PUMP CALCULATION SHEET

SHEET 1.A. (With considering suction and discharge equipments) ( )

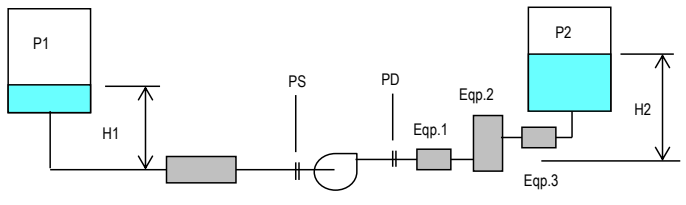
CLIENT :
PROJECT
TITLE :
JOB NO. :
DOC. NO. : ( )

REV.	1	2	3	MADE	
BY				CHKD	
CHKD				APVD	
APVD					
DATE				DATE	

ITEM NO. :
SERVICES :

FLUID			Code	Formula
PUMPED LIQUID		CONDENSATE		
OPERATING TEMPERATURE	°C	90		Data
VISCOSITY AT OPERERATING TEMP.	cP	0.23	VIS	Data
VAPOR PRESSURE	kg/cm²A	0.15	PV	Data
SP. GR. AT OPERATING TEMP.		0.99	SG	Data
GRAVITY	m/s²	9.81	g	Data
CAPACITY	m³/hr	5	Q	Data
EXCESS CAPACITY	%	0	X	Data
MAX. CAPACITY	m³/hr	5	Qe	Qe = 0.01(100+X)(Q)
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm²A	1.3	P1	Data
MIN. STATIC HEAD (+ or -)	m	-6	H1	Data
PIPE FRICTION	kg/cm²	0.12	DPp1	Data
EQUIPMENT(.....)	kg/cm²	0.15	DPe1	Data
SUCTION PUMP DIA.	m	P	ID	See Appendix, or **Fill with P if by program**
	m	0.041		Nom. Dia. by progr (inc) **1.5** ID (m)= **0.041**
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	1.05	V	V=Q/(0.25x3.14xID²x3600)
VELOCITY HEAD AT SUCTION	kg/cm²	0.0056	HV	HV=0.05(SG)(V²)/g
NET SUCTION PRESSURE	kg/cm²A	0.4304	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
NPSH AVAILABLE	m	2.83	NPSHA	NPSHA=10(PS-PV)/SG
NPSH MARGIN TO NPSHR	m	1		Or may from % NPSHA, example 20 % (m) = 0.57
NPSH AVAILABLE (TAKEN)	m	1.83		
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm²A	2	P2	Data
STATIC HEAD	m	1	H2	Data
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm²	0.2		Data
Equipment 1 (.....	kg/cm²	0.11		Data
Equipment 2(.....)	kg/cm²	0.1		Data
Equipment 3 (.....	kg/cm²	0.05		Data
Equipment 4 (.....	kg/cm²	0		Data
DISCHARGE PRESSURE DROP	kg/cm²	0.46	DPp2	DPp2 = total discharge pressure drop
TOTAL DISCHARGE PRESSURE	kg/cm²A	2.559	PD	PD = P2+0.1(H2)(SG)+DpP2
SUCTION PRESSURE	kg/cm²A	0.4304	PS	
DIFF. PRESSURE	kg/cm²	2.1286	DP	DP=PD-PS
TOTAL HEAD (NET)	m	21.50	H	H=10(DP)/SG
TOTAL HEAD (TAKE)	m	22.00	H	
LIQUID HORSE POWER	kW	0.30	LHP	
ESTIMATED EFFICIENCY	%	26.62	E	See Efficiency curve
ESTIMATED POWER	kW	**1.11**	BHP	BHP=(100/E)(0.00272)(Q)(H)
ESTIMATED NPSHR-SINGLE SUCTION	m	**1.830**	NPSHR	SS 1.830 1.439 1.223 1.070 0.953
ESTIMATED SPEED-SINGLE SUCTION	RPM	2980		RPM 2980 1480 980 730 580
ESTIMATED NPSHR-DOUBLE SUCTION	m	**1.800**	NPSHR	NPSHR(m) 1.830 1.439 1.223 1.070 0.953
ESTIMATED SPEED-DOUBLE SUCTION	RPM	2980		DS 1.800 1.430 1.218 1.068 0.952
				RPM 2980 1480 980 730 580
				NPSHR(m) 1.800 1.430 1.218 1.068 0.952

REMARKS :



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

ID based on STD thickness

PUMP CALCULATION SHEET

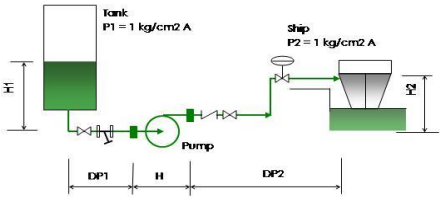
SHEET 2.A **(When NPSHA is low and select vertical type)** ( )

CLIENT :
PROJECT
TITLE :
JOB NO. :
DOC. NO. : ( )

REV.	1	2	3	MADE	
BY				CHKD	
CHKD				APVD	
APVD					
DATE				DATE	

ITEM NO. :
SERVICES :

FLUID				
PUMPED LIQUID		Ammonia		
OPERATING TEMPERATURE	°C	-33		
VISCOSITY AT OPERERATING TEMP.	cP	0.26		
VAPOR PRESSURE	kg/cm²A	1		
SP. GR. AT OPERATING TEMP.		0.7		
GRAVITY	m/s²	9.81		
CAPACITY	m³/hr	200		
EXCESS CAPACITY	%	10		
MAX. CAPACITY	m³/hr	220		
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm²A	1.025	1.025	
MIN. STATIC HEAD (+ or -)	m	2	7	New H1, based on impeller eye
PIPE FRICTION	kg/cm²	0.14	0.14	
EQUIPMENT(.....)	kg/cm²	0	0	
SUCTION PUMP DIA.	m	p	0.154	Or fill with P if by program
	m	0.202	0.154	
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	1.91	3.28	
VELOCITY HEAD AT SUCTION	kg/cm²	0.0130	0.0384	
NET SUCTION PRESSURE	kg/cm²A	1.0120	1.3366	
NPSH AVAILABLE	m	0.17	4.81	
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm²A	1	1	
STATIC HEAD	m	15	20	
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm²	0.4	0.4	
Equipment 1 (.....CV.....	kg/cm²	0.11	0.11	
Equipment 2(.....	kg/cm²	0	0	
Equipment 3 (.....	kg/cm²	0	0	
Equipment 4 (.....	kg/cm²	0	0	
DISCHARGE PRESSURE DROP	kg/cm²	0.51	0.51	
TOTAL DISCHARGE PRESSURE	kg/cm²A	2.56	2.91	
SUCTION PRESSURE	kg/cm²A	1.0120	1.3366	
DIFF. PRESSURE	kg/cm²	1.5480	1.5734	
TOTAL HEAD (NET)	m	22.11	22.48	
TOTAL HEAD (TAKE)	m	23	23	
LIQUID HORSE POWER	kW	9.63	9.63	
ESTIMATED EFFICIENCY	%	64.44	64.44	See Efficiency curve
ESTIMATED POWER (BHP)	kW	**14.95**	**14.95**	
ESTIMATED NPSHR	m	**0.000**	**4.365**	See NPSHR curve
NPSHA-NPSHR	m	**0.17**	**0.44**	
ESTIMATED SPEED	RPM		**2980**	
Pump need well to give more H1			Vertical centrifugal	
			Single suction	



D (inc) | 8 | 8
ID (m) | 0.202 | 0.202

Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

ID based on STD thickness

REMARKS :

Number of suction ---->	1	220	220	220	220	220
1 for single suction		4.365	2.268	1.607	1.256	1.027
2 for double suction	RPM	2980	1480	980	730	580
	NPSHR(m)	4.365	2.268	1.607	1.256	1.027

When NPSHR is not available from above table
replace number in red cell with 2 for double suction

PUMP CALCULATION SHEET

SHEET 5.A (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Example: Small capacity, low head)

1	ITEM NO. :				
2	SERVICES :				
3	**FLUID**			**Code**	**Formula**
4	PUMPED LIQUID		Water		
5	LIQUID CHARACTERISTIC		D		A. Plastic imp., B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
6	OPERATING TEMPERATURE	°C	33		Data
7	VISCOSITY AT OPERERATING TEMP.	cP	0.23	VIS	Data
8	VAPOR PRESSURE	kg/cm²A	0.15	PV	Data
9	SP. GR. AT OPERATING TEMP.		0.99	SG	Data
10	GRAVITY	m/s²	9.81	g	Data
11					
12					
13	CAPACITY	m³/hr	5	Q	Data
14	EXCESS CAPACITY	%	30	X	Data
15	MAX. CAPACITY	m³/hr	6.5	Qe	Qe = 0.01(100+X)(Q)
16	**SUCTION**				
17	PRESSURE AT EQUIPMENT	kg/cm²A	1.03	P1	Data
18	MIN. STATIC HEAD (+ or -)	m	-6	H1	Data
19	PIPE FRICTION	kg/cm²	0.1	DPp1	Data
20	*EQUIPMENT(.....)*	kg/cm²	0.05	DPe1	Data
21	SUCTION PUMP DIA.	m	0.052	ID	See Appendix or **fill with P if by program**
22		m	0.052		Nom. Dia. by progr (inc) **1.5** ID (m)= **0.041**
23	LIQUID VELOCITY AT SUCTION NOZZLE	m/s	0.85	V	V=Q/(0.25x3.14xID²x3600)
24	VELOCITY HEAD AT SUCTION	kg/cm²	0.0036	HV	HV=0.05(SG)(V²)/g
25	NET SUCTION PRESSURE	kg/cm²A	0.2824	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
26	NPSH AVAILABLE	m	1.34	NPSHA	NPSHA=10(PS-PV)/SG
27	NPSH margin to NPSHR	m	0.1		
28	NPSHR shall be maximum of:	m	1.24		Max. NPSHR=NPSHA-Margin NPSH
29	**DISCHARGE**				
30	PRESSURE AT EQUIPMENT	kg/cm²A	2	P2	Data
31	STATIC HEAD	m	1	H2	Data
32	PRESSURE DROP AT :				
33	PIPE (include fittings & valves)	kg/cm²	0.1		Data
34	*Equipment 1 (.....*	kg/cm²	0		Data
35	*Equipment 2(.....)*	kg/cm²	0.1		Data
36	*Equipment 3 (.....*	kg/cm²	0		Data
37	*Equipment 4 (.....*	kg/cm²	0		Data
38					
39					
40	DISCHARGE PRESSURE DROP	kg/cm²	0.2	DPp2	DPp2 = total discharge pressure drop
41					
42	TOTAL DISCHARGE PRESSURE	kg/cm²A	2.299	PD	PD = P2+0.1(H2)(SG)+DpP2
43	SUCTION PRESSURE	kg/cm²A	0.2824	PS	
44	DIFF. PRESSURE	kg/cm²	2.0166	DP	DP=PD-PS
45	TOTAL HEAD (NET)	m	20.37	H	H=10(DP)/SG
46	TOTAL HEAD (TAKE)	m	21.00	H	
47	LIQUID HORSE POWER	kW	0.37		
48	1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
49	Estimated Speed	RPM	2980	2980	
50	Estimated Higher NPSHR	m	**0.69**	**0.437**	AT NSS = 10000 (M3/H, RPM, M)
51	Estimated Lower NPSHR	m	**0.40**	**0.25**	AT NSS = 15000 (M3/H, RPM, M)
52	Maximum tip speed, Umax	m/s	55	55	Note 1
53	Approached tip speed, U	m/s	**17**	17	Note 1
54	Approached head coefficient, Y		**0.765**	0.765	Trial with 0.4 up to 0.9
55	Max. head per impeller, Hmax	m	22.54	22.54	Hmax=Y.U^2/g
56	Number of impeller, ni		1	1	
57	Average head eah impeller, Hi	m	21	21	
58	Tip speed, Us	m/s	16.41	16.41	
59	Average tip diameter, D2	mm	**105.2**	**105.2**	
60					
61	Cap. at each impeller eye of 1'st impelle	m3/h	6.5	3.25	
62	Specific speed of first impeller	m3/h,rpm,	774	548	
63	Calculated 1'st impeller efficiency	%	34.58	20.30	
64	Specific speed of next impellers	m3/h,rpm,	0	0	
65	Calculated next impellers efficiency	%	0.00	0.00	
66	Average efficiency	%	**34.58**	**20.30**	
67	ESTIMATED POWER	kW	**1.06**	**1.81**	
68					
69	REMARKS :				
70					
71					
72					
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74					
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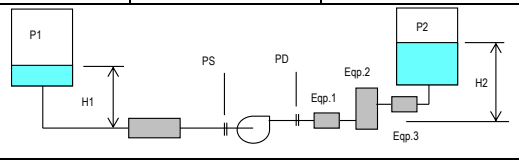
76					
77					



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

ID based on STD thickness

Calculation steps:

- Calculate NPSHA
- Select NPSHR in table (by program)
- Provide RPM (by program)
- Decide U and Y (manual input)
- Decide Flow coef Cq (manual input)
- Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

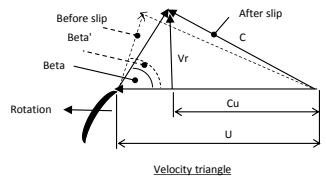
Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	0.078	0.046	0.049	0.029	580		
730	0.106	0.062	0.067	0.039	730		
980	0.157	0.092	0.099	0.058	980		
1480	0.273	0.159	0.172	0.100	1480		
2980	0.693	0.404	0.437	0.254	2980		
3000	0.693	0.404	0.437	0.254	2980		
Estimation result (basen on input data)							
Single Suction							
Speed	2980	RPM	at speed		2980	RPM	
Higher NPSHR	0.693	meter	Higher NPSHR		0.693	meter	
Lower NPSHR	0.404	meter	Lower NPSHR		0.404	meter	
Double Suction							
Speed	2980	RPM	at speed		2980	RPM	
Higher NPSHR	0.437	meter	Higher NPSHR		0.437	meter	
Lower NPSHR	0.254	meter	Lower NPSHR		0.254	meter	

Note 1: When at max tip speed, number of stage (line 56) =1, try to reduce approached tip speed (line 53) until max. head per impeller (line 545 almost same or just higher than average head of each impeller (line 57)

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	**0.1**	0.1	0.1	0.1	Input, 0.05-0.1 for small, 0.1 - 0.2 for larger pump
No of blade, Z	8	8	8	8	Input
Blade thickness(mm), t	3	3	3	3	Input
Capacity, Qms (m3/s)	0.00180556	0.00180556	0.000903	0.0009	Qms = Capacity in m3/s
Head coef, Y	0.765	0.765	0.765	0.765	
Tangensial vel, U (m/s)	16.41	16.41	16.41	16.41	
Head each impelle, H (m)	21.00	21.00	21.00	21.00	
Cu2 (m/s) as per selected Y	12.55	12.55	12.55	12.55	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	1.64	1.64	1.64	1.64	Vr = Cq . U
(U-Cu)	3.86	3.86	3.86	3.86	
Vr / (U-Cu)	0.426	0.426	0.426	0.426	
Impeller tip dia, D (mm)	105.2	105.2	105.2	105.2	
Exit angle (Beta) after slip (deg)	**23**	**23**	**23**	**23**	
First trial Slip factor, S1	0.794	0.794	0.794	0.794	
First trial Cu' 1(m/s)	15.80	15.80	15.80	15.80	
First trial Vr / (U-Cu')1	2.706	2.706	2.706	2.706	
First trial Exit angle (Beta'1) before slip (deg)	69.7	69.7	69.7	69.7	
Slip factor, S	0.765	0.765	0.765	0.765	Wiesner eq.
Cu' (m/s)	16.40	16.40	16.40	16.40	
Vr / (U-Cu')	182.95	182.95	182.95	182.95	Backward up to radial exit
Exit angle (Beta') before slip (deg)	**90**	**90**	**90**	**90**	
Radial blade thickness, Lb (mm)	24.0	24.0	24.0	24.0	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.00110027	0.00110027	0.00055	0.00055	
Exit width, b (mm)	**3.6**	**3.6**	**1.8**	**1.8**	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U



Velocity triangle

PUMP CALCULATION SHEET

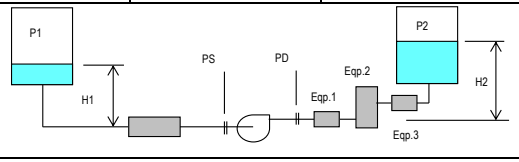
SHEET 5.B (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Example: Medium capacity,high head)

ITEM NO. :
SERVICES :

FLUID			Code	Formula
PUMPED LIQUID		Hot Water		
LIQUID CHARACTERISTIC		D		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
OPERATING TEMPERATURE	°C	103		Data
VISCOSITY AT OPERERATING TEMP.	cP	0.27	VIS	Data
VAPOR PRESSURE	kg/cm²A	1.233	PV	Data
SP. GR. AT OPERATING TEMP.		0.955	SG	Data
GRAVITY	m/s²	9.81	g	Data
CAPACITY	m³/hr	143	Q	Data
EXCESS CAPACITY	%	0	X	Data
MAX. CAPACITY	m³/hr	143	Qe	Qe = 0.01(100+X)(Q)
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm²A	2.5	P1	Data
MIN. STATIC HEAD (+ or -)	m	4	H1	Data
PIPE FRICTION	kg/cm²	0.12	DPp1	Data
EQUIPMENT(.....)	kg/cm²	0.15	DPe1	Data
SUCTION PUMP DIA.	m	P	ID	See Appendix or **fill with P if by program**
	m	0.102	ID	Nom. Dia. by progr (inc) 4 ID (m)= 0.102
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	4.86	V	V=Q/(0.25x3.14xID²x3600)
VELOCITY HEAD AT SUCTION	kg/cm²	0.1150	HV	HV=0.05(SG)(V²)/g
NET SUCTION PRESSURE	kg/cm²A	2.4970	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
NPSH AVAILABLE	m	13.24	NPSHA	NPSHA=10(PS-PV)/SG
NPSH margin to NPSHR	m	1		
NPSHR shall be maximum of:	m	12.24		Max. NPSHR=NPSHA-Margin NPSH
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm²A	70	P2	Data
STATIC HEAD	m	8	H2	Data
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm²	0.1		Data
Equipment 1 (.....	kg/cm²	0.1		Data
Equipment 2(.....)	kg/cm²	0		Data
Equipment 3 (.....	kg/cm²	0		Data
Equipment 4 (.....	kg/cm²	0		Data
DISCHARGE PRESSURE DROP	kg/cm²	0.2	DPp2	DPp2 = total discharge pressure drop
TOTAL DISCHARGE PRESSURE	kg/cm²A	70.964	PD	PD = P2+0.1(H2)(SG)+DpP2
SUCTION PRESSURE	kg/cm²A	2.4970	PS	
DIFF. PRESSURE	kg/cm²	68.4670	DP	DP=PD-PS
TOTAL HEAD (NET)	m	716.93	H	H=10(DP)/SG
TOTAL HEAD (TAKE)	m	717.00	H	
LIQUID HORSE POWER	kW	266.33		

1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
Estimated Speed	RPM	2980	2980	
Estimated Higher NPSHR	m	**5.44**	**3.429**	AT NSS = 10000 (M3/H, RPM, M)
Estimated Lower NPSHR	m	**3.17**	**2.00**	AT NSS = 15000 (M3/H, RPM, M)
Maximum tip speed, Umax	m/s	55	55	Note 2
Approached tip speed, U	m/s	**40**	40	Note 2
Approached head coefficient, Y		**0.55**	0.55	Trial with 0.4 up to 0.9
Max. head per impeller, Hmax	m	89.70	89.70	Hmax=Y.U^2/g
Number of impeller, ni		8	8	
Average head eah impeller, Hi	m	89.63	89.63	
Tip speed, Us	m/s	39.98	39.98	
Average tip diameter, D2	mm	**256.2**	**256.2**	
Cap. at each impeller eye of 1'st impelle	m3/h	143	71.5	
Specific speed of first impeller	m3/h,rpm,	1223	865	
Calculated 1'st impeller efficiency	%	71.76	63.23	
Specific speed of next impellers	m3/h,rpm,	1223	1223	
Calculated next impellers efficiency	%	71.76	71.76	
Average efficiency	%	**71.76**	**70.69**	
ESTIMATED POWER	kW	**371.14**	**376.74**	

REMARKS :



Calculation steps:

- Calculate NPSHA
- Select NPSHR in table (by program)
- Provide RPM (by program)
- Decide U and Y (manual input)
- Decide Flow coef Cq (manual input)
- Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	0.614	0.358	0.387	0.225	580		
730	0.834	0.486	0.526	0.306	730		
980	1.236	0.720	0.778	0.453	980		
1480	2.141	1.247	1.349	0.785	1480		
2980	5.443	3.170	3.429	1.997	2980		
2980	5.443	3.170	3.429	1.997	2980		

Estimation result (basen on input data)						
Single Suction						
Speed	2980	RPM	at speed	2980	RPM	
Higher NPSHR	5.443	meter	Higher NPSHR	5.443	meter	
Lower NPSHR	3.170	meter	Lower NPSHR	3.170	meter	
Double Suction						
Speed	2980	RPM	at speed	2980	RPM	
Higher NPSHR	3.429	meter	Higher NPSHR	3.429	meter	
Lower NPSHR	1.997	meter	Lower NPSHR	1.997	meter	

Note 2: When at max tip speed, number of stage (line 56) more than 1, keep approached tip speed (line 53) same to max tip speed (line 52) or adjust lower value with following consideration :
Much number of impeller will be more expensive but give higher efficiency
Less number of impeller will be less expensive but give lower efficiency.

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	0.15	0.15	0.15	0.15	Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	6	6	6	6	Input
Blade thickness(mm), t	5	5	5	5	Input
Capacity, Qms (m3/s)	0.03972222	0.03972222	0.019861	0.01986	Qms = Capacity in m3/s
Head coef, Y	0.55	0.55	0.55	0.55	
Tangensial vel, U (m/s)	39.98	39.98	39.98	39.98	
Head each impelle, H (m)	89.63	89.63	89.63	89.63	
Cu2 (m/s) as per selected Y	21.99	21.99	21.99	21.99	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	6.00	6.00	6.00	6.00	Vr = Cq . U
(U-Cu)	17.99	17.99	17.99	17.99	
Vr / (U-Cu)	0.333	0.333	0.333	0.333	
Impeller tip dia, D (mm)	256.2	256.2	256.2	256.2	
Exit angle (Beta) after slip (deg)	18	18	18	18	
First trial Slip factor, S1	0.770	0.770	0.770	0.770	
First trial Cu' 1(m/s)	28.57	28.57	28.57	28.57	
First trial Vr / (U-Cu')1	0.525	0.525	0.525	0.525	
First trial Exit angle (Beta'1) before slip (deg)	27.7	27.7	27.7	27.7	
Slip factor, S	0.728	0.728	0.728	0.728	Wiesner eq.
Cu' (m/s)	30.22	30.22	30.22	30.22	
Vr / (U-Cu')	0.61	0.61	0.61	0.61	Backward up to radial exit
Exit angle (Beta') before slip (deg)	32	32	32	32	
Radial blade thickness, Lb (mm)	57.3	57.3	57.3	57.3	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.0066233	0.0066233	0.003312	0.00331	
Exit width, b (mm)	8.9	8.9	4.4	4.4	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

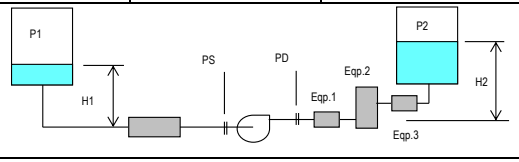
SHEET 5.C (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Example: Medium capacity,high head)

ITEM NO. :
SERVICES :

FLUID			Code	Formula
PUMPED LIQUID		BFW		
LIQUID CHARACTERISTIC		D		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
OPERATING TEMPERATURE	°C	130		Data
VISCOSITY AT OPERERATING TEMP.	cP	0.2	VIS	Data
VAPOR PRESSURE	kg/cm²A	2.78	PV	Data
SP. GR. AT OPERATING TEMP.		0.934	SG	Data
GRAVITY	m/s²	9.81	g	Data
CAPACITY	m³/hr	334	Q	Data
EXCESS CAPACITY	%	0	X	Data
MAX. CAPACITY	m³/hr	334	Qe	Qe = 0.01(100+X)(Q)
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm²A	3.81	P1	Data
MIN. STATIC HEAD (+ or -)	m	0	H1	Data
PIPE FRICTION	kg/cm²	0	DPp1	Data
EQUIPMENT(.....)	kg/cm²	0	DPe1	Data
SUCTION PUMP DIA.	m	P	ID	See Appendix or **fill with P if by program**
	m	0.154	ID	Nom. Dia. by progr (inc) 6 ID (m)= 0.154
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	4.98	V	V=Q/(0.25x3.14xID²x3600)
VELOCITY HEAD AT SUCTION	kg/cm²	0.1181	HV	HV=0.05(SG)(V²)/g
NET SUCTION PRESSURE	kg/cm²A	3.6919	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
NPSH AVAILABLE	m	9.76	NPSHA	NPSHA=10(PS-PV)/SG
NPSH margin to NPSHR	m	1		
NPSHR shall be maximum of:	m	8.76		Max. NPSHR=NPSHA-Margin NPSH
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm²A	135	P2	Data
STATIC HEAD	m	0	H2	Data
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm²	0		Data
Equipment 1 (.....	kg/cm²	0		Data
Equipment 2(.....)	kg/cm²	0		Data
Equipment 3 (.....	kg/cm²	0		Data
Equipment 4 (.....	kg/cm²	0		Data
DISCHARGE PRESSURE DROP	kg/cm²	0	DPp2	DPp2 = total discharge pressure drop
TOTAL DISCHARGE PRESSURE	kg/cm²A	135	PD	PD = P2+0.1(H2)(SG)+DpP2
SUCTION PRESSURE	kg/cm²A	3.6919	PS	
DIFF. PRESSURE	kg/cm²	131.3081	DP	DP=PD-PS
TOTAL HEAD (NET)	m	1405.87	H	H=10(DP)/SG
TOTAL HEAD (TAKE)	m	1406.00	H	
LIQUID HORSE POWER	kW	1193.02		

1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
Estimated Speed	RPM	1480	2980	
Estimated Higher NPSHR	m	**3.77**	**6.036**	AT NSS = 10000 (M3/H, RPM, M)
Estimated Lower NPSHR	m	**2.19**	**3.52**	AT NSS = 15000 (M3/H, RPM, M)
Maximum tip speed, Umax	m/s	55	55	Note 2
Approached tip speed, U	m/s	**55**	55	Note 2
Approached head coefficient, Y		**0.55**	0.55	Trial with 0.4 up to 0.9
Max. head per impeller, Hmax	m	169.60	169.60	Hmax=Y.U^2/g
Number of impeller, ni		9	9	
Average head eah impeller, Hi	m	156.22	156.22	
Tip speed, Us	m/s	52.79	52.79	
Average tip diameter, D2	mm	**681.2**	**338.3**	
Cap. at each impeller eye of 1'st impelle	m3/h	334	167	
Specific speed of first impeller	m3/h,rpm,	612	871	
Calculated 1'st impeller efficiency	%	65.53	68.46	
Specific speed of next impellers	m3/h,rpm,	612	1232	
Calculated next impellers efficiency	%	65.53	75.69	
Average efficiency	%	**65.53**	**74.88**	
ESTIMATED POWER	kW	**1820.62**	**1593.14**	

REMARKS :



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

Calculation steps:

Calculate NPSHA

Select NPSHR in table (by program)

Provide RPM (by program)

Decide U and Y (manual input)
Decide Flow coef Cq (manual input)

Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	1.081	0.629	0.681	0.397	580		
730	1.469	0.855	0.925	0.539	730		
980	2.175	1.267	1.370	0.798	980		
1480	3.768	2.195	2.374	1.383	1480		
2980	9.581	5.580	6.036	3.515	2980		
2980	9.581	5.580	6.036	3.515	2980		

Estimation result (basen on input data)						
Single Suction						
Speed	1480	RPM	at speed	2980	RPM	
Higher NPSHR	3.768	meter	Higher NPSHR	9.581	meter	
Lower NPSHR	2.195	meter	Lower NPSHR	5.580	meter	
Double Suction						
Speed	2980	RPM	at speed	2980	RPM	
Higher NPSHR	6.036	meter	Higher NPSHR	6.036	meter	
Lower NPSHR	3.515	meter	Lower NPSHR	3.515	meter	

Note 2: When at max tip speed, number of stage (line 56) more than 1, keep approached tip speed (line 53) same to max tip speed (line 52) or adjust lower value with following consideration :
Much number of impeller will be more expensive but give higher efficiency
Less number of impeller will be less expensive but give lower efficiency.

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	**0.17**	0.17	0.17	0.17	Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	8	8	8	8	Input
Blade thickness(mm), t	5	5	5	5	Input
Capacity, Qms (m3/s)	0.09277778	0.09277778	0.046389	0.04639	Qms = Capacity in m3/s
Head coef, Y	0.55	0.55	0.55	0.55	
Tangensial vel, U (m/s)	52.79	52.79	52.79	52.79	
Head each impelle, H (m)	156.22	156.22	156.22	156.22	
Cu2 (m/s) as per selected Y	29.03	29.03	29.03	29.03	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	8.97	8.97	8.97	8.97	Vr = Cq . U
(U-Cu)	23.75	23.75	23.75	23.75	
Vr / (U-Cu)	0.378	0.378	0.378	0.378	
Impeller tip dia, D (mm)	681.2	681.2	338.3	338.3	
Exit angle (Beta) after slip (deg)	**21**	**21**	**21**	**21**	
First trial Slip factor, S1	0.758	0.758	0.758	0.758	
First trial Cu' 1(m/s)	38.30	38.30	38.30	38.30	
First trial Vr / (U-Cu')1	0.619	0.619	0.619	0.619	
First trial Exit angle (Beta'1) before slip (deg)	31.8	31.8	31.8	31.8	
Slip factor, S	0.767	0.767	0.767	0.767	Wiesner eq.
Cu' (m/s)	37.87	37.87	37.87	37.87	
Vr / (U-Cu')	0.60	0.60	0.60	0.60	Backward up to radial exit
Exit angle (Beta') before slip (deg)	**31**	**31**	**31**	**31**	
Radial blade thickness, Lb (mm)	77.6	77.6	77.6	77.6	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.01033881	0.01033881	0.005169	0.00517	
Exit width, b (mm)	**5.0**	**5.0**	**5.2**	**5.2**	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

SHEET 5.D (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Example: Large capacity, medium head)

1	ITEM NO. :				
2	SERVICES :				
3	**FLUID**			**Code**	**Formula**
4	PUMPED LIQUID		COOLING WATER		
5	LIQUID CHARACTERISTIC		C		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
6	OPERATING TEMPERATURE	°C	33		Data
7	VISCOSITY AT OPERERATING TEMP.	cP	0.12	VIS	Data
8	VAPOR PRESSURE	kg/cm²A	0.04	PV	Data
9	SP. GR. AT OPERATING TEMP.		0.97	SG	Data
10	GRAVITY	m/s²	9.81	g	Data
11					
12					
13	CAPACITY	m³/hr	4211	Q	Data
14	EXCESS CAPACITY	%	0	X	Data
15	MAX. CAPACITY	m³/hr	4211	Qe	Qe = 0.01(100+X)(Q)
16	**SUCTION**				
17	PRESSURE AT EQUIPMENT	kg/cm²A	1.03	P1	Data *at first impeller eye*
18	MIN. STATIC HEAD (+ or -)	m	4	H1	Data *at first impeller eye*
19	PIPE FRICTION	kg/cm²	0.12	DPp1	Data
20	*EQUIPMENT(.....)*	kg/cm²	0.15	DPe1	Data
21	SUCTION PUMP DIA.	m	P	ID	See Appendix or **fill with P if by program**
22		m	0.64114	ID	Nom. Dia. by progr (inc) **26** ID (m)= **0.64114**
23	LIQUID VELOCITY AT SUCTION NOZZLE	m/s	3.62	V	V=Q/(0.25x3.14xID²x3600)
24	VELOCITY HEAD AT SUCTION	kg/cm²	0.0649	HV	HV=0.05(SG)(V²)/g
25	NET SUCTION PRESSURE	kg/cm²A	1.0831	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
26	NPSH AVAILABLE	m	10.75	NPSHA	NPSHA=10(PS-PV)/SG
27	NPSH margin to NPSHR	m	1		
28	NPSHR shall be maximum of:	m	9.75		Max. NPSHR=NPSHA-Margin NPSH
29	**DISCHARGE**				
30	PRESSURE AT EQUIPMENT	kg/cm²A	5	P2	Data
31	STATIC HEAD	m	12	H2	Data
32	PRESSURE DROP AT :				
33	PIPE (include fittings & valves)	kg/cm²	0.2		Data
34	*Equipment 1 (.....*	kg/cm²	0.11		Data
35	*Equipment 2(.....)*	kg/cm²	0.1		Data
36	*Equipment 3 (.....*	kg/cm²	0.05		Data
37	*Equipment 4 (.....*	kg/cm²	0		Data
38					
39					
40	DISCHARGE PRESSURE DROP	kg/cm²	0.46	DPp2	DPp2 = total discharge pressure drop
41					
42	TOTAL DISCHARGE PRESSURE	kg/cm²A	6.624	PD	PD = P2+0.1(H2)(SG)+DpP2
43	SUCTION PRESSURE	kg/cm²A	1.0831	PS	
44	DIFF. PRESSURE	kg/cm²	5.5409	DP	DP=PD-PS
45	TOTAL HEAD (NET)	m	57.12	H	H=10(DP)/SG
46	TOTAL HEAD (TAKE)	m	58.00	H	
47	LIQUID HORSE POWER	kW	644.40		
48	1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
49	Estimated Speed	RPM	730	980	
50	Estimated Higher NPSHR	m	**7.96**	**7.422**	AT NSS = 10000 (M3/H, RPM, M)
51	Estimated Lower NPSHR	m	**4.63**	**4.32**	AT NSS = 15000 (M3/H, RPM, M)
52	Maximum tip speed, Umax	m/s	40	40	
53	Approached tip speed, U	m/s	**38**	38	
54	Approached head coefficient, Y		**0.45**	0.45	Trial with 0.4 up to 0.9
55	Max. head per impeller, Hmax	m	66.24	66.24	Hmax=Y.U^2/g
56	Number of impeller, ni		1	1	
57	Average head eah impeller, Hi	m	58.00	58.00	
58	Tip speed, Us	m/s	35.56	35.56	
59	Average tip diameter, D2	mm	**930.3**	**693.0**	
60					
61	Cap. at each impeller eye of 1'st impelle	m3/h	4211	2105.5	
62	Specific speed of first impeller	m3/h,rpm,	2254	2140	
63	Calculated 1'st impeller efficiency	%	84.46	83.85	
64	Specific speed of next impellers	m3/h,rpm,	0	0	
65	Calculated next impellers efficiency	%	0.00	0.00	
66	Average efficiency	%	**84.46**	**83.85**	
67	ESTIMATED POWER	kW	**762.99**	**768.52**	
68					
69	REMARKS :				
70					
71					
72					
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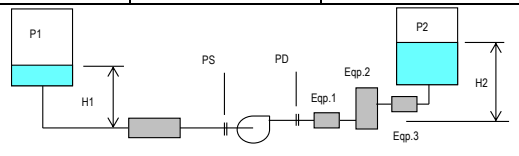
77					



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

Calculation steps:

- Calculate NPSHA
- Select NPSHR in table (by program)
- Provide RPM (by program)
- Decide U and Y (manual input)
- Decide Flow coef Cq (manual input)
- Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	5.854	3.410	3.688	2.148	580		
730	7.955	4.633	5.012	2.919	730		
980	11.781	6.861	7.422	4.322	980		
1480	20.413	11.888	12.860	7.489	1480		
2980	51.900	30.226	32.695	19.042	2980		
3725	69.884	40.700	44.025	25.640	3725		
Estimation result (basen on input data)							
Single Suction							
Speed	730	RPM	at speed		3725	RPM	
Higher NPSHR	7.955	meter	Higher NPSHR		69.884	meter	
Lower NPSHR	4.633	meter	Lower NPSHR		40.700	meter	
Double Suction							
Speed	980	RPM	at speed		3725	RPM	
Higher NPSHR	7.422	meter	Higher NPSHR		44.025	meter	
Lower NPSHR	4.322	meter	Lower NPSHR		25.640	meter	

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	**0.2**	0.2	0.2	0.2	Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	6	6	6	6	Input
Blade thickness(mm), t	5	5	5	5	Input
Capacity, Qms (m3/s)	1.16972222	1.16972222	0.584861	0.58486	Qms = Capacity in m3/s
Head coef, Y	0.45	0.45	0.45	0.45	
Tangensial vel, U (m/s)	35.56	35.56	35.56	35.56	
Head each impelle, H (m)	58.00	58.00	58.00	58.00	
Cu2 (m/s) as per selected Y	16.00	16.00	16.00	16.00	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	7.11	7.11	7.11	7.11	Vr = Cq . U
(U-Cu)	19.56	19.56	19.56	19.56	
Vr / (U-Cu)	0.364	0.364	0.364	0.364	
Impeller tip dia, D (mm)	930.3	930.3	693.0	693.0	
Exit angle (Beta) after slip (deg)	**20**	**20**	**20**	**20**	
First trial Slip factor, S1	0.739	0.739	0.739	0.739	
First trial Cu' 1(m/s)	21.67	21.67	21.67	21.67	
First trial Vr / (U-Cu')1	0.512	0.512	0.512	0.512	
First trial Exit angle (Beta'1) before slip (deg)	27.1	27.1	27.1	27.1	
Slip factor, S	0.684	0.684	0.684	0.684	Wiesner eq.
Cu' (m/s)	23.40	23.40	23.40	23.40	
Vr / (U-Cu')	0.58	0.58	0.58	0.58	Backward up to radial exit
Exit angle (Beta') before slip (deg)	**30**	**30**	**30**	**30**	
Radial blade thickness, Lb (mm)	59.4	59.4	59.4	59.4	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.16447902	0.16447902	0.08224	0.08224	
Exit width, b (mm)	**57.4**	**57.4**	**38.8**	**38.8**	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

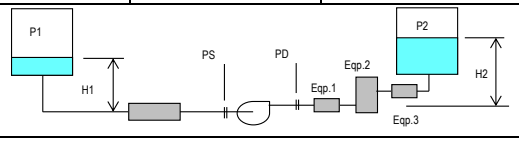
SHEET 5.E (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Example: Large capacity, medium head)

ITEM NO. :
SERVICES :

FLUID			Code	Formula
PUMPED LIQUID		COOLING WATER		
LIQUID CHARACTERISTIC		C		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
OPERATING TEMPERATURE	°C	33		Data
VISCOSITY AT OPERERATING TEMP.	cP	0.12	VIS	Data
VAPOR PRESSURE	kg/cm²A	0.04	PV	Data
SP. GR. AT OPERATING TEMP.		0.97	SG	Data
GRAVITY	m/s²	9.81	g	Data
CAPACITY	m³/hr	8145	Q	Data
EXCESS CAPACITY	%	0	X	Data
MAX. CAPACITY	m³/hr	8145	Qe	Qe = 0.01(100+X)(Q)
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm²A	1.03	P1	Data *at first impeller eye*
MIN. STATIC HEAD (+ or -)	m	4	H1	Data *at first impeller eye*
PIPE FRICTION	kg/cm²	0.12	DPp1	Data
EQUIPMENT(.....)	kg/cm²	0.15	DPe1	Data
SUCTION PUMP DIA.	m	P	ID	See Appendix or **fill with P if by program**
	m	0.89514	ID	Nom. Dia. by progr (inc) 36 ID (m)= 0.89514
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	3.60	V	V=Q/(0.25x3.14xID²x3600)
VELOCITY HEAD AT SUCTION	kg/cm²	0.0639	HV	HV=0.05(SG)(V²)/g
NET SUCTION PRESSURE	kg/cm²A	1.0841	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
NPSH AVAILABLE	m	10.76	NPSHA	NPSHA=10(PS-PV)/SG
NPSH margin to NPSHR	m	1		
NPSHR shall be maximum of:	m	9.76		Max. NPSHR=NPSHA-Margin NPSH
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm²A	3.8	P2	Data
STATIC HEAD	m	12	H2	Data
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm²	0.2		Data
Equipment 1 (.....	kg/cm²	0.11		Data
Equipment 2(.....)	kg/cm²	0.1		Data
Equipment 3 (.....	kg/cm²	0.05		Data
Equipment 4 (.....	kg/cm²	0		Data
DISCHARGE PRESSURE DROP	kg/cm²	0.46	DPp2	DPp2 = total discharge pressure drop
TOTAL DISCHARGE PRESSURE	kg/cm²A	5.424	PD	PD = P2+0.1(H2)(SG)+DpP2
SUCTION PRESSURE	kg/cm²A	1.0841	PS	
DIFF. PRESSURE	kg/cm²	4.3399	DP	DP=PD-PS
TOTAL HEAD (NET)	m	44.74	H	H=10(DP)/SG
TOTAL HEAD (TAKE)	m	45.00	H	
LIQUID HORSE POWER	kW	967.04		

1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
Estimated Speed	RPM	580	730	
Estimated Higher NPSHR	m	**9.09**	**7.780**	AT NSS = 10000 (M3/H, RPM, M)
Estimated Lower NPSHR	m	**5.29**	**4.53**	AT NSS = 15000 (M3/H, RPM, M)
Maximum tip speed, Umax	m/s	40	40	
Approached tip speed, U	m/s	**30**	30	
Approached head coefficient, Y		**0.5**	0.5	Trial with 0.4 up to 0.9
Max. head per impeller, Hmax	m	45.87	45.87	Hmax=Y.U^2/g
Number of impeller, ni		1	1	
Average head eah impeller, Hi	m	45.00	45.00	
Tip speed, Us	m/s	29.71	29.71	
Average tip diameter, D2	mm	**978.4**	**777.4**	
Cap. at each impeller eye of 1'st impelle	m3/h	8145	4072.5	
Specific speed of first impeller	m3/h,rpm,	3013	2681	
Calculated 1'st impeller efficiency	%	85.54	85.12	
Specific speed of next impellers	m3/h,rpm,	0	0	
Calculated next impellers efficiency	%	0.00	0.00	
Average efficiency	%	**85.54**	**85.12**	
ESTIMATED POWER	kW	**1130.49**	**1136.05**	

REMARKS :



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

Calculation steps:

Calculate NPSHA
↓
Select NPSHR in table (by program)
↓
Provide RPM (by program)
↓
Decide U and Y (manual input)
Decide Flow coef Cq (manual input)
↓
Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	9.088	5.293	5.725	3.334	580		
730	12.350	7.193	7.780	4.531	730		
980	18.289	10.652	11.522	6.710	980		
1480	31.689	18.455	19.963	11.626	1480		
2980	80.569	46.923	50.756	29.560	2980		
3725	108.487	63.182	68.343	39.803	3725		
Estimation result (basen on input data)							
Single Suction							
Speed	580	RPM	at speed		3725	RPM	
Higher NPSHR	9.088	meter	Higher NPSHR		108.487	meter	
Lower NPSHR	5.293	meter	Lower NPSHR		63.182	meter	
Double Suction							
Speed	730	RPM	at speed		3725	RPM	
Higher NPSHR	7.780	meter	Higher NPSHR		68.343	meter	
Lower NPSHR	4.531	meter	Lower NPSHR		39.803	meter	

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	0.2	0.2	0.2	0.2	Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	10	10	10	10	Input
Blade thickness(mm), t	10	10	10	10	Input
Capacity, Qms (m3/s)	2.2625	2.2625	1.13125	1.13125	Qms = Capacity in m3/s
Head coef, Y	0.5	0.5	0.5	0.5	
Tangensial vel, U (m/s)	29.71	29.71	29.71	29.71	
Head each impelle, H (m)	45.00	45.00	45.00	45.00	
Cu2 (m/s) as per selected Y	14.86	14.86	14.86	14.86	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	5.94	5.94	5.94	5.94	Vr = Cq . U
(U-Cu)	14.86	14.86	14.86	14.86	
Vr / (U-Cu)	0.400	0.400	0.400	0.400	
Impeller tip dia, D (mm)	978.4	978.4	777.4	777.4	
Exit angle (Beta) after slip (deg)	22	22	22	22	
First trial Slip factor, S1	0.739	0.739	0.739	0.739	
First trial Cu' 1(m/s)	20.12	20.12	20.12	20.12	
First trial Vr / (U-Cu')1	0.619	0.619	0.619	0.619	
First trial Exit angle (Beta'1) before slip (deg)	31.8	31.8	31.8	31.8	
Slip factor, S	0.786	0.786	0.786	0.786	Wiesner eq.
Cu' (m/s)	18.90	18.90	18.90	18.90	
Vr / (U-Cu')	0.55	0.55	0.55	0.55	Backward up to radial exit
Exit angle (Beta') before slip (deg)	29	29	29	29	
Radial blade thickness, Lb (mm)	207.6	207.6	207.6	207.6	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.38071749	0.38071749	0.190359	0.19036	
Exit width, b (mm)	132.8	132.8	85.2	85.2	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

SHEET 6.A (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Vertical Pump, Submerged: Sea water pump, River water pump)

1	ITEM NO. :				
2	SERVICES :				
3	**FLUID**			**Code**	**Formula**
4	PUMPED LIQUID		Sea Water		
5	LIQUID CHARACTERISTIC		C		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
6	OPERATING TEMPERATURE	^oC	32		Data
7	VISCOSITY AT OPERERATING TEMP.	cP	0.23	VIS	Data
8	VAPOR PRESSURE	kg/cm^2A	0.15	PV	Data
9	SP. GR. AT OPERATING TEMP.		0.99	SG	Data
10	GRAVITY	m/s^2	9.81	g	Data
11	CAPACITY	m^3/hr	11000	Q	Data
12	EXCESS CAPACITY	%	0	X	Data
13	MAX. CAPACITY	m^3/hr	11000	Qe	Qe = 0.01(100+X)(Q)
14	**SUCTION**				
15	PRESSURE AT EQUIPMENT	kg/cm^2A	1.033	P1	Data atmospheric condition
16	LIQUID VELOCITY AT SUCTION NOZZLE	m/s	2	V	Data (0.61 - 2.4 m/s, recommended 1.68 m/s)
17	VELOCITY HEAD AT SUCTION	kg/cm^2	0.0202	HV	HV=0.05(SG)(V^2)/g
18	BELL INLET AREA	m2	1.5278	Ab	Ab = (Qe/3600) / V
19	BELL INSIDE DIAMETER	m	1.3947	Db	Db = $(1.2732 \times Ab)^{0.5}$
20	MIN. SUBMERGENCE OF BELL	m	3.129	hL	hL = Db + 0.0002597(Qe/$Db^{1.5}$)
21	MIN. SUBMERGENCE OF 1'ST IMP. EYE	m	2.432	hL1	
22	BASE PL. OR NOZZLE TO MIN. LEVEL	m	5.5	L1	Data
23	NET SUCTION PRESSURE	kg/cm^2A	1.2536	PS	PS = P1+0.1(hL1)(SG)-HV
24	NPSH AVAILABLE	m	11.15	NPSHA	NPSHA=10(PS-PV)/SG
25	NPSH margin to NPSHR	m	2.5		Or from % NPSHA, typical 20 % = 2.229412 m
26	NPSHR shall be maximum of:	m	8.65		Max. NPSHR=NPSHA-Margin NPSH
27	**DISCHARGE**				
28	PRESSURE AT EQUIPMENT	kg/cm^2A	5.92	P2	Data
29	STATIC HEAD	m	7.932	L	L = L1+hL1
30	PRESSURE DROP AT :				
31	PIPE (include fittings & valves)	kg/cm^2	0		Data
32	*Equipment 1 (.....*	kg/cm^2	0		Data
33	*Equipment 2(.....)*	kg/cm^2	0		Data
34	*Equipment 3 (.....*	kg/cm^2	0		Data
35					
36	DISCHARGE PRESSURE DROP	kg/cm^2	0	DPp2	DPp2 = total discharge pressure drop
37					
38	TOTAL DISCHARGE PRESSURE	kg/cm^2A	6.71	PD	PD = P2+0.1 (L)(SG)+DpP2 (at impeller exit)
39	SUCTION PRESSURE	kg/cm^2A	1.254	PS	
40	DIFF. PRESSURE	kg/cm^2	5.452	DP	DP=PD-PS
41	TOTAL HEAD (NET)	m	55.07	H	H=10(DP)/SG
42	TOTAL HEAD (TAKE)	m	56	H	
43	LIQUID HORSE POWER	kW	1658.76		
44	1'st Impeller Type		SINGLE SUCTION	DOUBLE SUCTION	
45	Estimated Speed	RPM	580	580	
46	Estimated Higher NPSHR	m	-	6.995	AT NSS = 10000 (M3/H, RPM, M)
47	Estimated Lower NPSHR	m	6.47	4.074	AT NSS = 15000 (M3/H, RPM, M)
48	Maximum tip speed, Umax	m/s	40	40	Note 1
49	Approached tip speed, U	m/s	32	32	Note 1
50					
51	Approached head coefficient, Y		0.55	0.55	Trial with 0.4 up to 0.9
52	Max. head per impeller, Hmax	m	57.41	57.41	Hmax=Y.U^2/g
53	Number of impeller, ni		1	1	
54	Average head eah impeller, Hi	m	56	56	
55	Tip speed, Us	m/s	31.60	31.60	
56	Average tip diameter, D2	mm	1040.7	1040.7	
57					
58	Cap. at each impeller eye of 1'st impelle	m3/h	11000	5500	
59	Specific speed of first impeller	m3/h,rpm,	2972	2101	
60	Calculated 1'st impeller efficiency	%	85.58	84.16	
61	Specific speed of next impellers	m3/h,rpm,	0	0	
62	Calculated next impellers efficiency	%	0.00	0.00	
63	Average efficiency	%	85.58	84.16	
64	ESTIMATED POWER	kW	1938.25	1971.07	
65					
66	REMARKS :				
67					
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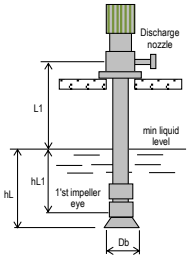


Calculation steps:

Calculate NPSHA

Select NPSHR in table (by program)

Provide RPM (by program)

Decide U and Y (manual input)
Decide Flow coef Cq (manual input)

Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

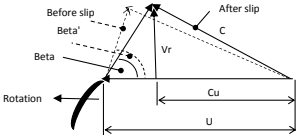
Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	11.104	6.467	6.995	4.074	580		
730	15.089	8.788	9.506	5.536	730		
980	22.346	13.014	14.077	8.198	980		
1480	38.717	22.549	24.391	14.205	1480		
2980	98.439	57.330	62.013	36.116	2980		
2980	98.439	57.330	62.013	36.116	2980		
Estimation result (basen on input data)							
Single Suction							
Speed	580	RPM	at speed		2980	RPM	
Higher NPSHR	0.000	meter	Higher NPSHR		98.439	meter	
Lower NPSHR	6.467	meter	Lower NPSHR		57.330	meter	
Double Suction							
Speed	580	RPM	at speed		2980	RPM	
Higher NPSHR	6.995	meter	Higher NPSHR		62.013	meter	
Lower NPSHR	4.074	meter	Lower NPSHR		36.116	meter	

Note 1: When at max tip speed, number of stage (line 56) =1, try to reduce approached tip speed (line 53) until max. head per impeller (line 545 almost same or just higher than average head of each impeller (line 57)

Image of impeller	Single suction		Double suction. Each side		
Flow coef., Cq	0.2	0.2	0.2	0.2	Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	16	16	16	16	Input
Blade thickness(mm), t	12	12	12	12	Input
Capacity, Qms (m3/s)	3.05555556	3.05555556	1.527778	1.52778	Qms = Capacity in m3/s
Head coef, Y	0.55	0.55	0.55	0.55	
Tangensial vel, U (m/s)	31.60	31.60	31.60	31.60	
Head each impelle, H (m)	56.00	56.00	56.00	56.00	
Cu2 (m/s) as per selected Y	17.38	17.38	17.38	17.38	Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	6.32	6.32	6.32	6.32	Vr = Cq . U
(U-Cu)	14.22	14.22	14.22	14.22	
Vr / (U-Cu)	0.444	0.444	0.444	0.444	
Impeller tip dia, D (mm)	1040.7	1040.7	1040.7	1040.7	
Exit angle (Beta) after slip (deg)	24	24	24	24	
First trial Slip factor, S1	0.739	0.739	0.739	0.739	
First trial Cu' 1(m/s)	23.54	23.54	23.54	23.54	
First trial Vr / (U-Cu')1	0.783	0.783	0.783	0.783	
First trial Exit angle (Beta'1) before slip (deg)	38.1	38.1	38.1	38.1	
Slip factor, S	0.849	0.849	0.849	0.849	Wiesner eq.
Cu' (m/s)	20.48	20.48	20.48	20.48	
Vr / (U-Cu')	0.57	0.57	0.57	0.57	Backward up to radial exit
Exit angle (Beta') before slip (deg)	30	30	30	30	
Radial blade thickness, Lb (mm)	388.5	388.5	388.5	388.5	Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.48340709	0.48340709	0.241704	0.2417	
Exit width, b (mm)	167.8	167.8	83.9	83.9	

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U



Velocity triangle

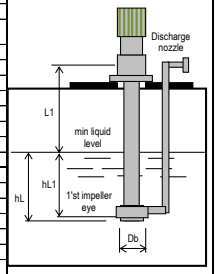
PUMP CALCULATION SHEET

SHEET 6.B (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Vertical Pump, Submerged: Process)

ITEM NO. :
SERVICES :

FLUID			Code	Formula
PUMPED LIQUID		Solution		
LIQUID CHARACTERISTIC		B		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
OPERATING TEMPERATURE	^{o}C	90		Data
VISCOSITY AT OPERERATING TEMP.	cP	0.23	VIS	Data
VAPOR PRESSURE	kg/cm^2A	0.2	PV	Data
SP. GR. AT OPERATING TEMP.		0.99	SG	Data
GRAVITY	m/s^2	9.81	g	Data
CAPACITY	m^3/hr	35	Q	Data
EXCESS CAPACITY	%	0	X	Data
MAX. CAPACITY	m^3/hr	35	Qe	Qe = 0.01(100+X)(Q)
SUCTION				
PRESSURE AT EQUIPMENT	kg/cm^2A	1.033	P1	Data atmospheric condition
LIQUID VELOCITY AT SUCTION NOZZLE	m/s	1.5	V	Data (0.61 - 2.4 m/s, recommended 1.68 m/s)
VELOCITY HEAD AT SUCTION	kg/cm^2	0.0114	HV	HV=0.05(SG)(V^2)/g
BELL INLET AREA	m2	0.0065	Ab	Ab = (Qe/3600) / V
BELL INSIDE DIAMETER	m	0.0908	Db	Db = $(1.2732 \times Ab)^{0.5}$
MIN. SUBMERGENCE OF BELL	m	0.423	hL	hL = Db + 0.0002597(Qe/$Db^{1.5}$)
MIN. SUBMERGENCE OF 1'ST IMP. EYE	m	0.377	hL1	
BASE PL. OR NOZZLE TO MIN. LEVEL	m	1.5	L1	Data
NET SUCTION PRESSURE	kg/cm^2A	1.0590	PS	PS = P1+0.1(hL1)(SG)-HV
NPSH AVAILABLE	m	8.68	NPSHA	NPSHA=10(PS-PV)/SG
NPSH margin to NPSHR	m	2.5		Or may from % NPSHA, example 20 % (m) = 1.74
NPSHR shall be maximum of:	m	6.18		Max. NPSHR=NPSHA-Margin NPSH
DISCHARGE				
PRESSURE AT EQUIPMENT	kg/cm^2A	5	P2	Data
STATIC HEAD	m	1.877	L	L = L1+hL1
PRESSURE DROP AT :				
PIPE (include fittings & valves)	kg/cm^2	0		Data
Equipment 1 (.....	kg/cm^2	0		Data
Equipment 2(.....)	kg/cm^2	0		Data
Equipment 3 (.....	kg/cm^2	0		Data
DISCHARGE PRESSURE DROP	kg/cm^2	0	DPp2	DPp2 = total discharge pressure drop
TOTAL DISCHARGE PRESSURE	kg/cm^2A	**5.19**	PD	PD = P2+0.1(L)(SG)+DpP2 (at impeller exit)
SUCTION PRESSURE	kg/cm^2A	1.059	PS	
DIFF. PRESSURE	kg/cm^2	4.127	DP	DP=PD-PS
TOTAL HEAD (NET)	m	41.69	H	H=10(DP)/SG
TOTAL HEAD (TAKE)	m	42	H	
LIQUID HORSE POWER	kW	3.96		
1'st Impeller Type		SINGLE SUCTION	SINGLE SUCTION-LOWER SPEED	
Estimated Speed	RPM	2980	1480	
Estimated Higher NPSHR	m	**2.13**	**0.838**	AT NSS = 10000 (M3/H, RPM, M)
Estimated Lower NPSHR	m	**1.24**	**0.488**	AT NSS = 15000 (M3/H, RPM, M)
Maximum tip speed, Umax	m/s	30	30	Note 1
Approached tip speed, U	m/s	**29**	**29**	Note 1
Approached head coefficient, Y		**0.55**	**0.55**	Trial with 0.4 up to 0.9
Max. head per impeller, Hmax	m	47.15	47.15	Hmax=Y.U^2/g
Number of impeller, ni		1	1	
Average head eah impeller, Hi	m	42	42	
Tip speed, Us	m/s	27.37	27.37	
Average tip diameter, D2	mm	**175.4**	**353.2**	
Cap. at each impeller eye of 1'st impelle	m3/h	35	35	
Specific speed of first impeller	m3/h,rpm,	1069	531	
Calculated 1'st impeller efficiency	%	59.49	50.50	
Specific speed of next impellers	m3/h,rpm,	0	0	
Calculated next impellers efficiency	%	0.00	0.00	
Average efficiency	%	**59.49**	**50.50**	
ESTIMATED POWER	kW	**6.65**	**7.84**	

REMARKS :



Calculation steps:

Calculate NPSHA

Select NPSHR in table (by program)

Provide RPM (by program)

Decide U and Y (manual input)
Decide Flow coef.Cq (manual input)

Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	0.240	0.140	0.151	0.088	580		
730	0.326	0.190	0.206	0.120	730		
980	0.483	0.282	0.305	0.177	980		
1480	0.838	0.488	0.528	0.307	1480		
2980	2.130	1.240	1.342	0.781	2980		
3000	2.130	1.240	1.342	0.781	2980		

Estimation result (basen on input data)						
Single Suction						
Speed	2980	RPM	at speed	2980	RPM	
Higher NPSHR	2.130	meter	Higher NPSHR	2.130	meter	
Lower NPSHR	1.240	meter	Lower NPSHR	1.240	meter	
Double Suction						
Speed	2980	RPM	at speed	2980	RPM	
Higher NPSHR	1.342	meter	Higher NPSHR	1.342	meter	
Lower NPSHR	0.781	meter	Lower NPSHR	0.781	meter	

Note 1: When at max tip speed, number of stage (line 56) =1, try to reduce approached tip speed (line 53) until max. head per impeller (line 545 almost same or just higher than average head of each impeller (line 57)

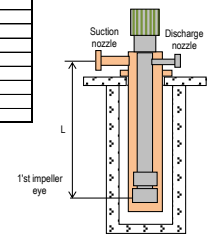
Image of impeller	Single suction				
Flow coef., Cq	0.15	0.15			Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	6	6			Input
Blade thickness(mm), t	5	5			Input
Capacity, Qms (m3/s)	0.00972222	0.00972222			Qms = Capacity in m3/s
Head coef, Y	0.55	0.55			
Tangensial vel, U (m/s)	27.37	27.37			
Head each impelle, H (m)	42.00	42.00			
Cu2 (m/s) as per selected Y	15.05	15.05			Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	4.11	4.11			Vr = Cq . U
(U-Cu)	12.32	12.32			
Vr / (U-Cu)	0.333	0.333			
Impeller tip dia, D (mm)	175.4	175.4			
Exit angle (Beta) after slip (deg)	18	18			
First trial Slip factor, S1	0.770	0.770			
First trial Cu' 1(m/s)	19.56	19.56			
First trial Vr / (U-Cu')1	0.525	0.525			
First trial Exit angle (Beta'1) before slip (deg)	27.7	27.7			
Slip factor, S	0.728	0.728			Wiesner eq.
Cu' (m/s)	20.69	20.69			
Vr / (U-Cu')	0.61	0.61			Backward up to radial exit
Exit angle (Beta') before slip (deg)	32	32			
Radial blade thickness, Lb (mm)	57.3	57.3			Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.00236808	0.00236808			
Exit width, b (mm)	4.8	4.8			

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

SHEET 6.C (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Vertical canned pump: Process with high vapor pressure)

	FLUID			Code	Formula
1	ITEM NO. :				
2	SERVICES :				
3	**FLUID**			**Code**	**Formula**
4	PUMPED LIQUID		Ammonia Liq.		
5	LIQUID CHARACTERISTIC		D		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
6	OPERATING TEMPERATURE	°C	-33.1		Data
7	VISCOSITY AT OPERERATING TEMP.	cP	0.272	VIS	Data
8	VAPOR PRESSURE	kg/cm²A	1.046	PV	Data
9	SP. GR. AT OPERATING TEMP.		0.682	SG	Data
10	GRAVITY	m/s²	9.81	g	Data
11					
12					
13	CAPACITY	m³/hr	1620	Q	Data
14	EXCESS CAPACITY	%	0	X	Data
15	MAX. CAPACITY	m³/hr	1620	Qe	Qe = 0.01(100+X)(Q)
16	**SUCTION**				
17	PRESSURE AT EQUIPMENT	kg/cm²A	1.033	P1	Data
18	MIN. STATIC HEAD (+ or -)	m	3	H1	Data up to suction nozzle
19	PIPE FRICTION LOSS	kg/cm²	0.02	DPp1	Data up to suction nozzle
20	*EQUIPMENT(.....)*	kg/cm²	0	DPe1	Data
21	PRESSURE AT SUCTION NOZZLE	kg/cm²A	**1.2576**		
22	SUCTION PUMP DIA.	m	0.489	ID	See Appendix or **fill with P if by program**
23		m	0.489	ID	Nom. Dia. by progr (inc): **16** ID (m)= **0.387**
24	LIQUID VELOCITY AT SUCTION NOZZLE	m/s	2.40	V	V=Q/(0.25x3.14xID^2x3600)
25	VELOCITY HEAD AT SUCTION	kg/cm²	0.0200	HV	HV=0.05(SG)(V²)/g
26	NET SUCTION STATIC PRESSURE	kg/cm²A	1.2376	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
27	**DISCHARGE**				
28	PRESSURE AT EQUIPMENT	kg/cm²A	9.28	P2	Data
29	STATIC HEAD	m	12	H2	Data
30	PRESSURE DROP AT :				
31	PIPE (include fittings & valves)	kg/cm²	0.1		Data
32	*Equipment 1 (.....*	kg/cm²	0.1		Data
33	*Equipment 2(.....)*	kg/cm²	0		Data
34	*Equipment 3 (.....*	kg/cm²	0		Data
35	*Equipment 4 (.....*	kg/cm²	0		Data
36	DISCHARGE PRESSURE DROP	kg/cm²	0.2	DPp2	DPp2 = total discharge pressure drop
37	TOTAL DISCHARGE PRESSURE	kg/cm²A	**10.30**	PD	PD = P2+0.1(H2)(SG)+DpP2 AT DISCHARGE NOZZLE
38	SUCTION PRESSURE	kg/cm²A	1.2576	PS	
39	DIFF. PRESSURE	kg/cm²	9.0408	DP	DP=PD-PS
40	TOTAL HEAD (NET)	m	132.56	H	H=10(DP)/SG
41	TOTAL HEAD (TAKE)	m	133.00	H	
42	LIQUID HORSE POWER	kW	399.69	LHP	AT NOZZLES
43	PRESSURE DROP INSIDE PUMP	kg/cm2	0.16		Has to be calculated, but may be approach 8 x HV
44	TOTAL HEAD REQUIRED AT IMPELLER	m	135.34	Hi	
45	LIQUID HORSE POWER	kW	406.72	LHPi	AT IMPELLERS
46	**PUMP LENGTH**				
47	ESTIMATED/TRIAL PUMP LENGTH		9	L	From suction nozzle to first impeller eye
48	SUCTION IMPELLER PRESSURE		1.851		
49	NPSHA AT IMPELLER EYE		11.81		
50	NPSH MARGIN	m	0.5		Or may from % NPSHA, example 20 % (m) = 2.362007
51	NPSH shall be maximum of:	m	11.31		Max. NPSHR=NPSHA-Margin NPSH
52	1'st Impeller Type		SINGLE SUCTION		
53	Estimated Speed	RPM	1480		If this speed too low try to increase pump length
54	Estimated Higher NPSHR	m	**10.80**		AT NSS = 10000 (M3/H, RPM, M)
55	Estimated Lower NPSHR	m	**6.29**		AT NSS = 15000 (M3/H, RPM, M)
56	Maximum tip speed, Umax	m/s	55		
57	Approached tip speed, U	m/s	**36**		
58					
59	Approached head coefficient, Y		**0.55**		Trial with 0.4 up to 0.9
60	Max. head per impeller, Hmax	m	72.66		Hmax=Y.U^2/g
61	Number of impeller, ni		2		
62	Average head eah impeller, Hi	m	67.67		
63	Tip speed, Us	m/s	34.74		
64	Average tip diameter, D2	mm	**448.3**		If this diameter too large due too low speed, increase pump length
65					
66	Cap. at each impeller eye of 1'st impelle	m3/h	1620		
67	Specific speed of first impeller	m3/h,rpm,	2525		
68	Calculated 1'st impeller efficiency	%	84.36		
69	Specific speed of next impellers	m3/h,rpm,	2525		
70	Calculated next impellers efficiency	%	84.36		
71	Average efficiency	%	**84.36**		**At impellers**
72	ESTIMATED POWER	kW	**482.13**		
73					
74	REMARKS :				
75					
76					
77					
78					
79					
80					
81					
82					



Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

ID based on STD thickness

Calculation steps:

Calculate NPSHA
↓
Select NPSHR in table (by program)
↓
Provide RPM (by program)
↓
Decide U and Y (manual input)
Decide Flow coef Cq (manual input)
↓
Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	3.097	1.804	1.951	1.136	580		
730	4.208	2.451	2.651	1.544	730		
980	6.232	3.629	3.926	2.286	980		
1480	10.798	6.289	6.802	3.962	1480		
2980	27.453	15.989	17.295	10.072	2980		
	27.453	15.989	17.295	10.072	2980		

Estimation result (basen on input data)						
Single Suction						
Speed	1480	RPM	at speed		2980	RPM
Higher NPSHR	10.798	meter	Higher NPSHR		27.453	meter
Lower NPSHR	6.289	meter	Lower NPSHR		15.989	meter
Double Suction						
Speed	1480	RPM	at speed		2980	RPM
Higher NPSHR	6.802	meter	Higher NPSHR		17.295	meter
Lower NPSHR	3.962	meter	Lower NPSHR		10.072	meter

Image of impeller

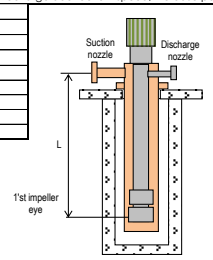
	Single suction				
Flow coef., Cq	0.15	0.15			Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	6	6			Input
Blade thickness(mm), t	5	5			Input
Capacity, Qms (m3/s)	0.45	0.45			Qms = Capacity in m3/s
Head coef, Y	0.55	0.55			
Tangensial vel, U (m/s)	34.74	34.74			
Head each impelle, H (m)	67.67	67.67			
Cu2 (m/s) as per selected Y	19.11	19.11			Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	5.21	5.21			Vr = Cq . U
(U-Cu)	15.63	15.63			
Vr / (U-Cu)	0.333	0.333			
Impeller tip dia, D (mm)	448.3	448.3			
Exit angle (Beta) after slip (deg)	18	18			
First trial Slip factor, S1	0.770	0.770			
First trial Cu' 1(m/s)	24.82	24.82			
First trial Vr / (U-Cu')1	0.525	0.525			
First trial Exit angle (Beta'1) before slip (deg)	27.7	27.7			
Slip factor, S	0.728	0.728			Wiesner eq.
Cu' (m/s)	26.26	26.26			
Vr / (U-Cu')	0.61	0.61			Backward up to radial exit
Exit angle (Beta') before slip (deg)	32	32			
Radial blade thickness, Lb (mm)	57.3	57.3			Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.08635126	0.08635126			
Exit width, b (mm)	63.9	63.9			

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

PUMP CALCULATION SHEET

SHEET 6.D (More detail, with considering RPM, tip speed, head coef. & impeller dimension)
(Vertical canned pump: Process with high vapor pressure)

	FLUID			Code	Formula
	PUMPED LIQUID		Ammonia Liq.		
	LIQUID CHARACTERISTIC		D		A. Plastic, B. With slury, C. Dirty, D. Clean Hot, E. Clean Cold
	OPERATING TEMPERATURE	°C	-33.1		Data
	VISCOSITY AT OPERERATING TEMP.	cP	0.272	VIS	Data
	VAPOR PRESSURE	kg/cm²A	1.046	PV	Data
	SP. GR. AT OPERATING TEMP.		0.682	SG	Data
	GRAVITY	m/s²	9.81	g	Data
	CAPACITY	m³/hr	1620	Q	Data
	EXCESS CAPACITY	%	0	X	Data
	MAX. CAPACITY	m³/hr	1620	Qe	Qe = 0.01(100+X)(Q)
	SUCTION				
	PRESSURE AT EQUIPMENT	kg/cm²A	1.033	P1	Data
	MIN. STATIC HEAD (+ or -)	m	3	H1	Data up to suction nozzle
	PIPE FRICTION LOSS	kg/cm²	0.02	DPp1	Data up to suction nozzle
	EQUIPMENT(.....)	kg/cm²	0	DPe1	Data
	PRESSURE AT SUCTION NOZZLE	kg/cm²A	**1.2576**		
	SUCTION PUMP DIA.	m	P	ID	See Appendix or **fill with P if by program**
		m	0.387	ID	Nom. Dia. by progr (inc): **16** ID (m)= **0.387**
	LIQUID VELOCITY AT SUCTION NOZZLE	m/s	3.83	V	V=Q/(0.25x3.14xID^2x3600)
	VELOCITY HEAD AT SUCTION	kg/cm²	0.0509	HV	HV=0.05(SG)(V²)/g
	NET SUCTION STATIC PRESSURE	kg/cm²A	1.2067	PS	PS = P1+0.1(H1)(SG)-Dpe1-DPp1-HV
	DISCHARGE				
	PRESSURE AT EQUIPMENT	kg/cm²A	9.28	P2	Data
	STATIC HEAD	m	12	H2	Data
	PRESSURE DROP AT :				
	PIPE (include fittings & valves)	kg/cm²	0.1		Data
	Equipment 1 (.....)	kg/cm²	0.1		Data
	Equipment 2(.....)	kg/cm²	0		Data
	Equipment 3 (.....)	kg/cm²	0		Data
	Equipment 4 (.....)	kg/cm²	0		Data
	DISCHARGE PRESSURE DROP	kg/cm²	0.2	DPp2	DPp2 = total discharge pressure drop
	TOTAL DISCHARGE PRESSURE	kg/cm²A	**10.30**	PD	PD = P2+0.1(H2)(SG)+DpP2 AT DISCHARGE NOZZLE
	SUCTION PRESSURE	kg/cm²A	1.2576	PS	
	DIFF. PRESSURE	kg/cm²	9.0408	DP	DP=PD-PS
	TOTAL HEAD (NET)	m	132.56	H	H=10(DP)/SG
	TOTAL HEAD (TAKE)	m	133.00	H	
	LIQUID HORSE POWER	kW	399.69	LHP	AT NOZZLES
	PRESSURE DROP INSIDE PUMP	kg/cm2	0.41		Has to be calculated, but may be approach 8 x HV
	TOTAL HEAD REQUIRED AT IMPELLER	m	138.97		
	LIQUID HORSE POWER	kW	417.62		AT IMPELLERS
	PUMP LENGTH				
	ESTIMATED/TRIAL PUMP LENGTH		6.7	L	From suction nozzle to first impeller eye
	SUCTION IMPELLER PRESSURE		1.664		
	NPSHA AT IMPELLER EYE		9.06		
	NPSH MARGIN	m	0.5		Or may from % NPSHA, example 20 % (m) = 1.811351
	NPSHR shall be maximum of:	m	8.56		Max. NPSHR=NPSHA-Margin NPSH
	1'st Impeller Type		SINGLE SUCTION		
	Estimated Speed	RPM	980		If this speed too low try to increase pump length
	Estimated Higher NPSHR	m	**6.23**		AT NSS = 10000 (M3/H, RPM, M)
	Estimated Lower NPSHR	m	**3.63**		AT NSS = 15000 (M3/H, RPM, M)
	Maximum tip speed, Umax	m/s	55		
	Approached tip speed, U	m/s	**25**		
	Approached head coefficient, Y		**0.55**		Trial with 0.4 up to 0.9
	Max. head per impeller, Hmax	m	35.04		Hmax=Y.U^2/g
	Number of impeller, ni		4		
	Average head eah impeller, Hi	m	34.74		
	Tip speed, Us	m/s	24.89		
	Average tip diameter, D2	mm	**485.1**		If this diameter too large due too low speed, increase pump length
	Cap. at each impeller eye of 1'st impelle	m3/h	1620		
	Specific speed of first impeller	m3/h,rpm,	2756		
	Calculated 1'st impeller efficiency	%	84.63		
	Specific speed of next impellers	m3/h,rpm,	2756		
	Calculated next impellers efficiency	%	84.63		
	Average efficiency	%	**84.63**		**At impellers**
	ESTIMATED POWER	kW	**493.46**		
	REMARKS :				



Calculation steps:

Calculate NPSHA
↓
Select NPSHR in table (by program)
↓
Provide RPM (by program)
↓
Decide U and Y (manual input)
Decide Flow coef Cq (manual input)
↓
Calculate Diameter, number of stage, exit angle, tip width, efficiency & BHP (by program)

Suction nozzle diameter

D (inc)	ID(mm)
1.5	0.041
2	0.052
3	0.078
4	0.102
6	0.154
8	0.202
10	0.254
12	0.305
14	0.337
16	0.387
18	0.438
20	0.489

Speed can be modified as per motor hertz (blue fonts) or higher speed at last row (yellow)

NPSHR range (in meter)							
Speed	Single Suction		Double Suction		Speed		
	Higher	Lower	Higher	Lower			
0	0	0	0	0	0		
580	3.097	1.804	1.951	1.136	580		
730	4.208	2.451	2.651	1.544	730		
980	6.232	3.629	3.926	2.286	980		
1480	10.798	6.289	6.802	3.962	1480		
2980	27.453	15.989	17.295	10.072	2980		
3000	27.453	15.989	17.295	10.072	2980		

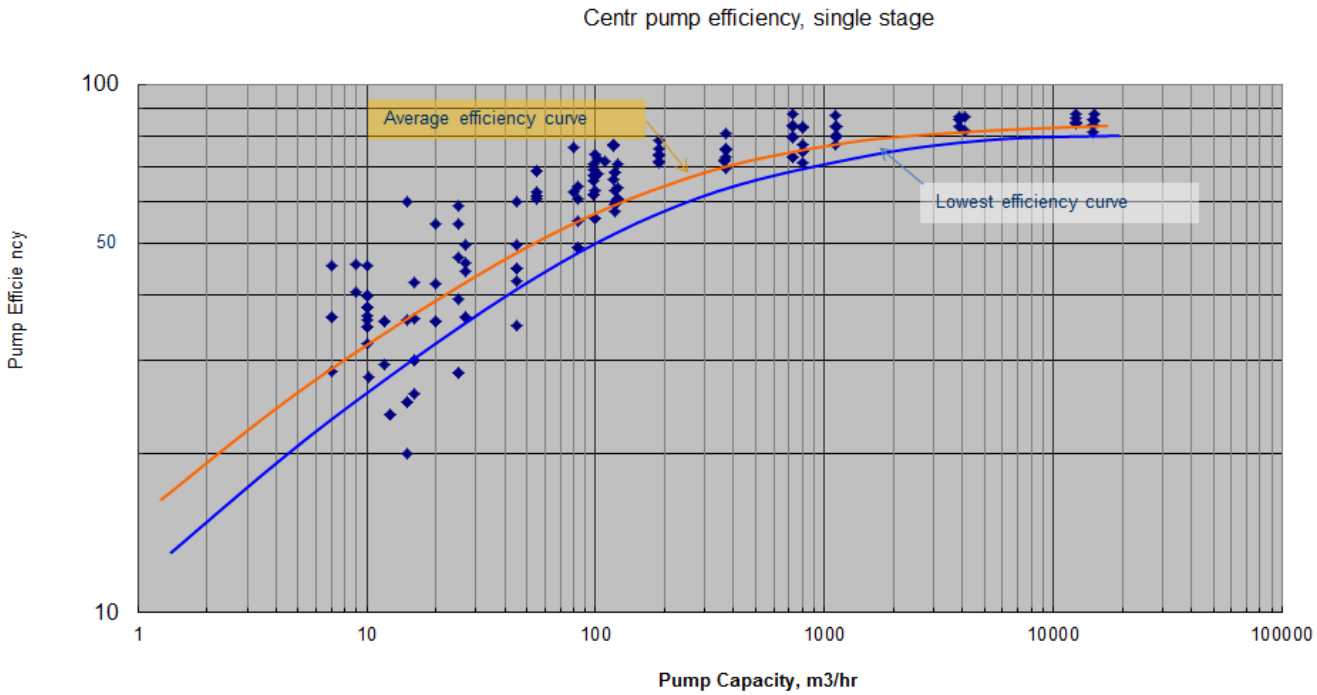
Estimation result (basen on input data)

Single Suction						
Speed	980	RPM	at speed	2980	RPM	
Higher NPSHR	6.232	meter	Higher NPSHR	27.453	meter	
Lower NPSHR	3.629	meter	Lower NPSHR	15.989	meter	
Double Suction						
Speed	1480	RPM	at speed	2980	RPM	
Higher NPSHR	6.802	meter	Higher NPSHR	17.295	meter	
Lower NPSHR	3.962	meter	Lower NPSHR	10.072	meter	

Image of impeller	Single suction				
Flow coef., Cq	0.15	0.15			Input, 0.05-0.1 for small pump, 0.1 - 0.2 for larger pump
No of blade, Z	6	6			Input
Blade thickness(mm), t	5	5			Input
Capacity, Qms (m3/s)	0.45	0.45			Qms = Capacity in m3/s
Head coef, Y	0.55	0.55			
Tangensial vel, U (m/s)	24.89	24.89			
Head each impelle, H (m)	34.74	34.74			
Cu2 (m/s) as per selected Y	13.69	13.69			Cu = Y.U
Radial vel as per selected Cq, Vr (m/s)	3.73	3.73			Vr = Cq . U
(U-Cu)	11.20	11.20			
Vr / (U-Cu)	0.333	0.333			
Impeller tip dia, D (mm)	485.1	485.1			
Exit angle (Beta) after slip (deg)	18	18			
First trial Slip factor, S1	0.770	0.770			
First trial Cu' 1(m/s)	17.79	17.79			
First trial Vr / (U-Cu')1	0.525	0.525			
First trial Exit angle (Beta'1) before slip (deg)	27.7	27.7			
Slip factor, S	0.728	0.728			Wiesner eq.
Cu' (m/s)	18.81	18.81			
Vr / (U-Cu')	0.61	0.61			Backward up to radial exit
Exit angle (Beta') before slip (deg)	32	32			
Radial blade thickness, Lb (mm)	57.3	57.3			Lb = Z . T / sin (beta)
Exit area, A2 = Q/Vr (m2)	0.12051528	0.12051528			
Exit width, b (mm)	82.2	82.2			

Cq will effect to exit angle and width of impeller tip exit design. Cq = Vr / U

EFFICIENCY ESTIMATION BASED ON PUMP CAPACITY



Average efficiency formula (appoached, in %):

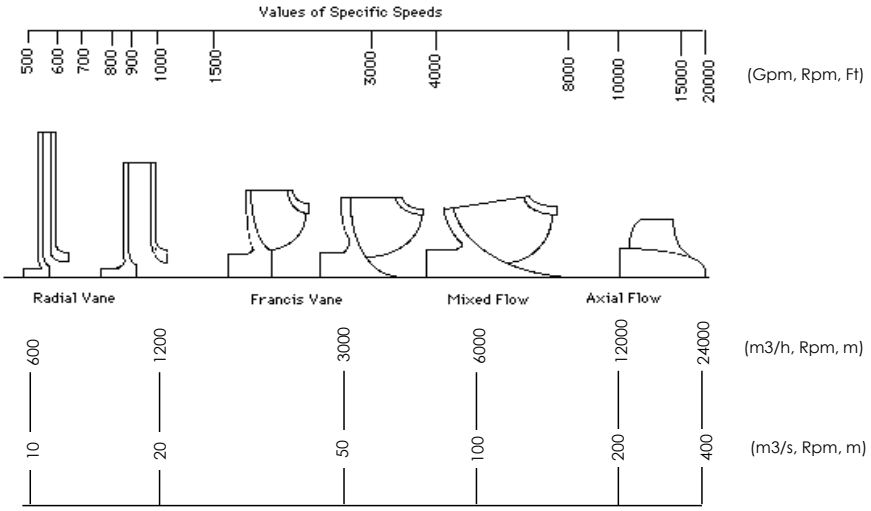
Below 1000 m3/h, Eff. (%) = 9.9943 x Ln (Q) + 10.535 (1)

1000 m3/h and above, Eff. (%) = 2.6178 x Ln (Q) + 60.972

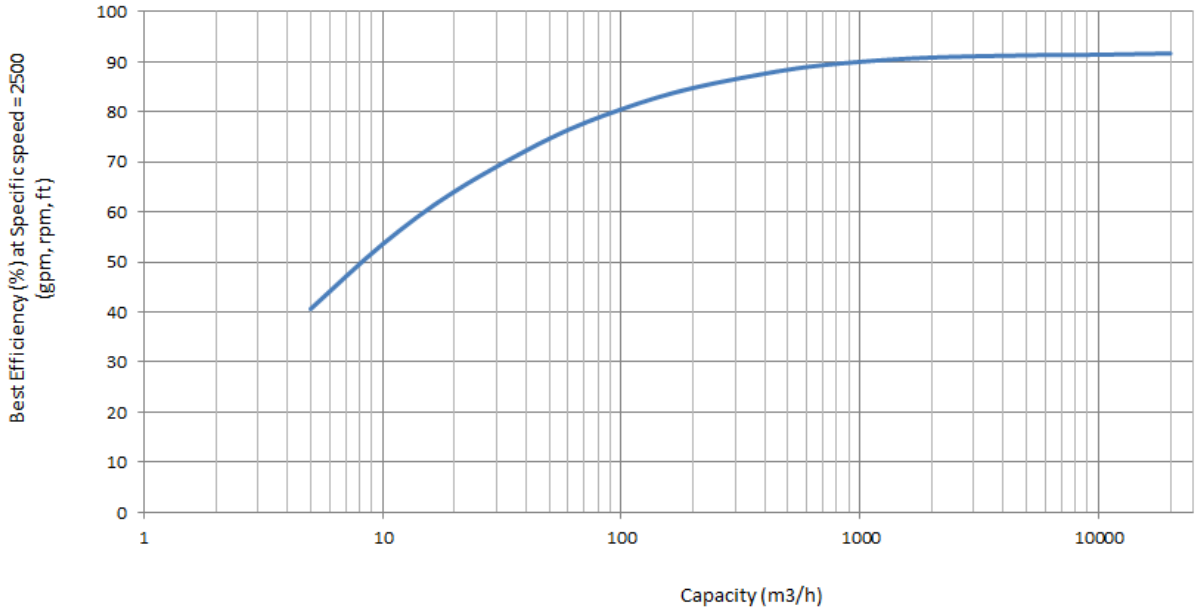
EFFICIENCY ESTIMATION BASED ON PUMP SPECIFIC SPEED

Specific speed, Ns = $N.Q^{0.5} / H^{0.75}$ (2)

N	Rotation speed in RPM
Q	Capacity in GPM or in m3/h
H	Head in Ft or in meter
Ns	Specific speed can be in (GPM, RPM, FT) or in (m3/h, RPM, m)



BEST EFFICIENCY

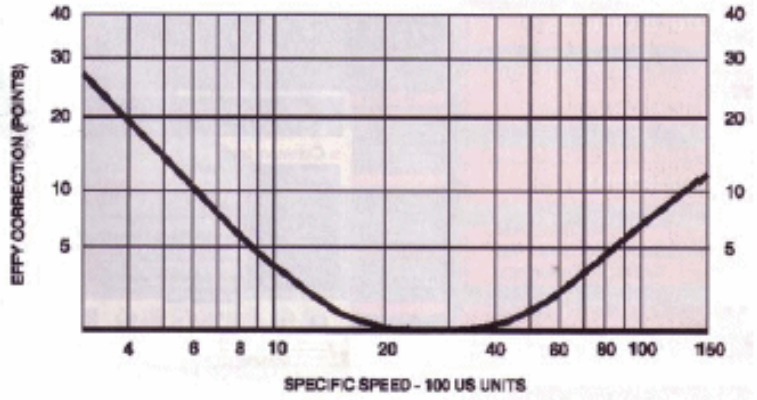


Best efficiency assume at Ns = 2500 (GPM, RPM, FT) can be expressed in formula:

Efb (%) = 0.1279(ln(Q))^3 - 3.4119(ln(Q))^2 + 30.521(ln(Q)) - 5.1945 , if Q in m3/h (3)

Efb (%) = 0.1279(ln(0.2271Q))3 - 3.4119(ln(0.2771Q))2 + 30.521(ln(0.2771Q)) - 5.1945, if Q in GPM

Efficiency shall be corrected if Ns not at 2500 (gpm, rpm, ft) by following curve.



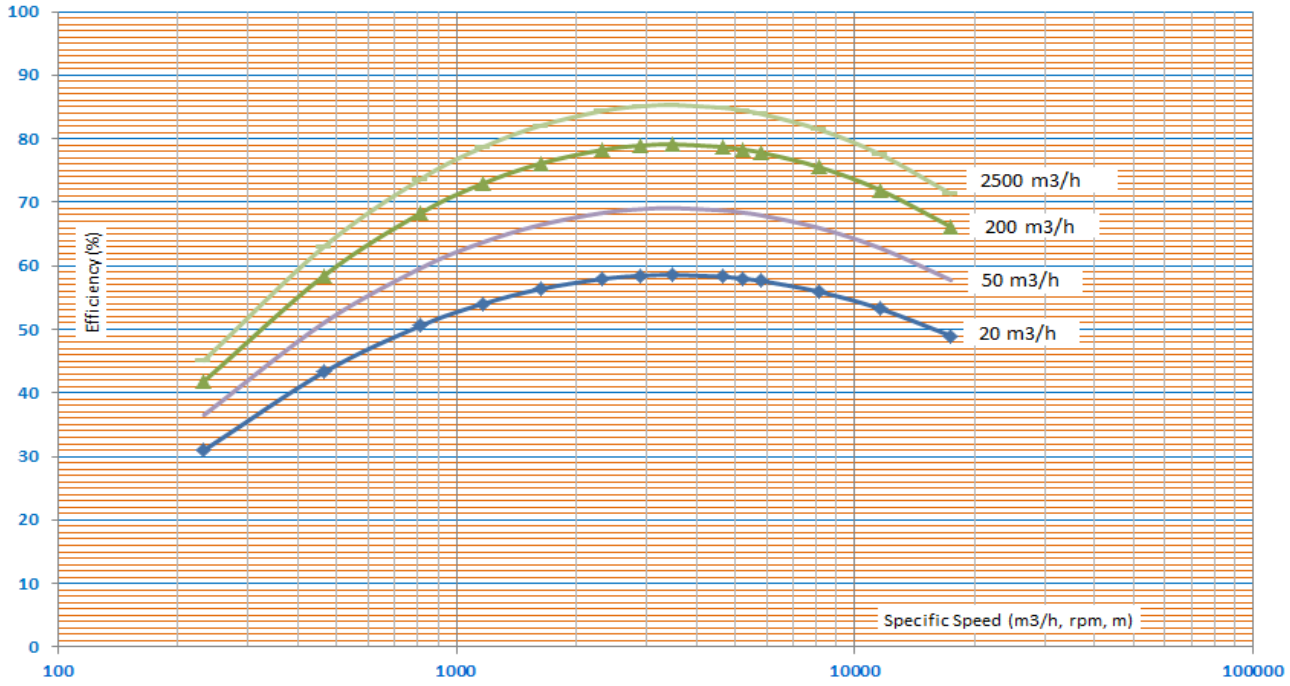
This curve can be expressed in formula:

Efcor (point) = 6.3328(Ln(0.861Ns))^2 - 101.5029*Ln(0.861Ns) + 407.5364, if Ns in (m3/h, RPM, m)* (4)

Efcor (point) =6.3328*(Ln(Ns))^2 - 101.5029*Ln(Ns) + 407.5364, if Ns in (GPM, RPM, Ft)

Corrected efficiency become:

Ef = Efb (1-0.01Efcor) (5)



FOLLOWING EXAMPLE IS APPLICABLE FOR SINGLE IMPELLER (SINGLE STAGE) PUMP.

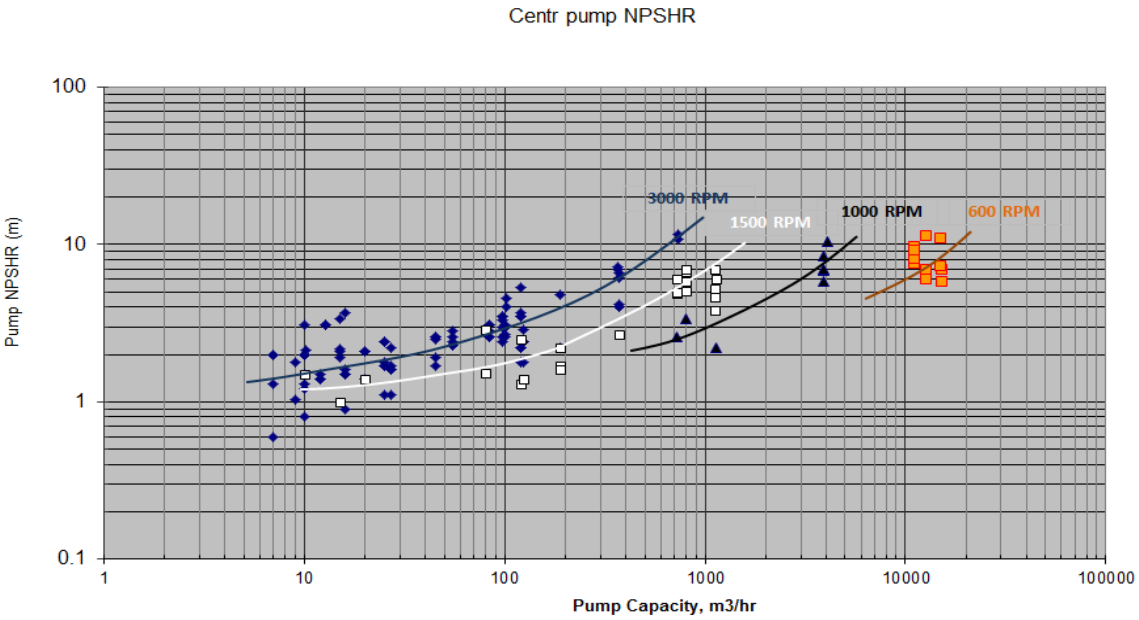
INPUT :

Capacity (Q, m3/h)	150	
Head (H, m)	32	This head shall be for single impeller only
Speed (N, rpm)	2980	

OUTPUT :

Spec. speed (Ns)	2712.69	*Specific speed, Ns = $N.Q^{0.5} / H^{0.75}$*
Best eff (Efb, %)	78.16	*Efb (%) = 0.1279(ln(Q))^3 - 3.4119(ln(Q))^2 + 30.521(ln(Q)) - 5.1945 , if Q in m3/h*
Eff Corr (Efcor, point)	1.23	*Efcor (point) = 6.3328*(Ln(0.861Ns))^2 - 101.5029*Ln(0.861Ns) + 407.5364, if Ns in (m3/h, RPM, m)*
Efficiency (Ef, %)	**77.20**	*Ef = Efb (1-0.01Efcor)*
Avrg eff as per eq (1)	60.61	

FOR MULTI STAGE SEE OTHER SHEETS ("Efficiency & NPSH", "More detail horizontal" and "More detail vertical")



Approached formula for NPSHR (Average, in meter) $= Q \times (5.8082 \times 10^{-10} \times N^2 + 2.7012 \times 10^{-6} \times N - 1.4161 \times 10^{-3}) + \{0.501 * \mathrm{Ln}(N) - 2.237\}$
Where Q in m3/h and N in RPM

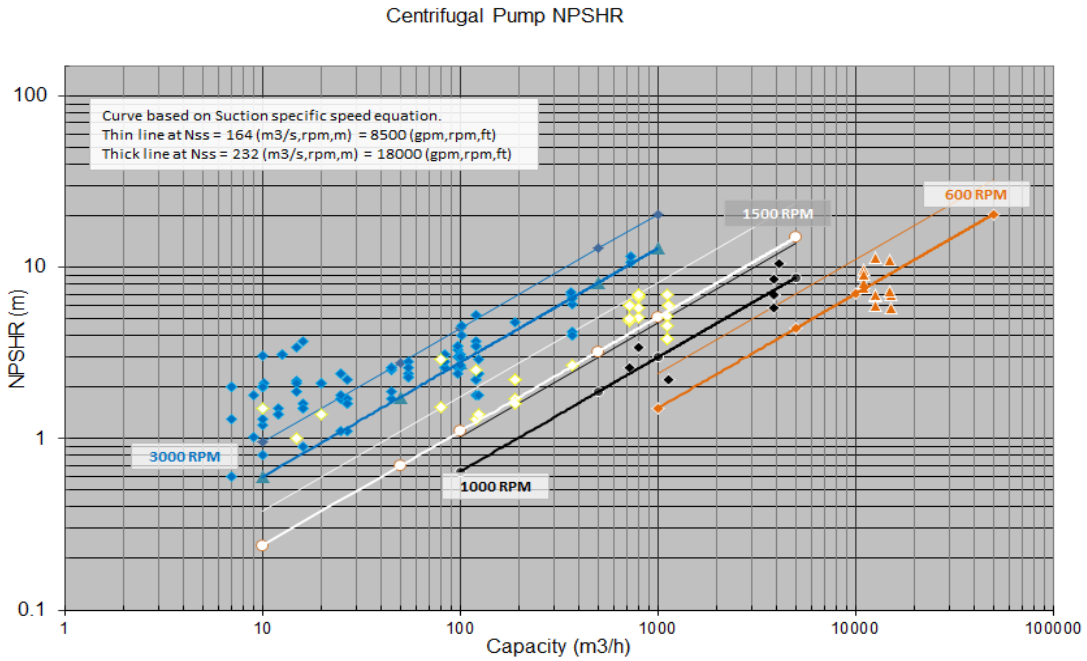
NPSHR estimation using Suction Specific Speed, Nss

Suction Specific Speed, Nss (=N.Q^0.5 / NPSHR^0.75)

Suction Specific Speed, Nss			Category or level
m3/s,rpm,m	(gpm,rpm,ft)	(m3/h,rpm,m)	
<164	<8500	<9874	very high NPSHR
165	8500	9874	high NPSHR
232	12000	13940	medium NPSHR
349	18000	20910	low NPSHR
465	24000	27880	very low NPSHR

How to reduce or select lower NPSHR
Using formula NPSHR = (N.Q^0.5 / Nss)^1.333:
1. Select lower speed (lower N) when NPSHR is not available
2. Lower speed cause bigger diameter. When bigger diameter is not prefered, select double suction
3. When double suction is not prefered, use inducer or can be vertical type when suction level is limited or combined

<u>Below chart based on formula NPSHR = (N.Q^0.5 / Nss)^1.333</u>



MANUALY ESTIMATION FOR CENTRIFUGAL PUMP NPSHR

INPUT:

Capacity (Q, m3/h)	150	75
Speed (N, rpm)	2980	2980

OUTPUT:

	Single suction				Double suction				Single suction with inducer		
	at Nss (m3/h, rpm, m)			Use average formula	at Nss (m3/h, rpm, m)			Use average formula	at Nss (m3/h, rpm, m)		
		10000	15000		10000	15000	20000			27000	
	at Nss (m3/s, rpm, m)				at Nss (m3/s, rpm, m)				at Nss (m3/s, rpm, m)		
		167	250		167	250	333			450	
	Highest NPSH	High NPSH	Middle NPSH		Middle NPSH	Low NPSH	Very Low NPSH			Very Low NPSH	
NPSHR (m) =		**5.62**	**3.27**	3.54	**3.54**	**2.06**	**1.40**	2.66	**Can be:**	**1.49**	

EFFICIENCY, NPSHR, SPEED, AND TIP DIAMETER ESTIMATION

Input data to be filled in red and brown cells only

This calculation method is applied in "More detail horizontal" and "More detail vertical" worksheets

Description	Unit	Quantity	Note, remark
Capacity, Q	m3/h	300	
Head, H	m	64	
NPSHA	m	9.2	
Margin for NPSH	m	1	
NPSHR shall be lower than	m	8.2	
Trial Speed, N (example: when driven by motor 2980, 1480, 980, 730, 580 for 50 Hz motor, or 3580, 1780, 1180, 890, 700 for 60 Hz motor:	RPM	**3500**	*Selected and trialed speed shall give one NPSH in table below smaller than required NPSHR. For turbine driven or with increasing gear, speed may higher than motor driven direct couple.*
Check whether selected speed still give NPSHR below (NPSHA-margin), (Y/N)		Y	
Possibility suction type (1'st impeller)		Single Suction without inducer	
Select suction type using code number *Fill with: A. Single suction without inducer,* *B. Double Suction, C. Single suction with inducer*		**A**	
Possibility NPSHR, lower	m	**6.44**	
higher	m	**11.05**	
highest	m		
Select and trial max. tip speed, U	m/s	**35**	*Select untill Hmax near but higher than Havg*
Design head coefficient, Yd		**0.55**	*Head coefficient, most data: 0.4 up to 0.6, except low speed to provide low NPSHR may near 1 (radial exit)*
Check whether selected U and Yd is OK		OK	
Max. head per impeller, Hmax=Y.U^2/g where Y = Cu/U	m	68.7	
Number of impeller		**1**	
Average head eah impeller, Havg	m	64.00	
Average tip diameter	mm	**191.0**	
Head coefficient as per required condition, Y		0.513	
Capacity at each impeller eye of 1'st impeller *(half of capacity for double suction)*	m3/h	300	
Specific speed of first impeller	m3/h, rpm,m	2679	
Calculated 1'st impeller efficiency	%	80.58	
Specific speed of next impellers	m3/h, rpm,m	0.00	
Calculated next impellers efficiency	%	0.00	
Average efficiency	%	**80.58**	

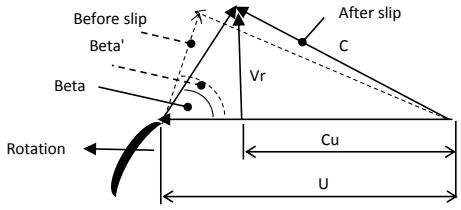
NPSHR range in meter based on Suction Specific Speed, Nss (=N.Q^0.5 / NPSHR^0.75)

Single suction			Double suction			Single suction with inducer		
at Nss (m3/h, rpm, m)			at Nss (m3/h, rpm, m)			at Nss (m3/h, rpm, m)		
	10000	15000		15000	20000		27000	
at Nss (m3/s, rpm, m)			at Nss (m3/s, rpm, m)			at Nss (m3/s, rpm, m)		
	167	250		250	333		450	
Highest NPSH	High NPSH	Middle NPSH	Middle NPSH	Low NPSH	Very Low NPSH		Very Low NPSH	
	11.05	**6.44**		**4.06**	**2.76**	**Can be:**	**2.94**	

Tip speed selection	m/s	
Pumps fitted with elastomer impellers	26	
Higher slurry concentrations and larger solids	30	
Medium slurries up to 25% solids and 200 micron solids	35	
Dirty water	40	Sea water, river water, etc.
Clean liquid & hot with suitable mat'l	55	BFW, clean process
Clean liquid cold & warm with suitable mat'l	85	Demin water, clean process

Head coefficient : Y = Cu / U

Flow coefficient : Cq = Vr / U



Velocity triangle

THIS CALCULATION METHOD IS APPLIED IN "More detail horizontal" and "More detail vertical" worksheets