REGULATOR DESIGN

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Current thinking about the design of the shunt regulator is about as follows:

1. The regulator is oil-filled, enclosed in a pressure vessel, since the regulator transistors are not pressure-tolerant. Since the shunt regulator is across the power line it requires only one pressurized power connector at 350v. It also requires a ground connection to be made to a seawater return electrode, and a pressurized signal connector to read the current through the regulator.

2. Inside the regulator there is a large number – perhaps 20 – of parallel elements, each consisting of a regulator (Zener-type) diode (or transistor)[1] of threshold near 350v, and a series resistance of about 600 ohms, with a 200w continuous rating. This limits the current to .57a, or about 200 watts, with the series diode full on. The cost per element is about $20.

The diodes are selected to have as nearly identical voltage-current characteristics as feasible – say, within a 5-volt range – so that they will all turn on sequentially over this range of voltage. Once a diode is turned on, increases in supply voltage will increase the current very slowly, since the 600-ohm resistor limits the current. Thus the regulator power diversion will increase from zero to 4000 watts in 200-watt steps as the voltage goes from 350 to 355.

It might even be desirable to broaden the triggering range of the diodes to, say, 20 volts, and then distribute the turn-on voltages of the diodes uniformly – one per volt – over this range. This enables the operator to select a particular multiple of 200 watts for the bypass power. The SBC regulated supplies that constitute the output load of the regulator will have no difficulty in coping with this range of input voltage.

The ground return should have a small resistance – one or two ohms – across which the voltage drop, which measures the regulator current, can be returned to shore. Fig. 1 shows the proposed circuit diagram, Fig. 2 the voltage-current characteristic of a single element, and Fig. 3 the overall regulation characteristic of the system (with a 20-volt range.)

3. With this arrangement the system is capable of handling a shunt current of 11.4a, or 4000 watts. In practice it should never be called on to take such a load except in dire emergencies. Under normal operating conditions the regulator current should be perhaps 20% of the array current:

1 The active element will probably be a MOSFET transistor rather than a diode; we omit the circuit complications this entails.

ca 1a for three strings, 3a for nine. When turning strings on and off, the regulator current can be increased to compensate for the change.

4. The number of regulator elements needed to regulate 3a is six. By providing 20 we allow, very inexpensively, for 14 possible element failures. The operating current of .57a is also well below the regulator diode rating as well. We can thus operate under fail-safe, long-life conditions, and be protected as well against many element failures.

5. Open-circuit diode failures pose no problems; there are plenty left until we get down to five or six. Short-circuit diode failures produce a fixed load on the power supply of 600 ohms, (which can be detected by watching the regulator current as the line voltage is raised with all strings turned off.) A good many of these can be tolerated with no ill effect other than raising the power bill. Resistor failures are almost exclusively open circuit failures. There seems to be little point in providing either fuses or switches in the individual regulator elements.

6. The power dissipated in the regulator box at full-load with 9 strings will be just over a kilowatt. The liquid-filled container is ideally suited to distributing the heat more or less uniformly within the vessel, and to transferring the heat to the ocean. The temperature rise of the regulator is probably around 20° C. The pressure vessel is located outside the junction box where RUM can get at it; consequently the heat is dissipated in the ocean, not in the junction box.

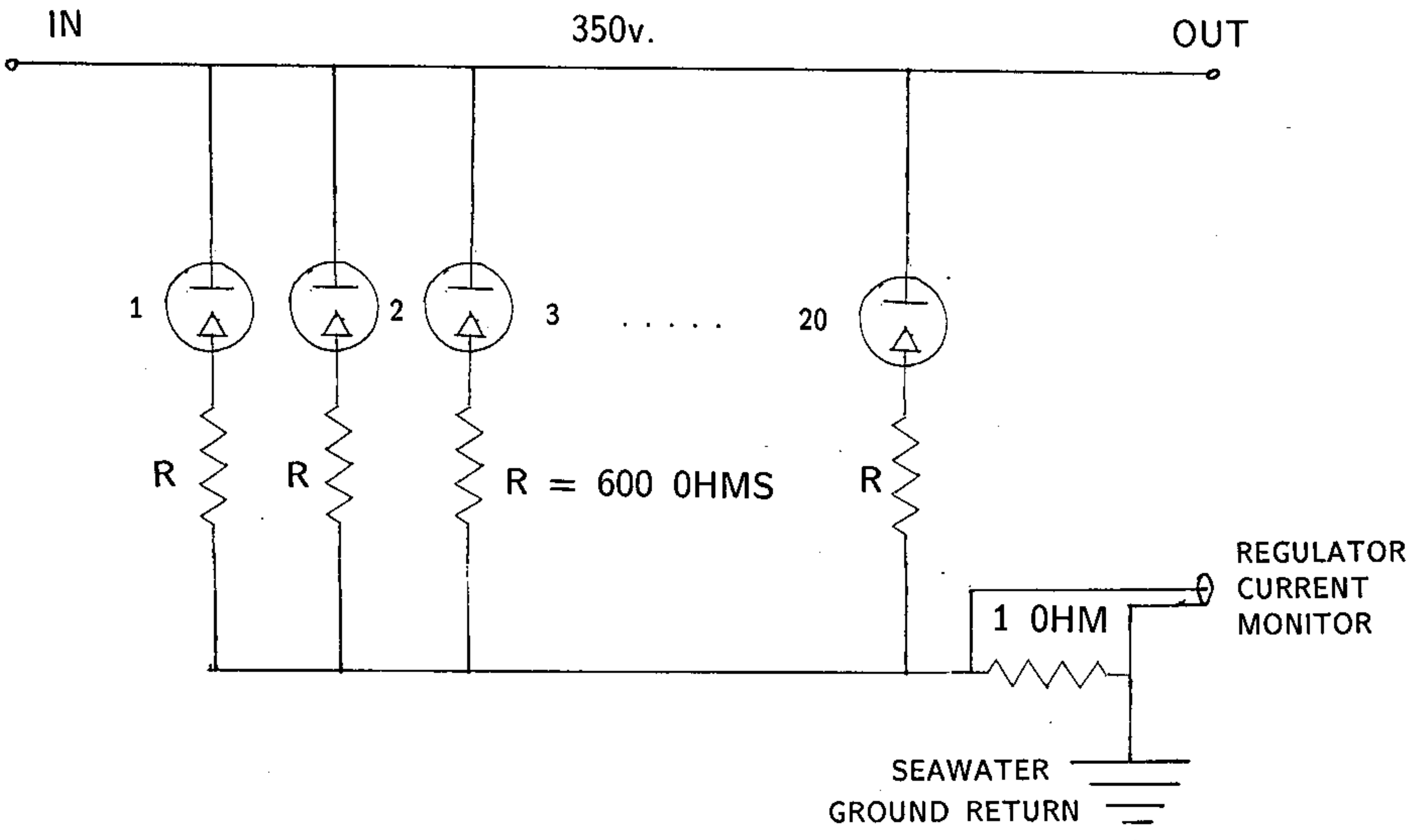

Fig. 1. Simplified circuit diagram of the shunt regulator.

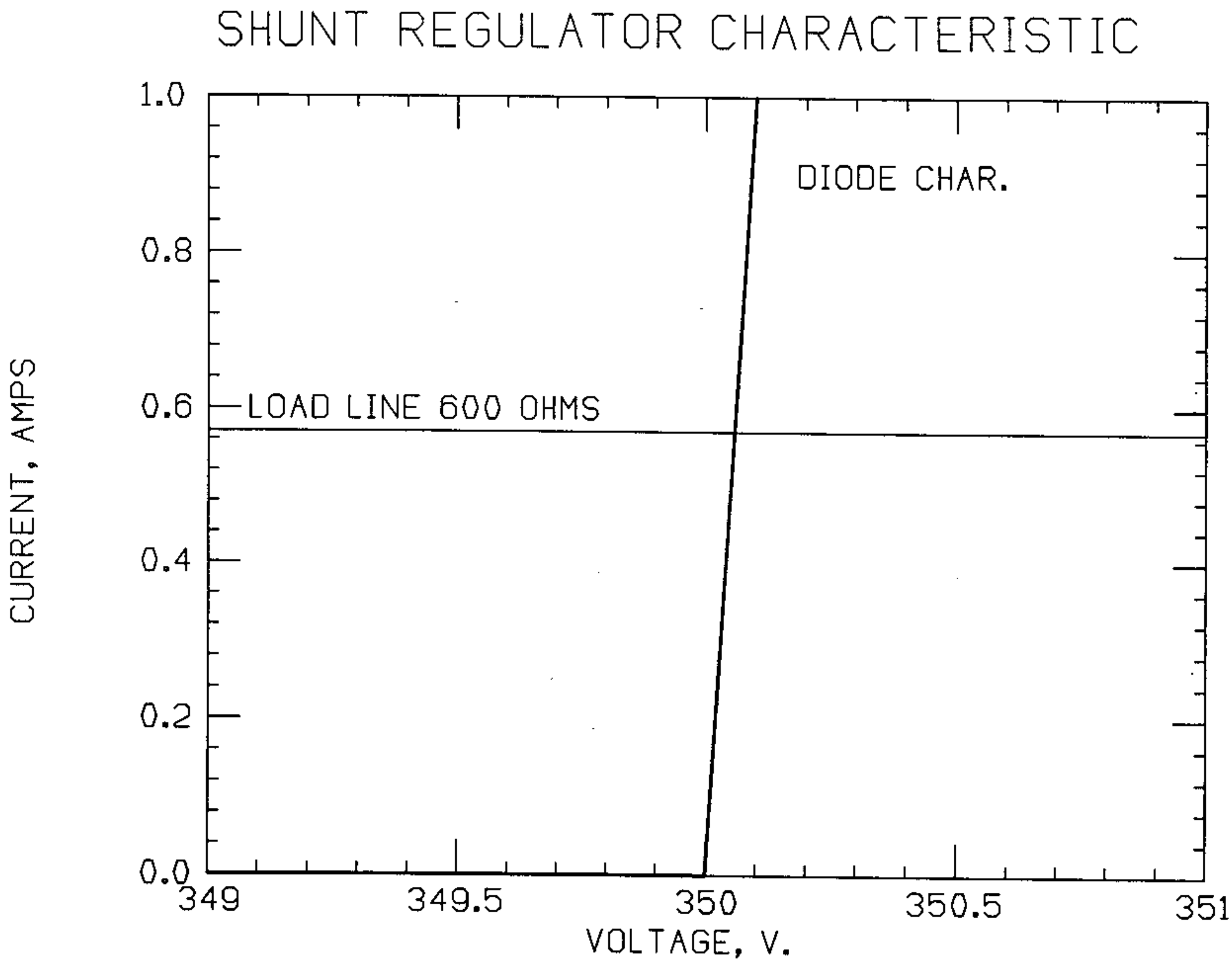

Fig. 2. Operating characteristic of a single shunt regulator element.

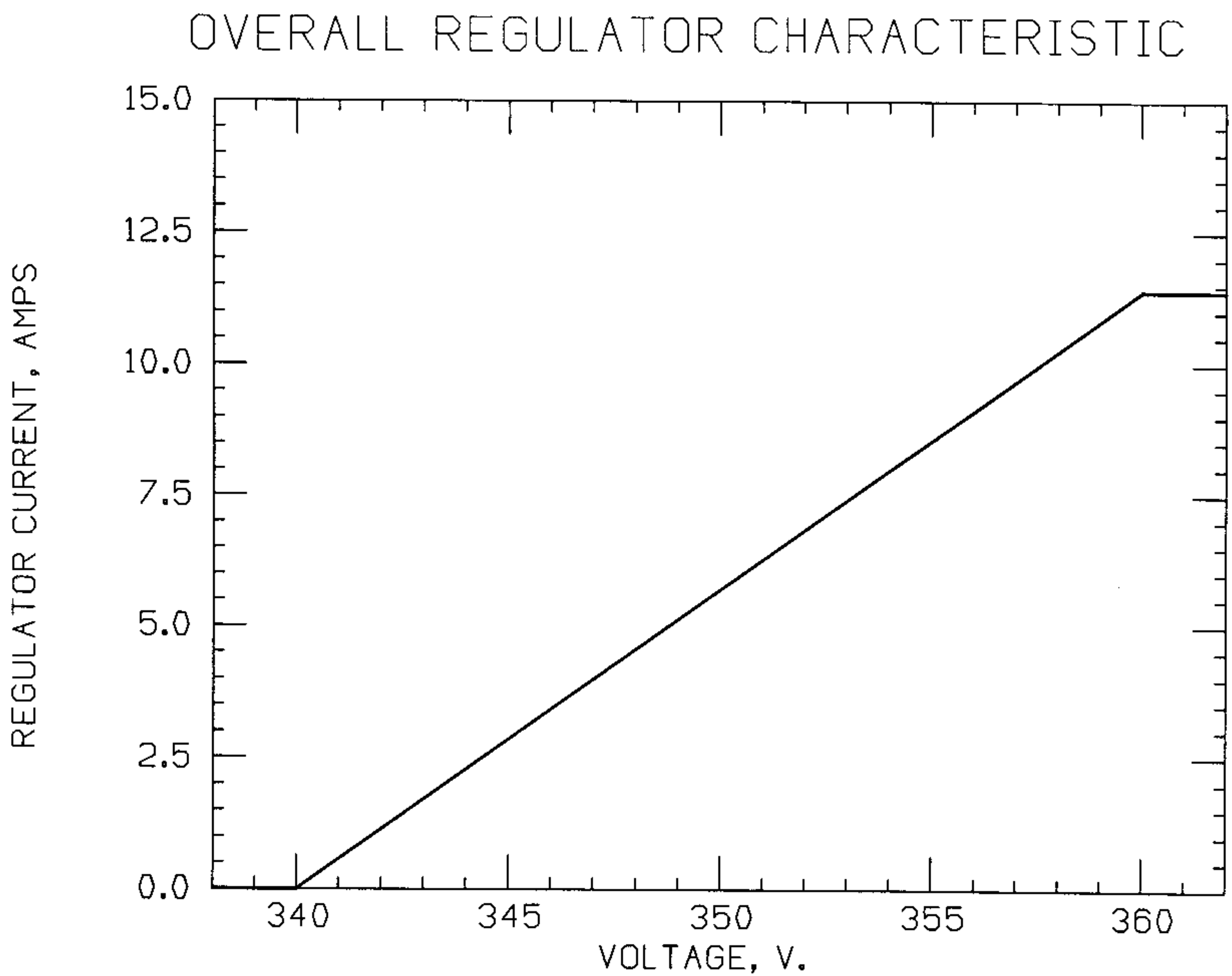

Fig. 3. Overall regulating characteristic of the shunt regulator. The 200w steps have been smoothed out.