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ELECTROFISHING LARGE RIVERS - THE YELLOWSTONE EXPERIENCE

By:

Larry Peterman
Aquatic Project Leader - Yellowstone River
Montana Department of Fish and Game
Miles City, Montana

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INTRODUCTION

There is presently in the fisheries literature a scarcity of published documents or available information concerning fish populations or the life history of fish inhabiting large, fast flowing rivers. The relative dearth of biological data from large rivers can probably be attributed to: 1) The difficulty of capturing the wide variety of fish species commonly found in large rivers, 2) the problem of sampling a large enough portion of any one fish population to obtain reliable data, and 3) sampling all of the habitat types of a large river. It is generally possible, using a variety of techniques, to capture a few individuals of most species found in even the larger rivers. The major problem is sampling a large enough segment of a particular fish population to obtain reliable estimates of certain population parameters such as population numbers, biomass, year class strength, relative abundance between species or even an index of a single species. In addition, reliability of certain types of data demands either random sampling of the population or random sampling of the different habitat types. While certain assumptions inherent in the reliability of data collected on small streams and rivers are routinely and easily met, these same assumptions can be major stumbling blocks on large rivers.

Since 1974, Montana has been forced into intensive biological sampling of the large and free-flowing Yellowstone River. The primary need for research on the lower Yellowstone came not from the river's uniqueness, not from its species composition, nor its populations of "rare" fishes, but from the fact that it flows through the western coal reserves known as the Fort Union Coal Formation. The Fort Union Coal Formation is of critical importance to the nation's long range energy plan as an intermediate energy source. The Yellowstone River is expected to supply much of the water for the energy conversion facilities. Direct, large scale industrial water withdrawals, interbasin transfer of Yellowstone water and the impending construction of a 2,100 megawatt coal-fired generating complex at Colstrip, Montana prompted the initial research efforts in 1974. Biological data had to be obtained for adequate impact analysis and mitigation and development of an instream flow request to protect the aquatic resource.

Prior to 1973, with the exception of paddlefish harvest information, lower Yellowstone fish populations were relatively unstudied. The first task in this endeavor was simply to develop new sampling equipment and techniques or adapt those already in existence to the particular conditions found on the lower Yellowstone. It became readily apparent, after initial attempts with various sampling methods, that electrofishing offered one of the best possibilities as a major sampling tool. Sampling with gill nets, seines, trammel nets, and trap nets was extremely difficult, and at times hazardous, due to the relatively high current velocities, numerous bottom obstructions and frequent debris conditions. Consequently, a major effort was directed towards construction of an electrofishing boat that was both effective in sampling the major fish populations found in the lower Yellowstone and which incorporated adequate safety features for crew safety during the electrofishing operations.

It is difficult to address the subject of sampling large rivers in a general sense due to the great physical and biological variability of rivers on a national or even regional scale. While the Yellowstone can certainly be considered a large river in terms of problems associated with electrofishing and fish sampling, it is not in the same category as the lower Missouri or Mississippi. The following is a discussion of some of the problems faced on the lower Yellowstone, the solutions or partial solutions to those problems, the effectiveness of the electrofishing equipment used, and some possible direction for future development.

Although the comments pertain principally to the lower Yellowstone and upper Missouri rivers, some of the information presented may be of use to others faced with the often frustrating task of sampling large, fast flowing rivers.

The Yellowstone River is free-flowing over its entire length, making it unique among the large rivers of the continental United States. The Yellowstone originates in the northwest corner of Wyoming and flows northeasterly through Montana before joining the Missouri River near Cartwright, North Dakota. It has a total drainage area of approximately 70,400 square miles and its length is 678 miles, 550 miles of which are in Montana.

The Yellowstone can be divided into three general zones related to fish distribution. From its headwaters in Wyoming to its mouth in North Dakota, the river changes from an alpine, salmonid fishery to a diverse, warm water ecosystem. The river contains a 222-mile cold water zone (headwaters to Big Timber), a 160-mile transition zone (Big Timber to Bighorn River) and a 296-mile warm water zone (Bighorn River to confluence with Missouri River). All of the experimental design testing was conducted on the warm water portion of the Yellowstone River. However, the basic design has also been used on the Missouri River as well as the smaller Tongue, Powder, Poplar and Marias rivers in Montana.

PROBLEMS OF LARGE RIVER ELECTROFISHING

Of the many variables influencing the effectiveness of large river electrofishing, the physical features of size, depth, water velocity and turbidity probably encompass the major problems to be overcome. The range of conductivity commonly experienced in the Yellowstone River was not a major deterrent to sampling. However in some drainages, conductivity (either high or low) can definitely be a limiting factor.

Size

Obviously, a major hindrance to sampling large rivers is physical size. As rivers increase in size (and usually in depth) more areas become available to fish both as habitat and for security. As rivers increase in size, the easily sampled areas decrease in proportion to the total water surface. For example, undercut banks (which are easily sampled) may be the major habitat component on smaller streams but become relatively less important or completely absent in relation to the total surface area in large rivers.

In addition, as rivers increase in size, the effective area sampled by the electrofishing boat in relation to total surface area becomes smaller and more effort per river mile is needed. Multiple sampling runs are common on sections of large rivers as are left bank, right bank and midstream sampling locations. As rivers increase in size, electrofishing efficiency (ability to capture a given percent of the population) decreases while population numbers and biomass per river mile generally increase.

The physical size of large rivers decreases the reliability of certain types of data by decreasing sampling efficiency and limiting the areas of river that can be readily sampled. Proper electrofishing boat design and component selection can, at least partially, overcome some of these problems.

Depth

Deep water conditions obviously limit the effectiveness of electrofishing boats. In large, fast flowing rivers, deep pools and deep runs often harbor a large segment of the fish population yet are untouched by most sampling methods. The inability to sample deep areas of rivers probably adds more bias to most types of data analysis than any other single factor.

Current Velocity

Current velocities greater than 5 feet per second can adversely affect electrofishing effectiveness of large rivers as well as increasing the hazards associated with river work. Current velocities are principally a function of river gradient and discharge and will increase with increasing flow or with an increase in gradient caused by channel alterations which result in an overall shortening of a given section of river.

Excessive current velocities adversely affect electrofishing efficiency by reducing the effective response area around the electrodes and the depth from which the fish can respond. In relatively high current velocities, unless a fish is well within the electrical field, the boat may float past the fish before it can be drawn close enough to be netted. Netting is also less effective at high current velocities.

Turbidity

While slightly turbid water conditions may actually increase sampling efficiency in some areas of large rivers (shallow water areas less than 3 feet deep), excessive turbidities severely limit the effectiveness of electrofishing by limiting the depths into which netters can see and consequently net fish. Turbid water conditions will generally have a greater effect on sampling efficiences in water 3 feet or more in depth than in shallower areas.

Yellowstone Description

A brief description of the lower Yellowstone River itself is necessary to obtain the proper perspective on the sampling problems encountered on this river in relation to those encountered on other rivers. The Yellowstone is a free-flowing river and has a flow regime and channel characteristics quite unlike that of most regulated river systems. It has a mean flow of approximately 13,000 cubic feet per second and discharges 8.8 million acre feet of water annually into the Missouri River. The flow regime is characterized by an annual spring flood which occurs during May, June and July, with the highest flows commonly occurring in June. A low water period normally occurs from late August through February. In most years there is an 8 to 10 fold increase from the normal range of flows (4,000 to 10,000 cfs) to the normal range of high flows

(40,000 to 100,000 cfs). Along with the change in flows is a concurrent change in those parameters directly related to flow, such as water depth, water velocity, water width, cross-sectional (conveyance) area, conductivity and, to some degree, turbidity.

At low flows, riffle areas range from 1 to 4 feet in depth, while pools vary from 8 to 15 feet deep. During spring high flow conditions, pools may increase their depth by 5 to 9 feet, depending on channel configuration and flow levels. During summer low flow conditions, water widths vary from 700 to 1,000 feet. Channel width varies from 900 to 1,200 feet except in braided sections where total channel width is significantly greater.

Water velocities are generally a function of gradient and discharge. The average river gradient for the lower Yellowstone is 2.8 feet per mile. Gradients for individual sections within this area vary from 1.0 to 5.7 feet per mile. Average water velocity for a cross-section of the Yellowstone at Miles City (river mile 185.0) varies from 2.5 feet per second at 5,000 cfs to over 7.0 feet per second at 60,000 cfs (Figure 1). Average velocity may reach 9 to 10 feet per second during uncommonly high spring flows.

Conductivity varies seasonally in the lower Yellowstone. Lowest conductivity occurs during spring run-off and highest conductivity from December through April. Conductivity during spring run-off may vary from 240 to 500 micromhos while December through April conductivity may range from 600 to 1,150 micromhos (USGS 1971-1974).

Turbidity also increases during spring run-off, however heavy precipitation during the low period may also result in short-term increases in turbidity. During spring run-off conditions, suspended

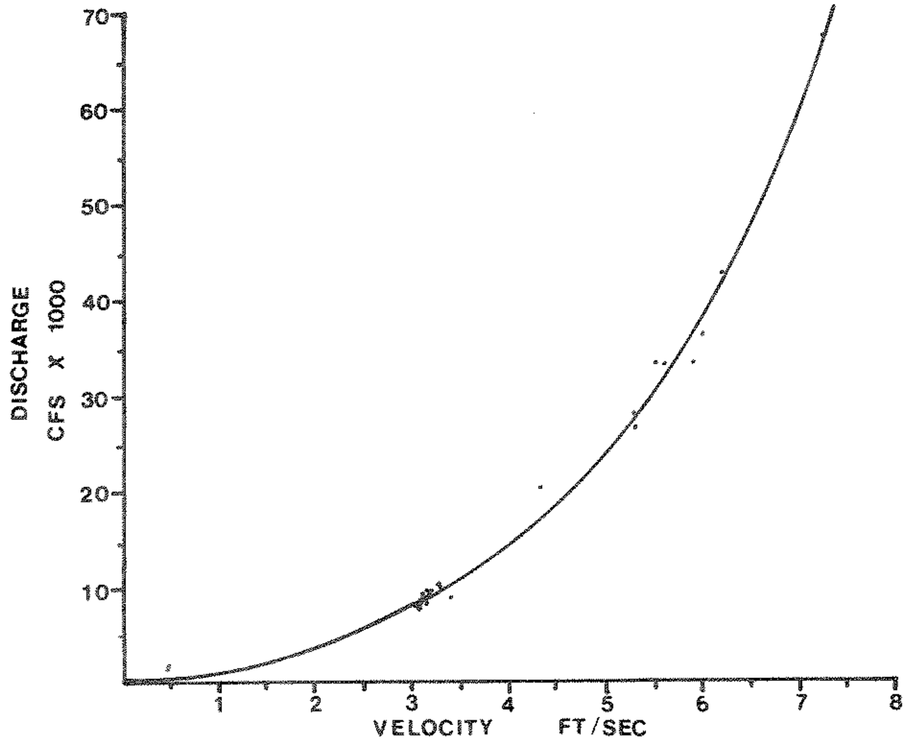

Figure 1. Curve illustrating the average water velocity for a cross-section of the Yellowstone River at Miles City at a given flow.

sediment concentrations of 500 to 3,500 ppm limit visibility from 0 to 6 inches. Visibility increases to nearly 4 feet during late summer and fall low flow conditions.

AN ELECTROFISHING BOAT FOR THE LOWER YELLOWSTONE

There are two basic current types available for electrofishing: alternating current and direct current. An alternating current (AC) system simply stuns and immobilizes the fish with little attraction of the fish to the electrodes (electrotetanus). A direct current (DC) or pulsed direct current system, causes a fish to exhibit a forced swimming response toward the positive electrode (electrotaxis).

It became readily apparent after initial sampling efforts that a direct current or pulsed direct current system would be essential for successful electrofishing on the lower Yellowstone. The major problems to overcome are water depths, velocities and occasionally high turbidities. The fish must be pulled up from the pools and held in the current long enough to be netted. During highly turbid conditions, fish often have to break the surface to be seen and netted.

The attractive force of DC far outweighs the disadvantages of the smaller electrical field. A good compromise between the attractive force and size of electrical field is obtained with pulsed DC (Novotony and Priegel 1974). After field testing a number of different boat and electrode designs, the electrofishing boat described below was, by far, the most successful combination (Figure 2). The positive and negative electrode designs largely follow those described by Novotony and Priegel (1974) and appear to have fairly universal application. Specific boats selected for certain types

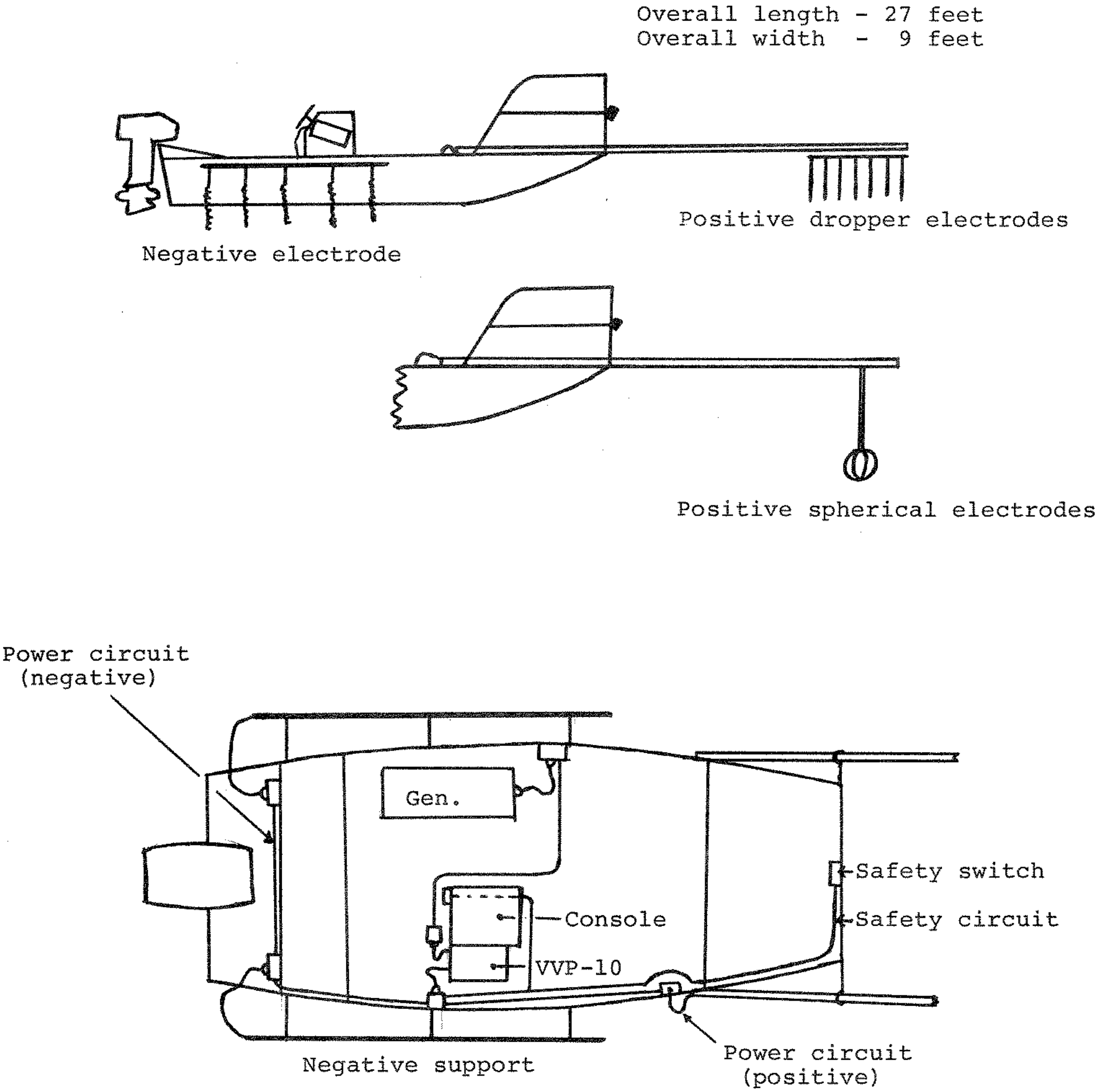

Figure 2. Major component location and electrode configuration.

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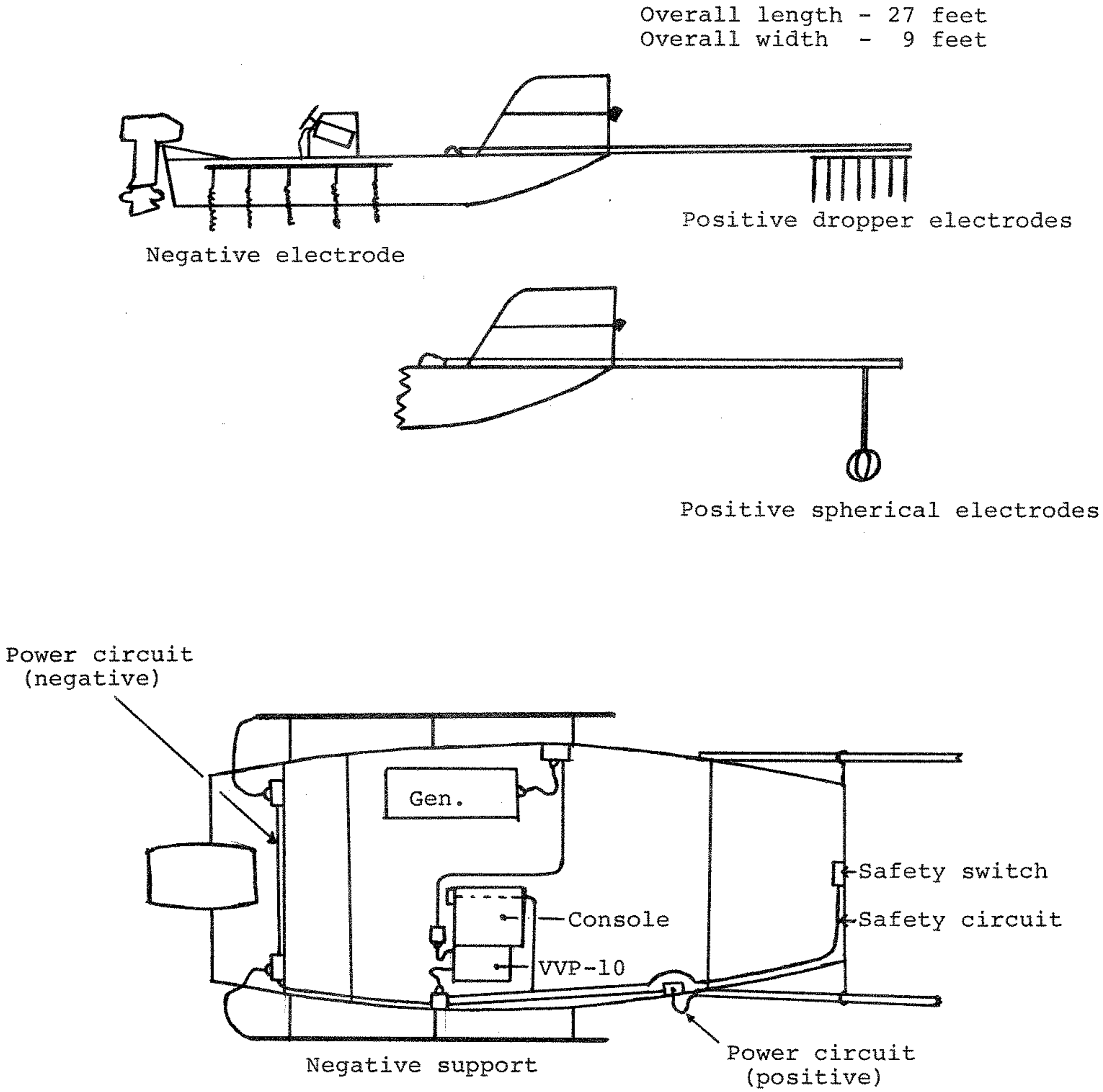

Figure 2. Major component location and electrode configuration.

of rivers may, however, exhibit less adaptability to varying conditions.

Power Source and Rectifying Unit

The electrical power source for the electrofishing system is a 4500 watt, 230 volt (60 Hz. single phase) alternating current generator. When electrofishing without lights, a 3500 watt generator is adequate. A Coffelt Model VVP-10 rectifying unit is used to change the alternating current to pulsed or continuous direct current output, or to regulate the alternating current output. Output from the rectifying unit is selectable from 0 to 300 volts and corresponding amperages from 0 to 25 amps is monitored. Pulse frequency is adjustable from 20 to 200 pulses per second and pulse width can be varied from 20 to 80 percent. Meters monitor DC and AC output voltage and amperage, percent pulse width, and frequency (pulses per second). In addition, the volt meter may be switched to monitor generator output.

Electrode Design

The electrode system of the boat consists of positive (anode) and negative (cathode) arrays and was designed primarily for operating in the direct current mode; however, this electrode system is also adequate for operation with alternating current. Although construction details may differ, the design of the positive dropper electrode assemblies (Figure 3) and the negative electrode arrays (Figure 4) follow closely that developed and described by Novotony and Priegel (1974) and the reader is referred to that publication for design details. The spherical electrodes described below were designed principally for the Yellowstone (Figure 5). Principal design features of the anode and cathode arrays are briefly described below.

Anode Array

The positive electrode system consists of two anodes suspended from fiberglass booms approximately 6 feet in front of the bow of the boat (Figure 3). The booms are spaced 7 feet apart and are adjusted for height by means of pin-locked adjustments. Each anode consists of either (1) a spherical electrode, 15 inches in diameter, constructed from 3/8 inch diameter copper tubing or (2) an array of 12 to 15 "dropper" electrodes clipped to a 3-foot diameter aluminum support ring. The support ring provides mechanical support and an electrical connection for the droppers which actually carry the current into the water. Individual "droppers" consist of 6-inch lengths of 5/8 inch diameter stainless steel tubing supported by an 18-inch length of heavy gauge insulated copper wire having a 20 amp test clip for attachment to the support ring. By adjusting a movable sleeve of insulating material (5/8 inch dia. auto. wiring loom), surface exposure of the "droppers" can be varied for waters of differing conductivity (Novotony and Priegel 1974).

The electrode arrangement of positive dropper electrodes suspended from an aluminum ring is superior to that of the spherical electrodes. The dropper arrangement offers greater flexibility over a range of conductivities, greater control of current output and less chance of snagging on obstructions. Fish generally exhibit similar response to both designs except at the lower conductivity range (250 micromhos) where small shovelnose sturgeon (less than 1.0 pound) and burbot respond better to the spherical design. The spherical design does offer the advantage of being inexpensive and easy to

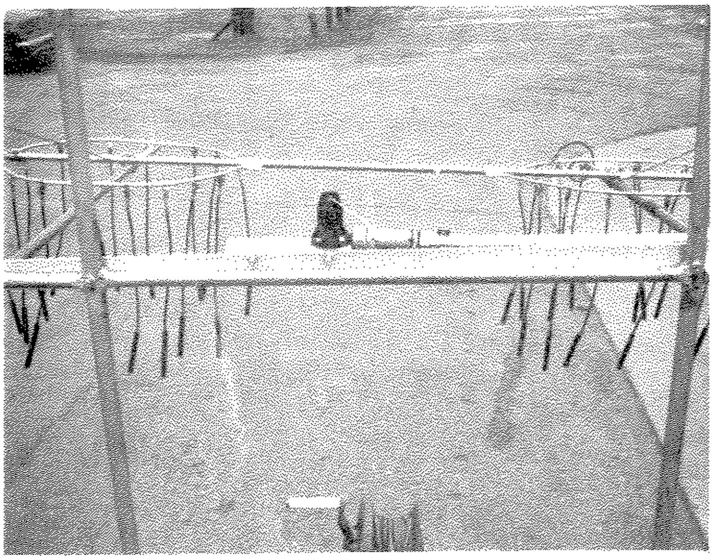

Figure 3. Positive dropper electrodes and safety switch for netter.

Figure 4. Negative electrode array

construct.

Cathode Array

The negative electrode system consists of two cathode arrays, one mounted on each side of the boat (Figure 4). Each array consists of one set of five 4-foot lengths of 3/4 inch diameter flexible conduit (Novotony and Priegel 1974) supported by an 8-foot length of fiberglass boom. Each length of conduit is fastened to the support boom by a chain and rubber insulator. The top of each length of conduit is insulated with electrical tape or shrink tube.

Boat and Motor Selection

Since large rivers vary considerably in their physical characteristics, a single boat or boat design cannot be expected to work equally well in all situations. Large river electrofishing operations are dependent on a certain amount of mobility, making the selection of the proper size and type of motor nearly as important as selecting the boat. Major factors to consider in boat/motor selection are water depth (or the lack of it), water velocity, substrate type and access.

Depth becomes important only by its absence; that is, when riffles or other portions of the channel are shallow (less than 1 foot deep) and the possibility of frequent grounding exists. Current velocity primarily influences the size of motor required, although in rivers with high current velocities boat design is of equal importance. Substrate type primarily influences the selection of hull thickness. Access to the river becomes a factor only when it is limited and may influence the size of boat and motor required.

It is frequently a combination of these factors which determine the choice of boat and motor. Generally, rivers having high or moderate gradients near mountainous or headwater areas tend to have high current velocities, relatively abundant shallow water areas, and a gravel or cobble substrate. A boat/motor combination selected for this type of river would have characteristics different from one chosen for a deep, slow moving river.

The above conditions as they exist on the lower Yellowstone are: Depth - under low summer flows, riffles are from 1 to 4 feet deep and the main channel contains many shallow areas and mid-stream gravel bars. Velocity - ranges from 2.5 to 4 feet/second under low summer flow conditions, to 5 to 8 feet/second during spring runoff (Figure 1). The substrate is predominantly gravel and cobble with occasional bedrock areas. Access is poor with four boat ramps on 300 miles of river; however, physical access to gravel bars or low bank areas is more frequent (every 15 to 25 miles).

The boat chosen for this reach was a 17-foot flat-bottom aluminum boat powered by an 85 hp. outboard motor fitted with a jet propulsion lower unit. The hull thickness is .125-inch (bottom) and .10-inch (sides). It has a load capacity of 1500 pounds, however additional flotation had to be added to obtain this capacity.

The aluminum boat offered the advantage of simple, reliable grounding of all electrical components. The thick hull material eliminated the problem of punctures or abrasion, however, the weight of the boat was nearly double that of a comparable size boat with standard .061-inch hull thickness. An outboard jet unit enabled the boat to be operated (when planing) over waters as shallow as 6 inches and offered no extensions below the hull to contact bottom obstructions. The 85 hp outboard motor was necessary for mobility to overcome the scarcity of access sites, i.e., to travel to sampling sites, however a much smaller outboard would have been adequate for mobility during the electrofishing operations itself.

The Missouri River offers a different problem. Although the physical characteristics are quite similar, main channel depths are greater and flows fluctuated less as a result of upstream dams. The main problem with the Missouri is access. Between Fort Benton, Montana and the Fred Robinson Bridge near Landusky (149 miles), there are only four acceptable sites with as many as 50 miles between two of the sites.

The relative inacessibility of the river requires week long sampling trips. The boat not only has to function as an electrofishing boat, but also has to carry the necessary food, fuel, camping gear and sampling equipment for 7 to 10 days. The boat chosen for this project is a 22-foot semi-vee aluminum boat powered by a 245 hp inboard jet (Figure 6). The boat is constructed of heavy gauge aluminum (.1875-inch bottom, .125-inch hull) and has a load capacity of 2500 pounds. Primary considerations in selecting this boat were: 1) a large load capacity, 2) shallow water capability, 3) dependable, low maintenance motor, and 4) acceptable fuel economy.

After four years of experience with the outboard jet boats and two years with the inboard jet, some general comments can be made. It is not advisable to use an outboard jet propulsion lower unit unless shallow water conditions demand it. There is approximately a 30 to 35 percent power loss when compared to the standard propeller-driven lower unit. Reverse thrust is also very poor. The heavy electrofishing boat makes necessary a fairly large jet outboard.

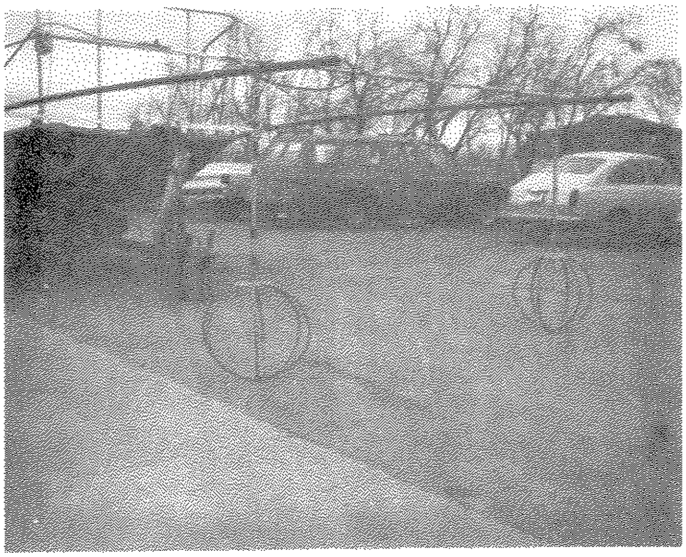

Figure 5. Positive spherical electrodes.

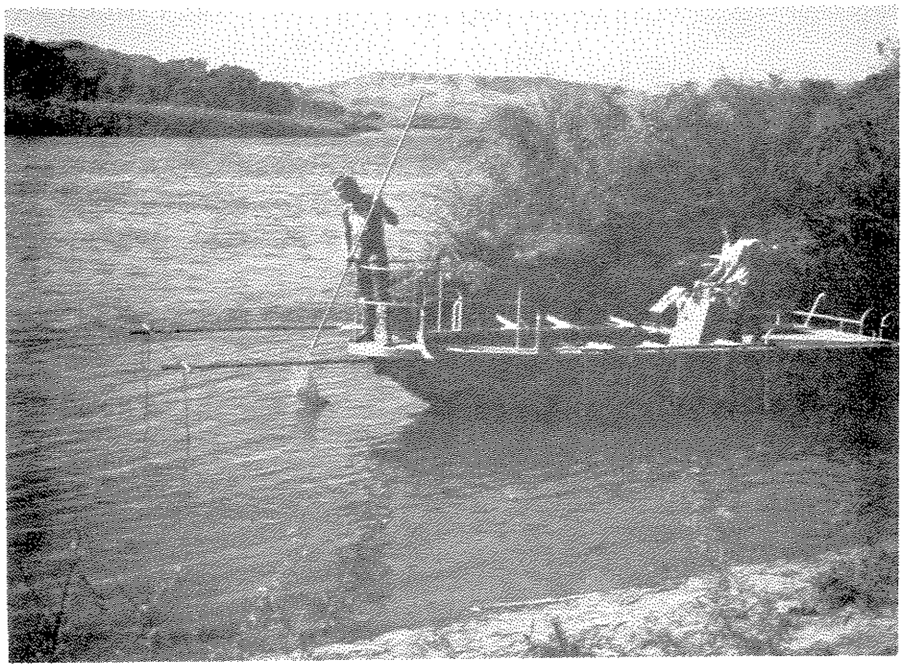

Figure 6. 22-foot inboard jet adapted for electrofishing on Missouri River.

The dependability of the outboard jet combination decreases drastically after approximately 500 hours of use. In addition, fuel consumption is high (1 to 3 miles/gallon).

The inboard jet unit does not suffer the large power loss as does the outboard jet. In addition, fuel economy and dependability are much greater. The initial cost of the inboard jet is only slightly higher, but operating costs are significantly less. The inboard jet requires a semi-vee hull design and at least one foot deeper water to operate in than the outboard jet.

Operating Guidelines For Electrofishing Large Rivers

The primary considerations in electrofishing effectiveness, given the wide variation in experience and capability of electrofishing crews, are the design features of the electrical system, including: the power source, the rectifying unit and the electrodes. There are, however, several operating procedures which may increase sampling efficiency.

Boat speed can be a major factor in the success of large river electrofishing. In general, it is advantageous to operate the boat relatively fast in relation to the current in shallow water areas. Slow boat speeds in shallow water may tend to scatter fish into deeper areas of the channel.

In most other cases with DC and pulsed DC electrofishing, slow boat speeds are desirable to allow sufficient time for the fish to respond. It is generally most effective, when sampling deep pool or run areas, to operate the boat at the same speed as the current. There is little advantage to moving slower than the current, since fish then tend to be carried downstream out of reach of the netters.

Moving faster than the current causes fish to come up under or behind the boat.

Intermittent use of the electrical current can increase sample sizes in certain areas. Drifting to the middle of a pool, the lower end of an island or mid stream gravel bar, or the mouth of a tributary stream before turning on the current has, at times, proven effective.

During clear water conditions and in sections of river containing pools too deep to electrofish, sample sizes may be significantly increased by electrofishing shallow water areas at night. Frequently, larger fish are also captured by night shocking. During turbid water conditions, however, the difference in sample size between day and night shocking is much less pronounced.

Sampling Effectiveness

The wide variation in flow conditions signficantly influences sampling effectiveness on an annual basis in the lower Yellowstone. While it is difficult to quantify effectiveness of electrofishing on a large river, certain qualitative assessments can be made.

An important factor in electrofishing is water velocity. Generally, velocities between 2.0 and 3.5 feet per second present few problems. Between 3.5 and 5.0 feet per second, problems with netting fish and fish response are noticed. At velocities greater than 5.0 feet per second and with the associated higher flow levels (Figure 1), sampling problems increase significantly.

Increasing turbidity generally tends to limit sampling to shallower portions of the channel. Fish are probably responding from the deeper waters, but they are not visible to the netter. In shallow waters, fish tend to break the surface more frequently.

Conductivity commonly ranges between 250 and 1,000 micromhos during the sampling season on the lower Yellowstone. Conductivity at either end of the range does not appear to significantly affect electrofishing effectiveness or fish response, even though a lower electrical output occurs at the lower conductivity range.

The electrical system with variable output control and exposure control on the dropper electrodes is flexible enough to handle the range of conductivity experienced on the Yellowstone. Brief sampling efforts in some tributaries, however, encountered conductivities that were definitely limiting sampling effectiveness. Electrofishing is possible with a conductivity between 1300 and 1600 micromhos, but care must be taken so that the electrical system is not overloaded. At conductivities over 2000 micromhos, drastic alterations in electrode surface areas are necessary and operation is limited to the AC mode.

Under ideal sampling conditions, fish can be captured with pulsed DC current from depths of 8 to 12 feet. As an example, shovelnose sturgeon were readily captured in mid-channel areas from those depths during October, 1977. The shovelnose is principally a bottom dwelling species and most of the sturgeon probably responded from or very near the bottom. Individual fish capture locations were marked and later measured with a depth recorder. Water clarity at the time allowed fish to be visible at depths of about 5 feet. Conductivity was approximately 800 micromhos and water temperatures varied between 45 F and 50 F. Average current velocities varied between 1.5 and 2.5 feet per second.

SAFETY GUIDELINES

The electrofishing boat for the lower Yellowstone was constructed with sampling effectiveness and crew safety as primary objectives. Many of the design and construction safety features incorporated into the electrofishing boat were the result of developmental efforts by Wisconsin (Novotony and Priegel 1974), consultation with a major electrofishing component manufacturer (Coffelt Electronics Inc.) and past experience. The discussion of safety guidelines is divided into electrical design and construction considerations, boat and mechanical components, general operational safety considerations and common river hazards.

Electrical Design and Construction

Two major safety considerations in designing an electrofishing boat are 1) design and construction of the electrical system to avoid the possibility of electrical shock within the boat through insulation or component failure and 2) to provide a safety circuit that automatically shuts off the power circuits (and hence electrodes) if a crew member steps out of place or accidentally falls into the water.

A major electrical safety consideration involved in the construction of an electrofishing boat is the grounding of all components of the power system and all metal parts involved with the boat proper. An aluminum boat hull offers the advantage of simple, reliable grounding of all electrical equipment by the physical attachment of the equipment to the boat. Where there is questionable grounding contact, grounding straps should be used.

The case and frame of the generator should be grounded to the hull. A battery grounding strap provides a reliable and durable connection. When the case and frame of the generator are grounded, the internal ground found in most generators must be disconnected. In addition, the generator should have a quick, positive shut-off device that has an ON and OFF position, rather than a "kill" button which must be held down until the generator stops.

All permanent wiring within the boat associated with the power, safety and lighting circuits should be enclosed in waterproof conduit and junction boxes. To facilitate grounding, metal conduit, junction boxes and conduit clamps should be used. To insure a reasonably waterproof conduit system, the following materials and procedure was used: Outdoor weatherproof junction boxes are fastened to conduit using screw-type conduit connectors which can be readily waterproofed with a suitable sealing compound. Amphenol type ms screw lock electrical plugs and chassis mount receptacles are used for all connections associated with the power outlets, such as positive and negative electrode connections, rectifying unit connections and power source (generator) connections. Amphenol screw lock connectors offer a secure connection which cannot shake or vibrate loose as well as a connection which is easily waterproofed (Figure 7).

The Amphenol chassis mount outlet is mounted in the side or back of the junction box by drilling a 1-1/8 inch hole and securing it with 4 bolts, gasket and sealant. Power circuit wires are then attached to the Amphenol chassis mount outlet by soldering and the entire junction box is filled with a non-conductive silicon rubber. The silicon rubber further weatherproofs the system and eliminates vibration of the wires. A rigid blank plate is used to cover the open side of the box. Screw caps are available for the exposed portion of the chassis mount outlet when the power circuit is not in use.

Amphenol type screw lock electrical plugs and chassis mount outlets are used for all connections in the power circuit except on the generator. The constant vibration and heat associated with the operation of a large generator can cause insulation failure of the mating plug and produce undesirable results. The standard plugs supplied with the generator are retained.

All wiring used in the boat is overrated for the particular current capacities anticipated to insure a margin of safety. The following types of wire are used in the permanent wiring circuits placed in conduit. Wiring used for the power circuit is 10 or 12 gauge AWG, Type THHN or THWN stranded. This wire is gas and oil resistant and 600-volt insulated. Similar, but smaller, wiring (14 gauge) is used for the lighting circuit. The safety circuit is low voltage (12 volt) so 16 or 18 gauge stranded automotive wire is used.

A 600-volt insulated, 12-2 or 12-4 power cord (gas and oil resistant) is used for all exposed wiring associated with the power circuit. This wiring is used for plugging the generator, rectifying unit and electrode arrays into the power circuit.

There are three electrical systems in many electrofishing boats which perform separate functions: the lighting system, the power system, and the safety system. The three electrical systems should be run in separate conduit systems. This prevents the possibility of an insulation or electrical failure of one system affecting another and is of particular concern in the safety circuit.

The positive and negative electrode arrays are insulated from the boat. The positive electrode arrays are insulated by using non-conducting fiberglass booms. Dip nets use non-conducting material (wood or fiberglass) for handles. The negative electrodes are isolated from the boat by using a link of non-conducting rubber in the chain suspending the negative electrode and a fiberglass boom for the entire array.

Both the boat operator and dip netter(s) should be provided with safety switches that shut off the power circuit when either person steps out of position. In addition, a low voltage relay built into the safety circuit provides the operator with the only opportunity to energize the power circuit, even though all safety switches are closed.

Three basic types of safety switches were tested: the foot tredle, the safety mat and an outboard ignition safety stop switch. While all performed satisfactorily, the outboard ignition safety stop switch (Figures 3 and 7), (Mercury) mounted on the bow railing and attached to the netter(s) waders by a nylon cord and clip, best met our needs. It provided a reliable, lightweight system with a minimum of restriction in movement.

Boat and Mechanical Components

The boat chosen for electrofishing should have a load capacity adequate to carry all the necessary persons and gear without jeopardizing either boat handling or freeboard. Good maneuverability and handling characteristics increase in importance on rivers with high current velocities. Motors should be of adequate horsepower to provide the necessary maneuverability. Flotation should be adequate to float the boat plus equipment.

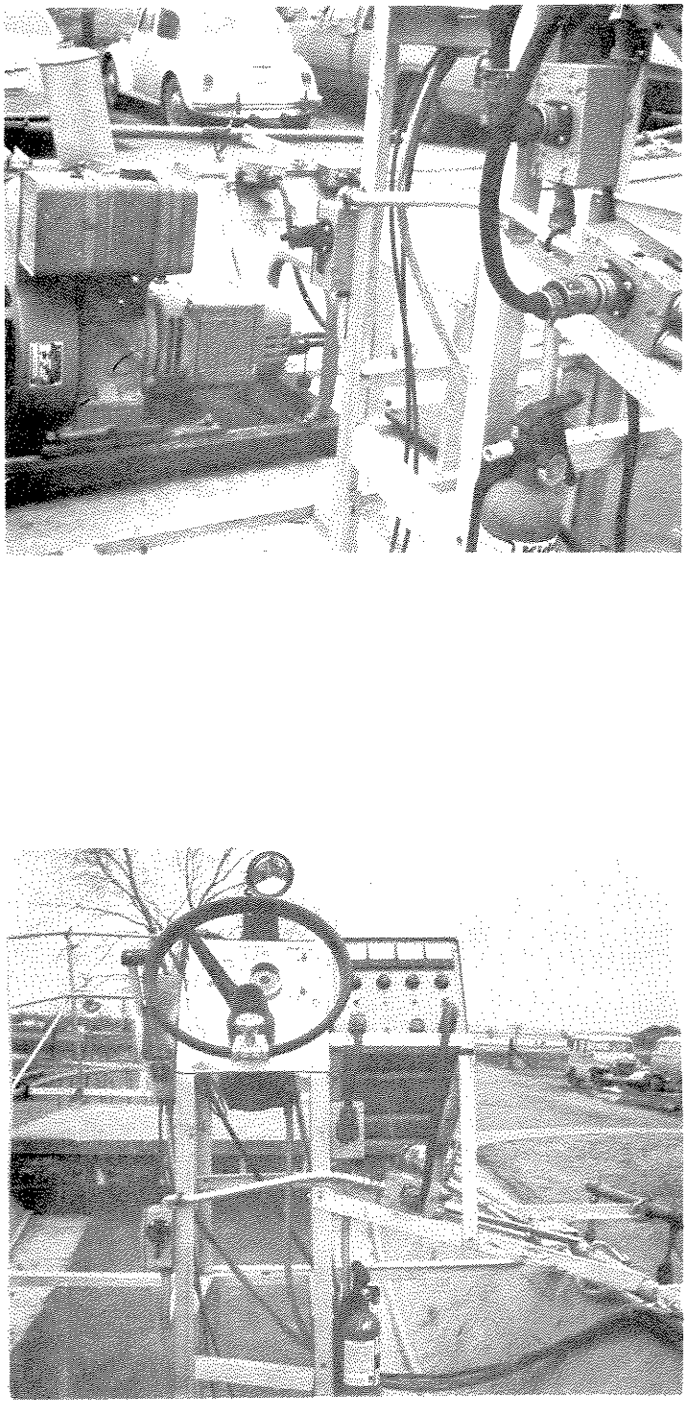

Figure 7. Amphenol screw-lock connectors, waterproof conduit system, and safety switch for boat operator.

An aluminum boat is desirable, since it greatly facilitates grounding of all electrical components within the boat. A bow railing partially encloses the work deck and provides a mounting location for lights.

An aluminum center console enables the boat operator to have a good view of the river immediately in front of the boat while providing a mounting location for the rectifying unit. The rectifying unit and generator should be close to and easily controlled by the operator. A fire extinguisher should be handily mounted in the boat.

Operational Safety Considerations

The single most important factor in operational safety and effectiveness in river electrofishing is the ability and experience of the crew. Regardless of the safety guidelines established, the capability of the crew in adhering to the guidelines and handling unforeseen circumstances is of overriding importance. With this in mind, the following safety precautions should be followed:

1. Always wear hip boots or waders.
2. Always wear rubber gloves.
3. Always wear coast guard approved life jackets.
4. Do not bypass safety circuit.
5. One person, usually the operator, should be in charge of the operation. He should be skilled in river navigation and have a working knowledge of the electrical and mechanical components of the electrofishing boat.
6. All crew members should be familiar with the operation of the boat and its electrical system. Electrical safety considerations (page 46 - Novotony and Priegel 1974) are

especially pertinent.

7. All crew members should have at least rudimentary knowledge of first aid procedures including cardio-pulmonary resuscitation.
8. All equipment, both electrical and mechanical, should be regularly inspected and maintained in good working condition.
9. The fire extinguisher should be readily available and located away from fuel tanks and generator.
10. Do not electrofish in the rain or when the major electrical components inside the boat are wet.
11. Night shocking on large, fast flowing rivers should only be done with the utmost caution.

Common River Hazards

Sampling large rivers by electrofishing presents certain hazards not normally encountered on lakes or reservoirs. On the lower Yellowstone, these are most commonly some form of navigational obstruction, and their danger increases with increases in water velocity.

The most common and perhaps dangerous form of obstruction on the lower river is the snag which generally consists of one or more dead trees having fallen into the water on an eroding bend or grounded in midstream. Snags are hazardous since, even at low or moderate current velocities, they can swamp or upset a boat and the current may carry the occupants beneath them. Snags are more common in wooded bottomlands or in braided sections of a river where eroding banks are common.

Bank stabilization projects can also present a hazard. These man-made projects are generally on badly eroding banks with relatively high current velocities. The most common material used is large rock riprap; however, car bodies and steel "jacks" have also been extensively used. Jacks are X-shaped devices made of 10-foot long pieces of channel iron cabled to the banks. They were originally designed to entrap debris. Both car bodies and jacks will often be found in mid-stream and, in addition to being a navigation hazard, can cause electrical problems if they come in contact with the electrodes.

Old bridge crossings are areas that should be viewed with caution. Several bridge pillars are likely to be in mid-stream and current velocities are generally higher around these structures. The channel is usually constricted and abutments are commonly stabilized with large rock riprap.

The importance of a capable, experienced operator and adequately maintained equipment cannot be overemphasized. Most of the hazardous situations that occur on rivers are generally the result of poor judgment on the part of the operator or equipment failure at the wrong time, or both.

FUTURE DEVELOPMENT

The development of electrofishing boats certainly is not a static field and the design and construction features are nearly as varied as there are agencies and departments involved in capturing fish with electricity. For the lower Yellowstone, the boat design described in this paper is not considered an end point, but rather a stepping stone toward a final goal. While we are reasonably well satisfied with the electrode design and power and conversion units, several aspects of the boat are less than satisfactory. The outboard jet unit has high initial and maintenance costs but only a relatively short life. Fuel consumption is high while dependability decreases after the first season. The boat itself is quite heavy.

New and lightweight electrical components offer useful opportunities for improved design and construction features. The ultimate goal for a boat on the lower Yellowstone is to maintain the effectiveness and mobility of the present boat, but in a lighter, more dependable and more fuel efficient design. In addition, the boat should have the capability to be controlled and maneuvered manually in the event of engine failure.

Hopefully, this electrofishing workshop will open lines of communication and provide a forum for the exchange of ideas to aid in the continued development of electrofishing boats and their adaptation to various water situations.

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