CENTRIFUGAL COMPRESSOR CALCULATION SHEET

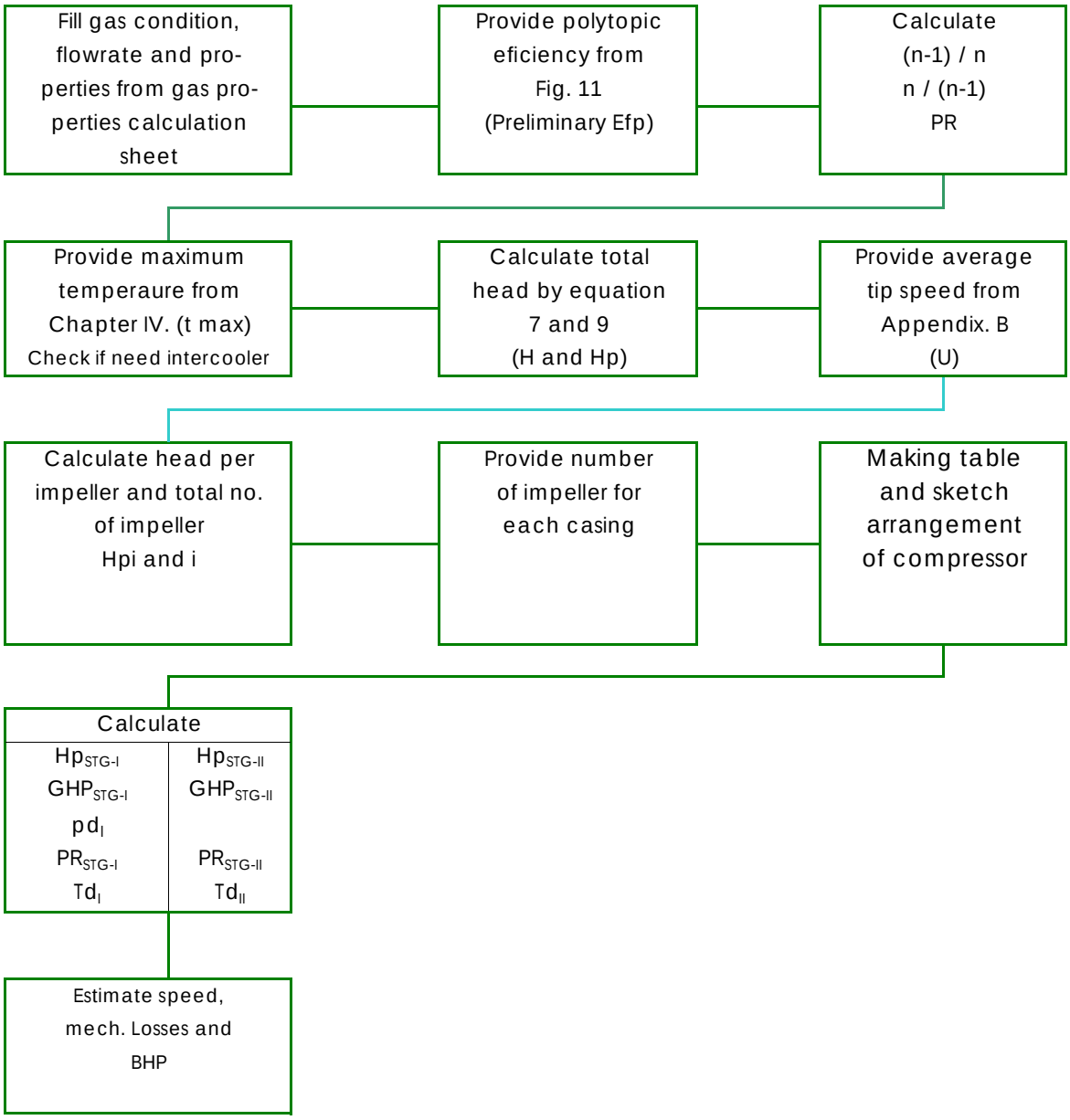
B. WITH CONSIDERING DETAIL OF IMPELLER

INPUT GIVEN CONDITION OR QUANTITY IN RED COLOR CELLS

WITHOUT INTERCOOLER

IN LINE CENTRIFUGAL COMPRESSOR

FLOW CHART



Gas properties, flowrate and conditions

(Sheet : 1 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

Compressor Calculation Sheet

	Item	Symbol	Unit	Quantity	Note
12					
13	**Check whether need intercooler**				
14	First Stage Volume flow	Qs	m3/hr	26046	
15	Preliminary efficiency	Efp		0.78	Fig. 11.
16	Total Pressure ratio (p_D / p_S)	PR	-	2.593	
17	$(n-1)/n = (k-1)/k.EF_P$	(n-1) / n	-	0.3676	
18	$n/(n-1) = k.EF_P/(k-1)$	n / (n-1)	-	2.721	
19	Max. temperature	t_{MAX}	^{O}C	180	SeeChapter VI.
20		T_{MAX}	^{O}K	453	
21	PR_{STGMAX}	$(p_D / p_S)_{MAX}$	-	2.93	Equation (11)
22	Need intercooler ? , $PR < (p_D / p_S)_{MAX}$			**No**	**no need intercooler and use this sheet**
23					
24	**Number of impeller and casing**				
25					
26	Total Hydrodynamic head	H_{TOTAL}	m	33193.4	Equation (7)
27	Total polytropic head	Hp_{TOTAL}	m	42555.6	Equation (9)
28	Average tip speed	Uavg	m/s	250	Appendix B.1.at MW of gas
29	Max tip speed = 0.9 a	Umax	m/s	569	where $a=(1000.k.Z.R.T)^{0.5}$
30	Preliminary tip speed selected	U	m/s	250	
31	Estimated head coef, one impeller	Y		1.05	See appendix B.
32	Polytropic head / impeller	Hpi	m	3344.8	Equation (14)
33	Total no. of impeller	i_{TOTAL}		13	$I = Hp_{TOTAL} / Hpi$ in integer number
34	Ratio speed by sound velocity	Mau		0.395	Equation at Fig. 13
35	Max. no. of impeller/casing			8	Fig. 13. at Mau and model = C
36	Need more than one casing ?			**Yes**	**, need more than one casing**
37	Preliminary no. of impeller in casing I	I_{STG-I}		8	
38	Preliminary no. of impeller in casing II	I_{STG-II}		5	$= I_{TOTAL} - I_{STG-I}$
39					
40					
41					
42					
43					
44					

Compressor Calculation Sheet (Cont.) (Sheet : 2 Of .....)

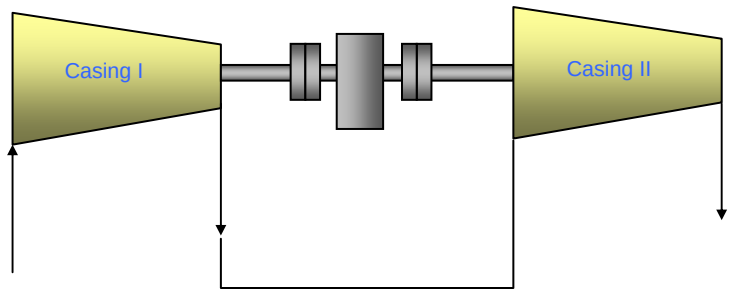
	Item	Casing I	Casing II	Casing III	
1	Preliminary no. of impeller	8	5	0	
2	Compressor discharge press. (barA)	70	70	70	
3	Max. temperature (C)	180	180	180	
4	Suction pressure, **ps** (barA)	27.00	46.02	71	
5	Suction temperature, **ts** (C)	32.0	107	-	
6	**Ts** (K)	305.0	380.0	#VALUE!	
7	**MW**	8.91	9	9	
8	**Rs** = 8.314/MW	0.93	0.93	0.93	
9	p_{CR}	19.0	19.0	19.0	
10	T_{CR}	60.0	60.0	60.0	
11	$p_R = p_{RED} = p / p_{CR}$	1.42	2.42	3.72	
12	$T_R = T_{RED} = T / T_{CR}$	5.08	6.33	#VALUE!	
13	Z_S	1.003	1.004	1.005	
14	MCp_S (kJ/kgmol.K)	29.00	29.1	29.1	
15	**k** = MCp/(MCp-8.314)	1.40	1.400	1.400	
16	Cp_S = R.k /(k-1), (kJ/kg.K)	3.25	3.266	3.266	
17	**G** (kg/hr)	247100.0	247100	247100	
18	**DSs** = 100.ps / (R.Ts), (kg/m3)	9.49	13	17	
19	Q_S = G / DSs, (m3/hr)	26046.0	19043	14637	
20	Q_N (Nm3/h)	621381	621381	621381	
21	**U** (m/s)	250	240	250	
22	Select impeller type from fig. 13	C	C	C	
23	Assume flow coefficient	0.05	0.05	0.05	
24	Calculated diameter (mm)	858	749	644	
25	Selected dia. With fig. 13, **D** (mm)	850	710	500	
26	Flow coefficient, **CQ**	0.051	0.056	0.083	
27	Correction factor with fig. 14, Cc	0.965	0.97	0.965	
28	Efficiency at CQ=0.09 at fig. 14 for 2-	0.72	0.76	0.767	
29	dim. Shrouded imp. at no. of impeller				
30	Head coef. Fig. 14 at no. of impeller	0.98	0.980	1.030	
31	Polytropic Efficiency, **EFp**. (Fig 11)	0.69	0.74	0.74	
32	**(n-1)/n** = (k-1)/k.EF_P	0.413	0.388	0.386	
33	**n/(n-1)** = k.EF_P/(k-1)	2.424	2.580	2.591	
34	Max. pressure ratio, **PRmax**	2.608	4.103	#VALUE!	
35	Ratio speed by sound velocity, **Mau**	0.40	0.34	#VALUE!	
36	Max. no. of impeller at casing, i_{MAX}	8	8	5	
37	Need intercooler ?	**No**	**No**	**#VALUE!**	
38	Equiv. space for nozzle	0	0	0	
39	**Trial no. of impeller** taken, **i**	8	8	5	
40	Comment on trial	Trial accepted	Trial accepted	Trial accepted	
41	Polytropic head, **Hp** (m)	3122	2877	3281	
42	Discharge pressure, **pd** (barA)	**46.02**	**70.71**	**#VALUE!**	
43	Compression continued ?	**Continue**	**Stop**	**#VALUE!**	
44	Discharge temperature, td (K)	380.05	448.91	#VALUE!	
45	(C)	**107.05**	**175.91**	**#VALUE!**	
46	Discharge density, **DSd** (kg/m3)	12.98	16.88	#VALUE!	
47	Discharge flow, **Qd** (m3/hr)	19043.11	14637.10	#VALUE!	
48	GHP per stage	16816.53	15498.11	0.00	
49	Speed, **N** (RPM)	5620	6459	9554	
50	Total **GHP** (kW)	32315			

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

Compressor Calculation Sheet (Cont.) (Sheet : 3 Of .....)

	Item		Casing I	Casing II	Casing III	
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)		91.597	18.774	0.000	
6	Losses at oil seal (kW)		48.957	10.013	0.000	
7	Losses at mechanical seal (kW)		0.000	0.000	0.000	
8	**Total BHP (kW)**		32484			

Sketch



CENTRIFUGAL COMPRESSOR CALCULATION SHEET

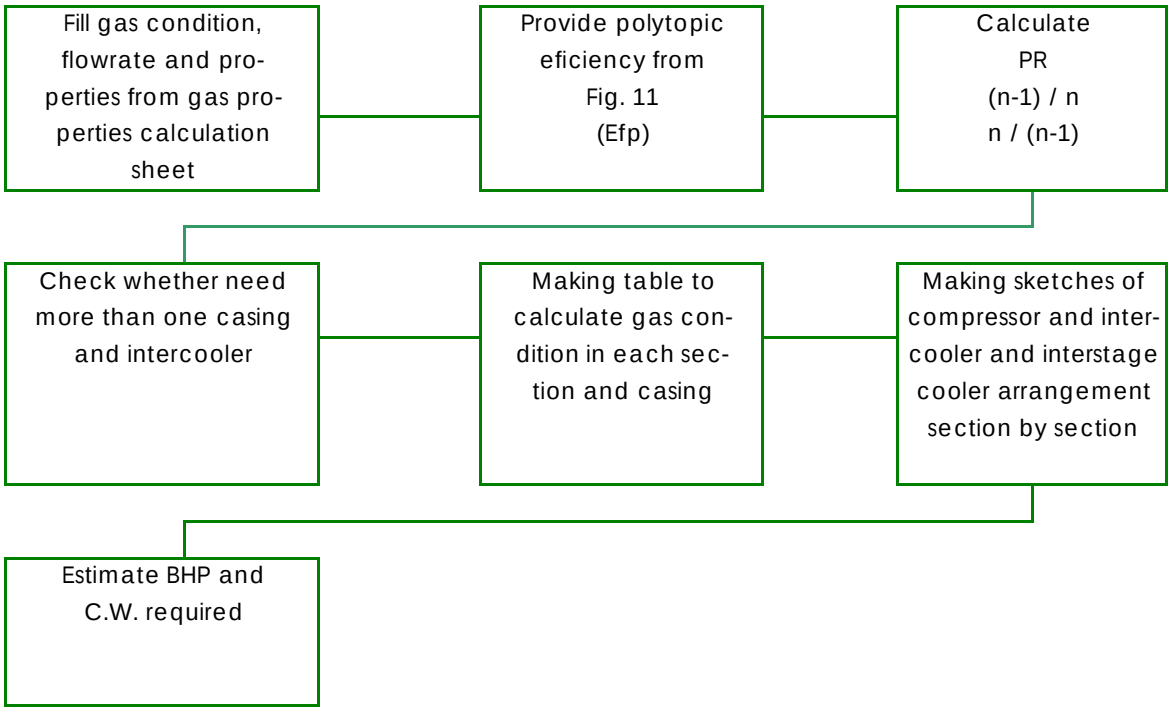
B. WITH CONSIDERING DETAIL OF IMPELLER

INPUT GIVEN CONDITION OR QUANTITY IN RED COLOR CELLS

WITH INTERCOOLER

IN LINE CENTRIFUGAL COMPRESSOR

FLOW CHART



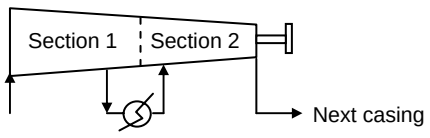
Gas properties, flowrate and conditions

(Sheet : 1 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	1.001	
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	73351.3	Equation (7)
28	Total polytropic head	Hp_{TOTAL}	m	92849.7	Equation (9)
29	Average tip speed	Uavg	m/s	310	Appendix B.1. at MW
	Max. tip speed	0.9 a	m/s	325	where a=$(1000.k.Z.R.T)^{0.5}$
	Preliminary tip speed selected	U	m/s	310	
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 : 2 Of .....)

	Item	Casing I		Casing II		Casing III		
		Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	
1	Compressor discharge pressure (barA)	40	40	40	40	40	40	
2	Max. temperature (C)	180	180	180	180	180	180	
3	Suction pressure, **ps** (barA)	1.00	1.876	3.454	9.29	24.526	Finish	
4	Suction temperature, **ts** (C)	40.0	45.0	40	45.0	40	153.8	
5	**Ts** (K)	313.0	318.0	313.0	318.0	313.0	426.8	
6	**MW**	28.00		28		28		
7	**Rs** = 8.314/MW	0.30		0.30		0.30		
8	p_{CR}	33.9		33.9		33.9		
9	T_{CR}	126.7		126.7		126.7		
10	$p_R = p_{RED}$ = p / p_{CR}	0.03	0.055	0.10	0.274	0.72	#VALUE!	
11	$T_R = T_{RED}$ = T / T_{CR}	2.47	2.510	2.47	2.510	2.47	3.369	
12	Z_S	1.001	1.001	1.002	1.002	1.003	1.003	
13	**MCp**$_S$ (kJ/kgmol.K)	29.10	29.1	29.1	29.1	29.1	29.1	
14	**k** = MCp/(MCp-8.314)	1.40	1.400	1.400	1.400	1.400	1.400	
15	**Cp**$_S$ = R.k /(k-1), (kJ/kg.K)	1.04	1.040	1.040	1.040	1.040	1.040	
16	**G** (kg/hr)	71730.0	71730	71730	71730	71730	71730	
17	**DSs** = 100.ps / (R.Ts), (kg/m3)	1.1	2.0	4	9.8	26	#VALUE!	
18	Q_S = G / DSs, (m3/hr)	66618.0	36118.7	19304	7293.9	2719	#VALUE!	
19	Q_N (Nm3/h)	57413		57413		57413		
20	Umax. = 0.9 a (m/s)	325	327	325	328	325	380	
21	**U** (m/s)	310	259	310	310	240	240	
22	Select impeller type from fig. 13	A	A	A	B	C	C	
23	Assume flow coefficient	0.10	0.10	0.1	0.075	0.03	0.03	
24	Calculated diameter (mm)	872	702	469	333	365	#VALUE!	
25	Selected dia. With fig. 13, **D** (mm)	850	710	425	425	300	300	
26	Flow coefficient, **CQ**	0.105	0.098	0.122	0.046	0.045	#VALUE!	
27	Correction factor with fig. 14, Cc	0.99	0.99	0.995	1	0.92	1	
28	Efficiency at CQ=0.09 at fig. 14 for	0.76	0.765	0.765	0.77	0.765	0.77	
29	selected type & no. of impeller							
30	Head coef. Fig. 14 at no. of impeller	1	1.03	1.03	1.03	1.03	1.03	
31	Polytropic Efficiency, **EFp**. (Fig 11)	0.75	0.76	0.76	0.77	0.70	0.77	
32	**(n-1)/n** = (k-1)/k.EF_P	0.380	0.377	0.375	0.371	0.406	0.371	
33	**n/(n-1)** = k.EF_P/(k-1)	2.633	2.651	2.664	2.695	2.463	2.695	
34	Tmax (K)	453.0	453.0	453.0	453.0	453.0	453.0	
35	Max. pressure ratio, PR_{MAX}	2.65	2.55	2.68	2.60	2.49	2.92	
36	Need intercooler ?	Yes		Yes		No		
37	If "Yes", outlet gas temp. (C)	45.0		45.0		45.0		
38	Pres. drop at inter/stg cooler (bar)	0.10		0.10		0.10		
39	Polytr. head / impeller , **Hpi** (m)	4898	3520	5045	5045	3024	3024	
40	Ratio speed by sound velocity, **Mau**	0.859	0.717	0.858	0.858	0.664	0.664	
41	Max. no. of impeller at casing, i_{MAX}	7		8		9		
42	Equiv. space for nozzle	2		2		0		
43	Number impeller /casing	5		6		9		
44	Max. head, **Hpmax** (m)	11172.9	10845.1	11314.9	11037.3	10472.5	17047.8	
45	Number of impeller (calculated)	2.28	3.08	2.24	2.19	3.46	5.64	
46	Trial (integer) but **td shall less tmax**	2	3	3	3	4	3	
47	Polytropic head, **Hp** (m)	9796	10560	15135	15135	12095	9072	
48	Discharge pressure, **pd** (barA)	**1.976**	**3.554**	**9.388**	**24.626**	**52.651**	**#VALUE!**	
49	Dsicharge temperature, **td** (C)	**132.4**	**131.7**	**182.5**	**183.6**	**153.8**	**#VALUE!**	
50	Compression continue ?	**Continue**	**Continue**	**Continue**	**Continue**	**Finish**	**#VALUE!**	
51	Need interstage cooler ?		**Yes**		**Yes**		**#VALUE!**	

Compressor Calculation Sheet (Cont.) (Sheet : 3 Of .....)

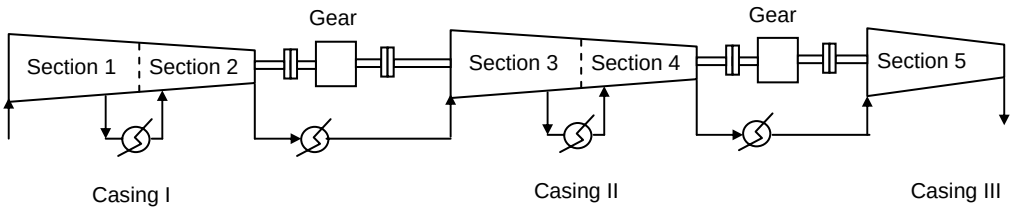
	Item		Casing I		Casing II		Casing III		
			Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	
1	Interstage cooler outlet temp.(C)			40		40		40	
2	Interstage cooler press. Drop (bar)			0.1		0			
3	**GHP**		1914.79	2064.09	2958.35	2958.35	2364.22	0.00	
4	Speed, **N** (RPM)		6969		13938		15287		
5	Mechanicall losses factor :	RL	2.90		0.45		0.13		
6		RS	1.55		0.24		0.07		
7		RD	0.00		0		0		
8	Losses at bearing (kW)		140.840		87.418		30.379		
9	Losses at oil seal (kW)		75.277		46.623		16.358		
10	Losses at mechanical seal (kW)		0.000		0.000		0.000		
11	BHP (kW)		4195		5917		2364		
12	**Total BHP (kW)**		12477						
13	C.W. inlet temp. to intercooler (C)		30		30		30		
14	C.W. outlet temp. (C)		38		38		38		
15	Cooling water for inter cooler (ton/hr)		194		305		0		
16	C.W. inlet to interstage cooler (C)			30		30			
17	C.W. outlet temp. (C)			40		40			
18	C.W. for inter stage cooler (ton/hr)			163		255			
19	**Total C.W.** required (ton/hr)		917						
20									
21									
22									
23									
24									
25									

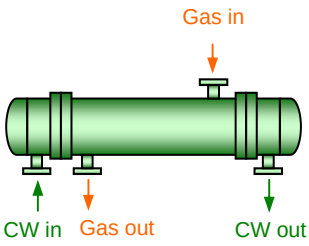
Note : **1. Input cell : Red letter in red cell is input without adjustment. White letter in red cell is input with adjustment**

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

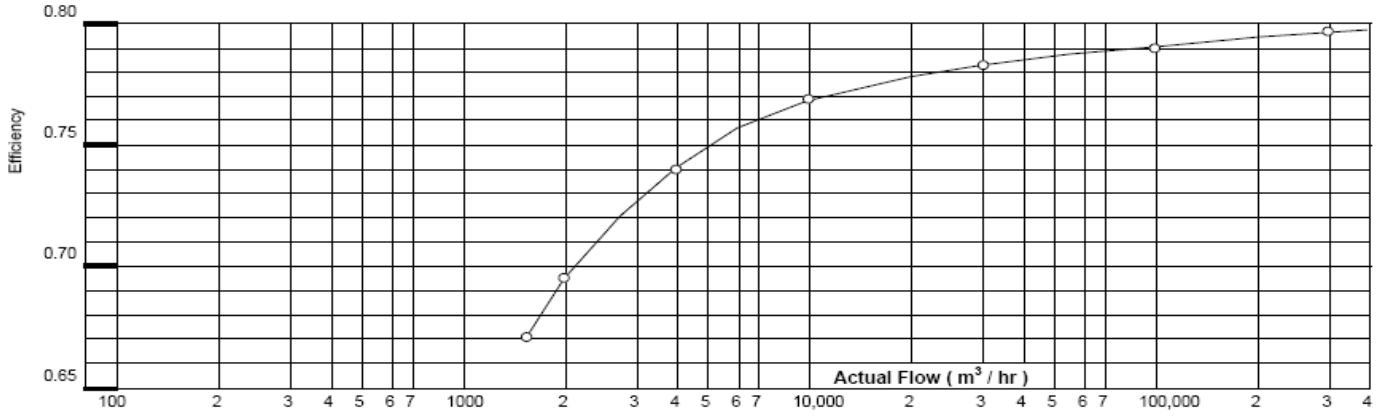
3. In this sheet, aftercooler is not included. If necessary, CW required for aftercooler can be calculated as following equation $G_{GAS} \cdot Cp_{GAS} \cdot (t_{IN} - t_{OUT})_{GAS} = G_{WATER} \cdot Cp_{WATER} \cdot (t_{OUT} - t_{IN})_{WATER}$ where temperature different of C.W. is about 10 degree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

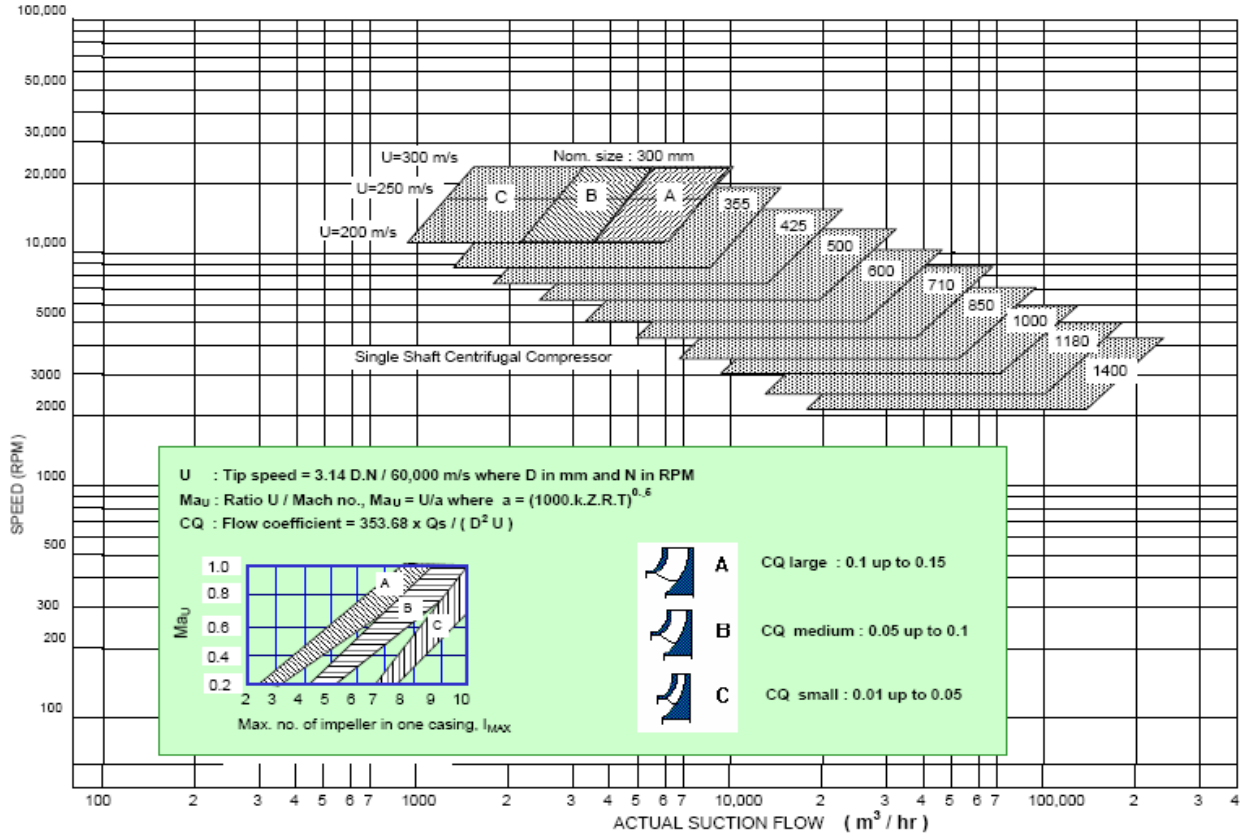
Sketches

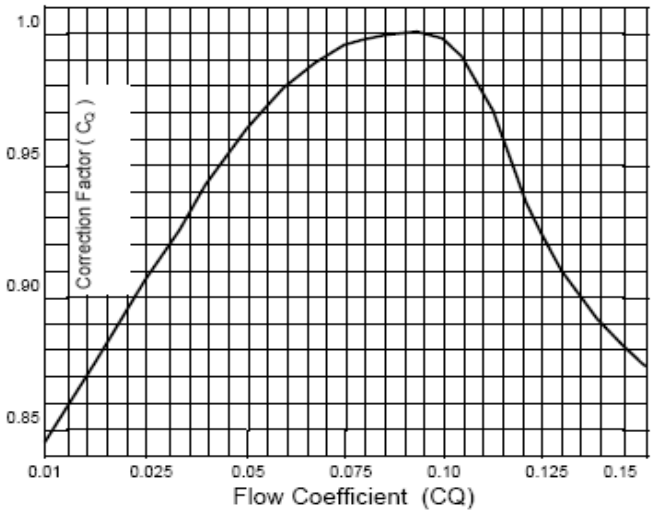


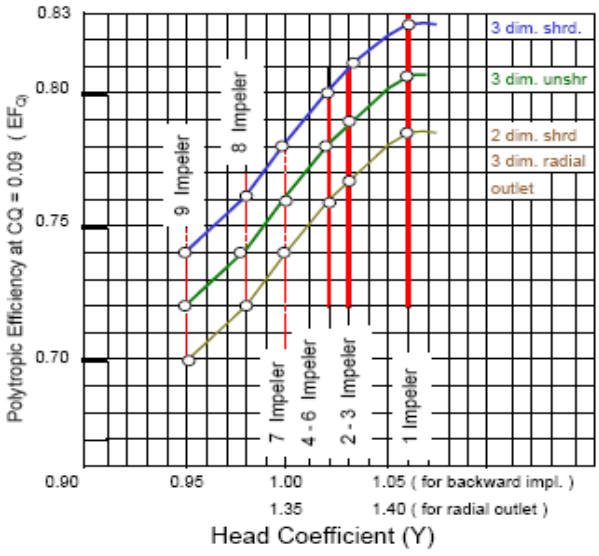


Intercooler and interstagecooler :
$T_{GAS\ OUT} - T_{CW\ OUT}$ shall be higher than 5 C


Efficiency
0.80
0.75
0.70
0.65
Actual Flow (m³ / hr)
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


SPEED (RPM)
100,000
50,000
30,000
20,000
10,000
5000
3000
2000
1000
500
300
200
100
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)
Mau
1.0
0.8
0.6
0.4
0.2
A
B
C
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)


1.0
0.95
0.90
0.85
Correction Factor (CQ)
0.01
0.025
0.05
0.075
0.10
0.125
0.15
Flow Coefficient (CQ)


0.83
0.80
0.75
0.70
0.90
Polytropic Efficiency at CQ = 0.09 (EFCQ)
9 Impeler
8 Impeler
7 Impeler
4 - 6 Impeler
2 - 3 Impeler
1 Impeler
3 dim. shrd.
3 dim. unshr
2 dim. shrd
3 dim. radial outlet
0.95
1.00
1.05 (for backward impl.)
1.35
1.40 (for radial outlet)
Head Coefficient (Y)