	4	4	2	5	0	**2.7**
T_{amb} >= 35 °F	5	5	4	4	4	7	7	7	2	4	4	5	**4.8**
T_{amb} >= 25 °F	4	4	4	4	5	0	0	0	7	2	4	4	**3.2**
T_{amb} < 25 °F	15	15	11	5	0	0	0	0	0	7	11	15	**6.6**
	24	24	24	24	24	24	24	24	24	24	24	24	**24.0**

Daily Saving @	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
T_{amb} >= 80 °F	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	**$0**
T_{amb} >= 75 °F	$0	$0	$0	$0	($19)	($26)	($13)	($13)	($13)	$0	$0	$0	**($7)**
T_{amb} >= 65 °F	$0	$0	$0	($59)	($119)	($79)	($79)	($79)	($79)	($99)	$0	$0	**($50)**
T_{amb} >= 55 °F	$0	$0	$0	($201)	($67)	($134)	($134)	($67)	($67)	($134)	$0	$0	**($67)**
T_{amb} >= 45 °F	$0	$0	($180)	($72)	($144)	($144)	($72)	($144)	($144)	($72)	($180)	$0	**($96)**
T_{amb} >= 35 °F	($178)	($178)	($142)	($142)	($142)	($249)	($249)	($249)	($71)	($142)	($142)	($178)	**($172)**
T_{amb} >= 25 °F	($137)	($137)	($137)	($137)	($171)	$0	$0	$0	($240)	($68)	($137)	($137)	**($108)**
T_{amb} < 25 °F	($514)	($514)	($377)	($171)	$0	$0	$0	$0	$0	($240)	($377)	($514)	**($225)**
Average Day	**($829)**	**($829)**	**($836)**	**($783)**	**($662)**	**($632)**	**($547)**	**($552)**	**($614)**	**($756)**	**($836)**	**($829)**	**($725)**
# of days	31	28	31	30	31	30	31	31	30	31	30	31	**365**
Average Month	**($25,684)**	**($23,198)**	**($25,902)**	**($23,496)**	**($20,532)**	**($18,954)**	**($16,963)**	**($17,109)**	**($18,410)**	**($23,425)**	**($25,067)**	**($25,684)**	**($264,423)**