CHAPTER - 11

OPERATION AND MAINTENANCE

11.1 INTRODUCTION

Generally the reliability of a pumping station depends on its design, construction, installation of equipment, reliability of the equiment, how you operate and the effectiveness of the regular preventive maintenance programmes. Finally after construction testing and commissioning the reliability of the pumping station depends on how you operate and maintain it. Therefore the operation and maintenance aspects of a pumping installation are of great importance in achieving the final goal. Having trained personnel, proper equipment, required spares, maintenance schedules, knowing the importance of the operation and maintenance and giving due consideration from the very beginning is very important.

11.2 OPERATION

Centrifugal pumps are designed to function at a designed head and a capacity at a given speed at this duty point the efficiency will be at its maximum value and this point is termed the best efficiency point (BEP). If you operate the pump well away from this point operational problems will set in and the pump will not run efficiently. Generally the range between 60% to 120% of the capacity at BEP can be termed as a satisfactory range to operate a pump provided $NPSH_A$ conditions and motor capacity are satisfied beyond 100% BEP capacity.

It should be noted that when you operate the pump at very low flows the temperature of the water within the pump will rise due to the difference between break power consumed and water power produced and hence the pump casing will also get heated up.

11.2.1 STARTING AND STOPPING METHODS

All centrifugal pumps must be fully primed before starting and the pump shaft can be rotated manually. Pump start-up procedure depends on the shape of the power curve. If the shut off head power does not exceed the safe motor power pump could be started with the delivery valve in closed position. Otherwise the pump should be started with delivery valve in the open position.

When the pump is started with the delivery valve in closed position after switching on the motor. the pressure gauge reading in the delivery side should be observed. If the pressure has developed then the delivery valve can be opened gradually watching the delivery side pressure gauge. When the valve is fully opened. delivery side gauge reading should indicate the correct delivery head. When stopping a similar pump. the delivery valve should be closed gradually until fully closed before stopping the motor. Suction side valves must be fully opened during starting and when a pump is in operation.

Whatever the case may be the operators should be trained to follow the pump manufacturer's starting and stopping procedures.

11.2.2 OPERATIONAL PROBLEMS

Operational problems in centrifugal pumps can be due to mechanical. electrical or hydraulic defects.

Mechanical defects can cause noise. vibration and overheating.

Hydraulic defects in the suction side and system can cause the pump to fail to deliver the expected capacity at the designed head. develop cavitation noise and vibration.

Electrical problems in the motor control section can fail to start the motor or to trip the running motor.

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Drop in capacity and power absorbed and loss of priming are usually due to air leakage into the pump from the suction side or through the stuffing box.

If the pipeline and the pump are not adequately protected against surge pressure damages can result to pump and pipeline.

Wrong determination of head will cause the pump to operate away from the best efficiency point either at a reduced or over capacity.

If sufficient NPSH is not available. cavitation will set in. Throttling the pump can solve the problem but energy will go waste. Trimming the impeller with pump manufacturers advice or to change the impeller to suit the system head are better solutions.

Running pumps in series and parallel can cause operational problems. This was discussed in Chapter 1.

Wrong mounting of the impeller or wrong direction of rotation of the impeller will cause drop in head and capacity and also create noise.

Impeller should be mounted in such a way so that the back side of the impeller vanes will rotate towards the volute opening in the delivery side with volute radius increasingly.

If the pump and the motor are not mounted with proper alignment, noise, vibration and premature failure of bearings will occur.

Stuffing box packing troubles are very common in centrifugal pumps. If they are not properly fitted air leakage, overheating and shaft sleeve wear can occur.

Another common problem is the premature failure of pump bearings. This can be due to improper fitting, misalignment, cavitation improper lubrication etc.

11.3 MAINTENANCE

Human beings who can talk and eat still fall sick and take treatment at various levels. Plant and Equipment cannot talk but do a lot of work. Therefore they need regular maintenance to prevent them from falling sick. If you do not maintain regularly the result will be a sudden break-down causing interruptions to the service and unnecessary costs.

Annual preventive maintenance programmes should be prepared taking into consideration the past records and strictly according to the manufacturer's instructions. Annual preventive maintenance can be divided into;

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* **Daily maintenance**
* **Monthly maintenance**
* **Quarterly**
* **Annual**
* **Complete, Over-hauls.**

Under each category, work that would be carried out should be identified and persons authorised to do the work should also be identified.

In pumping stations, pumps, motors, electrical switch gear and controls being the main equipment, need strict and closely monitored preventive maintenance programmes. The following should be recorded hourly by the operator

* **Voltage**
* **Current**
* **Suction gauge reading**
* **Delivery gauge reading**
* **Flow rate**
* **kilowatt - hour meter reading**

The above readings will be very useful to analyse operational problems. Any unusual observations should be recorded in the remarks column.

Preventive maintenance records should be readily available in the pumping station for inspection.

Preventive maintenance cannot stop the wear and tare of the moving parts of the machinery . Therefore the moving parts of machine wear, and the performance decreases. Performance or the efficiency of the pumping station can be checked by monitoring the factor kWh/m^3. Especially in the case of heavy duty pumps the efficiency of the pumps should be checked annually, and complete overhauls should be carried out whenever the efficiency falls below stipulated levels.

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Analysis of the vibration levels at the bearings can also predict the time to change bearings, however the economics of this should be studied.

Stocking of spare parts and other necessary items, tools etc. is also important.

Personnel required to carry out, their skills and training are also important to make the preventive maintenance a success.

11.4 MAINTENANCE OF ELECTRICAL EQUIPMENT

Most types of electrical machinery require a minimum of maintenance confined only to minor lubrication but preventive maintenance and routine inspection techniques conversely prolong the life of electrical machinery. Induction type machines require only periodic lubrication and blowing out dust. However the measurement of level of insulation of motors can predict a major break down before the failure. Because maintenance is usually confined merely to routine lubrication and inspection, it should not be ignored. Senses sight, noise, smell and touch can be made use of in detecting various defects in machines. A noisy motor is an indication of worn bearings, overloading or single phasing. A burnt odour is an indication of overload or insulation breakdown. Overheated bearings or windings can be detected by the touch. As a thumbs rule we can say that the surface should not be so hot that one cannot hold one's hand on it.

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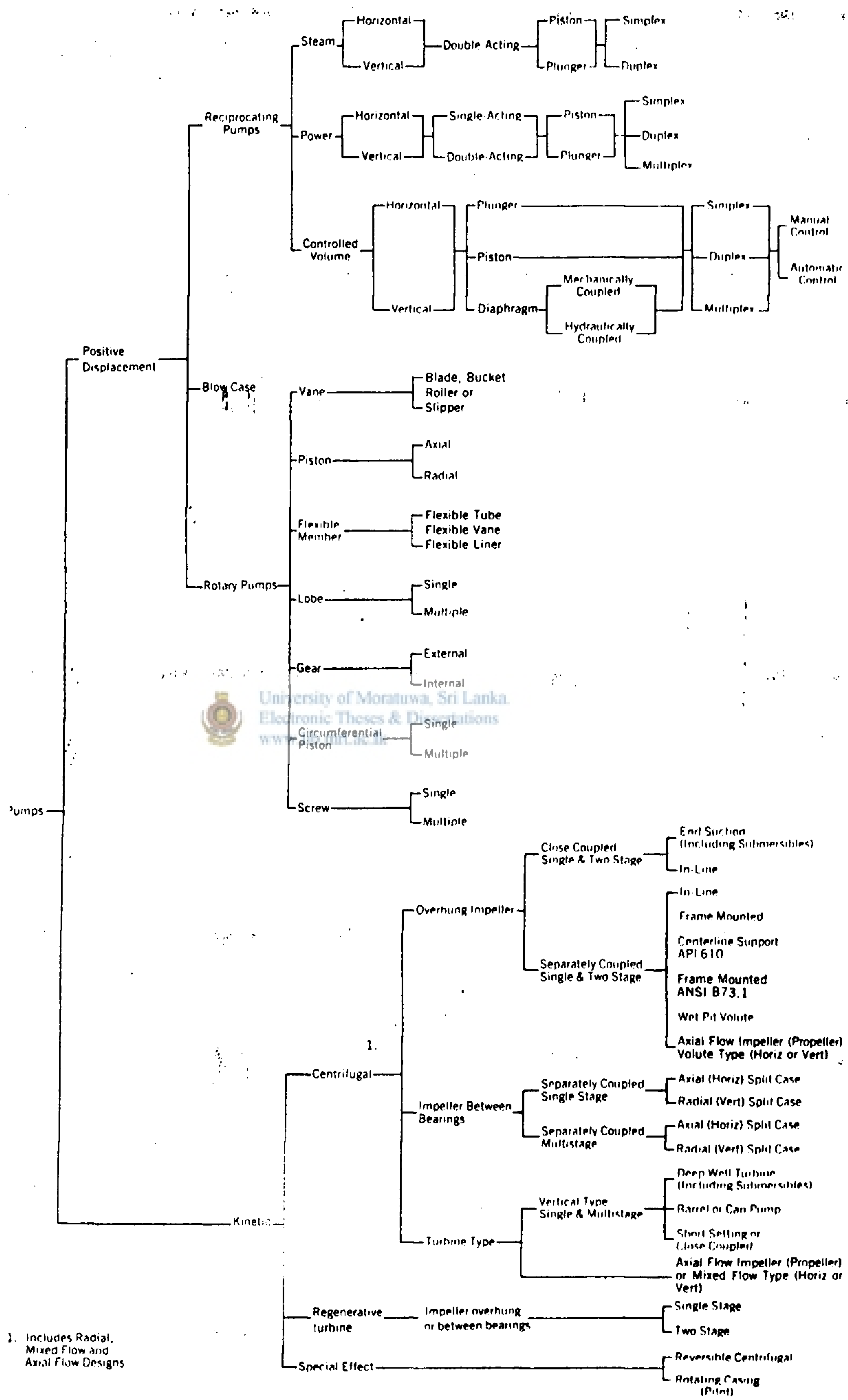
TYPES OF PUMPS



1. Includes Radial, Mixed Flow and Axial Flow Designs

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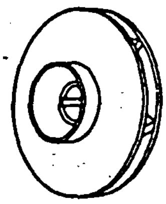
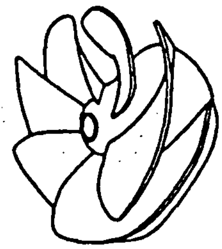
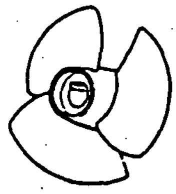
Centrifugal	Mixed Flow	Axial Flow
		

Impeller Types

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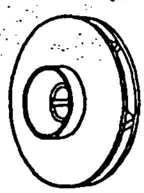
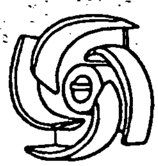
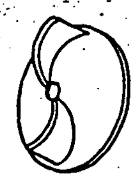
Closed	Open	Clogless
		

Closed and Open Impellers

Bore (mm)	High head centrifugal pumps	Medium head diffuser casing pumps	Bore (mm)	Low head pumps: Horizontal Mixed	Horizontal Axial	Vertical Mixed	Vertical Axial
200	65 %	-	600	79 %	77 %	78 %	76 %
250	68	-	700	80	78	79	77
300	71	69	800	81	79	80	78
350	74	71	900	82	80	81	79
400	75	73	1,000	83	81	82	80
450	77	75	1,200	84	82	83	81
500	79	76	1,350	84.5	82.5	83.5	81.5
600	83	79	1,500	85	83	84	82
700	83.5	80	1,650	85.5	83.5	84.5	82.5
800	84	81	1,800	86	84	85	83
900	84.5	82	2,000	86	84	85	83
1,000	85	-	2,200	-	-	86	84

Pump Efficiencies

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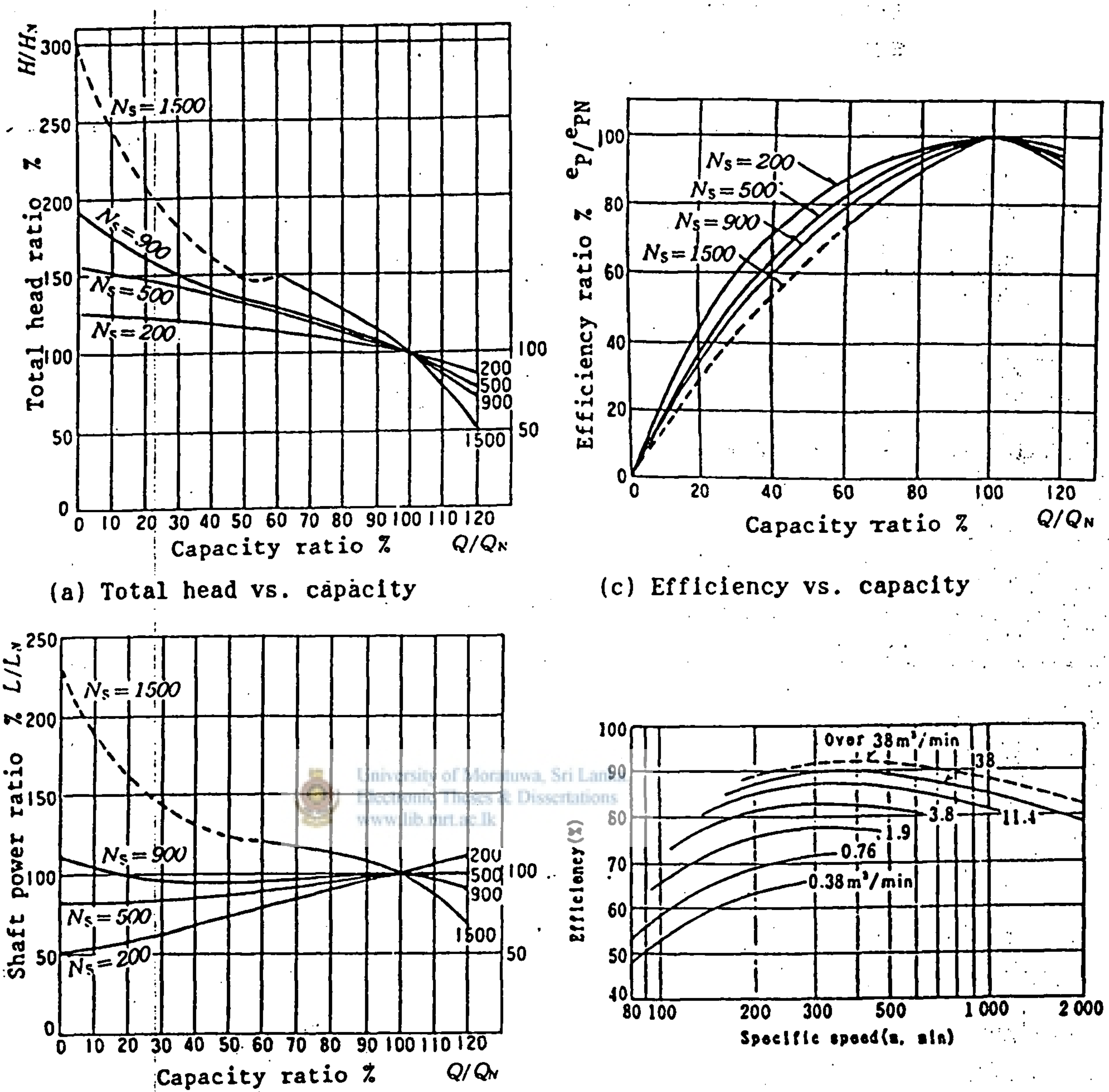
Transmission Method	Transmission Efficiency
Direct coupling	1.00
Gears (single stage)	
Helical gears	0.95 ~ 0.97
Bevel gears	0.94 ~ 0.96
Planetary gears	0.95 ~ 0.98
Fluid coupling	0.95 ~ 0.97
Flat belt drive	0.90 ~ 0.93
V-belt drive	0.93 ~ 0.95

Transmission Efficiencies

Annexure 1.4



(a) Total head vs. capacity

(c) Efficiency vs. capacity

(b) Shaft power vs. capacity

(d) Max. efficiency vs. specific speed

Pump Characteristics for Different Specific Speed

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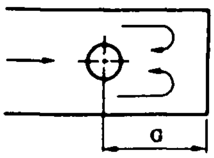
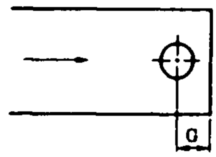
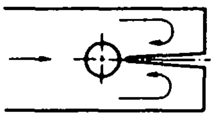
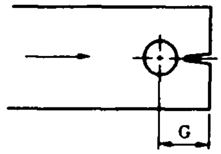
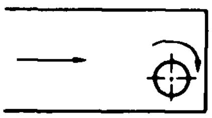
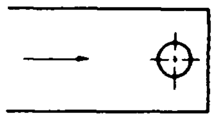
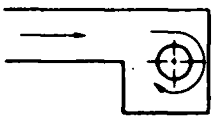
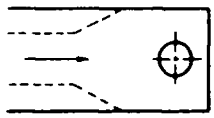
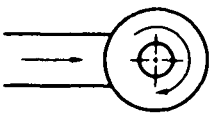
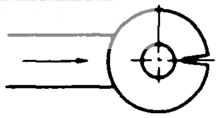
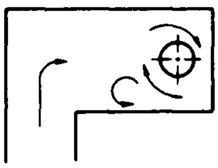
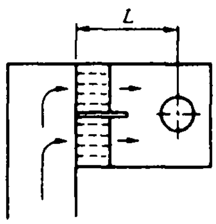
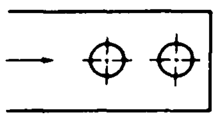
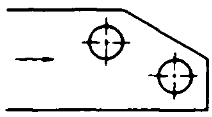
Undesirable suction sump		Improvement	
	Turbulent in flow behind suction pipe If the back wall clearance is excessive, vortexes develop and grow at the rear of suction pipe.		Back wall clearance should be about 1.0~1.2D.
	Same as above		Back wall clearance should be about 1.5D.
	Swirling flows develop		Suction pipe is shifted to the center of suction sump
	Same as above		The center of the intake channel should be aligned with the center of the suction sump.
	Swirling flows develop in a circular suction sump.		A swirling flow prevention wall should be installed.
	Swirling flows develop		① A laminar flow protection device should be installed upstream of the suction sump. ② The suction pipes should be separated sufficiently. ③ Flow velocity should be decreased.
	*1 Turbulent flows develop around the downstream suction pipe.		One suction pipe is slightly shifted in the transverse direction.

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Undesirable suction sump layouts and their improvements

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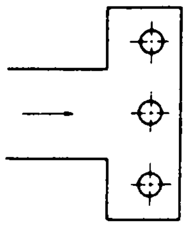
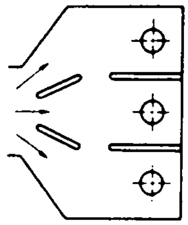
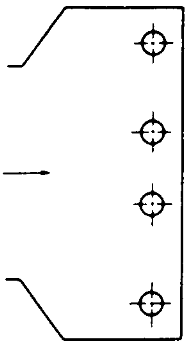
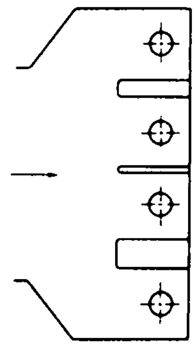
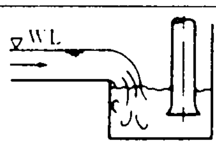
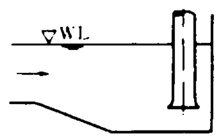
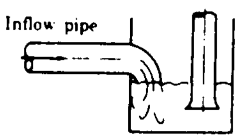
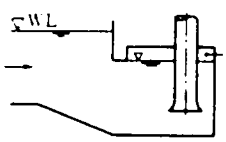
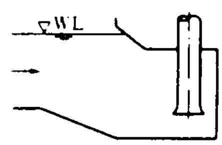
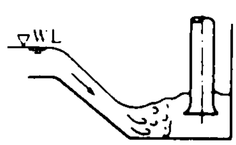
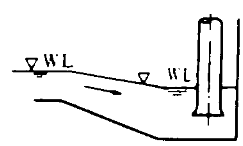
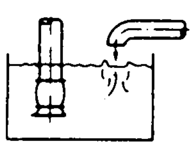
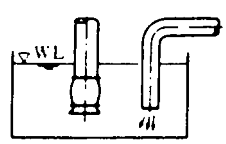
Undesirable suction sump shape		Improvement	
	Turbulent flows develop around the right and left suction pipes		Laminar flow protection walls or partition walls should be installed.
	Vortexes develop readily when the pump arrangement widens the suction sump.		Partition walls should be installed to control the flow velocity in the suction sump and the flow velocity to the bellmouth.
	Direct outlet into the suction sump produces turbulent flow and air entrainment.		The intake channel should be sloped.
	Same as above		The inflow pipe level should be lowered and the intake channel should be sloped.
	Air pocket		A vent pipe should be installed or the front of the sump should be tapered.
	Supercritical flow		The flow should be changed to ordinary flow.
	Above water release causes air entrainment.		Water should be released below sump surface.

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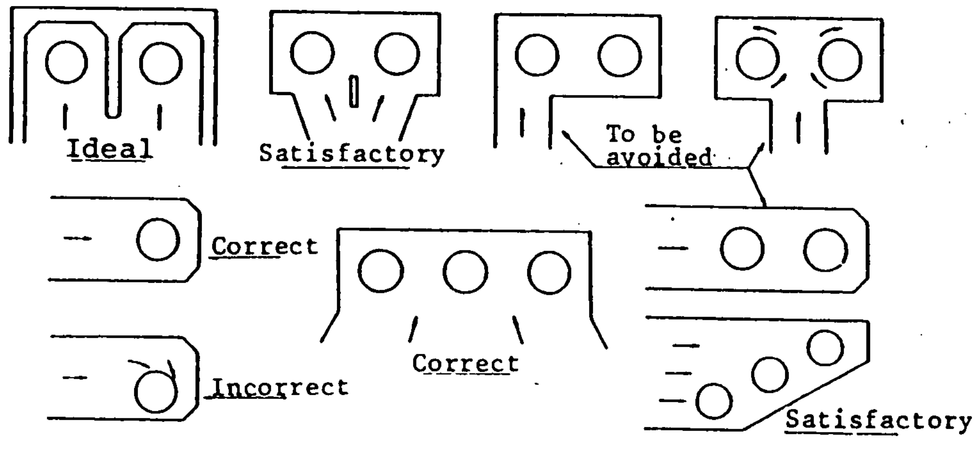
Undesirable suction sump shapes and their improvements



Sump Arrangements

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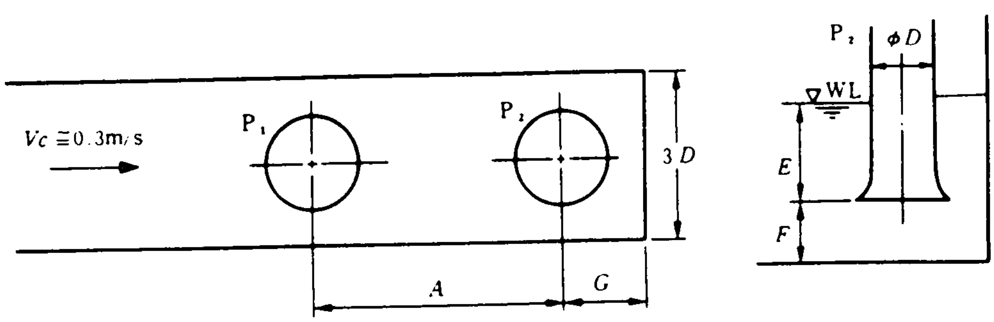
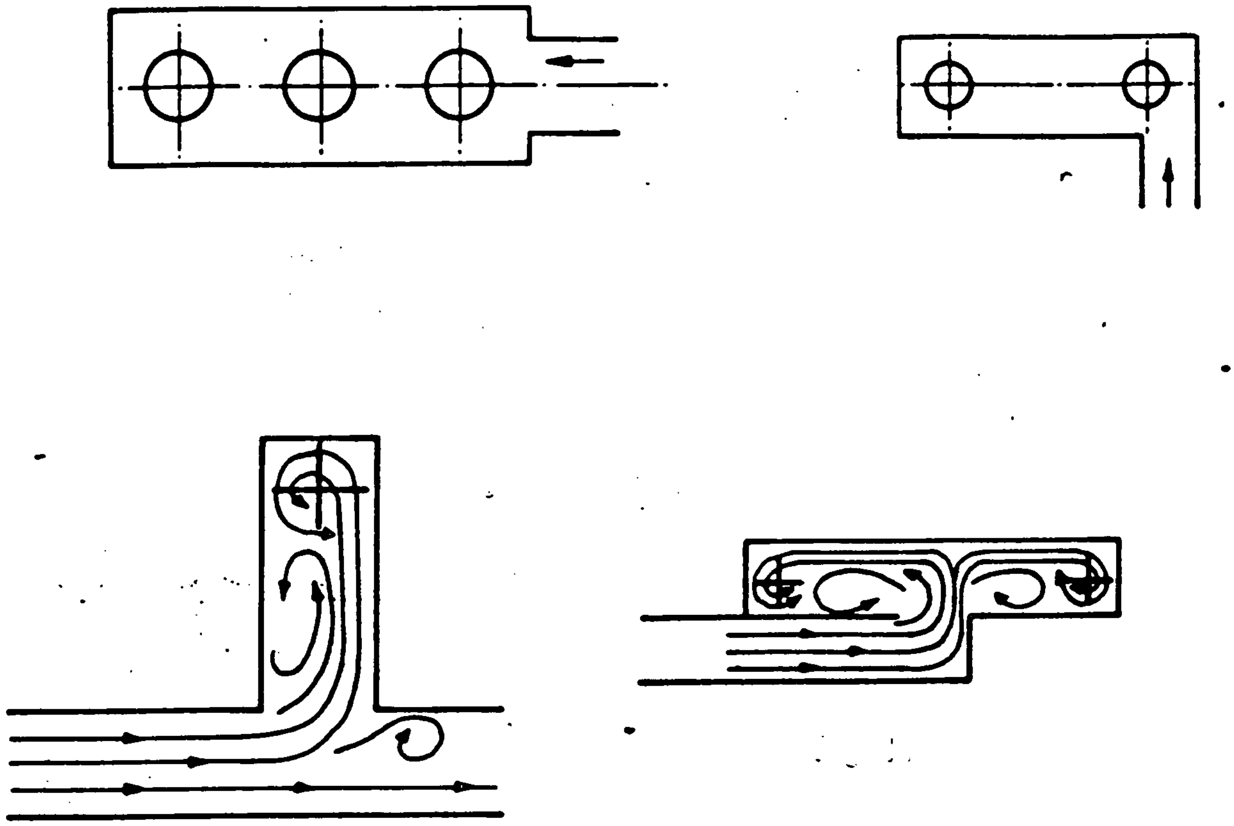


Pumps (suction pipes) arranged linearly in the direction of flow



UNSATISFACTORY SUMPS

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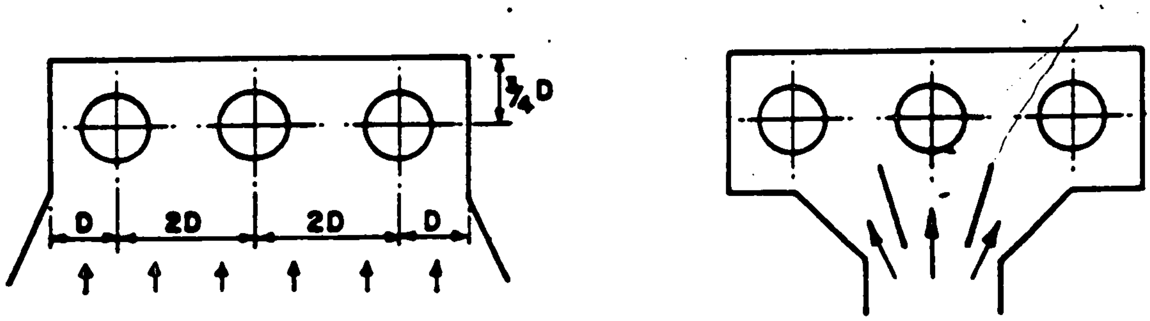


SATISFACTORY SUMPS

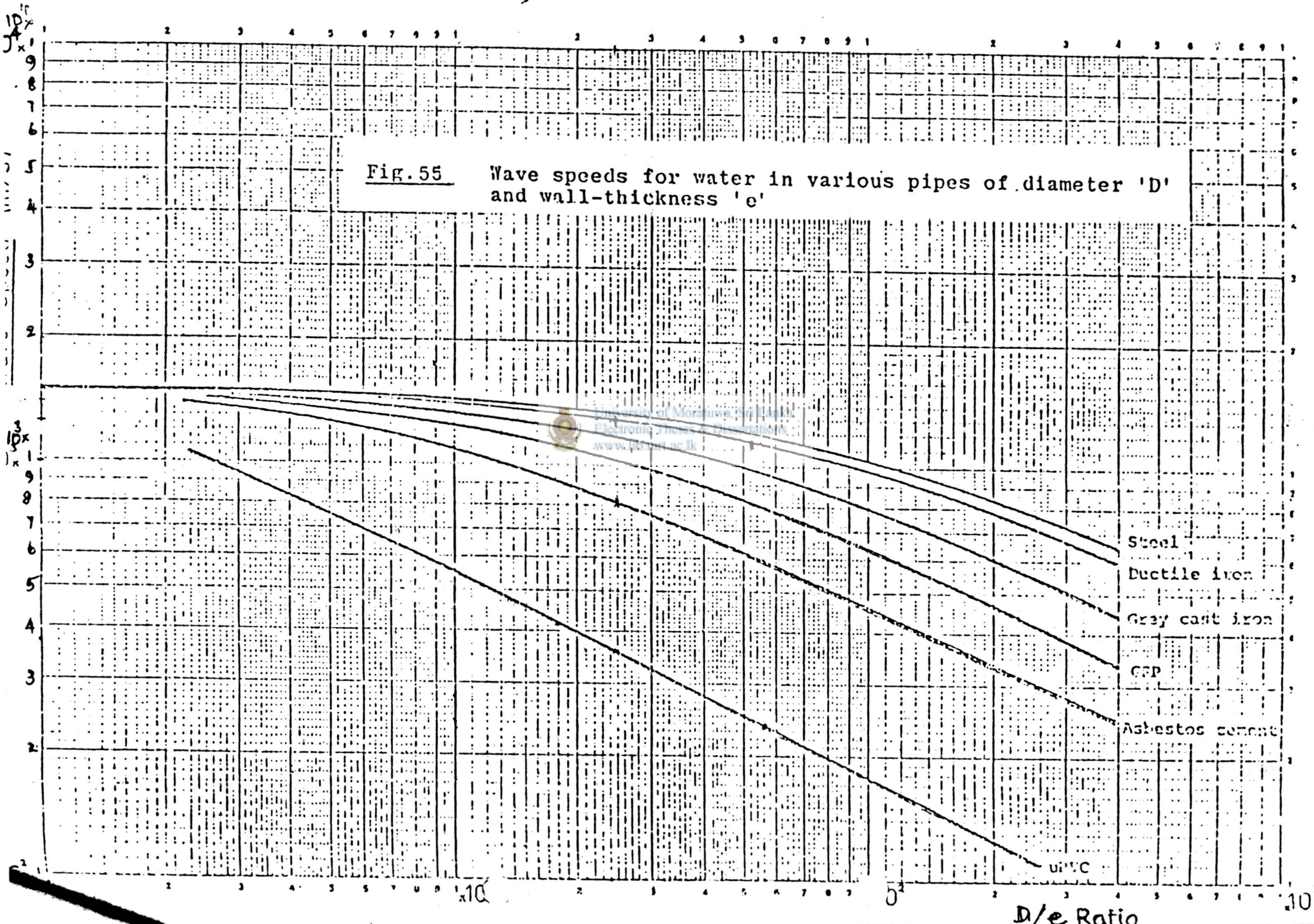


Fig.55 Wave speeds for water in various pipes of diameter 'D' and wall-thickness 'e'

Annexure 4.1

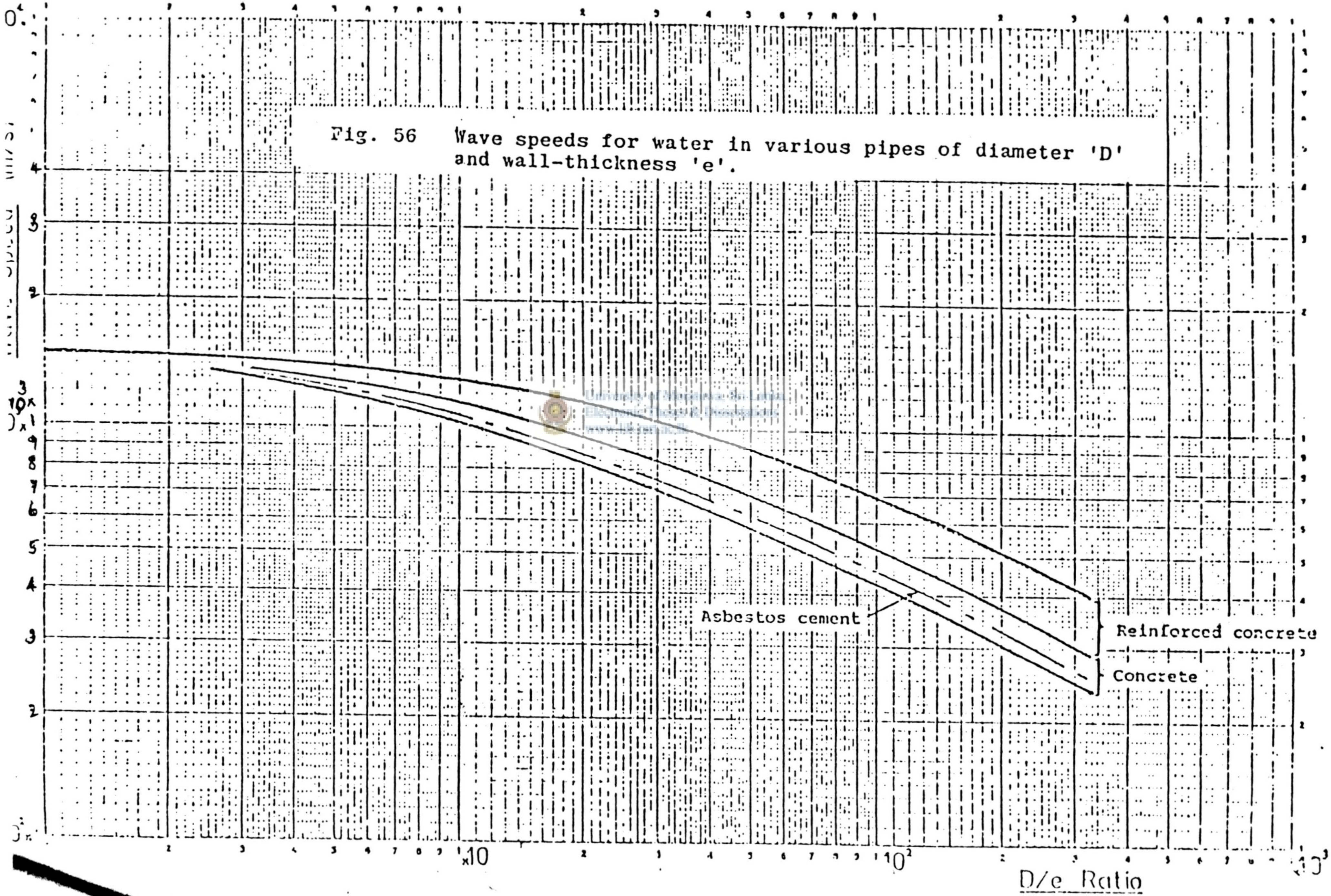
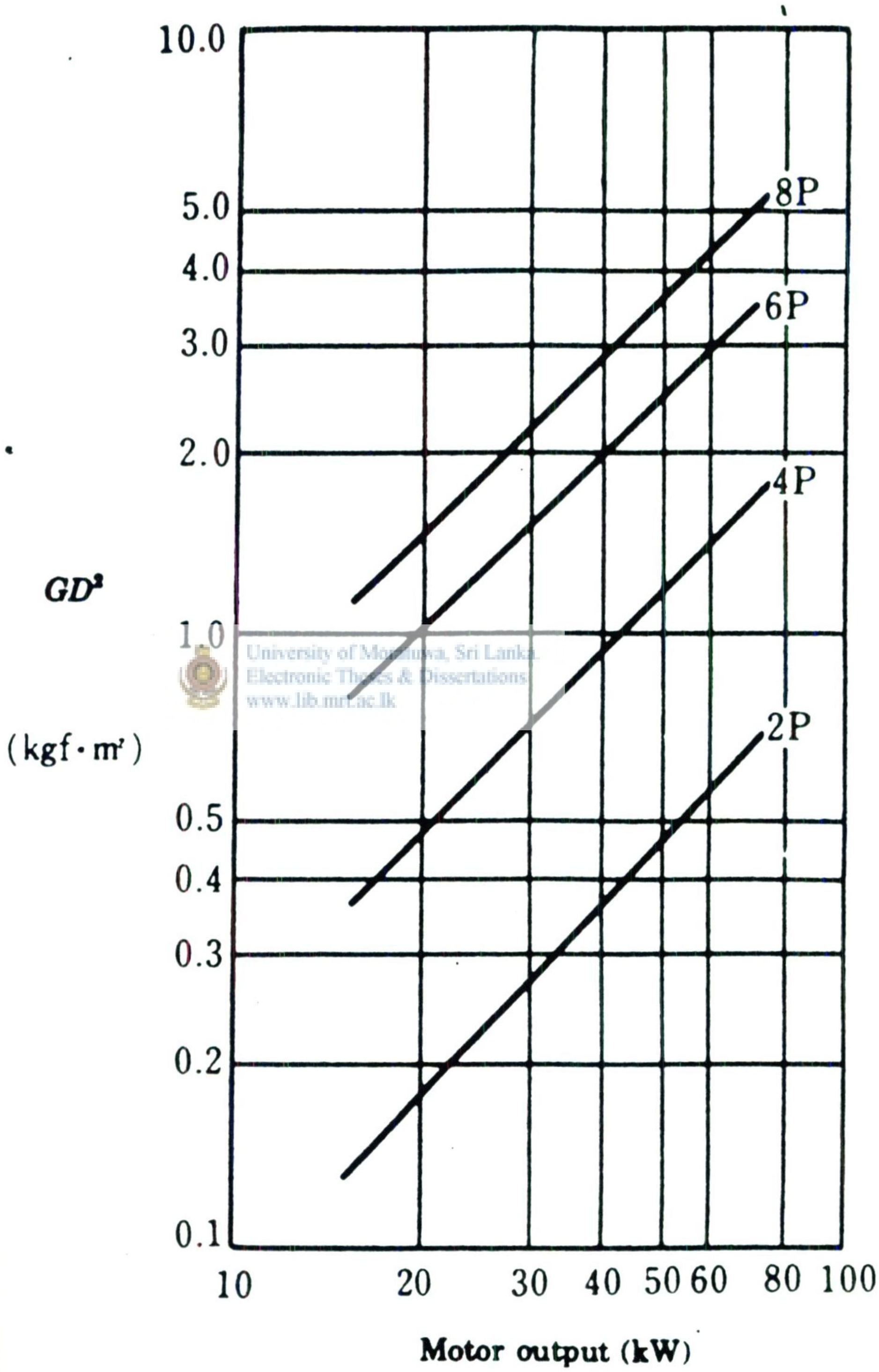


Fig. 56 Wave speeds for water in various pipes of diameter 'D' and wall-thickness 'e'.

Annexure 4.2

Annexure 4.3



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GD^2 diagram for squirrel cage type motor (200 and 400 V class)

The following nomograms serve to illustrate the ranges over which Class B and Class C can be used.

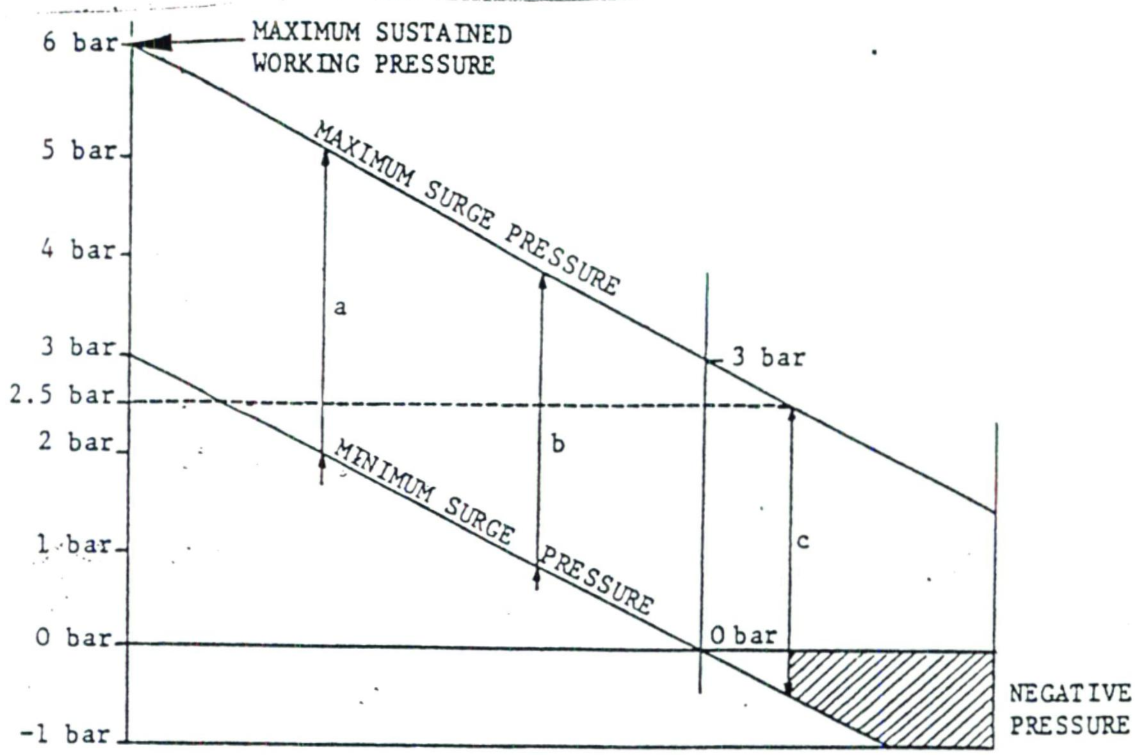

Fig 45

The vertical line(a) and (b) illustrate 2 possible surge pressures. The vertical line (c) is not allowable as it passes into the negative pressure area.

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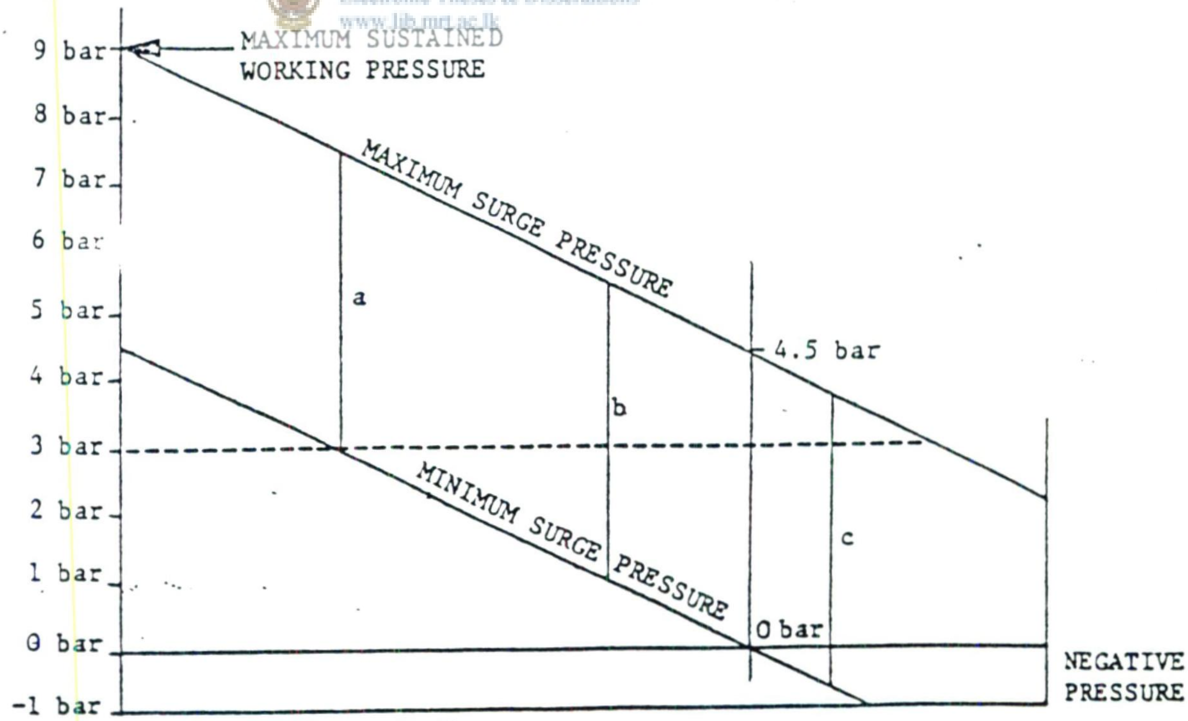
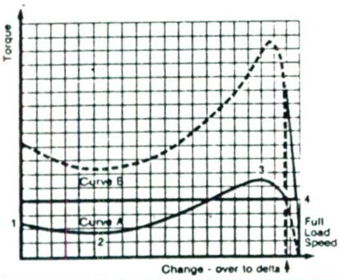


The vertical lines a, b and c illustrate 3 possible allowable surge pressures.

Annexure 5.1

Performance Data

STANDARD PERFORMANCE
Design NY (BS4999 Part 112)**
Suitable for Star Delta Starting
**** Previously Part 41, Design A**



Typical Speed/Torque Curve
(⅄△ Starting)

Curve (A) - Star connected
Curve (B) - Delta connected

1) Starting Torque or Locked Rotor Torque
2) Pull Up Torque or Run Up Torque
3) Pull Out Torque or Breakdown Torque
4) Full Load Torque (DELTA RUN)

Torque/Speed Curves for specific motors can be supplied on request.

kW	hp	Full Load Speed	Frame Size	FLC (Amps) 380 volts	FLC (Amps) 415 volts	Efficiency			Power Factor			D-O-L Starting % of Full Load		Star Delta Starting % of Full Load		Pull Up Torque % FLT Star	Pull Up Torque % FLT D-O-L	Pull Out Torque % FLT in △	Noise Levels dB(A)§		Rotor Inertia (J) WK² in kgm²
						FL	¾L	½L	FL	¾L	½L	LRT	LRC	LRT	LRC				Standard	Low Noise Option	
18.5	25	725	7-AD225S*	41	38	89.5	89	88	.75	.68	.56	190	500	53	150	35	120	280	64	—	0.73
22	30	725	7-AD225M*	49	45	90	89.5	88.5	.75	.68	.56	180	510	50	150	35	120	280	64	—	0.87
30	40	970	7-AD225M*	60	55	91	91	90	.83	.78	.70	190	650	60	200	40	135	280	72	—	0.87
		735	7-AD250S*	67	61	91	90.5	89	.75	.68	.57	180	520	50	160	35	120	280	66	—	1.17
37	50	1465	7-AD225S*	72	66	91	91	89	.86	.80	.72	200	680	60	220	45	150	300	80	76	0.57
		975	7-AD250S*	74	68	92	91	89	.83	.78	.70	180	630	55	200	40	135	280	76	—	1.07
		735	7-AD250M*	80	73	91.5	91	90	.77	.70	.60	180	520	50	160	35	120	280	66	—	1.28
45	60	2950	7-AD225M*	84	77	90	89	87	.91	.90	.84	200	670	60	210	40	135	300	84	—	0.31
		1465	7-AD225M*	86	79	91.5	91.5	89	.87	.81	.74	200	650	60	210	45	150	300	80	76	0.67
		975	7-AD250M*	88	81	92.5	92	90	.84	.79	.71	180	630	55	200	40	135	260	76	—	1.28
		735	7-AD280S	96	88	92	91.5	90	.77	.72	.60	170	680	50	210	35	120	230	71	—	2.24
55	75	2955	7-AD250S	102	93	90.5	89.5	87.5	.91	.90	.84	180	770	55	250	35	120	300	84	—	0.60
		1470	7-AD250S*	107	98	91.5	91	89	.85	.80	.70	240	600	75	190	50	170	280	81	77	1.07
		985	7-AD280S	105	96	92.5	92	90.5	.86	.81	.74	180	750	55	240	40	135	250	80	—	2.24
		735	7-AD280M	118	108	92.5	92	91	.77	.72	.60	170	680	50	210	35	120	230	71	—	2.56
75	100	2960	7-AD250M	135	124	91.5	90.5	88	.92	.91	.86	180	770	70	250	35	120	300	84	—	0.69
		1470	7-AD250M*	145	133	92	91.5	90	.85	.81	.72	240	600	75	190	50	170	280	81	77	1.37
		985	7-AD280M	143	131	93	92.5	91	.86	.81	.74	180	750	55	240	40	135	250	80	—	2.56
		735	7-AD315S	153	140	93	92.5	91.5	.80	.77	.69	150	770	45	240	30	100	220	74	—	3.83
90	125	2965	7-AD280S	157	144	92	91	88.5	.94	.93	.91	155	800	50	260	35	120	280	92	84	1.21
		1475	7-AD280S	164	150	92.5	92	90	.90	.87	.83	220	850	67	270	50	170	280	84	81	1.89
		985	7-AD315S	166	152	93.5	93	91.5	.88	.85	.78	160	850	50	260	35	120	250	80	—	3.83
		735	7-AD315M	183	168	93	92.5	91.5	.80	.77	.69	150	770	45	240	30	100	220	74	—	4.36
110	150	2965	7-AD280M	192	176	92.5	91.5	89	.94	.93	.91	155	800	50	260	35	120	280	92	84	1.35
		1475	7-AD280M	200	183	93	92.5	90.5	.90	.88	.84	220	850	75	270	50	170	280	84	81	2.14
		985	7-AD315M	203	186	93.5	93	91.5	.88	.85	.78	160	850	50	260	35	120	250	80	—	4.36
		735	7-AD315L	224	205	93.5	93	92	.80	.77	.69	150	770	45	240	30	100	220	74	—	5.09
132	175	2965	7-AD315S	230	211	92.5	91.5	89.5	.94	.93	.91	155	830	55	270	35	120	280	93	84	2.12
		1480	7-AD315S	237	217	93	92.5	90.5	.91	.89	.85	190	850	60	270	35	120	260	84	81	3.09
		985	7-AD315L	242	222	94	93.5	92	.88	.85	.78	160	850	50	260	35	120	250	80	—	5.09
		735	7R-AD315L	269	246	93.5	93	92	.80	.77	.69	150	770	45	240	30	100	220	74	—	8.35
150	200	2965	7-AD315M	261	239	93	92	90	.94	.93	.91	155	850	50	275	35	120	280	93	84	2.29
		1480	7-AD315M	268	245	93.5	93	91.5	.91	.89	.85	190	870	53	275	35	120	260	84	81	3.37
		985	7R-AD315L	275	252	94	93.5	92	.88	.85	.78	160	850	50	260	35	120	250	80	—	7.90
		735	7J-AD355S	288	264	94	93.5	92	.84	.80	.72	140	820	40	250	25	90	220	79	—	9.20
185	250	2965	7-AD315L	322	295	93	92	90	.94	.93	.91	155	850	60	275	35	120	280	93	84	2.63
		1480	7-AD315L	327	299	93.5	93	91.5	.92	.89	.86	190	870	60	275	35	120	260	84	81	3.79
		985	7J-AD355S	334	306	94.5	94	92.5	.89	.86	.79	150	850	45	260	25	90	260	81	—	9.20
		735	7-AD355M	356	326	94	93.5	92.5	.84	.80	.72	140	820	40	250	25	90	220	79	—	10.91
200	270	2965	7R-AD315L	347	318	93	92	90	.94	.93	.91	155	850	50	275	35	120	280	93	84	3.21
		1480	7R-AD315L	355	325	93.5	93	91.5	.92	.89	.86	190	870	60	275	35	120	260	84	81	4.65
		985	7-AD355S	360	330	94.8	94.3	93	.89	.86	.79	150	850	45	260	25	90	250	81	—	10.01
		735	7-AD355L	384	352	94	93.5	92.5	.84	.80	.72	125	820	35	250	25	90	220	79	—	12.44
225	300	2965	7Y-AD315L	391	358	93	92	90	.94	.93	.91	155	850	50	275	35	120	280	93	84	3.90
		1480	7V-AD315L	398	364	93.5	93	91.5	.92	.89	.86	190	870	60	275	35	120	260	84	81	5.18
		985	7J-AD355M	405	371	94.8	94.3	93	.89	.86	.79	145	870	45	270	25	90	250	81	—	10.00
		735	7R-AD355L	434	397	94	93.5	92.5	.84	.80	.72	125	820	35	250	25	90	220	79	—	15.60
250	335	2975	7-AD355S	425	389	94	93	91	.95	.94	.92	125	850	40	275	25	90	280	93	84	5.23
		1485	7-AD355S	432	396	94.5	94	92.5	.93	.91	.87	140	900	45	280	25	90	260	84	81	7.17
		985	7-AD355M	450	412	94.8	94.3	93	.89	.86	.79	145	870	45	270	25	90	250	81	—	10.91
280	375	2975	7P-AD355S	474	434	94.5	93.5	91	.95	.94	.92	120	850	37.5	275	25	90	280	93	84	5.90
		1485	7P-AD355S	478	438	94.6	94	92.7	.94	.92	.88	135	900	42	280	25	90	260	84	81	5.84
		985	7-AD355L	505	462	94.8	94.3	93	.89	.86	.79	135	900	42	280	25	90	250	81	—	12.44
315	420	2975	7-AD355M	533	488	94.5	93.5	91.5	.95	.94	.92	115	850	35	275	25	90	280	93	84	5.74
		1485	7-AD355M	537	492	94.7	94	92.8	.94	.92	.88	130	900	40	280	25	90	260	84	81	8.13
		985	7P-AD355L	568	520	94.8	94.3	93	.89	.86	.79	135	900	42	280	25	90	250	81	—	13.90
355	475	2975	7-AD355L	597	547	95	94	92	.95	.94	.92	100	850	30	275	25	90	280	93	84	6.40
		1485	7-AD355L	605	554	94.8	94	93	.94	.92	.88	130	900	40	280	25	90	260	84	81	8.94
375	503	2975	7R-AD355L	631	578	95	94	92	.95	.94	.92	115	880	35	280	25	90	280	93	84	7.75
		1485	7R-AD355L	640	586	94.8	94	93	.94	.92	.88	130	920	40	290	25	90	260	84	81	10.55
400	536	2975	7V-AD355L	674	617	95	94	92	.95	.94	.92	115	880	33	280	25	90	280	93	84	8.50
		1485	7V-AD355L	683	625	94.8	94	93	.94	.92	.88	130	920	40	290	25	90	260	84	81	11.30
425	570	2975	7Y-AD355L	715	655	95	94	92	.95	.94	.92	100	890	30	285	25	90	280	93	84	9.45

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Each frame size marked * has a single rotor design having Design N characteristics suitable for Star Delta and Direct-On-Line starting.

§ Mean Sound Pressure Level measured at 1m on no load Subject to 3dB(A) tolerance

$$J\ (WK^2 \text{ or } WR^2) = \frac{GD^2}{4} = kgm^2.\ J \text{ in lb ft}^2 = \frac{kgm^2}{0.042}$$

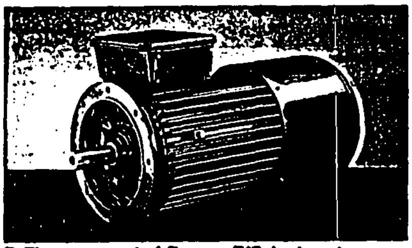
FL Full Load
FLC Full Load Current
LRT Locked Rotor Torque
LRC Locked Rotor Current
FLT Full Load Torque

To calculate FLC on special voltages, multiply the FLC at 415 volts by the following factors:

Voltage	220	346	365	400	420	440	500	550
Factor	1.89	1.2	1.13	1.03	0.99	0.94	0.83	0.75

Annexure 5.2

Performance Data Energy Efficient Motor



D Flange mounted Energy Efficient motor.

to BS4999 Part 112 (Previously Part 41) Suitable for Star Delta Starting

kW	hp	Full Load Speed rpm	Frame Size	FLC (Amps) 380 volts	FLC (Amps) 415 volts	Efficiency			Power Factor			D-O-L Starting % of Full Load		Star Delta Starting % of Full Load		Pull Up Torque % FLT Star	Pull Up Torque % FLT D-O-L	Pull Out Torque % FLT in △	Noise Levels dB (A)§	Design Letter	Rotor Inertia (J) WK² in kgm
						FL	¾L	½L	FL	¾L	½L	LRT	LRC	LRT	LRC						
18.5	25	735	7Z-HAD225S	41	38	92.2	92.1	90.5	.73	.67	.55	150	550	40	160	32	125	250	64	N,NY	0.95
22	30	735	7Y-HAD225M	50	46	92.3	92.2	90.8	.73	.67	.55	150	550	40	160	32	125	250	64	N,NY	1.0
30	40	980	7Y-HAD225M	60	55	93	93	92	.82	.76	.65	170	660	45	200	35	145	300	68	N,NY	1.0
		735	7Z-HAD250S	66	60	93.4	93.3	92.5	.74	.68	.57	160	570	42	170	35	135	250	66	N,NY	1.9
37	50	1470	7Z-HAD225S	70	64	94.1	94.2	93.5	.88	.80	.72	170	700	50	220	40	145	310	70	N,NY	0.8
		985	7Z-HAD250S	72	66	93.8	93.8	93	.83	.78	.70	170	660	45	200	35	145	270	69	N,NY	1.9
		735	7Y-HAD250M	81	74	93.6	93.6	93	.74	.69	.58	160	560	42	170	35	135	250	66	N,NY	2.2
45	60	2950	7Y-HAD225M	80	73	93.9	93.9	93	.91	.89	.85	190	700	55	220	45	160	320	79	N,NY	0.42
		1470	7Y-HAD225M	84	77	93.8	93.9	93.2	.87	.81	.74	160	670	47	210	38	140	300	70	N,NY	0.8
		985	7Y-HAD250M	87	80	94	94	93.5	.83	.78	.70	170	640	45	190	35	145	270	69	N,NY	2.2
		740	7Z-HAD280S	97	89	94	93.7	92.5	.75	.70	.57	170	580	45	175	37	140	250	71	N,NY	4.1
55	75	2960	7Z-HAD250S	97	89	94.6	94.5	93	.91	.89	.85	190	710	55	230	45	160	320	79	N,NY	0.75
		1475	7Z-HAD250S	104	95	94.5	94.6	93.9	.85	.80	.70	190	660	55	210	45	160	300	71	N,NY	1.6
		985	7Z-HAD280S	107	98	94.6	94.3	93	.83	.79	.70	170	640	45	190	35	145	270	72	N,NY	4.1
		740	7Y-HAD280M	118	108	94.3	94.1	93	.75	.70	.57	170	580	45	175	37	140	250	71	N,NY	4.4
75	100	2960	7Y-HAD250M	132	121	94.6	94.6	93.5	.91	.89	.86	180	710	50	230	40	150	320	79	N,NY	0.85
		1475	7Y-HAD250M	140	128	94.8	94.8	94	.88	.81	.71	190	670	55	210	45	160	300	71	N,NY	1.75
		985	7Y-HAD280M	145	133	94.8	94.6	93.5	.83	.79	.70	170	640	45	190	35	145	270	72	N,NY	4.4
		740	7Z-HAD315S	161	147	94.8	94.4	93	.75	.70	.57	170	650	45	190	37	140	290	74	G	6.5
90	125	2965	7Z-HAD280S	158	145	94.7	94.5	93.2	.91	.90	.87	170	710	50	230	40	145	320	79	N,NY	2.0
		1480	7Z-HAD280S	165	151	95.4	95.5	94.7	.87	.84	.75	200	680	55	210	45	170	300	73	N,NY	3.4
		985	7Z-HAD315S	167	153	95	94.7	93.5	.86	.83	.76	170	680	45	210	35	145	290	74	G	6.5
		740	7Z-HAD315M	189	173	95	94.7	93.4	.76	.71	.59	170	650	45	190	37	140	290	74	G	7.4
110	150	2965	7Y-HAD280M	193	177	94.9	94.7	93.5	.91	.90	.87	160	670	47	210	37	140	300	79	N,NY	2.2
		1480	7Y-HAD280M	201	184	95.5	95.6	95	.87	.84	.75	200	650	55	200	45	170	300	73	N,NY	3.6
		985	7Z-HAD315M	204	187	95.2	95	93.8	.86	.83	.76	170	680	45	210	35	145	290	74	G	7.4
		740	7Y-HAD315L	232	212	95.2	94.9	93.7	.76	.71	.59	170	650	45	190	37	140	290	74	G	8.4
132	175	2970	7Z-HAD315S	226	207	95.4	95.3	94.2	.93	.92	.90	120	725	35	230	30	100	330	79	G	3.4
		1485	7Z-HAD315S	236	216	95.7	95.7	95	.89	.86	.79	180	670	50	210	40	150	300	77	N,NY	5.5
		985	7Y-HAD315L	245	224	95.4	95.2	94	.86	.83	.76	170	690	45	220	35	145	290	74	G	8.4
		740	7R-HAD355S	270	247	95.5	95.3	94.8	.78	.72	.60	140	700	37	210	30	120	320	76	G	12
150	200	2970	7Z-HAD315M	257	235	95.5	95.4	94.3	.93	.92	.90	120	750	35	240	30	100	330	79	G	3.9
		1485	7Z-HAD315M	268	245	95.9	95.9	95	.89	.86	.79	170	670	50	210	40	145	300	77	N,NY	6.2
		990	7P-HAD355S	273	250	95.8	95.6	94.5	.87	.82	.72	140	750	40	230	32	120	330	76	G	11.5
		740	7V-HAD355S	305	279	95.6	95.6	94.2	.78	.72	.60	140	700	37	210	30	120	320	76	G	13
185	250	2970	7Y-HAD315L	317	290	95.4	95.3	94.2	.93	.92	.90	120	770	35	250	30	100	330	79	G	4.4
		1485	7Y-HAD315L	325	298	96	96	95.3	.90	.87	.81	180	750	50	230	40	150	330	77	G	7.0
		990	7V-HAD355S	336	308	96	95.8	94.8	.87	.82	.72	140	750	40	230	32	120	330	76	G	13
		740	7Y-HAD355M	371	340	95.9	95.7	94.5	.79	.73	.61	140	700	37	210	30	120	320	76	G	17.5
200	270	2975	7R-HAD355S	335	307	95.5	95.3	94.4	.95	.94	.92	140	850	45	275	35	120	350	79	G	6.7
		1485	7R-HAD355S	348	319	95.8	95.7	94.8	.91	.89	.84	160	800	47	250	38	140	340	77	G	9.5
		990	7Y-HAD355S	364	333	96.1	95.9	95	.87	.82	.72	140	750	40	230	32	120	330	76	G	14
		740	7Y-HAD355L	401	367	96	95.7	94.5	.79	.73	.61	140	700	37	210	30	120	320	76	G	20
225	300	2975	7V-HAD355S	376	344	95.8	95.5	94.6	.95	.94	.92	135	850	42	275	33	115	350	79	G	7.2
		1485	7V-HAD355S	392	359	95.9	95.8	94.9	.91	.89	.84	160	800	47	250	38	140	340	77	G	10
		990	7V-HAD355M	408	374	96.2	96	95.1	.87	.82	.72	140	780	40	240	32	120	330	76	G	16.3
250	335	2975	7Y-HAD355S	416	381	96	95.7	94.8	.95	.94	.92	125	850	40	275	32	105	350	79	G	7.8
		1485	7Y-HAD355S	435	398	96.1	95.9	95	.91	.89	.84	150	800	46	250	37	140	340	77	G	11
		990	7Y-HAD355M	454	416	96.2	96.1	95.2	.87	.82	.72	140	780	40	240	32	120	330	76	G	17.5
280	375	2975	7V-HAD355M	465	426	96.2	96	95	.95	.94	.92	120	850	38	275	30	100	350	79	G	8.9
		1485	7V-HAD355M	488	445	96.2	96	95.2	.91	.89	.84	150	830	46	260	37	140	340	77	G	12.9
		990	7Y-HAD355L	507	464	96.5	96.3	95.4	.87	.82	.72	140	800	40	250	32	120	330	76	G	20
315	420	2975	7Y-HAD355M	523	479	96.3	96.1	95.3	.95	.94	.92	120	850	37	275	29	100	350	79	G	9.9
		1485	7Y-HAD355M	548	500	96.3	96.2	95.4	.91	.89	.84	140	830	45	260	37	140	340	77	G	13.7
355	475	2975	7Y-HAD355L	589	539	96.5	96.3	95.5	.95	.94	.92	115	850	35	275	28	95	350	79	G	11
		1485	7Y-HAD355L	614	562	96.5	96.3	95.5	.91	.89	.84	140	850	45	270	37	140	340	77	G	15.5

§ Mean Sound Pressure Level measured at 1m on no load
Subject to 3dB(A) tolerance

J (WK^2 or WR^2) $= \frac{GD^2}{4} =$ kgm². J in lb ft² $= \frac{kgm^2}{0.042}$

FL - Full Load. FLC - Full Load Current. LRT - Locked Rotor Torque
LRC - Locked Rotor Current
FLT - Full Load Torque

To calculate FLC on special voltages, multiply the FLC at 415 volts by the following factors:

Voltage	220	346	365	400	420	440	500	550
Factor	1.89	1.2	1.13	1.03	0.99	0.94	0.83	0.75

Design Letter

Pre Feb '87	After Feb '87
A	G
B	N
—	NY (Star Delta start with limited starting current)

Annexure 6.1

Values of C in Hazen Williams Equation

TYPE OF PIPE		Condition	C
Cast Iron	New	All Sizes	130
	5 years old	300 mm and Over	120
		200 mm	119
		100 mm	118
	10 years old	600 mm and Over	113
		300 mm	111
		100 mm	107
	20 years old	600 mm and Over	100
		300 mm	96
		100 mm	89
	30 years old	750 mm and Over	90
		400 mm	87
		100 mm	75
	40 years old	750 mm and Over	83
		400 mm	80
		100 mm	64
	50 years old	1000 mm and Over	77
		600 mm	74
		100 mm	55
Welded Steel	Values of C the same as for cast-iron pipes, 5 years older		
Riverted Steel	Values of C the same as for cast-iron pipes, 10 years older		
Wood Stave	Average value, regardless of age		120
Concrete or concrete lined	Large sizes, good workmanship, steel forms		140
	Large sizes, good workmanship, wooden forms		120
	Centrifugally spun		135
Vitrified	In good condition		110

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Annexure 6.2

Values of K for the Darcy Weisbach Equation

MATERIAL	K (m)
Riveted steel	0.0009-0.009
Concrete	0.0003-0.003
Cast iron	0.00026
Galvanized iron	0.00015
Asphalted cast iron	0.00012
Commercial steel or wrought iron	0.000045
Drawn tubing and plastic pipe	0.0000015

$$h_{LP} = \frac{f L V^2}{2 g D}$$ (Darcy Weisbach Equation)

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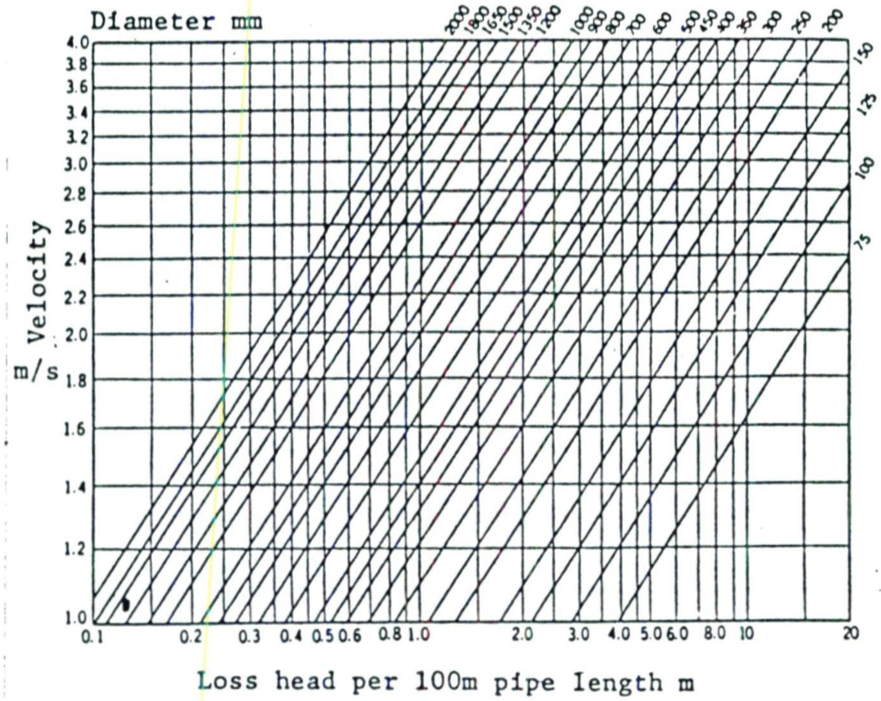
$$f = \frac{0.25}{\left\{\log\left[\frac{K}{3.7D} + \frac{5.74}{R^{.9}}\right]\right\}^2}$$

f = friction factor
R = Reynolds Number
K = roughness (m)

$$R = \frac{V D}{\nu}$$ where V = Velocity
D = diameter
ν = kinematic viscosity.

FRICTION HEAD LOSSES BY HAZEN-WILLIAMS' FORMULA

Values of friction loss head per 100m pipe length are shown in Figs. for respective values of C.



Friction Loss Head (Hazen-Williams C=80)

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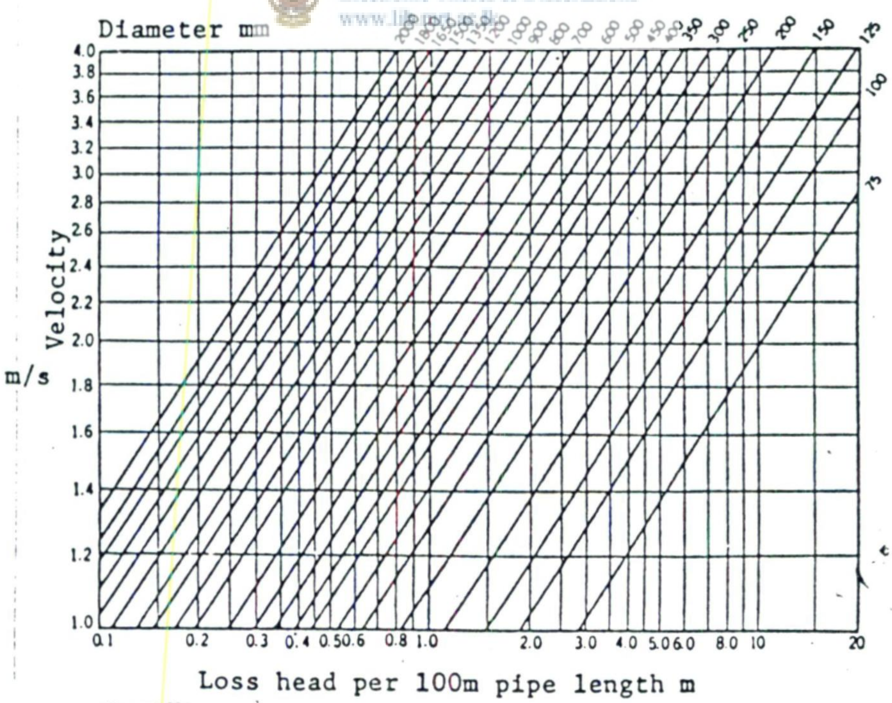
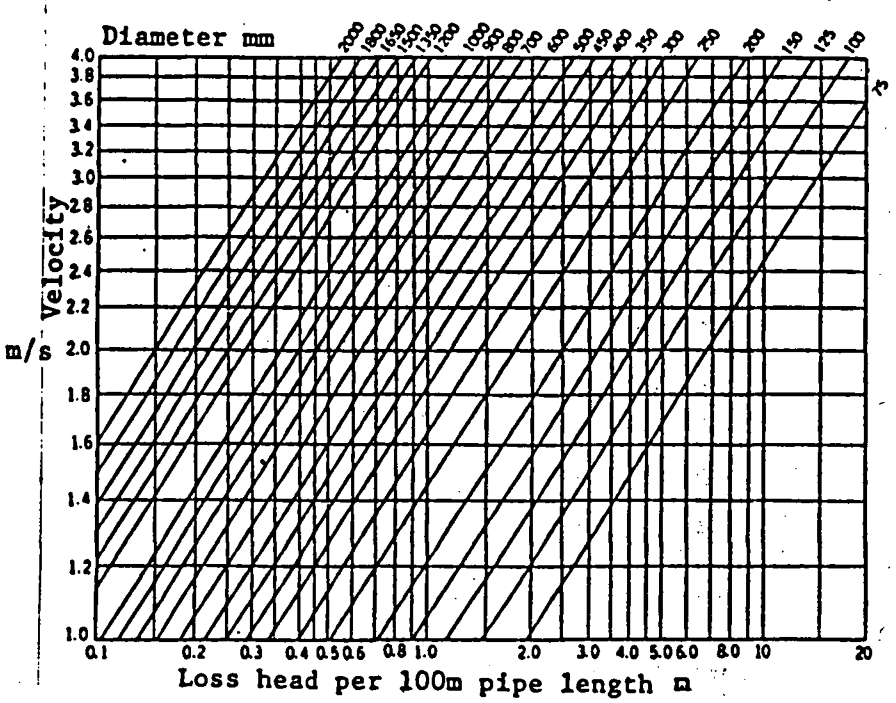


Friction Loss Head (Hazen-Williams C=100)

Annexure 6.4



Friction Loss Head (Hazen-Williams C=120)

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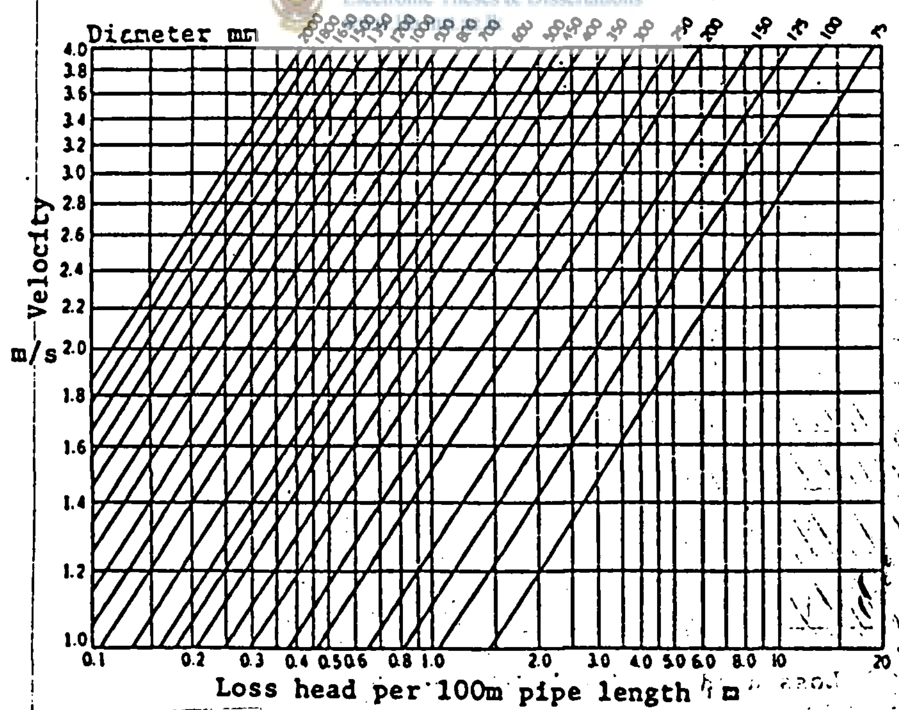

Friction Loss Head (Hazen-Williams C=140)

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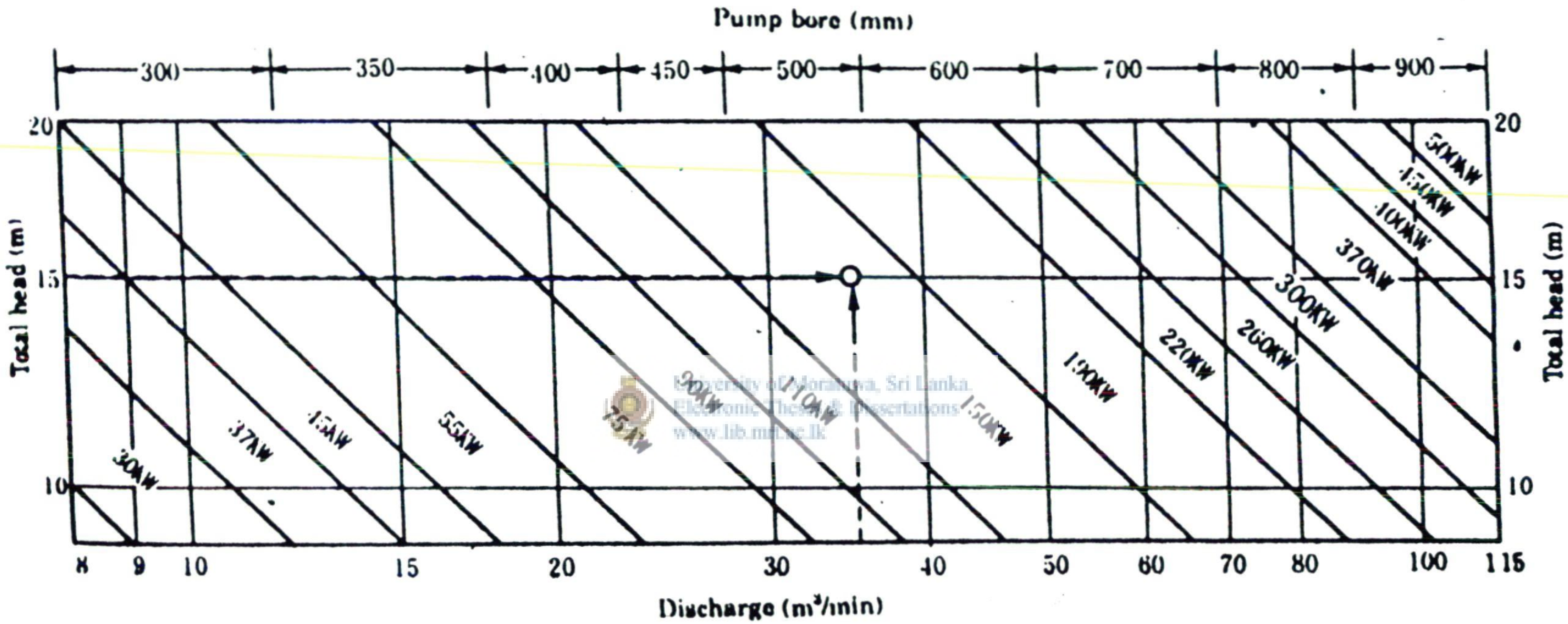

Applicable diagram for high-head vertical shaft mixed flow pumps (50, 60Hz)

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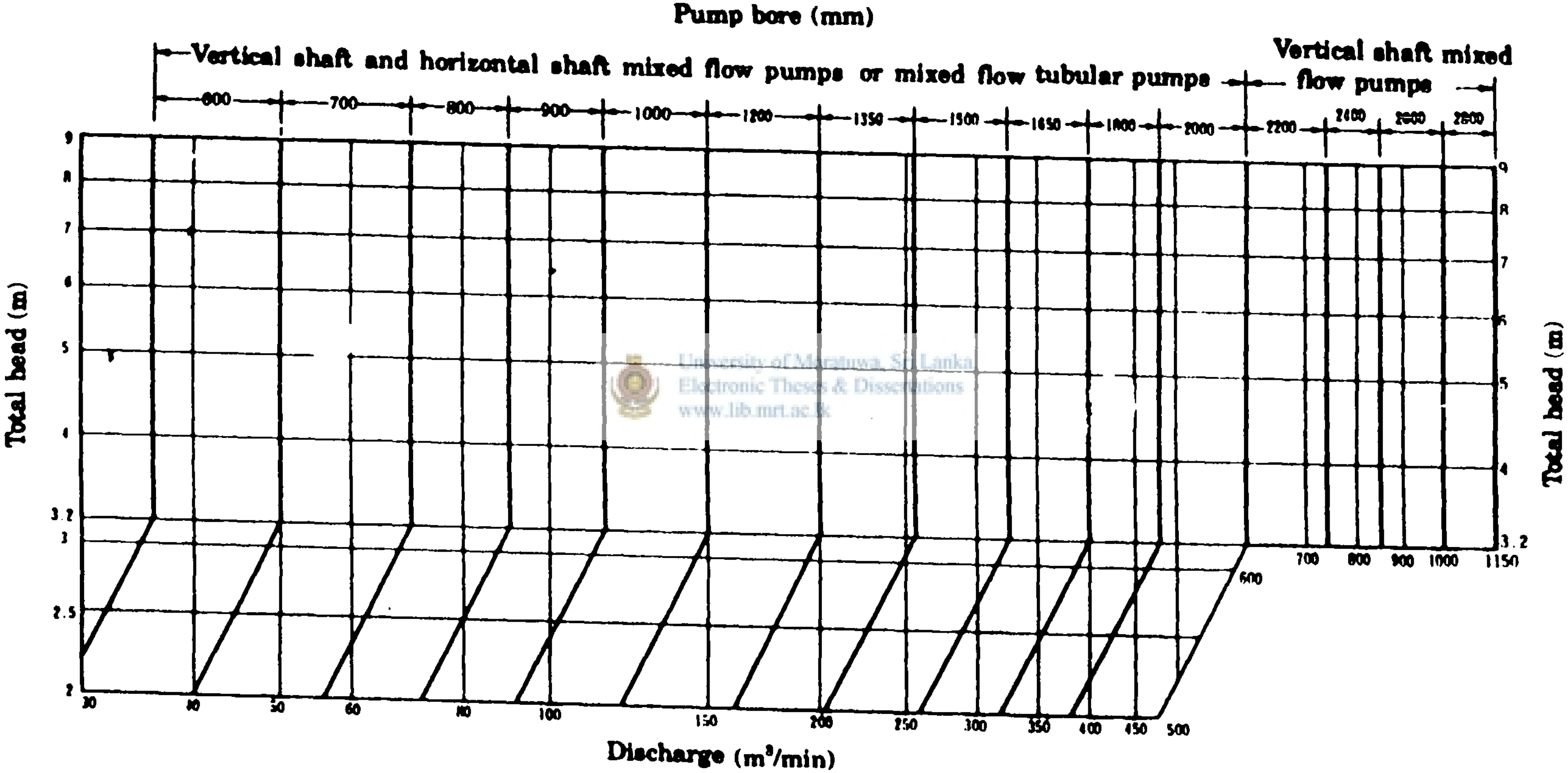
Annexure 7.1



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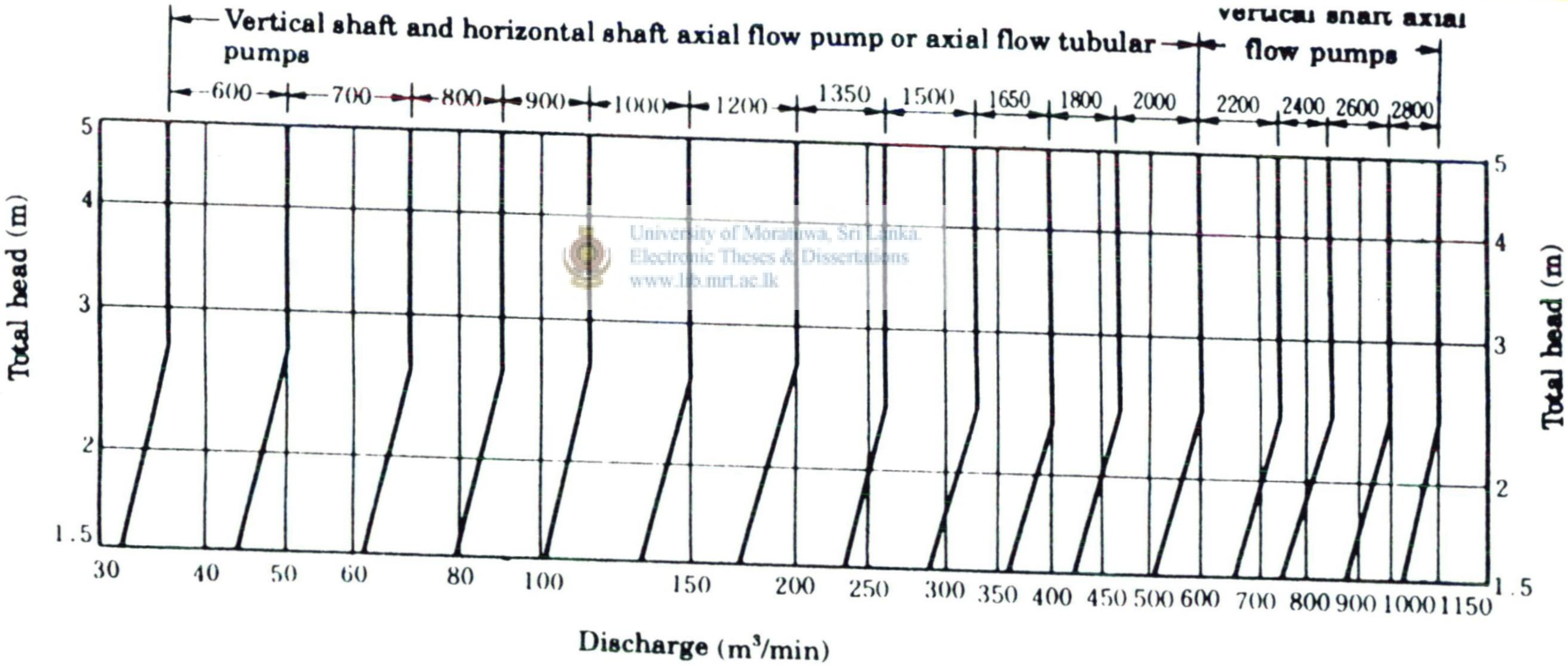
Applicable diagram for low-head mixed flow pumps

Annexure 7.2



Applicable diagram for low-head axial flow pumps

Annexure 7.3

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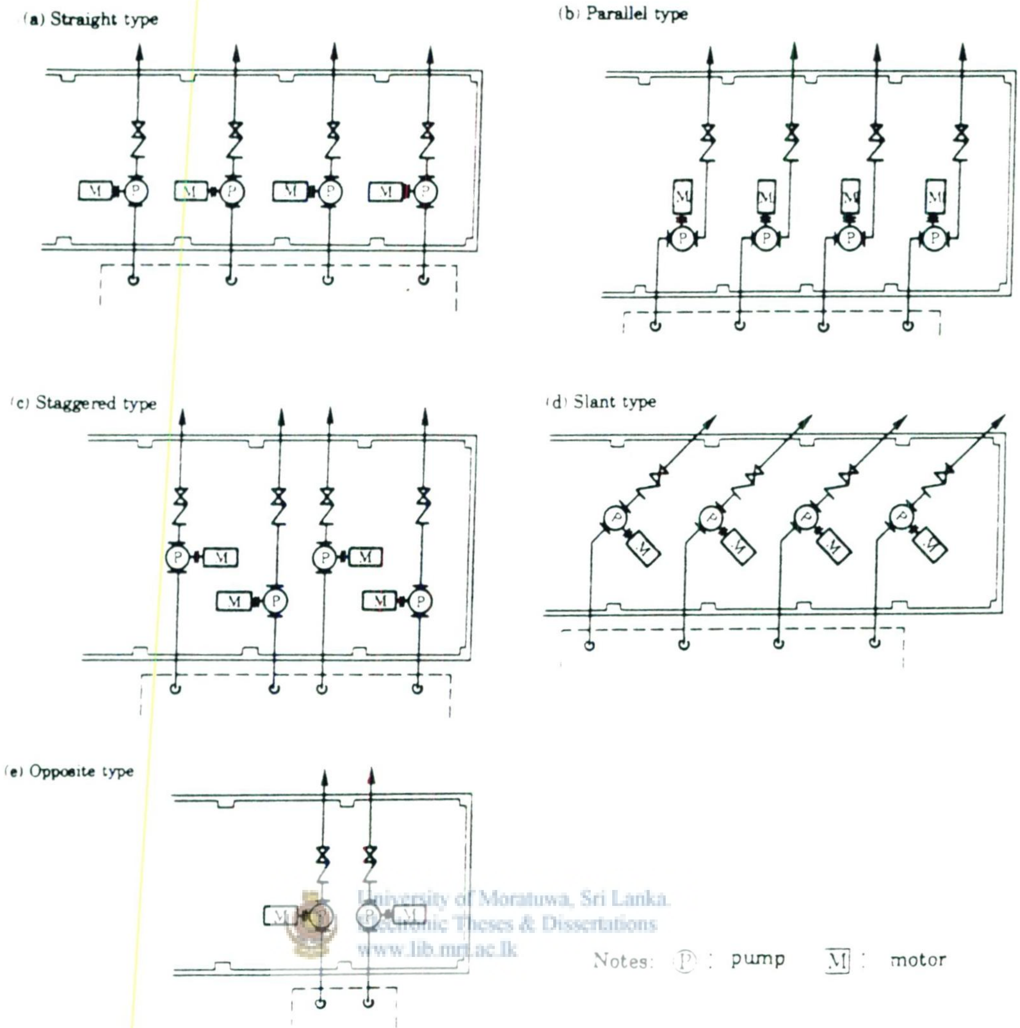
Annexure 7.4



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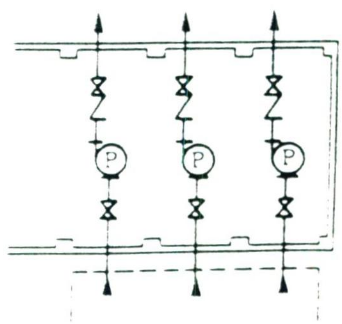
Layouts of horizontal shaft centrifugal pumps



Layout of vertical shaft centrifugal pumps

Annexure 10.1

WATER SUPPLY AND INJECTOR SELECTION CHART

CL_2 GAS FLOW (PPD)	NOZZLE SIZE	BACK PRESSURE AT INJECTOR (PSIG)											
		0	5	10	20	30	40	50	60	70	80	90	100
		PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM	PSIG @ GPM
1.5	1/8"	16 @ 1.7	22 @ 2.3	29 @ 2.3	46 @ 2.7	62 @ 3.1	82 @ 3.5	102 @ 3.9	121 @ 4.1	144 @ 4.5	163 @ 4.6	187 @ 5.0	204 @ 5.1
4	1/8"	16 @ 1.7	22 @ 2.3	29 @ 2.3	46 @ 2.7	62 @ 3.1	82 @ 3.5	102 @ 3.9	121 @ 4.1	144 @ 4.5	163 @ 4.6	187 @ 5.0	204 @ 5.1
10	1/8"	17 @ 1.8	23 @ 2.1	30 @ 2.4	47 @ 2.8	63 @ 3.2	83 @ 3.6	103 @ 4.0	123 @ 4.2	145 @ 4.6	165 @ 4.8	188 @ 5.1	206 @ 5.3
25	1/8"	**18 @ 1.9***	**25 @ 2.2***	**32 @ 2.5***	**48 @ 2.9***	**65 @ 3.25***	**84 @ 3.7***	**105 @ 4.1***	**125 @ 4.3***	**147 @ 4.7***	**167 @ 5.0***	**190 @ 5.2***	**210 @ 5.5***
	3/16"	12 @ 4.0	21 @ 5.0	30 @ 5.7	45 @ 6.8	67 @ 8.0	84 @ 8.6	105 @ 9.4	125 @ 10	145 @ 10.4	165 @ 11.0	190 @ 11.6	205 @ 12
50	1/8"	31 @ 2.4	38 @ 2.7	45 @ 2.9	60 @ 3.2	76 @ 3.6	95 @ 3.9	115 @ 4.2	**135 @ 4.5***	**155 @ 4.8***	**175 @ 5.1***	**195 @ 5.3***	**218 @ 5.6***
	3/16"	**14 @ 4.2***	**21 @ 5.1***	**30 @ 5.8***	**48 @ 7.0***	**70 @ 8.0***	**84 @ 8.6***	**104 @ 9.4***	124 @ 10.0	144 @ 10.4	164 @ 11.0	184 @ 11.5	205 @ 12.0
	1/4"	12 @ 5.8	20 @ 7.2	28 @ 8.4	42 @ 9.6	63 @ 11.6	84 @ 13.0	104 @ 14.5	122 @ 15.6	145 @ 17.5	160 @ 18	180 @ 19.4	205 @ 20.8
75	1/8"	38 @ 2.6	46 @ 2.9	54 @ 3.8	72 @ 3.4	90 @ 3.75	108 @ 4.1	**128 @ 4.3***	**148 @ 4.7***	**168 @ 5.0***	**188 @ 5.2***	**208 @ 5.5***	**226 @ 5.8***
	3/16"	**18 @ 4.8***	**26 @ 5.4***	**33 @ 6.0***	**48 @ 7.0***	**70 @ 8.0***	**92 @ 9.0***	110 @ 9.5	128 @ 10.0	147 @ 10.5	165 @ 11.0	185 @ 11.5	208 @ 12.1
	1/4"	15 @ 6.5	23 @ 7.5	30 @ 8.4	44 @ 10.0	63 @ 11.4	83 @ 13.0	104 @ 14.4	124 @ 15.6	144 @ 17.0	165 @ 18.5	185 @ 19.6	208 @ 20.9
100	1/8"	54 @ 3.1	62 @ 3.3	70 @ 3.4	86 @ 3.7	105 @ 4.0	121 @ 4.3	140 @ 4.6	160 @ 4.9	178 @ 5.1	198 @ 5.3	218 @ 5.7	238 @ 5.9
	3/16"	**20 @ 5.0***	**30 @ 5.8***	**38 @ 6.3***	**52 @ 7.2***	**70 @ 8.1***	**88 @ 8.8***	110 @ 9.5	**130 @ 10.0***	**150 @ 10.8***	**170 @ 11.0***	**188 @ 11.6***	**210 @ 12.2***
	1/4"	18 @ 7.0	26 @ 8.0	33 @ 9.0	46 @ 10.0	65 @ 11.6	83 @ 13.0	**104 @ 14.2***	124 @ 15.8	144 @ 17.0	165 @ 18.5	185 @ 19.5	210 @ 21.0
	5/16"	14 @ 9.5	20 @ 11.0	28 @ 13.0	45 @ 15.8	67 @ 18.5	84 @ 20.5	104 @ 22.5	124 @ 24.0	144 @ 25.5	165 @ 27.0	185 @ 28.0	210 @ 29.5
200	3/16"	39 @ 6.5	46 @ 7.0	56 @ 7.5	74 @ 8.2	90 @ 8.8	105 @ 9.4	**122 @ 10.0***	**140 @ 10.4***	**160 @ 10.8***	**178 @ 11.3***	**197 @ 11.9***	**216 @ 12.4***
	1/4"	**27 @ 8.2***	**35 @ 9.0***	**43 @ 9.8***	**61 @ 11.4***	**77 @ 12.5***	**90 @ 13.5***	110 @ 15.0	128 @ 16.0	148 @ 17.4	170 @ 18.8	192 @ 20.0	215 @ 21.4
	5/16"	19 @ 11.0	28 @ 13.0	36 @ 14.5	50 @ 16.7	68 @ 19.0	90 @ 21.2	110 @ 23.0	128 @ 24.2	145 @ 25.6	165 @ 26.7	185 @ 28.2	210 @ 29.5
300	1/4"	**36 @ 9.2***	**47 @ 10.2***	**58 @ 11.2***	**72 @ 12.2***	91 @ 13.5	106 @ 14.6	**122 @ 15.6***	**143 @ 17.0***	**162 @ 18.2***	**180 @ 19.3***	**195 @ 20.1***	**218 @ 21.6***
	5/16"	28 @ 13.0	34 @ 14.0	45 @ 15.5	58 @ 17.2	**76 @ 19.5***	**92 @ 21.5***	110 @ 23.0	130 @ 24.5	150 @ 26.0	170 @ 27.0	190 @ 28.5	210 @ 29.5
400	1/4"	45 @ 10.0	60 @ 11.2	73 @ 12.2	90 @ 13.5	110 @ 14.8	**120 @ 15.5***	**140 @ 16.8***	**165 @ 18.5***	**185 @ 19.5***	**210 @ 21.0***	**225 @ 22.0***	**235 @ 22.5***
	5/16"	**35 @ 14.0***	**43 @ 15.5***	**50 @ 16.7***	**68 @ 19.0***	**85 @ 20.5***	105 @ 22.5	123 @ 24.0	144 @ 25.5	162 @ 27.0	184 @ 28.0	202 @ 29.0	222 @ 30.0
500	5/16"	**43 @ 15.5***	**51 @ 16.5***	**62 @ 18.0***	**80 @ 20.0***	**96 @ 22.0***	**115 @ 23.5***	**135 @ 25.0***	**154 @ 26.0***	**178 @ 27.5***	**190 @ 28.5***	**210 @ 29.5***	**230 @ 31.0***

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NOTES:

1. This chart shows the **absolute minimum** requirements for satisfactory operation. Pump and/or water supply **must** be chosen to insure these requirements.
2. Back pressure must include all pressure losses after injector such as solution hoses, diffuser valves, manifolds, etc.
3. 10% overdesign is recommended on pump selection to protect against ageing.
4. Curves are based on 65°F supply water, add 5% for each 10°F increase in supply water temperature.

EXAMPLE: Supply 200 PPD of Cl_2 gas @ 40 PSIG Back Pressure. Water Supply of 50 PSIG is available.

ANSWER: 3 Possibles:
(a) 3/16" - 105 @ 9.4 (b) 1/4" - 90 @ 13.5 (c) 5/16" - 90 @ 21.2
➡ Choose 1/4" and use a centrifugal pump supplying 40 PSIG Boost @ 13.5 GPM

*** - Recommended Size based on most economical Booster Pump requirements**

All Capacities are in US Gallons.

Annexure 10.1

Annexure 10.2

CHLORINATOR SIZING GUIDE

DOSAGE[CHLORINE FEED RATE] FOR CHLORINATION OF WATER

REASON FOR CHLORINATION	TYPICAL DOSAGE IN PPM
Disinfection of water with free residual	1-10
Disinfection of water with combined residual	1-5
Control of Taste and odor	8.4 x NH content of 10 x NH-N content plus excess
Algae	1-10
Slime	1-10
Iron and sulfur bacteria	1-10
Removal of Ammonia (NH -N)	10 x NH -N content
Iron	0.64 x FE content
Manganese	1.3 x MN content
Color	1-10
Hydrogen Sulfide	2.1 H S or 2.22 x S content to free sulphu 8.4 x H_2S or 8.9 x S content to sulfide
Water Washdown	25-50
Water chilling	5-25
Preparation of coagulants	
activated silica	1.56 lb./gal., 41 Baume NA Si O
chlorinated copperas	1 part chlorine per 7.8 parts FE SO water

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COMBINED RESIDUAL-That portion of the total residual chlorine remaining in the chlorinated water or waste at the end of a specified contact period, which will react chemically and biologically as choramines or organic C.

RESIDUAL-Available chlorine remaining after the reaction interval and still available to combat the more resistant organisms and to safeguard against any later pollution: i.e. the amount in excess of the demand.

DEMAND Chlorine actually absorbed to satisfy substances present such as organic matter, sulfides, unoxidized iron and maganese, etc. also the difference between the amount remaining at the end of a specified contact period.

FREE AVAILABLE CHLORINE-That portion of the total residual chlorine remaining in the chlorinated water or waste at the end of a specified contact period, which will react chemically and biologically as hypochlorous or hypochlorite ion.

Annexure 10

DOSAGE (CHLORINE FEED RATE) FOR CHLORINATION OF TREATMENT WASTE

REASON FOR CHLORINATION	TYPICAL DOSAGE IN PPM
Disinfection of:	
Raw Sewage	6-12
Septic Raw Sewage	12-25
Settled Sewage	5-10
Septic Settled Sewage	12-40
Chemical Precipitation Effluent	3-10
Trickling Filter Effluent	3-10
Activated Sludge Effluent	2-8
Sand Filter Effluent	1-5
Odor Control of:	
Up Sewer	1-10
Plant Effluent	1-10
Trickling Filter Effluent	1-5
Digester Supernatant	200-300
B.O.D. Reduction of:	
Raw Screened Sewage	5-12
Activated Sludge Effluent	5-12
Control of:	
Trickling Filter Ponding	7-20
Trickling Filter Flies	3-10
Return Activated Sludge Bulking	40-100
Waste Activated Sludge Thickening	varies
Imhoff Tank	3-15
Cyanide Destruction:	
To Cyanate	3.2 x Cyanide Content
To Complete	8.0 x Cyanide Content

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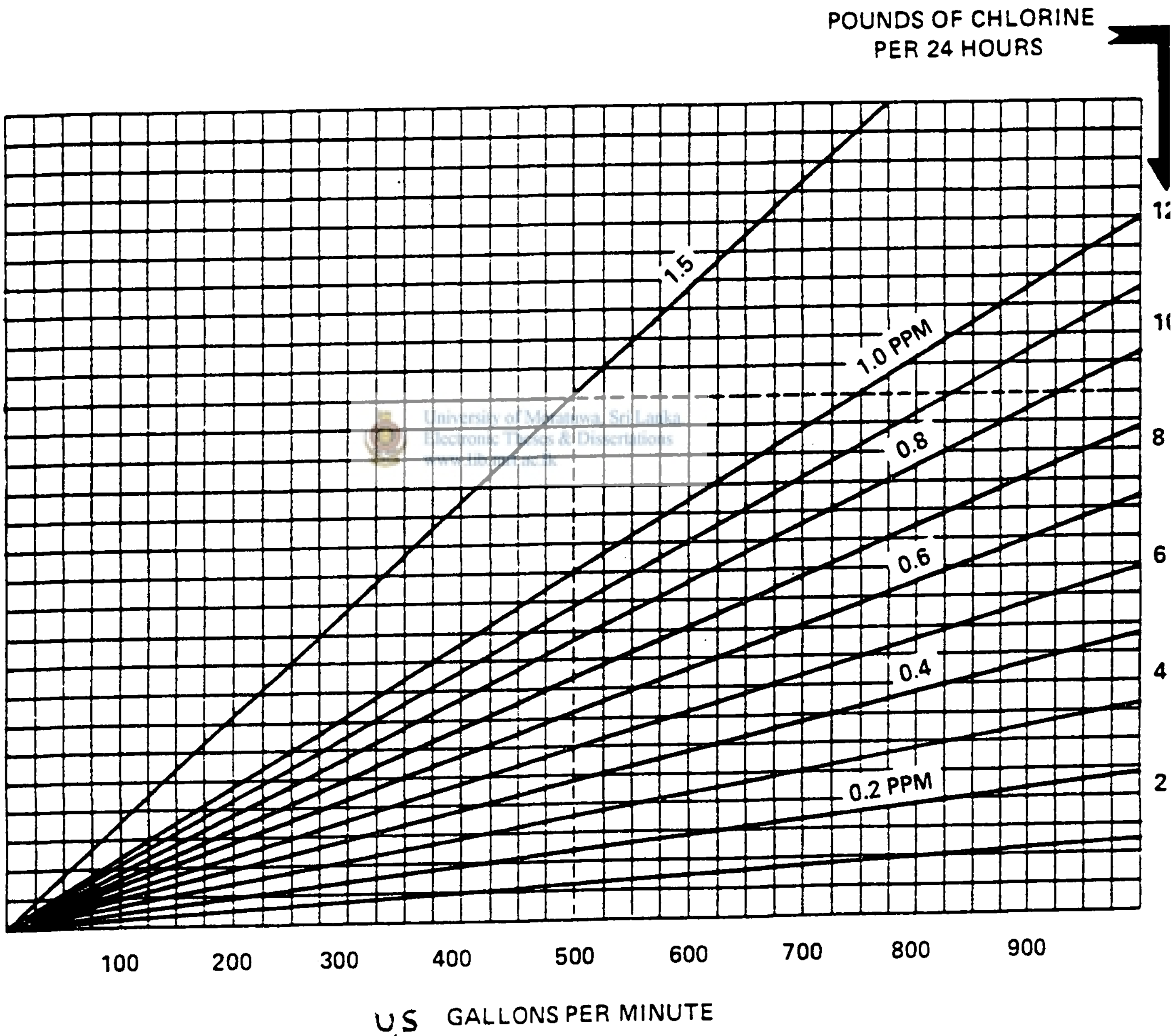
Annexure 10.4

SIZING CHART

FOR DETERMINING POUNDS OF CHLORINE PER 24 HRS. REQUIRED FOR VARIOUS PARTS PER MILLION AND VARIOUS FLOWS.
EXAMPLE – AT 500 GPM 1.5 PPM REQUIRES 9 LBS. OF CHLORINE PER 24 HRS.



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Annex : 11

SAMPLE DESIGN CALCULATIONS FOR A TREATED WATER PUMPING STATION

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Basic Design Calculations For A Treated Water Pumping Station

1. **Basic Data**

Water demand = 4800 m^3/day

Number of Hours of pumping = 20

Rate of Pumping = 4 m^3 / min

Static Head 36 m

Coefficient of pipe smoothness (C) = 120

Pipe line Length = 750 m

2. **Basic Calculations**

Suction Pipe diameter (mm) = √(14 x liters / min) (Page 104 of the Manual)

= √ (14 X 4000)

= 236.6 mm

Say 250 mm

Delivery Pipe diameter (mm) = √ (7 x liters / min) (- do -)

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= √ (7 x 4000)

= 167.3 mm

Say 200 mm

Suction Flow Velocity $= \frac{Q}{A_S}$

$$= \frac{4}{60 \times \frac{\pi}{4} \times \frac{[250]^2}{[1000]^2}}$$

= 1.36 m/s

Delivery Flow Velocity $$= \frac{4}{60 \times \frac{\pi}{4} \times \frac{[200]^2}{[1000]^2}}$$

= 2.12 m/s

Friction loss in pipe line $= \dfrac{10.666 \times Q^{1.852} \times L}{C^{1.852} \times D^{4.87}}$

$= \dfrac{10.666 \times 0.0666^{1.852} \times 750}{120^{1.852} \times (0.2)^{4.87}}$

$= 18.4$ m

Bend losses should be calculated and added. If drawings are not available an allowance of 5% to 10% can be added.

Adding 5% as bend losses and adding 2m for the Pump House losses, total head can be estimated.

$\therefore$ Estimated Total Head $= 18.4 + \dfrac{5}{100} \times 18.4 + 2 + 36$

$= 57.3$ m

Say 58 m

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3. Power

Water Power $= \dfrac{Q \times H}{367}$ kW

$= \dfrac{240 \times 58}{367}$

$= 37.9$ kW

Power absorbed by pump $= \dfrac{\text{Water Power}}{\text{Pump Eff:}}$

$= \dfrac{37.9}{.65}$ (Para 5 of the sample calculation and Annex 1.3)

$= 58.3$ kW

Motor Power

Add 10% Safety Margin (Page 8 of the Manual)

∴ Motor Power = 1.1 x 58.3

= 64.13 kW

∴ Power of the next motor frame size is 75 kW.

4. Pump Type

From figure 7.1 (B) of page 122, Pump Type can be;

(i) Horizontal Shaft Double Suction Single Stage

(ii) Vertical Shaft Single Suction Single Stage

as indicated in cage "C" in the figure.

Generally, Horizontal Shaft type is acceptable if there is no restrictions on site area. Otherwise, advantages and disadvantages between horizontal and vertical pumps should be considered on Civil Engineering Works, Installations, Operation and Maintenance cost and Performance.

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5. Pump Bores and Motor Power

As per the table 7.1 in page 125 of the Manual, Number of Pumps for this case is one duty, one stand by and as per the figure 7.1 (B) in page 122 of the Manual, the Motor Power is 75 kW and the pump bore is 200 mm.

However, when the daily demand exceeds 2,500 m^3/day. Pump combination can be as indicated under para 7.3.4 of the Manual and then the selection is not straight forward.

In such a situation, a detailed cost comparison should be done taking into consideration the following;

- Civil Engineering Costs
- Main Equipment Costs
- Other Equipment Costs
- Pipes, valves and fitting Costs
- Installation Costs
- Operational Costs

(please refer pages 123 and 124 of the Manual for details)

6. **Installation Method**

A cost comparison between positive suction and negative suction should be made by considering the respective Civil Engineering costs and equipment costs.

Generally, positive suction method is preferable if the Civil Engineering costs are not high.

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6. **Pump Layout**

As we have selected two pumps of the same capacity in this case, the possible layouts are as follows;

- Straight line
- Opposite to each other
- In Parallel

(Please refer annex 7.4)

Select the most appropriate method according to the availability of space. Care should be taken to leave sufficient room between pumping sets, and walls.

(please refer Page 127 of the Manual)

8. Determination Of The Actual Total Head

Once the layout of pumps is finalized, the total frictional losses on the suction side and the pump room can be calculated. $\left(\frac{\Sigma kv^2}{2g}\right)$

By adding the static head, pipe line losses and friction losses in pump house and suction side the total head can be worked out.

If there is a major variation in the intake water levels, maximum and minimum heads should be worked out and the two respective system head curves should be plotted.

Assume the following;

Maximum Static Head (Low Suction Water Level)	=	36 m
Minimum Static Head (High Suction Water Level)	=	33 m
Suction Side and Pump House losses $\left(\frac{\Sigma kv^2}{2g}\right)$	=	1.5 m
Delivery Pipe Line losses	=	18.4 m
Bend losses in delivery line	=	1.0 m
∴ Maximum Total Head	=	36+1.5+18.4+1.0
	=	56.9 m
	Say	57 m

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9. Pump Speed

$$N = \frac{S\,(9.4 \pm H_{sl})^{3/4}}{\sqrt{(Q/2)}}$$ (Page 25 of the Manual)

$$N = \frac{1000\,(9.4 \pm 1.6)}{\sqrt{(4/2)}}$$

N = 4271 RPM (assuming $H_{sl} = 1.6$ at LWL)

Figure 1.20 Page 25 of the Manual also gives a speed above 2900 RPM.

Hence, the Pump Speed can be taken as 2P, 2900 RPM.

10. Main Pumps

Hence, main pumps will be as follows;

02 Nos. side suction side delivery double suction centrifugal pumps each delivering 4 m^3/min against a total head of 57 m at 2900 RPM Coupled to 75 kW motors.

Specific Speed $N_S = \frac{N \times Q^{1/2}}{H^{3/4}}$ (Page 22)

$= \frac{2900 \times 2^{1/2}}{57^{3/4}}$

$=$ 198 (Radial Flow)

11. Valve Selection

11.1 Suction Valves

Because of the positive suction head, valves on the suction side is a must. They should be gate valves of 200 mm diameter as the pump bore is 200 mm.

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11.2 Discharge Valves

The pump head is 57 m. For this head, gate valves and butterfly valves are applicable. The size of the valves shall be 200 mm for the same reason indicated above.

11.3 Check Valve (Non Return Valve)

This should be determined after surge calculations.

12. **Overhead Crane**

The maximum weight to be lifted in the pump house will be the 75 kW motor whose weight is about 500 kg. Hence, a manual chain block of 1MT would suffice.

13. **Surge Analysis**

Basic Data

Flow rate 4 m^3/min

Total Head 57 m

Pump Speed 2900 RPM

Pump Efficiency 65%

Pipe Bore 200 mm

Pipe Material Ductile Iron (NP 16)

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Length of Pipe 750 m

Thickness of Pipe 6.4 mm

Calculations

Motor Inertia ≅ 0.75 kg m^2 (Annex 4.3 and Page 81 of the Manual)

Assuming motor inertia is 90% of the total inertia.

Total Inertia (GD^2) = 0.75 x 100/ 90

= 0.833 $kgfm^2$

$K_1 = 450 \times g \times w \times H \times Q / \pi^2 \times GD^2 \times \eta_p \times N^2$

$= 450 \times 9.81 \times 1000 \times 57 \times 240 / \pi^2 \times .833 \times .65 \times 2900 \times 2900 \times 3600$

$K_1 = 0.373$

Wave Velocity

Pipe diameter D = 200 mm

Pipe thickness e = 6.4 mm

∴ Ratio D/e ≐ 31.25

∴ Wave Velocity (a) = 1070 m / sec (Annex 4.1)

Flow Velocity = 2.12 m /sec

$$\text{Maximum Surge Pressure} = \pm \frac{aV}{g}$$

$$= \frac{1070 \times 2.12}{9.81}$$

$$= \pm 231.2 \text{ m}$$

$$\text{Line Constant} \quad 2\rho = \frac{aV}{gH}$$

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$$= \frac{1070 \times 2.12}{9.81 \times 57}$$

$$2\rho = 4.06$$

$$\text{Pipe line Period (T)} = \frac{2L}{a}$$

$$T = \frac{2 \times 750}{1070}$$

$$= 1.4 \text{ sec}$$

$$\therefore \quad K_1 \times \frac{2L}{a} = 0.373 \text{ X } 1.4$$

$$= 0.52$$

Therefore from the Charts

Down Surge at Pump = $57 \times \frac{102}{100}$ = 58.14 m (Extrapolated)

Up Surge at Pump = $57 \times \frac{42}{100}$ = 23.94 m

Down Surge at Mid Length = $57 \times \frac{72}{100}$ = 41.0 m

Up Surge at Mid Length = $57 \times \frac{23}{100}$ = 13.1 m

Over and below the pumping head. (57 m)

Therefore,

Minimum Pressure at Pump = -1.14 m

Maximum Pressure at Pump = 80.94 m

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Minimum Pressure at Mid Length = 16.0 m

Maximum Pressure at Mid Length = 70.1 m

Here the negative pressure is very nominal and also (av/gH) is >> 1,

Therefore Pump bypass reflex valve can arrest the negative surge.

The pipe and pump casing can withstand the maximum pressures that will develop as the allowable working pressure of the pipe is 16 Bar and the pump casing can withstand twice the head at duty point.

14. Reflex Valve (Non Return Valve)

$$\text{Pipe line period (T)} = \frac{2L}{a}$$

$$= 1.4 \text{ sec}$$

This is less than 5 sec which is the normal time a pump will rotate due to inertia of the rotating elements after a sudden stoppage.

Therefore, rapid closing check valve has to be installed to prevent reverse flow, and it should be in such a way that it will close completely in 1.4 sec.

15. Flow Meter

A Woltmann meter which allows a continuous flow greater than 240 m^3/h is recommended.

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16. Chlorinator Sizing

Kg/Hr = 1×10^{-3} x Dosage in PPM x m^3/Hr

= $1 \times 10^{-3} \times 2.5 \times 240$

= 0.6

Say 1kg/Hr i.e. 52.8 pounds per day

Back Pressure = Delivery Head + losses in Cl_2 feed line

Say 55 + 1 m = 79.5 psi

∴ Booster Pump requirements from Annex 10.1 is 188 PSIG at 5.2 US Gallons that is 4.33 IGPM at 132.4 ft. (19.7 l/m at 40.4 m)

17. <u>Design of Electrical Facilities</u>

Available Power Supply 400 V, 3 Phase, 4 Wire, 50 Hz.

18. <u>Operation Modes (One Pump at a time)</u>

- Manual ON - OFF at the Pump House
- Automatic ON - OFF operation according water level signals from the discharge tank provided the water level in the suction sump is above the pre- set low water level.

19. Transformer Capacity

Load	No. of Units at a time	Unit Out Put (KW)	Efficiency	Power factor	Input (KVA)
Main Pump Motor	01	75	0.94	0.90	88.65
Cl_2 Pump	01	.75	0.74	0..72	1.41
Drainage Pump	01	.75	0.55	0.72	1.89
Lighting etc.	-	1.0	0.75	0.90	1.48
				Sub Total	93.43
				Add 10%	9.30
				Total	102.73

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∴ Next available size is 160 KVA

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20. Condenser Capacity For Main Motors

Motor Power	=	75 kW
Power factor Cos θ_0	=	0.9
Targeted Power factor Cos θ_1	=	0.95
Motor Efficiency	=	0.93

$$\therefore \text{Condenser Bank Capacity} = \frac{\text{Motor Power}}{\text{Motor Efficiency}} \left[\sqrt{\{(1/\cos^2\theta_0) - 1\}} - \sqrt{\{(1/\cos^2\theta_1) - 1\}}\right]$$

$$= 75/.93 \left[\sqrt{\{(1/.9^2) - 1\}} - \sqrt{\{(1/.95^2) - 1\}}\right]$$

$$= 12.56 \text{ KVA}$$

21. Method of Starting

Motor Power 75 kW

Use Auto Transformer starting Method (Page 87 of the Manual)

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Tappings depends on the Variation of load. Generally motors driving centrifugal Pumps 60%, 80% & 100% tappings are suitable.

22. Motor Enclosure

Motor enclosure shall be IP 5A (Page 99 of the Manual)

This is suitable for operating in water splashing area.

23. Rated Current

$$\text{Power} = \sqrt{3}\ VI\ \cos\phi$$

$$\therefore \text{Rated Current} = \frac{75 \times 1000}{\sqrt{3} \times 400 \times 0.18}$$

$$= 135 \text{ A}$$

24. Full Load Starting Current

If the Auto Transformer tappings are 60%, 80% & 100%

Starting Current = 135 x 5 x 0.6

= 405 A

25. Cable Sizes

The maximum current in the motor cable is 405 A.

Cable Size should be selected to limit the voltage drop to 10% maximum.

Voltage drop per metre/Ampere is given in the cable data book for different cable sizes. Hence, the particular cable size would depend on the length of the cable.

26. Generator Capacity

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Please refer page 128 of the manual.

Use of a computer software programme is recommended as the method of determining the generator capacity is not straight forward.

27. Breaking Capacity

The breaking capacity and the set value of the main circuit breaker relay depends on the power system and the load. Generally for a system of this nature 20 KA is specified as the breaking current.