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TECHNOLOGY

INSTRUCTION MANUAL

Investigation of :

Efficiency of a Pelton Wheel

Turbine

P6240

TSD/MW/9/82

MANUFACTURERS LIABILITY

U.K. STATUTE CHAP: 37 - HEALTH AND SAFETY AT WORK ETC. ACT 1974

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Should any advice be needed on safety aspects of the use of our equipment we shall of course be glad to provide it.

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LIST OF SYMBOLS

g	acceleration due to gravity 9.807	m/s^2
k	velocity reduction factor due to losses	-
r	radius of turbine rotor	m
u	velocity of wheel	m/s
V_1	velocity of jet stream	m/s
H	head across the machine	m
N	rotational speed of turbine	rpm
N_s	specific rotational speed of turbine	
P	power transferred from fluid to rotor	watts
Q	rate of flow of jet stream	m/s
R	relative velocity of jet with respect to wheel	m/s
ρ	density of water 1000	kg/m^3
θ	angle through which fluid is deflected by bucket on Pelton wheel	
η	wheel efficiency	%
C_v	coefficient of velocity for jet	

DATA SHEET

Pelton Wheel Degener Type 4717

Number of blades	16
Diameter of blade wheel	100 mm
Diameter of brake wheel	60 mm
Mass of weight carrier	350 gms.

1. Description of Apparatus (Figs. 1, 2 and 3) The apparatus consists of a model Pelton wheel typical in design of larger units and affording relevant practical results. Spoon shaped buckets are mounted on a wheel positioned so that the jet of water from the input spear valve impinges tangentially on them. Each "bucket" is divided by a "splitter" ridge which divides the jet into two equal parts. After flowing round the inner surface of the bucket, the fluid leaves with a relative velocity almost opposite in direction to the original jet. The buckets are shaped so as to prevent the jet to the preceding bucket being intercepted too soon. The desired maximum deflection of the jet (180^{o}) cannot be achieved without the fluid leaving one bucket striking the following one, and so in practice the deflection is limited to approx. 160^{o}. A control valve typical of those in use with larger machines is included. This consists of a spear valve where movement of a spear along the axis of the nozzle alters the annular space between the spear and the housing, the spear being shaped so as to induce the fluid to coalesce into a circular jet of varying diameter according to the position of the spear.

2. <u>Relevant Theory.</u> The Pelton wheel is a hydraulic turbine of the impulse type and is particularly suited for use with high heads. The power imparted to the wheel by the input jet of water delivering Q m^3/s from a head of Hm is given by

$$P = HgQ\rho \text{ where } g = 9.807 \text{ m/s}^2 \text{ and}$$

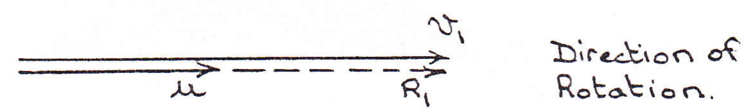
$$\rho \text{ for water} = 10^3 \text{ kg/m}^3$$

The jet velocity $v_1 = C_v\sqrt{2gH}$ and the velocity of the Pelton wheel bucket under consideration equals u. The jet is assumed to strike the bucket wheel at a radius r metres, and to leave the bucket at an angle of θ to direction of rotation with a loss of velocity of (1 - k)

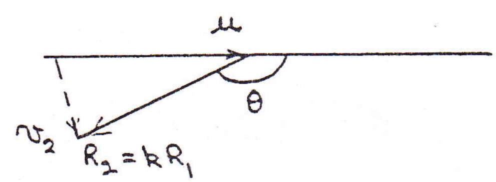
i.e. Relative velocity $R_1 = v_1 - u$

and $R_2 = kR_1$

Inlet to bucket



Outlet from bucket



It can be shown that

$$\eta_w = \frac{2u(v_1 - u)(1 - k\cos\theta)}{v_1^2}$$

which has a maximum value when $\frac{u}{v_1} = \frac{1}{2}$ if k is assumed constant

$$u = 2\pi Nr$$

and $$v_1 = \frac{\text{volume/s}}{\text{CSa of nozzle}}$$

Thus the maximum efficiency will occur at different speeds for different spear value settings. The specific speed for turbines is defined as

$$\frac{NP^{1/2}}{C^{1/2}(gH)^{5/4}}$$

Normally the values of C and g are omitted since water is almost invariably the fluid used and g can be considered constant

$$\text{i.e.} \quad N_s = \frac{NP^{1/2}}{H^{5/4}}$$

when N = rotational speed rev/sec

P = power transferred between fluid and runner

H = fluid head difference across machine, m

For single jet Pelton wheels, values of dimensionless specific speed range from 15 to 30 for working models having reasonable inlet jet velocities.

3. Method.

1. Position the Pelton wheel baseplate on the retaining studs provided on the bench top.

2. Assemble the Prony brake to the brake wheel.

3. Connect the bench delivery pipe to the inlet pipe and clamp with the "Jubilee" clips provided.

4. Adjust the spear valve to the desired setting.

5. Switch on the pump and open the bench delivery valve to the test apparatus measuring the flowrate by recording the time taken to fill the measuring tank to a predetermined level.

6. Measure and record the speed of the Pelton wheel shaft using P4740 light sensitive tachometer or other rotational speed measuring instrument.

7. Record the values of the masses added to the weight carrier and the weight indicated on the spring dynamometer.

8. Record the value of the head immediately prior to the nozzle as indicated on the pressure gauge.

9. Vary the speed of the turbine by loading the Prony brake. For each incremental increase of load record the value of the rotational speed. Ensure that a sufficient range of experiments is undertaken so that the maximum efficiency point can be determined. This can be checked by ensuring that a maximum value of the product of applied load and rotational speed is reached as the speed is decreased by successive increments.

10. Repeat the range of results for different values of spear valve settings.

4. Results and Calculations. The results for the different valve settings and inlet pressures are given in Tables 1 to 3, together with the calculated values for efficiency. From the graphs of efficiency against rotational speed the following figures were obtained.

Valve setting	0 mm shut	5 mm shut	7 mm shut
Max. η %	63.5	72	70.5
Speed at η rpm N	920	1080	1280
Max. Power Output (W/HP)	28.5/0.038	35.6/0.048	35.8/0.048
Head bar/m H	0.68/6.94	0.90/9.18	1.12/11.4
Specific Speed K_n (dimensionless) $\frac{N\ HP^{1/2}}{H_m^{5/4}}$	16.0	14.8	13.4

Notes relating to Tables 1 to 3

1. Flow $= \frac{30,000}{t}$ cm^3/sec

$= \frac{30,000}{46} = 652\ cm^3/s$

2. Power input to turbine

$P_i = HgQ\rho$ watts

$= \frac{(1 \times 9.807)}{10^3} HQ$ watts

H head m

Q flow cm^3/s

H = 0.68 bar = 6.936 m   H = 0.90 bar = 9.180 m   H = 1.12 bar = 11.42 m

3. Power output

$P_o = \pi D(W - S)g\,N'$

$= \pi 0.06 \times 9.807\ (W - S)\ N' = \frac{1.849}{60}\ (W - S)\ N$

$= 0.03081\ (W - S)\ N$

4. H metres

Pressure in bars $= \frac{H\rho g}{10^5}$ with H = head in metres

ρ = 1000 kg/m^3 for water

g = 9.807 m/s^2

$\therefore H = \frac{10^5 (Bars)}{\rho\ 9.807} = 10.20\ (Bars)$ metres

Table 1

Valve setting 0mm shut: Inlet pressure 0.68 bar

Time for 30,000 cm^3 = 46 secs i.e. 652 cm^3/s

RPM N	Brake Load W . S	kg	Power in (Watts)	Power out (Watts)	η%
1350	0.60 - 0.16 =	0.44	44.35	18.30	41.3
1215	0.80 - 0.15 =	0.65		24.33	54.9
1060	1.00 - 0.15 =	0.85		27.76	62.6
820	1.20 - 0.10 =	1.10		27.79	62.7
690	1.30 - 0.07 =	1.23		26.15	59.0
580	1.40 - 0.06 =	1.34		23.95	54.0
470	1.50 - 0.06 =	1.44		20.86	47.0

Table 2

Valve setting 5 mm shut: Inlet pressure 0.90 bar

Time for 30,000 cm^3 = 54.9 secs i.e. 546 cm^3/s

1760	0.20 - 0.04 =	0.16	49.16	8.68	17.7
1580	0.40 - 0.07 =	0.33		16.06	32.7
1460	0.60 - 0.08 =	0.52		23.39	47.6
1300	0.80 - 0.10 =	0.70		28.04	57.0
1220	1.00 - 0.10 =	0.90		33.83	68.8
1020	1.20 - 0.08 =	1.12		35.20	71.6
750	1.40 - 0.09 =	1.31		30.27	61.6
600	1.50 - 0.09 =	1.41		26.07	53.0

Table 3

Valve setting 7 mm shut: Inlet pressure 1.12 bar

Time for 30,000 cm^3 = 66.0 secs i.e. 455 cm^3/s

1960	0.20 - 0.03 =	0.17	50.96	10.27	20.2
1810	0.40 - 0.05 =	0.35		19.52	38.3
1670	0.60 - 0.07 =	0.53		27.27	53.5
1510	0.80 - 0.11 =	0.69		32.10	63.0
1350	1.00 - 0.15 =	0.85		35.35	69.4
1040	1.20 - 0.16 =	1.04		33.32	65.4
740	1.40 - 0.15 =	1.25		28.50	55.9

5. Interpretation of Results

5.1 List the possible sources of inefficiency in the turbine and discuss how they can be minimised.

5.2 Discuss ways of governing a Pelton wheel of the type presented.

5.3 Explain why the overall efficiency usually occurs at a u/v ration slightly lower than the theoretical value of 0.5.

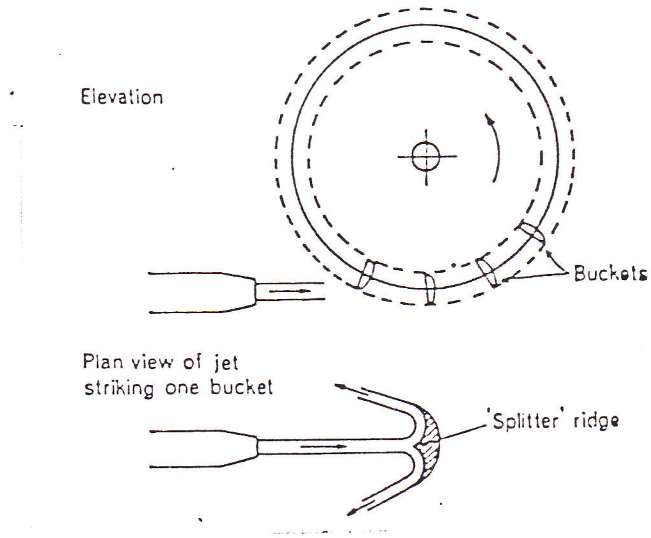
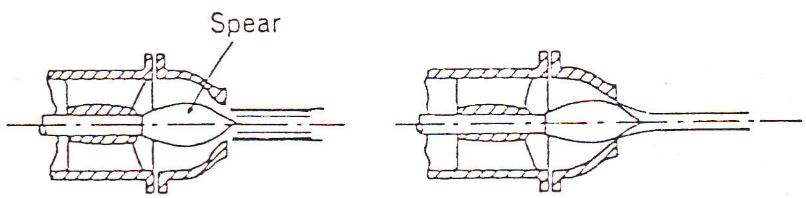


FIG 1. Pelton Wheel showing bucket shape.



Spear valve to alter jet diameter.

FIG 2 Action of Spear (Control) Valve.

FIG. 3 PELTON WHEEL WITH PRONY BRAKE

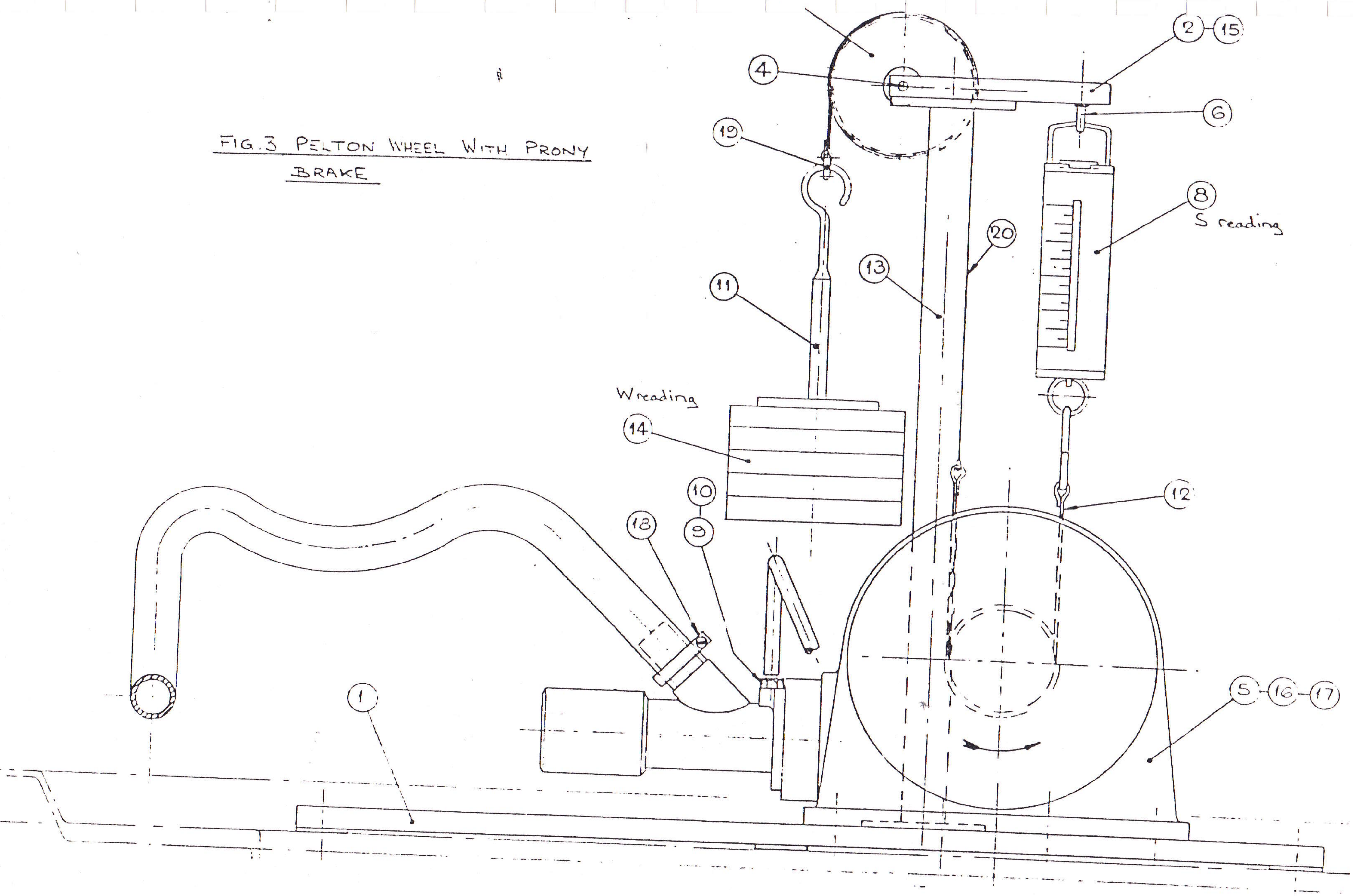


Fig 5 Pelton Wheel Output/Speed Characteristics

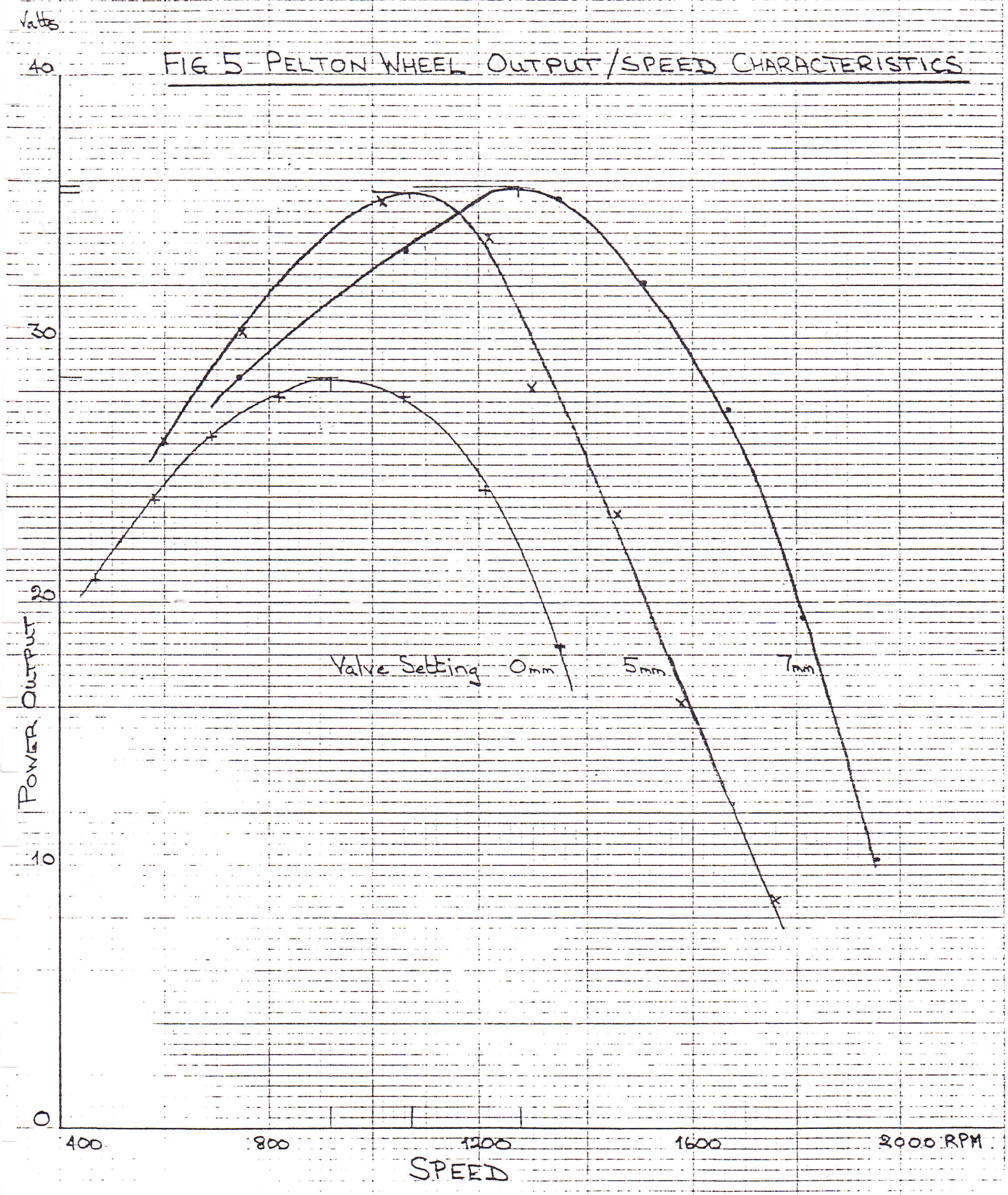
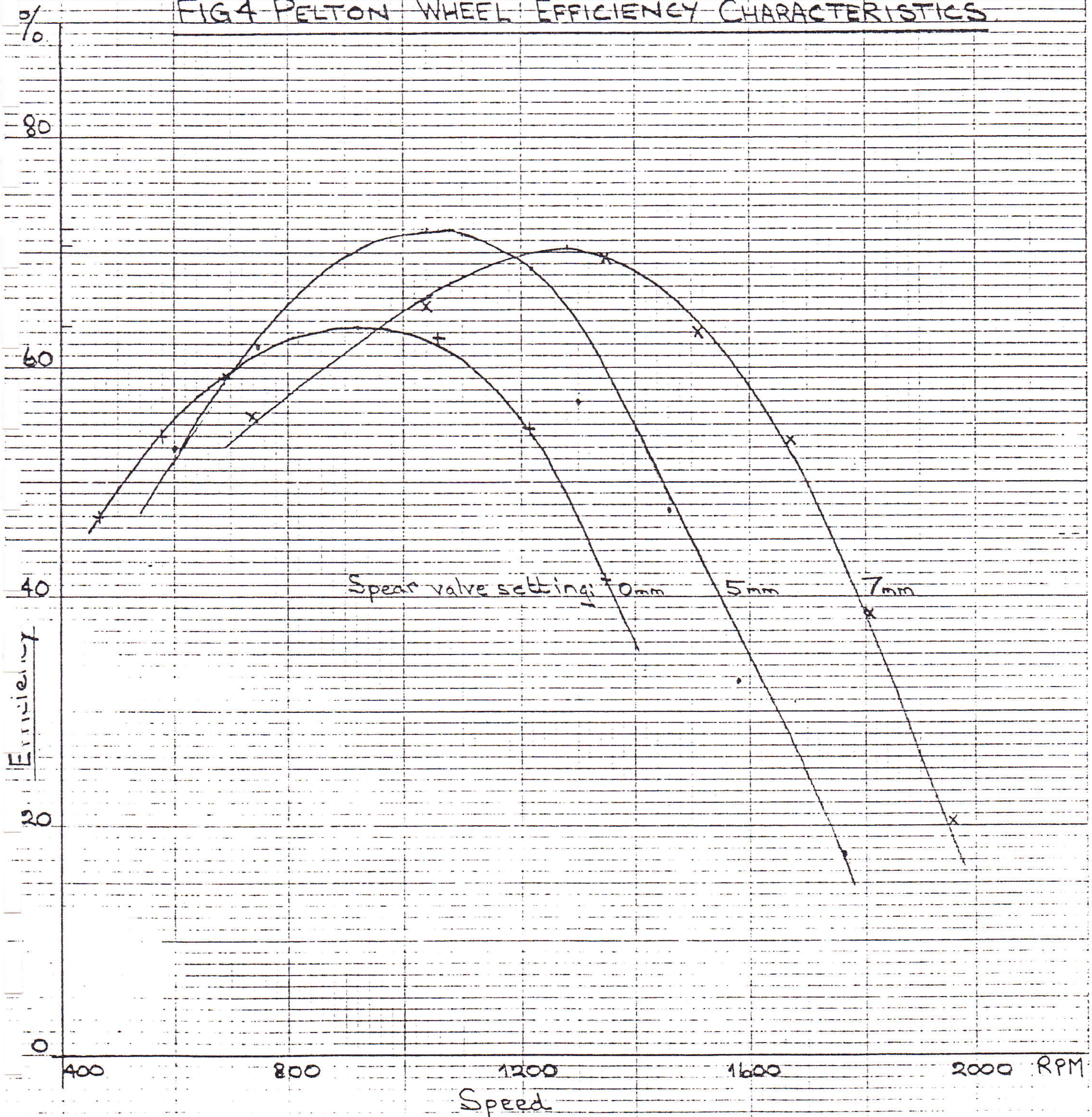


FIG 4 PELTON WHEEL EFFICIENCY CHARACTERISTICS



DRG. No. P6240/14	DISPATCH CHECK LIST			
ORDER NO. 21957	PRODUCT NO. P6240	SERIAL NO. 131	CHECKED BY [signature]	DATE CHECKED 18-10-90

ITEM NO.	DESCRIPTION	QTY.	CHK.	REMARKS
1	Pelton Wheel mounted on baseboard with attachments for Prony brake. Drg. No. P6240/1	1	✓	
2	0 - 1 kg spring balance 025002018, complete with belt P6240/12 and cord 092000002	1	✓	
3	Set of weights comprising : 1 - 0·1 kg 039001017 2 - 0·2 kg 039001016 1 - 0·5 kg 039001002 1 - 1·0 kg 039001012	1	✓	
4	Hooked weight carrier to Drg. P6240/7	1	✓	
5	1 metre long clear PVC tube PVC/F:6 x 1·5:01	1	✓	
6	Hose clip 010301009	1	✓	
7	Allen key (supplied with Pelton wheel)	1	✓	
8	Spare belt and cord	1	✓	
9	Spare bucket for Pelton wheel	1	✓	
10	Cussons instruction manual	1	✓	

GENERAL REMARKS

ISSUE		ISSUE		ISSUE		G. CUSSONS LTD., 102 GREAT CLOWES STREET, MANCHESTER M7 9RH. ENGLAND.
SGN.	DATE	SGN.	DATE	SGN.	DATE	

TITLE : DISPATCH CHECK LIST FOR P6240 PELTON WHEEL					DRG. NO. P6240/14	ISSUE A
BATCH NO.	T.S. REF. P6240DCL/10	DATE 02.03.90	DRN. G.H.	APP.	SHEET 1 OF 1 SHEETS	

G. CUSSONS LTD.
102 Great Clowes Street, Manchester M7 9RH, England.
Telephone: 061-833 0036. Cables: CUSTEC MANCHESTER.
TELEX: 667279 CUSTEC G. FAX: 061-834 4688.