UNIVERSITY OF Southampton
School of Civil Engineering and the Environment

Talk

The Rotary Hydraulic Pressure Machine for very low head hydropower sites

James A. Senior, 13/06/2008

Overview

1. Introduction
   - Demand for very low head hydropower
2. The Rotary Hydraulic Pressure Machine
   - Principle
   - Description
   - Model testing
3. Case Study
4. Conclusions

Introduction

- Small hydropower: installations under 10MW
- European target: An additional 2.4GW by 2010
- No suitable technology for head range 0 – 5m
- New technology is one of the FP7 targets

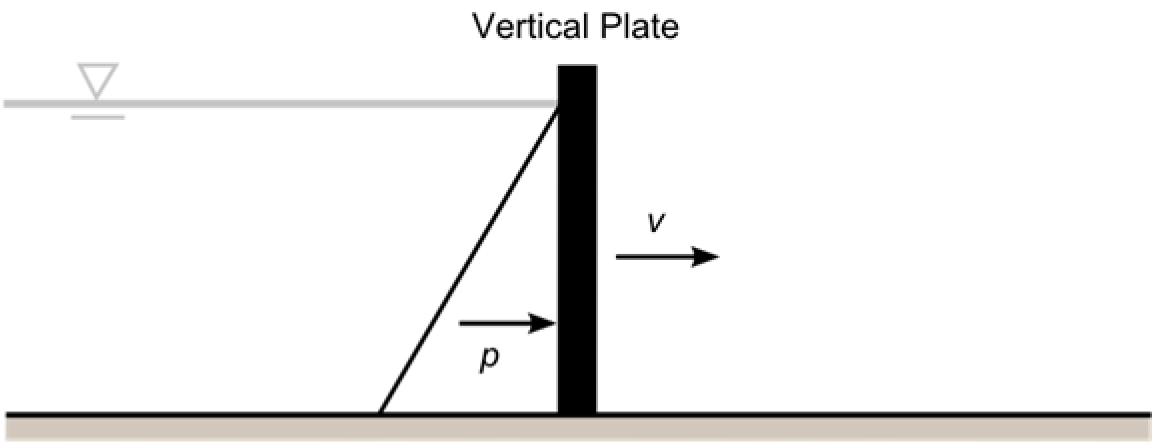
Conventional technologies operate using three principles:

- **Impulse**, e.g undershot waterwheels, Pelton turbines, Cross flow turbines.
- **Reaction**, e.g. Kaplan turbines
- **Potential**, e.g. Overshot waterwheels

These technologies have been well developed.

Is there a fourth operating principle which has not been commercially exploited?

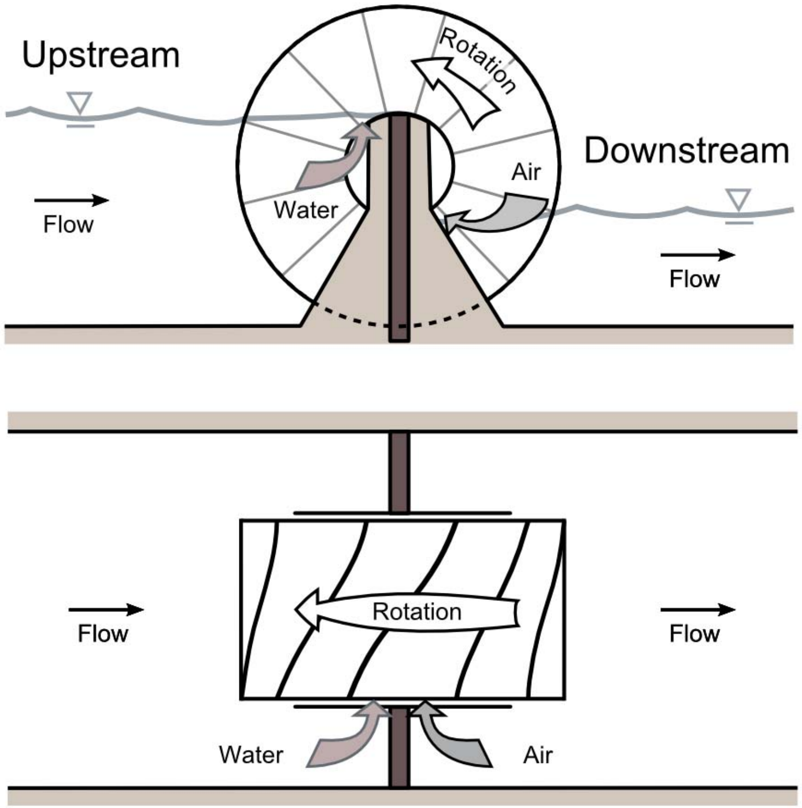
Operational principle: Hydrostatic pressure

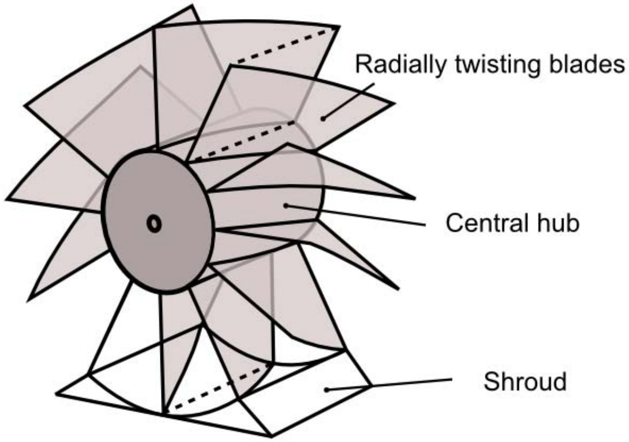


- Force = Pressure x Area
- Power = Force x velocity

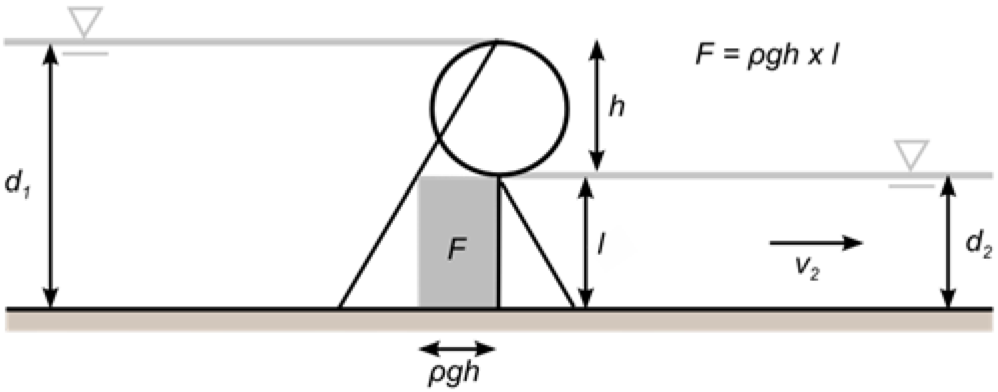
The Rotary Hydraulic Pressure Machine

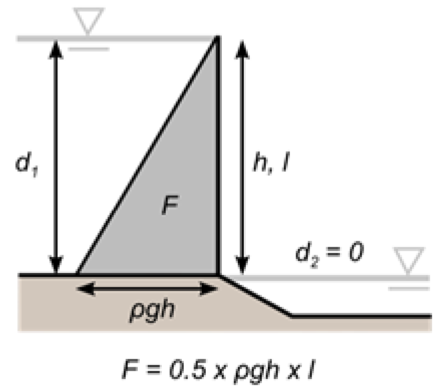
Description





Theory





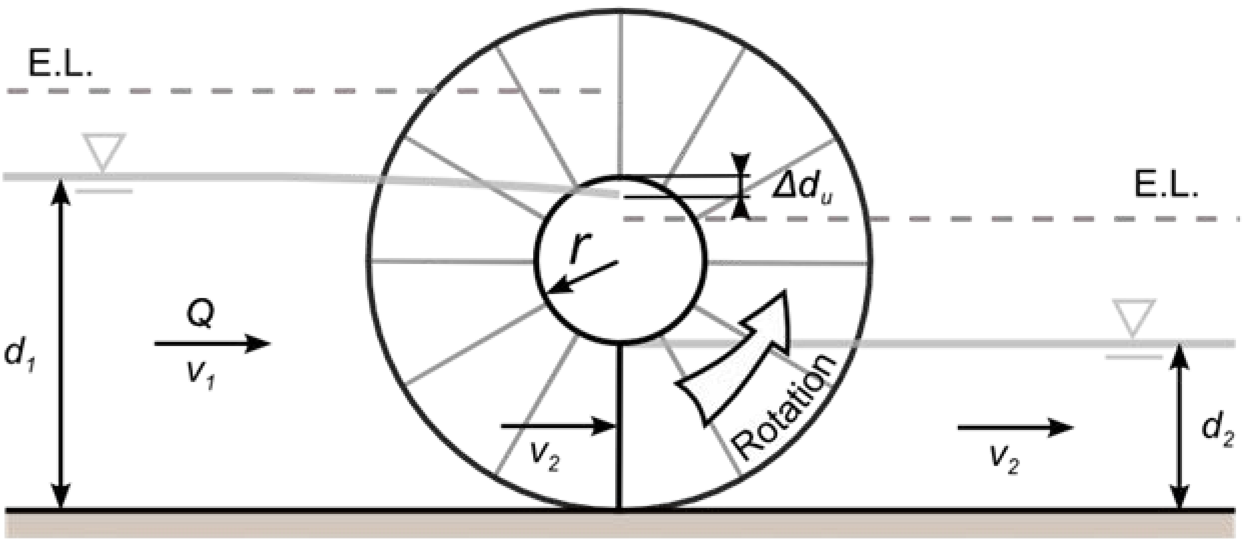
Hub allows maximum force to develop over entire length of the blade, through which RHPM exploits the pressure.

Hub also ensure gradual and constant transition of water surface from upstream to downstream, preventing undue wave generation.

Theory

Water accelerates from v_1 *to* v_2

Energy equation shows drop in level of: $$\Delta d_u = \frac{v_2^2 - v_1^2}{2\,g}$$

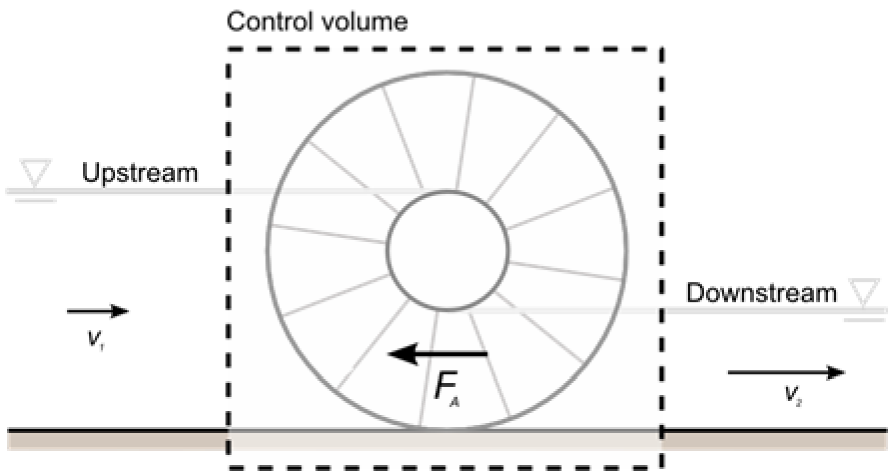


Thus power resulting from pressure is:

$$F_p = \rho\, g\, (d_1 - d_2 - \Delta d_u)\, A$$

Theory

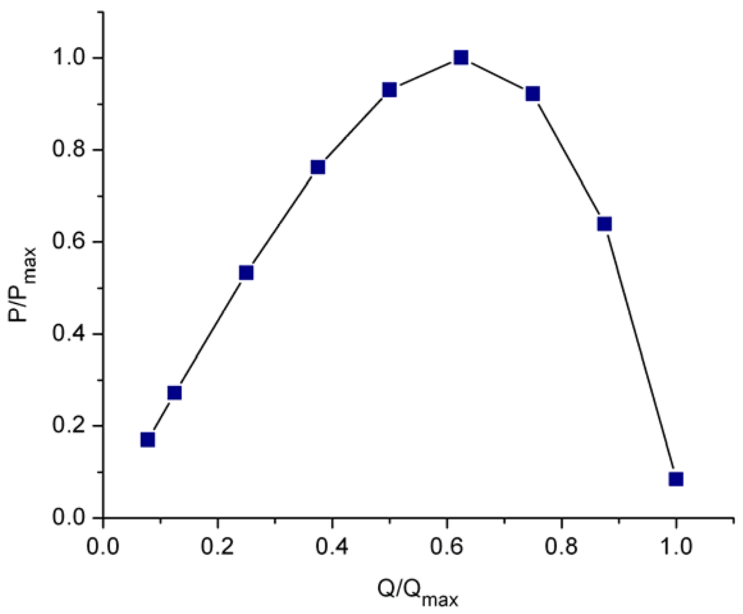
Reaction of installation to the acceleration of water from v_1 to v_2 - can be thought of as a ‘nozzle‘.



$$F_A = \rho Q (v_2 - v_1)$$

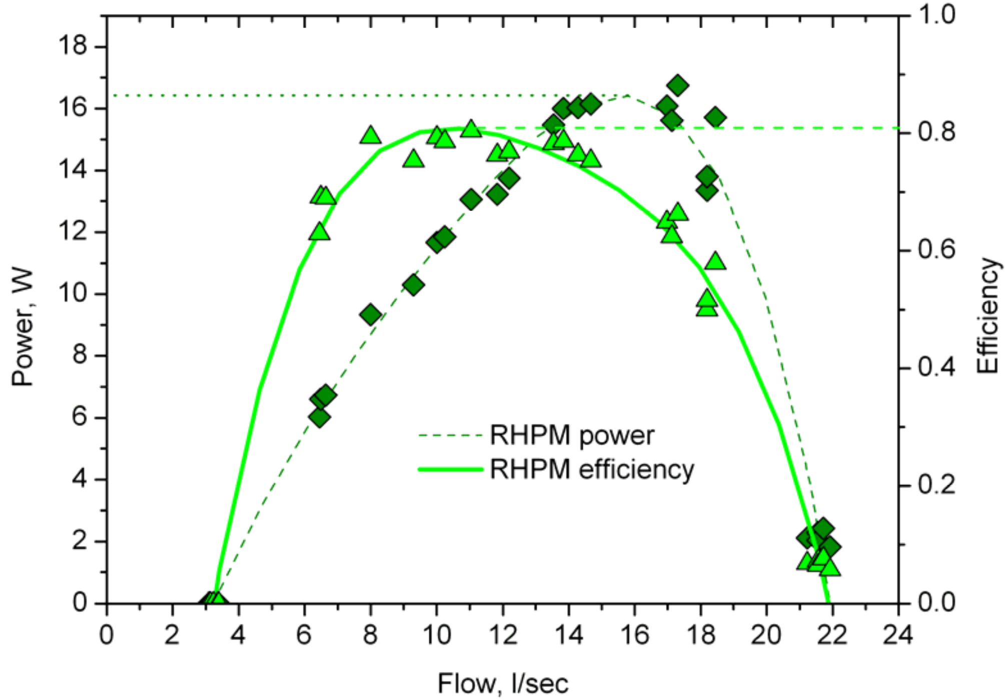
Theory

$$P_{out\ ideal} = (F_P - F_A)\, v_2$$



Model Testing

Conducted with constant water depths whilst increasing rotational speed from stationary to freewheel, at no load



Peak efficiency: 80%, P_{max}: 16.5W, Q_{max}: 18 l/s

Model Testing

Data from Model tests was scaled using Froude scaling laws, maintaining the proportions of the test model:

Scaled prototype head, m	Q_{max}, m^3/s per m width	P_{max}, kW per m width
0.5	0.5	1.4
1.0	1.3	7.7
1.5	2.3	21.3
2.0	3.6	43.7

In 2m head case, Q_{max} and P_{max} are 300% that of a traditional Zuppinger waterwheel.

Case Study

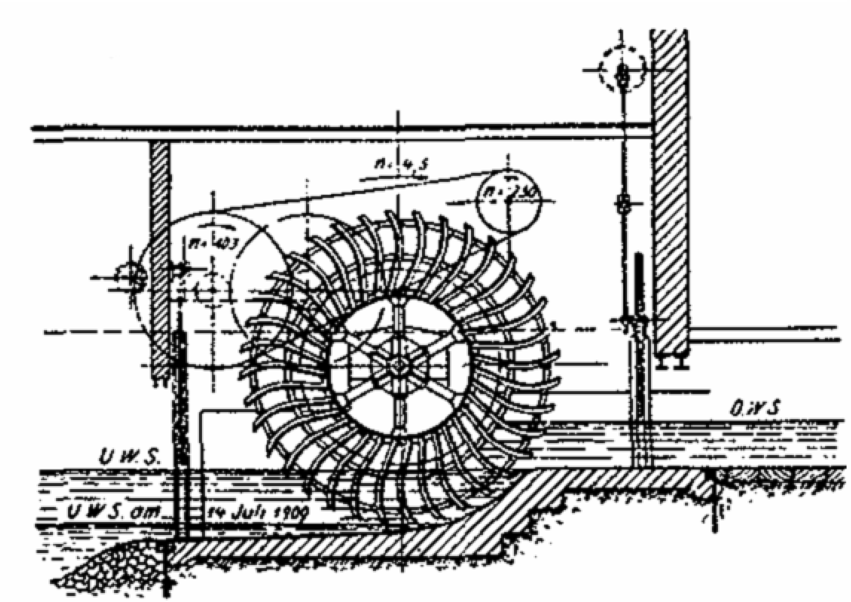
Site in Southern Germany with:

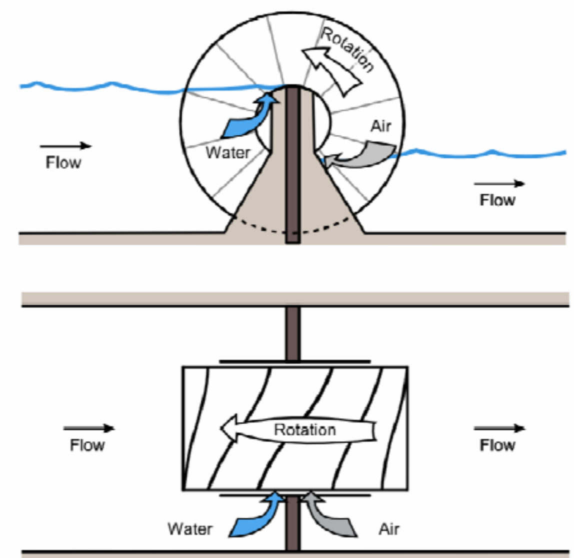
Head – 0.9m

Average flow – $10m^3/s$

Width restriction of 6m

Obtained two Quotes for Zuppinger waterwheels





Quotes broken down into 3 cost groups:

- The wheel – with RHPM estimated at 50% to 80%
- The inlet – not required by RHPM installation
- Common components – quoted prices unaltered

	Zuppinger quotes (averaged)	**RHPM, *best case***	**RHPM, *worst case***
Diameter, m	6.25	4.3	4.3
Width, m	6	5.0	5.0
Q_{max}, m^3/sec	7.9	10	10
$Q_{max,}$ m^3/sec per m width of wheel	1.32	2.0	2.0
Wheel efficiency, maximum, %	73	80	80
Gearbox / belts / generator efficiency, %	87	87	87
$P_{electrical}$, kW	**37**	**54**	**54**
Wheel, €	94,000	47,000	75,200
Inlet, €	15,200	0	0
Common components and installation, €	92,300	92,300	92,300
Total before tax, €	**201,500**	**139,300**	**167,500**
Specific cost, € / kW installed	**5,450**	**2,650**	**3,150**

Power output: 50% greater

Total cost: 70 – 80% of Zuppinger waterwheel

Specific cost: 50 – 60% of Zuppinger waterwheel

Conclusions

The Rotary Hydraulic Pressure Machine is a novel form of hydropower machine, being driven by the hydrostatic pressure of water, and not impulse, reaction or potential.

It has a higher peak hydraulic efficiency, larger flow capacity, and greater power output than traditional waterwheels.

For a 2m head, these are 80%, 4m^3/s and ~45kW per metre width respectively.

With an estimated specific cost of ~3000€ , the RHPM makes very low head hydropower more economically attractive.

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Thank you for your attention!

Questions?

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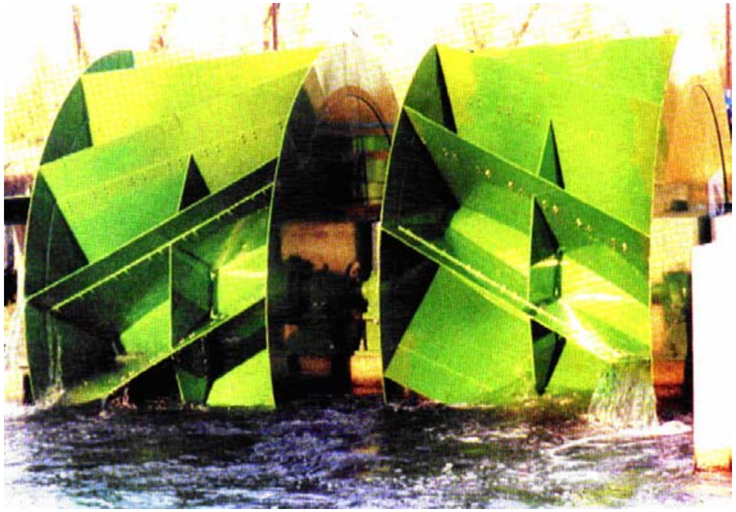

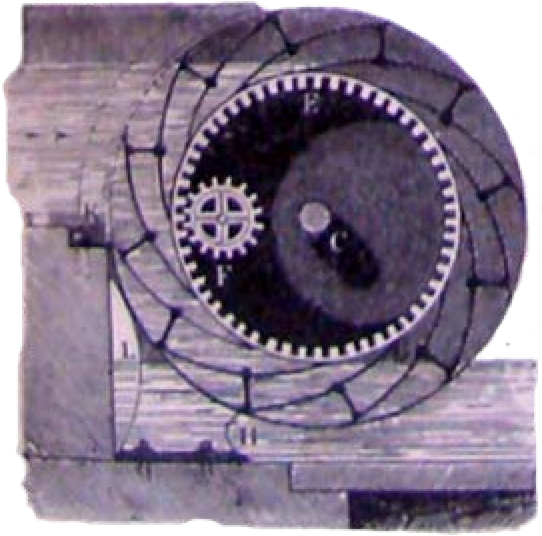

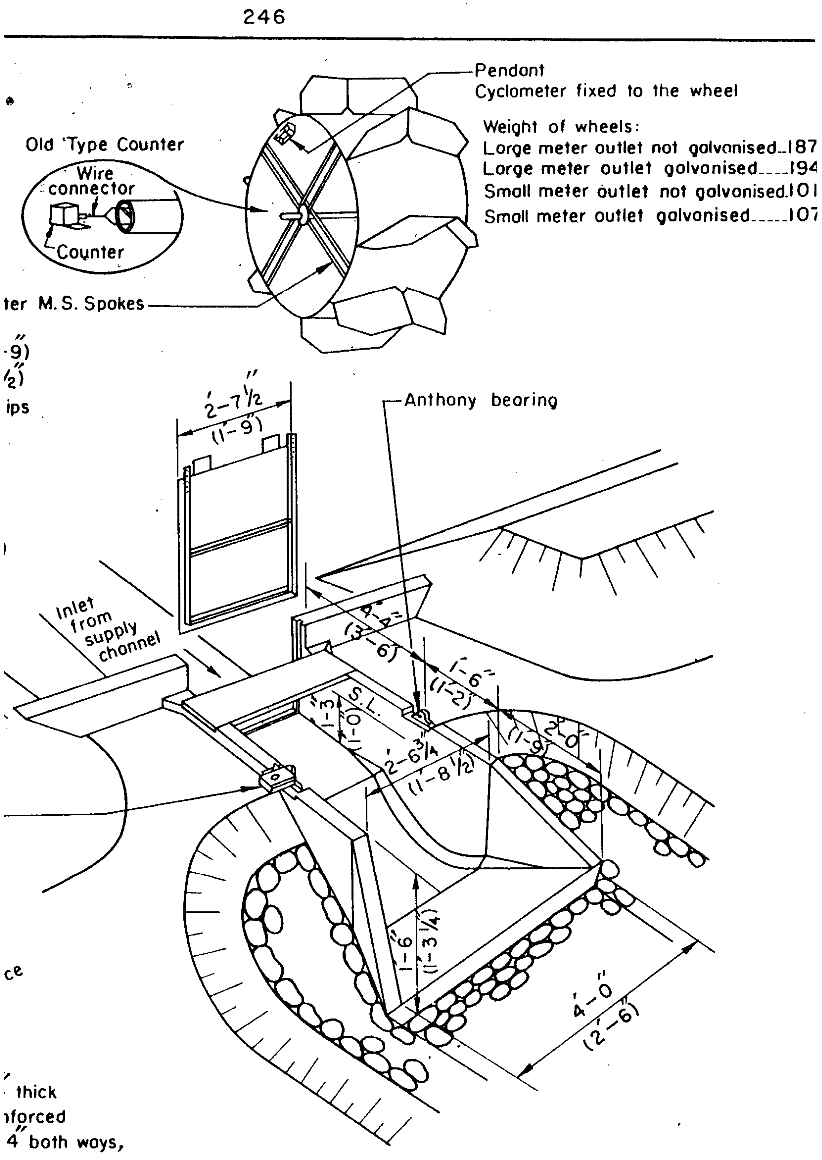
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Pendant
Cyclometer fixed to the wheel
Weight of wheels:
Large meter outlet not galvanised_187
Large meter outlet galvanised____194
Small meter outlet not galvanised.101
Small meter outlet galvanised_____107
Old 'Type Counter
Wire connector
Counter
ter M.S. Spokes
Anthony bearing
Inlet from supply channel
S.L.
thick
nforced
4" both ways,