June 15 2016

By The Numbers

Compressor Performance

Compressor Performance Report

Compressor Cylinder ID	IHP @ RPM	IHP/ MMSCFD	Capacity MMSCFD	Date	Time
1> Comp 1H Pressure	209.8 @ 334.0	35.1	5.9848	4-11-05	10:33:25
2> Comp 1C Pressure	266.4 @ 334.0	35.5	7.5090	4-11-05	10:33:25
3> Comp 2H Pressure	511.4 @ 339.0	41.0	12.4747	4-11-05	10:33:25
4> Comp 2C Pressure	533.0 @ 339.0	39.8	13.3883	4-11-05	10:33:25
5> Comp 3H Pressure	463.9 @ 337.0	37.7	12.3089	4-11-05	10:33:26
6> Comp 3C Pressure	437.5 @ 337.0	36.4	12.0220	4-11-05	10:33:26

Without an accurate TDC, the report information has no value!

Comp	%VOL Dis	EFF Suc	%POW/VAL LOSS Dis	Suc	%Flow Bal Suc/Dis	Toe Press Pd	Ps	Ratio	Temp F Dis	Suc	%Rod Load Ten	Comp	Gas Reversal
1>	40.6	63.9	2.3	1.4	1.01	478.1	251.4	1.85	215.6	111.6	25.4	36.3	160 T
2>	57.1	89.2	2.2	1.9	1.00	474.2	247.5	1.86	215.6	111.6	25.4	36.3	160 T
3>	41.2	73.3	1.0	1.5	1.11	975.6	467.1	2.06	243.7	97.6	56.3	75.9	168 T
4>	49.7	86.4	0.9	2.0	1.09	965.2	466.4	2.04	243.7	97.6	56.3	75.9	168 T
5>	48.6	74.6	3.3	3.5	1.05	1758.2	951.6	1.83	258.9	136.7	36.4	71.9	157 T
6>	59.5	88.3	2.6	2.8	1.02	1750.4	952.2	1.83	258.9	136.7	36.4	71.9	157 T

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)
1	13.4937	6	
2	25.8631	7	
3	24.3309	8	
4		9	
5		10	

Total IHP = 2422.0 @ 336.7 average RPM
Total BHP = 2549.5 Current load = 96.4%
@ 95.0 efficiency with 0.0 Hp auxiliary load
Rated BHP = 2750.0 @ 350.0 RPM

Compressor report p. 1/2
Smoothing factor = 4 (diagnostic level)
Nozzle is OFF
Run number = 0

Compressor Performance Report

IHP @ RPM	IHP/ MMSCFD	Capacity MMSCFD
209.8 @ 334.0	35.1	5.9848
266.4 @ 334.0	35.5	7.5090
511.4 @ 339.0	41.0	12.4747
533.0 @ 339.0	39.8	13.3883
463.9 @ 337.0	37.7	12.3089
437.5 @ 337.0	36.4	12.0220

Capacity is the average of the calculated flow rate at both suction and discharge conditions. This number is a good indicator of the actual capacity only when the cylinder is healthy and all collected data is accurate.

IHP accuracy is not dependent on the cylinder health; however, the geometry, TDC accuracy, and sensor linearity must be accurate.

IHP/MMSCFD is

IHP/calculated average capacity

Compressor Indicated Horsepower

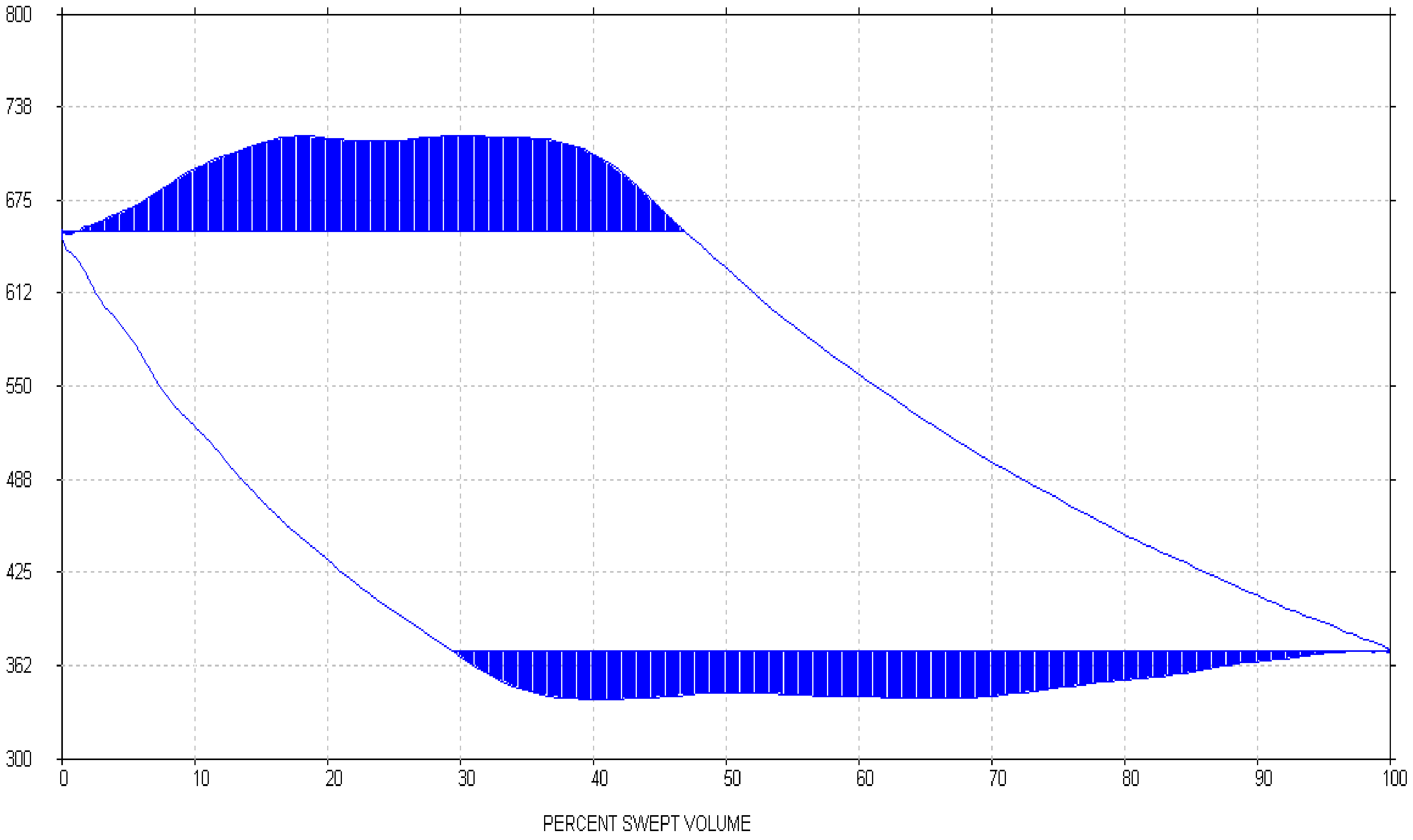
- The horsepower measured at the compressor piston face with an indicating device (e.g.: 100 IHP)
- Includes all thermodynamic losses
- Thermodynamic losses are equal to the indicated horsepower minus the theoretical horsepower
- Thermodynamic or compression efficiency equals the theoretical or gas horsepower divided by the compressor indicated horsepower

Indicated Horsepower

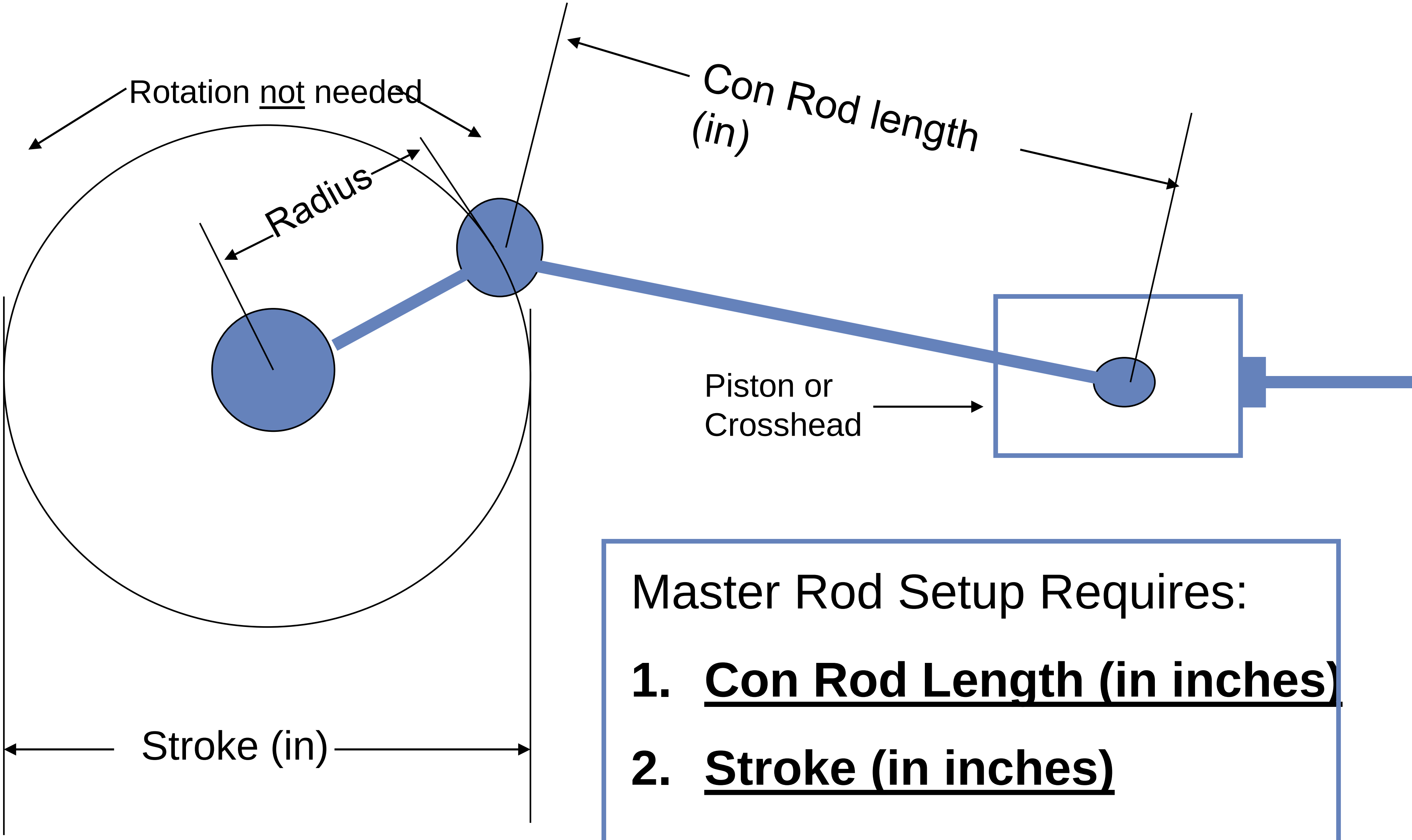
- The horsepower measured at the power piston face with an indicating device
- Includes all thermodynamic losses
  - PLAN/33,000
  - P = IMEP
  - L = STROKE in FEET
  - A = AREA
  - N = RPM
  - 33,000 ft-lb/minute = 1 Horsepower

33,000 lbs.


New wheel 5-21-79
OK 11-18-80
OK 12-20-79
K·E 4237
Serial No. 9399
Area of Neutral Circle = 357.56
One revolution of the wheel
One revolution of the dial
2399
K·E


800
738
675
612
550
488
425
362
300
0
10
20
30
40
50
60
70
80
90
100
PERCENT SWEPT VOLUME

Compressor & Power Master Rods



Master Rod Setup Requires:

1. **Con Rod Length (in inches)**
2. **Stroke (in inches)**

Formulas

Force = Pressure * Area

Work = Force * Distance (stroke)

Power = Work/Time

Compressor Cylinder Horsepower Relationships

- Brake Horsepower = Indicated Horsepower + Friction Horsepower
- Brake Horsepower = Indicated Horsepower / Compressor Mechanical Efficiency

Friction Horsepower

- Ring / Liner Friction
- Wrist Pin / Bushing Friction
- Connecting Rod Bearing / Crankshaft Friction

Compressor Performance Report

Stage#	Capacity (MMSCFD)
1	13.4937
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3	24.3309
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5	

Total IHP = 2422.0 @ 336.7 average RPM
Total BHP = 2549.5 Current load = 96.4%
@ 95.0 efficiency with 0.0 Hp auxiliary load
Rated BHP = 2750.0 @ 350.0 RPM

These are the average calculated capacities for each stage. They should have a reasonable agreement for the same product stream. The calculated capacities have a tendency to increase when there are internal cylinder leakages, while the actual capacities are diminishing.

These values are extremely dependent on the TDC accuracy.

Capacity

- scfd = (dv * VE * rpm * 1440 * pressure correction * temperature correction) / Z
- scfd = flow in std cu ft of gas/day
- dv = area*stroke/1728
- VE = volumetric efficiency
- rpm = compressor shaft revolutions per minute
- pressure correction = absolute pr / standard pr
- temperature correction = 520/absolute temperature
- Z = compressibility (compensates for the compression characteristics of the gas)
- Calculated at suction and/or discharge conditions
- mmscfd = million standard cubic feet a day.

Calculated Capacity

<u>Is only valid for a healthy cylinder</u>

Suction calculated capacity goes up with a suction valve, packing or ring leak.

Suction calculated capacity goes down with a discharge valve leak.

Discharge calculated capacity goes up with a discharge valve leak.

Discharge calculated capacity goes down with a suction valve leak or ring leak.

The average of the calculated suction and discharge capacity goes up significantly with ring leakage and, generally, up slightly for valve and packing leakage.

Compressor Performance Report

Comp	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press			Temp F	
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc
1>	40.6	63.9	2.3	1.4	1.01	478.1	251.4	1.85	215.6	111.6
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These items are used in the flow calculation at suction conditions. All 3 can be affected by the mechanical condition of the cylinder. Even in a healthy cylinder, the values could be wrong. The temperature at the cylinder valve port is difficult to obtain. The pressure and volumetric efficiency accuracy can be affected by channel resonance. The pressure can be affected by the sensor zero and linearity.

Compressor Performance Report

Comp	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press			Temp F	
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc
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5>	48.6	74.6	3.3	3.5	1.05	1758.2	951.6	1.83	258.9	136.7
6>	59.5	88.3	2.6	2.8	1.02	1750.4	952.2	1.83	258.9	136.7

Absolute compression ratio

These items are used in the flow calculation at discharge conditions. All 3 can be affected by the mechanical condition of the cylinder. Even in a healthy cylinder, the values could be wrong. The temperature at the cylinder valve port is difficult to obtain. The pressure and volumetric efficiency accuracy can be affected by channel resonance. The pressure can be affected by the sensor zero and linearity.

VOLUMETRIC EFFICIENCIES

	%VOL EFF		%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
1>	41.5	60.5	8.6	5.4	1.01	1146.6	691.8	1.64	175.1	104.1	48.2	64.5	129 T
2>	58.1	84.6	7.0	5.6	1.01	1148.5	696.0	1.64	175.1	104.1	48.2	64.5	129 T
3>	40.2	71.2	8.6	5.2	0.94	690.2	297.7	2.26	217.8	98.4	39.9	47.8	137 T
4>	41.6	80.5	5.3	5.2	1.00	708.5	296.8	2.32	217.8	98.4	39.9	47.8	137 T
5>	32.9	73.6	7.6	5.2	1.00	302.3	100.7	2.75	215.9	82.0	52.2	54.4	145 T
6>	35.5	79.0	5.4	4.7	0.99	303.9	100.4	2.77	215.9	82.0	52.2	54.4	145 T
7>	37.9	72.2	8.6	6.0	0.99	685.1	293.3	2.27	209.3	97.2	40.0	47.9	137 T
8>	41.2	80.5	5.8	5.1	0.99	700.1	290.9	2.34	209.3	97.2	40.0	47.9	137 T

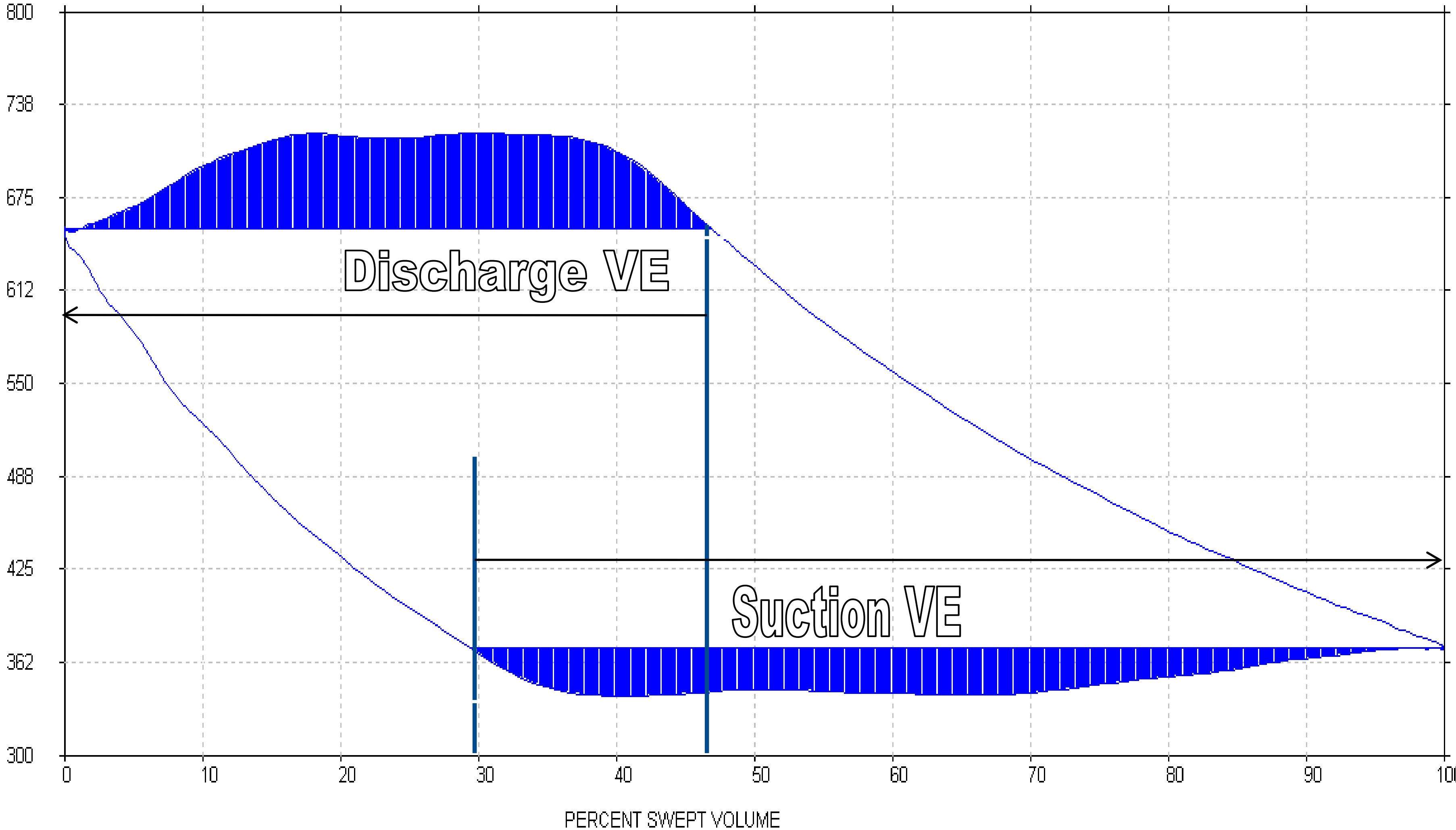
Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)
1	3.7645		
2	8.3687		
3	10.7310		

Compressor Volumetric Efficiencies

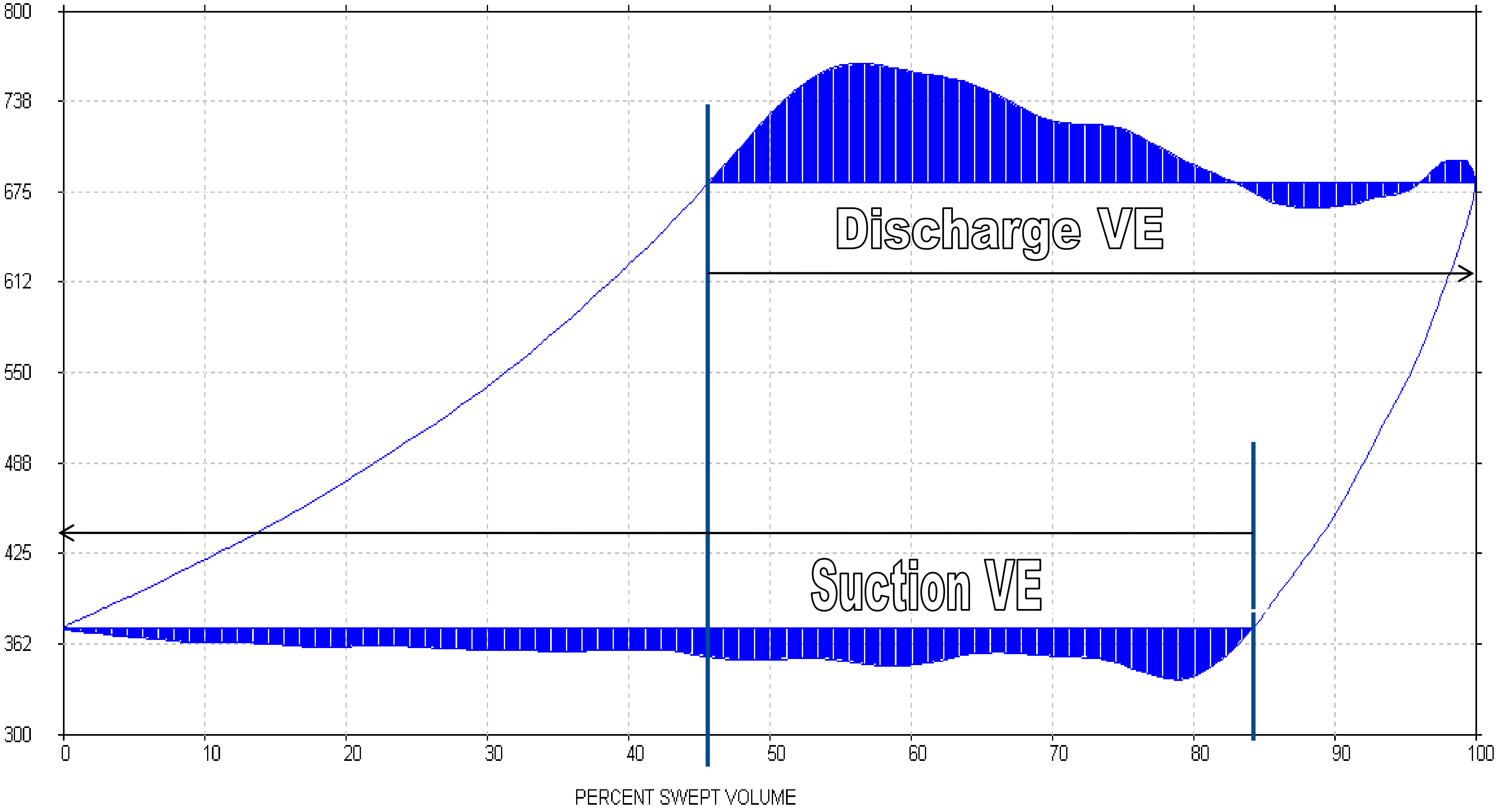
Suction Volumetric Efficiency (VEs) is the percent of the cylinder end's displacement measured by an imaginary line extended from the suction toe to the expansion line.

Discharge Volumetric Efficiency (VEd) is the percent of the cylinder end’s displacement that is measured from an imaginary line extended from the discharge toe to the compression line.

Compressor
(HE Volumetric Efficiencies)



Compressor
(CE Volumetric Efficiencies)



Power Loss

	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
1>	41.5	60.5	8.6	5.4	1.01	1146.6	691.8	1.64	175.1	104.1	48.2	64.5	129 T
2>	58.1	84.6	7.0	5.6	1.01	1148.5	696.0	1.64	175.1	104.1	48.2	64.5	129 T
3>	40.2	71.2	8.6	5.2	0.94	690.2	297.7	2.26	217.8	98.4	39.9	47.8	137 T
4>	41.6	80.5	5.3	5.2	1.00	708.5	296.8	2.32	217.8	98.4	39.9	47.8	137 T
5>	32.9	73.6	7.6	5.2	1.00	302.3	100.7	2.75	215.9	82.0	52.2	54.4	145 T
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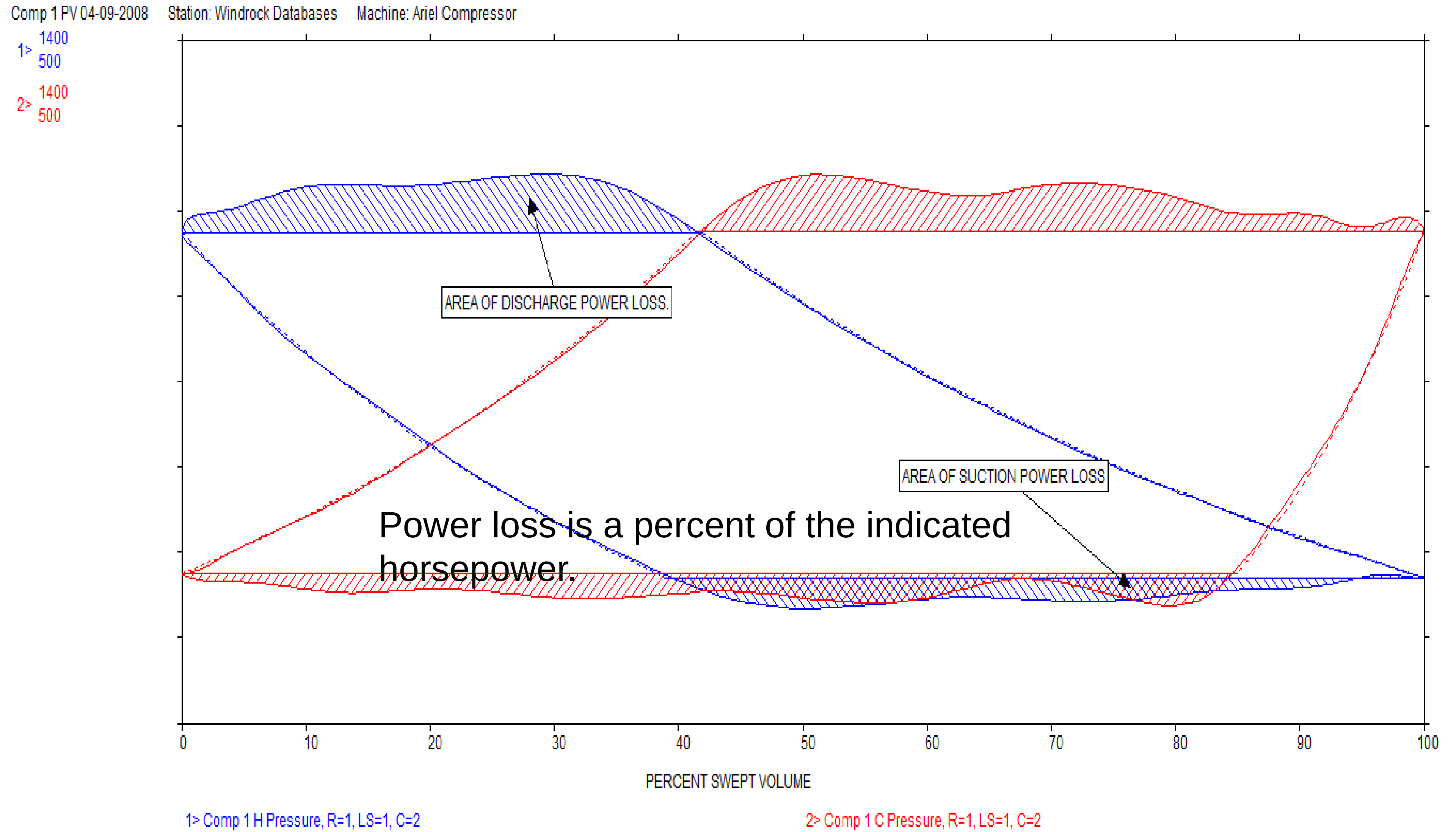

Power loss is a percent of the indicated horsepower.

FLOW BALANCE

	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
1>	41.5	60.5	8.6	5.4	1.01	1146.6	691.8	1.64	175.1	104.1	48.2	64.5	129 T
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3>	40.2	71.2	8.6	5.2	0.94	690.2	297.7	2.26	217.8	98.4	39.9	47.8	137 T
4>	41.6	80.5	5.3	5.2	1.00	708.5	296.8	2.32	217.8	98.4	39.9	47.8	137 T
5>	32.9	73.6	7.6	5.2	1.00	302.3	100.7	2.75	215.9	82.0	52.2	54.4	145 T
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3	10.7310		

Flow Balance

Accurate flow balance is dependent on the accuracy of the TDC reference, toe pressures, suction and discharge temperatures at the valve ports, gas compressibility, and VE picks.

Flow balance, by itself, is not a reliable way to determine the health of the compressor cylinder.

Do <u>not</u> adjust the TDC offset in an effort to improve flow balance alone.

TOE PRESSURE

	%VOL EFF		%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
1>	41.5	60.5	8.6	5.4	1.01	1146.6	691.8	1.64	175.1	104.1	48.2	64.5	129 T
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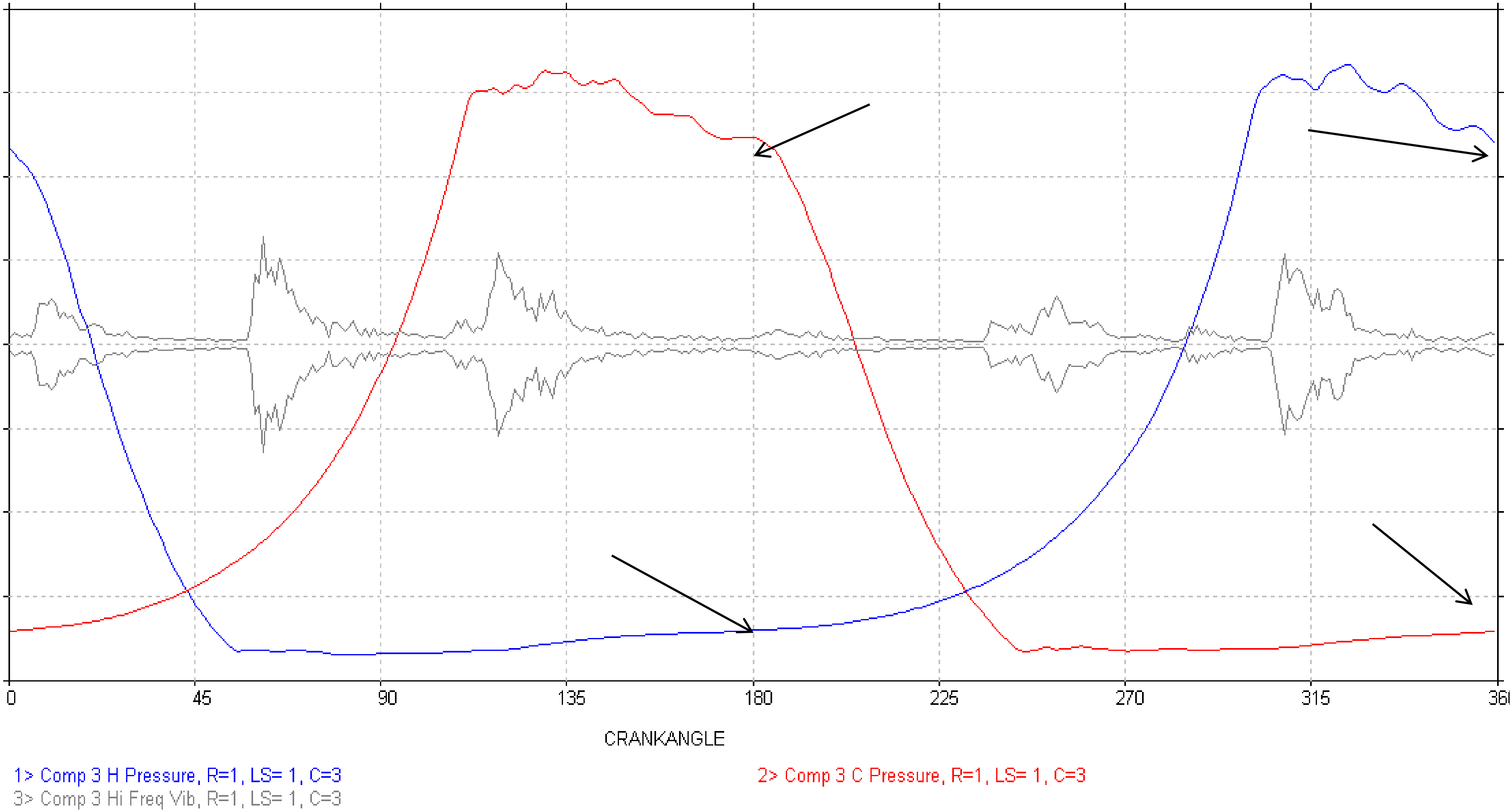
Pressure & Vibration Vs. Crank-Angle (toe points)



All PT and PV compressor plots use gauge (psig) pressure

COMPRESSION RATIO

	%VOL EFF		%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
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Compressor Pressure

- Compressor calculations use absolute pressure
- Absolute pressure = gauge pressure + atmospheric pressure
  - (100 psig + 14.7 = 114.7 psia)
  - (200 psig + 14.7 = 214.7 psia)
- The atmospheric pressure at the test location is not corrected to sea level
- Compression ratio = absolute discharge pressure divided by absolute suction pressure
  - (214.7 psia / 114.7 psia = 1.872 CR)
- Standard pressure or standard atmosphere is the pressure of a standard cubic foot of gas

SUCTION AND DISCHARGE TEMPERATURES

	%VOL EFF		%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
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Compressor Temperature

- Theoretical compressor calculations use absolute temperature (deg Rankin)
- Absolute temperature (R) = degrees F + 460
- The Standard temperature for gas measurement is 60 degrees F
- (60 deg F + 460) = 520 deg R

ROD LOAD

	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
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Rod Load

The piston rod is alternatively under compression and tension and, being of a relatively narrow cross-section, is subject to high mechanical loads and high cyclic fatigue stresses.

The gas rod load is the force in pounds applied to the reciprocating parts due to internal cylinder pressure and area differentials across the piston ends.

Some manufactures may include the effect of inertia forces of the crosshead and piston assemblies in their load limits.

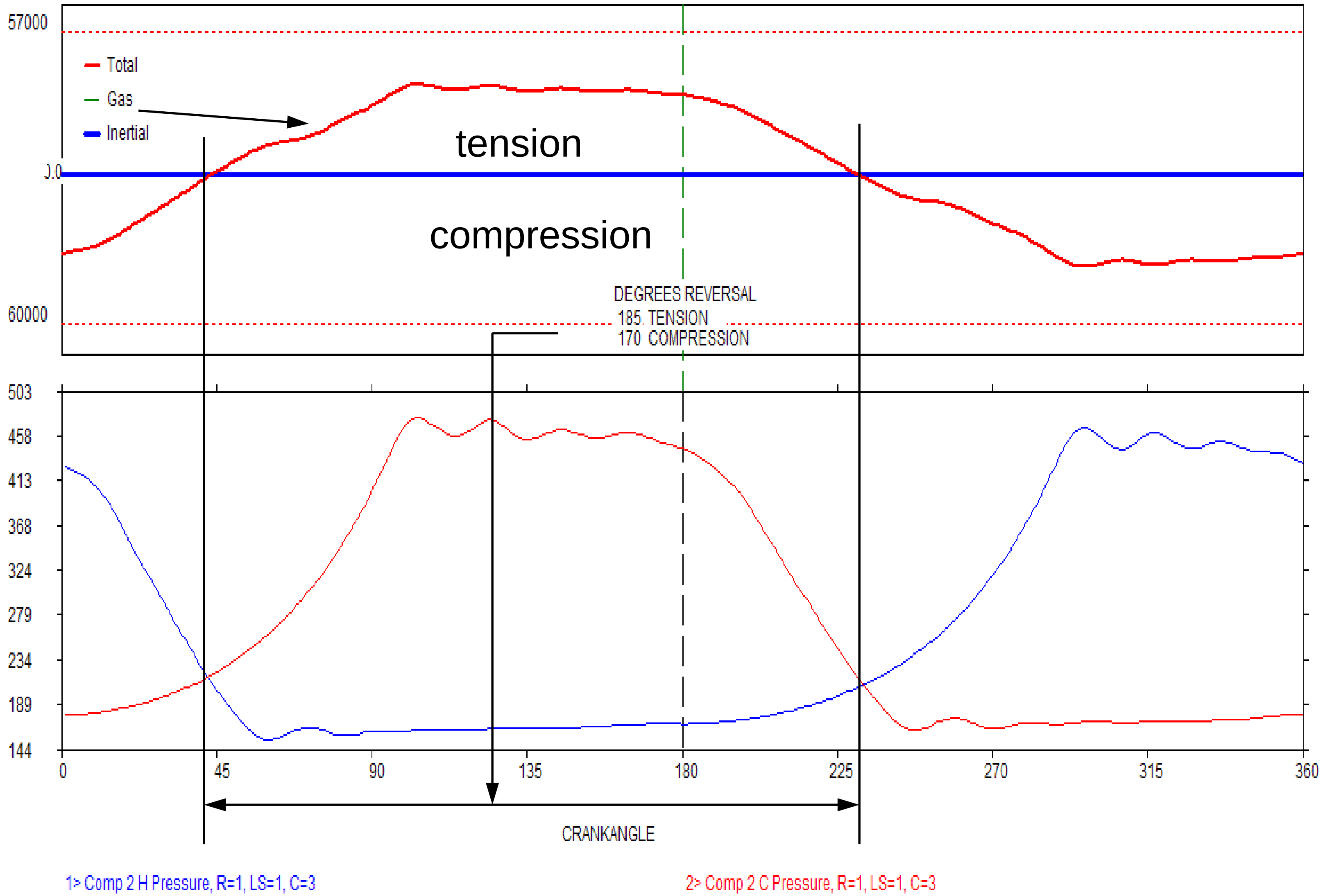
Static or Gas Load

Static or gas load is the force on the cylinder reciprocating components resulting from the gas pressure applied to the surface area of the piston faces.

Analyzers calculate and plot the results for each degree of crankshaft rotation.

Gas forces alone may or may not cause a force reversal at the crosshead pin and bushing.

Static Gas Load



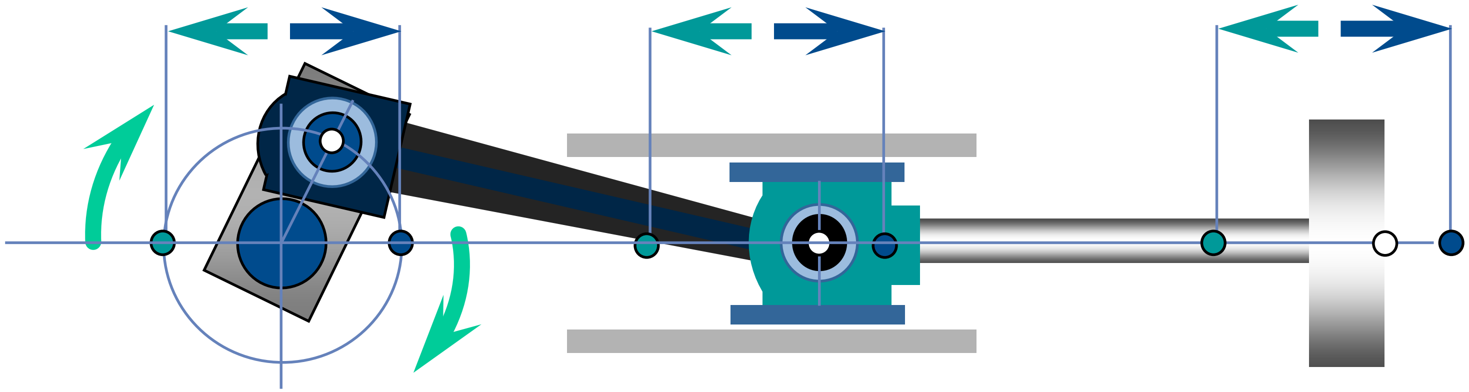
Inertia Load

Inertia load is the force on the cylinder reciprocating components resulting from the change in their velocity.

Analyzers calculate and plot the results for each degree of crankshaft rotation.

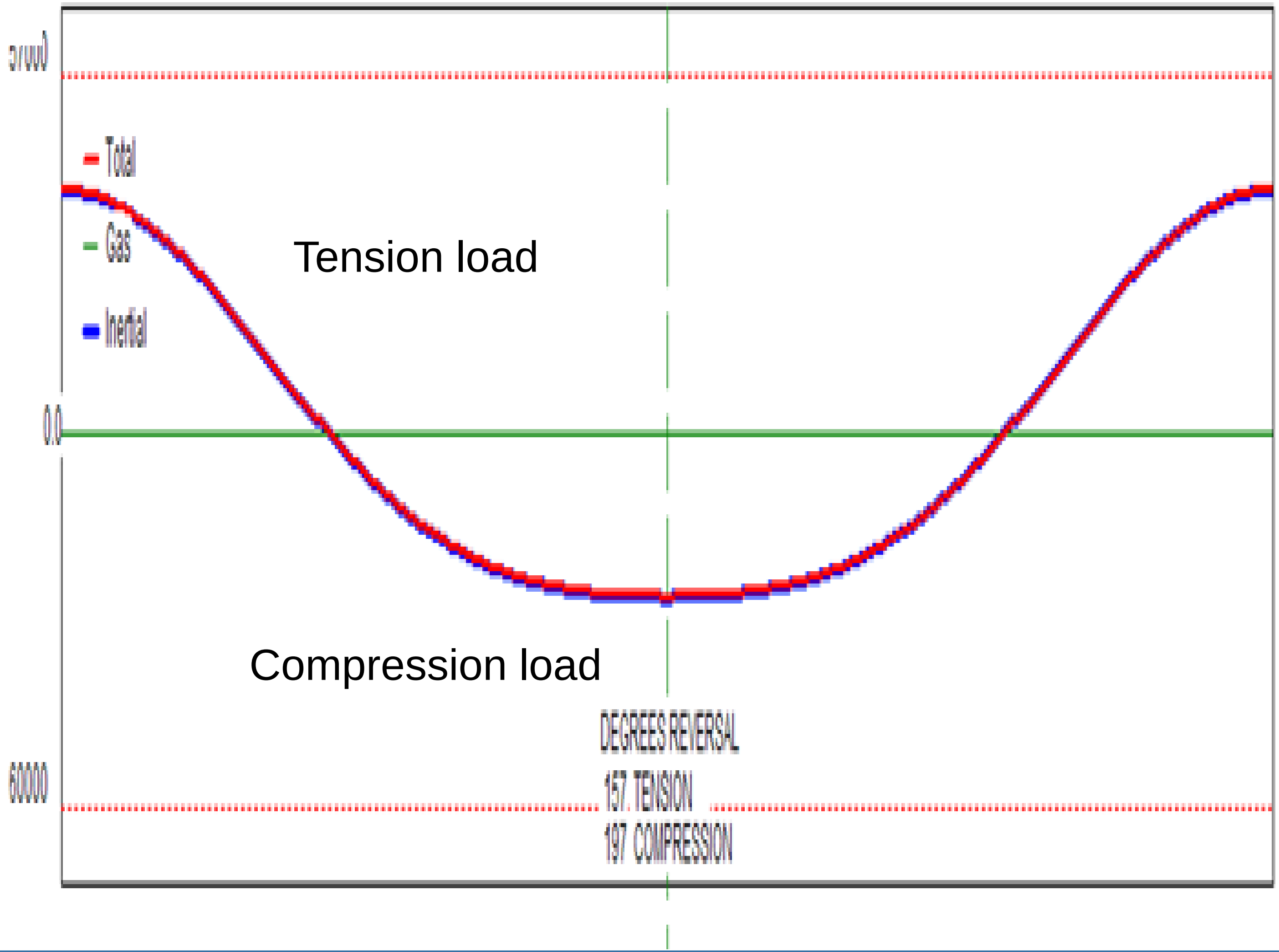
Inertia forces are always reversing on every revolution of the crankshaft.

Crank Mechanism



Reciprocating inertia forces are caused by the acceleration and deceleration of the reciprocating masses.

Inertia Loading



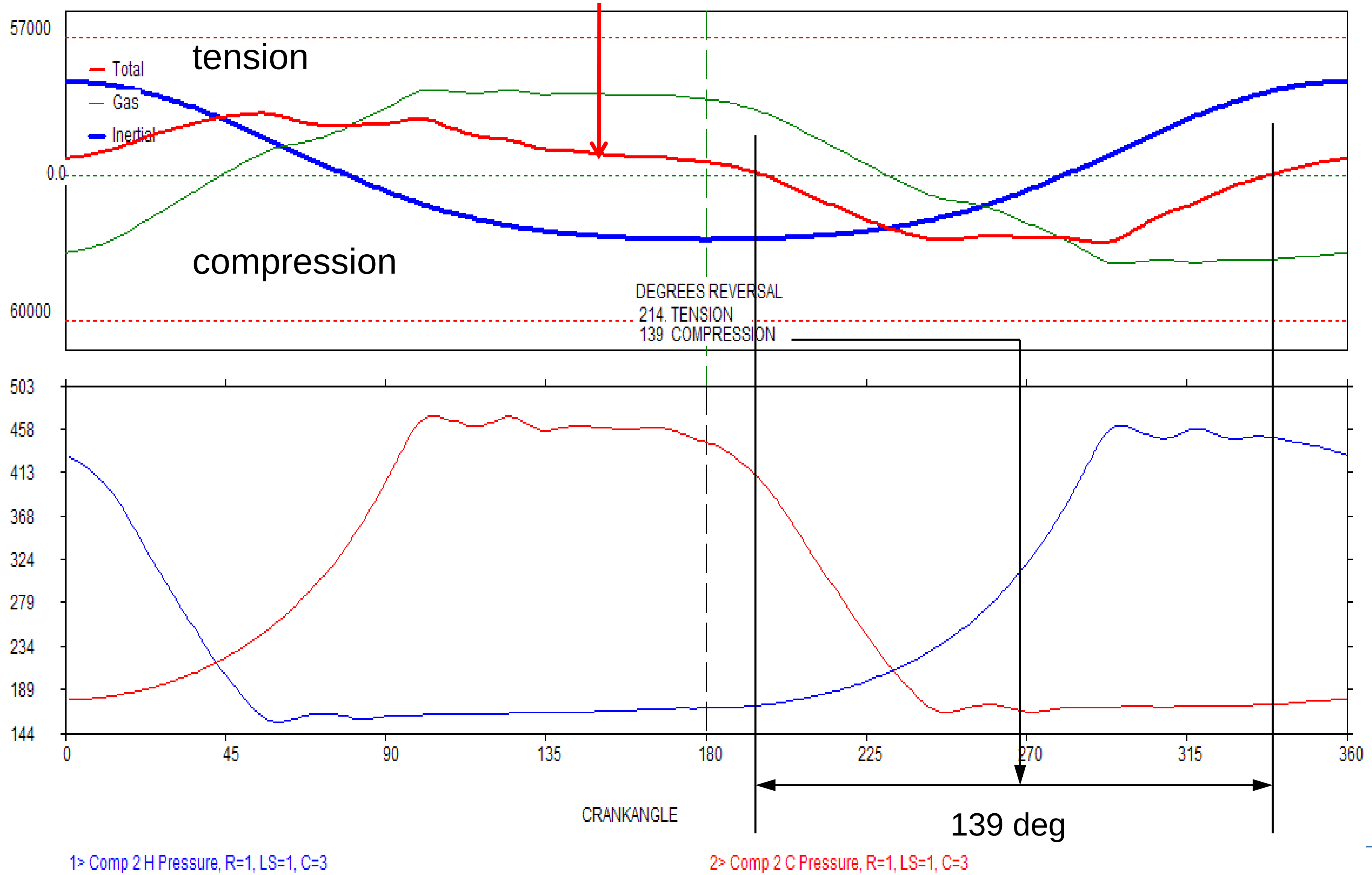
Net Load

Is simply the sum of the inertia and gas load forces

Is calculated for each degree of crankshaft rotation

Reversal occurs after the net rod load passes through 0 pounds and has met the Manufacturer's requirements for a reversal.

Net Load


57000
Total
Gas
Inertial
tension
0.0
compression
60000
DEGREES REVERSAL
214. TENSION
139 COMPRESSION
503
458
413
368
324
279
234
189
144
0
45
90
135
180
225
270
315
360
CRANKANGLE
139 deg
1> Comp 2 H Pressure, R=1, LS=1, C=3
2> Comp 2 C Pressure, R=1, LS=1, C=3

ROD REVERSAL

	%VOL	EFF	%POW/VAL LOSS		%Flow Bal	Toe Press		Comp	Temp °F		Rod Load (%)		Min Rod
	Dis	Suc	Dis	Suc	Suc/Dis	Pd	Ps	Ratio	Dis	Suc	Ten	Comp	Reversal
1>	41.5	60.5	8.6	5.4	1.01	1146.6	691.8	1.64	175.1	104.1	48.2	64.5	129 T
2>	58.1	84.6	7.0	5.6	1.01	1148.5	696.0	1.64	175.1	104.1	48.2	64.5	129 T
3>	40.2	71.2	8.6	5.2	0.94	690.2	297.7	2.26	217.8	98.4	39.9	47.8	137 T
4>	41.6	80.5	5.3	5.2	1.00	708.5	296.8	2.32	217.8	98.4	39.9	47.8	137 T
5>	32.9	73.6	7.6	5.2	1.00	302.3	100.7	2.75	215.9	82.0	52.2	54.4	145 T
6>	35.5	79.0	5.4	4.7	0.99	303.9	100.4	2.77	215.9	82.0	52.2	54.4	145 T
7>	37.9	72.2	8.6	6.0	0.99	685.1	293.3	2.27	209.3	97.2	40.0	47.9	137 T
8>	41.2	80.5	5.8	5.1	0.99	700.1	290.9	2.34	209.3	97.2	40.0	47.9	137 T

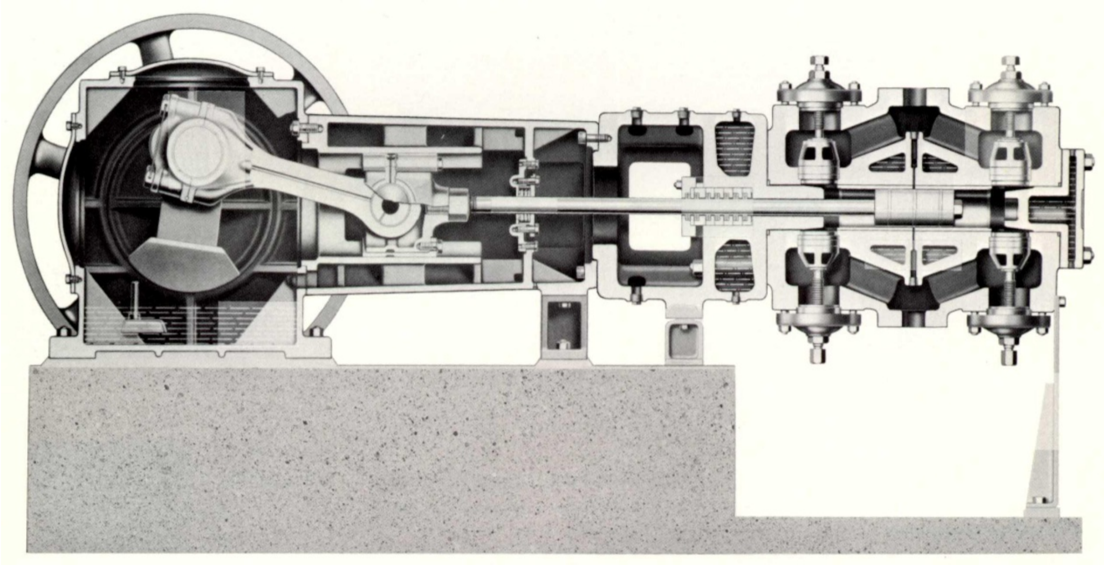
Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)
1	3.7645		
2	8.3687		
3	10.7310		

Rod Reversal

Rod reversal occurs when the combination of pressure and inertia forces on the reciprocating components cause a reversal in the loading of the crosshead pin and bushing.

This is sometimes referred to as load reversal.

Mechanical Specifications and Dimensions Required for Inertia Load Measurement



- Connecting Rod Length
- Stroke
- Mass of Reciprocating Components
- Crank Phase

Reciprocating Mass Combinations

For force at the piston-to-rod connection

Piston Weight

For force at the rod in front of crosshead

Piston and rod assembly weight

For force at the piston rod-to-crosshead connection

Piston, piston rod and jam nut weight

Reciprocating Mass Combinations

For force at the cross-head pin and bushing (rod reversal measurement)

- All reciprocating weight excluding any portion of the connecting rod
- For pin fixed to crosshead, include pin weight
- For pin fixed to connecting rod, do not include pin weight
- For full floating pin, consult the manufacturer or split the weight

Design Requirements API 618

The rod loads shall be calculated based on the internal pressure during discharge stroke (including ventilation losses) and shall not exceed the manufacturer's maximum allowable load at any specified operating load step.

The duration of the rod load reversal shall be 15° rotation angle minimum. The magnitude of peak shall be 3% minimum of the opposite peak.

Simple bushing designs (un-grooved) may require a minimum of 45 ° of rod reversal and a 20% magnitude.

Individual Manufacturer's Requirements May Vary.

Rod Reversal Requirements

Ariel: minimum of 30 degrees and 25% opposite force

Ajax: minimum of 30 degrees and 3% opposite force

Dresser-Rand: minimum of 30 degrees and X% opposite force (suggest 3%)

GE Oil & Gas: minimum of 60 degrees and 15% opposite force

Knox Western: minimum of 30 degrees and 15% opposite force

Superior: minimum of X degrees and X% opposite force (suggest 30 degrees and 15%)

Theoretical Temperature

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Set	Clearances (percent) Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Theoretical Temperature

T2 = ((T1+460) * R^((K-1)/K))-460

T2 = Theoretical discharge temperature

T1 = Beginning temperature degrees F.

R = Absolute toe compression ratio

(absolute disch pr / absolute suct pr)

K = Ratio of specific heats

The calculated discharge temperature goes up with any increase in suction temperature, compression ratio or K-value.

Compressor Performance Report

Compressor Cylinder ID	Theo Dis Temp (F)	Theo Dis Temp (delta)	Temp F Dis	Temp F Suc
1> Comp 1H Pressure	217.4	-1.8	215.6	111.6
2> Comp 1C Pressure	218.7	-3.1	215.6	111.6
3> Comp 2H Pressure	220.1	23.6	243.7	97.6
4> Comp 2C Pressure	218.4	25.3	243.7	97.6
5> Comp 3H Pressure	245.1	13.8	258.9	136.7
6> Comp 3C Pressure	244.1	14.8	258.9	136.7

calculated

difference

Measured
(from page 1)

The Theoretical discharge temperature is calculated from the measured suction temperature, the compression ratio of the toes and the K-value of the gas.

The delta temperature will elevate as the cylinder leakage rates increase.

Clearances

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Clearances (percent) Set	Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Compressor Performance Report

	Clearances (percent)			
Set	GPSA->Ave	Suc	Dis	SWR
65.90	65.9	65.20	66.51	64.83
19.20	19.2	19.17	19.17	19.17
44.50	44.5	40.71	48.36	38.96
24.60	24.6	21.12	28.06	20.18
53.90	53.9	51.72	55.99	50.69
23.90	23.9	24.15	23.68	24.21

In a healthy cyl end, the SWR calculation will normally agree closely with the set clearance **if** the set clearance is an accurate value.

The Set value is used in the creation of the theoretical PV models, log/log plots, and the polytropic values (n). It must represent the actual clearances in the individual cylinders.

These are the calculated clearances using the GPSA method. The actual clearance is not needed to make this calculation. The average value should be used as the set clearance for good diagnostic plots of theoreticals. In a healthy cylinder with an accurate TDC, the Suction and Discharge calculations will be close together.

Z FACTOR

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Clearances (percent) Set	Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	[illegible]				Load	N ratio	Theoretical			Capacity		Polytropic		Leak
	Z dis	Z suc	Z std	K	step	Exp/Comp	Eff	HP	STG	Suc	Dis	Exp	Comp	Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Redlich-Kwong 1949

The Redlich-Kwong equation of state was a considerable improvement over other equations of the time. It is still of interest primarily due to its relatively simple form. While superior to the van der Waals equation of state, it performs poorly with respect to the liquid phase and thus cannot be used for accurately calculating vapor–liquid equilibria. However, it can be used in conjunction with separate liquid-phase correlations for this purpose.

The Redlich-Kwong equation is adequate for calculation of gas phase properties when the ratio of the pressure to the critical pressure (reduced pressure) is less than about one-half of the ratio of the temperature to the critical temperature (reduced temperature).

Benedict-Webb-Rubin 1951

The **Benedict–Webb–Rubin equation** (**BWR**), named after Manson Benedict, G. B. Webb, and L. C. Rubin, is the calculation most used today. Working at the research laboratory of M. W. Kellogg Limited, the three researchers rearranged the Beattie-Bridgeman Equation of State and increased the number of experimentally determined constants to eight. The last modification to the BWR was by Younglove-Ely in 1987 which evolved into a 32-term version by fitting the equation to empirical data for a reference fluid. Other fluids then are described by using reduced variables for temperature and density.

K FACTOR

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Set	Clearances (percent) Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

K-Value

The ratio of specific heats is a physical property of pure gases and gas mixtures and is known by many other names including: adiabatic exponent, isentropic exponent, and k-value. It is used to define basic gas processes including adiabatic and polytropic compression. It also appears in many of the traditional equations and is commonly used to determine a compressor head, gas discharge temperature, gas power, and polytropic exponent.

Ratio Of Specific Heats

The BTU required to raise one **mole** of a gas 1 degree F at sea level and 60 degrees F.

The specific heat ratio of a gas is the ratio of the specific heat at constant pressure to the specific heat value at constant volume.

MOLE

The mole is defined by BIPM to be the amount of substance of a system which contains the same number of elementary entities (e.g. atoms, molecules, ions, electrons, photons) as atoms in 12 grams of carbon-12 (^{12}C), the isotope of carbon with relative atomic mass 12. By this definition, a mole of methane is 379.48 cubic feet at sea level and 60 degrees F.

N RATIO

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Set	Clearances (percent) Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Compressor Performance Report

K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp
1.381	A	1.01	94.4	198.0	1	6.01	5.96	1.41	1.39
1.381	A	1.00	93.8	249.8	1	7.49	7.53	1.40	1.40
1.381	A	1.11	96.9	495.5	2	13.13	11.82	1.53	1.38
1.381	A	1.17	97.7	520.6	2	13.99	12.79	1.61	1.38
1.379	A	1.05	91.0	422.0	3	12.60	12.01	1.57	1.49
1.379	A	0.99	92.0	402.5	3	12.13	11.91	1.51	1.52

If accurate gas data is available and the cylinder end is healthy, the Adiabatic K and the Polytropic N values will be very close.

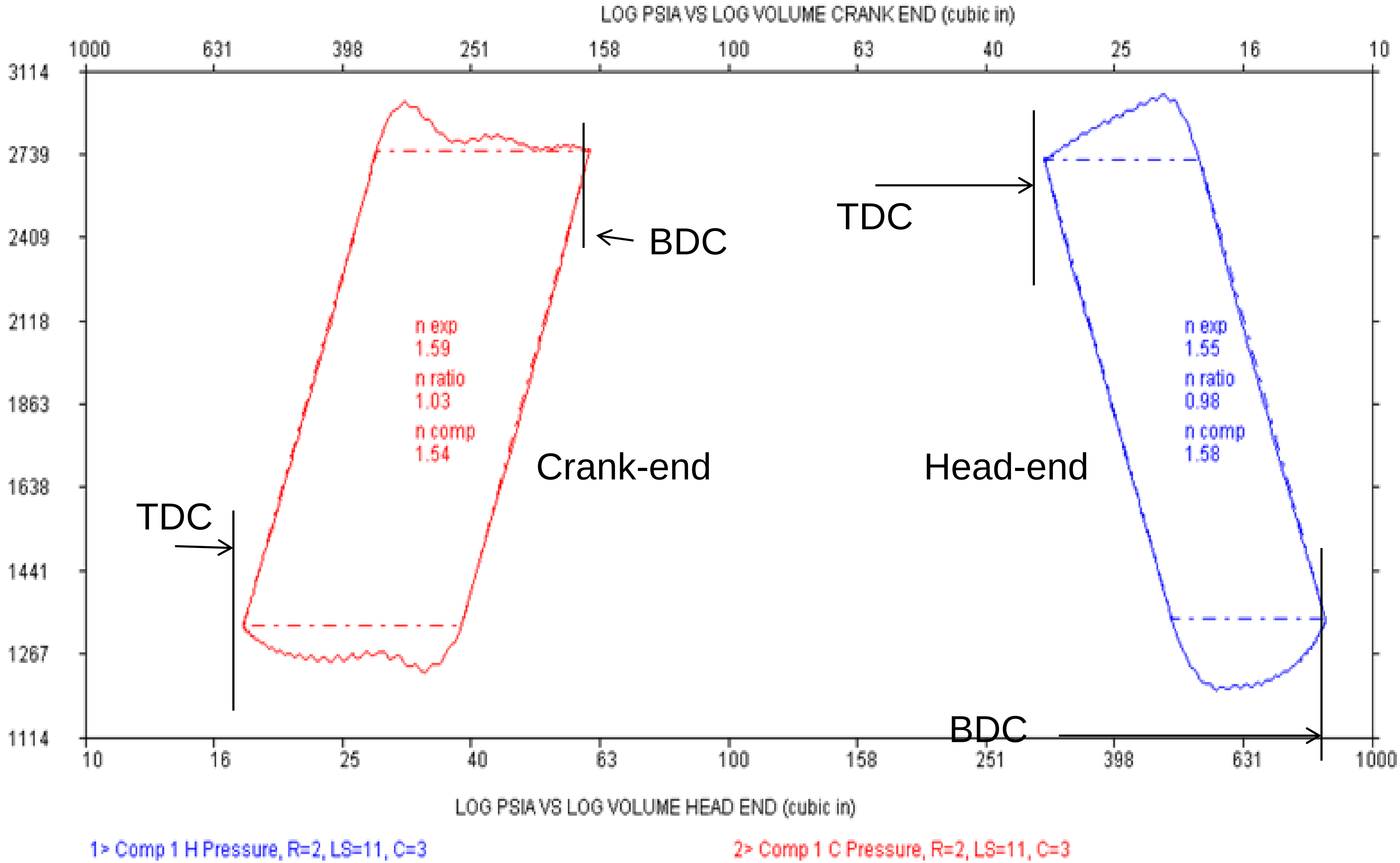
The N ratio is

N comp/N Exp

and is comparable to flow balance when all data is accurate.

These N values are calculated from the slope of the compression and re-expansion lines and generally agree with each other in a healthy cylinder. Accurate clearance data is required.

Log PSIA vs. Log Volume



THEORETICAL HP

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Clearances (percent) Set	Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Compressor Performance Report

K	Load step	N ratio Exp/Comp	Theoretical Eff	Theoretical HP	STG	Capacity Suc	Capacity Dis	Polytropic Exp	Polytropic Comp
1.381	A	1.01	94.4	198.0	1	6.01	5.96	1.41	1.39
1.381	A	1.00	93.8	249.8	1	7.49	7.53	1.40	1.40
1.381	A	1.11	96.9	495.5	2	13.13	11.82	1.53	1.38
1.381	A	1.17	97.7	520.6	2	13.99	12.79	1.61	1.38
1.379	A	1.05	91.0	422.0	3	12.60	12.01	1.57	1.49
1.379	A	0.99	92.0	402.5	3	12.13	11.91	1.51	1.52

The theoretical IHP and efficiency are determined by comparing the measured IHP to the theoretical HP.

These are the calculated capacities at suction and discharge conditions. Their accuracy is dependent on the health of the cylinder and the accuracy of the collected data.

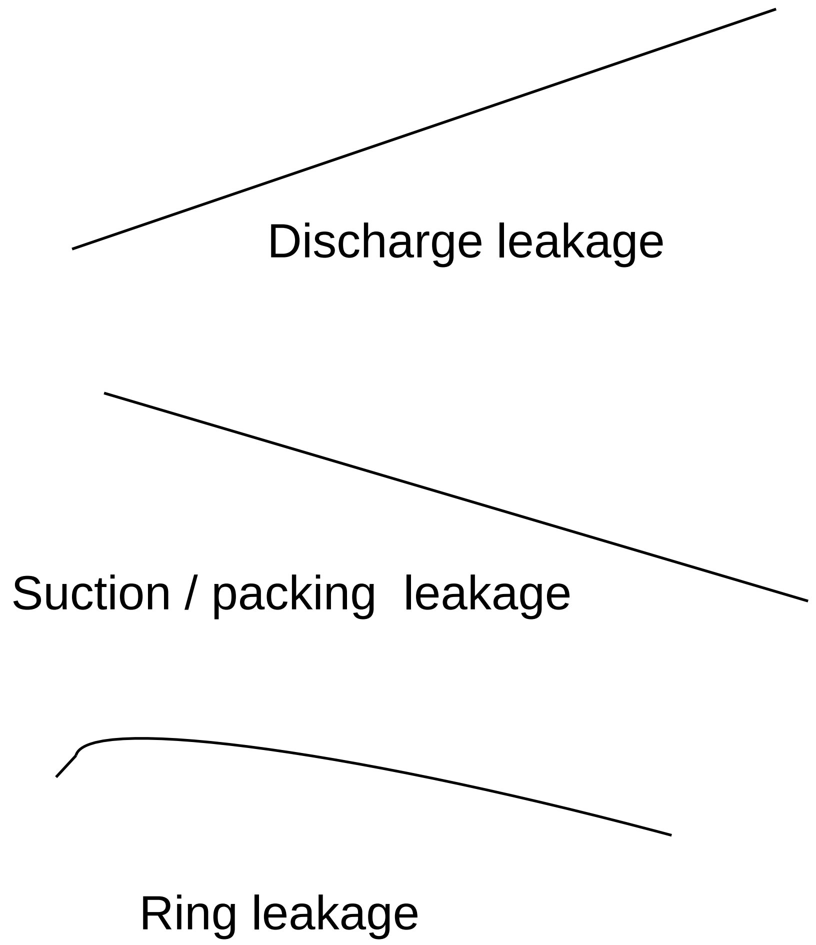
LEAK INDEX

Compressor Cylinder ID	Theo Dis Temp (°F)	(delta)	Set	Clearances (percent) Calc->Avg	Suc	Dis	SwRI
1> Comp 1 H Pressure	168.4	6.8	84.70	85.77	85.86	85.69	85.20
2> Comp 1 C Pressure	167.8	7.4	33.13	34.15	34.03	34.27	33.61
3> Comp 2 H Pressure	205.0	12.9	28.20	28.32	31.47	25.18	32.92
4> Comp 2 C Pressure	208.7	9.1	18.70	19.76	20.31	19.22	20.13
5> Comp 3 H Pressure	214.0	1.9	20.00	21.52	21.48	21.56	20.87
6> Comp 3 C Pressure	215.1	0.9	15.50	16.66	16.91	16.40	16.62
7> Comp 4 H Pressure	204.7	4.7	28.60	29.44	29.96	28.92	29.82
8> Comp 4 C Pressure	208.8	0.5	18.70	19.49	19.93	19.06	19.81

	Compressibility Z dis	Z suc	Z std	K	Load step	N ratio Exp/Comp	Theoretical Eff	HP	STG	Capacity Suc	Dis	Polytropic Exp	Comp	Leak Index
1>	0.906	0.896	0.998	1.277	1	1.00	85.3	108.2	3	4.75	4.70	1.30	1.31	0.47
2>	0.906	0.896	0.998	1.277	1	0.99	87.0	137.7	3	6.11	6.03	1.29	1.30	0.79
3>	0.947	0.956	0.998	1.273	1	0.89	82.1	84.7	2	2.08	2.20	1.16	1.30	2.28
4>	0.945	0.956	0.998	1.272	1	0.95	88.7	90.1	2	2.13	2.13	1.18	1.24	0.71
5>	0.975	0.983	0.998	1.275	1	0.97	87.1	96.2	1	1.86	1.85	1.20	1.24	0.90
6>	0.975	0.983	0.998	1.275	1	0.95	89.1	99.7	1	1.91	1.92	1.19	1.25	0.90
7>	0.944	0.956	0.998	1.274	1	0.97	85.1	85.1	2	2.07	2.09	1.21	1.25	0.49
8>	0.943	0.956	0.998	1.274	1	0.96	88.5	89.2	2	2.09	2.11	1.19	1.24	0.68

Stage#	Capacity (MMSCFD)	Stage#	Capacity (MMSCFD)

Leak Index (general shapes)



LEAK INDEX

Smoothing Factor 6

Leak index calculations typically need a high smoothing factor. 6 is recommended as a default for slow speed units. High speed units or units with a lot of pulsation may need higher (up to 14).

Leak Index Window

from 3 % above suction toe pressure

to 9 % below discharge toe pressure

Leak index normally evaluates from 3% above suction toe pressure to 9% below discharge toe pressure. Increasing these values (starting and stopping further from the toe points) can help avoid problems with pulsations.

Sensitivity 0.00 %

A higher sensitivity results in more leaks being called. Less than zero results in fewer leaks being called. Currently:

A slight leak will be called if leak index is above +/- 3.00%.
A more serious leak will be called if leak index is above +/- 5.70%.