Fundamentals of Vapor Recovery

"Associated Gas" IS LOST PRODUCT

*And **LOST REVENUE***

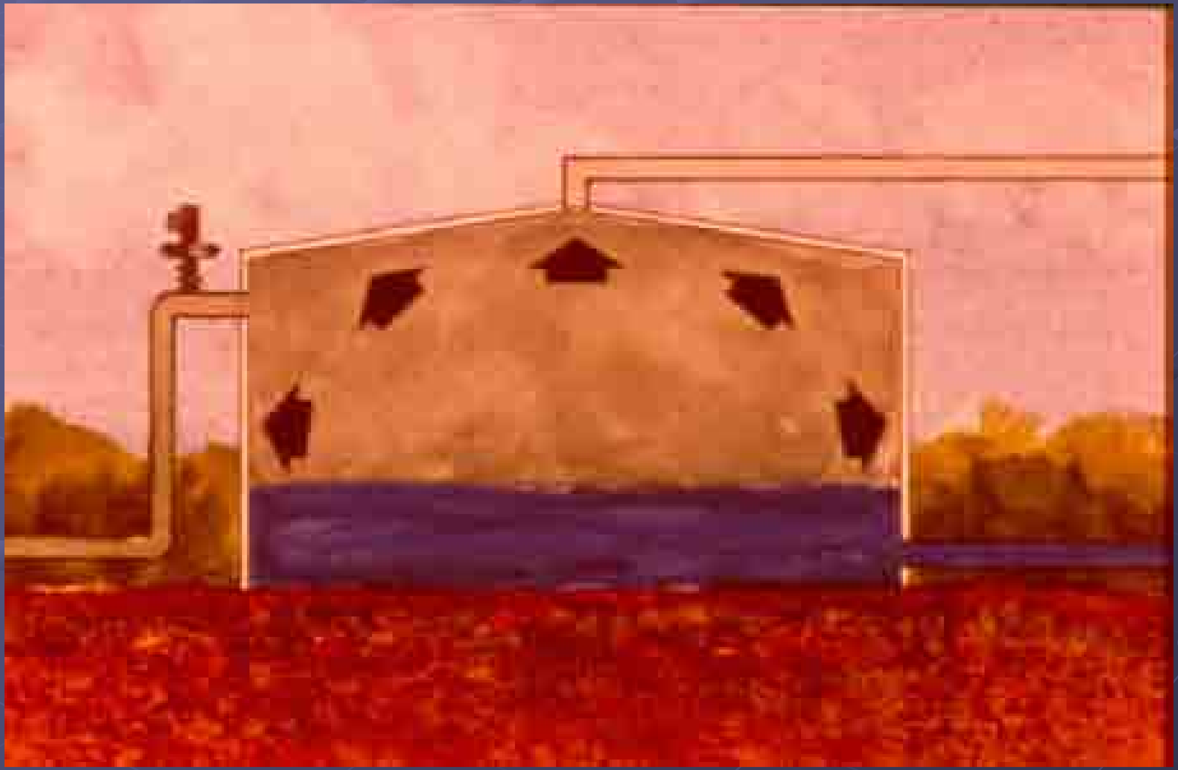
Presented by:

Larry S. Richards

Hy-Bon Engineering Co.

TANK OPERATIONS

As the oil resides in the tanks, it gives off vapors, thereby increasing the pressure inside the tank.



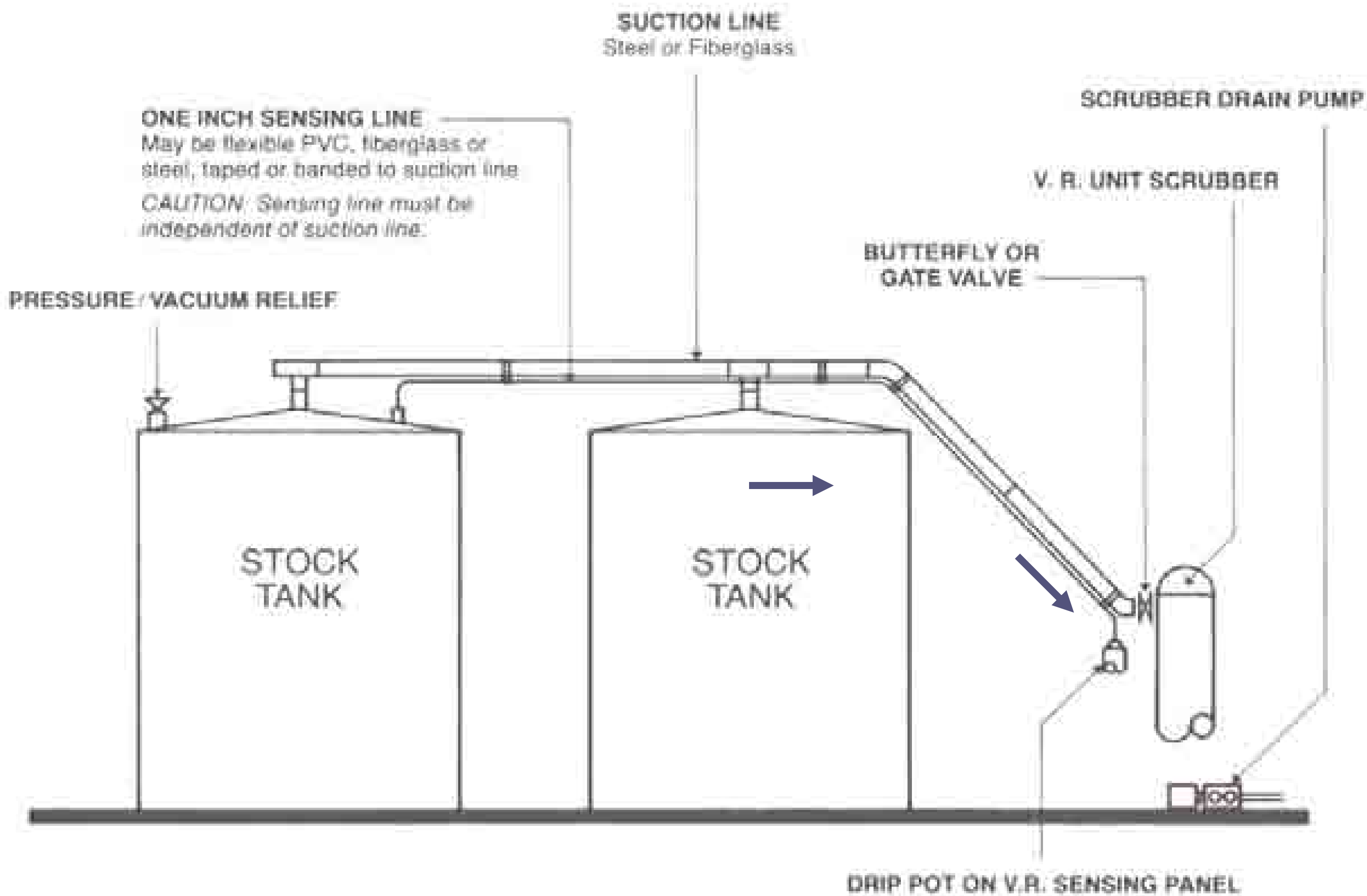
Sources of Methane Losses

- Approximately 9 Bcf/yr of Methane
  are lost from storage tanks in the United States market alone
  - Flash losses
    - occur when crude is transferred from containment at a high pressure to containment at a lower pressure
  - Working losses
    - occur when crude levels change and when crude in the tank is agitated
  - Standing losses
    - occur with daily and seasonal temperature and pressure changes

Source: Natural Gas STAR Partners

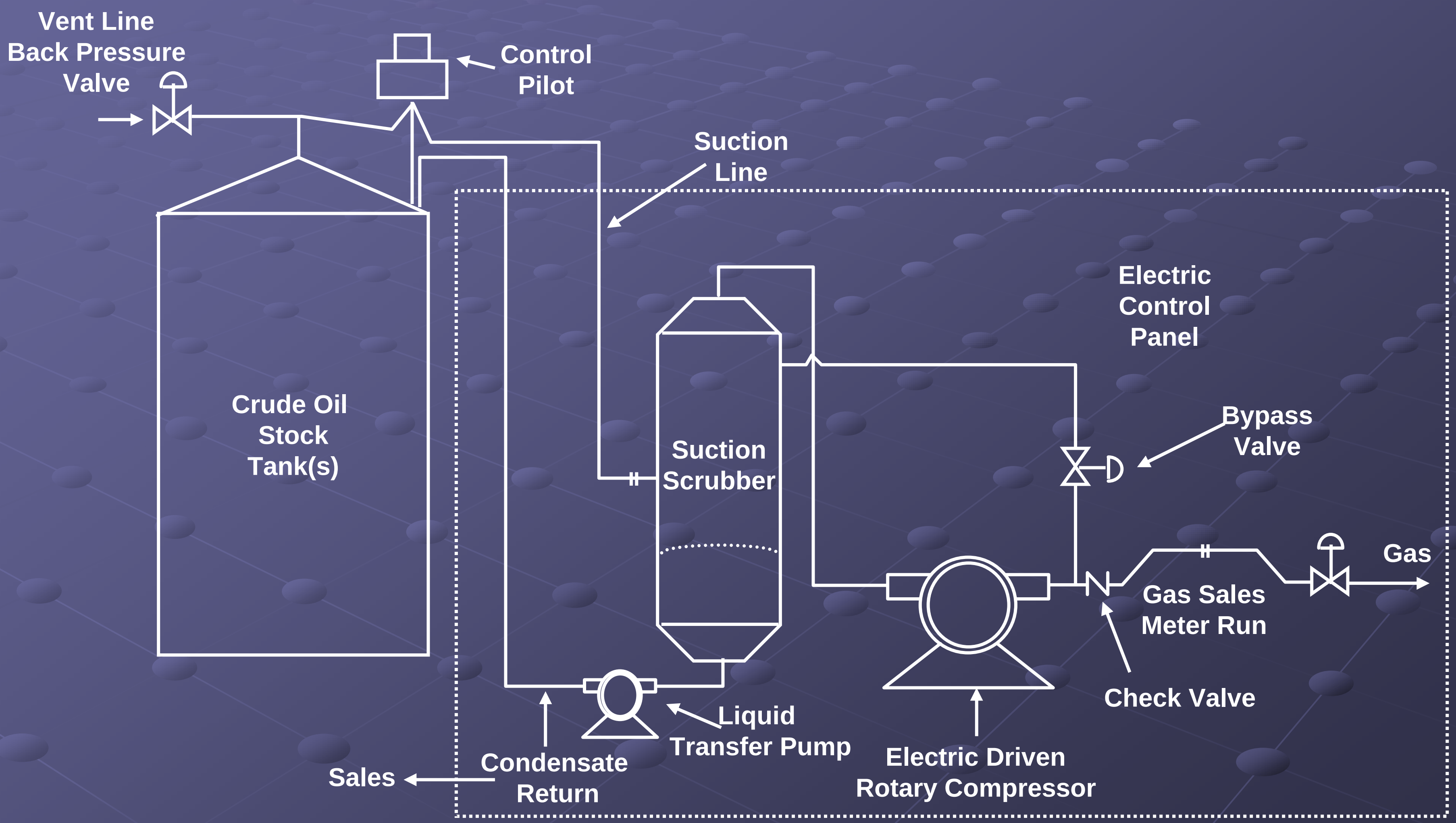
WHY LET $ ESCAPE INTO THE AIR?

Besides being an environmental hazard, escaping vapors actually cost the operator money. What money? Uncaptured profits!! An average tank battery can emit from $15,000 to $50,000 in natural gas per



NOTES
All lines must be horizontal, or sloped down to V.R.U. suction as shown.
Scrubber fluid is piped back to tanks or to waste.
The system must be closed — no air entry.

Standard Vapor Recovery Unit



VAPOR RECOVERY

Typical stock tank vapor recovery unit in operation. This unit is configured to capture 90 mcfd of gas and discharge into a 40 psig sales line.

Benefits of Vapor Recovery Units

- Capture up to 95 percent of hydrocarbon vapors that accumulate in tanks
- Recovered vapors have much higher Btu content than pipeline quality natural gas
- Recovered vapors can be more valuable than methane alone
- Reduce regulatory & liability exposure

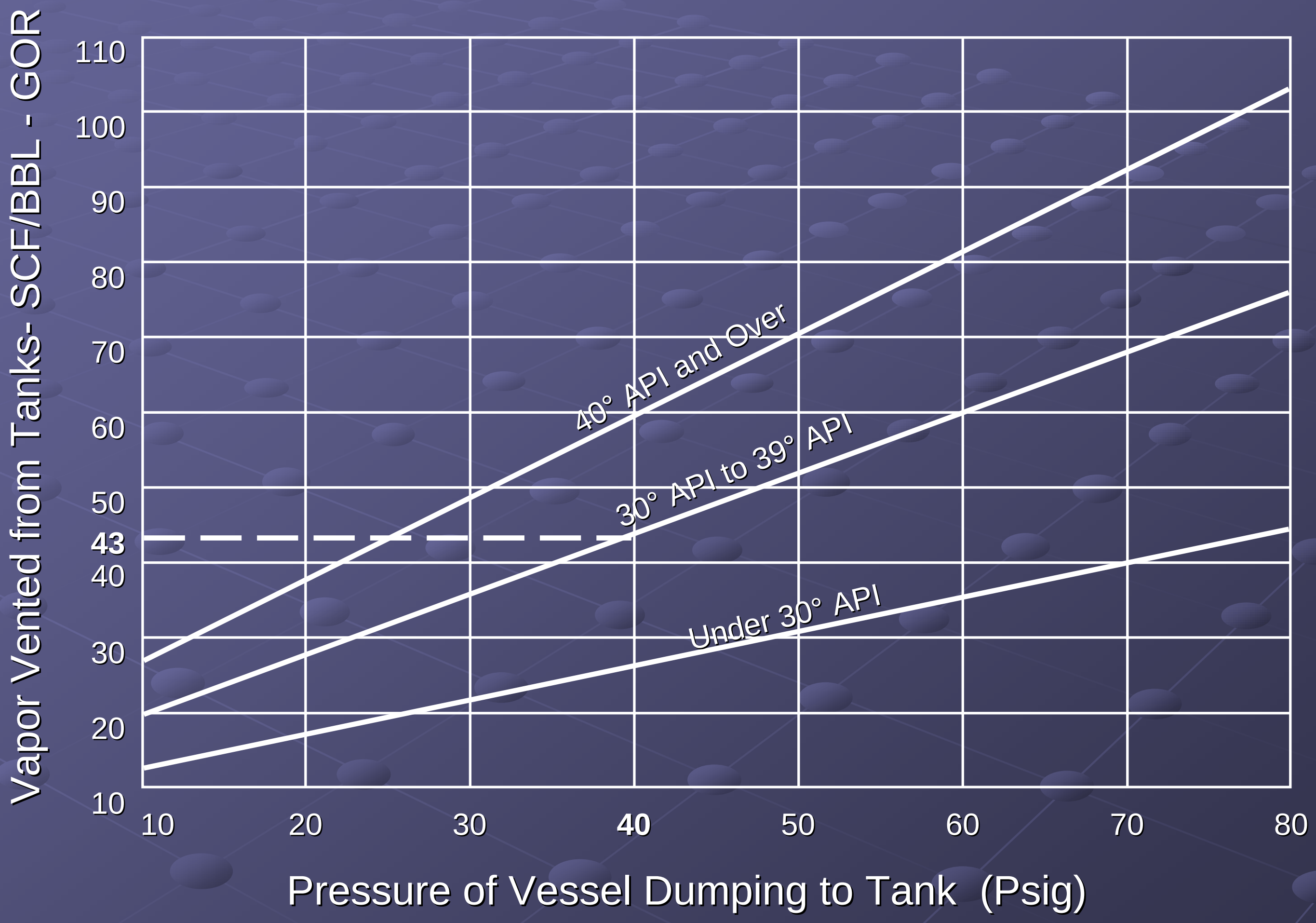
VRU Decision Process

1. Identify possible locations for VRUs
2. ***Quantify the volume of losses***
3. Determine the value of recoverable losses
4. Determine the cost of a VRU project
5. Evaluate VRU project economics

Quantify Volume of Losses

- Estimate losses from chart based on oil characteristics, pressure, and temperature at each location
- Estimate emissions using the *E&P Tank Model*
- Measure losses using orifice well tester and recording manometer

Estimated Volume of Tank Vapors

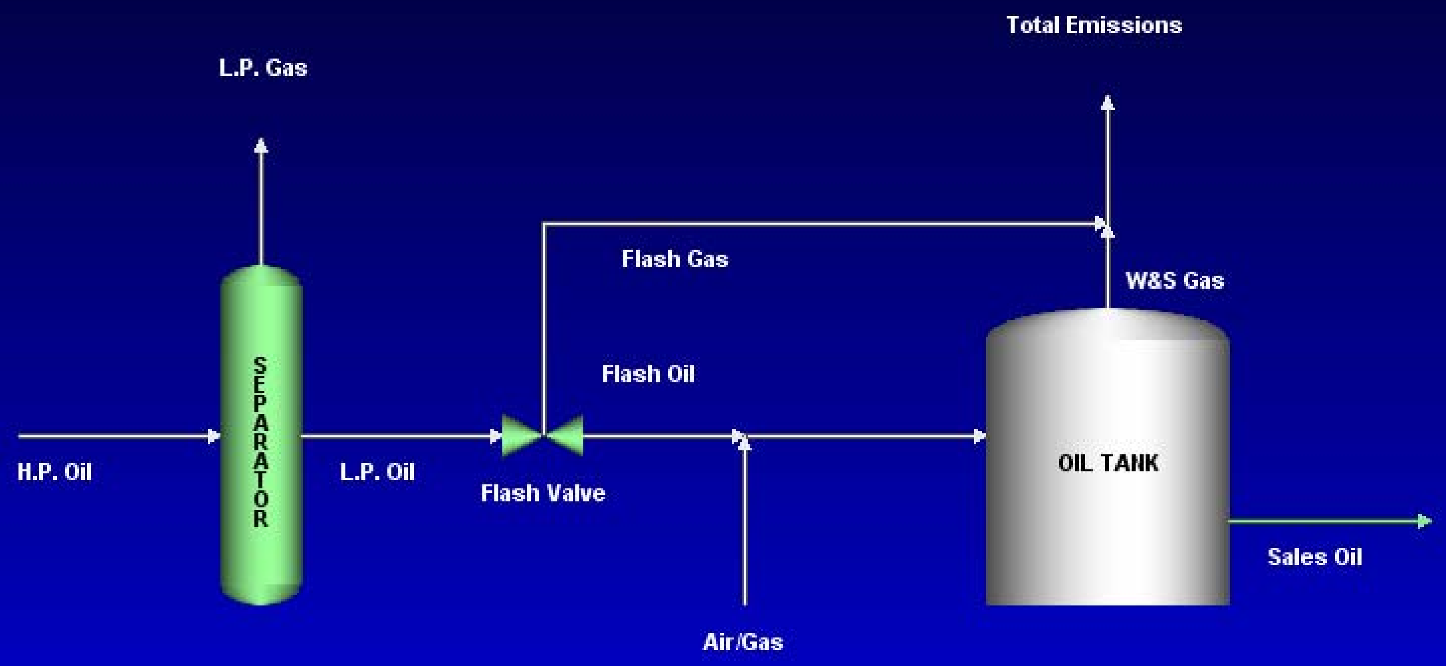


Estimating Tank Emissions

- Chart method is a quick and easy way to get a fast ballpark estimate
- Notice the impact of higher gravity oil, as well as higher separator pressures
- This method is VERY CONSERVATIVE and generally underestimates actual emission levels

Quantify Volume of Losses

- *E&P Tank* Model
  - Computer software developed by API and GRI
  - Estimates flash, working, and standing losses
  - Calculates losses using specific operating conditions for each tank
  - Provides composition of hydrocarbon losses


Total Emissions
L.P. Gas
Flash Gas
W&S Gas
Flash Oil
SEPARATOR
H.P. Oil
L.P. Oil
Flash Valve
OIL TANK
Sales Oil
Air/Gas

-- Emission Composition ---

Component	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
H2S	12.137	2.771	0.607	0.139
O2	0.000	0.000	0.000	0.000
CO2	85.667	19.559	85.667	19.559
N2	2.284	0.521	2.284	0.521
C1	122.391	27.943	6.120	1.397
C2	159.072	36.318	7.954	1.816
C3	415.158	94.785	20.758	4.739
i-C4	96.442	22.019	4.822	1.101
n-C4	261.360	59.671	13.068	2.984
i-C5	82.901	18.927	4.145	0.946
n-C5	97.357	22.228	4.868	1.111
C6	28.130	6.422	1.407	0.321
C7	26.984	6.161	1.349	0.308
C8	10.294	2.350	0.515	0.118
C9	2.081	0.475	0.104	0.024
C10+	0.544	0.124	0.027	0.006
Benzene	2.029	0.463	0.101	0.023
Toluene	0.250	0.057	0.013	0.003
E-Benzene	0.032	0.007	0.002	0.000
Xylenes	0.264	0.060	0.013	0.003
n-C6	19.202	4.384	0.960	0.219
224Trimethylp	0.000	0.000	0.000	0.000
Total	1424.579	325.246	71.229	16.262

-- Emission Summary --

Item	Uncontrolled [ton/yr]	Uncontrolled [lb/hr]	Controlled [ton/yr]	Controlled [lb/hr]
Total HAPs	21.780	4.973	1.089	0.249
Total HC	1324.491	302.395	66.225	15.120
VOCs, C2+	1202.100	274.452	60.105	13.723
VOCs, C3+	1043.029	238.134	52.151	11.907

Uncontrolled Recovery Info.

Vapor	71.3400	[MSCFD]
HC Vapor	66.3900	[MSCFD]
GOR	35.67	[SCF/bbl]

TANK TEST

A chart recorder is set up on the tank battery for a 24-hour pressure test. The resultant chart is brought into the office for evaluation. Information such as ambient temperature, test apparatus size and orifice size is recorded and used in the calculation of volume of tank vapors.

TANK TEST

Ultrasonic meters and Mass flow meters are also effective

The key is DURATION – a minimum of 24 hours of emissions must be charted for accurate results

Value of Recovered Gas

Gross revenue per year = (Q x P x 365 x B) + NGL

Q = Rate of vapor recovery (Mcfd)

P = Price of natural gas

B = Btu adjustment (typically 2.5)

NGL = Value of natural gas liquids

EPA Website – PRO Tools

To evaluate this practice for your situation, fill in the values below and click "Calculate Results".

NATURAL GAS & CRUDE OIL TANK VALUES

Pressure of the vessel dumping to the tank (PSIG)	23 psi
API gravity (degrees)	42 api gravity
Amount of crude oil cycled through the tank (bbl/d)	2,000 bbl/day
Number of days per year the Vapor Recovery Unit will be operated (days/yr)	351 days

CALCULATE CAPITAL AND O&M COST ESTIMATES

Click to calculate estimates for capital equipment costs and O&M costs.

Calculate

EPA Website – PRO Tools

CAPITAL EQUIPMENT AND O&M COSTS

Enter your own values for the capital equipment listed below or accept the estimates.

Vapor Recovery Unit cost ($)	$30,068
Vapor Recovery Unit installation cost ($)	$22,551
Depreciable life of equipment (Years)	10
Vapor Recovery Unit O&M cost ($/year)	$8,649

http://www.ergweb.com/gasstar/analytical_tool/VaporRecovery.asp

EPA Website – PRO Tools

GENERAL ECONOMIC VALUES

Natural gas cost ($/Mcf)

Natural gas cost escalator (%)

O&M cost escalator (%)

Discount rate (%)

Marginal tax rate* (%)

Investment tax credit (%)

Working interest for capital costs (%)

Working interest for O&M costs (%)

Working interest for gas savings (%)

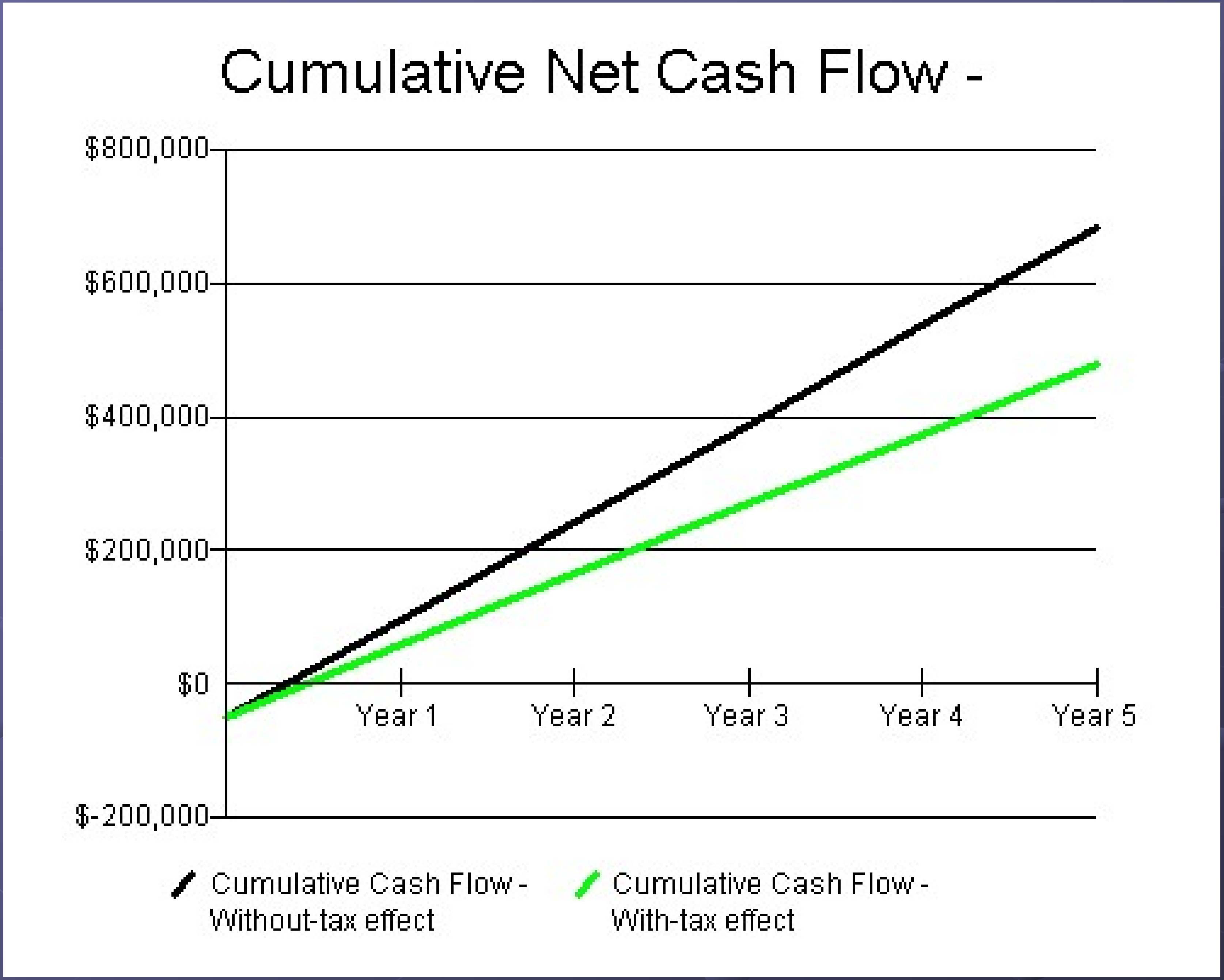
Each variable can be added based on your companies specific conditions and contract terms

EPA Website – PRO Tools

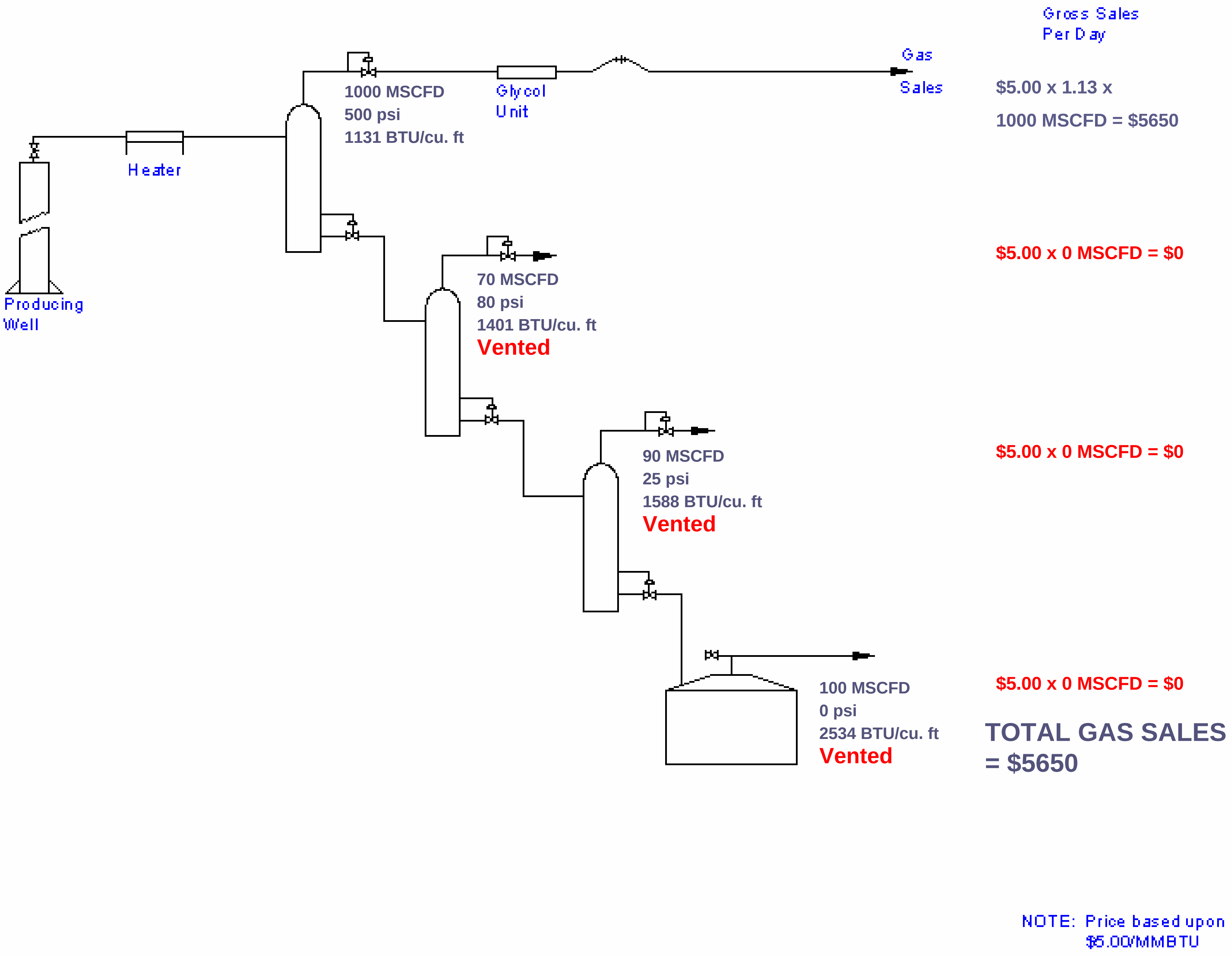
Analysis results for:
INSTALLING VAPOR RECOVERY UNITS ON CRUDE OIL STORAGE TANKS

Gas emission reduction	
5 Year gas savings	**141,453**
First Year gas savings	**28,291 (mcf)**
Without-tax effect	
5 Year NPV	**$504,434**
Payback (Years)	**0.36**
DCFIRR	**279%**
Simple ROI	**279%**
With-tax effect	
5 Year NPV (AT)	**$350,477**
Payback (AT) (Years)	**0.47**
DCFIRR (AT)	**208%**
Simple ROI (AT)	**201%**

To save this specific case for viewing in the Results Summary page, provide a name and click "Save"


Cumulative Net Cash Flow -
$800,000
$600,000
$400,000
$200,000
$0
$-200,000
Year 1
Year 2
Year 3
Year 4
Year 5
Cumulative Cash Flow - Without-tax effect
Cumulative Cash Flow - With-tax effect

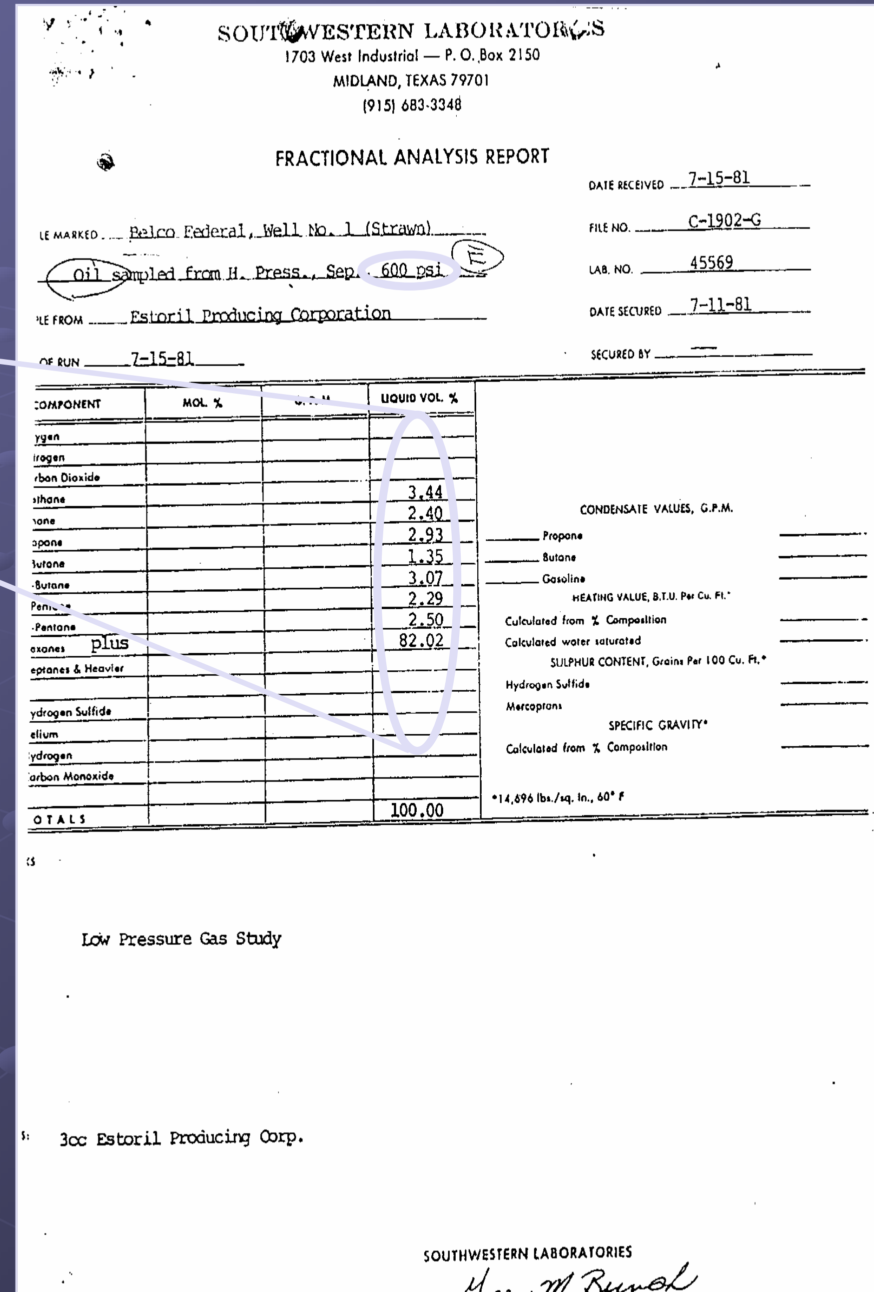
CASE STUDIES


Gross Sales
Per Day
Gas
Sales
$5.00 x 1.13 x
1000 MSCFD = $5650
Glycol
Unit
1000 MSCFD
500 psi
1131 BTU/cu. ft
Heater
Producing
Well
70 MSCFD
80 psi
1401 BTU/cu. ft
Vented
$5.00 x 0 MSCFD = $0
90 MSCFD
25 psi
1588 BTU/cu. ft
Vented
$5.00 x 0 MSCFD = $0
100 MSCFD
0 psi
2534 BTU/cu. ft
Vented
$5.00 x 0 MSCFD = $0
TOTAL GAS SALES
= $5650
NOTE: Price based upon
$5.00/MMBTU

THE SOLUTION

A system was designed to allow the customer to capture the vented gas from all phases of his separation process. A multi-stage unit was designed and built that took the gas from the tank vapors at atmospheric pressure, gathered the vent gas from the other separators and delivered the stream to the sales line at 500 psig.

Crude Oil Analysis



SOUTHWESTERN LABORATORIES
1703 West Industrial — P. O. Box 2150
MIDLAND, TEXAS 79701
(915) 683-3348

FRACTIONAL ANALYSIS REPORT

DATE RECEIVED 7-15-81
FILE NO. C-1902-G
LAB. NO. 45569
DATE SECURED 7-11-81
SECURED BY —

LE MARKED Belco Federal, Well No. 1 (Strawn)
Oil sampled from H. Press. Sep. 600 psi
LE FROM Estoril Producing Corporation
OF RUN 7-15-81

OMPONENT	MOL. %	G.P.M.	LIQUID VOL. %
ygen			
irogen			
rbon Dioxide			
thane			3.44
hane			2.40
opane			2.93
Butane			1.35
-Butane			3.07
Pentane			2.29
-Pentane			2.50
exanes plus			82.02
eptanes & Heavier			
ydrogen Sulfide			
elium			
ydrogen			
arbon Monoxide			
OTALS			100.00

CONDENSATE VALUES, G.P.M.
Propane
Butane
Gasoline

HEATING VALUE, B.T.U. Per Cu. Ft.*
Calculated from % Composition
Calculated water saturated

SULPHUR CONTENT, Grains Per 100 Cu. Ft.*
Hydrogen Sulfide
Mercaptans

SPECIFIC GRAVITY*
Calculated from % Composition

*14,696 lbs./sq. In., 60° F

Low Pressure Gas Study

3cc Estoril Producing Corp.

SOUTHWESTERN LABORATORIES

600 PSIG SEPARATION

At 500 psig separation pressure the gas has a BTU content of 1131 BTU/cu. ft.

500 PSIG SEPARATION

SOUTHWESTERN LABORATORIES
1703 West Industrial — P. O. Box 2150
MIDLAND, TEXAS 79701
(915) 683-3348

FRACTIONAL ANALYSIS REPORT

DATE RECEIVED 7-15-81
FILE NO. C-1902-G
LAB. NO. 45564
DATE SECURED 7-11-81
SECURED BY —

MARKED Belco Federal, Well No. 1 (Strawn)
Sampled from sales line 500 psi (D)
FROM Estoril Producing Corporation
RUN 7-15-81

COMPONENT	MOL. %	G. P. M.	LIQUID VOL. %
	0.95		
Dioxide	0.17		
	88.48		
	6.42	1.712	
	2.13	0.585	
	0.36	0.124	
	0.64	0.201	
	0.21	0.077	
	0.24	0.087	
plus	0.38	0.164	
& Heavier			
Sulfide	*None Det.		
Monoxide			
TOTALS	100.00	2.950	

CONDENSATE VALUES, G.P.M.

100% Propane	0.585
Excess Butane	[illegible]
26/70 Gasoline	0.500

HEATING VALUE, B.T.U. Per Cu. Ft.*

Calculated from % Composition	1131
Calculated water saturated	1111

SULPHUR CONTENT, Grains Per 100 Cu. Ft.

Hydrogen Sulfide	
Mercaptans	

SPECIFIC GRAVITY*

Calculated from % Composition	0.644

*14,696 lbs./sq. in., 60° F

Propane + GPM — 1.238

*Determined on laboratory sample.

Low Pressure Gas Study

[illegible] Estoril Producing Corp.

SOUTHWESTERN LABORATORIES
Gary M. Burch

At 80 psig separation pressure the gas has reached a BTU value of 1401 BTU/ cu. ft.

SOUTHWESTERN LABORATORIES
1703 West Industrial -- P. O. Box 2150
MIDLAND, TEXAS 79701
(915) 683-3348

FRACTIONAL ANALYSIS REPORT

DATE RECEIVED 7-15-81
FILE NO C-1902-G
LAB. NO. 45566
DATE SECURED 7-11-81
SECURED BY —

E MARKED Beloo Federal, Well No. 1 (Strawn)
Sampled from low press. sep. vent, 10" Hg press. (A)
E FROM Estoril Producing Corporation 80psi O.P
OF RUN 7-15-81

OMPONENT	MOL. %	G. P. M.cf	LIQUID VOL. %
en			
gen	0.27		
on Dioxide	0.25		
ane	69.88		
e	16.03	4.275	
ane	7.60	2.086	
ane	1.45	0.473	
tane	2.23	0.701	
tane	0.69	0.252	
ntane	0.70	0.253	
nes plus	0.90	0.387	
nes & Heavier			
ogen Sulfide	*None Det.		
m			
ogen			
n Monoxide			
ALS	100.00	8.427	

CONDENSATE VALUES, G.P.M.

100%	Propane	2.086
Excess	Butane	0.724
26/70	Gasoline	1.342

HEATING VALUE, B.T.U. Per Cu. Ft.*

Calculated from % Composition 1401
Calculated water saturated 1377

SULPHUR CONTENT, Grains Per 100 Cu. Ft.

Hydrogen Sulfide
Mercaptans

SPECIFIC GRAVITY*

Calculated from % Composition 0.812

*14,696 lbs./sq. in., 60° F

Propane + GPM — 4.152

*Determined on laboratory sample.

BTU Most Equitable way to sell Gas.

Propane 36 cu ft per gal

Low Pressure Gas Study

c Estoril Producing Corp.

Home Gas 95 to 97% Methane.

5 lbs water per 1MM cu ft.

SOUTHWESTERN LABORATORIES
[signature]

80 PSIG SEPARATION

At 25 psig separation, the gas stream is at its richest point yet, with a BTU value of 1588 BTU/cu. ft.

SOUTHWESTERN LABORATORIES
1703 West Industrial — P. O. Box 2150
MIDLAND, TEXAS 79701
(915) 683-3348

FRACTIONAL ANALYSIS REPORT

...RKED	Belco Federal, Well No. 1 (Strawn)	DATE RECEIVED	7-15-81
...mpled from	Heater-Treater Vent - 2" Hg (B)	FILE NO.	C-1902-G
...ROM	Estoril Producing Corporation 25 psi OP	LAB. NO.	45567
...RUN	7-15-81	DATE SECURED	7-11-81
		SECURED BY	—

...PONENT	MOL. %	G. P. M.	LIQUID VOL. %
...n	5.17		
...Dioxide	0.31		
...e	48.04		
	23.49	6.264	
...	13.10	3.596	
...e	2.60	0.848	
...ne	3.96	1.245	
...ne	1.23	0.449	
...ne	1.08	0.390	
... plus	1.02	0.439	
...es & Heavier			
...en Sulfide	*None Det.		
...en			
...Monoxide			
...LS	100.00	13.231	

CONDENSATE VALUES, G.P.M.

100%	Propane	3.596
Excess	Butane	1.496
26/70	Gasoline	1.875

HEATING VALUE, B.T.U. Per Cu. Ft.*

Calculated from % Composition	1588
Calculated water saturated	1560

SULPHUR CONTENT, Grains Per 100 Cu. Ft.*

Hydrogen Sulfide	
Mercaptans	

SPECIFIC GRAVITY*

Calculated from % Composition	0.985

*14.696 lbs./sq. in., 60° F

Propane + GPM — 6.967

*Determined on laboratory sample.

Low Pressure Gas Study

3cc Estoril Producing Corp.

SOUTHWESTERN LABORATORIES

Gary M. Burch

25 PSIG SEPARATION

This gas stream reaches its most valuable point during storage in the oil tank. This gas has a BTU value of 2514 BTU/ cu. Ft. Obviously, this gas is worth capturing!

OIL TANK STORAGE

1703 West Industrial — P. O. Box 2150
MIDLAND, TEXAS 79701
(915) 683-3348

FRACTIONAL ANALYSIS REPORT

MARKED Belco Federal, Well No. 1 (Strawn)
Sampled from stock tank vent 4-8 oz. pressure (C)
FROM Estoril Producing Corporation
RUN 7-15-81

DATE RECEIVED 7-15-81
FILE NO. C-1902-G
LAB. NO. 45568
DATE SECURED 7-11-81
SECURED BY —

...PONENT	MOL. %	G. P. M.	LIQUID VOL. %
...l			
...n	3.95		
... Dioxide	0.10		
...e	8.29		
	21.63	5.768	
...e	29.20	8.015	
...e	8.56	2.793	
...ne	14.93	4.694	
...ne	5.22	1.906	
...ane	5.02	1.814	
...s plus	3.10	1.335	
...es & Heavier			
...en Sulfide	*None Det.		
...en			
... Monoxide			
...LS	100.00	26.325	

CONDENSATE VALUES, G.P.M.

100%	Propane	8.015
Excess	Butane	5.260
26/70	Gasoline	7.281

HEATING VALUE, B.T.U. Per Cu. Ft.*

Calculated from % Composition	2534
Calculated water saturated	2489

SULPHUR CONTENT, Grains Per 100 Cu. Ft.*

Hydrogen Sulfide	
Mercaptans	

SPECIFIC GRAVITY*

Calculated from % Composition	1.578

*14.696 lbs./sq. in., 60° F

Propane + GPM -- 20.557

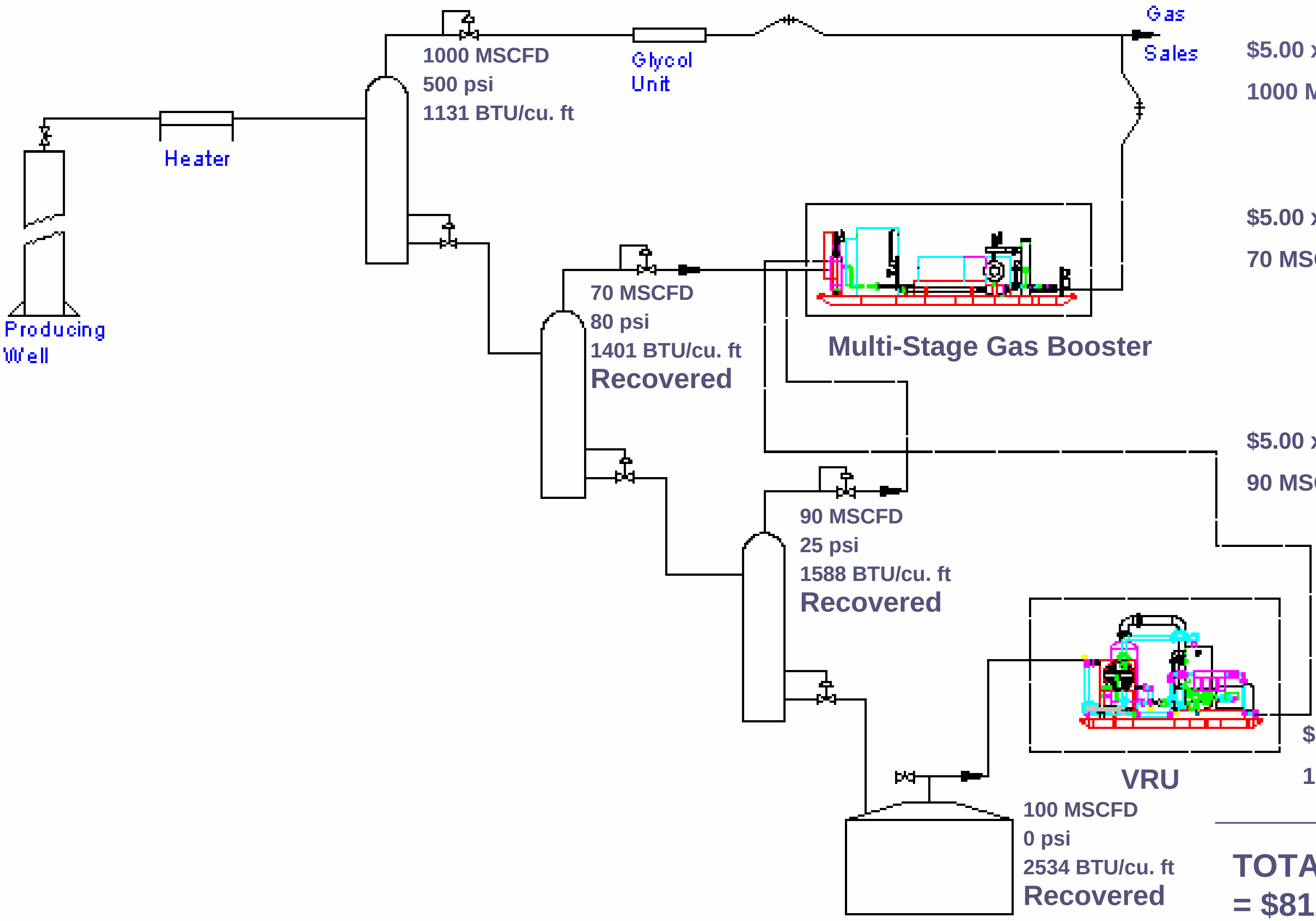
*Determined on laboratory sample.

Low Pressure Gas Study.

3cc Estoril Producing Corp.

SOUTHWESTERN LABORATORIES
Harry M. Bunch

Gross Sales Per Day



$5.00 x 1.13 x 1000 MSCFD = $5650

$5.00 x 1.40 x 70 MSCFD = $490

$5.00 x 1.59 x 90 MSCFD = $716

$5.00 x 2.53 x 100 MSCFD = $1267

TOTAL GAS SALES = $8123

MONTHLY GAS SALES INCREASE = $74,190

NOTE: Price based upon $5.00/MMBTU

Case Study 2

Mid Size Independent in Hobbs, NM area March ‘04

Installation of 2 VRU’s on 2 stock tank batteries, each emitting approximately 90 MSCFD of 2500 btu tank vapors / 45 psig sales line

Previous gas sales revenue: $0 (venting)

Monthly gas revenue: $5 X 2.5 X 90 MSCFD X 30 days x 2 tanks = $ 67,500

Capital expense: $24,000 X 2 units = $48,000

Payback: 21 DAYS

Case Study 3

- Large Independent in North Texas in June '04
- Installation of 1 VRU on a stock tank battery emitting approximately 190 MSCFD of 2400 btu tank vapors / 50 psig sales line

- Previous gas sales revenue: $0 (venting)

- Monthly gas revenue: $5 X 2.4 X 190 MSCFD X 30 days = $ 68,400

- Capital expense: $32,000

- Payback: 14 DAYS

Case Study 4 – Chevron

- Chevron installed eight VRUs at crude oil stock tanks in 1996

Project Economics – Chevron				
Methane Loss Reduction (Mcf/unit/yr)	Approximate Savings per Unit[1]	Total Savings	Total Capital and Installation Costs	Payback
21,900	$43,800	$350,400	$240,000	<1 yr
[1] Assumes a $2 per Mcf gas price; excludes value of recovered NGLs. Refer to the *Lessons Learned* for more information.				

Source: Natural Gas Star Partners

ENVIRONMENTAL HAZARDS

This flare in Eastern Venezuela was causing a variety of health and environmental concerns – a gas stream now generating over $150,000 per month in additional revenue. Methane gas has 23 times the impact as a greenhouse gas as CO2 – although almost 100% of industry focus is currently on CO2.

VAPOR RECOVERY

Dual VRU bound for Venezuela… one of 17 units capturing gas currently for Petroleos de Venezuela. What started as an environmental project in one area became an economic addition to every major production station. Flooded screw compressor for volumes to 5.0 MMSCFD; up to

VAPOR RECOVERY

At this installation, three dual rotary screws compressor packages are set in tandem to move 15 MMSCFD of 2500-2600 BTU/cu ft. tank vapors. Condensate recovery more than doubled PDVSa estimates.

VAPOR RECOVERY

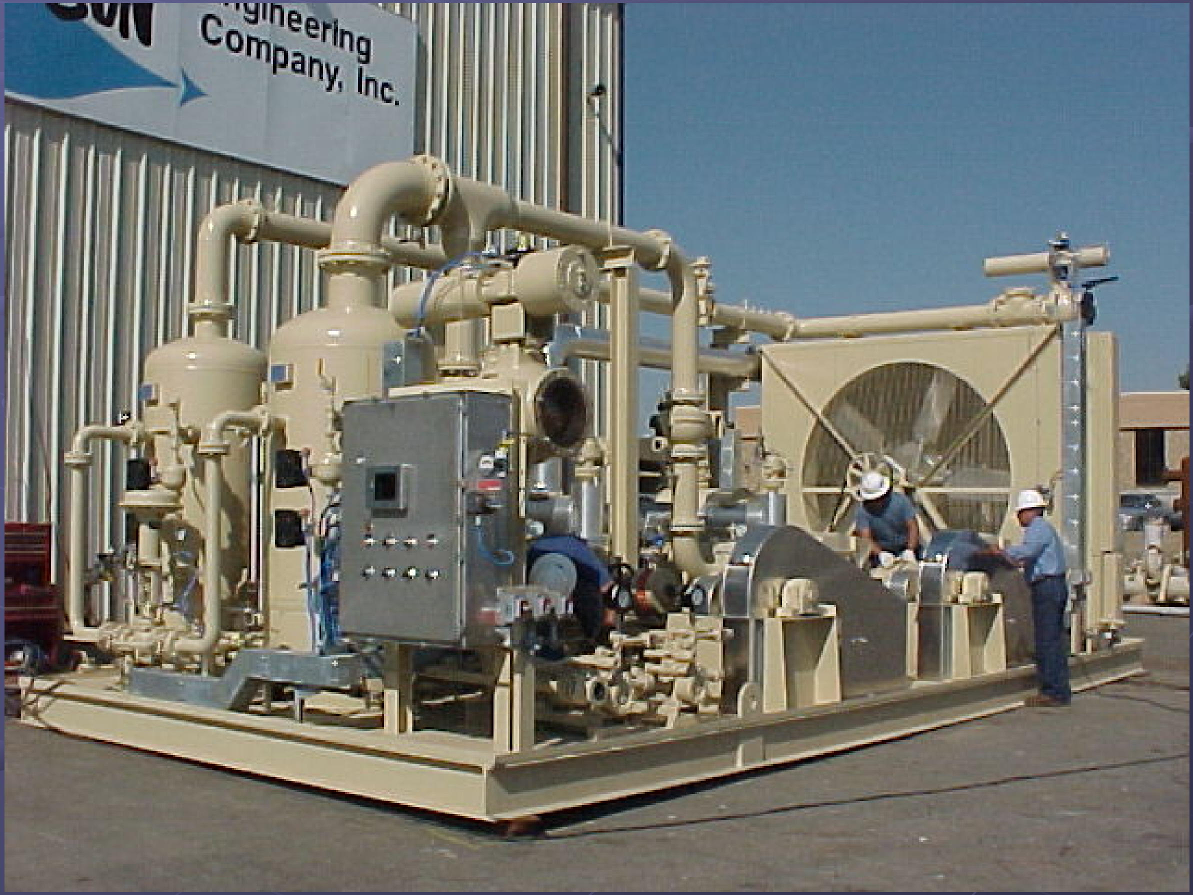
Two large rotary screw compressor systems installed by ENI in Dacion, Venezuela– designed to move 1.4 MMcfd of gas at pressures to 230 psig. Each skid is now recovering between 100 and 150 barrels of 70 API condensate PER DAY from gas stream previously vented to the atmosphere.

VAPOR RECOVERY

Condensate recovery was maximized on the ENI project by utilizing large heat exchangers to reduce the temperature of the gas.

VAPOR RECOVERY

A 2004 project for Amerada Hess for service in Algeria. This unit is a dual rotary vane system capable of moving 4MMCFD at pressures from 0 to 40 psig



VAPOR RECOVERY

This VRU for Anadarko is currently capturing 300 mcfd of tank vapors and compressing them to 70 psi discharge in Rock Springs, WY

(installed 2004)

Burlington Resources has installed 9 VRU’s in their Montana and North Dakota fields in 2005 on tank batteries ranging from 50 mcfd to 200 mcfd in methane emmissions, and discharging into a 40 psig pipeline.


HY-BON
CAUTION

HY-BON ENGINEERING COMPANY, INC.

Setting a New Standard!!

HY-BON®

COMPRESSOR SELECTION CRITERIA

HOW DO WE CHOOSE THE APPROPRIATE COMPRESSOR?

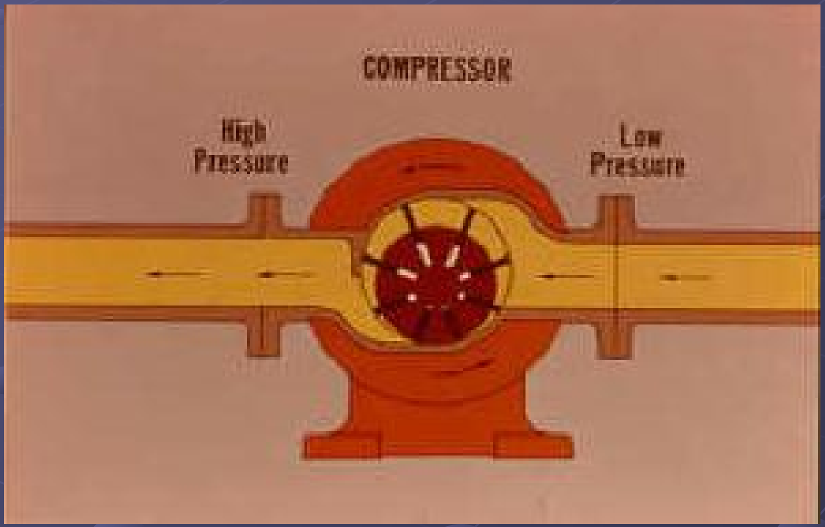
TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

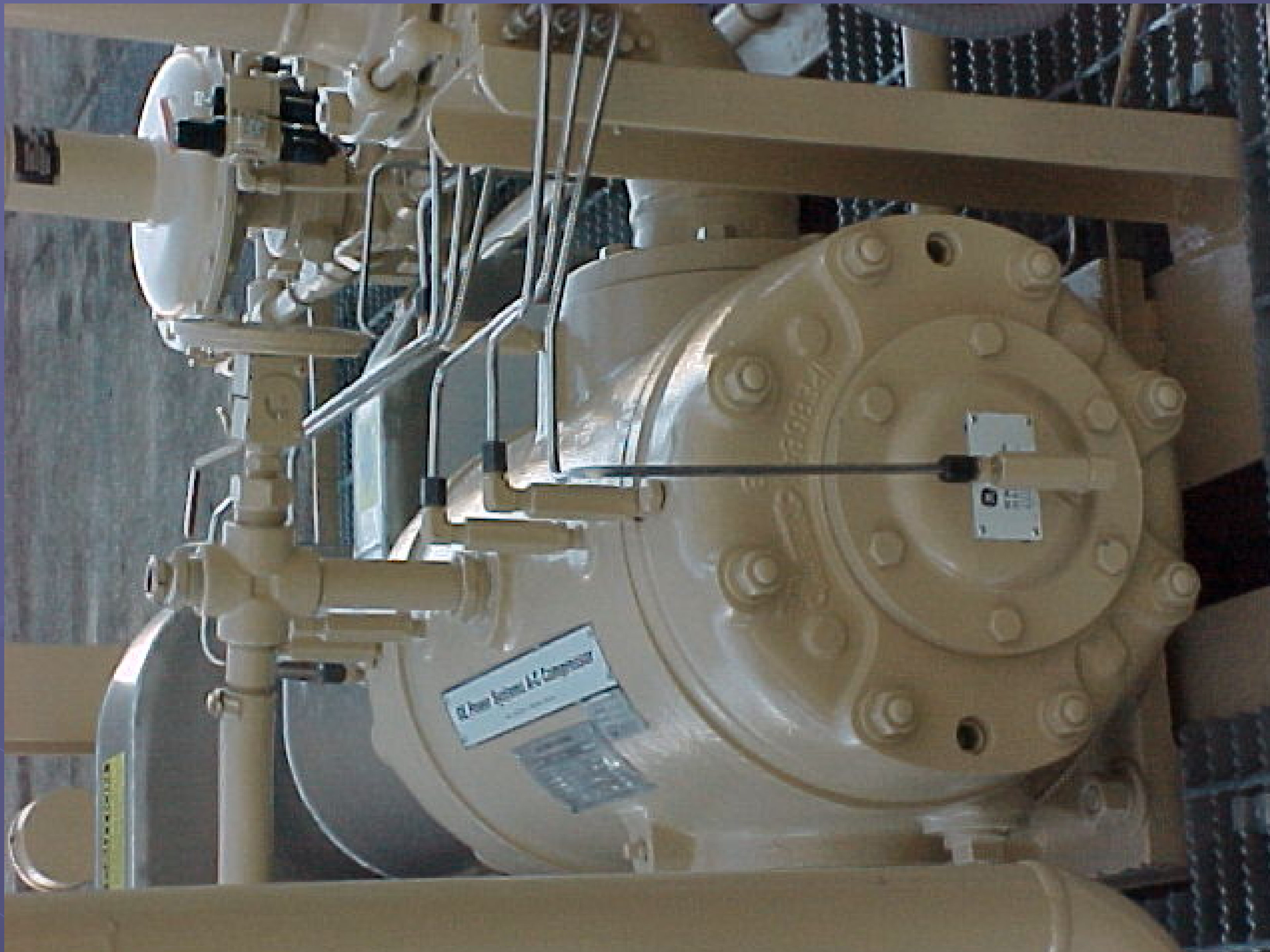
Rotary Vane Compressors

- Eccentrically mounted rotor
- Centrifugal force causes vanes to slide in or out
- Gas is forced into decreasing space thereby causing compression
- Jacket water cooling system
- RPM range 400 to 1600

ROTARY VANE OPERATING PRINCIPLE

Gas enters the suction flange at low pressure. The rotor is mounted eccentrically toward the bottom of the compressor. Centrifugal force imparted as the rotor turns forces the blades out against the cylinder wall. The gas is forced into a ever decreasing space, thereby compressing the gas which then exits the discharge. The rotor clearance at the bottom (typically .005”) is sealed with lubricating oil to create a closed system within the cylinder.

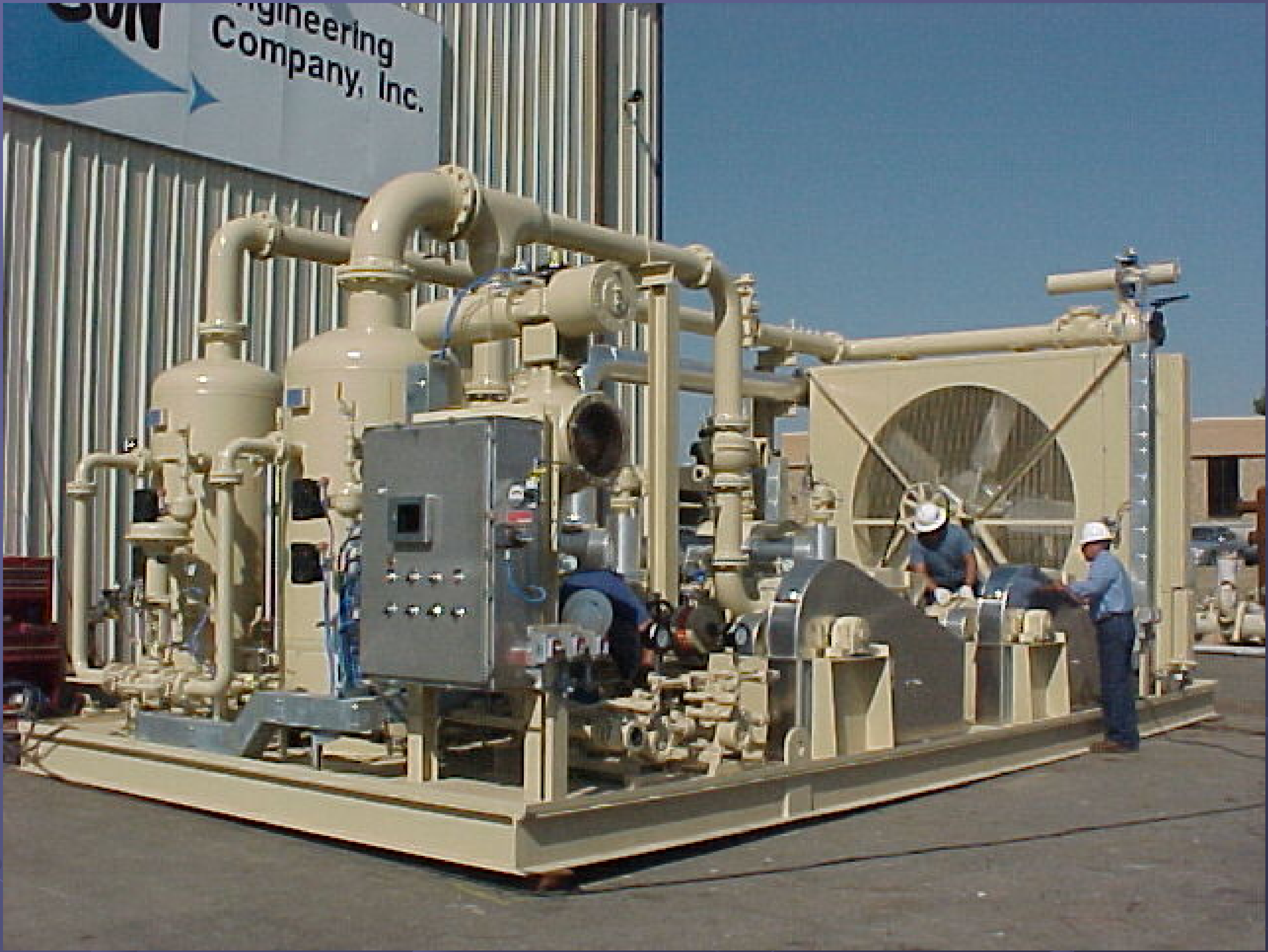





HY-BON


HY-BOW
TII 36
HY-BOW
2004 4 7


CAUTION
DANGER
29 1:12PM


Company, Inc.

Rotary Vane Compressor Typical Operating Parameters

- Differential pressure equal to or less than 60 psig (for single-stage models).
- Volume from approximately 15 MSCFD to 2 MMSCFD (for single-compressor units).
- Relatively low suction temperatures
  (< 120° F)

Rotary Vanes

Advantages

- Excellent for relatively high volumes and relatively low differential pressures
- Efficient at low pressures
- Can handle wet gas relatively easy
- Comparatively low initial cost and ongoing maintenance

Disadvantages

- Limited as to discharge pressure
- Limited as to suction temperature capabilities
- Free liquid causes blade breakage problems

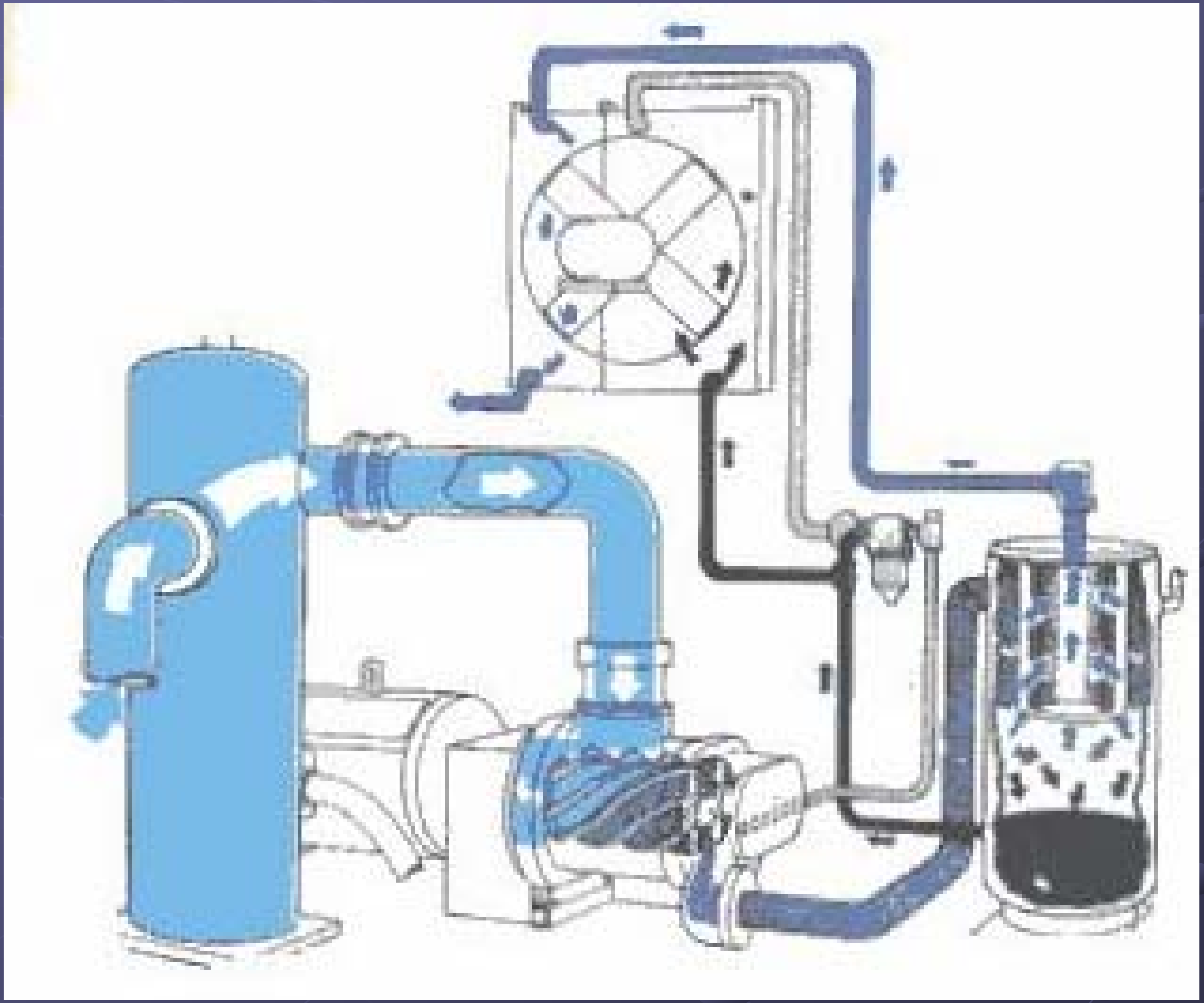
TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

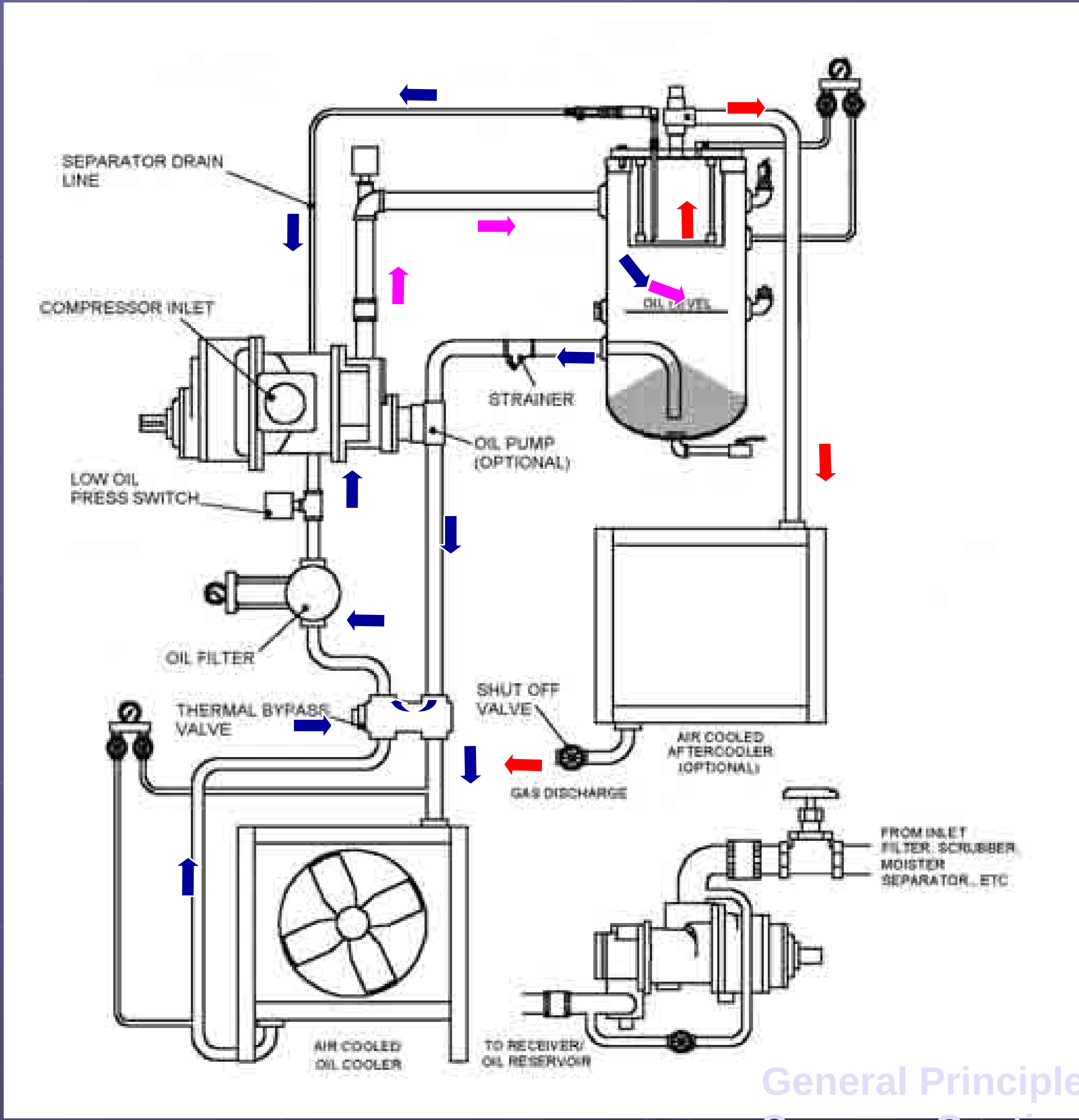
Flooded Screw Compressors

- Twin helical rotors
- Oil is both the cooling medium and the compression medium
- Various configurations of gears, internal porting and loader/unloader valves available
- Gas mixed with oil. Must be separated after compression

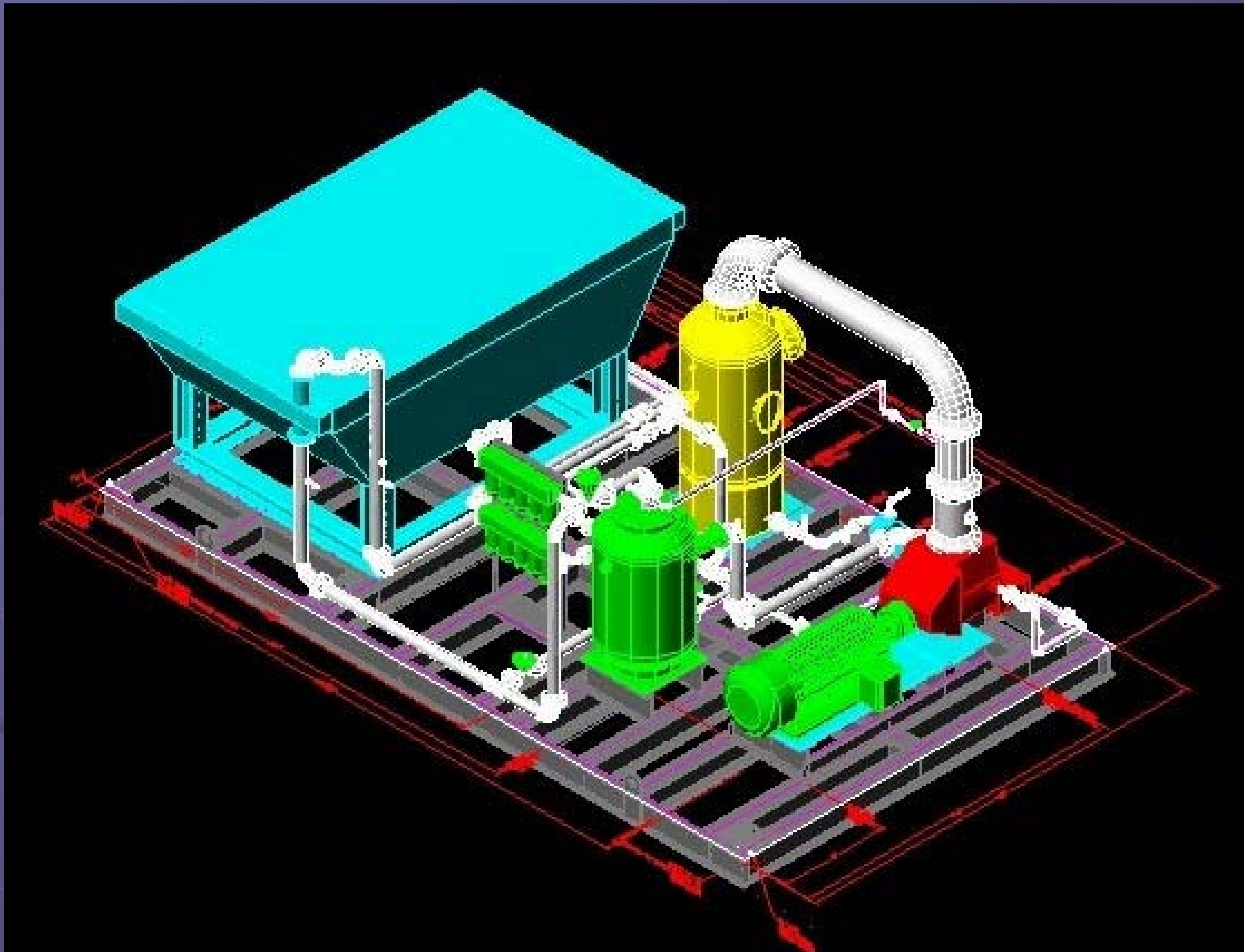
Rotary Screw Packages

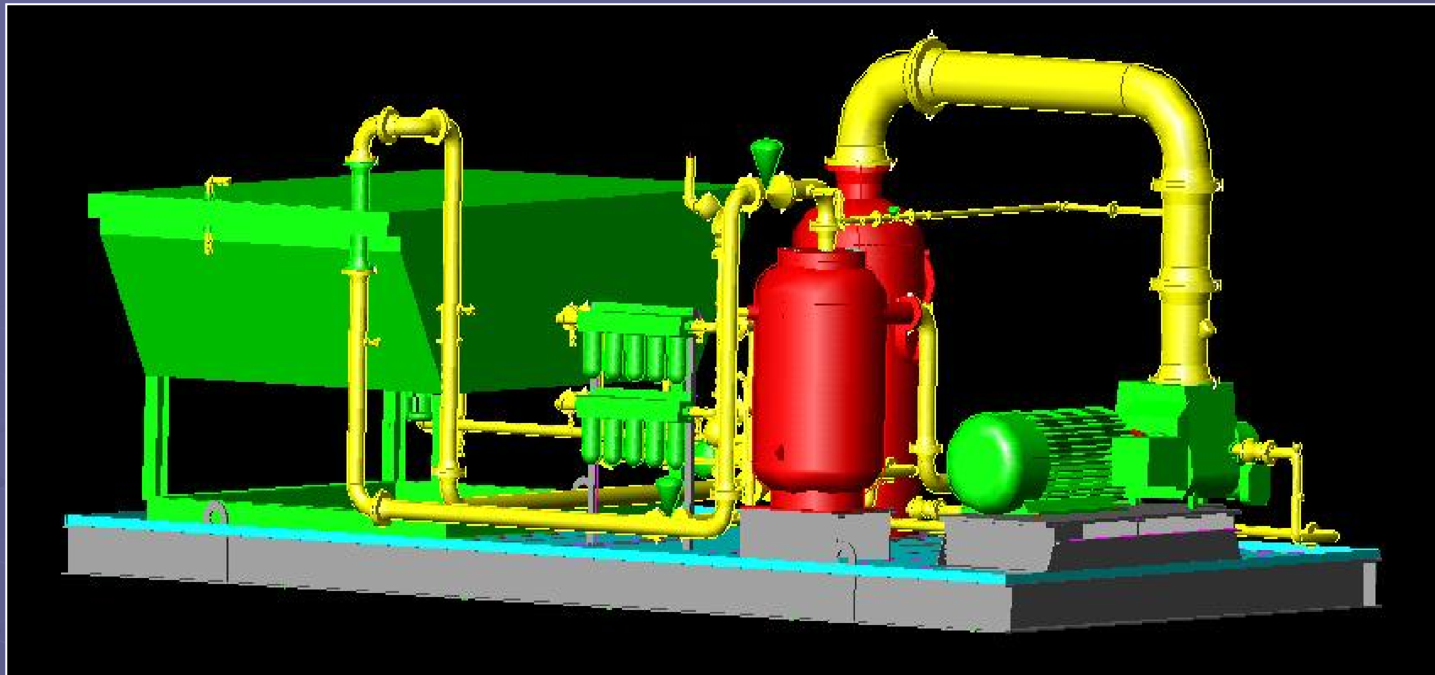
General Principle - Rotary Screws





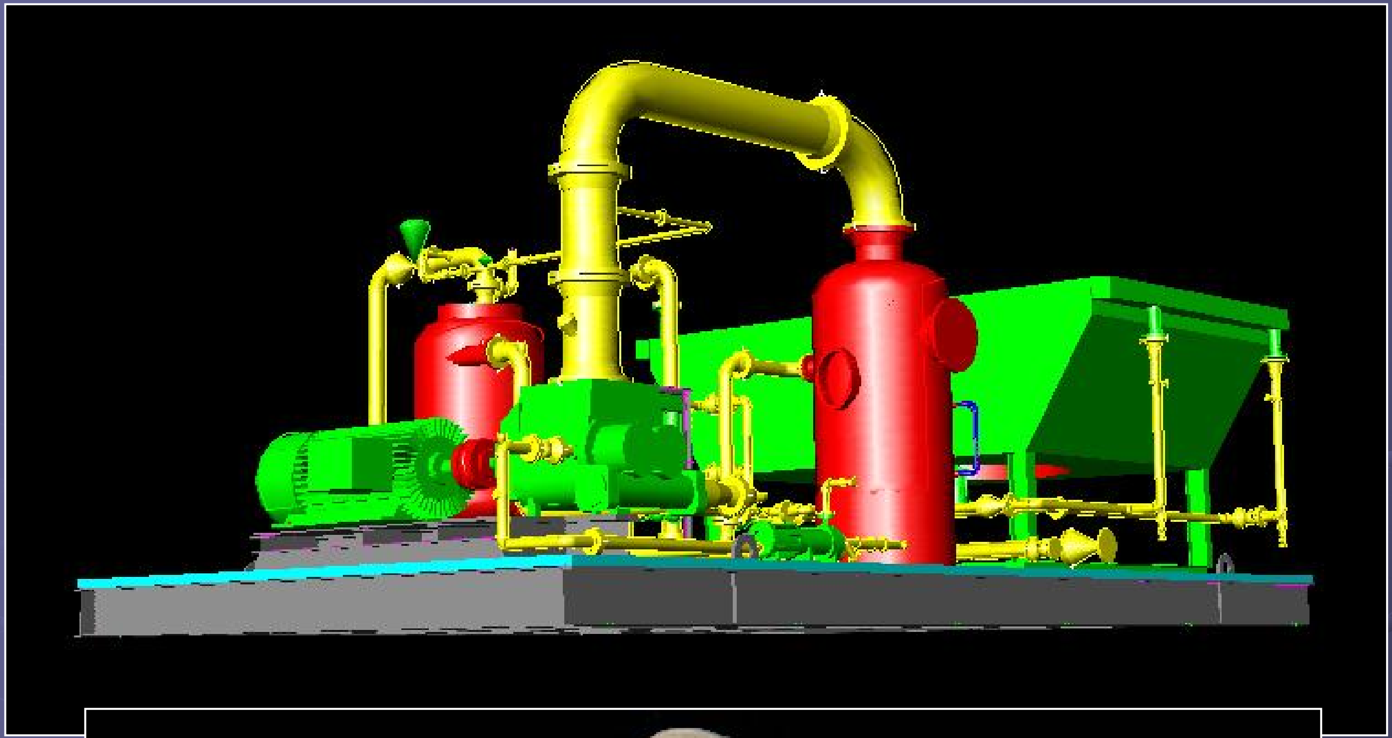
General Principle - Rotary Screws - Continued



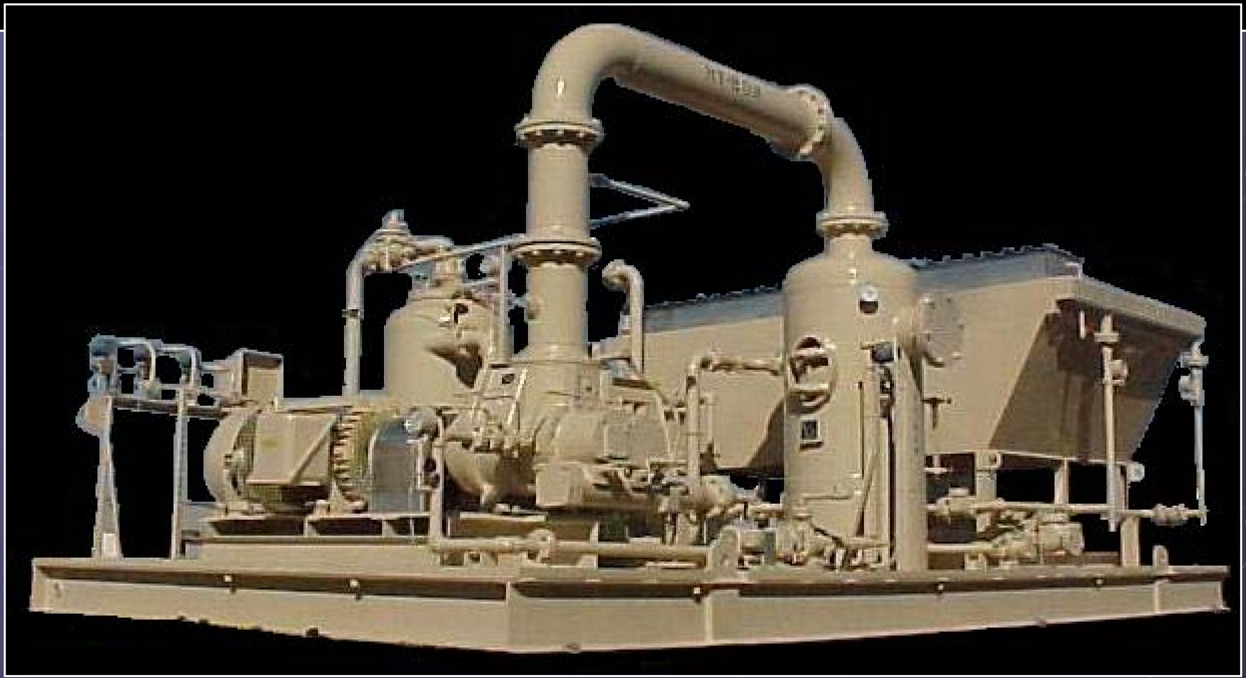


3-D MODEL

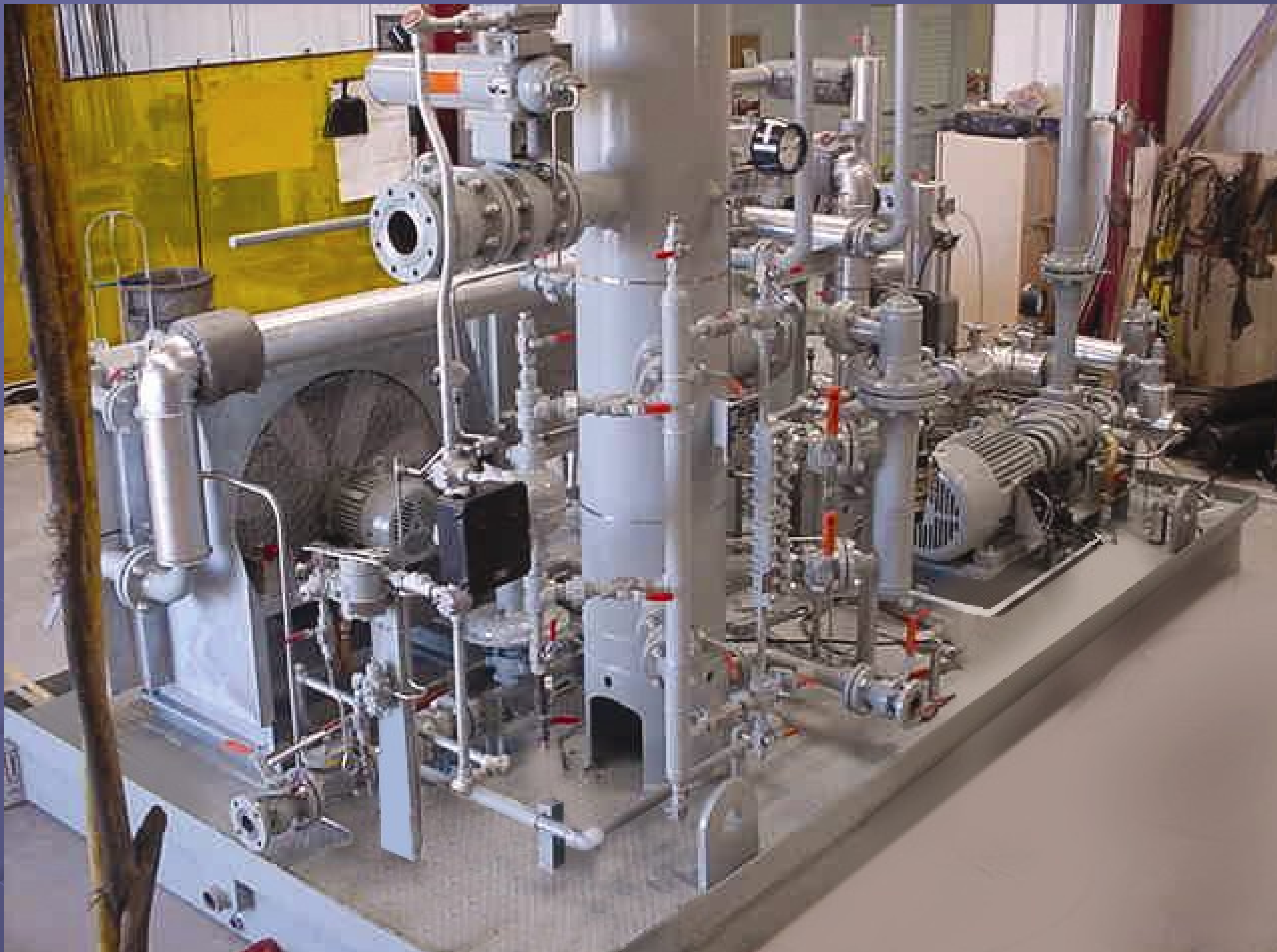
FINISHED PRODUCT



3-D
MODEL



FINISHED
PRODUCT

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Oil Flooded Screw Compressor Typical Operating Parameters

- **Differential pressure equal to or less than 300 psig (for single-stage models).**
- **Volume from approximately 20 MSCFD to 2.5 MMSCFD (for single-compressor units).**
- **Virtually any temperature (< 180° F)**

Oil Flooded Screws

Advantages

- Excellent in a large volume/medium differential pressure range
- Can handle wet gas better than rotary vanes
- Excellent temperature control for controlling condensate fallout

Disadvantages

- More sophisticated system w oil/gas separator
- Higher maintenance
- Higher operational expense (oil, filters, etc.)

TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

Liquid Ring Compressors

- Vacuum pump technology
- Uses lobes rather than vanes
- Gas is mixed with non-lubricating oil. Must be separated after compression.
- Good for extremely low differential pressures.
- Compression oil must be segregated from lubrication oil

Liquid Ring Compressor Typical Operating Parameters

- Differential pressure equal to or less than 25 psig (for single-stage models).
- Volume from approximately 15 MSCFD to 2.5 MMSCFD (for single-compressor units).
- Virtually any suction temperature (< 180° F)

Liquid Rings

<u>Advantages</u>

- High volumetric efficiency
- Few moving parts

<u>Disadvantages</u>

- Extremely limited on discharge pressure
- Used primarily in vacuum applications
- Higher operational expense (oil, filters, etc.)

TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

Reciprocating Compressors

- Piston/cylinder arrangement
- May be air, water or oil cooled
- Ages old technology
- May be slow speed or high speed


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Reciprocating Compressor Typical Operating Parameters

- Differential pressure in excess of 2000-3000 psig (for multi-stage models).
- Volumes in excess of 20 MMSCFD (dependent upon suction pressure).
- Relatively high suction temperatures (< 200° F)

Reciprocating Compressors

Advantages

- High volume/high pressure
- Able to handle spikes in pressure
- Relatively low maintenance

Disadvantages

- Low suction pressure results in large first stage cylinder size
- Inefficient at low pressures
- Rings and valves fail in wet gas applications
- Control is difficult at atmospheric pressures

TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

Dry Screw Compressors

- Similar in design to flooded screw
- Lubricating oil never comes in contact with process gas
- Extremely high rpm / very sophisticated seal systems
- Noise suppression systems req'd

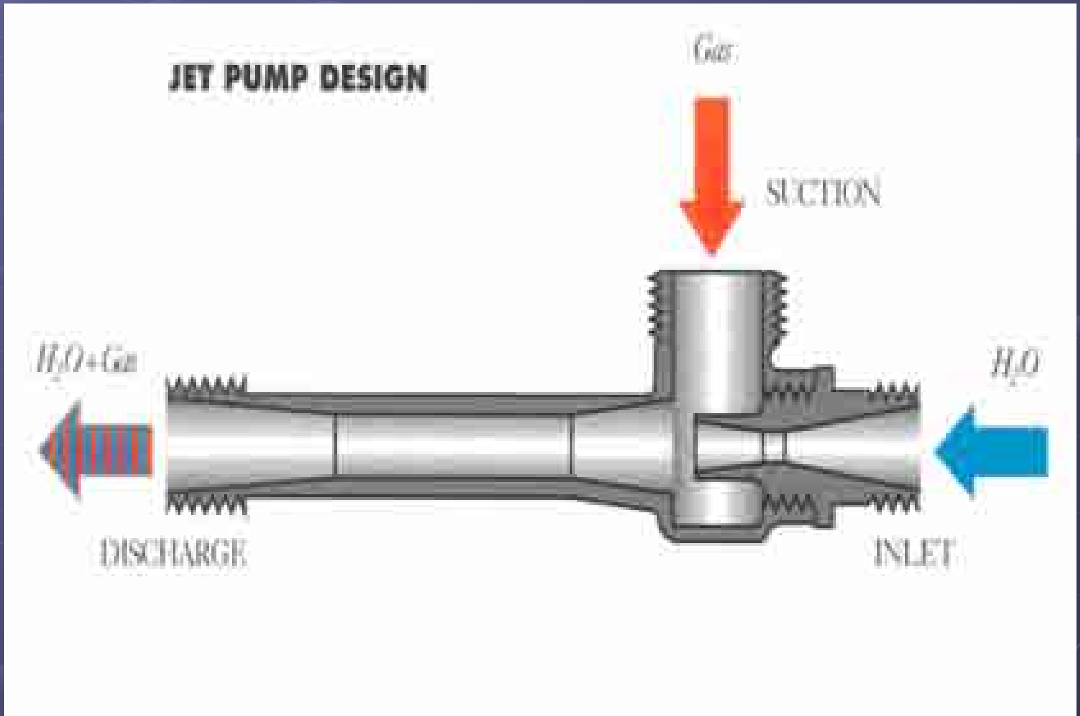
Dry Screw Compressor Typical Operating Parameters

- Not recommended for volumes less than 2 MMSCFD.
- Discharge pressure up to 600 psi
- Volumes in excess of 25 MMSCFD

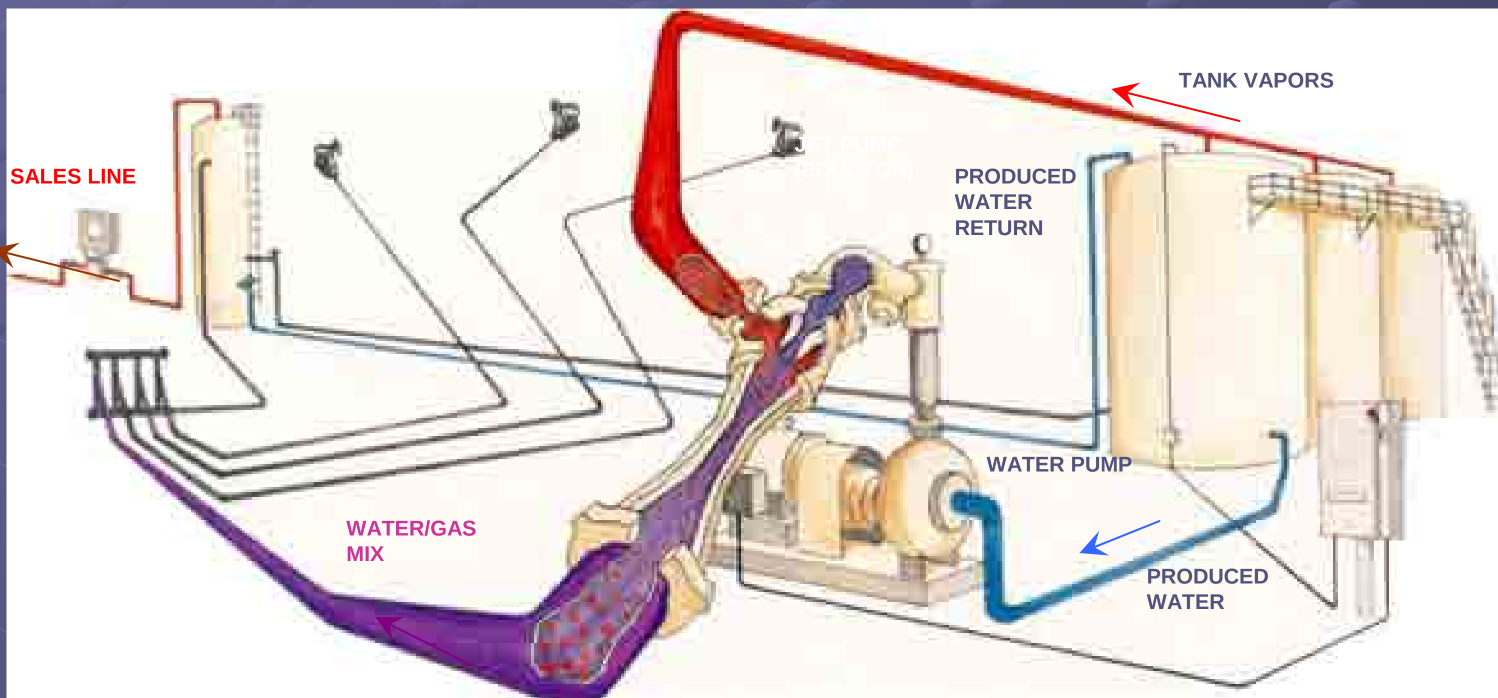
TYPICAL COMPRESSOR TYPES USED IN LOW PRESSURE

Vapor Jet

- Utilizes pressurized water to affect gas gathering
- No moving internal parts
- Uses produced water in a closed system
- Separation of gas and water required

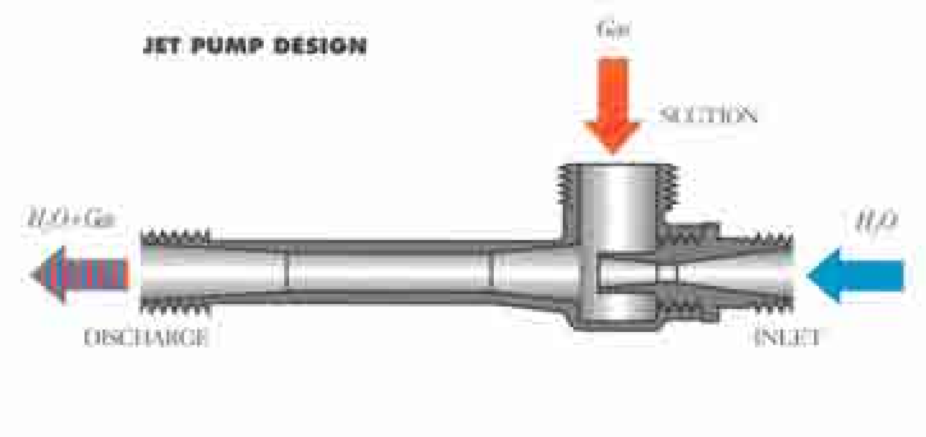


VAPOR JET VAPOR RECOVERY TECHNOLOGY



Vapor Jet Typical Operating Parameters

- **Differential pressure equal to or less than 40 psig (for single-stage models).**
- **Volume from approximately 5 MSCFD to 75 MSCFD (for single-compressor units).**
- **Suction Temperature is not an issue.**
- **Gas composition and saturation level is not an issue.**
- **Gas can be sent down the pipeline, or re-injected into the formation**



JET PUMP VAPOR RECOVERY RANGES

Jet Pump Size (in.)	1 1/2	2	2 1/2
Operating Medium Pressure (psig)	200	200	200
Operating Medium Rate (gpm)	45	82	143
Gas Volume Recovered (Mcfpd)	25	45	77
Centrifugal Pump Eff. (%)	26	42	53
Motor Eff. (%)	0.9	0.9	0.9
KW-HR/day	401	453	625
Power Cost ($/KW-HR)	0.045	0.045	0.045
Electrical Cost ($/Mcf)	0.74	0.45	0.36

Technological Advancements

Low Pressure Gas Management Systems

Sensing Technology

Pressure sensing achieved with diaphragm actuated mechanical device / set pressures achieved by manually setting counter weights in conjunction with proximity switch

Sensing Technology

- High sensitivity electronic transmitters are now commercially viable for low pressure applications

Sensing Technology

These transmitters are highly accurate to extremely minute pressures – and do not require a highly trained technician to calibrate.

Lubrication Systems

- Advancements in lubrication systems monitoring and control have dramatically increased bearing life

Lubrication Systems

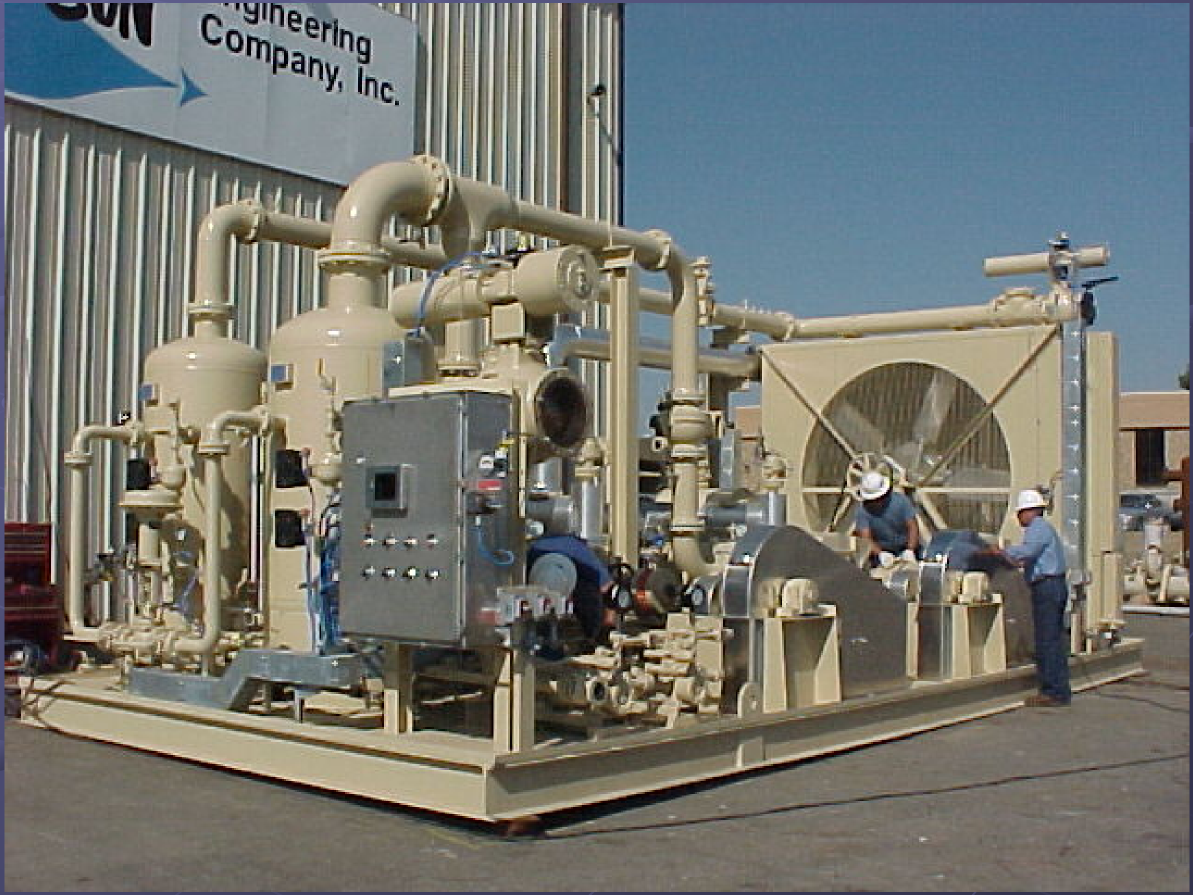
- Lubrication requirements are precisely monitored and detailed reporting capabilities are easily downloaded into handheld “palm” devices or directly into Excel format.

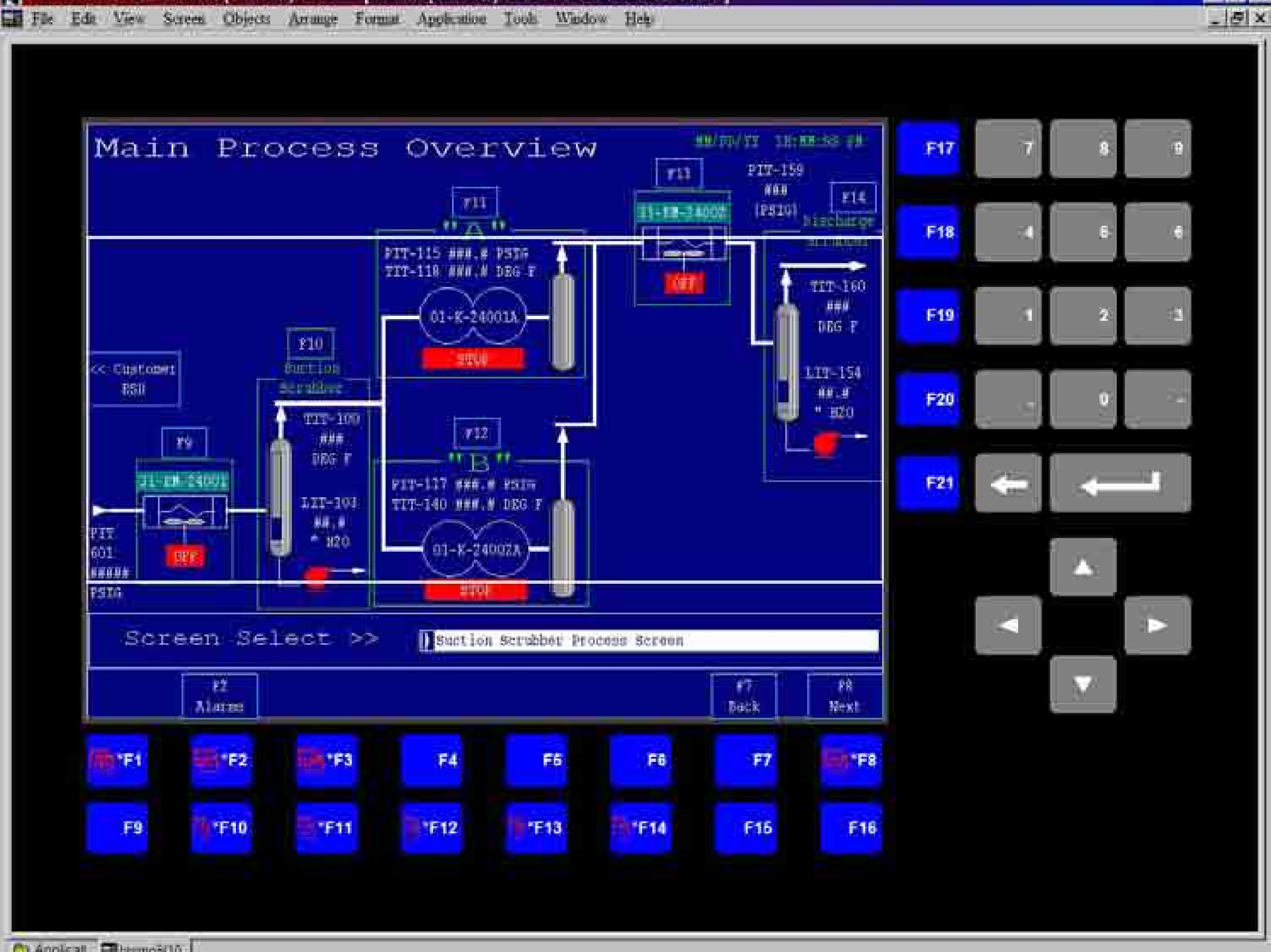
Control Systems

PLC driven auto ignition for natural gas drive engines reduce compressor downtime and pumper requirements

Technology Advancements

Control systems can range from almost completely manual to incredibly sophisticated.




File Edit View Screen Objects Arrange Format Application Tools Window Help
Main Process Overview
F9
F10
Suction Scrubber
F11
"A"
PIT-115 ###.# PSIG
TIT-118 ###.# DEG F
01-K-24001A
STOP
F12
"B"
PIT-117 ###.# PSIG
TIT-140 ###.# DEG F
01-K-24002A
STOP
PIT-159
###
(PSIG)
F14
Discharge
TIT-160
###
DEG F
LIT-154
##.#
" H2O
TIT-100
###
DEG F
LIT-193
##.#
" H2O
<< Customer ESD
PIT
601
#####
PSIG
OFF
Screen Select >>
Suction Scrubber Process Screen
F2
Alarms
F7
Back
F8
Next
F17
F18
F19
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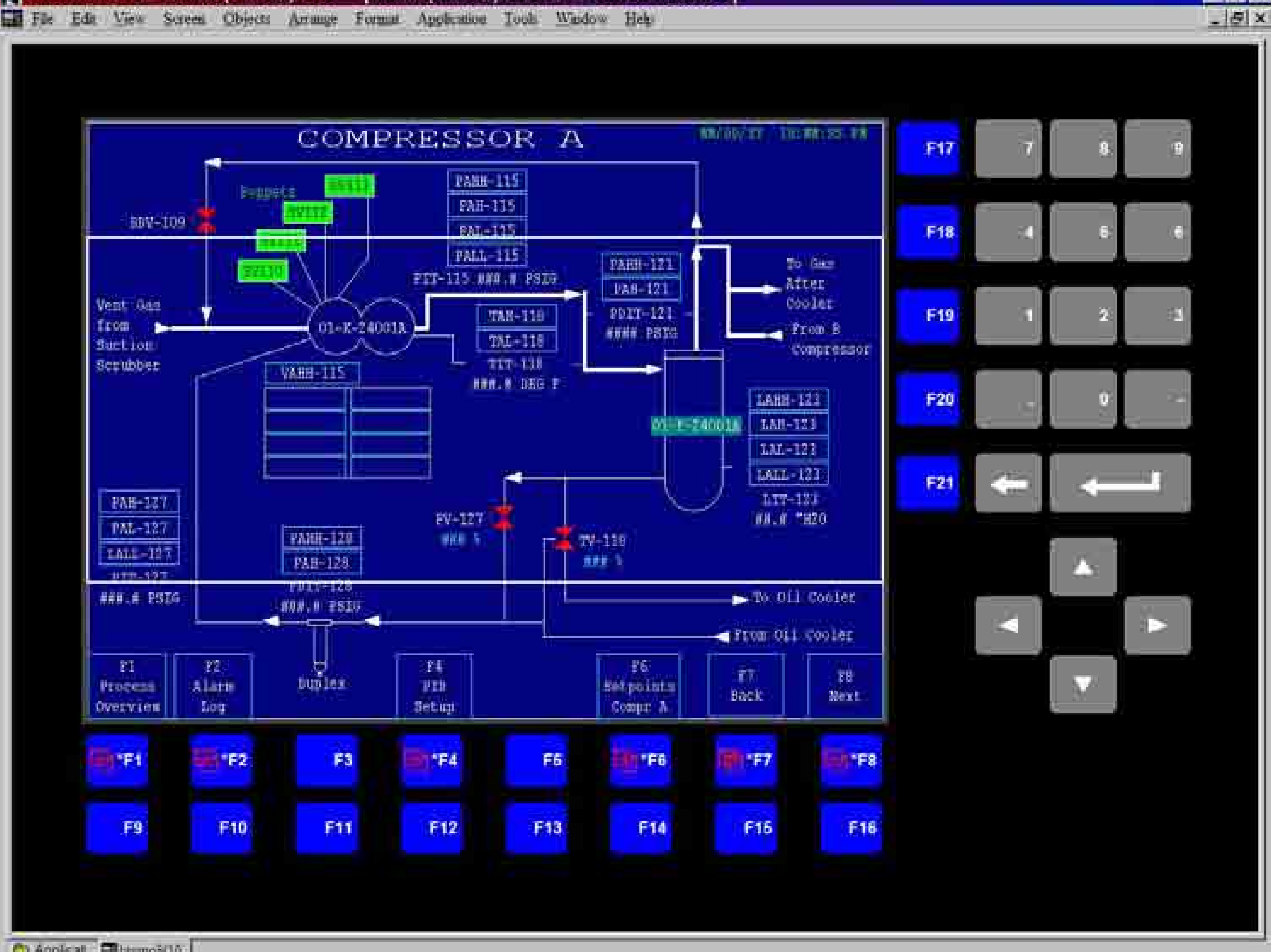

File Edit View Screen Objects Arrange Format Application Tools Window Help
COMPRESSOR A
BDV-109
Vent Gas from Suction Scrubber
01-K-24001A
PAHH-115
PAH-115
PAL-115
PALL-115
PIT-115 ###.# PSIG
TAH-118
TAL-118
TIT-118
###.# DEG F
PAHH-121
PAH-121
PDIT-121
PSIG
To Gas After Cooler
From B Compressor
VAHH-115
LAHH-123
LAH-123
LAL-123
LALL-123
LTT-123
##.# "H2O
PV-127
%
TV-118
%
PAH-127
PAL-127
LALL-127
###.# PSIG
PAHH-128
PAH-128
PDIT-128
###.# PSIG
To Oil Cooler
From Oil Cooler
Duplex
F1 Process Overview
F2 Alarm Log
F4 PID Setup
F6 Setpoints Compr A
F7 Back
F8 Next
F17
F18
F19
F20
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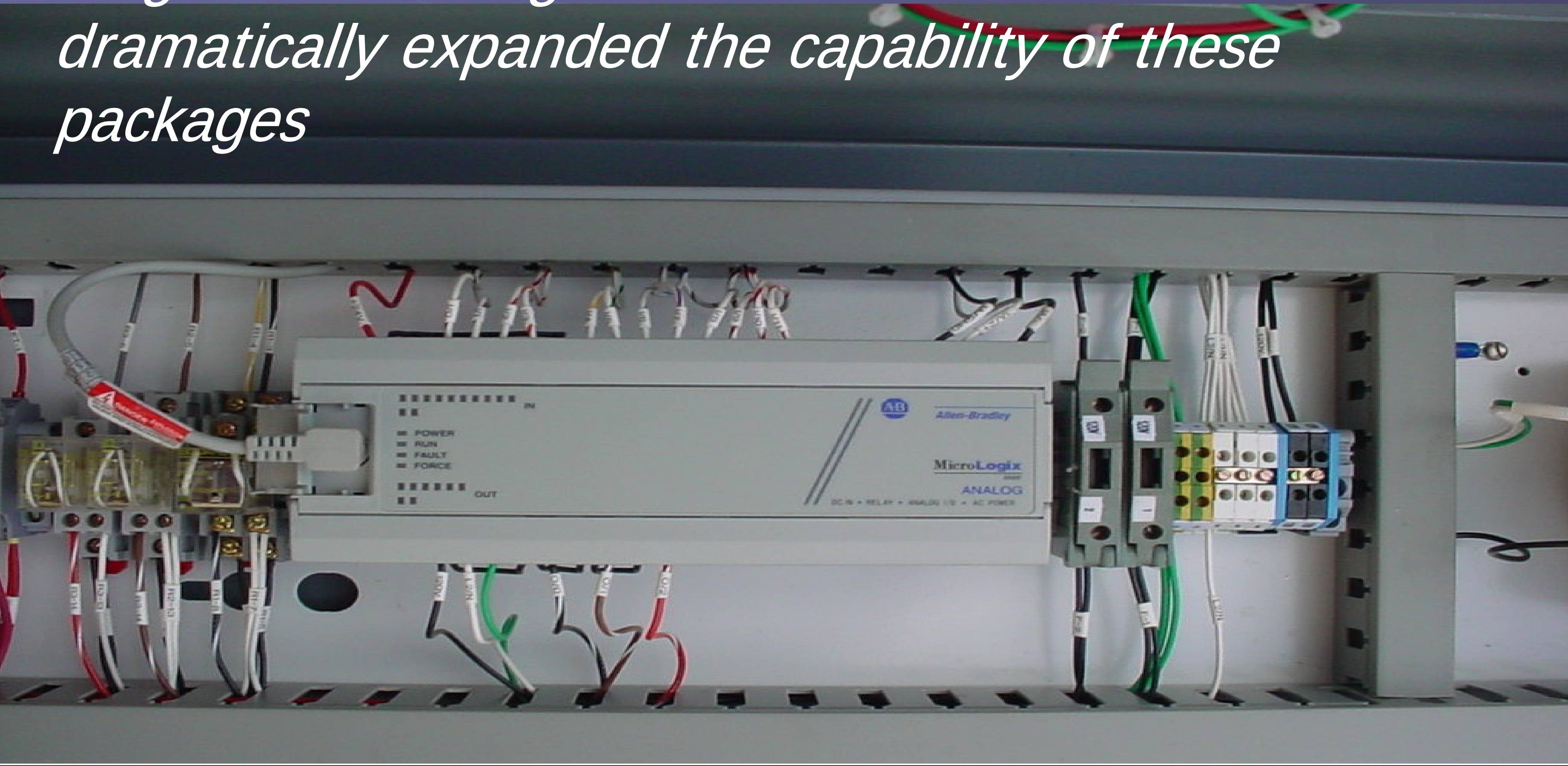
F16

Technology Advancements

Programmable Logics Controllers have dramatically expanded the capability of these packages



Automated restart is now possible on BOTH electric and engine drive units

Technology Advancements

Typical Shutdown indicators include:
High Discharge Temperature
High Discharge Pressure
High Liquid Level
Low Suction Pressure
Lube Oil No-Flow
Excessive Vibration

Technology Advancements

Allen-Bradley

Even the most basic PLC can be configured to automatically call the cell phone number of the correct field personnel based on the specific cause of the shutdown.

Technology Advancements

Remote Monitoring

- Now commercially available on this size equipment
- Ability to remotely monitor all variables captured by the PLC from an internet link for a couple hundred dollars a month
- Ability to view actual real time video footage of the unit if required

HY-BON ENGINEERING COMPANY, INC.

Setting a New Standard!!