A MICRO-SCALE N_2 REJECTION PLANT TO UPGRADE LOW-BTU MARGINAL GAS

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(The Pennsylvania State University)

Steve Moore: Proposed the initial plant design and the idea behind cost-effective low-BTU upgradation

Alan DeGood: Fianancial Support, Encouragement, and Patience

Problem Statement

U.S. natural gas reserves around 204 tcf (EIA, 2006)

Sub pipeline quality gas - CO_2 and/or N_2 contaminated

- **17.5 tcf in Midcontinent region (Hugman and others, 1990)**
- **9 tcf in Rocky Mountain region (Hugman and others, 1990)**
- **60 tcf in the U.S. (Lokhandwala and Zammerille, 2006)**

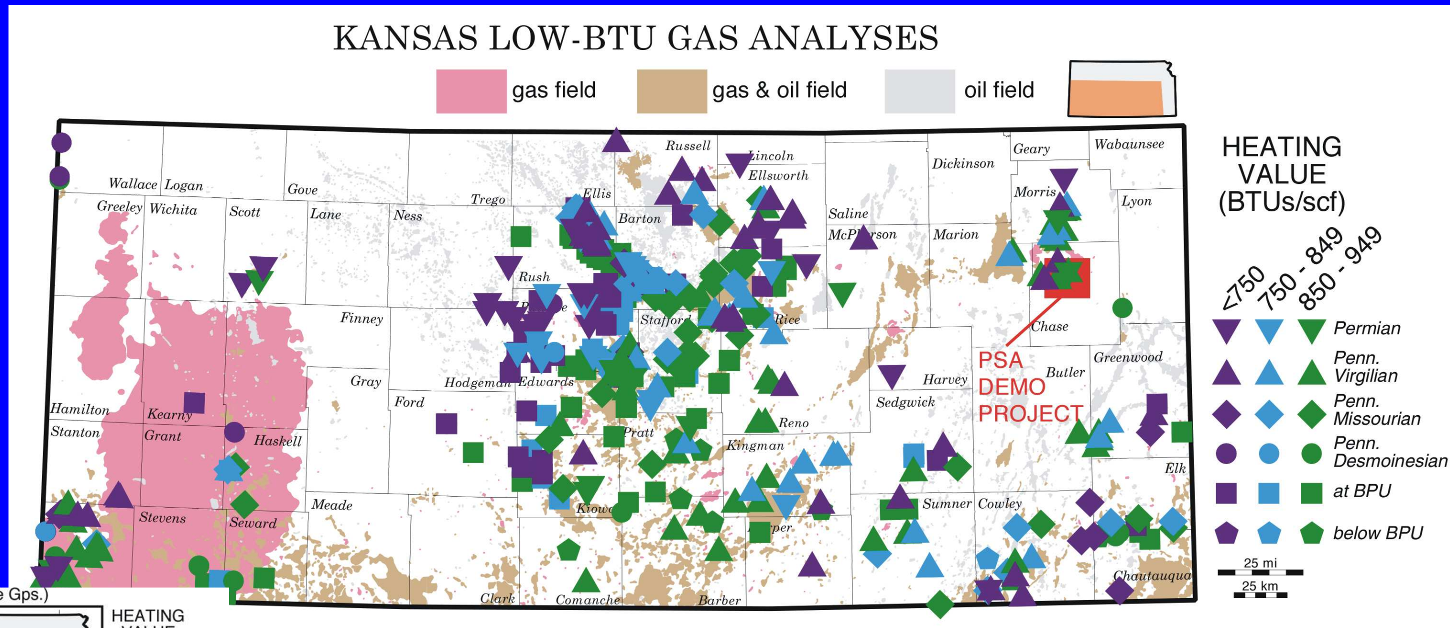
Kansas - 33% (of 1253 samples) tested low-BTU (Newell, 2007)

Sub-quality - due to N_2 contamination

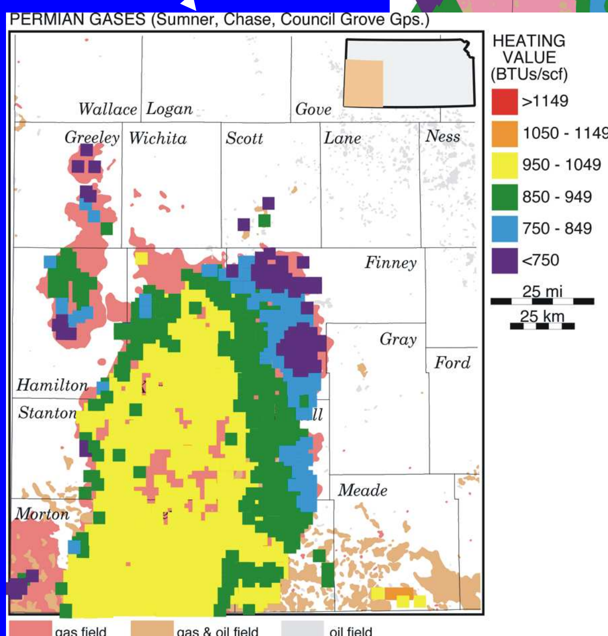
- **15+% N_2 reduces heat value to less than 950 BTU/cu ft**
- **Mid-continent - N_2 primary cause (Beebe, 1968; Jenden et al., 1988)**
- **17% of gas (> 32 tcf) nationwide (Lokhandwala and Zammerille, 2006)**
  - **Significantly in modest/small fields**
  - **Isolated location, low pressure & flow rates, rapid declines**

How to upgrade marginal low-BTU gas within resource reach of small producers?

Low-BTU Gas in Kansas



Significant volumes of Low-BTU – periphery of Hugoton field



Low-BTU gas is widely prevalent in Kansas. **33% of 1253** samples collected and tested were found to be of low-BTU.

Centralized upgradation plants

- Cryogenic (>5 mmcf/d)
- Conventional PSA/TSA (0.5 - 20 mmcf/d)

Low-BTU in Elmdale Field

Most of the wells produce pipeline quality gas from deeper Lansing horizon.

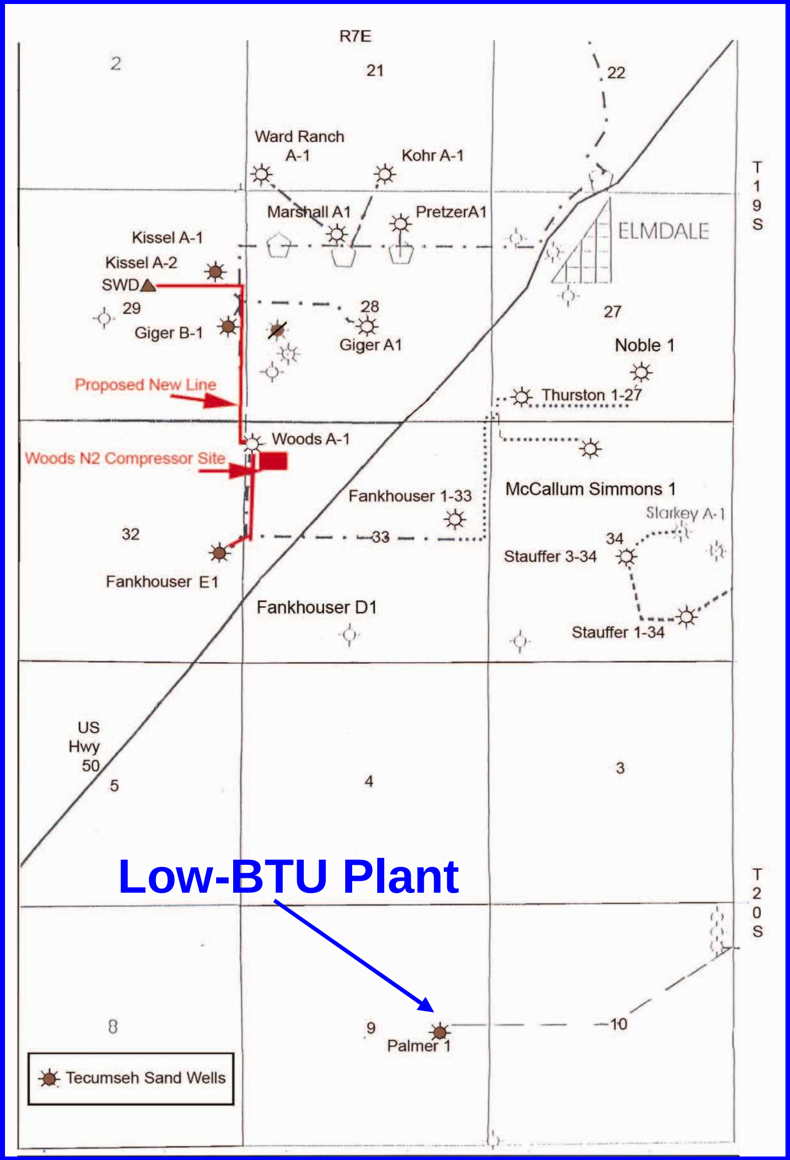
Lansing production declining between 15 to 20% annually.

Low-BTU gas has been tested in shallower intervals (Ireland, Tecumseh, Douglas) at several wells.

Currently, limited low-BTU gas produced by blending with higher BTU

What happens when Lansing gas runs out?

NOTE: Complex geology – gas pockets and compositional variation within a zone



Plant Layout

Footprint - around 400 sq ft.
Low-BTU feed to plant – 2" line
Upgraded gas to the scrubber and compressor – 3" line
N_2-rich vent gas to flare tower – 2" line
Plant tested - 105 psi and held 28" of Hg vacuum
Expected to process - 150 mcf/d feed

Process Towers

Diameter = 48"

Height = 8'

Feed line

Upgraded gas line

Surge Tank

Knockout vessel in feed line

Surge tank – 25' long and 5' feet diameter
Holding time = 1 hour
- Desorbed gas attains uniform composition

Gas Compressor & Engine

Engine - 6-cylinder 50 HP VGG-330 gas-fired engine
- operates on low-BTU feed
Compressor - Ingersoll-Rand compressor designed for vacuum service

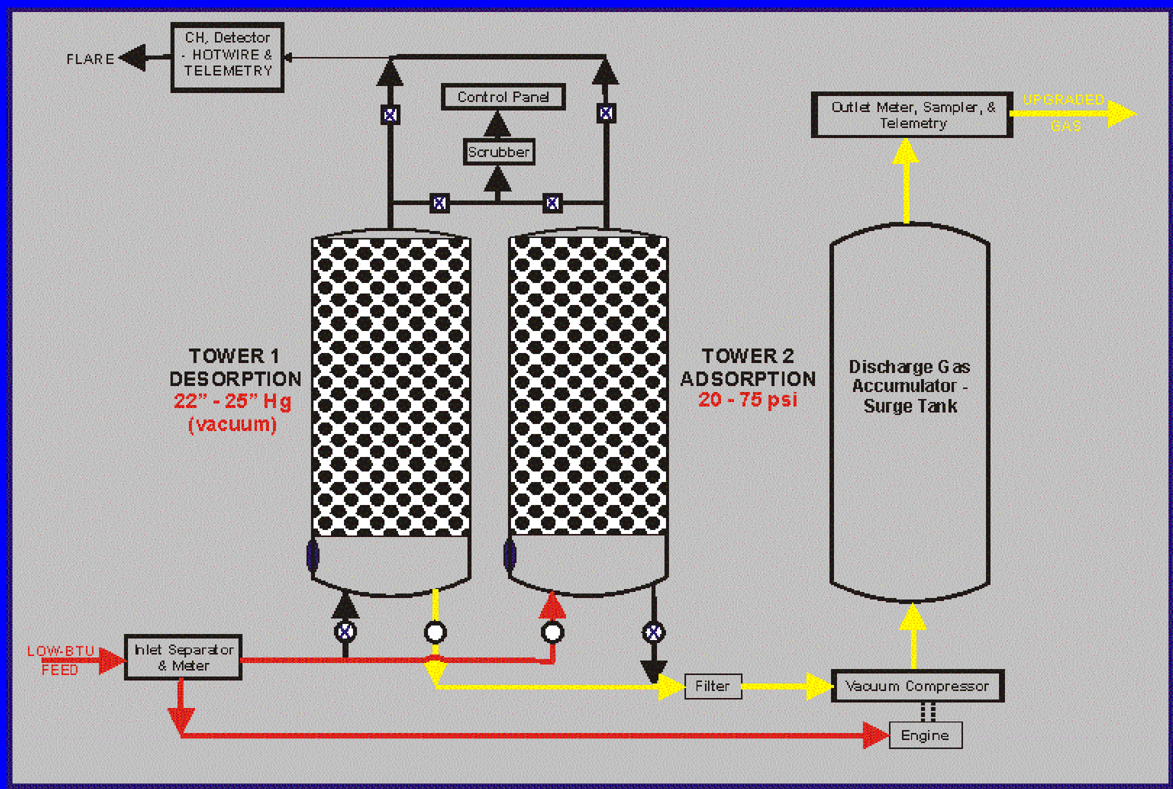
Adsorption Bed

Commonly available activated carbon made from coconut husks was used as adsorption bed

Activated carbon was purchased in 1100 lb bags and costs around 7 cents/lb

Each tower was charged with 2200 lb of carbon

PLANT BLUE PRINT



STEP 1 - Tower 1 Adsorption, Tower 2 Desorption

STEP 2 - Tower 1 Venting, Tower 2 in Vacuum

STEP 3 - Tower 1 Desorption, Tower 2 Adsorption

CRITICAL FACT ABOUT LOW-BTU UPGRADATION

BTU CONTENT

	BTU/cu ft
Methane	1010
Ethane	1770
Propane	2516
i-Butane	3253
n-Butane	3264
i-Pentane	4000
n-Pentane	4006
n-Hexane	4722
n-Heptane	5500

Heavy HCs (C_2H_6+) significantly contribute to the BTU content of natural gas.

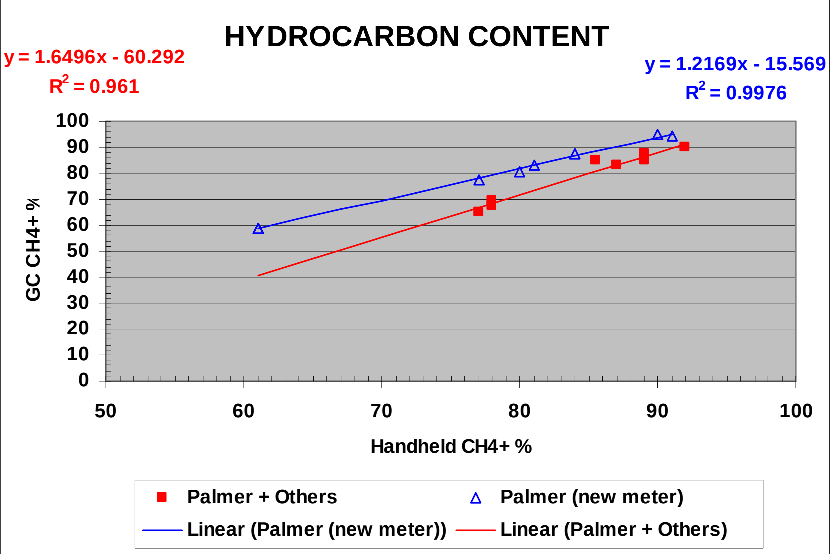
Low-BTU upgraded to pipeline quality if process captures and recovers maximum C_2H_6+ content.

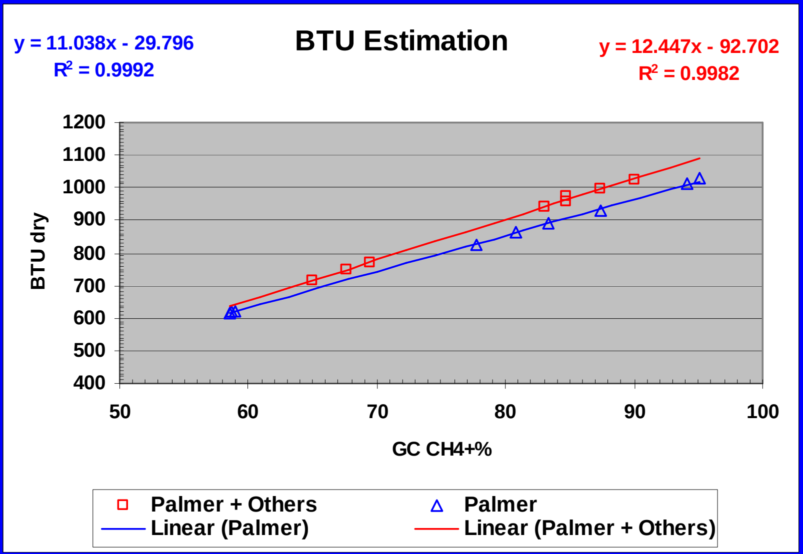
Also, success of upgradation depends on how rich low-BTU feed is in terms of its C_2H_6+ content.

CALIBRATION FOR GAS ANALYSIS

Correlations are dependent on both the feed BTU and gas composition (ratio of heavy hydrocarbons to total hydrocarbons, C_2H_6+/CH_4+)

Portable handheld hydrocarbon detector





FEED 615 BTU/cu ft, avg C2H6+/CH4+ = 3.8%

FEED 700 BTU/cu ft, avg C_2H_6+/CH_4+ = 7.9%

Feed @ 700 BTU/cu ft, C_2H_6+/CH_4+=7.9%

Vent from Top

Pipeline Quality

Tower Charge Pr	Vent to psi	Corrected Avg Feed CH4+, fr	Corrected Avg Sales CH4+, fr	Sales/Feed	Efficiency N2 stripping	Efficiency CH4+ Rec	N2 % in Vent Gas	BTU feed	BTU sales	BTU rec %
34	2	0.63	0.84	0.54	76.7	73.2	63.1	687	953	75.7
20	2	0.65	0.85	0.60	73.8	77.4	63.2	722	964	79.7

Sales/Feed ratio - indicative of gas (CH_4+ & N_2) lost from the system

- HIGH - tower charge pressure low, dead space volume minimized
- LOW - tower charge pressure high, dead space volume significant

N_2 Stripping Efficiency - % of feed N_2 volume that is rejected (vented)

- HIGH - high tower charge pressure (more HCs adsorbed)
- LOW - low tower charge pressure (less HCs adsorbed)

CH_4+ Recovery Efficiency - % of feed HC captured for sales

- HIGH - low tower charge pressure (less HCs lost during vent)
- LOW - high tower charge pressure (more HCs lost during vent)

BTU Recovery Efficiency - (Sales BTU*Sales mcf)/(Feed BTU*Feed mcf)

- Follows CH_4 recovery efficiency - HCs determine BTU content

GAS ANALYSIS

Sample date	30-May-08	
Sample No.	KGS 1	
Sample description	Feed gas	

Component	Mole %	BTU/scf
Hydrogen	0.0000	0.00
Helium	0.6495	0.00
CO2	0.2135	0.00
Neopentane	0.0014	0.00
Nitrogen	33.7049	0.00
Argon	0.1748	0.00
Methane	60.3800	609.84
Ethane	2.8948	51.23
Propane	1.3320	33.52
i-Butane	0.1826	5.94
n-Butane	0.3161	10.31
i-Pentane	0.0664	2.66
n-Pentane	0.0665	2.67
n-Hexane	0.0135	0.64
n-Heptane	0.0040	0.22

CH4+	65.3
C2H6+	4.9
C2H6+/CH4+	0.075

Sample date	6-Jun-08	
Sample No.	KGS 5	
Sample description	Sales gas	

Component	Mole %	BTU/scf
Hydrogen	0.0000	0.00
Helium	0.1225	0.00
CO2	0.1820	0.00
Neopentane	0.0000	0.00
Nitrogen	14.5400	0.00
Argon	0.3692	0.00
Methane	75.3267	760.80
Ethane	5.2381	92.70
Propane	2.7426	69.01
i-Butane	0.3890	12.65
n-Butane	0.7116	23.22
i-Pentane	0.1574	6.30
n-Pentane	0.1640	6.58
n-Hexane	0.0363	1.73
n-Heptane	0.0205	1.13

CH4+	84.8
C2H6+	9.5
C2H6+/CH4+	0.112

Most heavy HCs are adsorbed by the activated carbon and subsequently recovered.

Calls in question the feasibility of capturing vent gas for secondary upgradation given that it lacks heavy HCs that significantly add to the BTU of the upgraded gas.

HOW POOR A GAS CAN BE UPGRADED? Feed 615 BTU/cu ft, HHC = 3.8%

Tower Charge Pr	Vent to psi	Corrected Avg Feed CH4+ %	Corrected Avg Sales CH4+ %	Sales/Feed	Efficiency N2 stripping	Efficiency CH4+ Rec	N2 % in Vent Gas	BTU feed	BTU sales	BTU rec %
15	2 T*	59	78	0.64	66	85	75	619	831	86
30	2 T*	59	82	0.49	79	69	64	622	881	70
70	13 T*	59	86	0.45	85	66	63	621	920	67
66	9.5 T*	59	84	0.49	84	73	68	618	923	74
66	4 T&B**	58	88	0.42	88	64	64	607	940	65
69	3 T&B**	60	89	0.39	90	58	59	633	958	59
72	4 T&B**	60	89	0.40	89	59	59	634	956	60

T - vent from top; T&B** - vent from top and bottom of the tower*

Pipeline Quality

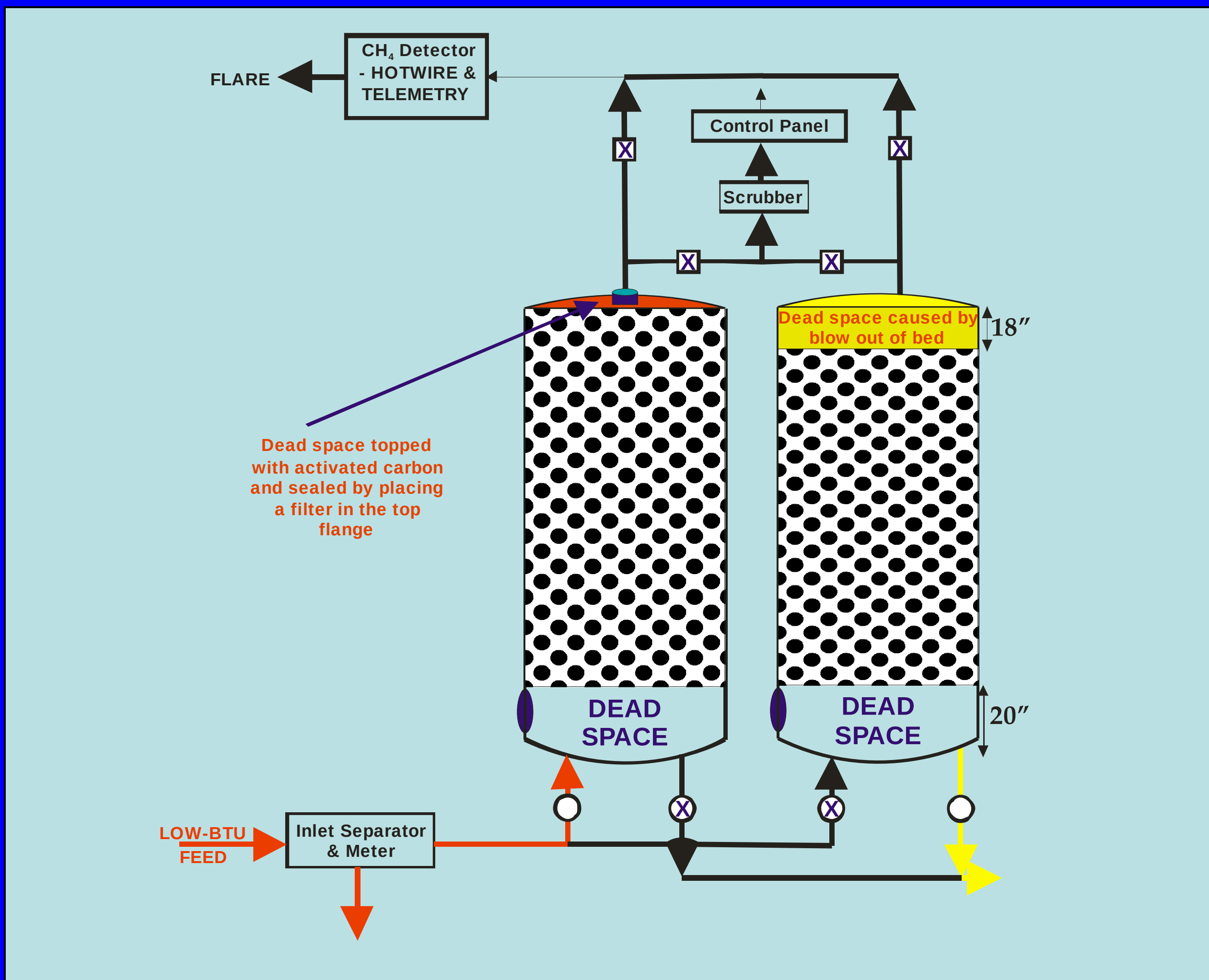
As feed quality changed, lower BTU and lower C_2H_6+/CH_4+ ratio, the plant settings had to be changed dramatically to achieve pipeline quality output that resulted in lower sales/feed ratios.

SIMULTANEOUS VENTING FROM TOP & BOTTOM

Dead space remains at the bottom of each tower and this is filled with N_2-rich feed gas after the vent phase. Upon desorption, this remaining feed gas enters the surge tank and lowers the BTU of the sales gas.

Attempts were made to flush out much of this feed gas in the bottom dead space by simultaneously venting from both the top and bottom of the tower.

DEAD SPACE IN TOWER



Minimize dead space in tower especially relative to the tower volume.

Higher bed mass, increases volume of adsorbed gas and therefore results in higher sales/feed ratios.

PERFORMANCE COMPARISON WITH COMMERCIAL PLANT

Daily Feed, mcf	Seller's %
1,300 to 1,750	72
1,100 to 1,299	70
900 to 1,099	68
650 to 899	64
550 to 649	59
450 to 549	55
< 450	51

ADDITIONAL DETAILS

Feed limitations: Often cant have too high N_2 (< 28% N_2) concentration

Transportation costs if pipeline is available to connect source to plant (would additionally cost 13% of volume transported in this case)

SELL TO COMMERCIAL PLANT (if feed qualifies??)

Feed 100 mcf/d - Seller paid 51 mcf/d, Transportation costs 13 mcf/d

Seller's revenue - 36 mcf/d

USE OUR PLANT (feed with as high as 40% N_2)

Feed 100 mcf/d - Transportation costs zero

Seller's revenue - 40 mcf/d (Feed - 40% N_2, 615 BTU/cu ft, C_2H_6+/CH_4+ = 3.8%)

Seller's revenue - 60 mcf/d (Feed - 35% N_2, 700 BTU/cu ft, C_2H_6+/CH_4+ = 7.9%)

PLANT ECONOMICS

Feed 150 mcf/d, Gas Price = $7/mcf

Plant Construction Costs = $120,000

@ 615 BTU/cu ft feed, Sales = 60 mcf/d, Revenue = $420/daily,

Pay out = 9.5 months

@ 700 BTU/cu ft feed, Sales = 90 mcf/d, Revenue = $630/daily,

Pay out = 6.5 months

FUTURE PLANS

1. Fill-up towers to reduce dead space (at the bottom).

2. Test Towers - Feed at 615 BTU/cu ft. Optimize charge and vent pressures to maximize sales/feed at pipeline quality.

3. Complete building 2nd set of towers where dead space is insignificant to tower volume and operationalize tower at an American Energies (Corp) field.

4. American Energies (Corp) plans to build, install, and sell many more plants.

Height = 20', Diameter = 6'

CONCLUSIONS

"YES, WE CAN" – its is possible to upgrade low-BTU gas to pipeline quality using a simple cost-effective plant.

Approximating plant construction costs at $120,000 and assuming a feed of 150 mcf/d, payout is estimated at 9.5 months for 615 BTU/cu ft feed and 6.5 months for 700 BTU/cu ft feed.

Minimize dead space relative to tower volume. Greater the bed mass, more HCs adsorbed and better the sales/feed ratio.

Need to evacuate (desorb) towers to maximum vacuum (≈25" Hg) quickly to recover heavy HCs adsorbed and increase plant throughput. This improves bed life and BTU of desorbed gas.

SO DO NOT GO CHEAP ON THE COMPRESSOR.

Optimum plant settings will change as per feed composition (BTU and C_2H_6+/CH_4+ ratios).