Ignitron-Pulsed Electric Fence

GUIDES MIGRATING SALMON

By CHARLES D. VOLZ, U.S. Fish and Wildlife, Sand Point Naval Air Station, Seattle 15, Washington.

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Direct-current pulses fed to immersed electrodes keep fish out of hydroelectric turbines, help them reach their breeding grounds without mishap. Sequential ignitron triggering gives pulse-sweeping effect.

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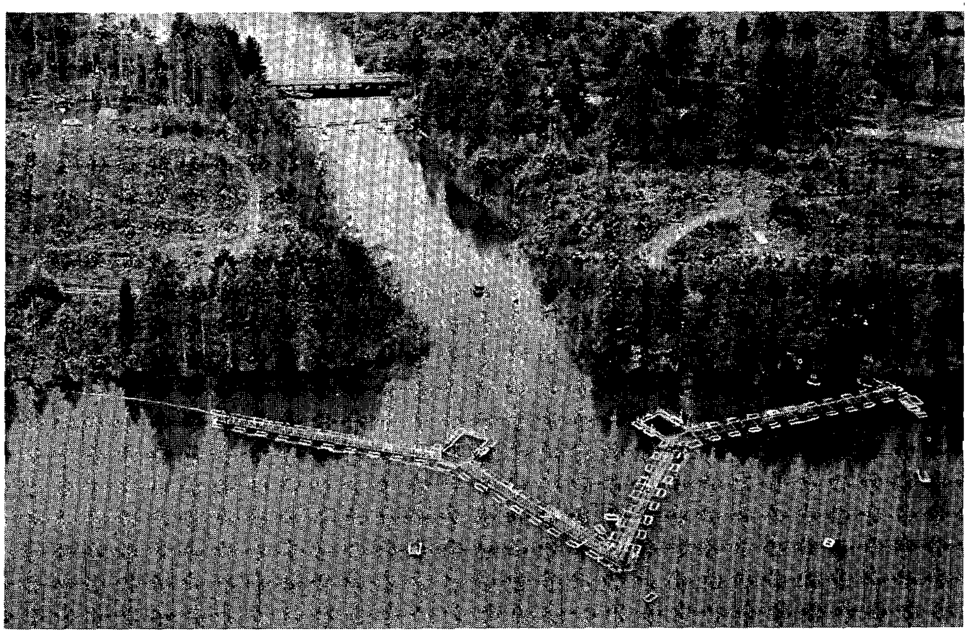


FIG. 1—Electric fence, powered by 360 Kw d-c generator, is on Lake Tapps, near Auburn, Washington

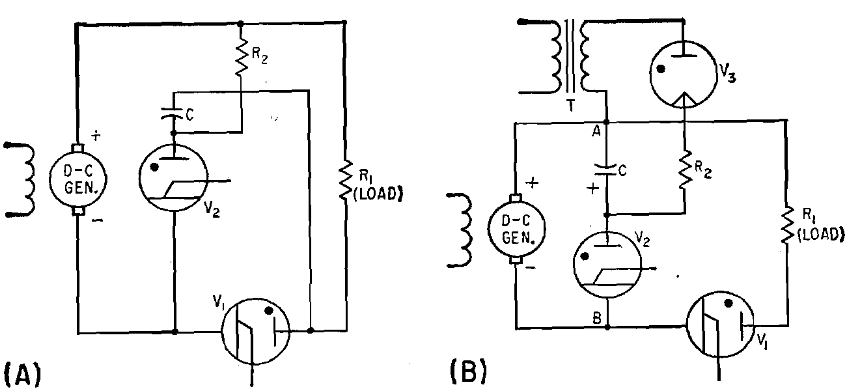


FIG. 2—Ignitron V_1 (A) passes pulses to fish fence, second ignitron V_2 turns V_1 off. In (B), precharged capacitor C is connected by V_2 across the terminals to reverse ignitron V_1 polarity and terminate the pulse

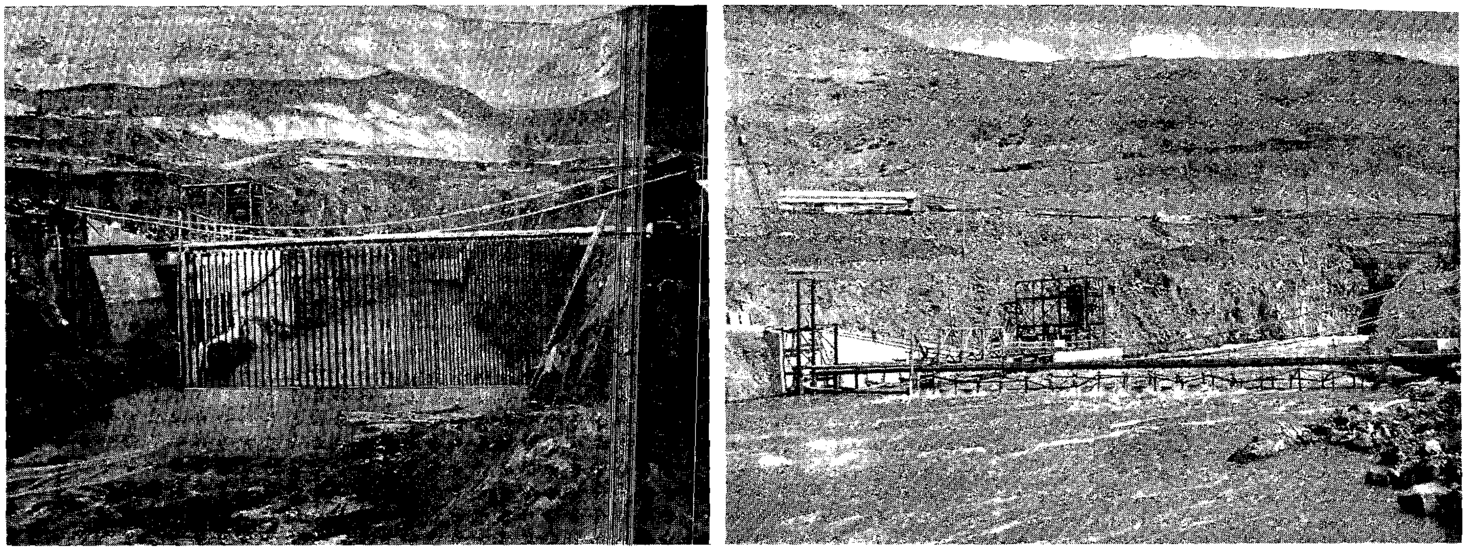
THE U. S. DEPARTMENT OF FISHERIES has taken a cue from the cattlemen and is now using an underwater electric fence to shepherd migrating and spawning salmon into the right traffic lanes for their journey to and from the ocean.

Construction projects for dams and hydroelectric power station frequently bypass the water flow by using diversionary tunnels; since the water velocity in these tunnels is high, salmon returning to their breeding grounds cannot swim against the current. In such cases, the salmon are diverted to fishtraps, where they are caught and put into fish tanks for transportation to a calmer region upstream.

Using d-c pulses,[1,2,3,4] electric fish screens are successful in guiding fish into fish traps, and at the Brownlee dam site on the Snake River between Oregon and Idaho an electric fish fence about 105 feet long and 40 feet high diverted 16,000 salmon and steelhead trout during a period of several months.

An improved model of the equipment has been built for studies on salmon fingerlings at Lake Tapps, an artificial impoundment near Sumner, Washington. An outlet from the lake leads to the intake for a hydro-electric generating plant. This arrangement, Fig. 1 uses a W shaped array using two traps and has given encouraging results over a two-year operating period.

The pulse generator uses a pair of high-current ignitron tubes, one



Electric fence (left) under construction at Brownlee dam site. Fish traps are seen through opening on left. Fence in use (right) prevents fish fighting upstream against current in diversionary tunnel, directional electric field urges them into fish traps where they are caught and transported past the diversion

to turn-on the pulse, the second one to turn the pulse off. A basic circuit is Fig. 2A while Fig. 2B shows an elementary version of the actual circuit. In Fig. 2A tube V_1 is turned on by an input signal to its grid, so applying the pulse to the underwater electrodes. To turn the pulse off, tube V_2 is triggered and while the capacitor C is charging, tube V_2 effectively parallels V_1. By using a turnoff tube with a lower arc-drop than the turnon tube the plate potential of V_1 is depressed below its conduction level by the low arc-drop of V_2, hence is extinguished.

In the actual circuit, Fig. 2B, commutating capacitor C is connected to the generator bus rather than to the anode of the load tube V_1. This gives a better pulse shape with sharper cutoff, and moreover allows a number of load sections each powered by its own ignitron, to be controlled by one commutating capacitor and turnoff tube. An auxiliary power source is needed in Fig. 2B to charge the commutating capacitor.

Operation of the pulse generator of Fig. 2B is as follows. Capacitor C is charged by its auxiliary power source to approximately the same voltage as the generator output. Control tube V_1 fires (time t_1) and the load current builds up with a time constant determined by armature inductance and circuit resistances, Fig. 3A. The generator voltage drops momentarily then follows Fig. 3B for the duration of its cycle.

To end the pulse, turnoff tube V_2 is fired and connects the commutating capacitor directly across the generator output. Since the commutating capacitor voltage cannot change instantaneously (there is a finite time-constant involved) the voltage at the positive bus is forced negative and in doing so, cuts off the control tube, V_1.

Load current when V_1 goes off, is diverted through V_2, which discharges through the armature. As it does so the voltage across the busses rises sinusoidally (time t_3) to a high positive value owing to armature inductance. If the bus voltage remains initially negative sufficiently long for control tube V_1 to become deionized, this tube will remain off when the bus voltage returns to its normal level and will be readied for the next triggering input.

The voltage across the generator busses may be approximated for the interval t_2 to t_3 by

$$V(t) = E_g + \sqrt{\frac{L}{C}} \times i(0) \times \sin \frac{t}{\sqrt{LC}} - (E_g - E_c) \times \cos \frac{t}{\sqrt{LC}}$$

where E_g is the generator voltage at t_2, $t = 0$, E_c is the capacitor voltage less the tube arc drop, i (0) is the load current at t_2 ($t = 0$), L is the armature inductance and C is the capacitance of the commutating capacitor.

Armature resistance has been assumed much smaller than armature inductance, and inductance is assumed constant. Then

$$\text{at } t_2, \quad t = 0, \quad V(t)1 = E_c$$

$$\text{at } t_3, \quad t = \pi\sqrt{LC}, \quad (t) = 2E_g - E_c$$

At midpoint of t_2 and t_3,

$$t = \frac{\pi}{2}\sqrt{LC}, \quad V(t) = E_g + \sqrt{\frac{L}{C}} \times i(0)$$

The interval available for deionization is represented by the "delta" symbol in Fig 3. This interval is determined by the value of t for $V(t) = 0$. The sine term is zero for $t = 0$ and $t = \pi\sqrt{LC}$ and maximum at

$$t = \frac{\pi}{2}\sqrt{LC}.$$

Figure 4 shows part of the control system. A special feature of the control arrangement is the provision for connecting up the 5 pairs of load switching ignitrons to the electrodes so that pulses are applied sequentially to bunches of electrodes, rather than to all of them simultaneously. The resulting effect is to give a moving pattern of electric charges in the same way that lights around a movie house provide a directional pattern of movements.

The off or commutating circuit is shown in detail in Fig. 5A. Positions of the capacitor and ignitron are the reverse of those shown in Fig. 2B to put the charging thyratron cathodes at generator negative. The diode charging rectifier of Fig. 2B is replaced by full-wave connected thyratrons, which are fired by a delayed gate so that

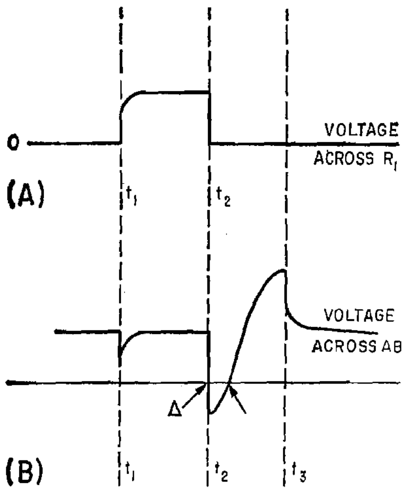


FIG. 3—Upper waveform shows pulse applied to electric fence; lower waveform shows generator terminal voltage

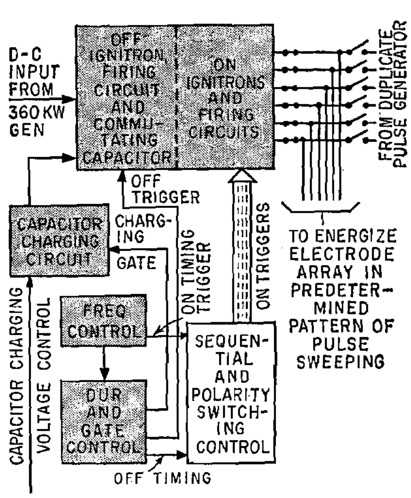


FIG. 4—Control equipment uses five pairs of load-control ignitrons to pulse sections of the electrode array in a sequence to steer the fish

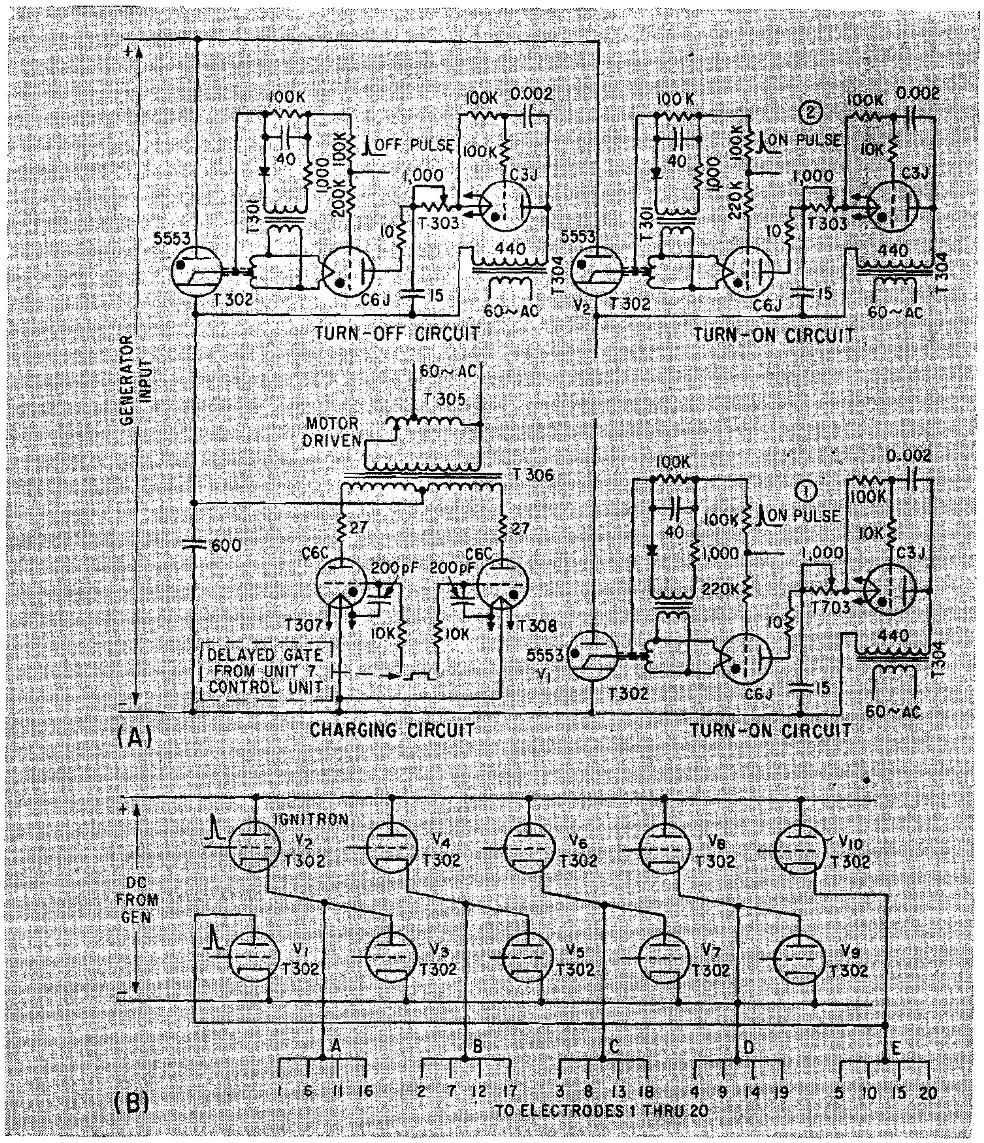


FIG. 5—Single turnoff ignitron terminates the pulse period of whichever load ignitrons are conducting (A). One arrangement of connecting the five pairs of load thyratrons to 20 immersed electrodes to give pulse sweeping effect as the ignitrons are sequentially triggered (B)

they do not fire while the commutating ignitron is conducting.

The five pairs of on or load ignitrons can be interconnected by jumpers in any desired fashion and fired in any sequence or combination. Three of the eleven ignitor firing circuits are shown in detail; all eleven are identical. Capacitor firing is used because of the d-c source and the range of frequency used. The C3J thyratron has a phase-advance network in the grid circuit which causes it to fire very early in the first positive half-cycle of plate voltage, eliminating the transients caused by irregular firing of diode rectifiers.

The polarity and sequential switching circuits use plug-in units, including cathode followers, inverters, gates, multivibrators and pulse amplifiers. These may be interconnected in various ways to produce different firing sequences; for example, the simplest produces a simple sequence firing in which one pair of ignitrons is fired at a time as shown in Fig. 5B.

Four years of operation of this type of equipment has produced highly encouraging results, as an overall diverting effectiveness of at least 90 percent is indicated. It is hoped that within a few years a simple, practical system of fish control and diversion, utilizing electrical techniques, may be developed, which will make a significant contribution to the management of the salmon fishery.

The author wishes to acknowledge the valuable cooperation given by the Idaho Power Company at Brownlee Dam and by the Puget Sound Power and Light Company at Lake Tapps. Charles C. Gillespie is responsible for the mechanical and much of the electrical design of the Lake Tapps equipment, including the automatic overload protection and standby changeover.

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