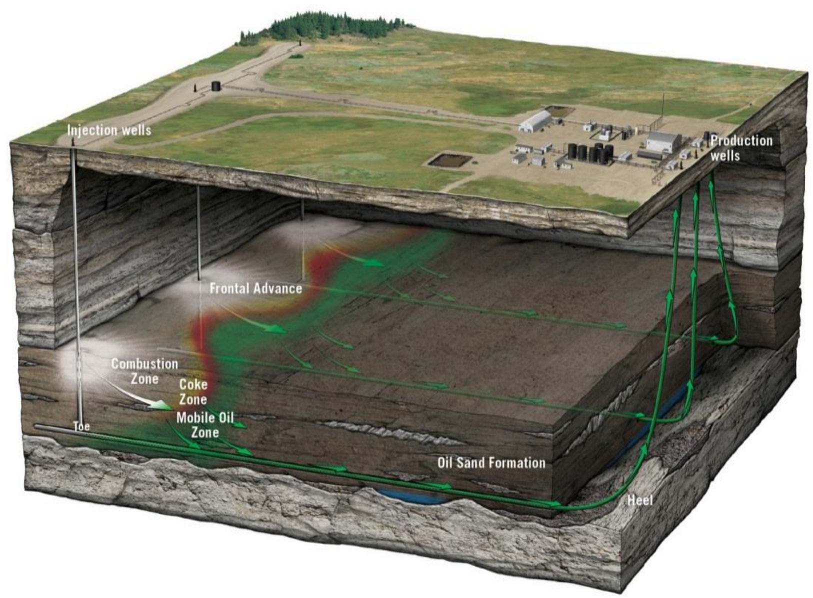
SPE Heavy Oil Special Interest Group

31 Ways that THAI is Superior to SAGD

Conrad Ayasse, Ph.D., FCIC

Calgary Winter Club
April 10, 2018



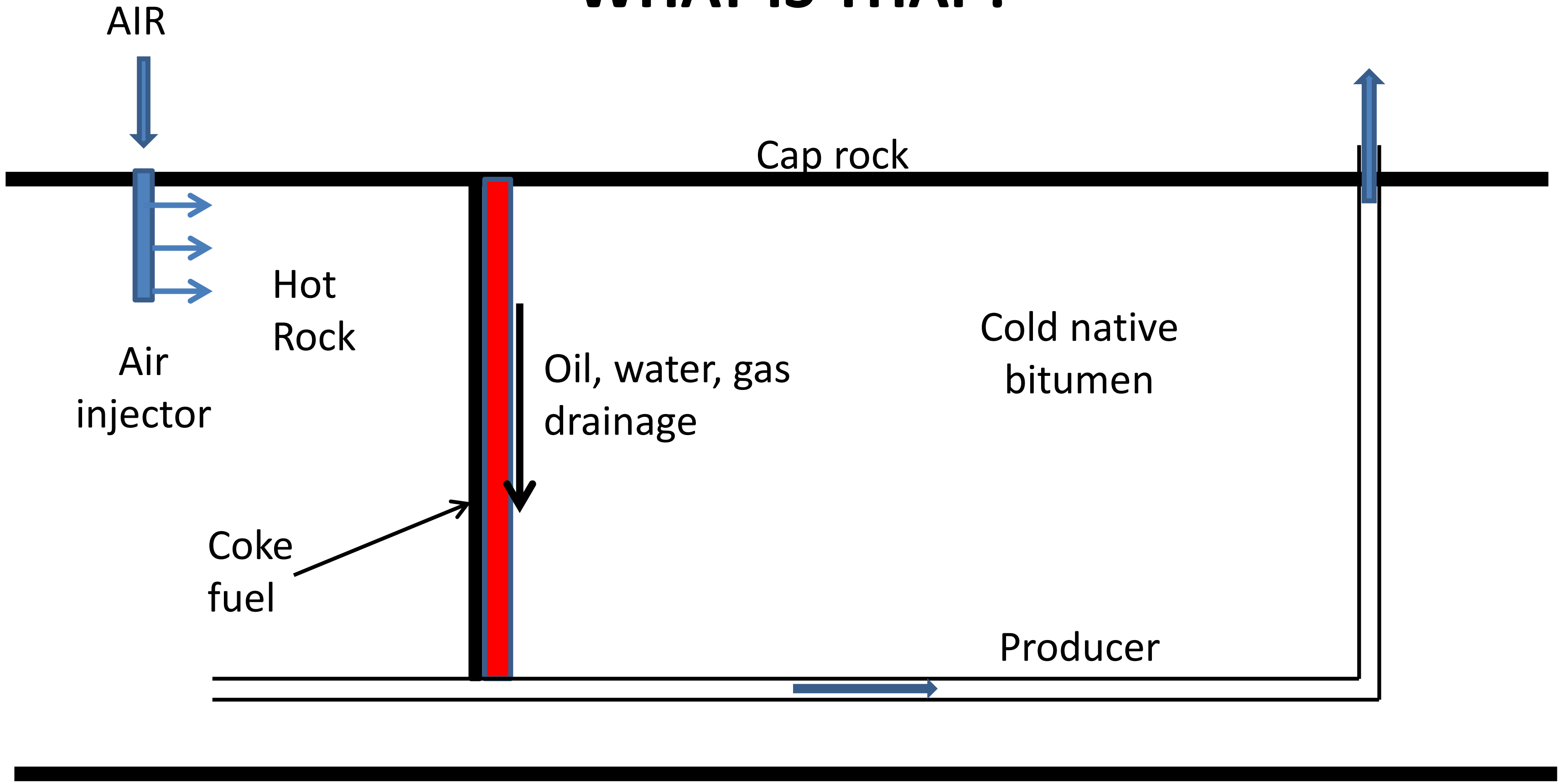
Capri Petroleum Technologies Ltd.,
24, 4807-32 Street, SE, Calgary, Alberta, T2B 2X3
(403) 560-7483

What is SAGD?

SAGD uses parallel horizontal wells separated
by 5-meters of bitumen pay.
The upper well is a steam injector and
the lower well a fluid producer.

Hot native bitumen is heated to enable drainage

WHAT IS THAI ?

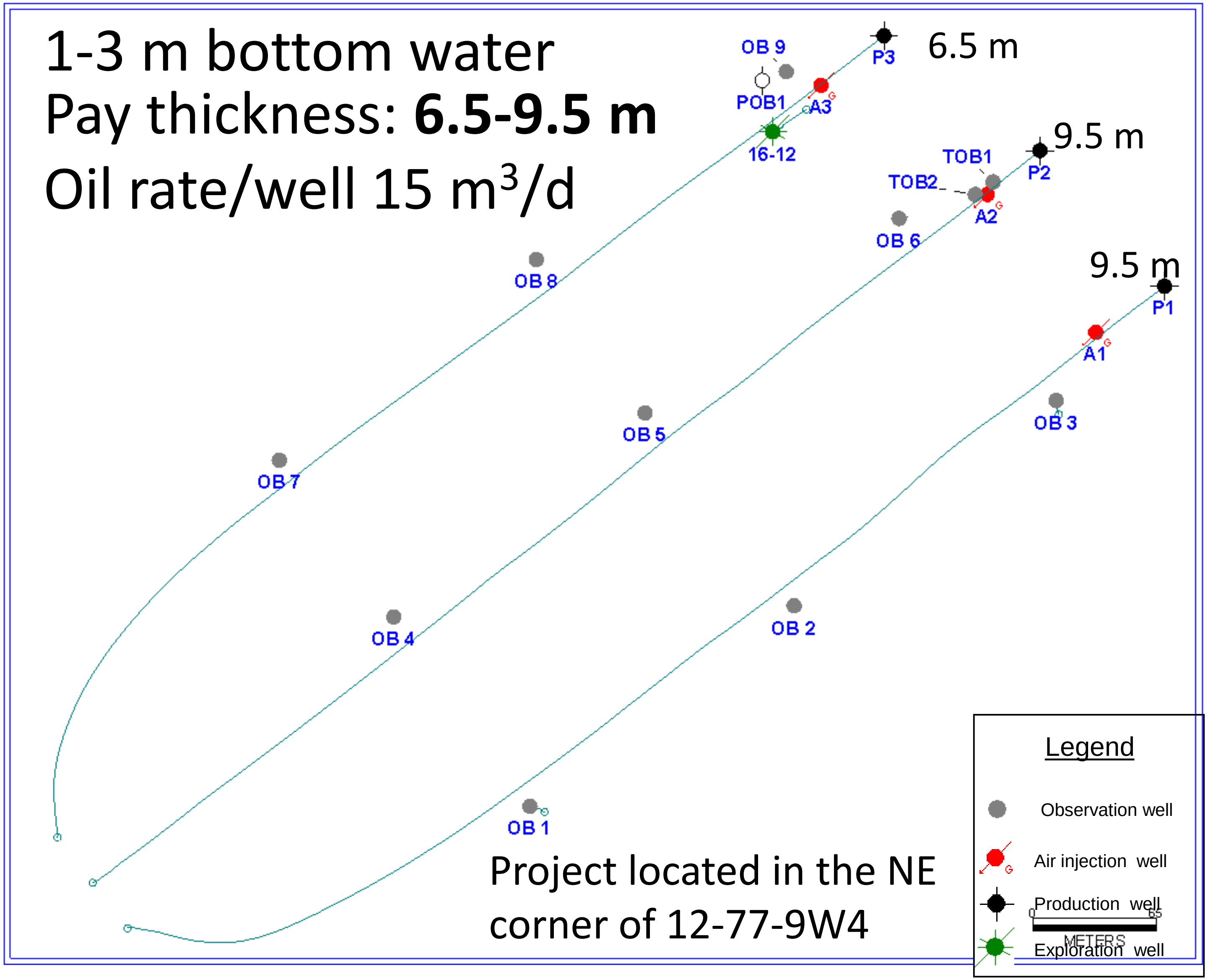

AIR
Cap rock
Hot
Rock
Air
injector
Cold native
bitumen
Oil, water, gas
drainage
Coke
fuel
Producer

What is THAI?

Toe-to-Heel-Air Injection uses a vertical air injector offset past the toe of a horizontal producer.

A vertical combustion front,
made up of previously-deposited coke,
provides fuel for the air.
Hot combustion gas contacts, heats and
partially upgrades the bitumen,
which drains with combustion gases
into the producer

Whitesands CONKLIN 4-YEAR PILOT PROJECT WELL LAYOUT



Whitesands Pilot summary

No oxygen to Producer or surface

No corrosion down hole or on surface

Robust, easy to restart

Where is SAGD best used?

It has been said that-

"SAGD is the Perfect Process for the Perfect Reservoir"

These Reservoirs are largely where SAGD has been successful:

Thick, homogeneous, high saturation and
high-permeability reservoirs

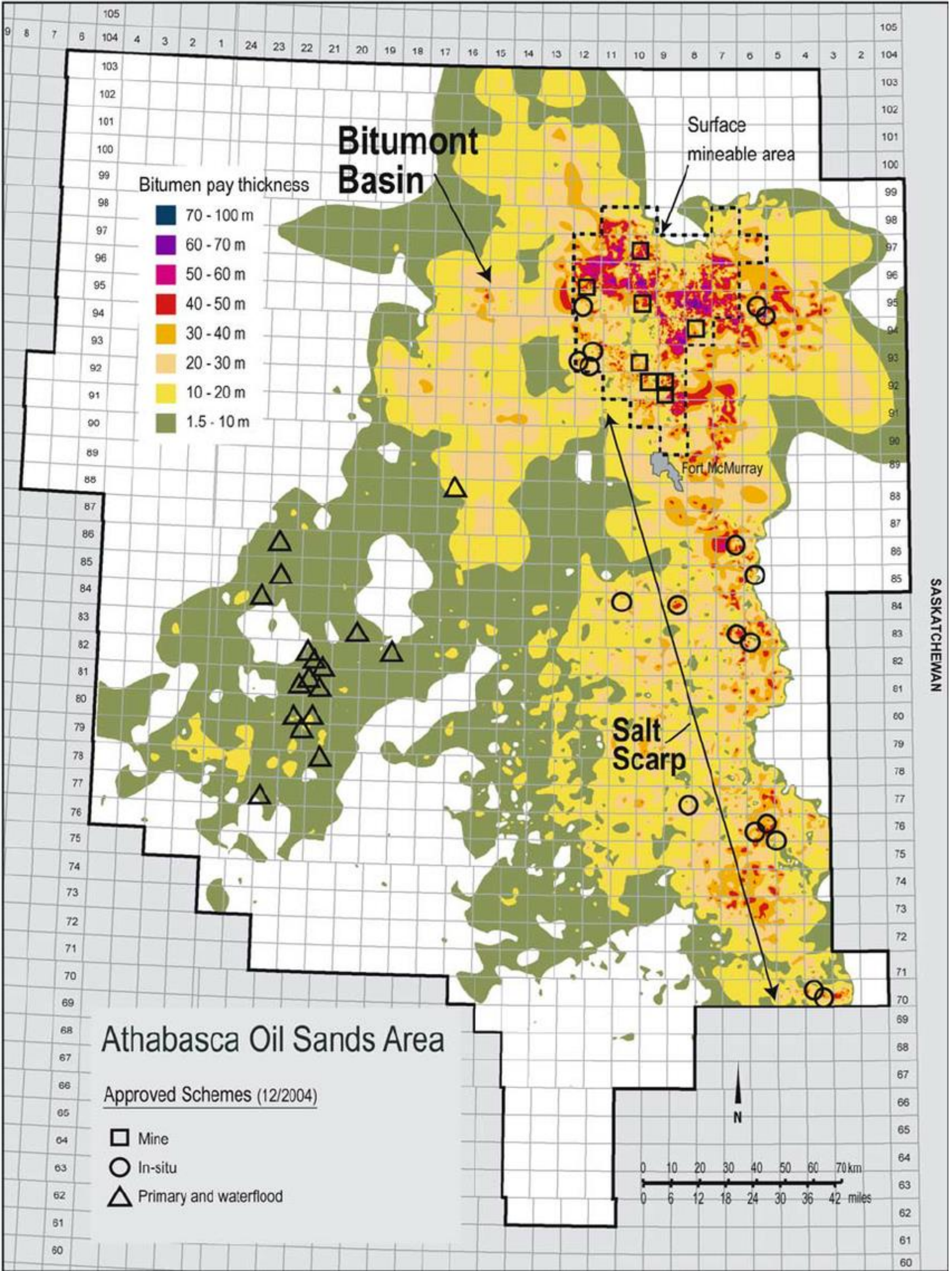
Where is THAI best used

Whenever SAGD does not qualify from:

Pressure: Reservoir too shallow or too deep
Pay is too thin: 5-15 m
Reservoir quality low: Shale lenses, low So

Or when

Natural gas price is too high
Diluent is too expensive or not available
Pipeline capacity is inadequate
Water not available



Vast majority of Alberta Bitumen is in pay thickness 10-20 m !

Excellent for THAI or Multi-THAI^{tm}

1. THAI needs no ongoing water source

Only cold air is injected

Water supply is not an issue

2. THAI eliminates ongoing produced <u>water treatment</u>

THAI Produced water sent to a disposal well or
used as SAGD source water

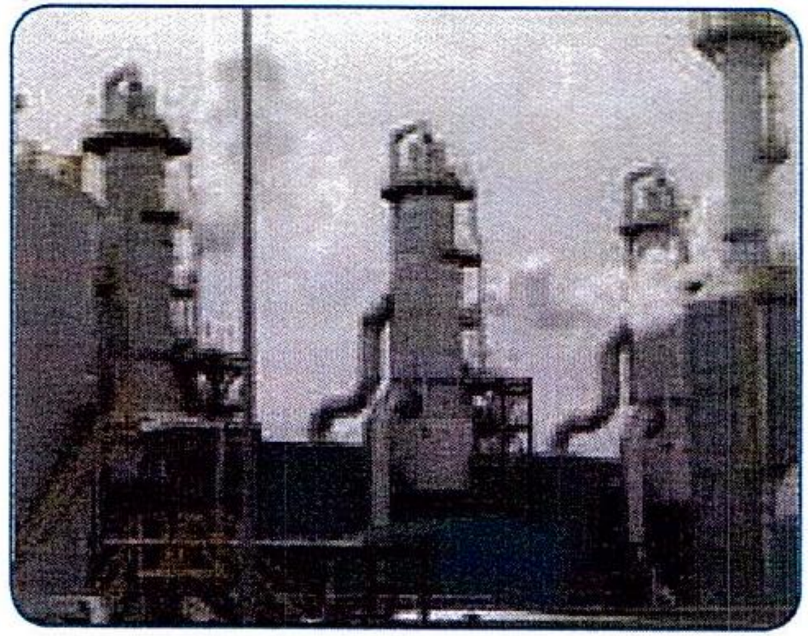
SAGD Mandated 95% produced water cleanup and recycle

Assume 50,000 bbl/d bitumen :
Water evaporation gas cost is 110 million/y,
producing 8,500 tonnes/d CO_2

SAGD Produced Water Evaporators are not needed

High energy, high blowdown waste

Connacher Oil & Gas
Great Divide Project,
Ft. McMurray, Alberta, Canada
Approx. 900 gpm 2007



Suncor Firebag Stage 2,
Ft. McMurray, Alberta, Canada,
Approx. 4,200 gpm 2005

Source: SUEZ Water Technologies & Solutions brochure

The price of water evaporation

Assume evaporation energy is 0.5-mscf/bbl water

10,000 b/d oil produces 30,000 bbl/d water

This takes 15,000 mscf methane at $2/mscf
or $30,000/d or
$11 million/y,
producing 785 tonnes/d CO2 or
0.49 tonnes CO2/m3 oil

3. THAI is a net producer of water

Produced water is a mixture of connate water and combustion water from burning the coke.

Combustion water dilutes the salinity of the connate water
and
Makes it eligible as SAGD source water

THAI Produces SAGD- quality water: Potential sales

		Whitesands Produced* Water*	SAGD Source Water*
Calculated Parameters	**Units**		
Total Dissolved Solids	mg/L	6620	6481
pH		7.64	8.3
Anions			
Bicarbonate (HCO_3)	mg/L	1610	625
Carbonate (CO_3)	mg/L	<0.5	12
Dissolved Sulphate (SO_4)	mg/L	<0.5	0.3
Dissolved Chloride (Cl)	mg/L	3630	3420
Elements			
Dissolved Sodium (Na)	mg/L	2100	2350
Dissolved Potassium (K)	mg/L	17	8.6
Dissolved Calcium (Ca)	mg/L	45	36.8
Dissolved Magnesium (Mg)	mg/L	22	28.2

* THAI water is Non Corrosive

* * Devon Jackfish-2 EIA

4. THAI^{TM} emulsions are easy to break

- No difficult emulsions
- Easy oil/water separation
- Usable water by-product with minimal treatment
- Non-corrosive

THAI™ Wellhead Emulsion

60 second separation time

5. THAI Generates its own compression energy

For a 10,000 bbl/d plant:

Air compression is the major energy input-
Total power requirement is 2074 GJ/D (24MW)

Generated by using the energy content of the produced waste gases:
0.21GJ/bbl of produced oil .

May River expected to generate a **40-45% IRR** at oil price US $60/bbl

6. THAI provides its own thermal fuel in situ

SAGD : Purchased natural gas
to make steam

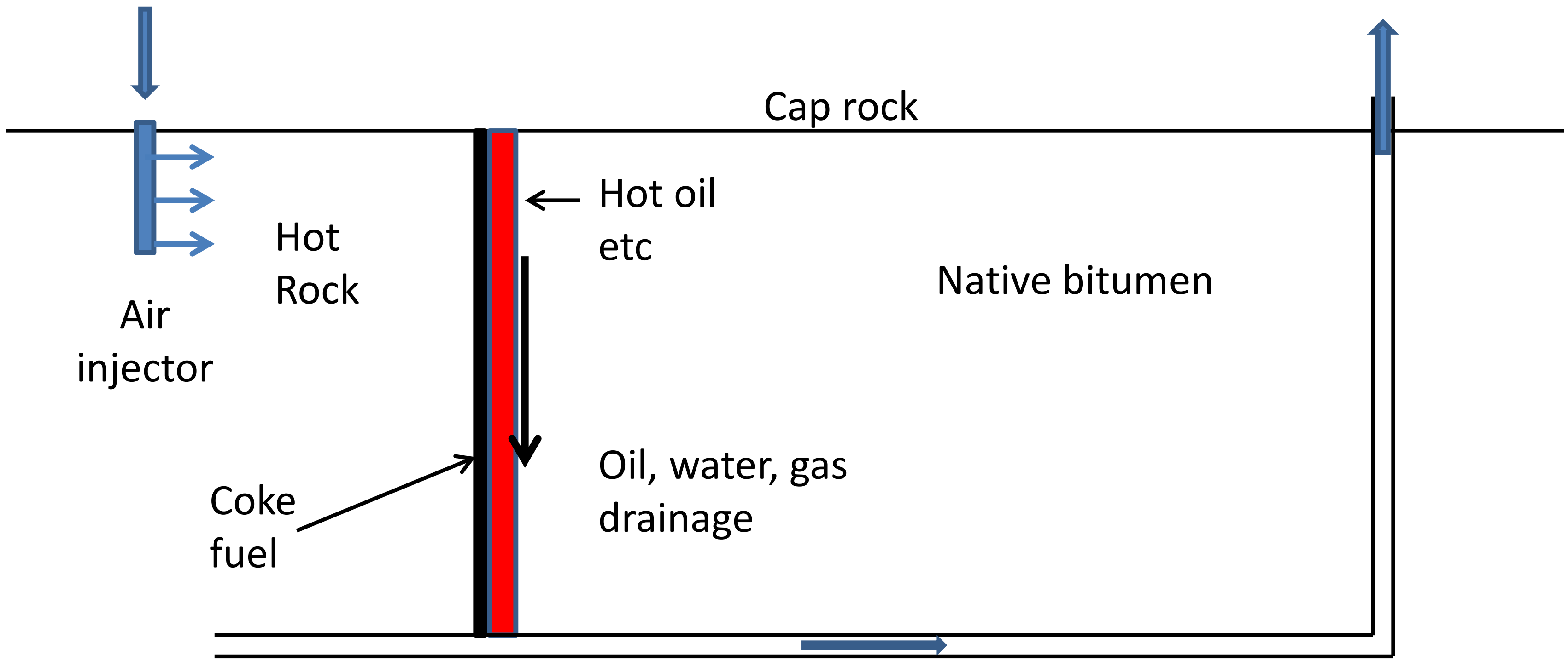
THAI : Free energy
Thermal energy from burning the heaviest 9% of the Bitumen at the oil face in the reservoir

7. THAI has better thermal efficiency

SAGD STEPS	Boiler →	Line to Wellhead →	Tubing to Perforations →	Perfs to Oil Face →	Cumulative Efficiency
	75-85	75-95	80-95	25-75	**11-58 %**
THAI STEPS	Comp. →	Line to Wellhead →	Tubing to Perforations →	Perfs to Oil Face →	Cumulative Efficiency
	100	100	100	125-175	**125-175 %**

From GravDrain's Black Book: Thermal Recovery of Oil and Bitumen, Roger M. Butler, 1997.

8. THAI scavenges reservoir heat



Air scavenges the reservoir heat of previous combustion and delivers it to the burning coke at 350 ºC.

FUEL REQUIRED TO SUPPLY 1-MILLION BTU AT OIL FACE

	EFFICIENCY %	FUEL REQUIRED Millions BTU	ENERGY COST $/Million BTU
Steam	45-77	1.3-2.2	**2.6-4.4**
Air in situ combustion	190	0.5	**1.0**
Oxygen in situ combustion	315	0.3	**0.6**

OXYGEN combustion is better than STEAM by a factor of 4.3-7.3

From GravDrain's Black Book: Thermal Recovery of Oil and Bitumen, Roger M. Butler, 1997.

9. THAI has low heat loss to cap rock

SAGD: Large latent heat loss to cap rock
- reduces steam quality at oil face

THAI: Air has no latent heat loss
- scavenges heat from previously heated rock and delivers air to the combustion at **350 ºC**

10. THAI has lower CO_2 emissions

1. Higher thermal efficiency
2. Lower heat losses
3. Scavenges heat from sand
4. No water treatment (Evaporators)
5. Less steel
6. Oil partially upgraded

50 %

11. THAI cannot mobilize water pollutants

Thermal mobilization and the regulatory response:

During the SAGD and CSS process, high-temperature steam is injected into the bitumen-saturated reservoirs to reduce viscosity and facilitate production.

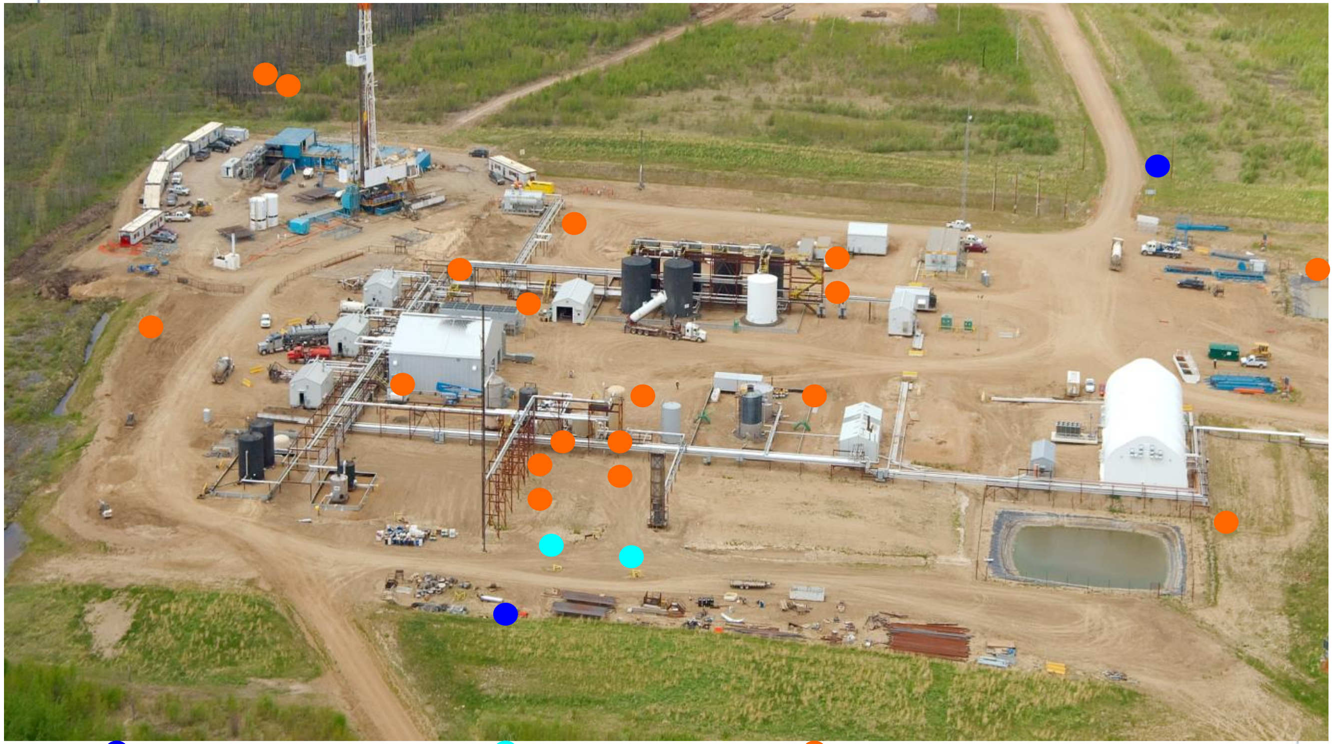
Conduction of heat from the steel casings into surrounding sediments (particularly non-saline aquifers) has been shown to mobilize certain trace constituents (Arsenic) to levels exceeding protective guidelines.

In response, the Alberta Energy Regulator (in conjunction with Alberta Environment and Parks) has developed a policy that will require all in-situ operators (new and existing) t o assess the risks of thermal mobilization and address them, as necessary. To fulfill this requirement, an understanding of site conditions will be required, as well as constituent mobility potential, and attenuating mechanisms.)

THAI air is cold so there can be such problems

12. Smaller surface foot-print

Sampling Points



● Passive monitors (4) ● Source Wells (2) ● Groundwater wells (18)

Fewer operating units,
no water treatment

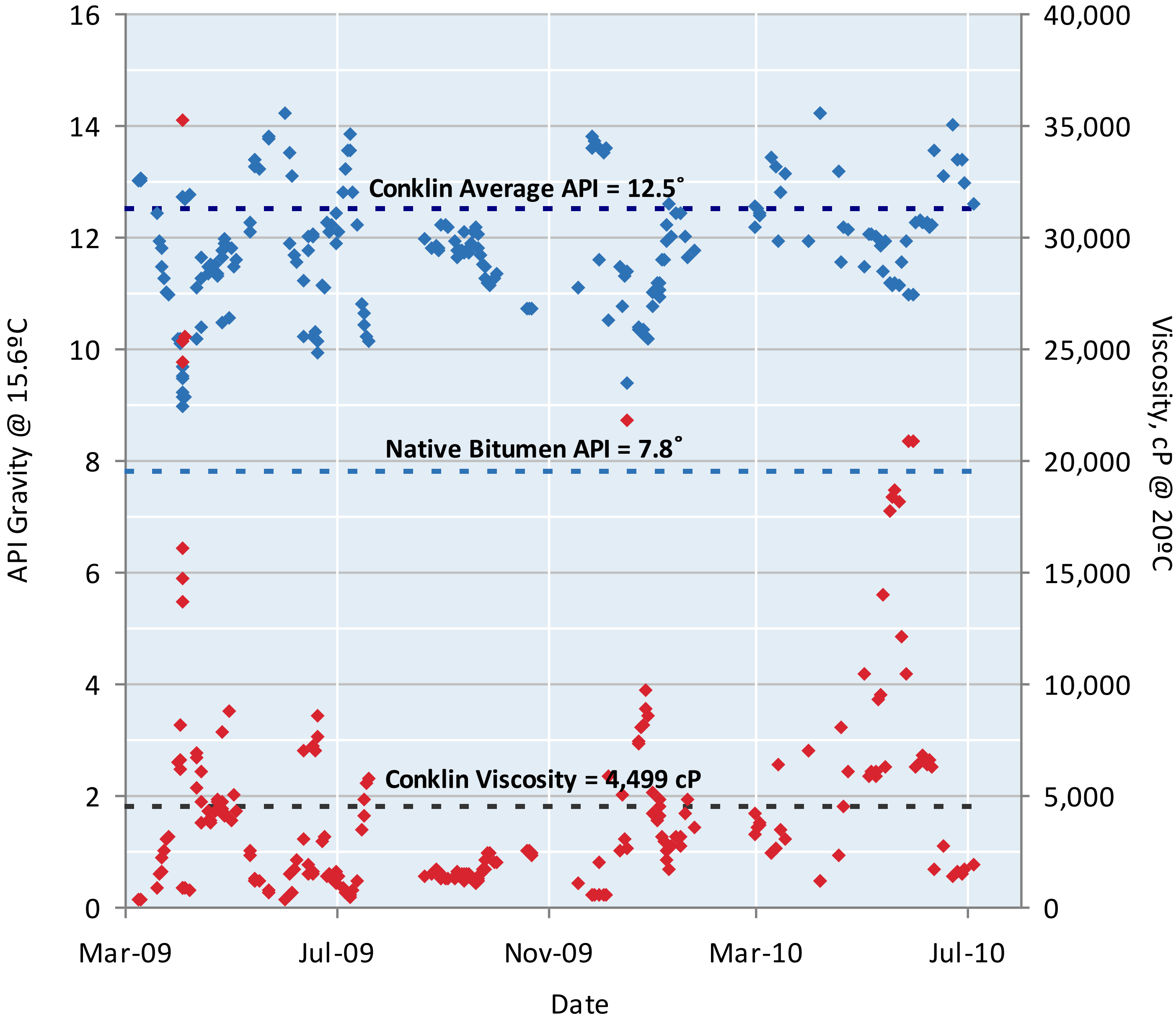
13. THAI Oil Viscosity Improved

At 20 ºC:

Bitumen	550,000 cP
THAI Oil	4,500 cP

10% of production was in the Secondary Separator at 36 ºAPI

14. API Density of THAI oil Improved 3+ Points



THAI Achieves **Free** in situ Partial Upgrading

In-Situ Upgraded
THAI® Oil

Native
Bitumen

THAI Condensate
36° API

15. THAI Oil has lower metals

THAI burns the heaviest 9% of the bitumen:

Asphaltenes form coke fuel ahead of the drainage front

Vanadium and Nickel reside in the asphaltenes

Heavy Metals in coke fuel are oxidized
and remain in the reservoir

Heavy Metals reduced 18%

16. THAI oil has lower Total Acid Number

Naphthenic acids reduced 17%

Catalytic reduction: Hot H_2
(to 650 ºC)/reservoir metals

Reaction with alcohols to form esters

Formation of coke removes asplaltenes
where acidic components

TAN Pipeline Penalties reduced

17. THAI Oil has lower sulphur

Sulphur in THAI oil is 19% lower

Caused by catalytic AQUA-THERMOLYSIS reactions

of oil with sub-critical Water

and

Catalyzed by in situ V and Ni at 400-650 ºC

18. THAI produces free hydrogen

3-8% of the Produced gas is Free H_2

At 2 % recovery, a Single producer gives
600 m^3/d Hydrogen.
Enough to upgrade 35 % of THAI oil
to pipeline specifications

19. THAI oil requires less diluent to pipeline

Impact of Reduced Blending Ratio	
Diluent Blending Ratio - SAGD Bitumen	0.30
Diluent Blending Ratio - THAI® Oil	0.20
bbl Diluent Saved / bbl Bitumen Blend	0.10

33.3 % DILUENT SAVINGS

&

INCREASED PIPELINE CAPACITY

Why Upgrade bitumen to pipeline specs?

Financial loses on diluent*

Differential loss on exported Dilbit:	USD 5.36/bbl
Transportation to US Gulf Coast	USD 5.15/bbl
Total financial loss USD	USD 10.51/bbl

*Altex Energy (internet)

Why Upgrade bitumen to pipeline specs?

Bitumen producers spent
CDN 13.3 Billion on diluent
in 2016*

Diluent elimination
would increase pipeline capacity
30 %*

Partial upgrading of oil sands
could fetch additional $10-15 per barrel**

* Alberta Government
**University of Calgary School of Public Policy

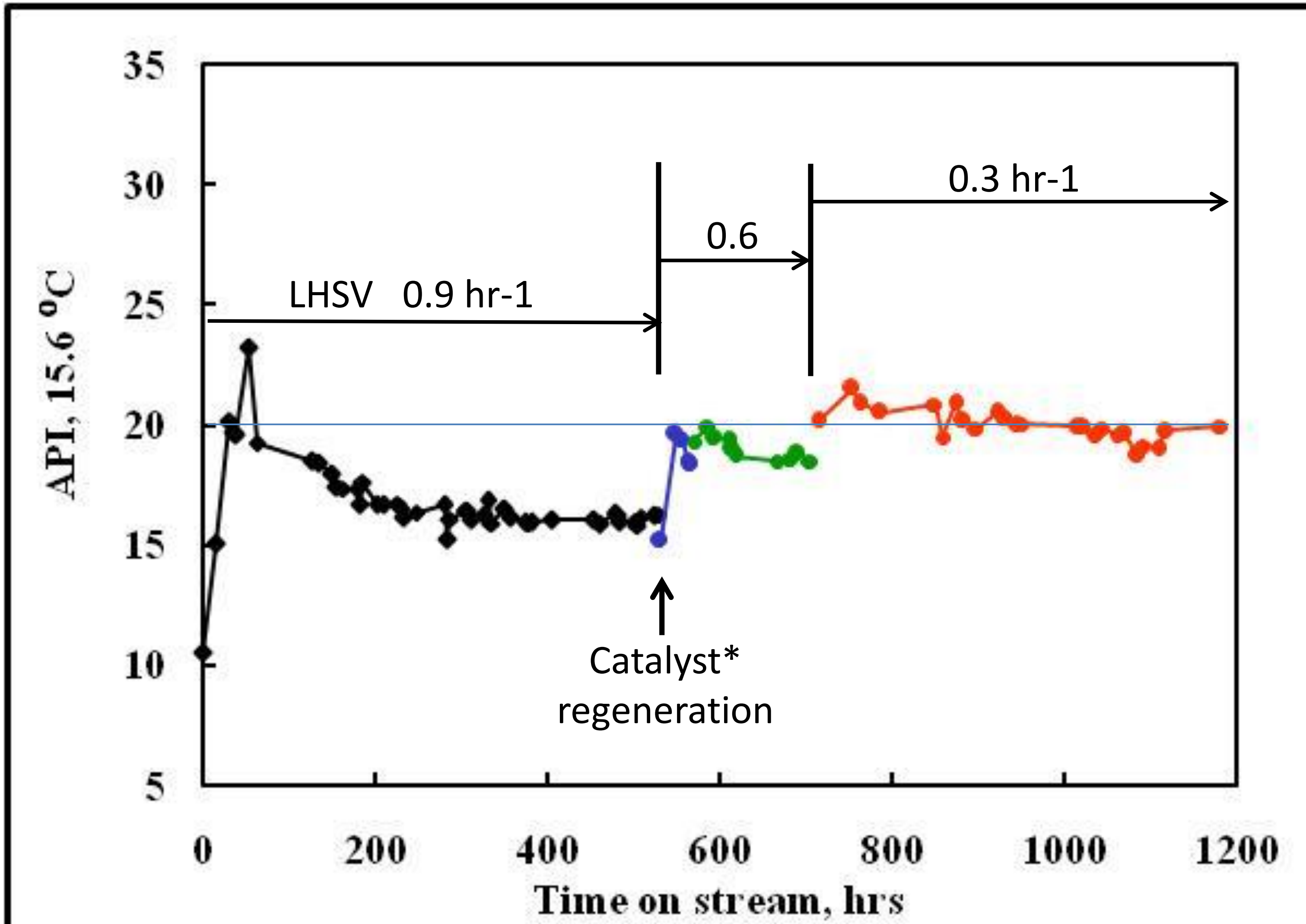
20. THAI oil easy to upgrade to pipeline specs.

Proven in 5-month continuous operation,
Demonstrated complete catalyst regeneration

Mild conditions:
400 ºC, 600 psia, 450-500 H_2 flow/oil flow
Modest catalyst cost *

*Using CPTL-UG^{tm} catalyst

Upgrading Conklin THAI oil



*CPTL-UG Catalyst

5-Month Continuous test with CPTL-UG™ Catalyst

Reaction temperature, °C	THAI™ oil	400 ° C, 600 psig			
LHSV, hr^{-1}	0	0.9	0.6	0.3	0.3
Time on stream, hrs	0	405	570	850	1181
H_2 consumption, H_2/Oil, STM m^3/m^3	0	147	150	175	
Density @ 15°C		0.9556	0.9382	0.9289	0.9343
API @15.5°C	10.5	16	19.3	20.8	19.9
Viscosity @20°C	**1,898**	112	51	24	**32**
Mol Wt.	393	289	256	239	255
Total sulfur, wt %	**4.34**	2.68	1.26	1.02	**1.46**
Conradson Carbon, wt%	11.7	9.64	6.34	5.51	7.40
Total acid number, mg KOH/g	**1.65**	0.25	0.21	0.16	**0.18**
Bromine number, g/100g	4.78	2.85	1.94	2.85	2.39
% distillate under 327°C	36.34	38.99	48.22	55.08	46.86
Bromine number of distillate, g/100g	13.1	7.32	4.03	5.17	5.10

5-Month Continuous test with CPTL Catalyst

Reaction temperature, °C	THAI™ oil	400 ° C, 600 psig			
Heavy metals, ppm	LHSV. Hr-1	0.9	0.6	0.3	0.3
Nickel	**61.5**	N/A	22	28	**27**
Vanadium	**160.1**	N/A	48	62	**57**
SARA analyses, %					
Asphaltene	**13.9**	9.65	7.3	5.61	**7.9**
Resin	**19.5**	15.21	11.41	8.75	**10.4**
Aromatics	**35.6**	32.82	33.26	30.07	**33.0**
Saturates	**14.6**	17.98	20.37	19.13	**21.0**
Volatile	**16.5**	24.34	27.66	36.45	**27.7**

21. Corporate asset value is increased

Your Bitumen reservoir is actually a heavy oil reservoir!

Higher income	3.50 USD/bbl *
Lower extraction costs	2.00 USD /bbl
Increased NPV	5.50 USD

24 % HIGHER RESOURCE NPV

* THAI diluent savings

22. THAI well costs are lower

Only one horizontal well is needed

23. Steam blowout not possible

THAI air has

High injectivity
even at
low injection pressure

24. THAI efficiency not reduced in low-pressure reservoirs

SAGD efficiency is hindered by low-pressure injection
Because of higher viscosities and
the inhibited dilation of the unconsolidated sandstone reservoir

25. THAI can be used in thin (6-15m) reservoirs

SAGD requires substantial bitumen
above the steam injector
to delay chamber arrival to the cap rock

THAI was stable,
robust and controllable
in pay thicknesses of 6.5 and 9.5 meters
even with bottom water

26. THAI can be used in deep reservoirs

Deep reservoirs are at high pressure,
so the SAGD steam temperature must be high,
which increases heat losses
and
renders SAGD uneconomical

THAI efficiency does not deteriorate with pressure

27. Better THAI sweep in low quality reservoirs

High THAI temperatures desiccates shale lens barriers

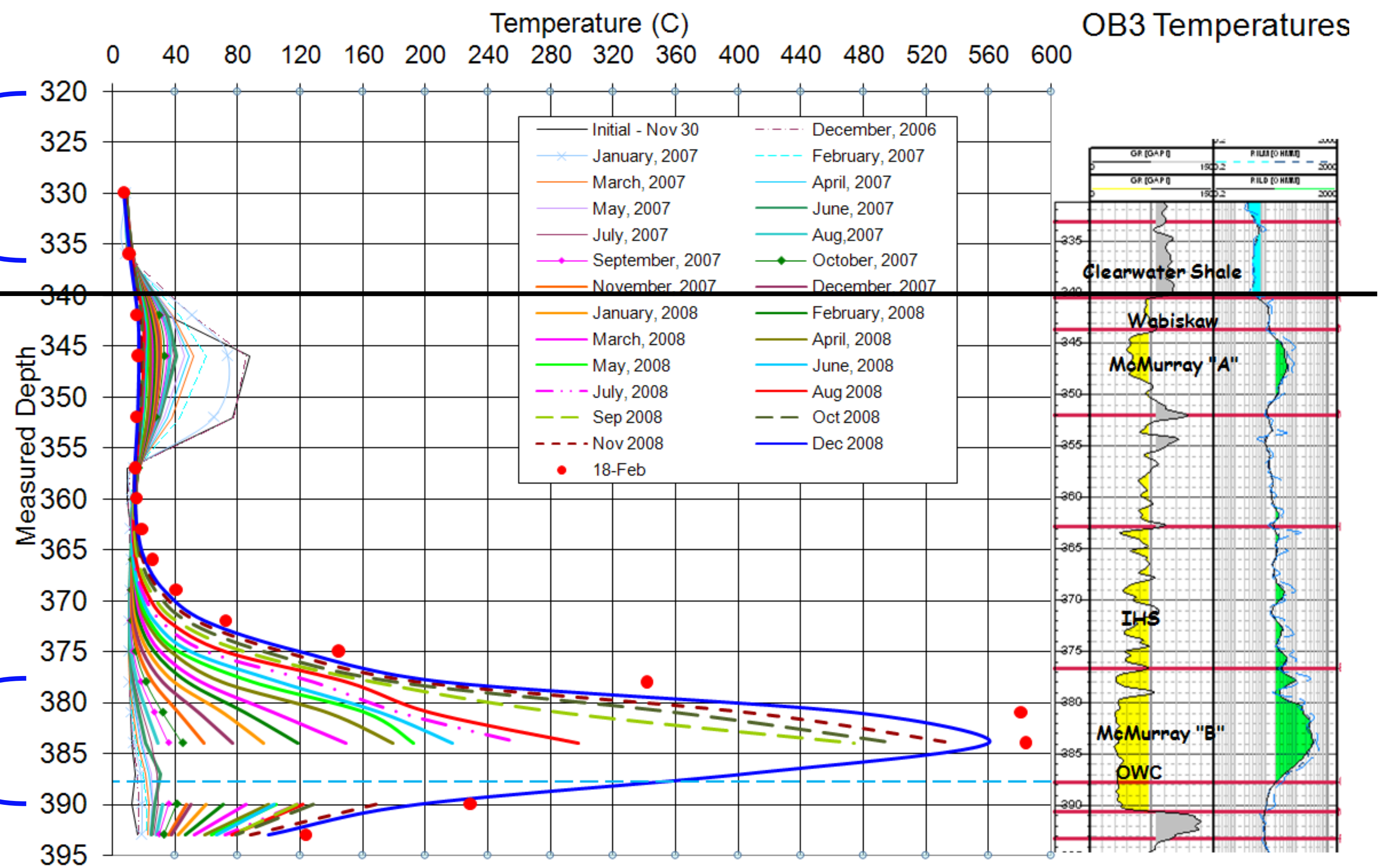
and

Enhances vertical permeability

Oil zone temperatures reach 650 ºC

Off-set Observation well Temperatures

Some IHS oil recovery occurs



No change in cap rock temperature

Combustion zone is at > 600 °c

OB well close to the toe of P-1 (Offset laterally 10 m)

28. THAI can be used with lighter oils

Because of its Energy Intensity
(Heating the entire reservoir)
SAGD is not economical for lighter oil recovery

THAI is limited only by the oil
Asphaltenic fuel content

29. Nitrogen in air enables pump-free lifting

…Provided the pay has not been de-pressured by primary production

30. THAI has total microscopic sweep

Everywhere combustion occurs there is <u>no residual oil</u>

31. Lower THAI CAPEX

No steam boilers
No water treatment
Uses vertical injectors
Very simple surface facilities

CAPEX of CAD 350 Million for a 10,000 BOPD plant*

Including Power generation from
Produced Gas Combustion and
flue gas desulphurization

*May River Project

32. Lower THAI OPEX

- No natural gas for boiling injected or produced water
- Lower heat losses
- No water recycling
- Smaller staffing
- Less diluent

For 10,000 BOPD May River THAI plant
OPEX 6-8 USD/bbl*

* Whitesands estimate

SUMMARY OF THAI BENEFITS*

No Fuel cost	No natural gas needed
No energy costs	Power from Tail Gas combustion
In situ upgrading	Lower Diluent use, higher oil value
Lower staffing	Fewer operating units
No water supply needed	Is a water producer
Less pollution	Lower CO_2, pollutant mobilization
Broadly applicable	Thinner, dirtier, shallower, deeper

*After start-up

The THAI Weakness

There is only a SINGLE oil drainage front

so

Only a small part of the horizontal well is in use an any time

and

this limits the oil production rate……

MULTI-THAI^{tm} is the solution

Multi-THAI^{tm} well configuration

Multiple air injectors

are placed directly over the producer

providing many oil drainage fronts

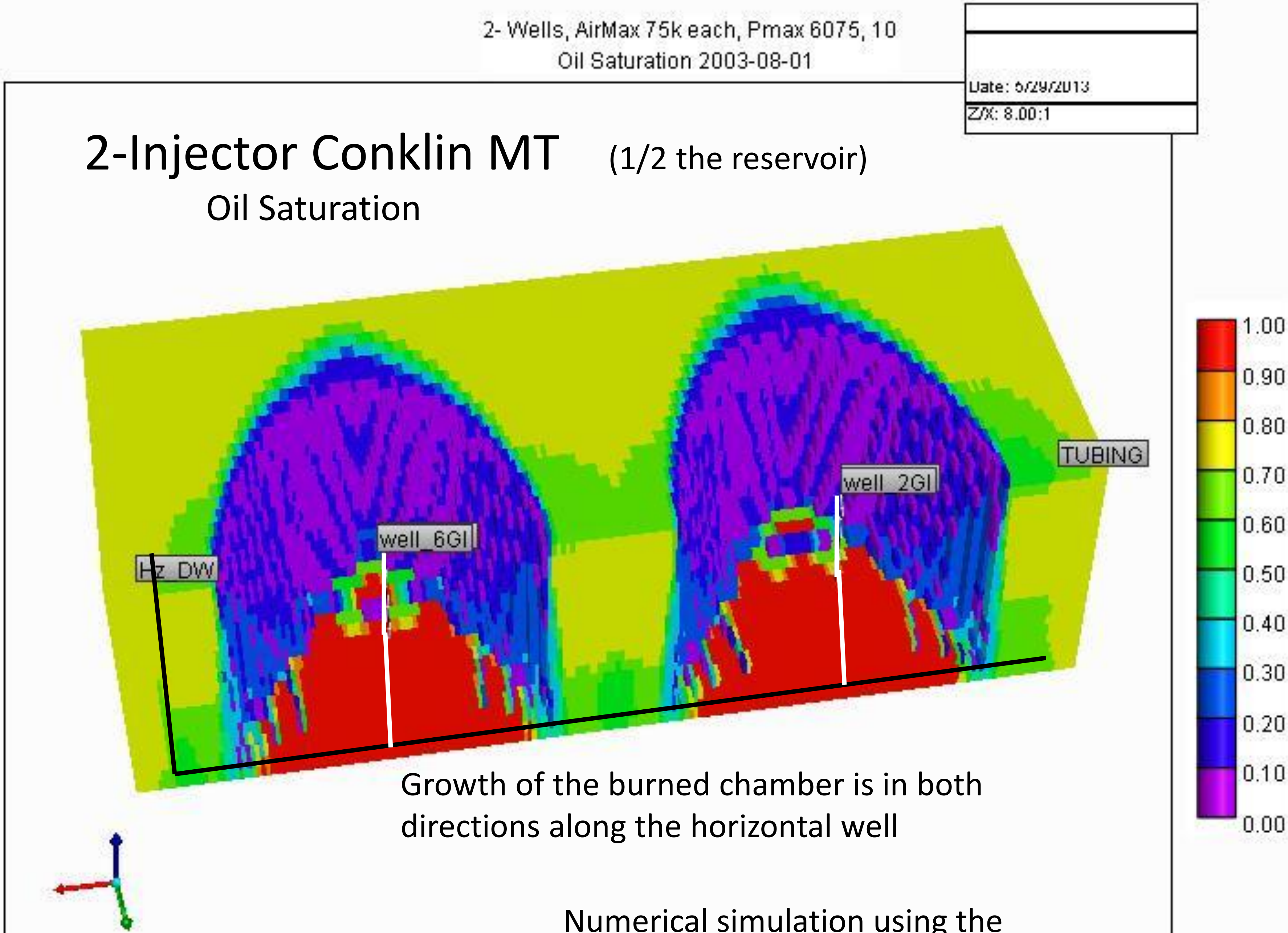
increasing producer utilization

and

greatly boosting the oil rate

2-Injector Conklin MT (1/2 the reservoir)

Oil Saturation

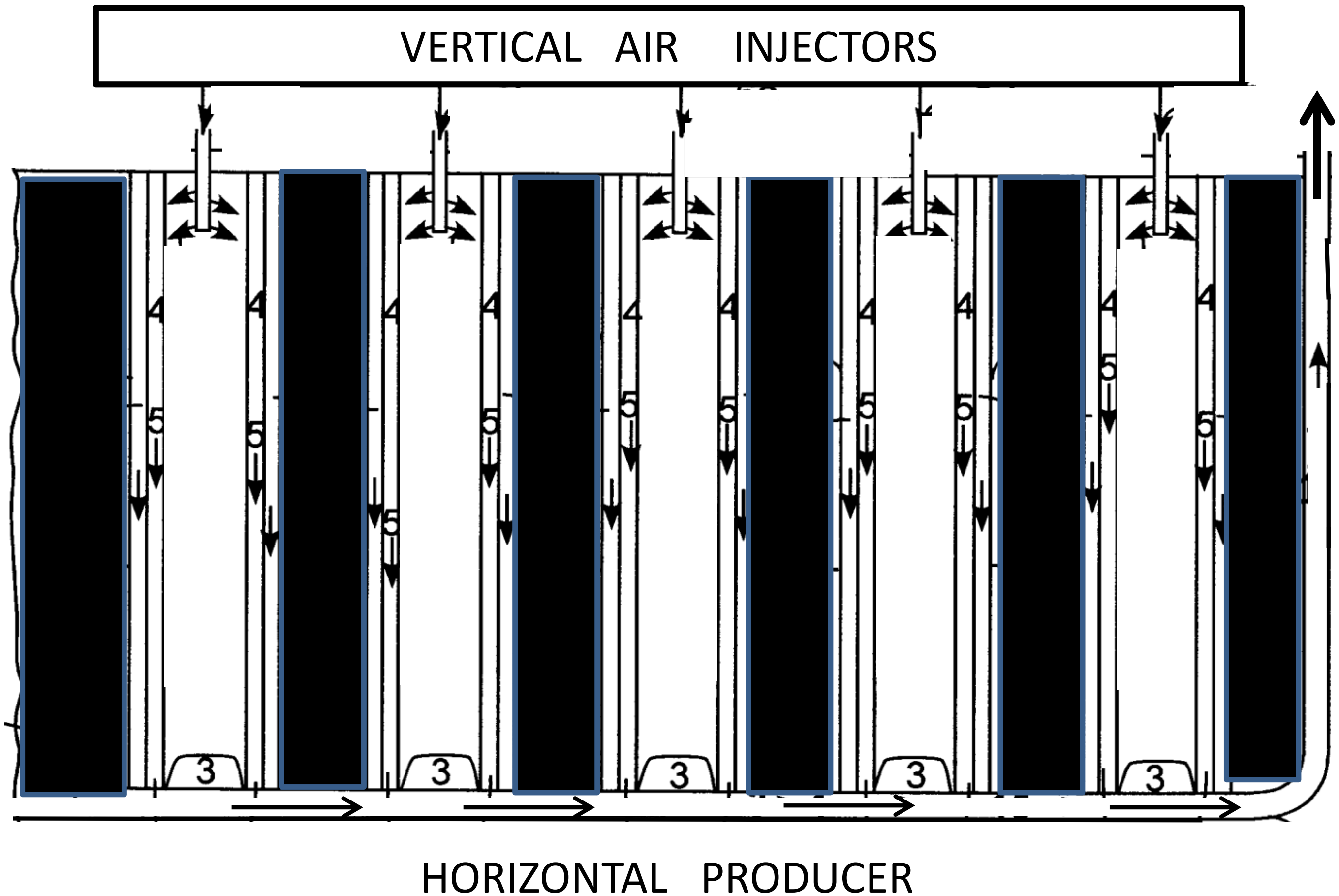


Growth of the burned chamber is in both directions along the horizontal well

Numerical simulation using the STARS (CMG) Thermal simulator

Multi-THAI^{tm} with 5-Vertical Air Injectors*

10-drainage fronts



*Capri Petroleum Technologies Ltd. Patent CA 2, 698,454 (Ayasse)

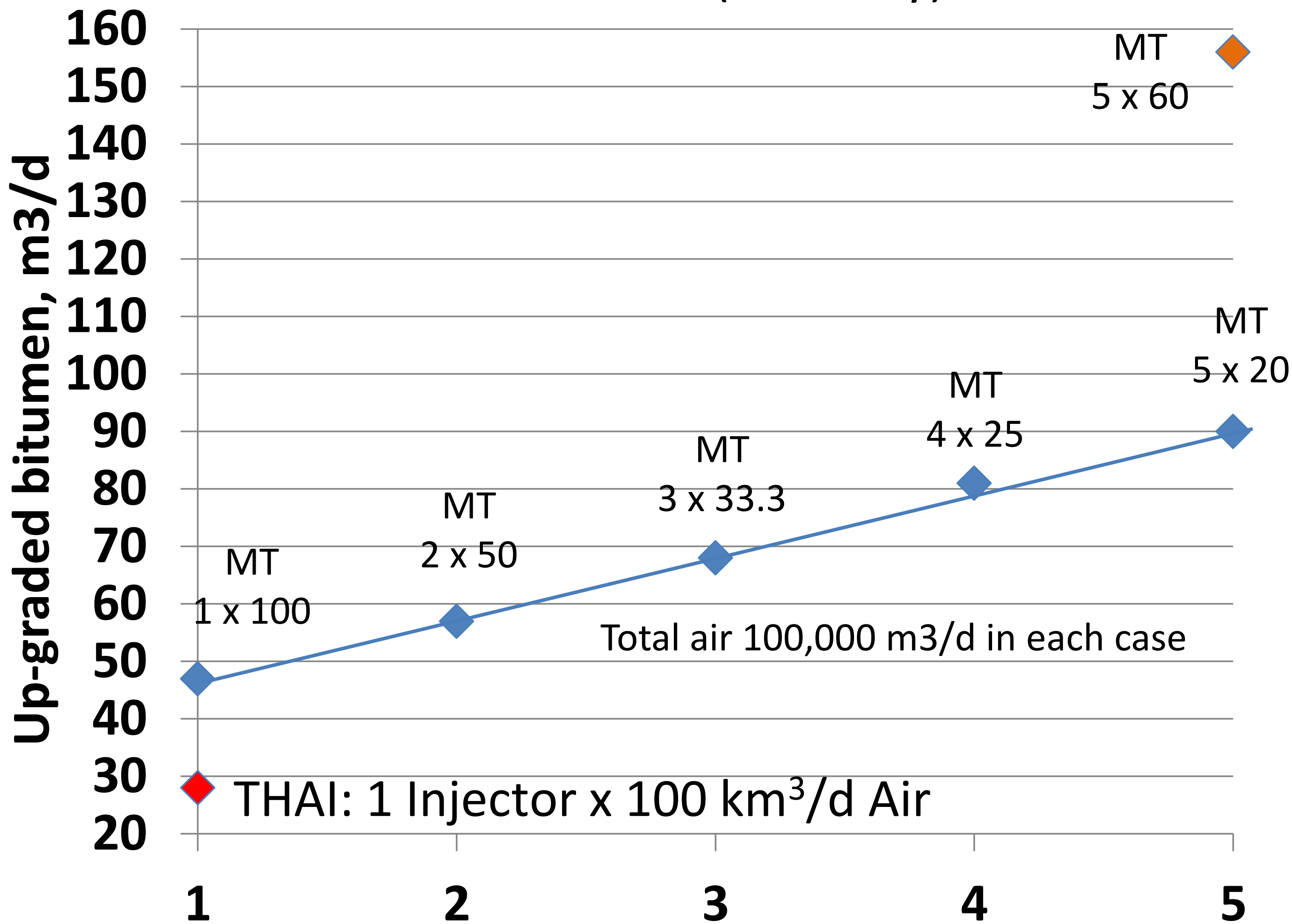
Multi-THAI^{tm} production with 100 km^3/d total air

Spreading the air over the entire producer

Table 2. Numerical simulation results (20-meters of pay)

Run number	1	2	3	4	5	6	7
# Air Injectors	1* THAI	1	2	3	4	5	5
Max. Air per injector, m^3/day.well	100k	100k	50k	33.3k	25k	20k	60k
Max. Total Air injected, m^3/day	100	100	100	100	100	100	300
Oil rate after first year, m^3/d	28	47	57	68	81	90	156
Peak oil rate, m^3/d	183	141	141	134	130	121	176
Days to 60% Oil Recovery Factor	2948	2067	2045	2019	1992	1990	1923
Recovery factor at $30m^3d$ oil rate, %	72	77	78	77	77	78	78
Minimum Cumulative Air/Oil ratio	1291	1023	1021	923	819	764	924

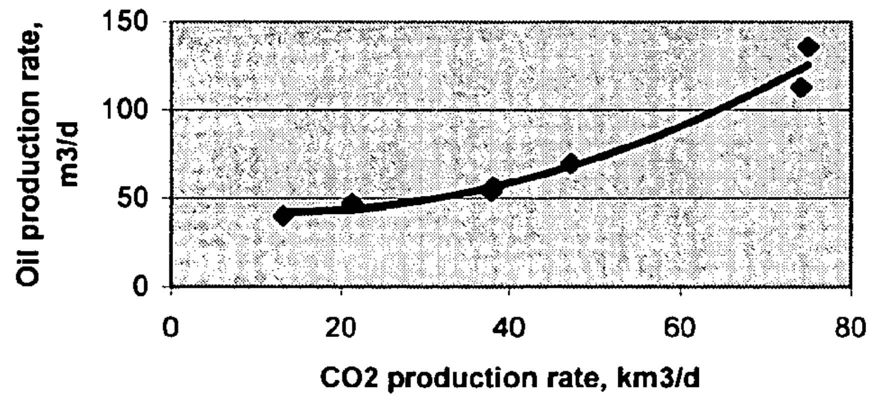
Numerical Simulation Comparison: THAI vs Multi-THAI[tm]
Conklin bitumen (20 m Pay)



3x oil production injecting O_2/CO_2*

50/50 or “Pseudo air”

Figure3. Effect of CO2 on oil production rate during THAI(tm) process.



Test	Injection Rate, km^3/day			Mol % Oxygen	Mol % CO2	Total Injection Rate,	Production Rate, km3/day		Produced Gas Mol %	Oil Rate m3/day	Cumulative Oil Recovery
#	O2	CO2	N2	Injected	Injected	km^3/day	CO2	N2	CO2	(1-year)	m3
1	17.85	0	67.15	21	0	85	13.1	67.2	16.3	41	9700
2	8.93	33.57	0	21	79	42.5	37.9	0.0	96.0	54	12780
3	25	0	0	100	0	25	21.3	0.0	96.0	47	10078
4	17.85	67.15	0	21	79	85	75.0	0.0	96.0	136	20000
5	42.5	0	0	100	0	42.5	38.1	0.0	96.0	57	12704
6	42.5	42.5	0	50	50	85	74.2	0.0	96.0	113	28104
7	8.93	42.5	33.57	11	50	85	47.2	33.6	57.4	70	12000

* Canadian Patent 2,579,854, Ayasse

The Alberta Dream Bitumen Process: MULTI-THAI^{tm}

1. Operate Multi-THAI^{tm} for excellent oil rates of > 10.5 ºAPI oil from thin bitumen reservoirs with zero external operating energy. Inject O_2/CO_2.

2. Use CPTL-DO^{tm} to convert H_2S to elemental sulphur* (net energy producer, piloted at Kerrobert, >95% eff.)

3. Upgrade Multi-THAI^{tm} oil to pipeline specifications using CPTL-UG^{tm}. (Proven over 5-months)

*Canadian Patents 2,768,359 (Ayasse et al), 2,782,944 (Ayasse et al)

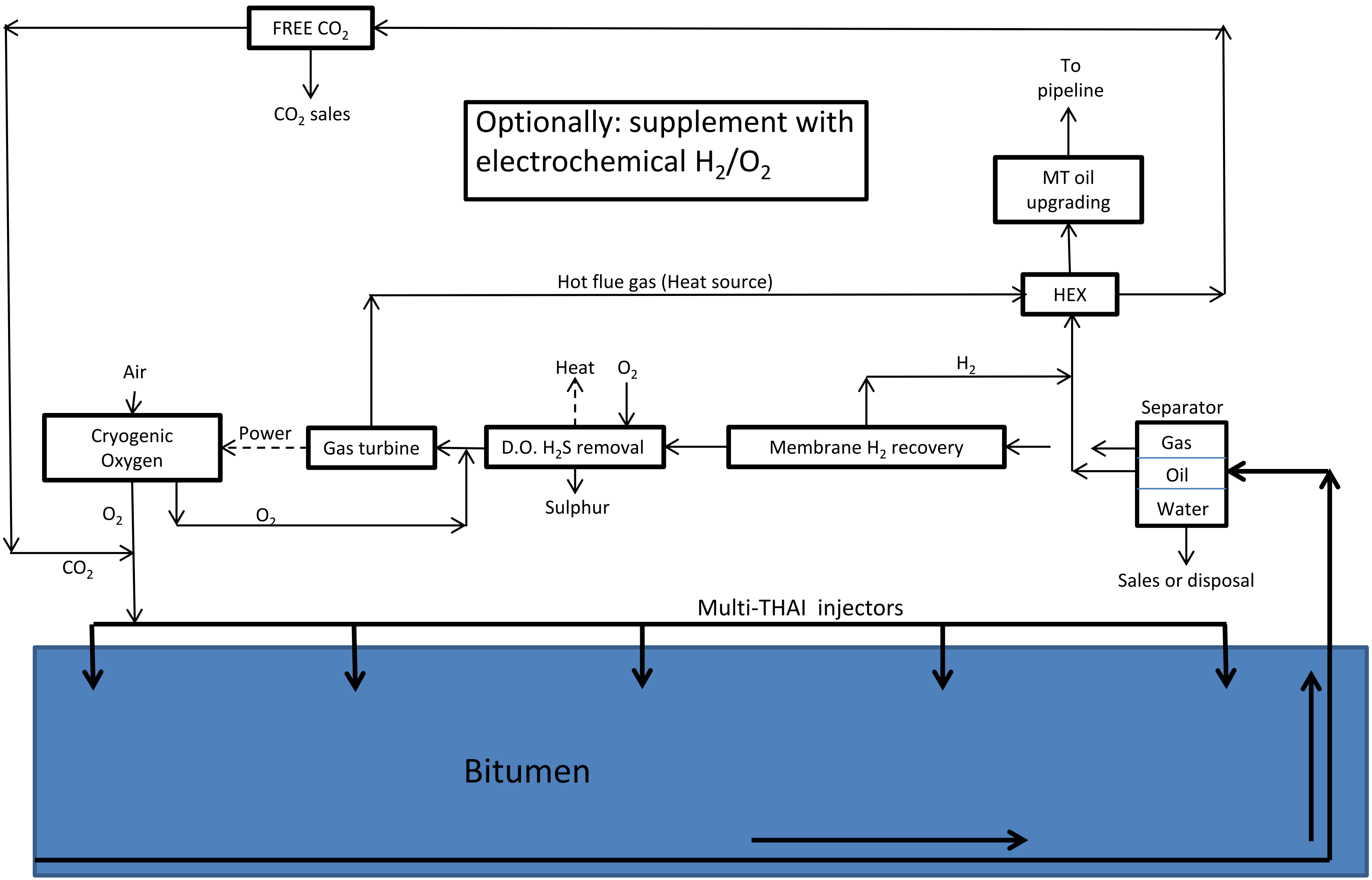
4. Recover hydrogen from produced gas and use CPTL-DO^{tm} waste heat and Tail Gas Combustion waste heat to upgrade MT oil to pipeline specifications

5. Produced gas becomes CO_2 without a separation process: Re-inject some CO_2 along with O_2 and sell the rest

The Alberta Dream Bitumen Process

High oil rates	Multi-THAI (O_2/CO_2)
No Fuel cost	Burn heaviest 9% of bitumen
No energy costs	Power from Tail Gas combust.
Eliminate diluent use	Get higher net back
Water not needed	Is a water producer
No GHG emissions	Zero CO_2emissions, CO_2 sales
Broadly applicable	Thin, dirty, shallow, deep pay
Boost pipeline capacity	30-40%
Access the West Coast	BC objects only to diluent

Alberta Dream Bitumen Schematic



The Alberta Dream Bitumen Process: PRODUCTS

INTERNAL PRODUCTS
Thermal combustion energy
Electrical power
Hydrogen

EXTERNAL PRODUCTS
Pipeline specification heavy oil
Sulphur
SAGD water
CO_2

Thank You!

Any questions?