FIJI NATIONAL UNIVERSITY

College of Engineering, Science & Technology (CEST)

SCHOOL OF MECHANICAL ENGINEERING

TRADE DIPLOMA IN MECHANICAL ENGINEERING

REE 592 HYDRO ENERGY SYSTEMS FINAL EXAMINATION Trimester 2 /2017

DURATION : 3 HOURS

Instructions to Students:

01. You are allowed *10* minutes *EXTRA* reading time to *familiarize, evaluate* and *study* the requirements being asked in all the problems before starting to write your solutions.

02. Begin each question on a *fresh page*, avoid too many erasures and use both sides of the answer sheet.

03. Write your *candidate number* at the top of each attached answer sheet.

04. Write clearly the number(s) of the question(s) attempted on the top of each sheet.

05. Insert all written foolscap, graph paper, drawing paper, etc. in their correct sequence and secure with string.

06. *Candidates are warned not to open any lecture notes. Any attempt to do so and was caught shall be outright disqualified to sit in the Final Examination and the student shall be subject to academic disciplinary action.*

07. **The paper consists of 2 parts A, four questions in B. Students must do all of A and B.. Check your paper thoroughly so that all parts are included.**

08. Use black or blue ball pen in answering, pencils are not allowed, except for drawing figures.

09. Number of pages:6

ATTEMPT ALL THE QUESTIONS IN Part A, Part B .

Part A Short Answers All questions earn equal marks. 40 marks

Questions

1. What is involved in Hydro Power Energy Systems and the energy conversions in each case. 2 marks

2. Many studies have to be undertaken to establish a sustainable Hydro scheme, name the studies

2 marks

3. Choose and explain 4 important components of a feasibility study 2 marks

4. Name the components of a typical small Hydro-electric power plant. Describe the interrelationships of these components of the same system. 2 marks

5. What are the pre-construction activities of such a project to site the mini hydro in locality A

2 marks

6. What are the two most important components that a locality should have for sustainable hydro activity. 2 marks

7. Describe the types of turbines available and the process of choosing the right type for a particular site.

2 marks

8. The catchment area of the hydro is the area above the weir supporting the continuous flow of water to the streams and the dam. List a few risks and the required maintenance aspects of the catchment area. 2 marks

9. Describe 3 Flow measurement methods and the equipment used. 2 marks

10. Describe what a weir is and its location and function. Discuss how the weir affects the SMH. Describe some maintenance steps for the weir. 2 marks

11. How is a hydro power turbine able to pump water back up to storage again. What is the purpose of such an arrangement? 2marks

12. Describe the process of feasibility study for a hydropower station. Describe the essence of each step.

2 marks

13. What types of bearings are used in mounting and running a Pelton wheel. Which bearings are able to withstand axial or thrust forces? Discuss how bearings are maintained for long life. 2 marks

14. The detailed design of a project is made after outline study for further consideration of the project. Describe the process and its components. 2 marks

15. What is Plant factor, the load factor and their importance 2 marks

16. Belts are tightened after proper alignment, discuss the correct tension of the belt after tightening.

2 marks

17. Financial evaluation, time value for money, annuity equation, net present value. Describe each of the terms and by examples provide values for a project. Example 9.5.1/8.4.2 2marks

18. Compare Internal Rate of Return(IRR) and Net Present Value (NPV) 2 marks

19. Describe Annuity , Bank loans and project considerations to be made for a new project. 2 marks

20. Turbine drives involve the following: shafts, Bearings, couplings pulleys, Flat and Vee belts. What are the issues to consider when making a choice of which type of coupling to use. 2 marks

Part B Answer all four (4) Questions each of equal marks 60 marks

Question 1. Calculation of area daily rainfall

a) Name the methods of calculating rainfall in an area under survey?

b) What is the effect of Run off on rainfall calculations?

c) The following is provided for a site under survey. Site is divided into areas W,Y and Z. Find the average daily rainfall.

1 and 2 Area and Rainfall Total number of squares in A = squares (total) = 135

	Gauge W	Gauge Y	Gauge Z
Squares	58	8	69
Rainfall mm/yr	2000	2700	3000

Total catchment area = 4.88 x 10E6 m3 Evaporation is given as 1.42m/yr

d) There are many ways of taking head measurements for purpose of height h, calculations. Name three (3) types and describe the process.

e) Describe three (3) types of head measuring equipment and how it is used. 15 marks

Question 2.

a) Impulse turbines like the Pelton wheels are used a lot in MH applications. Name and describe the functions of each component of the turbine.

b) Examine the forces acting on the bucket of the turbine and deduce the resultant force of the water jet.

c) The runner and bucket and nozzle jet diameter are all related, provide dimension for the remaining components from a jet diameter of 12mm?

d) Shaft diameter calculations

Belt tension T = 16.64 kN Speed rpm = 450rpm

Rotational speed is = 2 x^ x frequency = 47.12 rad /sec

Turbine shaft power is = 71kW Turbine runner pcd = 0.2m

From a sketch, deduce the Moments and forces acting and using ASME code with yield stress and ultimate strength, fing the diameter of the shaft. 15 marks

Question 3 15 Marks

a) Water jet velocity of 30m/s and static head of 150m provides power to a Pelton wheel turbine of 600mm diameter. What is the power generated? What is the force acting on the wheel and the velocity of the bucket?

b) Describe Reaction turbines.

c) Describe the following terms used in hydro power

- Cavitation
- Diversion
- Fish ladder
- Runner

Closed loop pumped storage
Draft tube
Impoundment
Non powered dams
Tail race
Wicket gates

d) Describe and snow the difference of laminar or streamline and turbulent flow?

e) Explain the effects of friction on fluid flow and provide calculation as proof.

Question 4 15 Marks

a) Describe the meaning of Present Value PV = future value/(1 + m)n

b) What is the internal rate of return, IRR. NPV = 0

c) Using Tables provided determine whether The following scheme is viable.

Prefeasibility study of a scheme makes quick estimates for a hydro scheme as follows

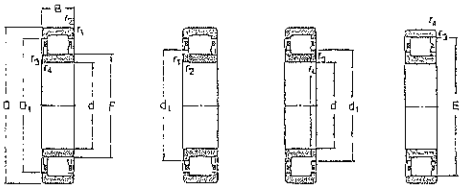
Revenue is $20000 each year for 15 years. Expenditure is start-up cost at $120,000 and yearly expenditure of $8000. Calculate the NPV for the scheme @ 12% discount factor and comment.

d) A 12 kW MHP for grain milling is proposed with a start-up cost of $20,000 and a discount rate of 20%.

Annual earnings of $7000 and maintenance costs of $1400/yr

END

Cylindrical roller bearings
single row
d 75–80 mm

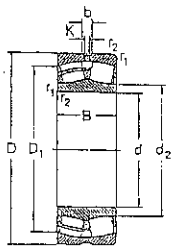


Type NU Type NJ Type NUP Type N

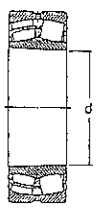
Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Lubrication grease	oil	Mass	Designation
d	D	B	C	C_0	P_u				
mm			N		N	r/min		kg	–
75	115	20	58 300	71 000	8 500	5 600	6 700	0,74	NU 1015
	130	25	130 000	156 000	20 400	4 500	5 300	1,25	NU 315 EC
	130	25	130 000	156 000	20 400	4 500	5 300	1,30	NJ 315 EC
	130	25	130 000	156 000	20 400	4 500	5 300	1,30	NUP 315 EC
	130	25	130 000	156 000	20 400	4 500	5 300	1,25	N 315 EC
	130	31	161 000	208 000	27 000	4 500	5 300	1,60	NU 2215 EC
	130	31	161 000	208 000	27 000	4 500	5 300	1,60	NJ 2215 EC
	130	31	161 000	208 000	27 000	4 500	5 300	1,65	NUP 2215 EC
	160	37	242 000	265 000	33 500	3 400	4 000	3,20	NU 315 EC
	160	37	242 000	265 000	33 500	3 400	4 000	3,25	NJ 315 EC
	160	37	242 000	265 000	33 500	3 400	4 000	3,45	NUP 315 EC
	160	37	242 000	265 000	33 500	3 400	4 000	3,20	N 315 EC
	160	55	330 000	400 000	50 000	3 400	4 000	4,90	NU 2315 EC
	160	55	330 000	400 000	50 000	3 400	4 000	5,00	NJ 2315 EC
	160	55	330 000	400 000	50 000	3 400	4 000	5,10	NUP 2315 EC
	190	45	264 000	280 000	34 000	3 400	4 000	6,25	NU 415
	190	45	264 000	280 000	34 000	3 400	4 000	6,40	NJ 415
80	125	22	86 000	81 500	10 400	5 300	6 300	0,89	NU 1016
	140	26	138 000	166 000	21 200	4 000	4 800	1,50	NU 216 EC
	140	26	138 000	166 000	21 200	4 000	4 800	1,55	NJ 216 EC
	140	26	138 000	166 000	21 200	4 000	4 800	1,60	NUP 216 EC
	140	26	138 000	166 000	21 200	4 000	4 800	1,50	N 216 EC
	140	33	167 000	245 000	31 000	4 000	4 800	2,00	NU 2216 EC
	140	33	167 000	245 000	31 000	4 000	4 800	2,05	NJ 2216 EC
	140	33	167 000	245 000	31 000	4 000	4 800	2,05	NUP 2216 EC
	170	39	260 000	290 000	36 000	3 200	3 800	3,95	NU 316 EC
	170	39	260 000	290 000	36 000	3 200	3 800	4,00	NJ 316 EC
	170	39	260 000	290 000	36 000	3 200	3 800	4,10	NUP 316 EC
	170	39	260 000	290 000	36 000	3 200	3 800	3,90	N 316 EC

Fig 7.5.2 Cylindrical roller bearings taken from SKF catalogue

Spherical roller bearings
d 60 – 85 mm



Cylindrical bore

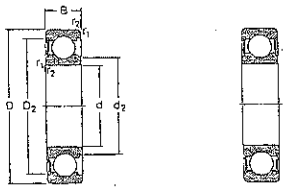


Tapered bore

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Lubrication grease	oil	Mass	Designations Bearings with cylindrical bore	tapered bore	Calculation factors	
d	D	B	C	C_0	P_u						e	Y_1
mm			N		N	r/min		kg	-			
60	110	28	122 000	146 000	16 300	4 000	5 000	1,10	22212 CC	22212 CCK	0,24	2,8
	110	28	140 000	173 000	19 000	4 300	5 300	1,15	22212 E	22212 EK	0,24	2,8
	130	31	161 000	200 000	22 200	3 000	3 800	1,95	21312 CC	21312 CCK	0,24	2,8
	130	46	235 000	280 000	30 000	3 000	3 800	2,95	22312 CC	22312 CCK	0,35	1,9
	130	46	271 000	335 000	36 500	2 800	3 600	2,90	22312 E	22312 EK	0,35	1,9
65	120	31	148 000	180 000	21 200	3 600	4 800	1,45	22213 CC	22213 CCK	0,24	2,8
	120	31	176 000	216 000	24 000	3 800	4 800	1,50	22213 E	22213 EK	0,25	2,7
	140	33	184 000	240 000	27 000	2 800	3 600	2,45	21313 CC	21313 CCK	0,24	2,8
	140	48	253 000	300 000	32 000	2 600	3 400	3,55	22313 CC	22313 CCK	0,36	1,9
	140	48	299 000	360 000	38 000	2 600	3 400	3,55	22313 E	22313 EK	0,35	1,9
70	125	31	148 000	186 000	21 200	3 600	4 500	1,55	22214 CC	22214 CCK	0,23	2,9
	125	31	179 000	228 000	25 500	3 600	4 500	1,55	22214 E	22214 EK	0,23	2,9
	150	35	207 000	260 000	29 000	2 600	3 400	3,00	21314 CC	21314 CCK	0,24	2,8
	150	51	311 000	380 000	40 000	2 400	3 200	4,30	22314 CC/W33	22314 CCK/W33	0,35	1,9
	150	51	345 000	430 000	45 000	2 200	3 000	4,30	22314 E	22314 EK	0,33	2
75	130	31	158 000	208 000	23 600	3 400	4 300	1,65	22215 CC	22215 CCK	0,22	3
	130	31	184 000	240 000	26 500	3 400	4 300	1,70	22215 E	22215 EK	0,22	3
	160	37	235 000	300 000	32 500	2 400	3 200	3,55	21315 CC	21315 CCK	0,23	2,9
	160	55	345 000	430 000	44 000	2 200	3 000	5,25	22315 CC/W33	22315 CCK/W33	0,35	1,9
	160	55	385 000	475 000	48 000	2 200	3 000	5,25	22315 E	22315 EK	0,35	1,9
80	140	33	176 000	228 000	26 000	3 200	4 000	2,05	22216 CC	22216 CCK	0,22	3
	140	33	207 000	270 000	29 000	3 200	4 000	2,10	22216 E	22216 EK	0,22	3
	170	39	258 000	335 000	36 000	2 200	3 000	4,20	21316 CC	21316 CCK	0,23	2,9
	170	58	374 000	455 000	46 500	2 000	2 800	6,20	22316 CC/W33	22316 CCK/W33	0,35	1,9
	170	58	431 000	540 000	54 000	2 000	2 800	6,20	22316 E	22316 EK	0,35	1,9
85	150	36	210 000	270 000	31 000	3 000	3 800	2,55	22217 CC/W33	22217 CCK/W33	0,22	3
	150	36	244 000	325 000	34 500	2 800	3 600	2,65	22217 E	22217 EK	0,22	3
	180	41	293 000	375 000	40 000	2 000	2 800	5,00	21317 CC	21317 CCK	0,23	2,9
	180	60	420 000	520 000	52 000	1 900	2 600	7,25	22317 CC/W33	22317 CCK/W33	0,33	2
	180	60	477 000	620 000	61 000	1 900	2 600	7,25	22317 E	22317 EK	0,33	2

Fig 7.5.3 Spherical roller bearings taken from SKF catalogue

Deep groove ball bearings
single row, with seal(s)
d 55–75 mm



With one RS1 seal

With two RS1 seals

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed rating	Mass	Designations Bearings with one seal	two seals
d	D	B	C	C_0	P_u				
mm			N		N	r/min		kg	–
55	72	9	8 320	6 200	325	5 300	0,063	61811-RS1	61811-2RS1
	80	13	15 900	11 400	560	5 000	0,19	61911-RS1	61911-2RS1
	90	18	26 100	21 200	900	4 300	0,39	6011-RS1	6011-2RS1
	100	21	43 600	29 000	1 250	4 300	0,61	6211-RS1	6211-2RS1
	100	25	43 600	29 000	1 250	4 300	0,70	–	62311-2RS1
	120	29	71 500	45 000	1 900	3 800	1,35	6311-RS1	6311-2RS1
	120	43	71 500	45 000	1 900	3 800	1,96	–	62311-2RS1
60	78	10	8 710	6 700	365	4 800	0,11	61812-RS1	61812-2RS1
	85	13	16 500	13 000	600	4 500	0,20	61912-RS1	61912-2RS1
	95	18	29 600	23 200	980	4 300	0,42	6012-RS1	6012-2RS1
	110	22	47 500	32 500	1 400	4 000	0,78	6212-RS1	6212-2RS1
	110	28	47 500	32 500	1 400	4 000	0,97	–	62212-2RS1
	130	31	81 900	52 000	2 200	3 400	1,70	6312-RS1	6312-2RS1
	130	46	81 900	52 000	2 200	3 400	2,50	–	62312-2RS1
65	85	10	11 700	9 150	490	4 500	0,13	61813-RS1	61813-2RS1
	90	13	17 400	13 400	560	4 300	0,22	61913-RS1	61913-2RS1
	100	18	30 700	25 000	1 060	4 000	0,44	6013-RS1	6013-2RS1
	120	23	55 300	40 500	1 700	3 600	0,99	6213-RS1	6213-2RS1
	120	31	55 300	40 500	1 700	3 600	1,25	–	62213-2RS1
	140	33	92 300	60 000	2 500	3 200	2,10	6313-RS1	6313-2RS1
	140	48	92 300	60 000	2 500	3 200	3,00	–	62313-2RS1
70	90	10	12 100	10 000	540	4 300	0,14	61814-RS1	61814-2RS1
	100	16	23 800	16 300	900	4 000	0,35	61914-RS1	61914-2RS1
	110	20	37 700	31 000	1 320	3 800	0,60	6014-RS1	6014-2RS1
	125	24	60 500	45 000	1 800	3 400	1,10	6214-RS1	6214-2RS1
	125	31	60 500	45 000	1 900	3 400	1,30	–	62214-2RS1
	150	35	104 000	68 000	2 750	3 000	2,50	6314-RS1	6314-2RS1
	150	51	104 000	68 000	2 750	3 000	3,55	–	62314-2RS1
75	95	10	12 500	10 800	585	4 000	0,15	61815-RS1	61815-2RS1
	105	16	24 200	19 300	965	3 800	0,37	61915-RS1	61915-2RS1
	115	20	39 700	33 500	1 430	3 400	0,64	6015-RS1	6015-2RS1
	130	25	66 300	49 000	2 040	3 200	1,20	6215-RS1	6215-2RS1
	160	37	114 000	76 500	3 000	2 600	3,00	6315-RS1	6315-2RS1

Fig 7.5.1 Deep groove ball bearings taken from SKF catalogue

Calculation factors X and Y for deep groove ball bearings **Table 7.5.2**

The following is taken from SKF catalogue.

F_a / C_0	e	X	Y
0.025	0.22	0.56	2.0
0.04	0.24	0.56	1.8
0.07	0.27	0.56	1.6
0.13	0.31	0.56	1.4
0.25	0.37	0.56	1.2
0.50	0.44	0.56	1.0

The above values for X and Y apply when $F_a / F_r > e$. When $F_a / F_r \leq e$ use X = 1 and Y = 0.

Table 9.2.1 Discount factors for single sums

Discount rate (r) $\frac{1}{(1+r)^n}$

Period (n)	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%	15%	16%	18%	20%	24%	28%	32%	36%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174	0.9091	0.8929	0.8772	0.8696	0.8621	0.8475	0.8333	0.8065	0.7813	0.7576	0.7353
2	0.9803	0.9612	0.9426	0.9246	0.9070	0.8900	0.8734	0.8573	0.8417	0.8264	0.7972	0.7695	0.7561	0.7432	0.7182	0.6944	0.6504	0.6104	0.5739	0.5407
3	0.9706	0.9423	0.9151	0.8890	0.8638	0.8396	0.8163	0.7938	0.7722	0.7513	0.7118	0.6750	0.6575	0.6407	0.6086	0.5787	0.5245	0.4768	0.4348	0.3975
4	0.9610	0.9238	0.8885	0.8548	0.8227	0.7921	0.7629	0.7350	0.7084	0.6830	0.6355	0.5921	0.5718	0.5523	0.5158	0.4823	0.4230	0.3725	0.3294	0.2923
5	0.9515	0.9057	0.8626	0.8219	0.7835	0.7473	0.7130	0.6806	0.6499	0.6209	0.5674	0.5194	0.4972	0.4761	0.4371	0.4019	0.3411	0.2910	0.2495	0.2149
6	0.9420	0.8880	0.8375	0.7903	0.7462	0.7050	0.6663	0.6302	0.5963	0.5645	0.5066	0.4556	0.4323	0.4104	0.3704	0.3349	0.2751	0.2274	0.1890	0.1580
7	0.9327	0.8706	0.8131	0.7599	0.7107	0.6651	0.6227	0.5835	0.5470	0.5132	0.4523	0.3996	0.3759	0.3538	0.3139	0.2791	0.2218	0.1776	0.1432	0.1162
8	0.9235	0.8535	0.7894	0.7307	0.6768	0.6274	0.5820	0.5403	0.5019	0.4665	0.4039	0.3506	0.3269	0.3050	0.2660	0.2326	0.1789	0.1388	0.1085	0.0854
9	0.9143	0.8368	0.7664	0.7026	0.6446	0.5919	0.5439	0.5002	0.4604	0.4241	0.3606	0.3075	0.2843	0.2630	0.2255	0.1938	0.1443	0.1084	0.0822	0.0628
10	0.9053	0.8203	0.7441	0.6756	0.6139	0.5584	0.5083	0.4632	0.4224	0.3855	0.3220	0.2697	0.2472	0.2267	0.1911	0.1615	0.1164	0.0847	0.0623	0.0462
11	0.8963	0.8043	0.7224	0.6496	0.5847	0.5268	0.4751	0.4289	0.3875	0.3505	0.2875	0.2366	0.2149	0.1954	0.1619	0.1346	0.0938	0.0662	0.0472	0.0340
12	0.8874	0.7885	0.7014	0.6246	0.5568	0.4970	0.4440	0.3971	0.3555	0.3186	0.2567	0.2076	0.1869	0.1685	0.1372	0.1122	0.0757	0.0517	0.0357	0.0250
13	0.8787	0.7730	0.6810	0.6006	0.5303	0.4688	0.4150	0.3677	0.3262	0.2897	0.2292	0.1821	0.1625	0.1452	0.1163	0.0935	0.0610	0.0404	0.0271	0.0184
14	0.8700	0.7579	0.6611	0.5775	0.5051	0.4423	0.3878	0.3405	0.2992	0.2633	0.2046	0.1597	0.1413	0.1252	0.0985	0.0779	0.0492	0.0316	0.0205	0.0135
15	0.8613	0.7430	0.6419	0.5553	0.4810	0.4173	0.3624	0.3152	0.2745	0.2394	0.1827	0.1401	0.1229	0.1079	0.0835	0.0649	0.0397	0.0247	0.0155	0.0099
16	0.8528	0.7284	0.6232	0.5339	0.4581	0.3936	0.3387	0.2919	0.2519	0.2176	0.1631	0.1229	0.1069	0.0930	0.0708	0.0541	0.0320	0.0193	0.0118	0.0073
17	0.8444	0.7142	0.6050	0.5134	0.4363	0.3714	0.3166	0.2703	0.2311	0.1978	0.1456	0.1078	0.0929	0.0802	0.0600	0.0451	0.0258	0.0150	0.0089	0.0054
18	0.8360	0.7002	0.5874	0.4936	0.4155	0.3503	0.2959	0.2502	0.2120	0.1799	0.1300	0.0946	0.0808	0.0691	0.0508	0.0376	0.0208	0.0118	0.0068	0.0039
19	0.8277	0.6864	0.5703	0.4746	0.3957	0.3305	0.2765	0.2317	0.1945	0.1635	0.1161	0.0829	0.0703	0.0596	0.0431	0.0313	0.0168	0.0092	0.0051	0.0029
20	0.8195	0.6730	0.5537	0.4564	0.3769	0.3118	0.2584	0.2145	0.1784	0.1486	0.1037	0.0728	0.0611	0.0514	0.0365	0.0261	0.0135	0.0072	0.0039	0.0021

To find the present value (PV) of a sum of money arising 'n' years in the future, given a discount or interest rate (r), multiply the future sum (FV) by the discount factor found in the table.

$$PV = FV \times \text{discount factor} = \frac{FV}{(1+r)^n}$$

Table 9.3.1 Discount factors for annuities

Discount rate (r) $\frac{(1+r)^n - 1}{r(1+r)^n}$

Period (n)	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	12%	14%	15%	16%	18%	20%	24%	28%	32%
1	0.9901	0.9804	0.9709	0.9615	0.9524	0.9434	0.9346	0.9259	0.9174	0.9091	0.8929	0.8772	0.8696	0.8621	0.8475	0.8333	0.8065	0.7813	0.7576
2	1.9704	1.9416	1.9135	1.8861	1.8594	1.8334	1.8080	1.7833	1.7591	1.7355	1.6901	1.6467	1.6257	1.6052	1.5656	1.5278	1.4568	1.3916	1.3315
3	2.9410	2.8839	2.8286	2.7751	2.7232	2.6730	2.6243	2.5771	2.5313	2.4869	2.4018	2.3216	2.2832	2.2459	2.1743	2.1065	1.9813	1.8684	1.7663
4	3.9020	3.8077	3.7171	3.6299	3.5460	3.4651	3.3872	3.3121	3.2397	3.1699	3.0373	2.9137	2.8550	2.7982	2.6901	2.5887	2.4043	2.2410	2.0957
5	4.8534	4.7135	4.5797	4.4518	4.3295	4.2124	4.1002	3.9927	3.8897	3.7908	3.6048	3.4331	3.3522	3.2743	3.1272	2.9906	2.7454	2.5320	2.3452
6	5.7955	5.6014	5.4172	5.2421	5.0757	4.9173	4.7665	4.6229	4.4859	4.3553	4.1114	3.8887	3.7845	3.6847	3.4976	3.3255	3.0205	2.7594	2.5342
7	6.7282	6.4720	6.2303	6.0021	5.7864	5.5824	5.3893	5.2064	5.0330	4.8684	4.5638	4.2883	4.1604	4.0386	3.8115	3.6046	3.2423	2.9370	2.6775
8	7.6517	7.3255	7.0197	6.7327	6.4632	6.2098	5.9713	5.7466	5.5348	5.3349	4.9676	4.6389	4.4873	4.3436	4.0776	3.8372	3.4212	3.0758	2.7860
9	8.5660	8.1622	7.7861	7.4353	7.1078	6.8017	6.5152	6.2469	5.9952	5.7590	5.3282	4.9464	4.7716	4.6065	4.3030	4.0310	3.5655	3.1842	2.8681
10	9.4713	8.9826	8.5302	8.1109	7.7217	7.3601	7.0236	6.7101	6.4177	6.1446	5.6502	5.2161	5.0188	4.8332	4.4941	4.1925	3.6819	3.2689	2.9304
11	10.3676	9.7868	9.2526	8.7605	8.3064	7.8869	7.4987	7.1390	6.8052	6.4951	5.9377	5.4527	5.2337	5.0286	4.6560	4.3271	3.7757	3.3351	2.9776
12	11.2551	10.5753	9.9540	9.3851	8.8633	8.3838	7.9427	7.5361	7.1607	6.8137	6.1944	5.6603	5.4206	5.1971	4.7932	4.4392	3.8514	3.3868	3.0133
13	12.1337	11.3484	10.6350	9.9856	9.3936	8.8527	8.3577	7.9038	7.4869	7.1034	6.4235	5.8424	5.5831	5.3423	4.9095	4.5327	3.9124	3.4272	3.0404
14	13.0037	12.1062	11.2961	10.5631	9.8986	9.2950	8.7455	8.2442	7.7862	7.3667	6.6282	6.0021	5.7245	5.4675	5.0081	4.6106	3.9616	3.4587	3.0609
15	13.8651	12.8493	11.9379	11.1184	10.3797	9.7122	9.1079	8.5595	8.0607	7.6061	6.8109	6.1422	5.8474	5.5755	5.0916	4.6755	4.0013	3.4834	3.0764
16	14.7179	13.5777	12.5611	11.6523	10.8378	10.1059	9.4466	8.8514	8.3126	7.8237	6.9740	6.2651	5.9542	5.6685	5.1624	4.7296	4.0333	3.5026	3.0882
17	15.5623	14.2919	13.1661	12.1657	11.2741	10.4773	9.7632	9.1216	8.5436	8.0216	7.1196	6.3729	6.0472	5.7487	5.2223	4.7746	4.0591	3.5177	3.0971
18	16.3983	14.9920	13.7535	12.6593	11.6896	10.8276	10.0591	9.3719	8.7556	8.2014	7.2497	6.4674	6.1280	5.8178	5.2732	4.8122	4.0799	3.5294	3.1039
19	17.2260	15.6785	14.3238	13.1339	12.0853	11.1581	10.3356	9.6036	8.9501	8.3649	7.3658	6.5504	6.1982	5.8775	5.3162	4.8435	4.0967	3.5386	3.1090
20	18.0456	16.3514	14.8775	13.5903	12.4622	11.4699	10.5940	9.8181	9.1285	8.5136	7.4694	6.6231	6.2593	5.9288	5.3527	4.8696	4.1103	3.5458	3.1129

To find the present value of constant annual sums arising 'n' years in the future, given a discount or interest rate (r), multiply the repeated future sum (the annuity) by the discount factor found in the table.

$$PV = \text{annuity} \times \text{discount factor} = \text{annuity} \times \frac{(1+r)^n - 1}{r(1+r)^n}$$

TABLE 3: SERVICE FACTORS

SPECIAL CASES	TYPES OF PRIME MOVER	
	'Soft' starts	'Heavy' starts
For speed increasing drives of: Speed ratio 1,00 – 1,24 multiply service factor by 1,00 Speed ratio 1,25 – 1,74 multiply service factor by 1,05 Speed ratio 1,75 – 2,49 multiply service factor by 1,11 Speed ratio 2,50 – 3,49 multiply service factor by 1,18 Speed ratio 3,50 and over multiply service factor by 1,25	Electric Motors: AC – Star Delta start DC – Shunt Wound Internal Combustion Engines with 4 or more cylinders All prime movers fitted with Centrifugal Clutches, Dry or Fluid Couplings or Electronic Soft Start devices	Electric Motors: AC – Direct-on-Line start DC – Series & Compound Wound Internal Combustion Engines with less than 4 cylinders Prime movers not fitted with soft start devices

	TYPES OF DRIVEN MACHINE	Hours per day duty					
		10 and under	Over 10 to 16	Over 16	10 and under	Over 10 to 16	Over 16
Class 1 Light Duty	Agitators (uniform density), Blowers, Exhausters and fans (up to 7,5 kW), Centrifugal compressors and pumps, Belt conveyors (uniformly loaded).	1,0	1,1	1,2	1,1	1,2	1,3
Class 2 Medium Duty	Agitators and mixers (variable density), Blowers, Exhausters and fans (over 7,5 kW), Rotary compressors and pumps (other than centrifugal), Belt conveyors (not uniformly loaded), Generators and exciters, Laundry machinery, Lineshafts, Machine tools, Printing machinery, Sawmill and woodworking machinery, Screens (rotary).	1,1	1,2	1,3	1,2	1,3	1,4
Class 3 Heavy Duty	Brick machinery, Bucket elevators, Compressors and pumps (reciprocating), Conveyors (heavy duty), Hoists, Mills (hammer), Pulverisers, Punches, Presses, Shears, Quarry plant, Rubber machinery, Screens (vibrating), Textile machinery.	1,2	1,3	1,4	1,4	1,5	1,6
Class 4 Extra Heavy Duty	Crushers (gyratory-jaw roll), Mills (ball-rod-tube).	1,3	1,4	1,5	1,5	1,6	1,8

Power Ratings—SPC Wedge Belts

Rev/min of faster shaft	RATED POWER (kW) PER BELT FOR SMALL PULLEY PITCH DIA (mm)																Belt Speed (m/s)
	224	236	250	265	280	300	315	335	355	375	400	425	450	475	500	530	560	
100	1,89	2,20	2,46	2,72	2,89	3,34	3,60	3,95	4,31	4,63	5,09	5,62	5,85	6,08	6,80	7,31	7,82	
200	3,59	4,00	4,48	4,96	5,49	6,17	6,67	7,33	8,00	8,66	9,48	10,30	11,11	11,92	12,72	13,69	14,64	
300	5,04	5,64	6,33	7,07	7,81	8,78	9,51	10,48	11,44	12,39	13,58	14,76	15,93	17,16	18,26	19,64	21,01	10
400	6,40	7,17	8,07	9,04	9,99	11,26	12,20	13,46	14,70	15,97	17,47	18,99	20,50	22,00	23,49	25,25	27,00	
500	7,67	8,62	9,72	10,90	12,06	13,61	14,76	16,28	17,80	19,30	21,16	23,00	24,82	26,63	28,42	30,54	32,64	
600	8,87	9,99	11,28	12,66	14,04	15,85	17,20	18,98	20,75	22,50	24,67	26,80	28,92	31,00	33,06	35,50	37,89	20
700	10,00	11,29	12,77	14,35	15,92	17,98	19,52	21,55	23,56	25,54	27,99	30,40	32,77	35,11	37,40	40,11	42,75	
720	10,22	11,54	13,05	14,68	16,28	18,40	19,97	22,05	24,10	26,13	28,63	31,08	33,51	35,89	38,23	40,99	43,67	
800	11,08	12,52	14,18	15,95	17,71	20,02	21,73	23,98	26,22	28,42	31,12	33,77	36,37	38,93	41,42	44,34	47,18	
900	12,10	13,69	15,53	17,48	19,41	21,95	23,82	26,30	28,73	31,12	34,05	36,92	39,71	42,44	45,09	48,18	51,15	
960	12,65	14,31	16,26	18,35	20,32	23,05	25,02	27,61	30,18	32,66	35,71	38,69	41,56	44,38	47,12	50,27	53,29	30
1000	13,05	14,79	16,80	18,92	21,02	23,77	25,80	28,47	31,08	33,64	36,77	39,82	42,77	45,63	48,39	51,58	54,61	
1100	13,96	15,83	18,00	20,28	22,53	25,48	27,65	30,48	33,27	35,98	39,37	42,65	45,82	48,87	51,78	54,41	57,63	
1200	14,81	16,81	19,12	21,55	23,96	27,08	29,38	32,37	35,28	38,12	41,64	44,82	47,86	50,77	53,53	56,98	60,34	40
1300	15,59	17,72	20,17	22,74	25,27	28,56	30,97	34,09	37,12	40,05	43,86	46,98	50,05	52,92	55,79	58,98	61,59	
1400	16,31	18,56	21,14	23,84	26,48	29,92	32,42	35,65	38,77	41,76	45,72	48,55	51,78	54,85	57,32	59,97	–	
1440	16,59	18,88	21,50	24,25	26,94	30,43	32,86	36,23	39,37	42,39	45,91	49,11	52,22	54,82	57,71	60,25	–	
1500	16,98	19,33	22,02	24,84	27,59	31,15	33,73	37,04	40,27	43,34	46,80	49,96	53,13	55,73	58,34	–	–	
1600	17,58	20,03	22,83	25,75	28,59	32,24	34,88	38,25	41,65	44,87	47,99	51,03	54,08	56,45	–	–	–	
1700	18,11	20,65	23,55	26,56	29,47	33,20	35,88	39,27	42,47	45,45	48,97	51,73	–	–	–	–	–	
1800	18,57	21,20	24,18	27,26	30,23	34,01	36,71	39,99	43,25	46,16	49,43	–	–	–	–	–	–	
1900	18,97	21,67	24,71	27,85	30,87	34,67	37,36	40,59	43,80	46,69	49,65	–	–	–	–	–	–	
2000	19,29	22,06	25,16	28,34	31,37	35,16	37,84	40,96	44,09	46,72	–	–	–	–	–	–	–	

Rev/min of faster shaft	ADDITIONAL POWER (kW) PER BELT FOR SPEED RATIO									
	1,00 to 1,01	1,02 to 1,05	1,06 to 1,11	1,12 to 1,18	1,19 to 1,26	1,27 to 1,38	1,39 to 1,57	1,58 to 1,94	1,95 to 3,38	3,39 and over
100	0,00	0,02	0,05	0,11	0,14	0,17	0,20	0,23	0,25	0,26
200	0,00	0,04	0,12	0,21	0,28	0,35	0,41	0,46	0,50	0,53
300	0,00	0,07	0,18	0,32	0,43	0,52	0,61	0,69	0,75	0,79
400	0,00	0,09	0,24	0,42	0,57	0,70	0,81	0,92	1,00	1,06
500	0,00	0,11	0,30	0,53	0,72	0,87	1,02	1,15	1,25	1,32
600	0,00	0,13	0,36	0,63	0,86	1,04	1,22	1,37	1,50	1,59
700	0,00	0,15	0,42	0,74	1,00	1,22	1,43	1,59	1,75	1,85
720	0,00	0,16	0,43	0,76	1,03	1,25	1,46	1,63	1,80	1,90
800	0,00	0,17	0,48	0,84	1,15	1,39	1,63	1,83	2,00	2,11
900	0,00	0,20	0,54	0,95	1,29	1,56	1,85	2,06	2,25	2,38
960	0,00	0,21	0,58	1,01	1,37	1,67	1,95	2,28	2,49	2,64
1000	0,00	0,22	0,60	1,05	1,43	1,74	2,04	2,38	2,59	2,74
1100	0,00	0,24	0,66	1,16	1,57	1,91	2,24	2,62	2,85	3,02
1200	0,00	0,26	0,72	1,26	1,72	2,09	2,44	2,85	3,10	3,28
1300	0,00	0,28	0,78	1,37	1,86	2,26	2,65	3,09	3,36	3,56
1400	0,00	0,31	0,84	1,47	2,00	2,43	2,85	3,32	3,61	3,82
1440	0,00	0,31	0,87	1,51	2,06	2,50	2,93	3,30	3,72	3,95
1500	0,00	0,33	0,90	1,58	2,15	2,61	3,05	3,44	3,75	3,96
1600	0,00	0,35	0,96	1,68	2,29	2,78	3,26	3,67	4,00	4,23
1700	0,00	0,37	1,02	1,79	2,43	2,96	3,46	3,90	4,25	4,49
1800	0,00	0,39	1,08	1,89	2,58	3,13	3,66	4,12	4,50	4,76
1900	0,00	0,42	1,14	2,00	2,72	3,30	3,87	4,35	4,75	5,02
2000	0,00	0,44	1,20	2,10	2,86	3,48	4,07	4,58	5,00	5,29

NOTE: Only pulleys of Fenner manufacture should be used where belt speed falls between 39 and 40 m/s.

Fig 7.4.1 Extracts from Fenner wedge belt catalogue *continued from previous page*

Power Ratings—SPB Wedge Belts

Rev/min of faster shaft	RATED POWER (kW) PER BELT FOR SMALL PULLEY PITCH DIA (mm)													Belt Speed (m/s)
	140	150	160	170	180	190	200	212	224	236	250	280	315	
100	0,73	0,82	0,92	1,01	1,10	1,20	1,29	1,40	1,51	1,62	1,74	2,01	2,33	
200	1,33	1,51	1,69	1,87	2,05	2,22	2,40	2,61	2,82	3,02	3,26	3,78	4,37	
300	1,89	2,16	2,41	2,67	2,93	3,18	3,44	3,74	4,04	4,35	4,70	5,44	6,30	
400	2,42	2,76	3,09	3,43	3,77	4,10	4,43	4,83	5,22	5,61	6,07	7,04	8,15	
500	2,92	3,33	3,76	4,16	4,57	4,98	5,39	5,87	6,36	6,84	7,39	8,58	9,94	
600	3,40	3,88	4,38	4,87	5,36	5,83	6,31	6,89	7,45	8,02	8,67	10,08	11,68	10
700	3,86	4,40	4,89	5,55	6,11	6,66	7,21	7,87	8,52	9,17	9,92	11,50	13,32	
720	3,95	4,50	5,11	5,69	6,26	6,82	7,39	8,06	8,73	9,39	10,16	11,75	13,65	
800	4,31	4,95	5,59	6,22	6,84	7,47	8,08	8,82	9,55	10,28	11,12	12,90	14,93	
900	4,75	5,46	6,16	6,86	7,56	8,25	8,93	9,75	10,56	11,36	12,28	14,26	16,47	
960	5,00	5,75	6,50	7,24	7,98	8,71	9,43	10,29	11,15	11,99	12,97	15,03	17,37	
1000	5,17	5,95	6,72	7,49	8,25	9,01	9,76	10,65	11,53	12,41	13,42	15,55	17,96	
1100	5,68	6,42	7,27	8,10	8,93	9,75	10,56	11,52	12,48	13,43	14,52	16,83	19,39	
1200	6,19	6,89	7,79	8,69	9,58	10,46	11,34	12,37	13,40	14,41	15,57	18,01	20,75	20
1300	6,68	7,54	8,51	9,27	10,22	11,16	12,09	13,19	14,28	15,36	16,59	19,17	22,06	
1400	6,73	7,77	8,81	9,83	10,84	11,84	12,82	13,99	15,14	16,27	17,57	20,28	23,28	
1440	6,88	7,95	9,00	10,05	11,08	12,10	13,11	14,30	15,47	16,63	17,96	20,70	23,78	
1500	7,08	8,20	9,29	10,37	11,44	12,49	13,53	14,76	15,97	17,15	18,51	21,33	24,49	
1600	7,44	8,61	9,76	10,89	12,02	13,12	14,21	15,50	16,76	18,00	19,41	22,33	25,61	
1700	7,78	9,01	10,21	11,40	12,58	13,73	14,87	16,21	17,52	18,81	20,27	23,27	26,51	
1800	8,11	9,39	10,65	11,89	13,12	14,32	15,50	16,89	18,25	19,58	21,08	24,16	27,43	30
1900	8,43	9,76	11,08	12,37	13,64	14,88	16,11	17,54	18,94	20,31	21,85	24,97	28,27	
2000	8,73	10,12	11,48	12,82	14,14	15,43	16,69	18,16	19,60	20,99	22,57	25,72	29,01	
2100	9,02	10,48	11,88	13,26	14,62	15,94	17,24	18,75	20,22	21,64	23,23	26,43	29,67	
2200	9,31	10,79	12,25	13,68	15,07	16,44	17,75	19,31	20,80	22,24	23,85	27,03	30,22	
2300	9,57	11,11	12,61	14,08	15,51	16,89	18,25	19,83	21,35	22,80	24,42	27,57	30,68	40
2400	9,83	11,41	12,95	14,46	15,92	17,34	18,72	20,32	21,85	23,31	24,93	28,05	31,04	
2500	10,08	11,70	13,28	14,82	16,31	17,76	19,18	20,77	22,31	23,76	25,38	28,44	-	
2600	10,31	11,97	13,59	15,16	16,68	18,14	19,56	21,19	22,73	24,19	25,78	28,76	-	
2700	10,53	12,23	13,88	15,47	17,02	18,50	19,93	21,56	23,11	24,58	26,12	28,99	-	
2800	10,73	12,47	14,16	15,77	17,33	18,83	20,27	21,90	23,44	24,87	26,40	-	-	
2850	10,83	12,55	14,25	15,88	17,47	19,07	20,51	22,14	23,67	25,08	26,57	-	-	
2900	10,83	12,59	14,30	16,04	17,62	19,13	20,67	22,20	23,72	25,12	26,61	-	-	
3000	11,10	12,90	14,63	16,30	17,89	19,40	20,84	22,46	23,96	25,33	26,76	-	-	

Rev/min of faster shaft	ADDITIONAL POWER (kW) PER BELT FOR SPEED RATIO									
	1,00 to 1,01	1,02 to 1,05	1,06 to 1,11	1,12 to 1,18	1,19 to 1,26	1,27 to 1,38	1,39 to 1,57	1,58 to 1,94	1,95 to 3,38	3,39 and over
100	0,00	0,01	0,02	0,04	0,04	0,06	0,07	0,07	0,08	0,08
200	0,00	0,01	0,04	0,07	0,09	0,11	0,13	0,15	0,16	0,17
300	0,00	0,02	0,05	0,10	0,14	0,17	0,20	0,22	0,24	0,25
400	0,00	0,03	0,07	0,13	0,18	0,22	0,26	0,29	0,32	0,34
500	0,00	0,04	0,09	0,17	0,23	0,28	0,33	0,37	0,40	0,43
600	0,00	0,04	0,12	0,20	0,28	0,34	0,40	0,45	0,48	0,51
700	0,00	0,05	0,13	0,24	0,33	0,39	0,46	0,52	0,57	0,59
720	0,00	0,05	0,14	0,25	0,33	0,41	0,48	0,54	0,59	0,62
800	0,00	0,06	0,16	0,28	0,37	0,46	0,53	0,60	0,65	0,69
900	0,00	0,07	0,18	0,31	0,42	0,51	0,60	0,66	0,72	0,77
960	0,00	0,07	0,19	0,32	0,44	0,54	0,62	0,70	0,77	0,81
1000	0,00	0,07	0,19	0,34	0,46	0,56	0,65	0,74	0,81	0,86
1100	0,00	0,08	0,22	0,37	0,51	0,62	0,72	0,81	0,89	0,94
1200	0,00	0,09	0,23	0,41	0,55	0,68	0,79	0,89	0,97	1,03
1300	0,00	0,09	0,25	0,44	0,60	0,73	0,85	0,96	1,05	1,11
1400	0,00	0,10	0,28	0,48	0,65	0,79	0,93	1,04	1,13	1,20
1440	0,00	0,10	0,28	0,48	0,66	0,79	0,94	1,06	1,15	1,21
1500	0,00	0,10	0,29	0,51	0,69	0,84	0,98	1,11	1,21	1,28
1600	0,00	0,11	0,31	0,54	0,75	0,90	1,05	1,19	1,29	1,37
1700	0,00	0,12	0,34	0,58	0,79	0,95	1,12	1,26	1,37	1,45
1800	0,00	0,13	0,35	0,61	0,84	1,01	1,19	1,34	1,46	1,54
1900	0,00	0,13	0,37	0,65	0,89	1,07	1,26	1,41	1,54	1,63
2000	0,00	0,14	0,39	0,68	0,93	1,13	1,32	1,48	1,62	1,71
2100	0,00	0,15	0,41	0,72	0,98	1,18	1,39	1,56	1,69	1,79
2200	0,00	0,16	0,43	0,75	1,02	1,24	1,45	1,63	1,78	1,88
2300	0,00	0,16	0,45	0,78	1,07	1,29	1,51	1,71	1,86	1,97
2400	0,00	0,17	0,47	0,82	1,11	1,35	1,58	1,78	1,94	2,05
2500	0,00	0,18	0,49	0,85	1,16	1,41	1,65	1,86	2,02	2,14
2600	0,00	0,19	0,51	0,89	1,21	1,46	1,72	1,92	2,10	2,22
2700	0,00	0,19	0,53	0,92	1,25	1,52	1,78	1,99	2,18	2,31
2800	0,00	0,20	0,54	0,95	1,29	1,57	1,84	2,07	2,26	2,39
2850	0,00	0,20	0,55	0,97	1,32	1,59	1,86	2,11	2,31	2,44
2900	0,00	0,21	0,57	0,99	1,34	1,63	1,91	2,16	2,24	2,48
3000	0,00	0,22	0,59	1,02	1,39	1,69	1,98	2,23	2,42	2,57

NOTE: Only pulleys of Fenner manufacture should be used where belt speed falls between 39 and 40 m/s.

Fig 7.4.1 Extracts from Fenner wedge belt catalogue *continued from previous pages*

Table 1 Ideal class of pull/belt type and optimum diameter of the small pulley for new drives

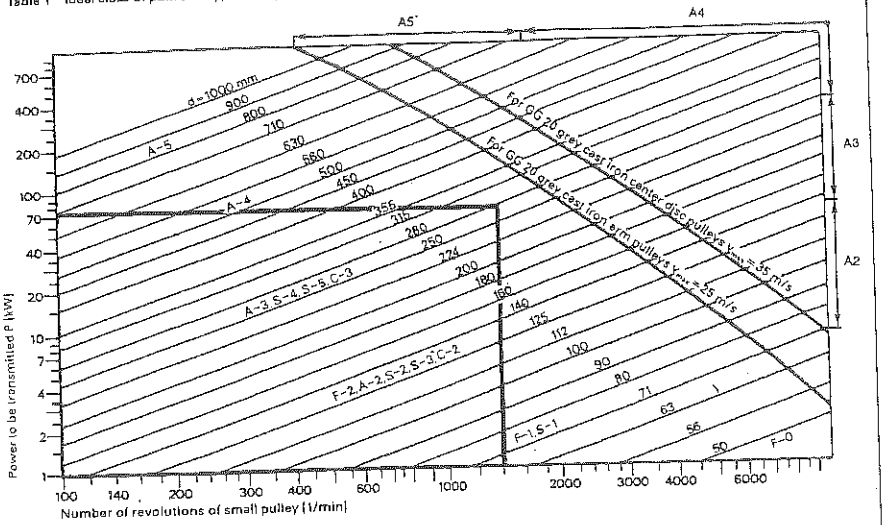


Table 2 Minimum center distance e_{min}

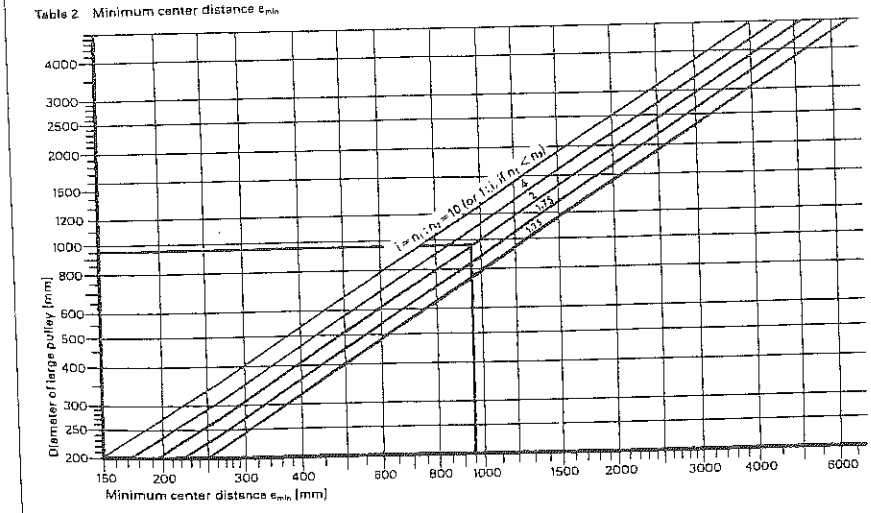


Fig 7.4.2 Extracts from Habasit catalogue *continued on following pages*

Fig 7.6.1 Torsion and bending

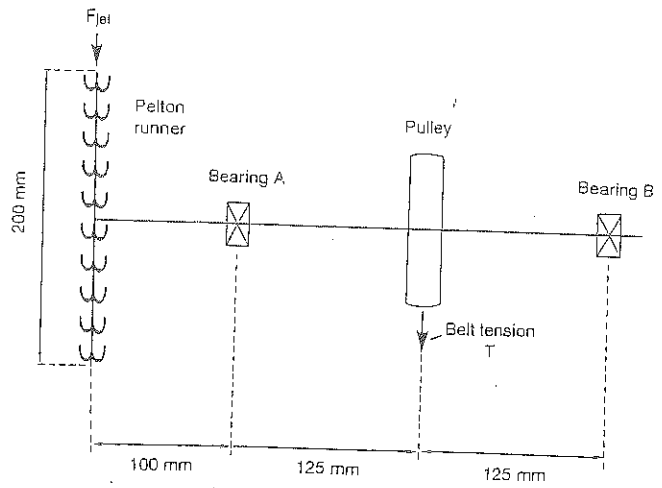
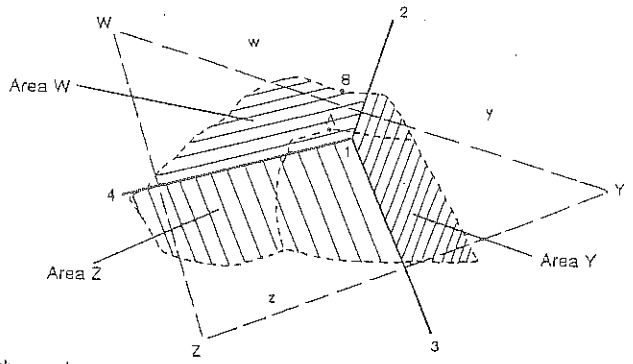


Fig 7.6.2 Pelton turbine and pulley drive. In this example the belt tension and turbine forces act in the same direction.



For example
W gauge: w = 2000 mm/year
Y gauge: y = 2700 mm/year
Z gauge: z = 3000 mm/year

If average annual rainfall at each gauge is w, y and z mm/year, then average rainfall in catchment (mm/year)

$$= \frac{\text{Area Z}}{\text{Area total}} \times z + \frac{\text{Area W}}{\text{Area total}} \times w + \frac{\text{Area Y}}{\text{Area total}} \times y$$

For example, Area Y is the area bounded by the catchment boundary and lines 1 to 2 and 1 to 3.
Total area is the area within dashed lines.

Fig 2.2.3 Estimating average rainfall