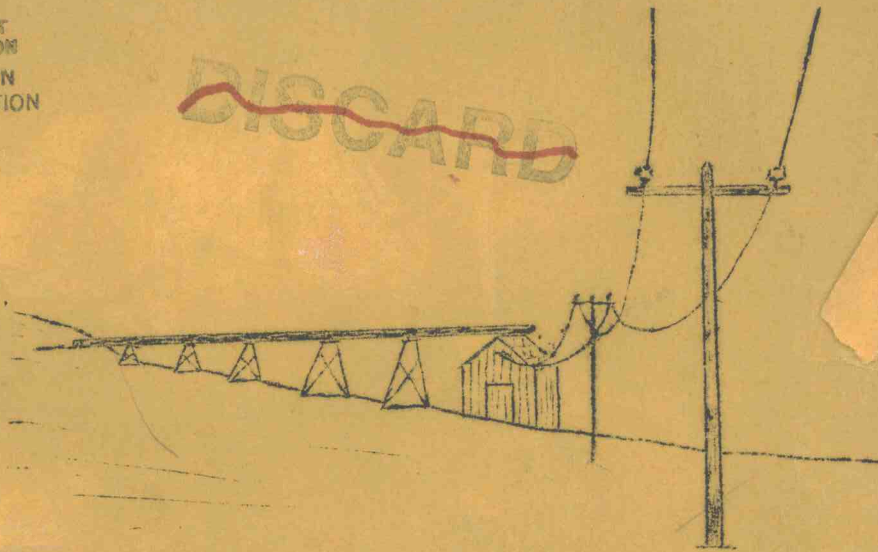
Extension Circular 332 July, 1939



A LOW-HEAD TURBINE FOR FARM HYDRO-ELECTRIC DEVELOPMENT

By
The Department of Civil Engineering
In Cooperation With
The Department of Agricultural Engineering

Federal Cooperative Extension Service
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Many farms are not within reach of electrical service from existing electrical distribution systems. Some of these farms are fortunately located near a stream which can be diverted and made to produce electrical power.

In order to determine the amount of power which can be produced by a stream, it is necessary to know the rate of flow of the water in cubic feet per second, and the vertical distance available for the water fall measured in feet. The flow of water should be measured under low-water conditions so that year-round operation of the electric plant is made certain. The simplest method of measuring the flow of water in a stream is by the use of a weir. A weir consists of an opening of specified shape and dimensions in the top edge of a temporary dam. Complete instructions for measuring water by the weir method are given on pages 1 to 7, inclusive, of U.S.D.A. Farmers' Bulletin No. 1683, "Measuring Water in Irrigation Channels." This bulletin may be obtained from the office of the County Agricultural Agent or from the Agricultural Engineering Department, Oregon State College.

Applications for water rights for power should be directed to the State Hydro-electric Commission, Salem, Oregon. A copy of the "Rules and Regulations of the Hydro-Electric Commission of Oregon Relative to Minor Projects" is available from the Commission without charge. Before investing in electrical generating equipment, any individual should first obtain a license from the Hydro-Electric Commission.

Data have been prepared by Dr. C. A. Mockmore, Head of the Civil Engineering Department, Oregon State College, to assist those interested in the design of a Banki water turbine. This turbine was invented by Donat Banki in Hungary, and several of the turbines have been installed in Western Oregon.* The turbine has been manufactured in Oregon and the cost has been much less than is ordinarily required to build a properly designed overshot water wheel which would produce an equivalent amount of electrical energy. The Banki turbine is well adapted to a head or fall of from 8 to 20 feet for small units, and has operated at 70 percent efficiency in laboratory tests. 1/ The recommended speed of the turbine is from 175 to 300 revolutions per minute, depending upon the design. Belts and sheaves (V-pulleys) required to turn the generator at 1750 r.p.m., Figure 9, are much less expensive with a Banki turbine than the corresponding equipment for an overshot water wheel. This is because an overshot water wheel usually turns very slowly, from 6 to 10 r.p.m., necessitating the use of a complicated and expensive set of gears and counter-shafts to step up the speed, Figures 10 and 11.

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* This turbine is sold in Budapest, Hungary, by Ganz and Company and the Farm Equipment and Tractor Company, Ltd.

1/ Tests conducted by Dr. C. A. Mockmore, Oregon State College, Department of Civil Engineering.

Figures 10 and 11 show the arrangement used by one Oregon farmer for stepping-up the speed of an overshot water wheel to the required speed for driving the generator. The sprocket wheel which is keyed to the shaft of the 13-foot overshot wheel is 3 feet in diameter. This is typical of the costly gearing required with overshot water wheels when used to operate electric generators.

Tangential water turbines, ordinarily called Pelton water wheels in honor of their inventor, are better adapted to conditions of relatively greater fall. This circular does not include information on the tangential water turbine, but some investigational work on this type of wheel is now in progress. Consult your county agricultural agent for assistance in planning a hydro-electric installation.

HOW TO DETERMINE THE AVAILABLE HORSE-POWER

The following equation can be used to estimate the power available at any site:

$$\text{Horse-power} = \frac{QHE}{8.8}$$

In this equation:

Q = cubic feet of water per second
H = the fall or head in feet measured vertically
E = the efficiency which may be 50 to 70 percent depending on the size and design of the unit

The following example will illustrate the use of this equation. Assume that at a given power site the flow is 3 cubic feet per second and that the head or fall is 12 feet. Assume an efficiency of 60 percent.

$$\text{Horse-power} = \frac{QHE}{8.8}$$

$$\text{Then: Horse-power} = \frac{(3.0)(12)(.60)}{8.8} = 2.46 \text{ h.p.}$$

COST OF THE BANKI TURBINE INSTALLATION

Judging from several experiences in constructing Banki turbines in Oregon which have been worked out completely within the last two years, the cost will vary from $100 to $150 for complete units of from 3 to 5 horse-power. This includes the turbine, turbine nozzle, hand operated governing valve, counter-shafts, and belts and pulleys necessary for connecting to the generator, but does not include the cost of the generator.

EQUIPMENT MAY BE OPERATED DIRECTLY FROM THE TURBINE

By connecting the turbine to an electric generator, current can be distributed through the farm wiring system to light lamps, run motors or produce heat. On some farms it will be possible to locate the turbine in or under a farm building where power equipment such as feed grinders, feed mixers, and shop equipment may be belted directly to the turbine, thus eliminating the need of a motor, and saving wear and tear on the generator.

CONSTRUCTION SPECIFICATIONS OF THE BANKI WATER TURBINE

A number of calculations have been made for water quantities of 2, 3, and 4 cubic feet per second and heads of 8 to 20 feet. Complete data for constructing Banki turbines to fit these combinations of head and flow are given in the following table:

Head in Feet	Rate of Flow in c.f.s.	Horse-power (E=.60)	Wheel Diameter (Inches)	Wheel Length (Inches)	Wheel Speed r.p.m.	Thickness of Jet (Inches)	No. of Blades	Radial Rim Width (Inches)	Radius of Blade Curv. (Inches)
12	2	1.64	11	11.3	270	0.96	18	1.87	1.80
14	2	1.91	11	10.4	294	0.96	18	1.87	1.80
16	2	2.18	10	10.6	344	0.87	18	1.70	1.63
18	2	2.46	10	10.0	366	0.87	18	1.70	1.63
20	2	2.72	10	9.4	385	0.87	18	1.70	1.63
8	3	1.64	14	16.0	174	1.22	22	2.38	2.28
10	3	2.25	13	15.4	210	1.13	22	2.21	2.12
12	3	2.46	13	14.0	230	1.13	22	2.21	2.12
14	3	2.87	12	13.5	270	1.05	20	2.04	1.96
16	3	3.25	12	13.0	288	1.05	20	2.04	1.96
18	3	3.89	12	12.4	306	1.05	20	2.04	1.96
20	3	4.10	12	11.3	323	1.05	20	2.04	1.96
8	4	2.18	16	18.7	152	1.39	24	2.72	2.61
10	4	2.73	16	16.5	170	1.39	24	2.72	2.61
12	4	3.28	15	16.4	188	1.31	22	2.55	2.45
14	4	3.82	15	15.2	215	1.31	22	2.55	2.45
16	4	4.37	14	15.1	246	1.22	22	2.38	2.28
18	4	4.92	14	14.3	262	1.22	22	2.38	2.28

Diameter of shaft is 1.375 in all cases.

DETERMINING THE WATTAGE OF THE ELECTRICAL GENERATOR

The wattage of the electrical generator required for a power site has been estimated below for various available horse-powers:

1 horse-power	750 Watts	6 horse-power	4500 Watts
2 "	1500 "	7 "	5200 "
3 "	2250 "	8 "	6000 "
4 "	3000 "	9 "	6700 "
5 "	4000 "	10 "	7500 "

A 3000 watt generator would operate all the following appliances at one time:

	Total Watts
10 (50 watt bulbs)	500
8 (100 watt bulbs)	800
1 Radio	100
1 Hot Plate	1000
1 Iron	600
Total	3000 watts

The following table will assist those interested in determining what appliances could be operated with generators of certain wattages:

WATTS REQUIRED BY APPLIANCES

Lamps	(7.5 up) Avg. 50 watts
Radio	60 to 100 "
Flat-iron, full size	660 to 1000 "
Flat-iron, $2\frac{1}{2}$ lb., small	250 to 400 "
Toaster, Percolator, Waffle Iron	450 to 660 "
Glow Heater	600 to 1000 "
Hot Plate, per burner	660 to 1000 "
Mangle (Ironer)	1200 to 1800 "
Vacuum Cleaner	200 to 275 "
Sewing Machine	100 to 150 "
Storage Tank Water Heater	1500 to 5000 "
Electric Range	6000 to 10000 "
Heating Pad	40 to 60 "
Curling Iron	25 to 50 "
Fan	25 to 50 "
Sun Lamp	275 to 850 "
Electric Drill (1/2 inch)	200 to 400 "
Washing Machine (see 1/4 h.p. motors - following table)	
Refrigerators (see 1/6 h.p. motors - following table)	
Poultry Water Warmer	150 to 200 "
Brooder	530 to 730 "

Motors require more generator capacity while starting than when operating under normal load. The following table gives approximate wattages for repulsion-induction and capacitor-types of single-phase motors.

WATTS REQUIRED BY MOTORS

Size of Motor	While Starting	While Running
1/6 Horse-power	500 Watts	275 Watts
1/4 "	750 "	350 "
1/3 "	1000 "	400 "
1/2 "	1200 "	550 "
3/4 "	2000 "	800 "
1 "	2700 "	1100 "

APPROXIMATE PRICES OF HORIZONTAL GENERATORS FOR SPEED OF 1750 R.P.M.

	Alternating Current 110 or 220 volt 60 cycle			Direct Current 110 volt			
Watts	Company B Single-Phase	Company C Single-Phase	Company D 3-Phase	Company A	Company B	Company C	Company D
350	$54				$54		
500	60			104 (1150 R.P.M.)	60		
750	75			104	75		
1000	90				90		221
1500				133		140	329
2000	145		453	150	145	158	345
3000	170		510	229	170	240	426
5000	248	419	630	280	248	294	554
7500		584	716	332		349	604
10,000		584	817	380		399	664

Company A - f.o.b. Pittsburgh, Pa. Prices include field rheostats.
Company B - f.o.b. Minneapolis, Minn.
Company C - f.o.b. Portland, Oregon
Company D - f.o.b. Destination. Alternating current generators operate at 220 or 440 volts at 1200 R.P.M. Prices include base and exciter. Direct current generators are self-regulating and are designed for ungoverned water wheels. They operate at variable speeds of 1150 to 2140 R.P.M.

FORMULAS FOR CALCULATING SPECIFICATIONS FOR THE BANKI TURBINE

The following illustrations indicate the method of calculating the data given in the table on page 3:

Given H, the head in feet, and Q, the flow in cubic feet per second. Assume E = Efficiency = 60%. This may be 70%, or smaller with smaller units. Then if Q = 3.0 c.f.s., and H = 12 feet:

(1) Horse-power $= \frac{QHE}{8.8} = \frac{(3)(12)(0.60)}{8.8} = 2.46$ horse-power

(2) Diameter and Length of Wheel

$$LD = \frac{210.6}{H^{\frac{1}{2}}} = \frac{(210.6)(3)}{12^{\frac{1}{2}}} = 184$$

The diameter and length should be kept about equal, but these can be varied to get speed and length within certain desired limits. In this case use D = 13 inches and L = 14 inches, then LD = (13)(14) = 182, which is close enough.

(3) Speed of Wheel

$$N = \frac{862\ H^{\frac{1}{2}}}{D} = \frac{(862)(12)^{\frac{1}{2}}}{13} = 230 \text{ r.p.m.}$$

(4) Thickness of Jet

$$S = 0.087\ D = (0.087)(13) = 1.13 \text{ inches}$$

(5) Number of Blades

$$n = \frac{\pi\ D}{2\ S} = \frac{(3.14)(13)}{(2)(1.13)} = 18.1 \text{ blades}$$

Use 22 blades to avoid pulsating power.

(6) Radial Rim Width

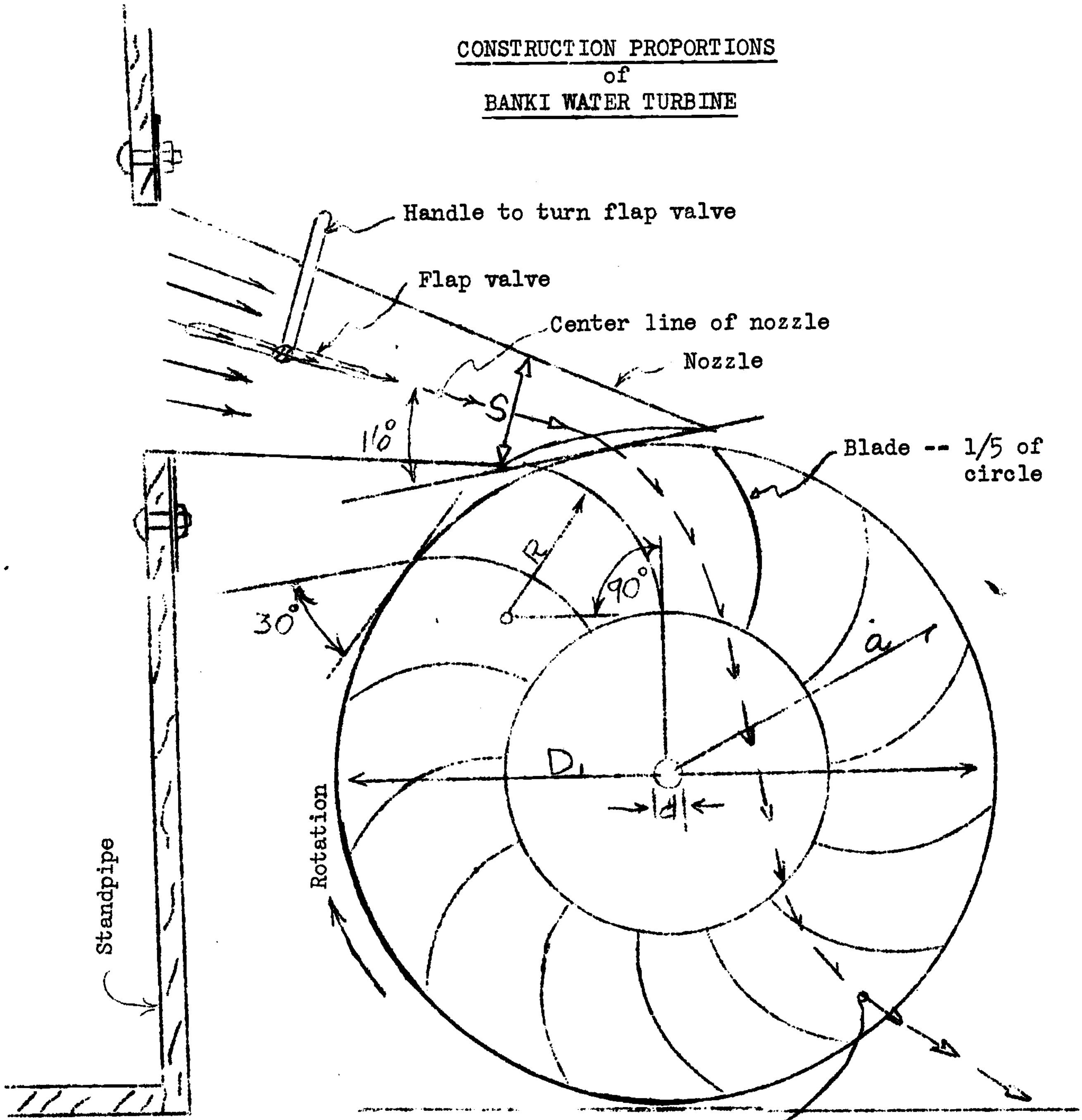
$$a = 0.17\ D = (0.17)(13) = 2.21 \text{ inches}$$

(7) Radius of Blade Curvature

$$R = 0.163\ D = (0.163)(13) = 2.12 \text{ inches}$$

Note: The drawing on the following page illustrates these proportions and shows how the various measurements are made upon the turbine wheel.

CONSTRUCTION PROPORTIONS
of
BANKI WATER TURBINE



D_1 = Diameter of Wheel
S = Thickness of Jet
R = Radius of Blade Curvature
a = Radial Rim Width
d = Diameter of Shaft

Fig. 1
Mrs. Thompson of Beaver Creek starts the generator from the house. The lever pulls a wire, opening the flap valve in the turbine nozzle. (Inset lower right.) The Banki turbine and nozzle.

Fig. 2
The power plant in operation. The turbine is mounted beneath the flume near the stream bed. Overflow water flows out the end of the flume.

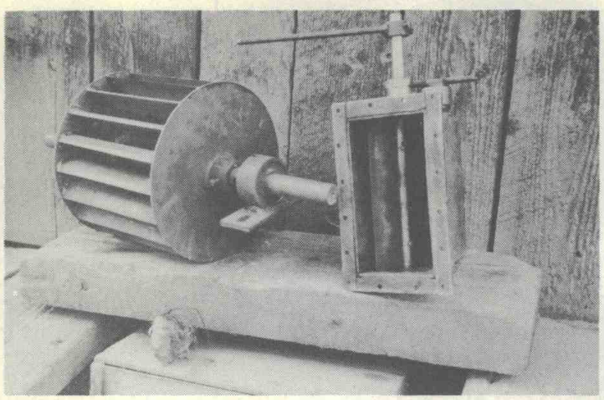


Fig. 3
The parts of a Banki turbine. Note the wheel with roller bearings, and the nozzle with internal flap valve.

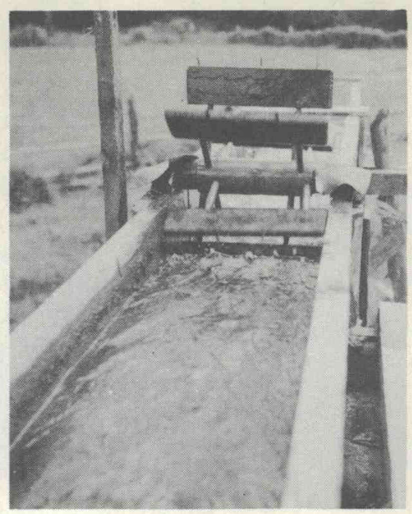
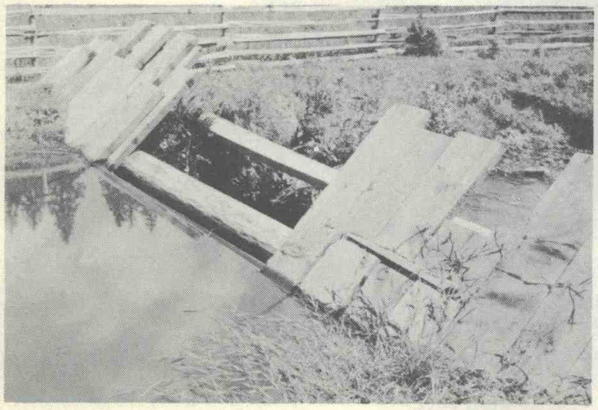


Fig. 4
A paddle wheel in the flume serves to clear debris away from the grill over the top of the penstock. The flow of water in the flume operates the paddle wheel.



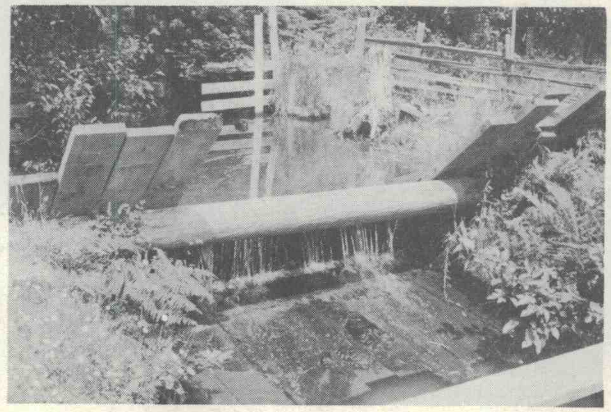


Fig. 5 Fig. 6

Two logs, one in the stream bed and the other at ground level support the planks used to dam the water. Center planks can be removed during periods of high water.

Fig. 7

The powerhouse, flume, and overflow arrangement used with a Banki turbine.

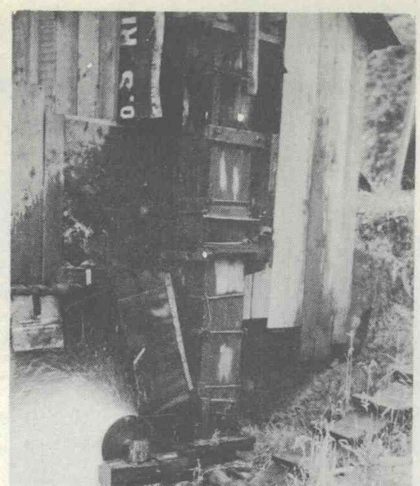


Fig. 8

Water is supplied to the turbine through the vertical wood penstock. The turbine nozzle bolts to the penstock.

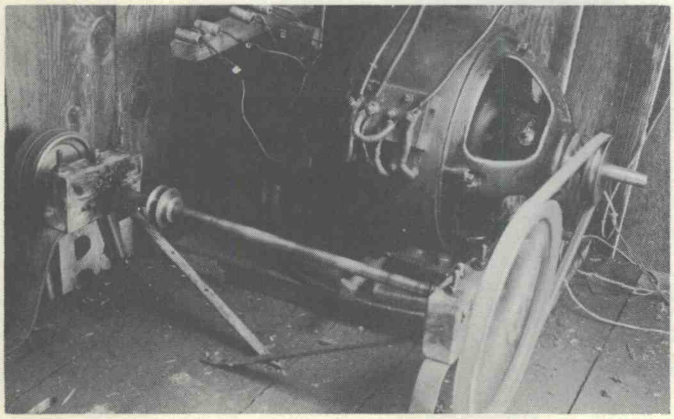


Fig. 9
The generator and a counter-shaft used to step up the turbine speed. The pulley at the extreme left is driven by a pulley on the turbine below. Note the inexpensive hard wood bearings.

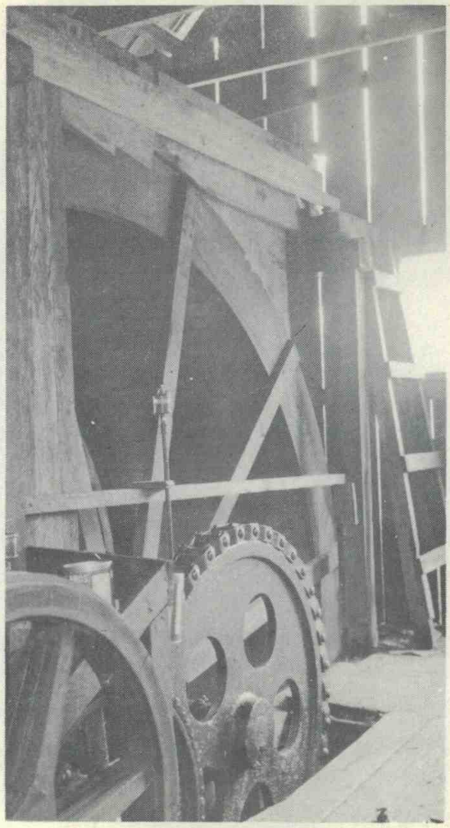


Fig. 10
A section of a 13' overshot water wheel operating in Clatsop County, Oregon

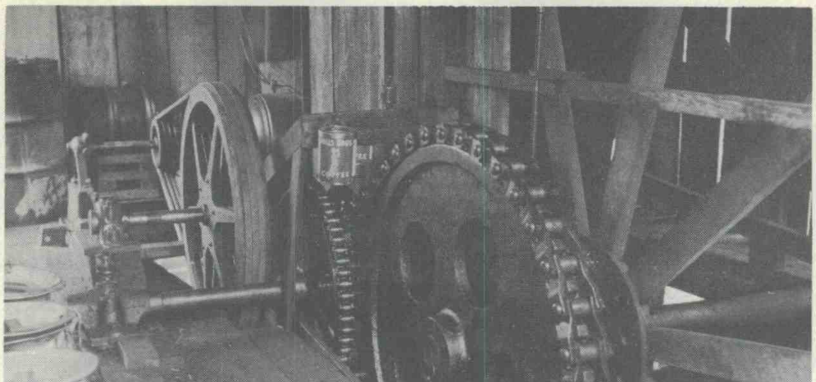


Fig. 11
Typical arrangement of costly gears and counter-shaft assembly used with overshot water wheels to step up the speed to drive a generator. Note generator in background.