RECIPROCATING COMPRESSOR CALCULATION SHEET

WITH INTERCOOLER

Gas properties, flowrate and conditions

(Sheet : ...1..... Of ...3.....)

1	Gas name	Air				
	Item or symbol	Quantity	Unit	Item or symbol	Quantity	Unit
2	Suction pressure, ps	1.013	bar A	Discharge pressure, pd	38.2	bar A
3	Suction temperature, ts	35	^{O}C			
4	Ts	308	^{O}K	p_{CR}	47.88	bar A
5	MW	28.4	kg/kgmol	T_{CR}	161.38	^{O}K
6	k_S	1.403		$p_R = p / p_{CR}$	0.021	
7	R_S	0.295	kJ/kg.^{O}K	$T_R = T / T_{CR}$	1.91	
8	DSs	1.115	kg/m3	Z_S	1.00	
9	MCp	29.10	kJ/kgmol.^{O}K	Cp_S	1.027	kJ/kg
10	G	26000	kg/hr	G_{mol}	917	kgmol/hr
11	Q_S	23320	m^3/hr	Q_N	20670	Nm^3/hr
12						

Compressor Calculation Sheet

	Item	Symbol	Unit	Quantity	Note
13	***Preliminary Calculation (General method)***				
14	**Check whether need intercooler**				
15	First Stage Volume flow	Qs	m3/hr	23320	
16	Cylinder intake pressure	ps'	barA	0.98261	
17	Cylinder exhaust pressure	pd'	barA	39.346	
18	Pressure ratio (p_D / p_S)	r'_{TOTAL}	-	40.042	
19	(k-1)/k		-	0.2872	
20	k/(k-1)		-	3.481	
25	**Check number of stage due to max. temp**				
21	Max. temperature	t_{MAX}	^{O}C	150	See Chapter VI.
22		T_{MAX}	^{O}K	423	
23	Max. pressure ratio	r_{MAX-T}	-	3.02	Equation (11)
24	Is r > r_{MAX} or need intercooler ?			Yes	
25	Total Hydrodynamic head	H_{TOTAL}	m	60816	Eq. 8.
26	**Expected minimum adiabatic vol. eff.**			0.850	
27	Max. clearance space vol.		%	12.53	Eq. A.3. If need intercooler, use r = r_{max-T}, otherwise use r_{Total}
28	Clearance space volume	c	%	10	Fill < max.at expected eff.
29	Volumetric efficiency	η_V		0.836	Eq. A.3 and A.4.

	Item	Symbol	Unit	Quantity	Note
1	Supply efficiency	λ/η_V		0.945	Eq. A.5.
2	Required piston capacity	Qp	m3/hr	29507.9	Eq. A.6 and A.7.
3	Max. hydr. Head for each stage	$H_{STG-MAX}$	m	12039	Eq. A.6.
4	Preliminary number of stage	i_{CAL}		5	= Htotal / Hstg-max
5	GHP			5452	
6	Mechanical efficiency			0.95	
7	BHP			5739	
8	**Frame BHP selection at first stage**			**Casing I**	
9	No. of compression acting			2	Fig. A.3
10	Stroke length, L			430	Fig. A.3
11	No. of throw at first stage, z			2	Fig. A.3
12	Crankshaft speed, N			360	Fig. A.1
13	Max. diameter, Dmax (= L / 0.4)			1075	
14	No. of frame			1	
15	Calculated frame BHP/throw, 0.11 Qp1			929	Chapter A.4.
16	Max. H per throw			10006	Eq.A.11

	Detail calculation	CASING I								Note
18		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	
19	**G** (kg/hr)	26000	26000	26000	26000	26000	26000	26000	26000	
20	Max. H per stage for parallel throws	10006.5	10006.5	10006.5	10006.5	10006.5	10006.5	10006.5	10006.5	= line 16
21	Last cylinder exhaust press. (barA)	39.346	39.346	39.346	39.346	39.346	39.346	39.346	39.346	
22	Cyl. intake pressure, **ps'** (barA)	0.98	2.418	5.936	14.720	36.651	-	-	-	Eq. A8
23	Suction temperature, **ts** (C)	35.0	45.0	45.0	45.0	45.0	51.5	#VALUE!	#VALUE!	
24	**Ts** (K)	308.0	318.0	318.0	318.0	318.0	324.5	#VALUE!	#VALUE!	
25	Max. discharge temp., **td** max. (C)	**140**	140	140	140	140	140	140	140	Chapter 6
26	**Td** max. (C)	413.0	413.0	413.0	413.0	413.0	413.0	413.0	413.0	
27	**MW**	28.36	28.36	28	28	28	28	28	28	
28	**Rs** = 8.314/MW	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
29	p_{CR}	47.9	47.9	47.9	47.9	47.9	47.9	47.9	47.9	
30	T_{CR}	161.4	161.4	161.4	161.4	161.4	161.4	161.4	161.4	
31	$p_R = p_{RED} = p / p_{CR}$	0.02	0.050	0.12	0.31	0.77	#VALUE!	#VALUE!	#VALUE!	Appendix B
32	$T_R = T_{RED} = T / T_{CR}$	1.91	1.971	1.97	1.97	1.97	2.01	#VALUE!	#VALUE!	
33	Z_S	1	1	1	1	1	1	1	1	
34	MCp_S (kJ/kgmol.K)	29.10	29.1	29.1	29.1	29.1	29.1	29.1	29.1	
35	**k** = MCp/(MCp-8.314)	1.40	1.400	1.400	1.400	1.400	1.400	1.400	1.400	
36	Cp_S = R.k /(k-1), (kJ/kg.K)	1.03	1.033	1.033	1.033	1.033	1.033	1.033	1.033	
37	**DSs** = 100.ps / (Z.R.Ts), (kg/m3)	1.1	2.6	6.3	15.7	39.1	#VALUE!	#VALUE!	#VALUE!	Eq. 3 up to 7
38	Q_S = G / DSs, (m3/hr)	23320.4	10087.7	4109	1656.9	665.5	#VALUE!	#VALUE!	#VALUE!	

	Detail calculation (cont)	CASING I								Note
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	
1	Q_N (Nm3/h)	20670	20670	20670	20670	20670	20670	20670	20670	
2	**(k-1)/k**	0.287	0.286	0.286	0.286	0.286	0.286	0.286	0.286	
3	**k/(k-1)**	3.481	3.500	3.500	3.500	3.500	3.500	3.500	3.500	
4	**Due to max. temperature**									
5	Pressure ratio, **r '** due to max. temp.	2.777	2.497	2.497	2.497	1.074	#VALUE!	#VALUE!	#VALUE!	Eq. 11, Eq. A.10
6	**Due to max. frame BHP**									
7	Max. **r'** due to max. frame BHP	2.562	2.498	2.498	2.498	2.498	2.458	#VALUE!	#VALUE!	
8	Selected **r'**	**2.562**	**2.497**	**2.497**	**2.497**	**1.074**	**#VALUE!**	**#VALUE!**	**#VALUE!**	
9	Discharge pressure, **pd** (barA)	2.518	6.036	14.820	36.751	39.350	#VALUE!	#VALUE!	#VALUE!	
10	Cylinder exhaust pressure, **pd'** (barA)	2.593	6.217	15.265	37.853	40.530	#VALUE!	#VALUE!	#VALUE!	Eq. A8
11	Clearance space volume, **c** (%)	10	10	10	10	10	10	10	10	
12	Volumetric efficiency, η_v	0.859	0.862	0.862	0.862	0.945	#VALUE!	#VALUE!	#VALUE!	Eq. A4
13	Supply efficiency, λ/η_v	0.957	0.958	0.958	0.958	0.998	#VALUE!	#VALUE!	#VALUE!	Eq. A5
14	Required piston capacity, **Qp** (m3)	28369.1	12204.7	4970.9	2004.6	705.8	#VALUE!	#VALUE!	#VALUE!	Eq. A7
15	Preliminary Piston speed (m/s)	5	**5**	**5**	**5**	**5**	**5**	**5**	**5**	
16	Stroke length, **L** (mm)	**430**	430	430	430	430	430	430	430	
17	No. of compression acting	2	2	2	2	2	2	2	2	
18	No. of throw for each stage, **z**	**2**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	Fill for D < Dmax
19	Crankshaft speed, **N** (RPM)	**360**	360	360	360	360	360	360	360	Adjust if U > 6 m/s
20	Piston speed, **U** (m/s)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	Eq. 12, **max. 6 m/s**
21	Piston displacement vol./stroke, m^3	0.328	0.283	0.115	0.046	0.016	#VALUE!	#VALUE!	#VALUE!	
22	Piston diameter, **D** (mm)	**985.2**	913.8	583.2	370.4	219.8	#VALUE!	#VALUE!	#VALUE!	Max.(mm)= **1075**
23	Hydrodynamic head, **H** (m)	10006.5	9999.1	9999.1	9999.1	686.4	#VALUE!	#VALUE!	#VALUE!	Eq. 8
24	**GHP**	**862**	**883**	**883**	**883**	**53**	**0**	**0**	**0**	**Eq. 9**
25	Exhaust temp before cooler, **td** (C)	**131**	**140**	**140**	**140**	**52**	**#VALUE!**	**#VALUE!**	**#VALUE!**	Eq. 10
26	Need intercooler ?	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**-**	**-**	**-**	
27	If "Yes", outlet gas temp. (C)	45	45	45	45	45	45	45	45	
28	Pres. drop at inter/stg cooler (bar)	0.10	0.10	0.10	0.100	0.100	0.100	0.100	0.100	
29	Compression continue ?	**Continue**	**Continue**	**Continue**	**Continue**	**Finish**	**-**	**-**	**-**	
30	**Total Adiabatic Compression GHP** (kW)	3563.54								
31	Adiabatic eff, when isn' t fully adiabatic	0.90								See figure below
32	Mechanical efficiency	0.94								Fig. A4
33	**Total BHP** (kW)	**4212**								
34	C.W. each cooler (ton/hr)	61.2	61.2	# 61.2	# 61.2	# 0.0	0	0 0	0	For Δt water = 10 C
35	Total C.W. required (ton/hr)	244.7								

RECIPROCATING COMPRESSOR CALCULATION SHEET

WITH INTERCOOLER

Gas properties, flowrate and conditions

1	Gas name	Dry Air				
	Item or symbol	Quantity	Unit	Item or symbol	Quantity	Unit
2	Suction pressure, ps	1.013	bar A	Discharge pressure, pd	45	bar A
3	Suction temperature, ts	35	°C			
4	Ts	308	°K	p_{CR}	37.70	bar A
5	MW	28.4	kg/kgmol	T_{CR}	132.80	°K
6	k_S	1.403		$p_R = p / p_{CR}$	0.027	
7	R_S	0.295	kJ/kg.°K	$T_R = T / T_{CR}$	2.32	
8	DSs	1.115	kg/m3	Z_S	1.00	
9	MCp	29.10	kJ/kgmol.°K	Cp_S	1.027	kJ/kg
10	G	6000	kg/hr	G_{mol}	212	kgmol/hr
11	Q_S	5382	m°/hr	Q_N	4770	Nm^3/hr
12						

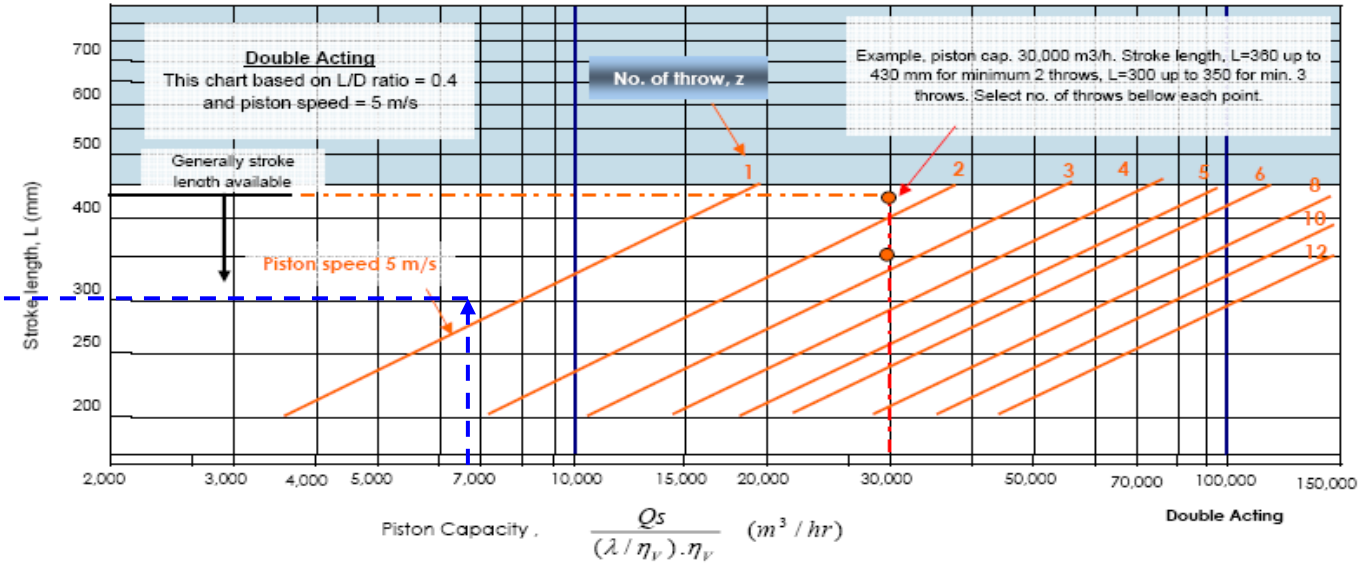
Compressor Calculation Sheet

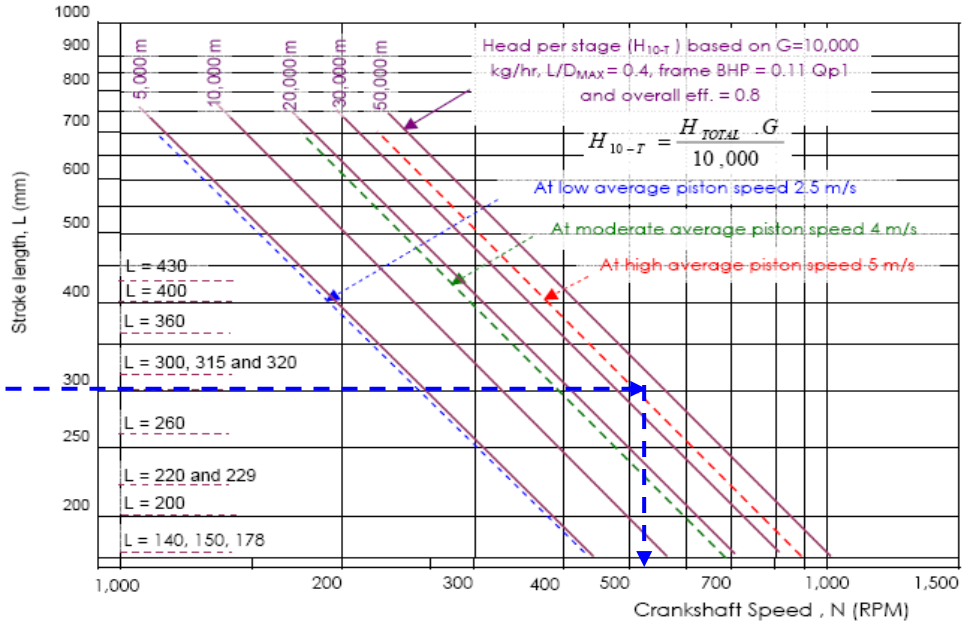
	Item	Symbol	Unit	Quantity	Note
13	***Preliminary Calculation (General method)***				
14	**Check whether need intercooler**				
15	First Stage Volume flow	Qs	m3/hr	5382	
16	Cylinder intake pressure	ps'	barA	0.98261	
17	Cylinder exhaust pressure	pd'	barA	46.35	
18	Pressure ratio (p_D / p_S)	r'_{TOTAL}	-	47.170	
19	(k-1)/k		-	0.2872	
20	k/(k-1)		-	3.481	
25	**Check number of stage due to max. temp**				
21	Max. temperature	t_{MAX}	°C	150	See Chapter VI.
22		T_{MAX}	°K	423	
23	Max. pressure ratio	r_{MAX-T}	-	3.02	Equation (11)
24	Is $r > r_{MAX}$ or need intercooler ?			Yes	
25	Total Hydrodynamic head	H_{TOTAL}	m	65300	Eq. 8.
26	**Expected minimum adiabatic vol. eff.**	η_{V-A}		0.850	
27	Max. clearance space vol.	c_{MAX}		12.53	Eq. A.3. If need intercooler, use $r = r_{max-T}$, otherwise use r_{Total}
28	Clearance space volume	c	%	10	Fill < max.at expected eff.
29	Volumetric efficiency	η_V		0.836	Eq. A.3 and A.4.

	Item	Symbol	Unit	Quantity	Note
1	Supply efficiency	λ/η_V		0.945	Eq. A.5.
2	Required piston capacity	Qp	m3/hr	6809.5	Eq. A.6 and A.7.
3	Max. hydr. Head for each stage	$H_{STG-MAX}$	m	12039	Eq. A.6.
4	Preliminary number of stage	i_{CAL}		5	= Htotal / Hstg-max
5	GHP	GHP	kW	1351	
6	Mechanical efficiency	η_M		0.95	
7	BHP	BHP	kW	1422	
8	**Frame BHP selection at first stage**			**Casing I**	
9	No. of compression acting			2	Fig. A.3
10	Stroke length, L	L	mm	300	Fig. A.3
11	No. of throw at first stage, z	z		1	Fig. A.3
12	Crankshaft speed, N	N	RPM	520	Fig. A.1 for U near 5 m/s or using graphical method below
13	Max. diameter, Dmax (= L / 0.4)	Dmax	mm	750	
14	No. of frame			1	
15	Calculated frame BHP/throw, 0.11 Qp1	BHP/throw	kW	456	Chapter A.4.
16	Max. H per throw	$H_{STG-MAX}$	m	21270	Eq.A.11

	Detail calculation	CASING I								Note
18		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	
19	**G** (kg/hr)	6000	6000	6000	6000	6000	6000	6000	6000	
20	Max. H per stage for parallel throws	21269.8	21269.8	21269.8	21269.8	21269.8	21269.8	21269.8	21269.8	= line 16
21	Last cylinder exhaust press. (barA)	46.35	46.35	46.35	46.35	46.35	46.35	46.35	46.35	
22	Cyl. intake pressure, **ps'** (barA)	0.98	2.865	7.678	20.744	-	-	-	-	Eq. A8
23	Suction temperature, **ts** (C)	35.0	45.0	45.0	45.0	127.1	#VALUE!	#VALUE!	#VALUE!	
24	**Ts** (K)	308.0	318.0	318.0	318.0	400.1	#VALUE!	#VALUE!	#VALUE!	
25	Max. discharge temp., **td** max. (C)	**150**	150	150	150	150	150	150	150	Chapter 6
26	**Td** max. (C)	423.0	423.0	423.0	423.0	423.0	423.0	423.0	423.0	
27	**MW**	28.36	28.36	28	28	28	28	28	28	
28	**Rs** = 8.314/MW	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
29	p_{CR}	37.7	37.7	37.7	37.7	37.7	37.7	37.7	37.7	
30	T_{CR}	132.8	132.8	132.8	132.8	132.8	132.8	132.8	132.8	
31	$p_R = p_{RED} = p / p_{CR}$	0.03	0.076	0.20	0.55	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Appendix B
32	$T_R = T_{RED} = T / T_{CR}$	2.32	2.395	2.39	2.39	3.01	#VALUE!	#VALUE!	#VALUE!	
33	Z_S	1	1	1	1	1	1	1	1	
34	MCp_S (kJ/kgmol.K)	29.10	29.1	29.1	29.1	29.1	29.1	29.1	29.1	
35	**k** = MCp/(MCp-8.314)	1.40	1.400	1.400	1.400	1.400	1.400	1.400	1.400	
36	Cp_S = R.k /(k-1), (kJ/kg.K)	1.03	1.033	1.033	1.033	1.033	1.033	1.033	1.033	
37	**DSs** = 100.ps / (Z.R.Ts), (kg/m3)	1.1	3.1	8.2	22.1	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. 3 up to 7
38	Q_S = G / DSs, (m3/hr)	5381.6	1964.3	733	271.3	#VALUE!	#VALUE!	#VALUE!	#VALUE!	

	Detail calculation (cont)	CASING I								Note
		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8	
1	Q_N (Nm3/h)	4770	4770	4770	4770	4770	4770	4770	4770	
2	**(k-1)/k**	0.287	0.286	0.286	0.286	0.286	0.286	0.286	0.286	
3	**k/(k-1)**	3.481	3.500	3.500	3.500	3.500	3.500	3.500	3.500	
4	**Due to max. temperature**									
5	Pressure ratio, **r '** due to max. temp.	3.018	2.715	2.715	2.234	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. 11, Eq. A.10
6	**Due to max. frame BHP**									
7	Max. **r'** due to max. frame BHP	5.834	5.595	5.595	5.595	4.183	#VALUE!	#VALUE!	#VALUE!	
8	Selected **r'**	**3.018**	**2.715**	**2.715**	**2.234**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	
9	Discharge pressure, **pd** (barA)	2.965	7.778	20.844	46.352	#VALUE!	#VALUE!	#VALUE!	#VALUE!	
10	Cylinder exhaust pressure, **pd'** (barA)	3.054	8.012	21.470	47.743	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. A8 for 3 % loss
11	Clearance space volume, **c** (%)	10	10	10	10	10	10	10	10	
12	Volumetric efficiency, η_v	0.836	0.851	0.851	0.876	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. A4
13	Supply efficiency, λ/η_v	0.945	0.953	0.953	0.965	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. A5
14	Required piston capacity, **Qp** (m3)	6809.5	2422.3	903.9	320.7	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. A7
15	Preliminary Piston speed (m/s)	5	**5**	**5**	**5**	**5**	**5**	**5**	**5**	
16	Stroke length, **L** (mm)	**300**	300	300	300	300	300	300	300	
17	No. of compression acting	2	2	2	2	2	2	2	2	
18	No. of throw for each stage, **z**	1	1	1	1	0	0	0	0	Fill for D < Dmax
19	Crankshaft speed, **N** (RPM)	**520**	520	520	520	520	520	520	520	Adjust if U > 6 m/s
20	Piston speed, **U** (m/s)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	Eq. 12, **max. 6 m/s**
21	Piston displacement vol./stroke, m^3	0.109	0.039	0.014	0.005	#VALUE!	#VALUE!	#VALUE!	#VALUE!	
22	Piston diameter, **D** (mm)	**680.0**	405.5	247.7	147.6	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Max.(mm)= **750**
23	Hydrodynamic head, **H** (m)	12039.4	11051.6	11051.6	8643.1	#VALUE!	#VALUE!	#VALUE!	#VALUE!	Eq. 8
24	**GHP**	**249**	**230**	**230**	**172**	**0**	**0**	**0**	**0**	**Eq. 9**
28	Exhaust temp before cooler, **td** (C)	**150**	**150**	**150**	**127**	**#VALUE!**	**#VALUE!**	**#VALUE!**	**#VALUE!**	Eq. 10
25	Need intercooler ?	**Yes**	**Yes**	**Yes**	**No**	**-**	**-**	**-**	**-**	
26	If "Yes", outlet gas temp. (C)	45	45	45	45	45	45	45	45	
27	Pres. drop at inter/stg cooler (bar)	0.10	0.10	0.10	0.100	0.100	0.100	0.100	0.100	
28	Compression continue ?	**Continue**	**Continue**	**Continue**	**Finish**	**-**	**-**	**-**	**-**	
29	**Total Adiabatic Compression GHP** (kW)	879.99								
30	Adiabatic eff, when isn' t fully adiabatic	0.90								See figure below
31	Mechanical efficiency	0.93								Fig. A4
32	**Total BHP** (kW)	**1051**								
33	C.W. each cooler (ton/hr)	17.0	15.6	15.6	0.0	0.0	0	0	0	For Δt water = 10 C
34	Total C.W. required (ton/hr)	48.2								

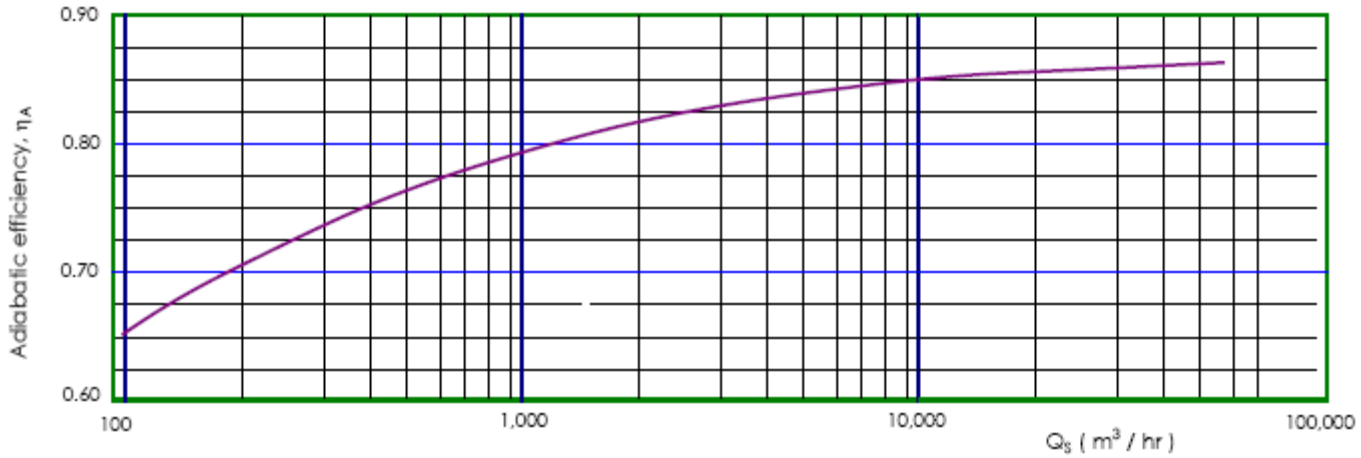




Example : Blue dot line

To find N (RPM) at expected overall efficiency 0.80

$$H_{10-T} = \frac{65,300 \times 6,000}{10,000} = 39,180 m$$



Interpretation of adiabatic efficiency from literature (0.65 for small, 0.80 for medium, 0.85 and higher for large reciprocating compressor) when the compressor doesn't work in fully adiabatic compression. Qs is suction flow at first stage of the compressor. When intercoolers and water jacket are applied, adiabatic efficiency higher than above figure.

BHP = GHP /(η_A . η_M)