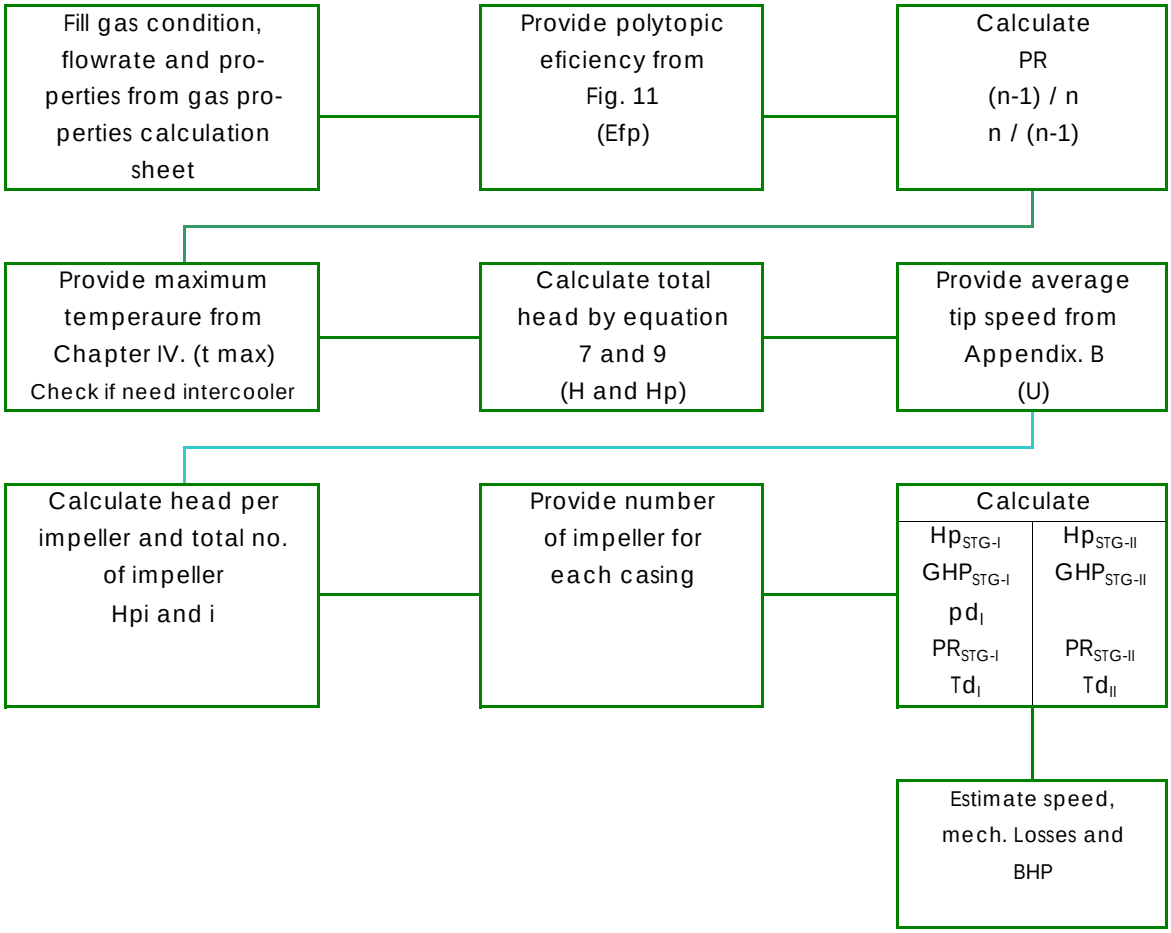
CENTRIFUGAL COMPRESSOR CALCULATION SHEET

A. WITHOUT CONSIDERING DETAIL OF IMPELLER

INPUT GIVEN CONDITION OR QUANTITY IN RED COLOR CELLS

WITHOUT INTERCOOLER

FLOW CHART



Gas properties, flowrate and conditions

(Sheet : ..... Of .....)

1	Gas name	Synthese gas				
	Item or symbol	Quantity	Unit	Item or symbol	Quantity	Unit
2	Suction pressure, ps	27	bar A	Discharge pressure, pd	70	bar A
3	Suction temperature, ts	32	^{O} C			
4	Ts	305	^{O} K	p_{CR}	19	bar A
5	MW	8.91	kg/kgmol	T_{CR}	60	^{O} K
6	k_S	1.402		$p_R = p / p_{CR}$	1.42	
7	R_S	0.933	kJ/kg.^{O}K	$T_R = T / T_{CR}$	5.08	
8	DSs	9.487	kg/m3	Z_S	1.003	
9	MCp	29	kJ/kgmol.^{O}K	Cp_S	3.25	kJ/kg
10	G	247100	kg/hr	G_{mol}	27733	kgmol/hr
11	Q_S	26046	m^3/hr	Q_N	621381	Nm^3/hr
12						

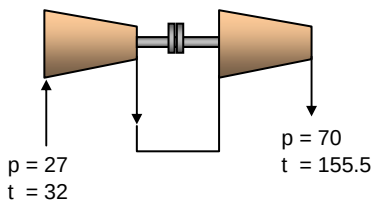
Compressor Calculation Sheet

	Item	Symbol	Unit	Quantity	Note
13					
14	**Check whether need intercooler**				
15	First Stage Volume flow	Qs	m3/hr	26046	
16	Efficiency			0.78	Fig. 11.
17	Total Pressure ratio (p_D / p_S)	PR	-	2.593	
18	(n-1)/n = (k-1)/k.EF_P	(n-1) / n	-	0.3676	
19	n/(n-1) = k.EF_P/(k-1)	n / (n-1)	-	2.721	
20	Max. temperature	t_{MAX}	^{O}C	180	SeeChapter VI.
21		T_{MAX}	^{O}K	453	
22	PR_{STGMAX}	$(p_D / p_S)_{MAX}$	-	2.93	Equation (11)
23	Is PR > $(p_D / p_S)_{MAX}$ or need interstage			**No**	**no need intercooler and use this sheet**
24	cooler ?				
25	**Number of impeller and casing**				
26					
27	Total Hydrodynamic head	H_{TOTAL}	m	33193.4	Equation (7)
28	Total polytropic head	Hp_{TOTAL}	m	42555.6	Equation (9)
29	Average tip speed	U	m/s	250	Appendix B.1.
30	Polytropic head / impeller at Y =1.05	Hpi	m	3344.8	Equation (14)
31	Total no. of impeller	i_{TOTAL}		13	I = Hp_{TOTAL} / Hpi
32	Ratio speed by sound velocity	Mau		0.395	Equation at Fig. 13
33	Max. no. of impeller/casing			8	Fig. 13. at Mau and model C
34	Need more than one casing ?			**Yes**	**, need more than one casing**
35	Preliminary no. of impeller in casing I	I_{STG-I}		8	
36	Preliminary no. of impeller in casing II	I_{STG-II}		5	= I_{TOTAL} - I_{STG-I}
37		-			

Compressor Calculation Sheet (Cont.) (Sheet : ..... Of .....)

	Item	Symbol	Unit	Quantity	Note
38					
39	**Casing I**				
40					
41	Head	Hp_{STG-I}	m	26758	= Hpi x I_{STG-I}
42	Gas Horse Power Casing I	GHP_{STG-I}	kW	18018	= $G.Hp_{STG-I}$ x g x10^{-6} / 3.6
43	Average diameter	D	mm	850	Fig. 13 for flow Qs
44	Speed	N	RPM	5620	= 60,000 x U / (3.14 x D)
45	Mechanical losses	Pmlb	kW	54	Chapter IX, at Qs
46	(assumed use seal oil for flamable gas)	Pmls	kW	28	RL = 1.7 RS = 0.9
47	Mechanical losses at casing I	Pml	kW	82	
48	Brake horse power casing I	BHP_I	kW	18100	
49	Discharge pressure	pd_{STG-I}	bar A	**51.03**	$Pd=Ps.\{Hp_{STG}.Efp.g.(n-1)/(1000.R.Z.T.n) + 1\}^{n/n-1}$
50	pressure ratio	PR_{STG-I}		1.89	= pd/ps
51	Discharge temperature	Td_{STG-I}	^{O}K	385.41	
52		td_{STG-I}	^{O}C	112.41	
53	**Casing I I**				
54	Suction pressure	ps_{STG-II}	bar A	51.03	assume pipe pressure drop is neglected
55	Suction temperature	Ts_{STG-II}	^{O}K	385.41	assume pipe heat loss is neglected
56	Density	DSs	kg/m3	14	=100 x ps / (RxTs)
57	Suction flow	Q_S	m3/hr	17413	= G / DSs
58	Mau			0.352	
59	Max. no. of impeller in casing			6	Fig. 13. at Mau and model B
60	Select no. of impeller below max.			5	untill pd at line no. 66 is achieved
61	Hydrodynamic head	H_{STG-II}	m	12766.7	= H_{TOTAL} x (I_{STG-II} / I_{TOTAL})
62	Polytropic efficiency	EFp_{STG-II}		0.775	Fig. 11
63	Polytropic head	Hp_{STG-II}	m	16473.2	Equation (9)
64	Gas Horse Power Casing II	GHP_{STG-II}	kW	11092	= $G.Hp_{STG-II}$ x g x10^{-6} / 3.6
65	$(n-1)/n = (k-1)/k.EF_P$	(n-1) / n	-	0.3699	
66	Discharge pressure	pd	bar A	**70.75**	
67		td_{STG-I}	^{O}K	434.91	
68	Mechanical losses	Pmlb	kW	34.74	Chapter IX, at Q
69	(assumed use seal oil for flamable gas)	Pmls	kW	17.37	RL = 1.1 RS = 0.55
70	Mechanical losses at casing II	Pml	kW	52.12	
71	Brake horse power casing II	BHP_{II}	kW	11144.27	
72					
73	Total BHP	BHP_{TOTAL}	kW	29244.1	
74					

75 **Note :**



Estimated BHP, kW	29244
Estimated RPM	5620
Intercooler	No need

CENTRIFUGAL COMPRESSOR CALCULATION SHEET

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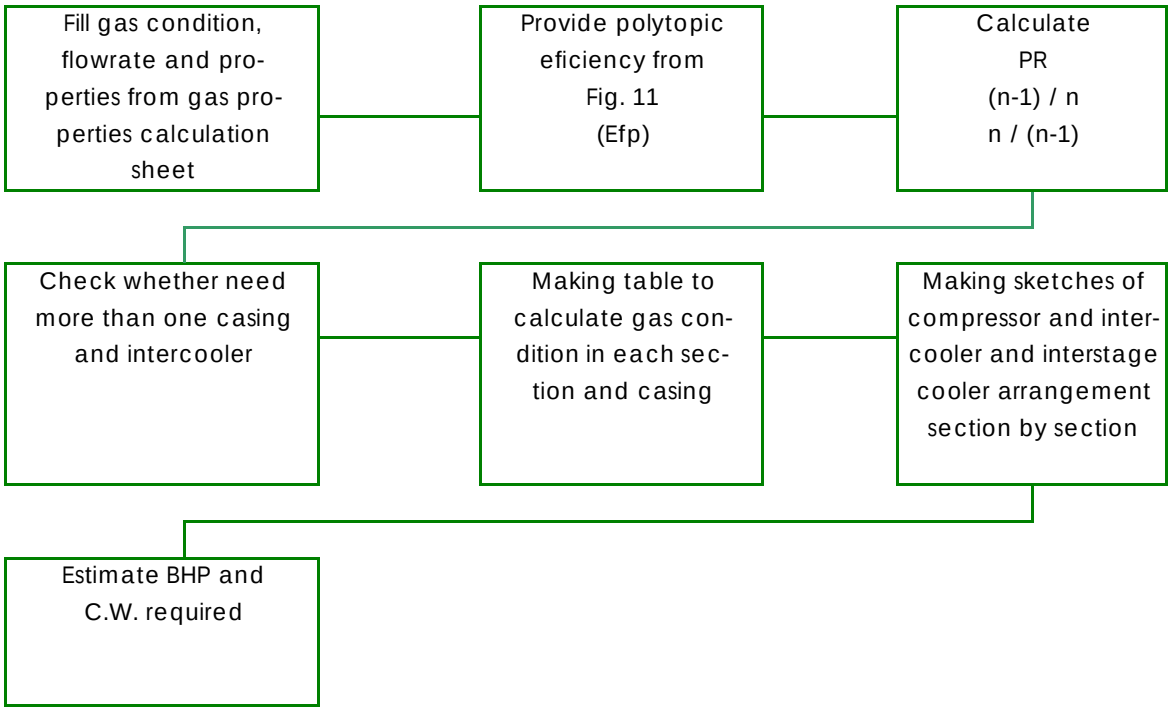


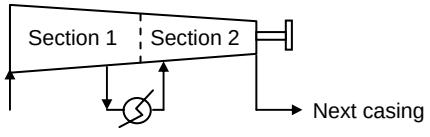
Gas properties, flowrate and conditions

(Sheet : ..... Of .....)

1	Gas name	Nitrogen (N2)				
	Item or symbol	Quantity	Unit	Item or symbol	Quantity	Unit
2	Suction pressure, ps	1	bar A	Discharge pressure, pd	40	bar A
3	Suction temperature, ts	40	^{O} C			
4	Ts	313	^{O} K	p_{CR}	33.90	bar A
5	MW	28.0	kg/kgmol	T_{CR}	126.70	^{O} K
6	k_S	1.400		$p_R = p / p_{CR}$	0.03	
7	R_S	0.297	kJ/kg.^{O}K	$T_R = T / T_{CR}$	2.47	
8	DSs	1.076	kg/m3	Z_S	1	
9	MCp	29.10	kJ/kgmol.^{O}K	Cp_S	1.04	kJ/kg
10	G	71730	kg/hr	G_{mol}	2560	kgmol/hr
11	Q_S	66618	m^3/hr	Q_N	57400	Nm^3/hr
12						

Compressor Calculation Sheet

	Item	Symbol	Unit	Quantity	Note
13					
14	**Check whether need intercooler**				
15	First Stage Volume flow	Qs	m3/hr	66618	
16	Efficiency			0.79	Figure 11
17	Total Pressure ratio (p_D / p_S)	PR	-	40.000	
18	$(n-1)/n = (k-1)/k.EF_P$	(n-1) / n	-	0.3617	
19	$n/(n-1) = k.EF_P/(k-1)$	n / (n-1)	-	2.765	
20	Max. temperature	t_{MAX}	^{O} C	180	SeeChapter VI. For mechanical seal
21		T_{MAX}	^{O} K	453	
22	PR_{STGMAX}	$(p_D / p_S)_{MAX}$	-	2.78	Equation (11)
23	Need intercooler ($PR > (p_D / p_S)_{MAX}$) ?			Yes	**need intercooler and use this sheet**
24					
25	**Check number of casing**				
26					
27	Total Hydrodynamic head	H_{TOTAL}	m	73278.0	Equation (7)
28	Total polytropic head	Hp_{TOTAL}	m	92757.0	Equation (9)
29	Preliminary average tip speed	U	m/s	310	Appendix B.1.
30	Polytropic head / impeller at Y =1.05	Hpi	m	5143.0	Equation (14)
31	Total no. of impeller	i_{TOTAL}		18	$I = Hp_{TOTAL} / Hpi$
32	Ratio speed by sound velocity	Mau		0.859	Equation at Fig. 13
33	Max. no. of impeller in 1 casing			7	Fig. 13. at Mau and model A
34	Is required no. of impeller need more			**Yes**	**Need more than 1 casing**
35	than one casing ?				
36					
37					
38					
39					



Casing I

Compressor Calculation Sheet (Cont.) (Sheet : ..... Of .....)

	Item	Casing I		Casing II		Casing III		
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	
1	Compressor discharge press. (barA)	40	40	40	40	40	40	
2	Suction pressure, **ps** (barA)	1.00	2.679	5	13.84	25	Finish	
3	Suction temperature, **ts** (C)	40.0	45.0	45	45.0	45	136.6	
4	**Ts** (K)	313.0	318.0	318.0	318.0	318.0	409.6	
5	**MW**	28.00		28		28		
6	**Rs** = 8.314/MW	0.30		0.30		0.30		
7	p_{CR}	33.9		33.9		33.9		
8	T_{CR}	126.7		126.7		126.7		
9	$p_R = p_{RED} = p / p_{CR}$	0.03	0.079	0.15	0.408	0.75	#VALUE!	
10	$T_R = T_{RED} = T / T_{CR}$	2.47	2.510	2.51	2.510	2.51	3.233	
11	Z_S	1	1	1	1	1	1.003	
12	**MCp**$_S$ (kJ/kgmol.K)	29.10	29.1	29.1	29.1	29.1	29.1	
13	**k** = MCp/(MCp-8.314)	1.40	1.400	1.400	1.400	1.400	1.400	
14	**Cp**$_S$ = R.k /(k-1), (kJ/kg.K)	1.04	1.040	1.040	1.040	1.040	1.040	
15	**G** (kg/hr)	71730.0	71730	71730	71730	71730	71730	
16	**DSs** = 100.ps / (R.Ts), (kg/m3)	1.1	2.8	5	14.7	27	#VALUE!	
17	Q_S = G / DSs, (m3/hr)	66618.0	25285.2	13222	4893.8	2673	#VALUE!	
18	Q_N (Nm3/h)	57413		57413		57413		
19	Polytropic Efficiency, **EFp**. (Fig 11)	0.79	0.79	0.773	0.75	0.773	0.75	
20	**(n-1)/n** = (k-1)/k.EF$_P$	0.362	0.362	0.370	0.381	0.370	0.381	
21	**n/(n-1)** = k.EF$_P$/(k-1)	2.765	2.765	2.706	2.625	2.706	2.625	
22	Average tip speed, **U** (m/s)	310		310		260		
	Head coef. (**Y**=1.05 to 1.4)	1.05	1.05	1.05	1.05	1.05	1.10	
23	Polytr. head / impeller , **Hpi** (m)	5143	5143	5143	5143	3618	3790	
24	Ratio speed by sound velocity, **Mau**	0.86	0.853	0.853	0.853	0.715	0.629	
25	Max. no. of impeller at casing, i_{MAX}	7		7		7		
26	Equiv. space for nozzle	2		2		0		
27	Number impeller /casing	5		5		7		
28	Max discharge temp., t_{MAX} (C)	180	180	180	180	180	180	
29	(K)	453.0		453.0		453.0		
30	Max. pressure ratio, PR_{MAX}	2.78		2.60		2.60		
31	Need intercooler ?	Yes		Yes		No		
32	If "Yes", outlet gas temp. (C)	45		45		45		
33	Max. polytr. Head, **Hpmax** (m)	14834.9		14305.5		14305.5		
34	Number of impeller (calculated)	2.88		2.78		3.95		
35	----------,,----- ---------(Take)	3	2	3	2	3	4	
36	Polytropic head, **Hp** (m)	15429	10286	15429	10286	10853	15160	
37	Discharge pressure, **pd** (barA)	**2.78**	**5.224**	**13.943**	**25.44**	**50.270**	#VALUE!	
38	Pres. drop at inter/stg cooler (bar)	0.10	0.10	0.10	0.100	0.10	0.100	
39	Dsicharge temperature, **td** (C)	180	131.8	187.4	128.0	136.6	#VALUE!	
40	Intercooler outlet temp. (C)	45		45		-		
41	Compression continue ?	**Continue**	**Continue**	**Continue**	**Continue**	**Finish**	**#VALUE!**	
42	Need interstage cooler ?		Yes		Yes		#VALUE!	
43	Interstage cooler outlet temp.(C)		45		45		45	
44	**GHP**	3015.80	2010.53	3015.80	2010.53	2121.41	0.00	
45	Average diameter, fig. 13, **D** (mm)	850		425		355		
46	Speed, **N** (RPM)	6969		13938		13995		

Note : if any cell contain "#VALUE!" in a column, this column shall be neglected because compression is finished in left last column. if volume flow (Qs) less than 1500 m3/hr, reciprocating compressor may be better

Compressor Calculation Sheet (Cont.) (Sheet : ..... Of .....)

	Item	Casing I		Casing II		Casing III		
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	
1								
2	Mechanicall losses factor : RL	2.90		0.45		0.13		
3	RS	1.55		0.24		0.07		
4	RD	0.00		0		0		
5	Losses at bearing (kW)	140.840		87.418		25.461		
6	Losses at oil seal (kW)	75.277		46.623		13.710		
7	Losses at mechanical seal (kW)	0.000		0.000		0.000		
8	BHP (kW)	5242		5027		2122		
9	**Total BHP (kW)**	**12391**						
10	C.W. inlet temp. to intercooler (C)	30		30		30		
11	C.W. outlet temp. (C)	38		38		38		
12	Cooling water for inter cooler (ton/hr)	300		316		0		
13	C.W. inlet to interstage cooler (C)		30		30			
14	C.W. outlet temp. (C)		38		38			
15	C.W. for inter stage cooler (ton/hr)		193		184			
16	**Total C.W.** required (ton/hr)	**992**						
17								
18								
19								
20								
21								
22								
23								

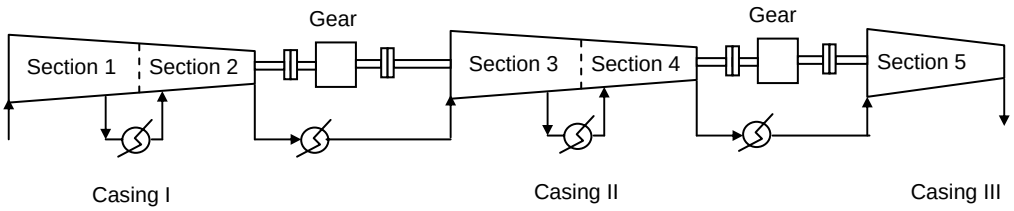
Note :

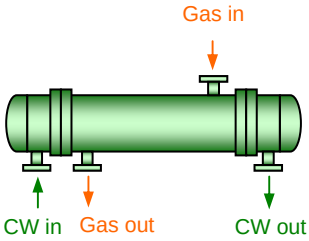
1. Input cell : Red letter in red cell is input without adjustment. White letter in red cell is input with adjustment

2. This calculation result indicates that "Integrally gear centrifugal compressor" is also may be accepted.

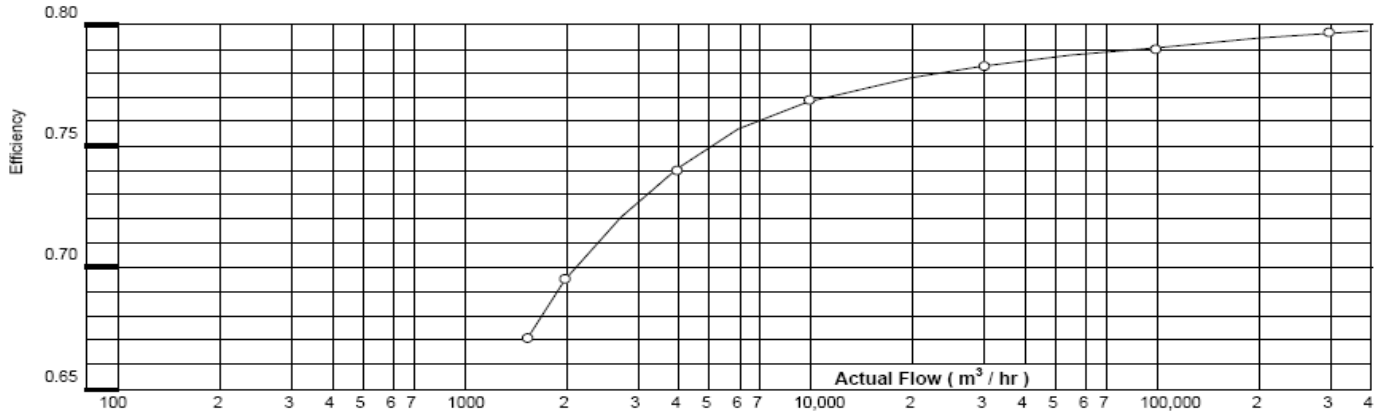
3. In this sheet, aftercooler is not included. If necessary, CW required for aftercooler can be calculated as following equation $G_{GAS} \cdot Cp_{GAS} \cdot (t_{IN} - t_{OUT})_{GAS} = G_{WATER} \cdot Cp_{WATER} \cdot (t_{OUT} - t_{IN})_{WATER}$ where temperature different of C.W. is about 10 degree centigrade and Cp near 4.17 kJ/kg.K

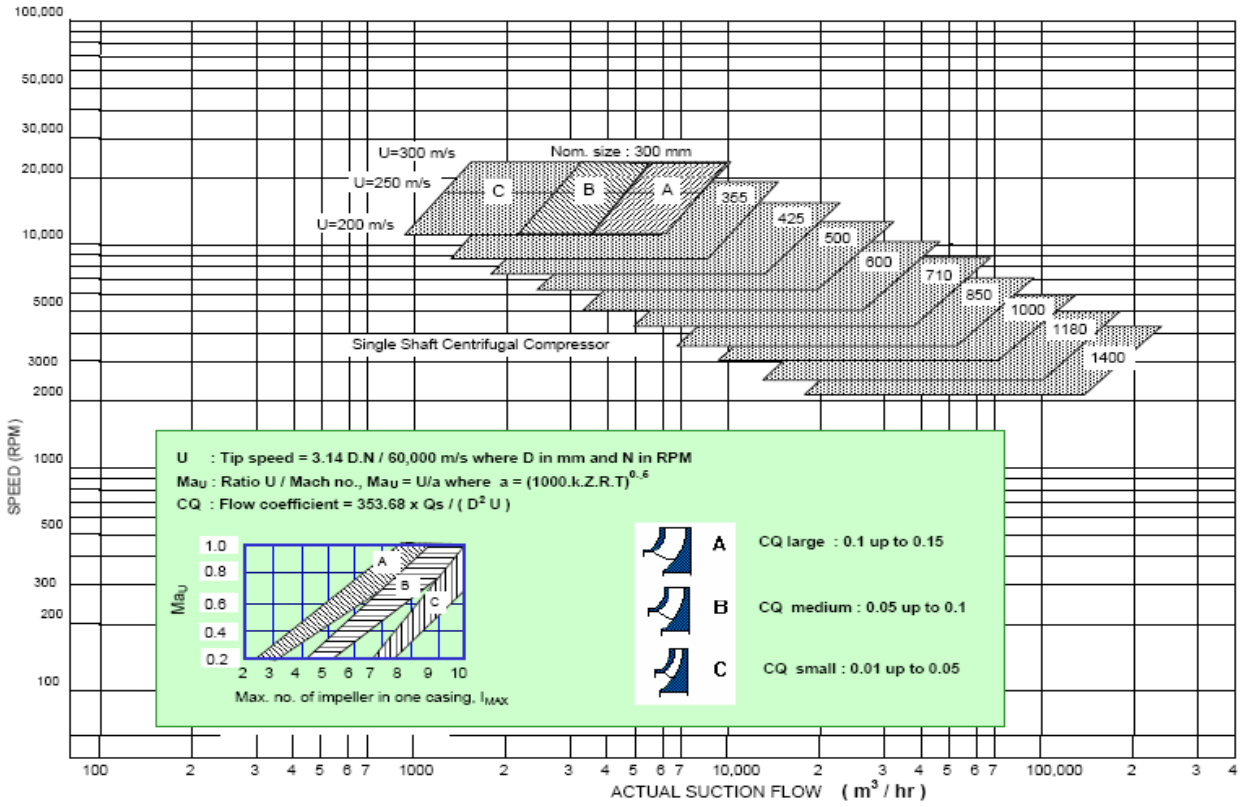
Sketches





Intercooler and interstagecooler :
$T_{GAS\ OUT} - T_{CW\ OUT}$ shall be higher than 5 C


0.80
0.75
0.70
0.65
Efficiency
100
2
3
4
5
6
7
1000
2
3
4
5
6
7
10,000
2
3
4
5
6
7
100,000
2
3
4
Actual Flow (m3 / hr)


100,000
50,000
30,000
20,000
10,000
5000
3000
2000
1000
500
300
200
100
SPEED (RPM)
U=300 m/s
U=250 m/s
U=200 m/s
Nom. size : 300 mm
C
B
A
355
425
500
600
710
850
1000
1180
1400
Single Shaft Centrifugal Compressor
U : Tip speed = 3.14 D.N / 60,000 m/s where D in mm and N in RPM
Mau : Ratio U / Mach no., Mau = U/a where a = (1000.k.Z.R.T)0.5
CQ : Flow coefficient = 353.68 x Qs / (D2 U)
1.0
0.8
0.6
0.4
0.2
Mau
2 3 4 5 6 7 8 9 10
Max. no. of impeller in one casing, IMAX
A
CQ large : 0.1 up to 0.15
B
CQ medium : 0.05 up to 0.1
C
CQ small : 0.01 up to 0.05
100
2
3
4
5
6
7
1000
2
3
4
5
6
7
10,000
2
3
4
5
6
7
100,000
2
3
4
ACTUAL SUCTION FLOW (m3 / hr)