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DE84 000395

DESIGNS AND APPLICATIONS FOR FLOATING-HYDRO POWER SYSTEMS IN SMALL STREAMS

Final Report

To the United States Department of Energy

Appropriate Energy Technology Small Grants Program

Grant No. DE-FG4481R410415

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January 1, 1983

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SUMMARY

The project focuses on an appropriate technology for small-scale hydro power: floating waterwheels and turbines. For background, relic and existing systems such as early floating mills, traditional Amish waterwheels, and micro-hydro systems are examined. In the design phase of the project, new designs for Floating Hydro Power Systems include: an analysis of floatation materials and systems; a floating undershot waterwheel design; a floating cylinder (fiberglass storage tank) design; a submerged tube design; and a design for a floating platform with submerged propellers. Finally, in the applications phase, stream flow data from East Tennessee streams are used in a discussion of the potential applications of floating hydro power systems in small streams.

1.0 PROJECT OBJECTIVES

The central theme of the project is the development of ideas and designs for an environmentally-sound floating platform with undershot wheels or turbines for the generation of hydroelectric or hydromechanical power in small, fast-flowing streams. Three phases of objectives constitute the nature of the project:

(1) to determine the nature of existing and relic small hydromechanical and hydroelectric systems;

(2) to develop ideas and designs of floating platforms with wheels or turbines for power production;

(3) to determine the appropriate applications of this technology for use in rural areas.

2.0 RELIC AND EXISTING HYDRO SYSTEMS

The purpose of briefly examining relic and existing systems has been to determine the nature and effectiveness of small, low head, hydro power systems. Too often, research and development projects are only concerned with futuristic ideas without giving attention to the technologies of the past.

2.1 Ancient Technology

The earliest recorded information on "floating waterwheels" cites documented evidence of floating mills on the Tiber River in Italy in 537 A.D. When aqueducts to Rome were cut off by invading Goths, the Roman general Belisarius and his engineers invented a floating mill. At a bridge point on the Tiber River, two boats of equal size were placed two feet apart and attached by ropes to the bridge at a spot where the current flowed fastest under the arches. A wheel was placed between the boats in an undershot fashion and was propelled by the flow with sufficient power to turn the millstones placed in one of the boats. At other points along the river other similar machines were set up to drive as many mills as was needed to grind the food for Rome (Forbes p. 106). The floating mill concept spread, with tenth century floating paper mills on the Tigris River near Bagdad (Iraq), boat mills near Venice, and later in France on the Seine River in Paris 1137-1296, on the Garonne River in 1290, and the Loire River in 1306. They were still in use on the Tiber in Italy and on the Danube River and on smaller streams in the Balkans until the 1800's. Few, if any, survive (Forbes, p. 105-106).

2.2 Amish Waterwheels in Lancaster County, Pennsylvania

The Amish people of Pennsylvania represent a religious and culturally separate group who live by an ancient, relic, yet effective, technology. They are perhaps best known for their use of animal powered and wind and water powered technologies: horse drawn buggies, wagons, plows, and reapers, wind powered mills, water powered pumps and the like reflect their hard-working 18th-19th century technology and culture (Rice and Shenk, Hostetler p. 126). Outsiders view them as quaint, odd, even obsolete, but they are to be admired for their efficient use of limited yet appropriate (for their culture) energy systems. What can we learn from their use of water power?

Amish waterwheels are small with diameters of three feet or less (Figures 1 and 2). Wheels are positioned for undershot use on small streams that are less than 20 feet wide with depths of 6 inches to 3 feet. Small dams and wheel enclosures create heads of from one to three feet. Flow rates are only 1.7 feet to 2.5 feet per second. Revolutions per minute are 9.5 to 16.6. Yet despite these meagre numbers the Amish have been able to put small diameter, low flow systems to work to produce hydro mechanical power that powers water pumps for household water and for domestic farm needs.

The system works as follows (Figure 3). A small dam or enclosure for the wheel creates a low head on the stream (Figure 4). Undershot flow turns a three foot diameter wheel at approximately 10 rpm. The rotary motion of the wheel is translated into a vertical motion by a rod attached to the wheel axle. The vertical rod moves up and down over a travel distance of 1 and 1/2 to 2 feet and is attached to a cinderblock counterweight. The counterweight represents the weighted corner of a triangular frame which moves up and down from a pivot point on a support post (Figure 5). At the peak of the triangle, motion now is translated to a horizontal motion which tugs a wire back and forth. The wire which may run from sixty feet to as much as a mile is supported by tall poles with hooks or eyes to prevent the wire from sagging. At the far end, the wire is attached to the top of another triangular frame that mirrors the first one, and this frame pivots on a support post. The horizontal motion of the wire is now translated back to a vertical motion by means of the counterbalanced triangle. At the

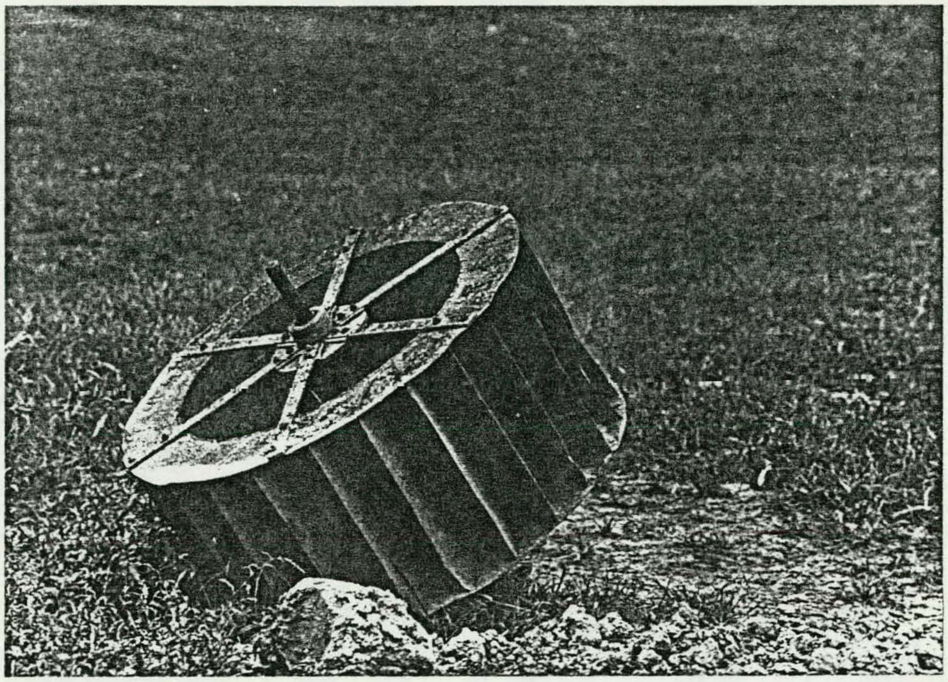
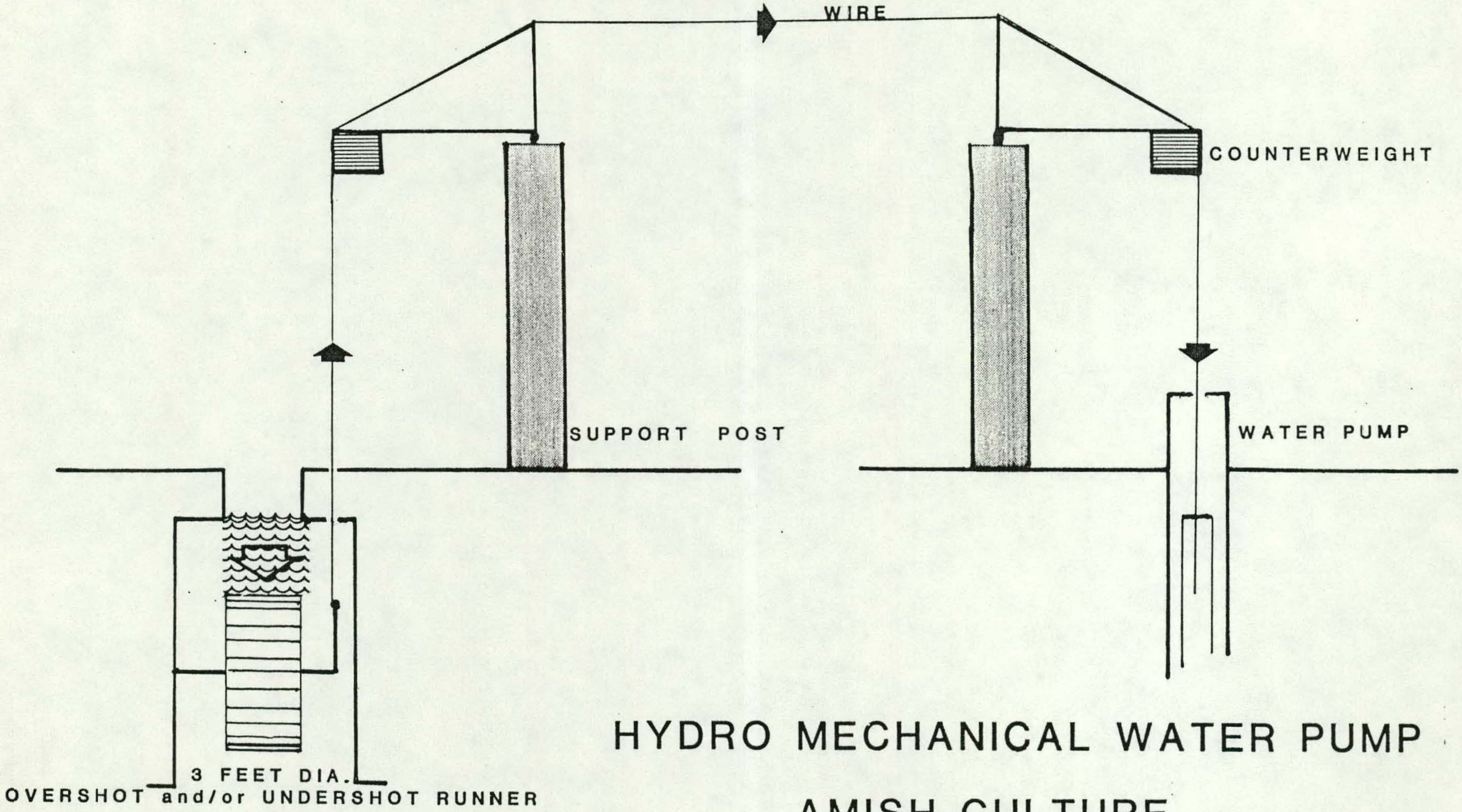


Figure 1. Traditional Amish waterwheel. Three foot diameter. Lancaster, Pennsylvania.

Figure 2. A "newer" type of Amish waterwheel. Lancaster County, Pennsylvania.



1" EQUALS 3'

HYDRO MECHANICAL WATER PUMP

AMISH CULTURE

LANCASTER COUNTY PA.

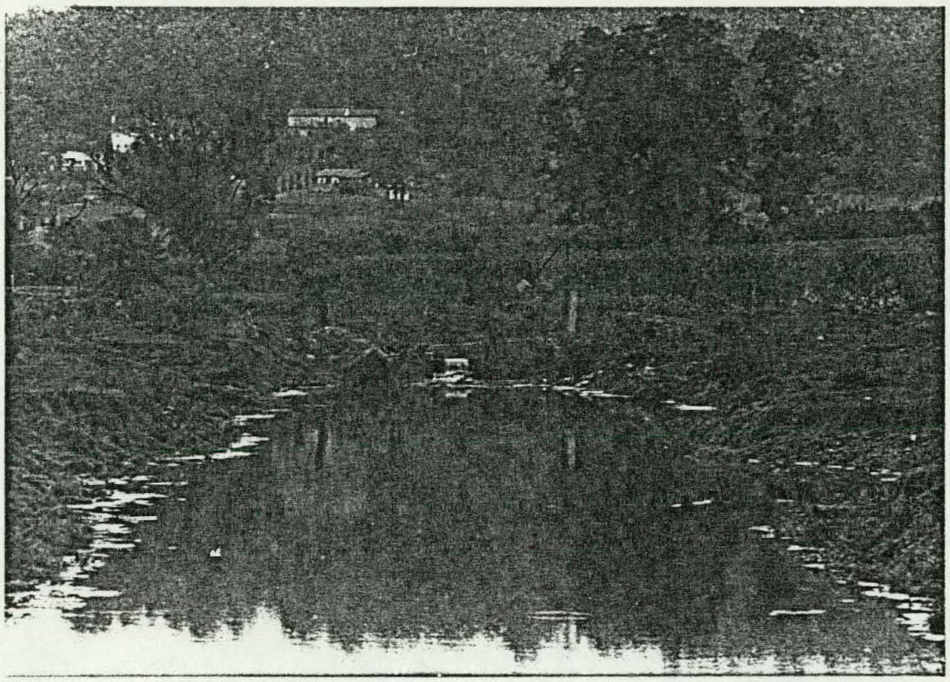


Figure 4. Dam and undershot enclosure. Lancaster County, Pennsylvania.

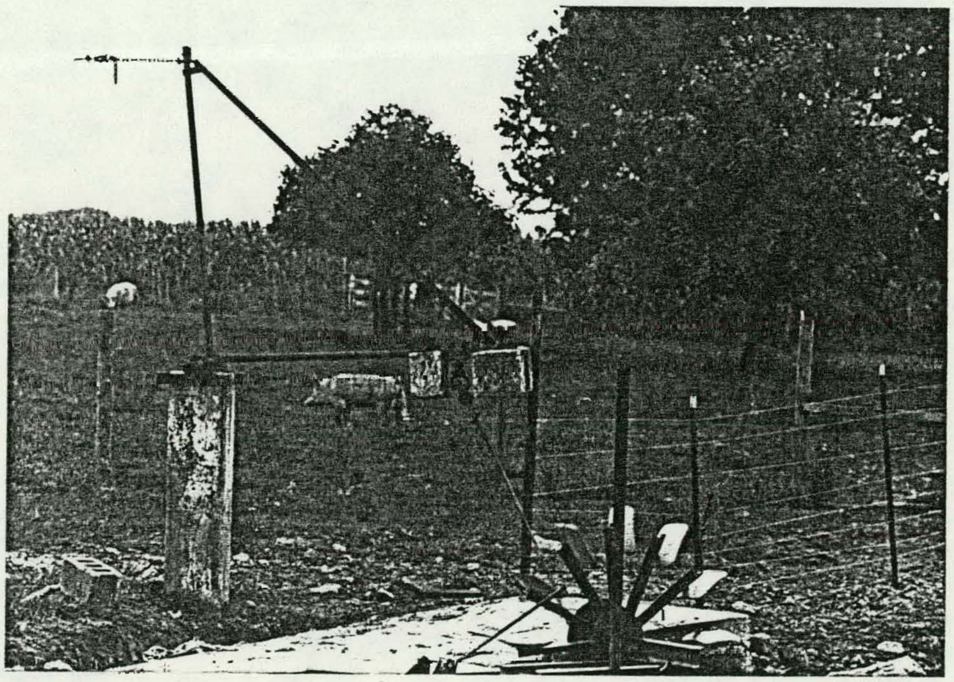


Figure 5. Amish counterweight and triangle system for hydro-mechanical power. Lancaster County, Pennsylvania.

cinderblock counterweighted end, a vertical rod now moves up and down to an underground pump. Water is then pumped up from the well to a water supply line and thence into the kitchen of the house. Water is in constant flow. Unused water and waste water from the kitchen sink now drain down to the barn into a watering trough for the farm livestock. The remaining flow and waste water then drain back to the creek from the barn. It is a system of apparent perpetual motion.

2.3 Modern Systems

During the course of this project, I observed two up-to-date fixed micro-hydro systems. Although these systems are different from a floating system, it was necessary to get ideas for required energy uses in a household situation, and the efficiency of small, but reliable, high-head, micro-hydro technology.

The first system belongs to Will Merritt, a retired civil engineer of Low Gap, North Carolina. Will has been operating his home built hydroelectric plant on his property since 1926. Located in northwestern North Carolina, Will's power site is situated at the base of the eastern escarpment of the Blue Ridge Mountains. A small perennial stream, called Powder Creek, with an 8-foot dam and pond are located 450 feet upslope above the power house. The system has a 150-foot head. At the power house, water can be diverted into one of three different nozzels and thence to one of three pelton runners. At present, the system is not in operation, but in the recent past all electrical needs in the house were provided by the system.

All parts of the pelton wheels and nozzels were designed and made by Mr. Merritt. The runner buckets on the pelton wheels were forged in Chattanooga according to Mr. Merritt's models and specifications. All other work was done by Mr. Merritt at the site. The first pelton was built in 1926 and had 4-inch diameter pipe serving it from the dam. In 1935, he built a new power house and in 1958 added a new pelton wheel and new cast iron 8-inch pipe. Approximately 14 kilowatts of power can be produced with this system.

The second system is a project of Dr. Harvard Ayers, a professor at Appalachian State University, Boone, North Carolina. Dr. Ayers' micro-hydro system is set up at Laurel Creek thirty minutes west of Boone. A small three-foot to four-foot dam and 1600 feet of eight-inch green plastic sewer pipe produce 175 feet of head. At the power house two nozzels jet water to a pelton wheel which turns up to 1750 rpm. A fifty horsepower induction motor is driven by two "V"-belts from the pelton. At this time, alternating current (AC) is run into the local power grid.

2.4 Significance

The significance of this review of ancient, relic, and current hydro technologies has been to discover ideas that may have application to the floating waterwheel concept and to examine micro-hydro technologies with which a floating system might be compared. We know that floating waterwheels once existed for the purpose of milling grain. I do not forsee a modern floating system used for milling, but perhaps it could be used as a generator of hydro mechanical power for pumping such as the Amish system or as a small hydroelectrical power system. It is doubtful that the no-head, low-head floating systems that follow in this report could produce as much power as the high-head, micro-hydro systems of Merritt and Ayers, but the examination of their systems provides background information of how small mountain streams can be tapped for electrical energy for rural residential use.

3.0 DESIGNS FOR FLOATING HYDRO POWER SYSTEMS

The following descriptions and diagrams incorporate various configurations of flotation systems and power generation systems for use in combinations as floating hydro power systems.

3.1 Floatation

The system for floatation is perhaps the easiest technical question to deal with in a floating waterwheel concept. Yet, there are many ways in which this can be accomplished: Foam filled barrels, canoes or pontoons lashed together, or foam floatation blocks normally used for floating boats docks constitute the main ways considered in this study.

The foam filled barrel concept is perhaps the minimum, easiest, simplest, and lowest cost system of floatation. The cost of a foam filled barrel is approximately $25. Strict regulations from T.V.A. forbid the use of rust-prone, air filled barrels so that foam filled ones or foam blocks are necessary within the T.V.A. region (See Figure 8).

Canoes, pontoon boats, or separate pontoons constitute the most expensive and risky method for floatation. Canoe prices begin at $350 each and go up to $1500 or more. Their instability is well known and unless they are decked or covered, they fill with rain water or capsize, and sink. Pontoon boats built for recreational purposes sell for approximately $3,000 and up. The best have a support capacity of only 100 pounds per linear foot for a twenty-four-foot decked craft.

Foam blocks or billets offer the best alternative for a floatation system (Table 1). Foam billets of polystyrene are available in lengths of 8, 10, and 12 feet. Other dimensions are 17 inches by 24 inches and 24 inches by 34 inches. It is also possible to special order 24 inches by 48 inches by 16 feet. The billets are available either bare without covering or covered with 24 gage marine aluminum to make them more durable as pontoons (Figure 6). The builder of a floating hydro platform may choose the covered billets as they are more durable and allow metal rails, bolts, rods, and other fasteners to be attached to the metal covered billet. Their low cost ranges from $35 to $100 for an 8-foot billet to $100 to $300 for a 12-foot billet. They are safe and unsinkable, and above all offer excellent stability and bouyancy. For example a 24 inch by 17 inch block offers 175 pounds support capacity per linear foot and a 24 inch by 34 inch block has a support capacity of 350 pounds per linear foot. Key advantages of this system over others are its low cost, low maintenance, light weight (30-100 pounds), low draft 3-6 inches),

marine systems INCORPORATED P.O. BOX 10765 / COGDILL ROAD / KNOXVILLE, TENNESSEE 37919
(615) 966-8700

TABLE 1

FLOTATION MATERIALS

PRICE LIST

BARE FOAM BILLETS

EXPANDED POLYSTYRENE 1.0# DENSITY

17" X 24" X 8'	$ 35.00
17" X 24" X 12'	50.00
24" X 34" X 8'	70.00
24" X 34" X 12'	100.00

ALUMINUM PONTOONS

EXPANDED POLYSTYRENE ENCASED IN 24 GAGE MARINE ALUMINUM

17" X 24" X 8'	$100.00
17" X 24" X 12'	150.00
17" X 24" X 10'	125.00
NOSE CONES - ADD	20.00
24" X 34" X 8'	200.00
24" X 34" X 12'	300.00
NOSE CONES - ADD	40.00

EFFECTIVE MARCH 1, 1980

ALL PRICES F.O.B. MARINE SYSTEMS PLANTSITE

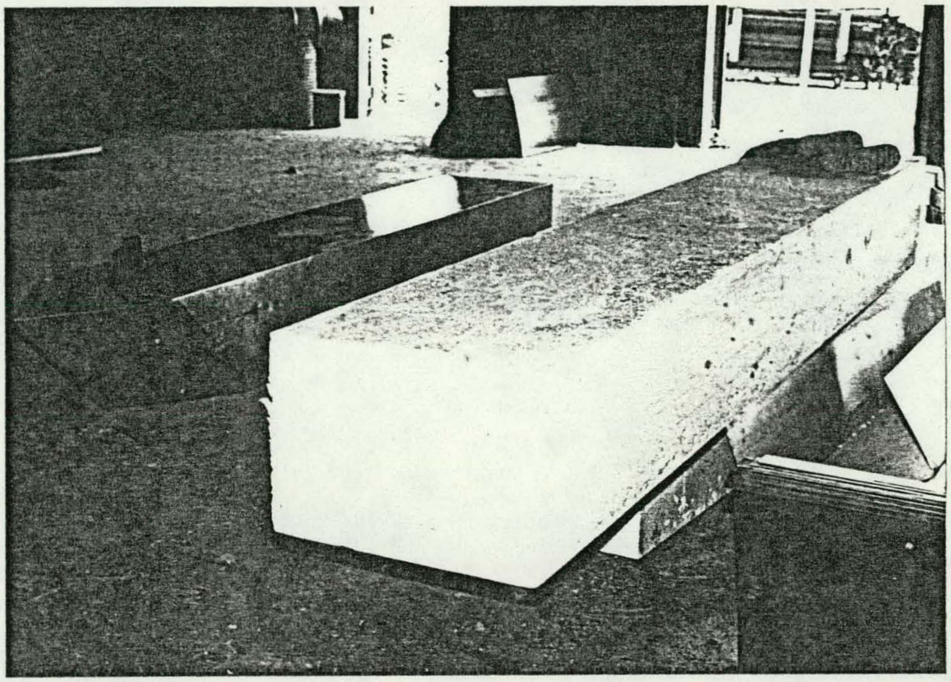


Figure 6. Foam Floatation Blocks

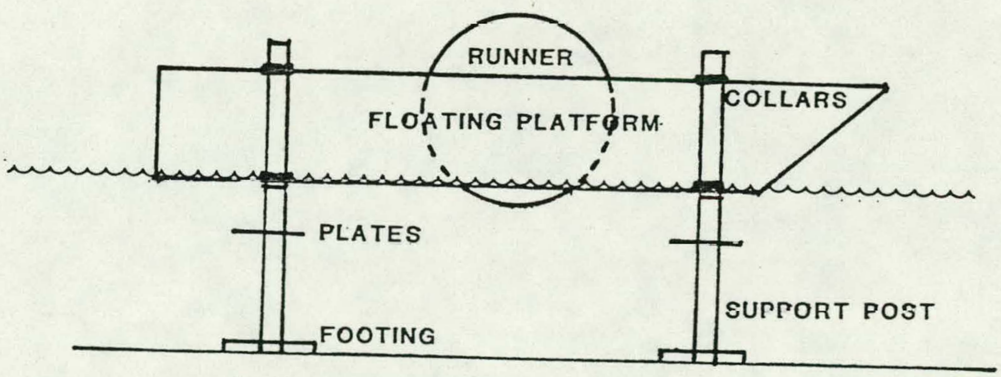


Figure 7. Support and Mooring System

reliability, and ready availability. One company, Marine Systems Incorporated, a manufacturer of floating docks is located on Interstates 40-75 at the Mabryhood Exit 12 miles west of Knoxville, Tennessee, and they will ship anywhere in the Southeastern U.S. (See Materials). Other manufacturers of foam billets and floating docks are located in many parts of the United States. A sample of companies that specialize in floating docks is in the section on materials. A potential builder may first call his local boat dealer, marina, or some other related contact for local availability of floatation materials.

As for anchorages and mooring, Figure 7 illustrates a method by which the floating platform could be prevented from touching the bottom of a shallow stream at low water levels. Four posts with wide footing surfaces would be attached to collars on the billets. Plates or rods could be set at adjustable points on the posts to prevent the runner from hitting the bottom of the stream.

3.2 Designs for Floating Hydro Power Systems: Floatation and Power Generation Systems

The following designs represent various configurations for floating hydro power systems. Most are designed for very shallow fast flowing streams with depths as shallow as one to two feet and widths as narrow as twenty feet. The four designs are:

(1) Floating Undershot Wheel

(2) Floating Undershot Cylinder

(3) Submerged Tube

(4) Floating Hydro Power System With Submerged Propellers

3.2.1 The Floating Undershot Wheel

The smallest and simplest system for a floating waterwheel is based on a floating undershot wheel supported by either foam filled barrels, or foam billets or blocks (Figure 8). The floatation system is relatively small, utilizing two floats ranging in size from 4 feet to 12 feet long. A twelve foot float platform could be used to accommodate multiple undershot wheels. The runner or undershot has dimensions of two feet wide by three feet in diameter. Built either of metal or wood, the runner can be built with exposed paddles or paddle blades or with internal vanes. Exposed paddles or blades are best because highest stream velocities are located just beneath the water surface at depths ranging from six inches to ten inches in streams of two to four feet in depth. An alternative runner could be built with long radial spokes with paddles on the ends such as the "newer" Amish undershot wheel shown in Figure 2. Large diameter V-belt sheaves (pulleys) attached to each side of the axle would in turn run smaller diameter sheaves (pulleys) so that rpm ratios might pass through a series of speed up drives and belts to reach the desired rpm for use with small alternators. For rpm ratios for sheaves (pulleys) and belts see Table 2 and Figure 9.

3.2.2 Floating Undershot Cylinder

The floating cylinder concept is a much larger system that utilizes floatation foam billets twelve feet to sixteen feet long. The runner consists of a large 20 foot long, 6 foot 5 inch diameter fiberglass gasoline storage tank (Figure 10). Other sizes range

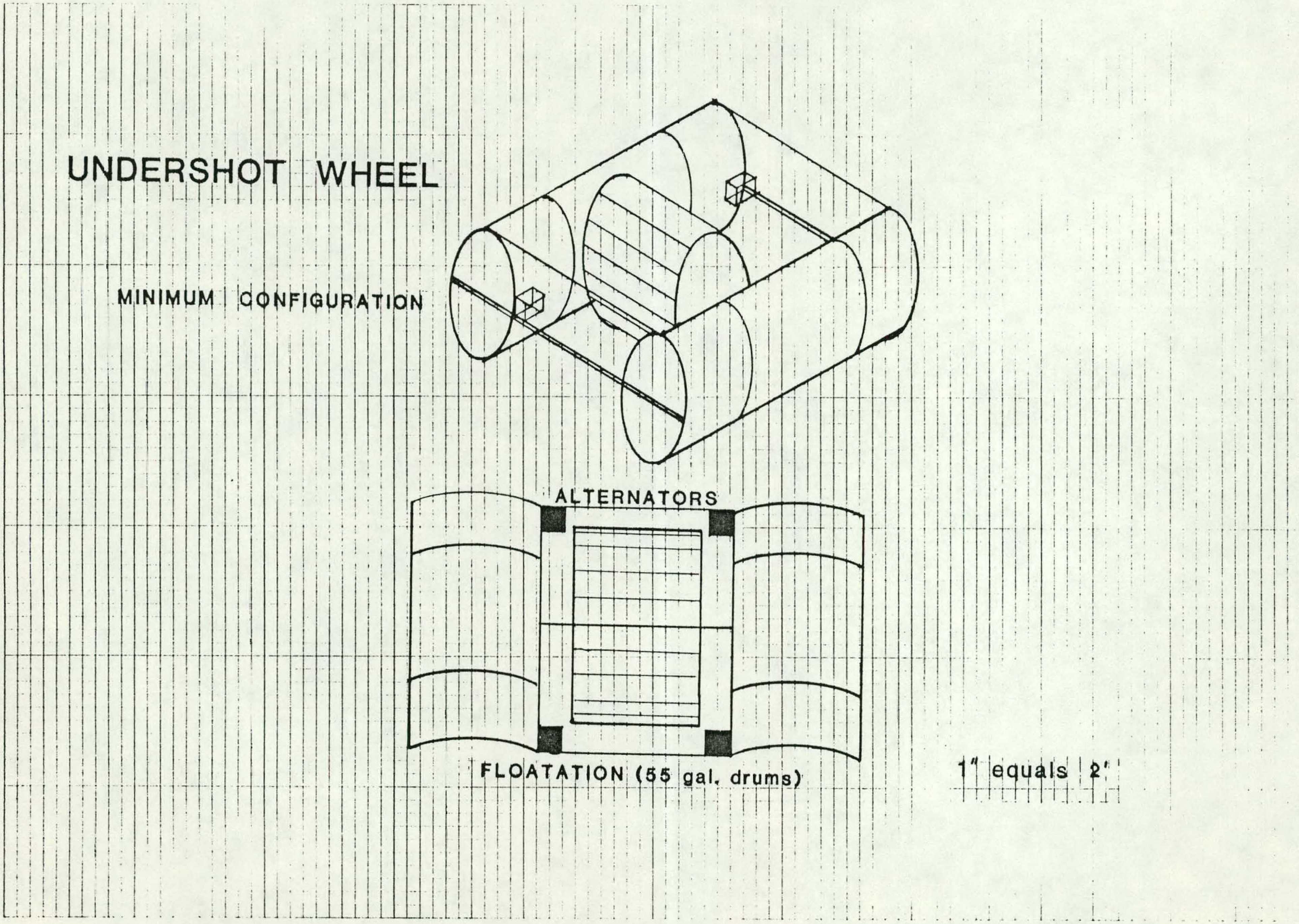


Figure. 8 Floating Undershot Wheel

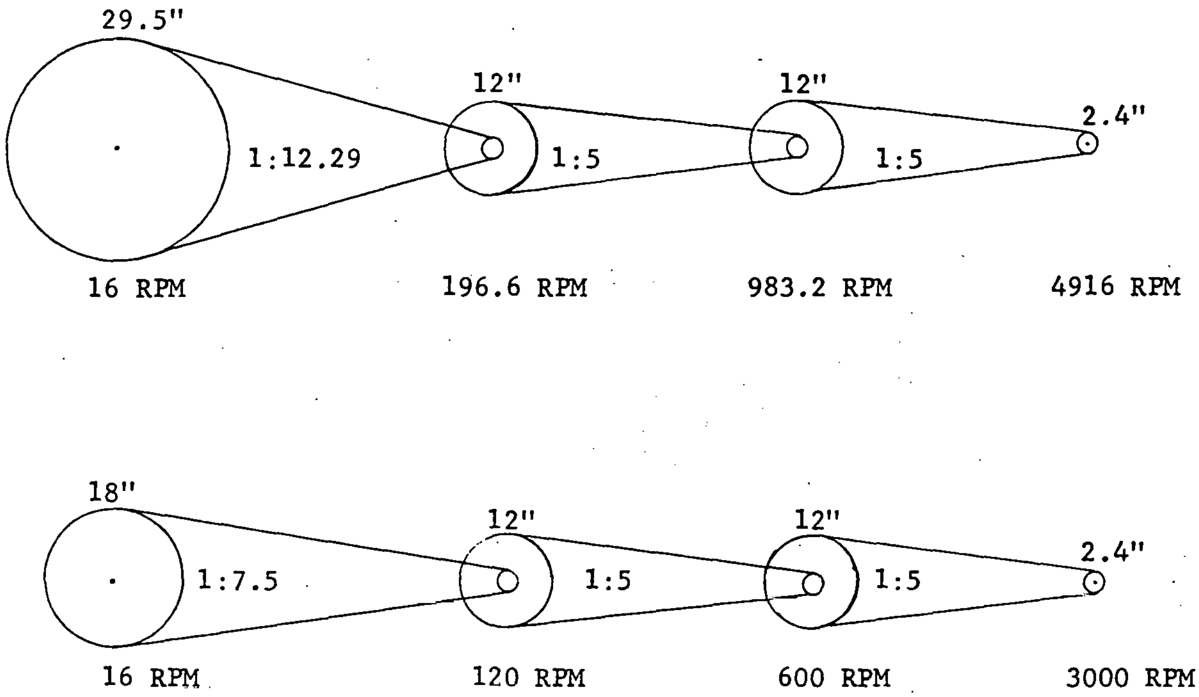


Figure 9 Examples of Increasing Speeds (revolutions per minute) with V Belts and Sheaves (Pulleys)

Table 2

Selected V Belts and Sheave Ratios

RATIO	12.67:1	12.29:1	7.5:1	5:1	3.96:1
Dia. Driver Sheave	38"	29.5"	18"	12"	9.5"
Dia. Driven Sheave	3"	2.5"	2.4"	2.4"	2.4"
Grooves Min.Max.	1,1	1,2	1,1	1,1	1,1
Belt No. C.D.	B120 23.5	A93 18	A58 11.3	A39 7.4	A32 6.2
Belt No. C.D.	B128 27.5	A95 19	A64 14.5	A47 11.9	A41 11.2
Belt No. C.D.	B136 31.9	A97 20	A70 17.9	A55 16.1	A50 15.9
Belt No. C.D.	B144 36.5	A100 21.5	A76 21.2	A63 20.3	A59 20.5
Belt No. C.D.	B154 42.1	A105 24	A82 24.4	A71 24.4	A68 25
Belt No. C.D.	B162 46.4	A112 28.4	A88 27.5	A79 28.4	A77 29.6
Belt No. C.D.	B180 55.9	A128 37.1	A94 30.6	A87 32.5	A86 34.1
Belt No. C.D.	B210 71.6	A144 45.6	A103 35.3	A95 36.5	A95 38.6
Belt No. C.D.	B360 146.8	A180 64.1	A180 74.2	A180 79.2	A180 81.2

C.D. = Center Distance in inches between sheaves (pulleys) as it relates to belt length

For more information and other ratios refer to pages A101-A274 in Browning Power Transmission Equipment Catalog from 4 feet by 6 feet to 12 feet by 63 feet. Such tanks are non-metallic, strong, and readily available. Axles located at the ends of the long axis of the cylinder would be attached to the tank and seated in pillow blocks and bearings at the center points on the floats. Metal or fiberglass blades eight to ten inches wide and running the length of the cylinder would be glued to the outside of the tank to provide the necessary propelled motion. Large diameter (18 inches to 29.5 inches) V-belt sheaves (pulleys) at the ends of the axle would serve as fly wheels and turn corresponding smaller diameter (2.4 inches to 12 inches) pulleys to the point of desired rpms for the generators or alternators. Dimensions for the entire system are 10 to 68 feet wide depending on the length of the tank, as much as 30 feet long and up to 10 feet high (Figure 11). The fiberglass storage cylinder is advantageous for use because it is: strong, non-corrosive, water tight, the correct shape and size, and readily available throughout the country. The larger tanks have potential applications in large scale rivers such as the Mississippi River where the width and depth of the river present no real problems for site applications. Disadvantages for the cylinder are its: cost--approximately $2000 to $9000 and weight--280 pounds to 2,615 pounds.

Information on gasoline storage tanks is available from the manufacturer:

Owens-Corning Fiberglass Corporation
Non-Corrosive Products Division
Fiberglass Tower
Toledo, Ohio 43659
Phone (419) 248-7000

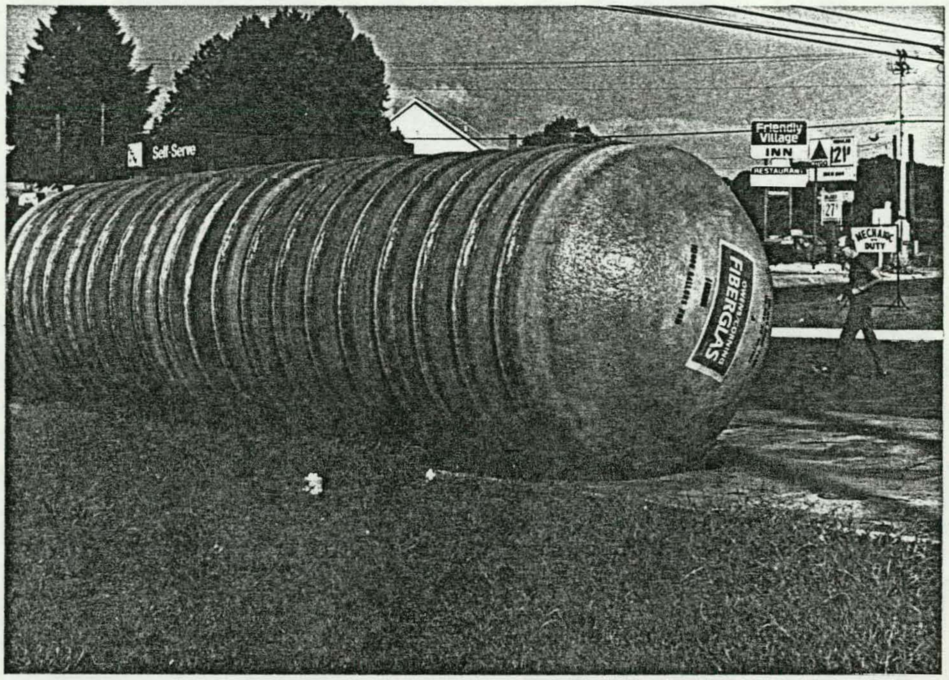


Figure 10. Fiberglass storage tank. Potential runner for a floating undershot cylinder design.

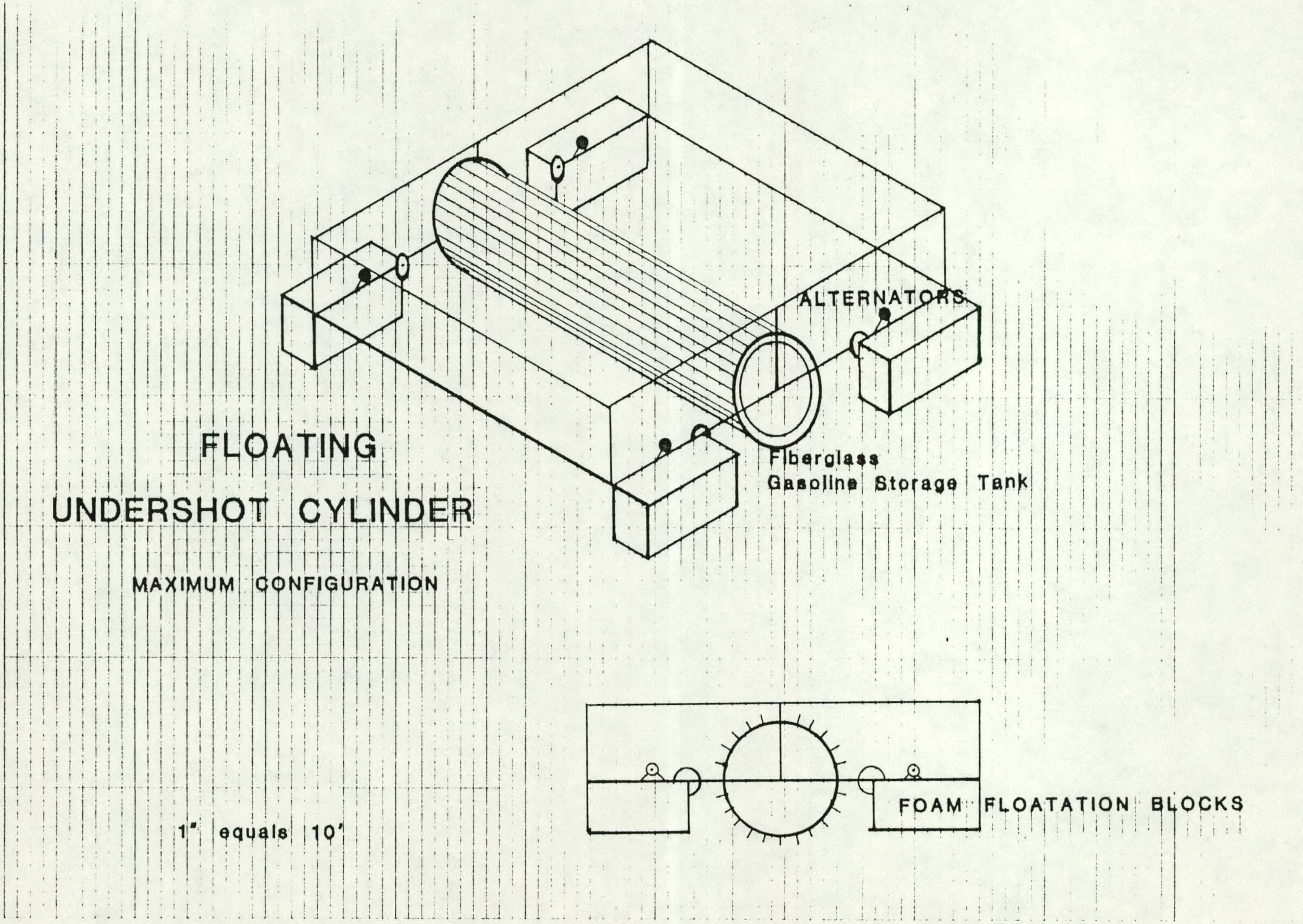

FLOATING
UNDERSHOT CYLINDER
MAXIMUM CONFIGURATION
1" equals 10'
ALTERNATORS
Fiberglass
Gasoline Storage Tank
FOAM FLOATATION BLOCKS

Figure. 11

3.2.3 Submerged Tube

The submerged tube configuration is in reality not entirely submerged, only partially so (Figure 12). Foam floatation blocks support the entire structure so that much of the structure is above the water surface. Corrugated culvert pipes constitute the main structure. It is likely any size can be used, but for purposes of this design three foot and one foot diameter pipe is used. At the intake end of the tube, three foot diameter corrugated pipe six feet long allows a large volume of water to flow into it. At a point six feet from the intake, the tube narrows to a one foot diameter. The small diameter section of the tube could either be designed as a straight shaft approximately 8 or more feet long or one with a diagonal bend in the middle as is shown in Figure 12. At this point it is not known which of these would be the most effective. Propellers or impellers placed inside the pipe and connected to water proofed alternators or generators would turn to create electrical power. Dimensions for the entire system are 12 feet long and 3 to 4 feet wide and 3 to 4 feet deep.

Advantages of the submerged tube concept are the low cost and availability of materials, ease of construction and applications to deeper streams. However it is unknown to what extent a submerged system can operate effectively.

3.2.4 Floating Hydro Power System with Submerged Propellers

The floating hydro power system with submerged propellers takes advantage of deeper, though small, streams. Floatation is entirely based on 12 foot or longer foam billets 17 inches by 24 inches or

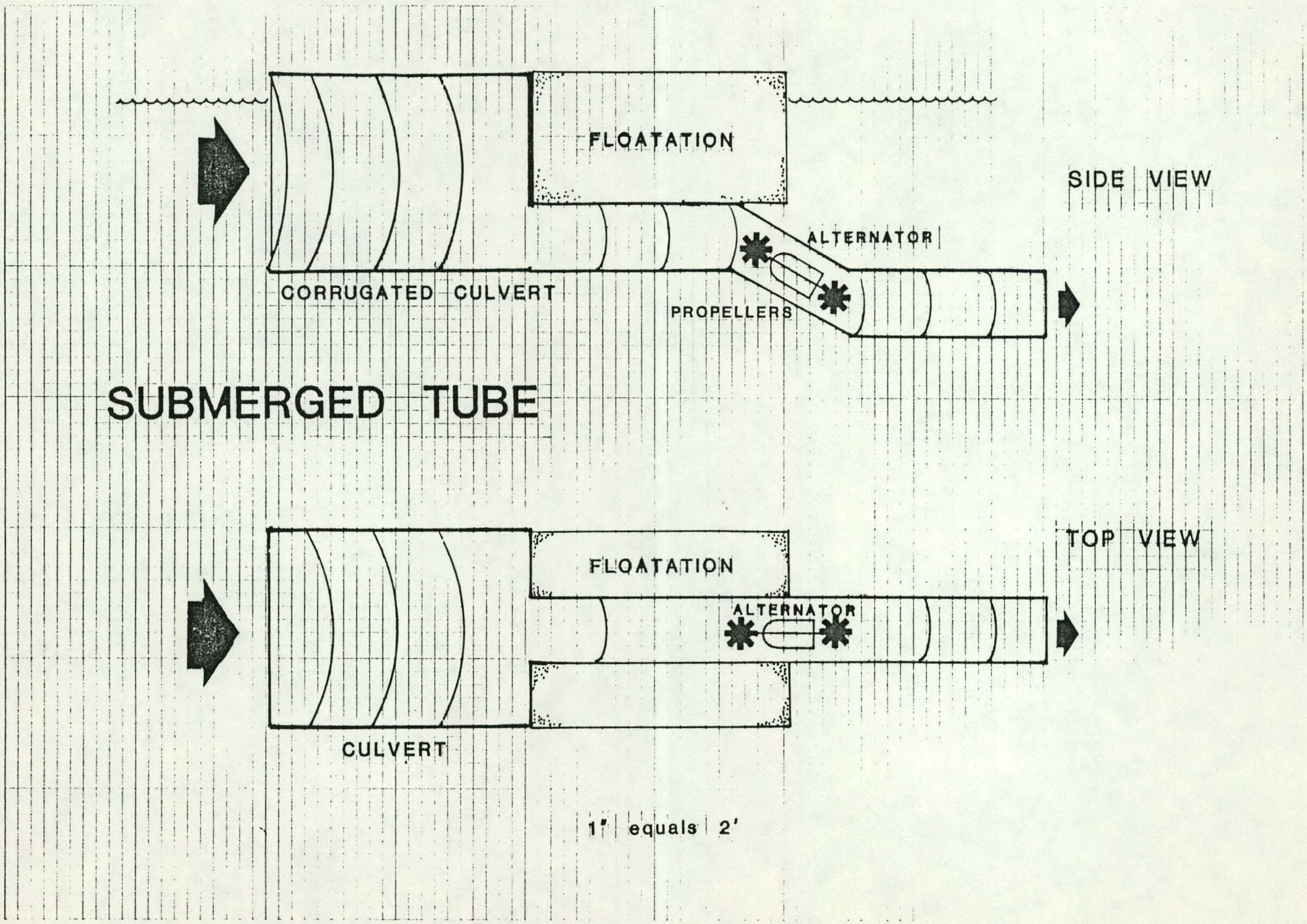

FLOATATION
SIDE VIEW
ALTERNATOR
CORRUGATED CULVERT
PROPELLERS
SUBMERGED TUBE
TOP VIEW
FLOATATION
ALTERNATOR
CULVERT
1" equals 2'

Figure. 12

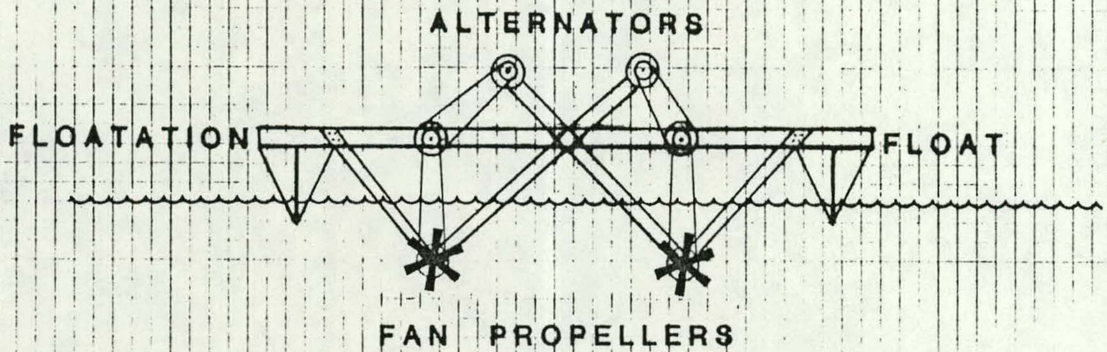
24 inches by 34 inches in width and height dimensions. With the use of metal beams, angle iron or aluminum supports, the runner system is submerged from one to five feet beneath the water surface (Figure 13). Large diameter 2 to 4 foot fan propellers from industrial exhaust fans are attached to the beams and take advantage of the higher velocities in the water just beneath the surface. Large diameter 18 inch to 29.5 inch sheaves (pulleys) with either V-belts or grip notch belts behind the propellers would turn smaller diameter 2.5 inch to 4 inch sheaves (pulleys) on the support beams on the floating craft. Through a series of smaller sheaves, ratios could be set up to maximize the rotary motion to speeds sufficient to run small alternators or generators at 3000 or more rpms. This system could be configured to have as many as five propellers built beneath the floating platform. Dimensions would be 12 feet to 16 feet long, 5 feet to 30 feet wide, and from 5 feet to 12 feet tall depending on the size and number of propellers and the size of the stream.

The advantages of a floating system with submerged propellers are: a reliable floatation system, expected improved efficiency from propellers rather than undershot wheels, low cost, light weight, availability of materials, and ease of construction. Disadvantages would be: the required depth of streams of 5 feet or more and problems of logs and other floating debris that could stop or damage the underwater mechanism.

FLOATING HYDROPOWER SYSTEM

With

SUBMERGED PROPELLERS



1" equals 10'

Figure. 13

4.0 APPLICATIONS OF FLOATING HYDRO POWER TECHNOLOGY

In the applications phase of the project, the primary concern is the expected siting and use of a floating hydro power system within small, fast-flowing streams in rural areas of the Southeastern United States. Questions arise such as: Where is the greatest stream flow velocity? Where will flow patterns and stream depths be optimal for a floating hydro power platform? It is known that in a "uniform", straight, smooth "U" shaped channel the maximum stream flow velocity is at mid channel and just beneath the surface of the water. As channel shape varies, points of high velocity tend to remain in the upper quadrant of the flow, however they will shift laterally. Velocity patterns in meandering streams will be highest near the concave bank just downstream from the axis of the bend. Again, maximum velocity will be just below the surface. In order to determine the potential suitability of streams and sites, I conducted field work in which selected streams in East Tennessee were measured for width, depth, and most important for stream flow characteristics. These streams included: Little River at Walland in Blount County; along the lower Holston River below Cherokee Dam to a point 30 miles downstream in Jefferson County; and the Hiawassee River between Apalachia Powerhouse and Reliance in Polk County (Tables 3-5).

Based on the data collected on the streams, the following conclusions can be reached on potential applications of floating hydro power systems. For Little River at all three test sites,

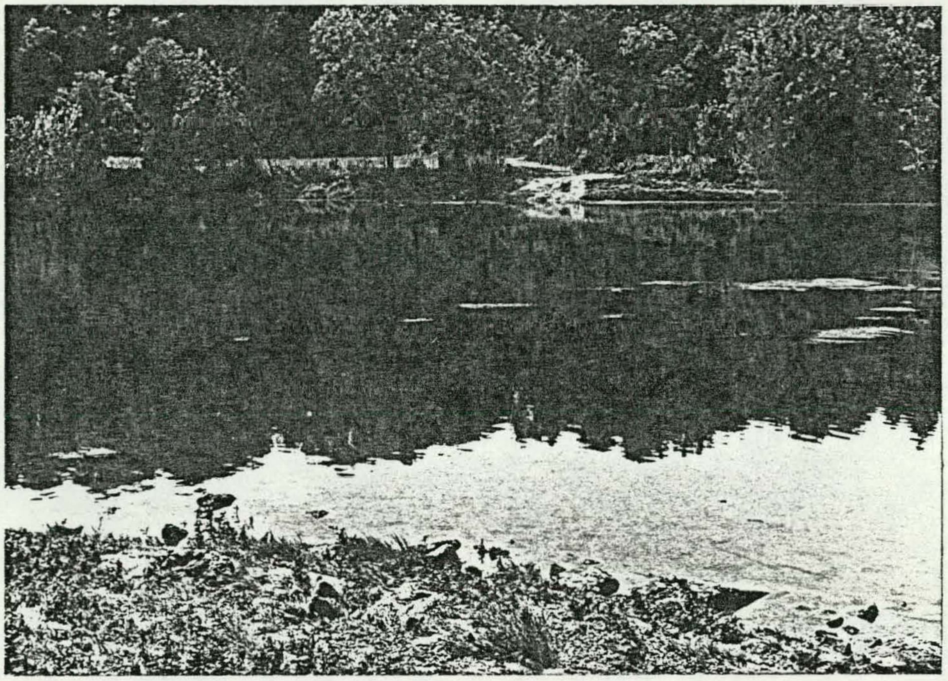


Figure 14. Holston River at Nance's Ferry. Jefferson County, Tennessee.

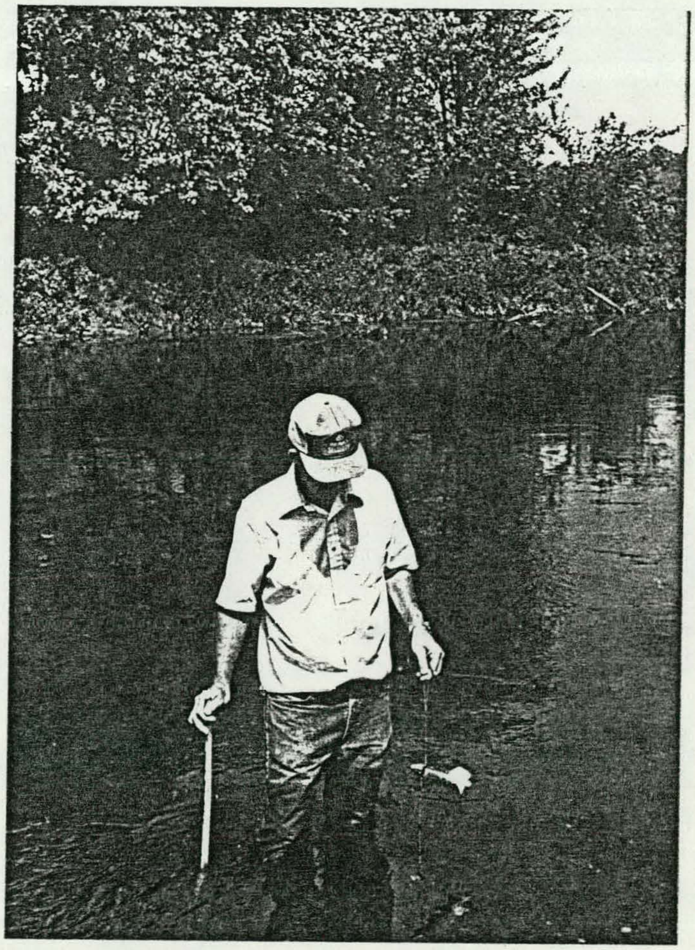


Figure 15. Techniques of stream flow measurement. Holston River, Tennessee.

Table 3

Stream Flow Rates on Little River, Walland Community, Blount County, TN

May 27, 1982

Test Site #1 - Old Mill Site

Instrument Location	Stream Width	Stream Depth	Instrument Depth	Stream Flow Rates CM/Sec	Ft/Sec
4' above dam	120'	4'	1'	16	.52
Left bank at dam	120'	8"	6"	45	1.47
30' below dam	120'	1'	6"	50	1.64
Left bank 12' out	120'	1'5"	1'	40	1.31
Left bank 12' out	120'	2'	6"	43	1.41
Left bank 20'from dam	120'	8"	6"	52	1.70
Left bank 20'from dam	120'	1'	6"	44	1.44

Test Site #2 - New Bridge at Walland

Instrument Location	Stream Width	Stream Depth	Instrument Depth	Stream Flow Rates CM/Sec	Ft/Sec
Left bank 25' out	80'	3'	6"	77	2.52
Left bank 25' out	80'	3'	10"	79	2.59
Left bank 25' out	80'	3'	16"	69	2.26
Right bank 25'out	80'	2'	6"	115	3.77
Right bank 25'out	80'	2'	9"	88	2.88
Right bank 25'out	80'	2'	1'	60	1.97
Mid Channel	80'	1'6"	6"	117	3.84
Mid Channel	80'	1'6"	8"	112	3.67
Mid Channel	80'	1'6"	10"	88	2.88

Test Site #3 -Old Bridge at Walland

Instrument Location	Stream Width	Stream Depth	Instrument Depth	Stream Flow Rates CM/Sec	Ft/Sec
Right bank 20'out	60'	4'	8"	24	.78
Right bank 20'out	60'	4'	1'	22	.72
Right bank 20'out	60'	4'	2'6"	22	.72
Left bank 20' out	60'	3'	8"	26	.85
Left bank 20' out	60'	3'	1'	25	.82
Left bank 20' out	60'	3'	2'	22	.72

Table 4

Stream Flow Rates on the Holston River, Jefferson County, Tennessee

August 19 / October 30, 1982

Test Site #1 - Cherokee Dam, Mile 50, no flow
Test Site #2 - Nances Ferry, Mile 33 August 19

Instrument Location	Stream Width	Stream Depth	Instrument Depth	Stream Flow Rates CM/Sec	Ft/Sec
9' from left bank	300'	15"	6"	16	.52
40' from left bank	300'	18.5"	7"	25	.82
40' from left bank	300'	24"	7"	24	.78
40' from left bank	300'	15"	3"	27	.88
50' from left bank	300'	17"	4"	28	.91
60' from left bank	300'	18"	6"	15	.49
60' from left bank	300'	24"	4"	26	.85
Test Site #3 - Big Bend, Trent Island, Mile 20, August 19					
5' from left bank	80'	18"	4"	46	1.51
5' from left bank	80'	18"	6"	46	1.51
18' from left bank	80'	19"	4"	58	1.90
mid channel	80'	22"	5"	59	1.93
mid channel	80'	24"	4"	61	2.00
30' from right bank	80'	24"	4"	52	1.70
30' from right bank	80'	24"	6"	50	1.64
30' from right bank	80'	24"	10"	40	1.54
Test Site #4 - Fish Trap, McKenny Islands, Mile 24.5, October 30					
Fish trap below wier	400'	12"	6"	35	1.14
Fish trap in wier	400'	10"	6"	77	2.52
Fish trap mid channel	400'	12"	6"	52	1.70
Fish trap 100' below	400'	30"	6"	62	2.03
Test Site #5 - Left bank, Mile 23.8, cut bank side, October 30					
20' from left bank	350'	60"	6"	38	1.24
20' from left bank	350'	60"	18"	38	1.24
20' from left bank	350'	60"	24"	42	1.37
20' from left bank	350'	60"	54"	28	.91
Test Site #6 - Right bank, Beyerly Bend, point bar, mile 22-23, Oct.30					
Mile 23, 12'from bank	350'	36"	6"	44	1.44
Mile 23, 15'from bank	350'	36"	6"	34	1.11
Mile 22½, 20' " bank	400'	36"	8"	78	2.56
Mile 22½, 20' " bank	400'	36"	12"	70	2.29
Mile 22, 20' from bank	400'	36"	8"	60	1.97
Mile 22, 20 from bank	400'	36"	10"	48	1.57

Table 5

Hiwassee River- between Apalachia Powerhouse and Reliance, Tennessee

August 24, 1982

Instrument Location	Stream Width	Stream Depth	Instrument Depth	Stream Flow Rates CM/Sec	Ft/Sec
Mile 53,L bank	100'	24"	6"	65	2.10
Mile 52, L bank	250'	30"	6"	59	1.93
Mile 52, island	300'	30"	6"	63	2.05
Mile 52, chute	300'	48"	6"	93	3.03
Mile 52, chute	300'	40"	6"	125	4.10
Mile 51½, Cane Island	40'	24"	6"	52	1.74
Mile 50½,Little Rock Is	400'	24"	6"	132	4.33
Mile 49½, " " "	400'	36"	6"	52	1.74

Table 6

Stream Parameters for Floating Hydro Power Systems

	Floating Undershot	Floating Cylinder	Submerged Tube	Submerged Propellers
Minimum Stream Depth	8 inches	1 foot	3-5 ft.	4-5 ft.
Minimum Stream Width	8 feet	12 feet	8 feet	20 feet
Estimated Minimum Range of Velocity	1.5-2.5 fps	2.5-3 fps	1.5-2.5 fps	2.5-3 fps

fps = feet per second

water depth is so low at points of maximum velocity that the systems applicable to these sites would be small undershot wheels and possibly small floating cylinders. The submerged tube and propeller systems would not apply because of insufficient depth. For the Hiawassee River the applications would be the same because most of the points of highest velocity are in shallow water. However in sites where chutes of 3.5 feet to 4 feet depth occur, the submerged tube concept would have good potential application. For the Holston River, all systems configurations could have potential application at points along the stream. Although velocities are not as great, the Holston's width and depth situations offer a wide variety of possibilities. However in all of these streams and others for which a floating hydro power system is being considered, the factors of stream depth, width, flow velocities, volume, draft of the platform, anchorages, bottom configuration and other factors should be thoroughly examined before selecting the power system for the particular site.

The expected utility applications of floating hydro power systems to rural areas are to generate hydroelectric power or hydromechanical power. Hydroelectric power generation, although small, would be in direct current form (DC) to recharge storage batteries. The batteries could be used to supply power for low watt lighting needs for a barn or shed in a remote area of a farm complex. Also, electric fences could be powered by the system. Hydromechanical applications could be either of the water pumping system similar to the Amish waterwheels or for use with a hydraulic ram. In another use, the floating turbine could power a small pump on the floating platform and via flexible plastic pipe transport water to a pumped storage location elsewhere on the property. Watering troughs, irrigation, and other water needs located on higher ground some distance from the stream could be served by this system.

CONCLUSIONS AND RECOMMENDATIONS

The floating hydro power system concept can be applied to a wide variety of stream conditions. The designs in this project take into account the variable widths, depths, and flow characteristics of many kinds of stream conditions. Until a design is built and put into the water either as a model or as a full-scale prototype, we cannot be sure of the ultimate contribution that the system can make toward power production and the efficiency thereof. However we can speculate on site parameters and the application of such a floating system to streams in Tennessee and elsewhere. Of the four designs, I personally would prefer to see the simple undershot wheel design built and put to power production as a prototype upon which others could be developed. Also it has the best chance for application to small, shallow streams. I also favor the fourth design--the floating platform with submerged propellers. Although this particular design requires deeper water, it has potential for not only deeper streams in Tennessee and the Southeast United States, but also it would have significant application to deep high volume rivers in the wet tropics. This summer I observed rivers in India and Chile, and in both locations rivers such as the Sutlej River in North India and the Mapocha in Chile would have been excellent river sites for appropriate floating hydro technology. Recently, I received a letter from Father G. Wenzel, a missionary in Zambia, Africa requesting information for a riverine power system that floats to take advantage of great variations in water level. It is thus conceivable that in many parts of the world, especially Third World areas, appropriate small scale technology such as a floating hydro power system would have acceptable applications.

MATERIALS

FLOATATION PLATFORMS

Foam Blocks

Marine Systems Inc.
P.O. Box 10756
Cogdill Road
Knoxville, TN 37923
(615) 699-8700

Drewfoam
Memphis, Tennessee
(909) 525-1569

Meeco Marinas Inc.
Box 518
McAlester, Oklohoma 74501
(800) 331-8150

Galva Foam Inc.
Rt.A Box A-15
Camdenton, MO. 65020
(313) 346-3323

Pontoons/Canoes

Harris Marine Division
2801 West State Blvd.
Fort Wayne, Indiana 46808
(219) 432-9402

Formall Plastics Inc.
3908 Fountain Valley Rd.
Knoxville, TN
(615) 922-7511

Mohawk Canoes
P.O. Box 668
Longwood, Florida 32750

for canoe suppliers contact
Canoe Magazine
Highland Mill
Camden, Maine 04843
(207) 236-9621

TURBINES

Fiberglas Storage Tanks
Owens-Corning Fiberglas Corporation
Fiberglas Tower
Toledo, Ohio 43659
*(615) 584-1517 = Knoxville rep

Industrial Fans
Allied Mechanical Equipment Corp.
2435 Burnside St.
Knoxville, TN
(615) 524-2031

Chicago Blower Sales of Atlanta
170 Dunhill Ct.
Atlanta, GA
(404) 393-4203

* Engineered Machinery Sales Inc.
4028 Papermill Rd.
Knoxville, TN
(615) 584-1517
also represents Owens-Corning
Fiberglas Storage Tanks

hydaulic lifting engine
Schneider Lift Translator Corp.
5310-D Power Inn Road
Sacramento, CA. 95820
(916) 381-4466
or
Schneider Engine Company
Rt 1 Box 81
Justin, Texas 76247
(817) 648-2293

conventional turbines
Allis Chalmers
Hydro-Turbine Div.
P.O. Box 712
York, PA. 17505

The James Leffel Co.
2126 East St.
Springfield, Ohio 45501
(513) 323-6431
represented by
Cumberland General Store
Rt. 3 Box 479
Crossville, TN 38555

<u>Industrial Fans</u>

Grainger, W.W.Inc.
6500 Baum Dr.
Knoxville, TN 37919
(615) 588-2956

Lancaster Associates
6321 Pleasant Ridge Rd.
Knoxville, TN
(615) 525-0416

GENERATORS/ALTERNATORS

Local

Bearden Motor Products
5543 Kingston Pike
Knoxville, TN 37919
(615) 588-2428

Knoxville Generator Co.
308 Randolph St.
Knoxville, TN
(615) 637-3493

Lane Magneto and Electric Co.
307 N. Central Ave.
Knoxville, TN
(615) 524-4604

Out-of-State

Lima Electric Co. Inc.
200 East Chapman Rd.
Box 918
Lima, Ohio 45802
(419) 227-7327

Windworks (Gemni synch. inverter)
Rt 3 Box 329
Mukwonago, Wisconsin 53149
(414) 363-4408

Thermax Corp. (TC256 Generator)
1 Mill Street
Burlington, VT 05401

SHEAVES, V BELTS/ BEARINGS/ BOLTS

<u>Sheaves & V Belts</u>

Electric Motor Sales & Supply Inc.
416 Troy Circle
Knoxville, TN 37919
(615) 588-0615 (rep for Browning)

Browning Manufacturing Division
Emerson Electric Co.
Maysville, KY 41056

B.F. Goodrich
Engineered Systems Div.
Dept. 0708
Akron, Ohio 44318

Tennessee Belting and Supply Inc.
2538 Sutherland Ave.
Knoxville, TN
(615) 637-1412 (rep for Goodrich)

Gates Rubber Co.
5324 N. Broadway
Knoxville, TN
(615) 687-5891

<u>Bearings</u>

Dixie Bearings Inc.
411 Dale Ave.
Knoxville, TN
(615) 525-4136

Reliance Electric Co.
318 Erin Dr.
Knoxville, TN
(615) 584-3979

Southern Bearings Service
401 Bernard Ave.
Knoxville, TN
(615) 546-7611

<u>Bolts/Anchors</u>

Knoxville Bolt and Screw Co.
614 Sevier Ave.
Knoxville, TN
(615) 573-1991

Southeastern Bolt and Screw Co.
1312 Chilhowee Ave.
Knoxville, TN.
(615) 525-8467

CONTACTS

Dr. Harvard Ayers Department of Anthropology Appalachian State University Boone, N.C. 28608	Micro-Hydro Systems
DOE Dept. of Energy Technical Information Center P.O. Box 62 Building 1916-T1 Oak Ridge, TN 37830 (615) 576-1302	Information on published materials
John D. Harder P.O. Box 139 Anahola, Hawaii 96703	Low-head, high-volume hydro generator
Dwight Magnuson P.O. Box 142 Seymour, TN 37865 (615) 428-0768	Micro-Hydro Systems
Will Merritt P.O.Box 7 Low Gap, N.C. 27024 (919) 352-4608	Micro-Hydro Electric System since 1926
Mother Earth News P.O. Box A East Flat Rock, N.C. 28726 The Mother Earth News Inc. 105 Stoney Mtn. Rd Hendersonville, N.C. 28791 (704) 693-0211	Micro-Hydro Systems and plans
DOE Technical Research Staff National Center for Appropriate Technology P.O. Box 3838 Butte, Montana 59701	Micro-Hydro Information
Tennessee Valley Authority 400 Commerce Ave. Knoxville, TN. (615)632-4100 (615)632-2101 ext 3791	information on discharge rates from dams dock permits
VITA Volunteers in Technical Assistance 3706 Rhode Island Blvd. Mt. Rainier, MD 20822	Information on Micro-Hydro Systems, plans and other energy related systems

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