INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

LIQUID RHEOSTAT

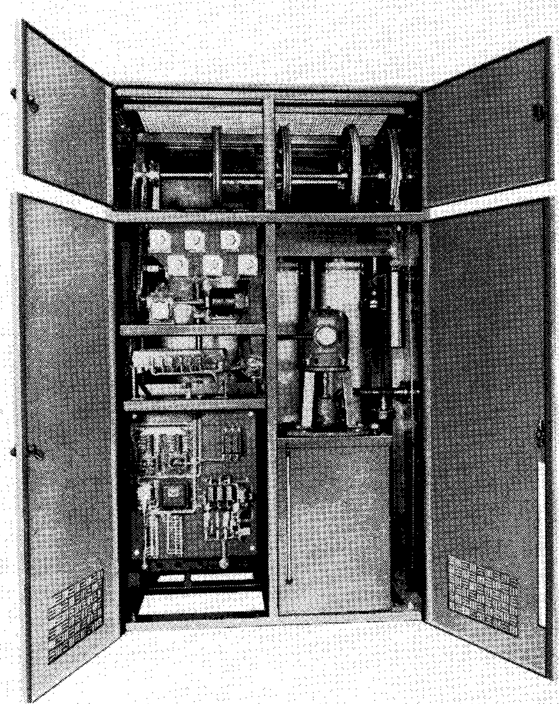

FIG. 1. Typical Cubicle Type Liquid Rheostat with Self-Contained Electrolyte Storage Tank

THE LIQUID RHEOSTAT provides a means of varying circuit resistance smoothly between predetermined limits. It is especially adapted to applications involving high current and relatively low resistances, where large quantities of energy are to be absorbed. Resistance is provided by using two electrodes immersed in an electrolyte solution of moderate conductivity; the value of resistance is varied by changing the distance between (or separation) of the two electrodes.

Liquid rheostats are supplied in various sizes depending upon their rating. All sizes have similar electrical characteristics, however, due to mechanical design, there are two general classifications. The smaller sizes (see Fig. 1) have their moving electrodes suspended from very flexible cable which is coiled around sheave wheels in order to raise or lower the moving electrodes. This size also usually has a self-contained sump tank for the electrolyte solution. The larger sizes (Figs. 3 and 4), because of the increased current ratings, have the moving electrodes suspended from a rigid structure by heavy copper tubes. For these sizes the greater sump tank capacity requires that a separate tank, usually built into the floor beneath the rheostat, be used.

Operating the moving electrodes is most commonly accomplished by use of a small direct current motor driving through a speed reduction gear. Another type of drive, which may be employed, involves use of a hydraulic or pneumatic operator working through a rack and pinion arrangement to rotate the shaft which moves the electrodes. Either arrangement provides good

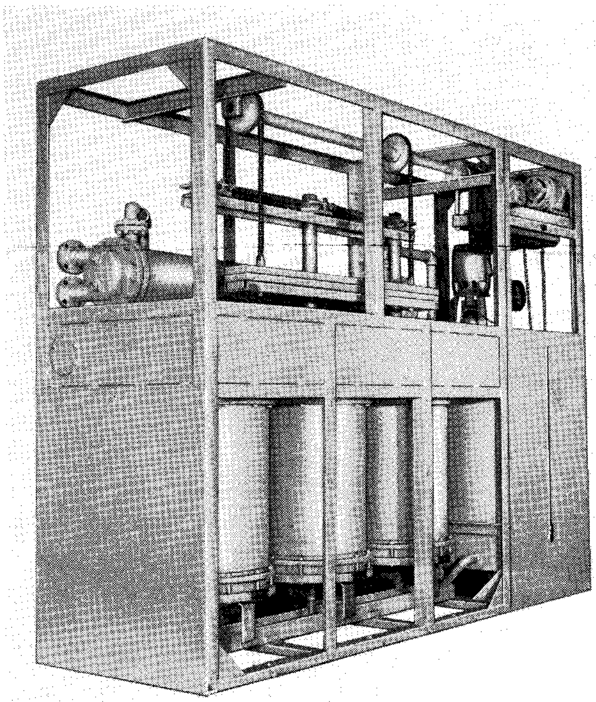

FIG. 2. Starting Duty Type Liquid Rheostat with Self-Contained Electrolyte Tank and Cooler

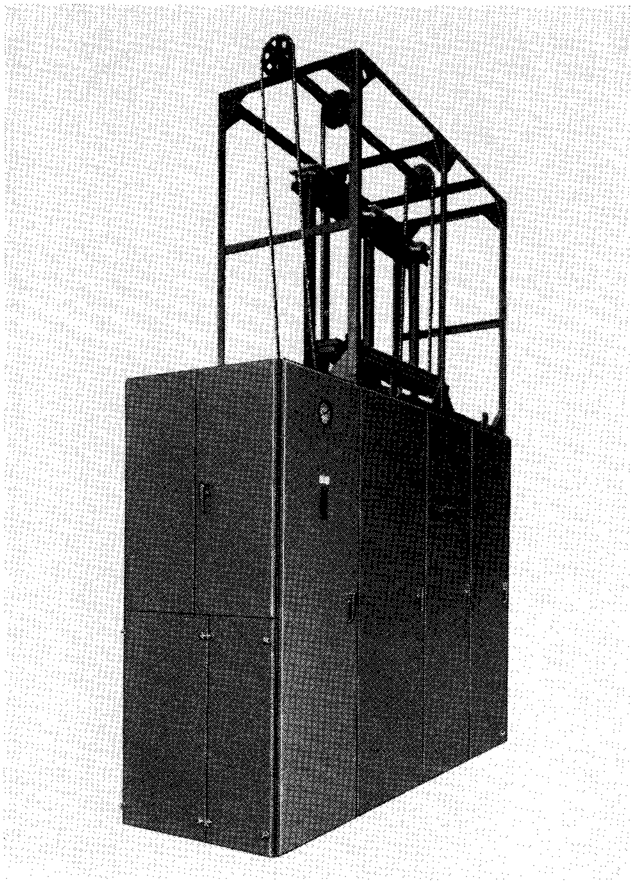

FIG. 3. Construction of Intermediate Rating Rheostat Requiring Separate Electrolyte Storage Tank

operation, the electric drive being particularly adaptable to a wide variety of conditions and remote control regulating type installations.

For both the large and small types of rheostats, the electrolyte to water heat exchangers are supplied for separate mounting to facilitate most advantageous location of this item. For those rheostats having separately mounted sump tanks, it should be borne in mind that the return of electrolyte from the rheostat to the tank is by gravity flow. The sump tank must be located below the level of the rheostat and the return piping made as direct as possible to keep friction-to-flow at a minimum.

DESCRIPTION

The liquid rheostat, as shown in the illustrations, is supplied in a cubicle or enclosed framework of steel construction. This cubicle is normally designed to be located indoors in an area protected from freezing temperatures, although special cubicles for outdoor mounting are available.

Inside the cubicle are located three vertical cylindrical cells filled with electrolyte and suspended from a common header tank from which electrolyte is circulated. The stationary electrodes to which the motor secondary leads are fastened are located at the base of these cells. The moving electrodes are suspended from a common overhead shaft which provides an electrical neutral between the three phases that is grounded to the rheostat frame.

To prevent overheating, the electrolyte is circulated through the cells and cooled in a heat exchanger. It is brought into the cell under pressure at the level of the stationary electrode and flows upward through offset holes in both electrodes, into a common outlet tank above the cells, from which it returns to the sump tank under atmospheric pressure. The heat exchanger is located between the sump tank and the inlet tank on the rheostat so that the electrolyte is at the lowest temperature in the cycle when it enters the cells. Fig. 5 shows schematically the flow cycle of the electrolyte.

Asbestos-cement pipe is used for the three cells. This material has high mechanical strength and is non-porous and non-conducting. It provides an excellent insulated support for the stationary electrode. Since the electrolyte inlet tube is inside the cell, possible sources of leaks are minimized. The

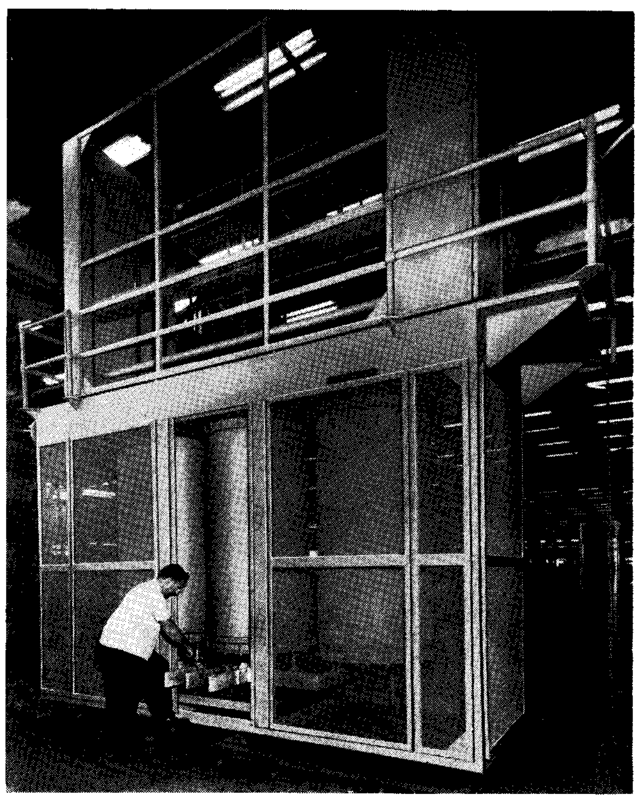

FIG. 4. Outdoor Type Rheostat of Large Capacity

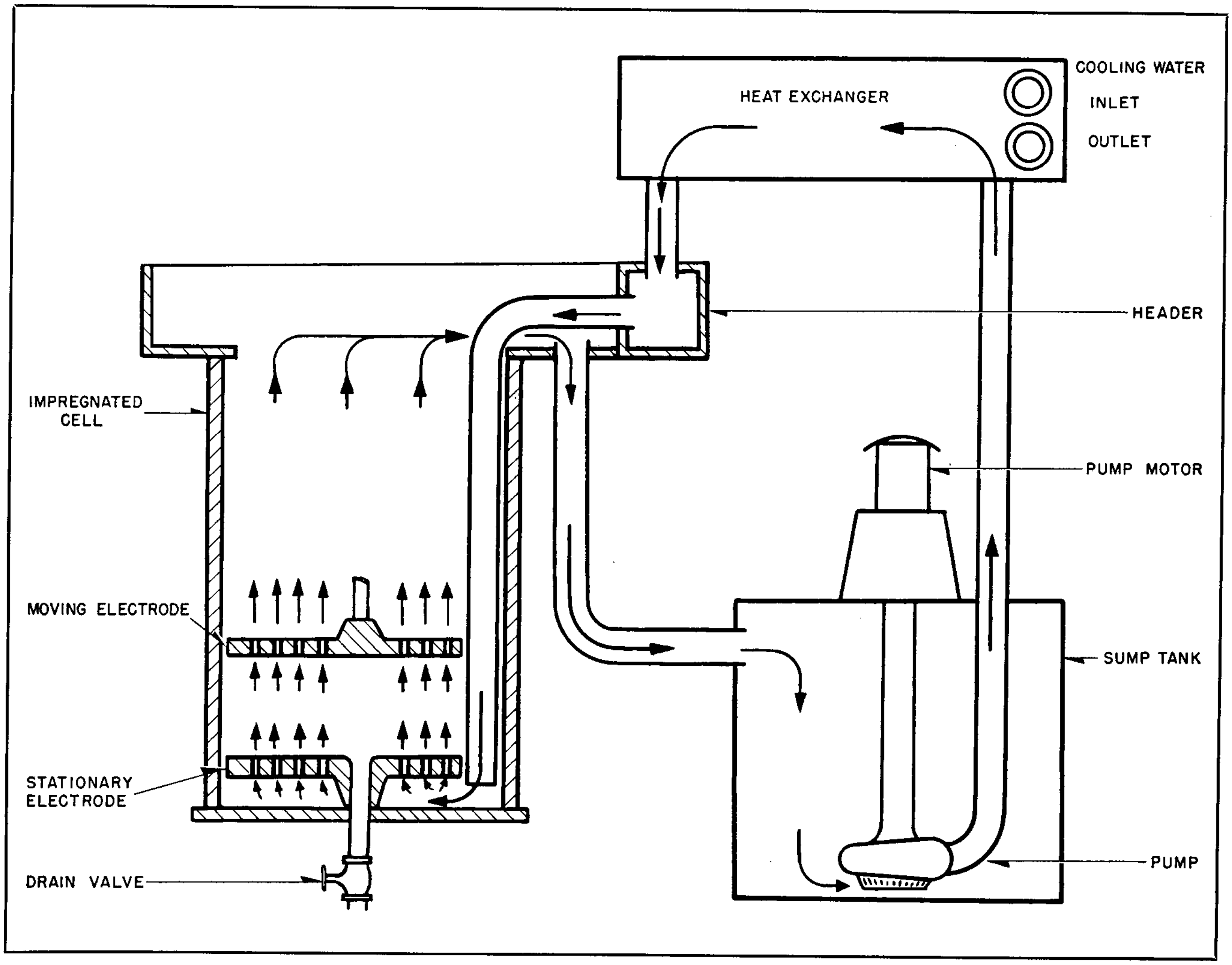

FIG. 5. Schematic View of Electrolyte Circulating System

base of the cell is sealed with a steel plate which is held against a gasket over the cell end under high pressure. The details of this seal will be evident by examination of Fig. 6.

INSTALLATION

Safety to Personnel. There is little danger of personal injury in actual operation of the rheostat. The connections from the motor secondary are well protected by the enclosing covers. ***Never operate the rheostat unless the covers protecting the high voltage terminals are in place.***

There is more danger of injury during installation because of the bulk and weight of the equipment. Handling must be under the direction of a qualified rigger or other person familiar with the dangers present and precautions necessary to safely handle large and heavy apparatus.

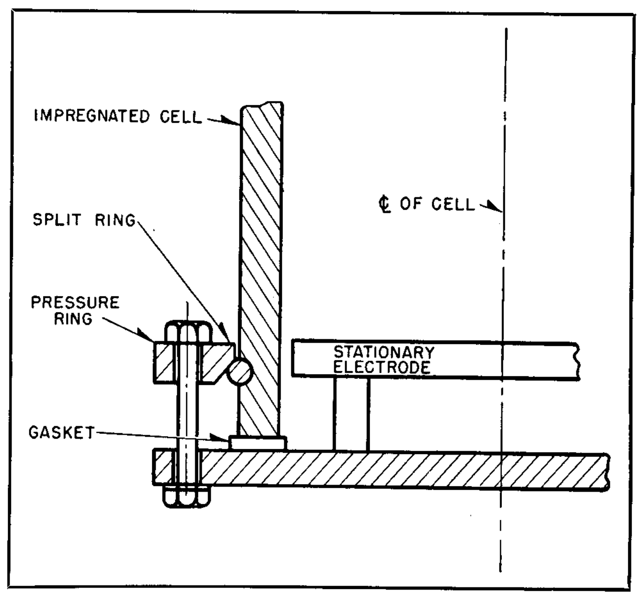

FIG. 6. Method of Clamping Stationary Electrode to Insulated Cell

Handling. The smaller size rheostats may be handled as a unit by use of the lifting holes provided in the frame. Care must be taken when lifting to keep the lift as even as possible to avoid deforming the frame or upsetting the shaft and bearing alignment of the electrode supporting parts. The rheostat should not be lifted while liquid is in the tanks or cells.

Rheostats having electrodes 16 inches or larger in diameter are shipped in sections for assembly at installation. Handling of these larger rheostats requries greater care because of increased size and weight. Lifting of any of the sections from other than the regular lifting holes will likely cause damage to the frame.

If the rheostats or sections are moved on rollers, avoid severe jolting from dropping the ends off the rollers. Keep as many rollers as possible in contact with the base to avoid undue stresses in the base members. Preferably set the rheostat on heavy timbers when moving by this means.

Keep the covers over the electrode cells at all times except when making adjustments or tests requiring their removal. Replace the covers as soon as possible to prevent the entry of dirt or other foreign objects of any kind. Small objects represent a greater hazard than large ones since they are more difficult to locate. If they are overlooked, they may lodge in one of the holes in the electrodes or between the electrode plates and prevent correct spacing when the electrodes are near minimum separation.

Mounting. The smaller rheostats may be set directly on a firm level floor or may be grouted in without any special precautions. Because all moving parts have slow speed there is extremely little vibration caused by the rheostat mechanism.

Much more care is required in permanently placing the larger rheostats. The preferable arrangement for mounting a large rheostat is to position it on a flat level rim formed of structural steel members set into the concrete flush with the floor. Shims should be used if required to assure a level position for the rheostat. The base of the rheostat may then be grouted in, if desired.

Care must be taken that the alignment of the electrode operating shaft is retained. Very low torque is required to drive the counterweighted mechanism and consequently only small torques are available at the lowest speed of electrode movement. Any variation in torque requirement resulting from bad shaft alignment may seriously interfere with proper movement of the electrodes.

Rheostats of all sizes are provided with a temporary shipping brace to steady the lower ends of the electrolyte cells. This brace should be removed as soon as possible after the rheostat has been set in its final position; it must be removed before the main circuits are connected. Electrolyte should not be placed in the rheostat until all pipe and electrical connections have been completed and are ready for final testing.

Heat Exchanger. The heat exchanger may be located several feet away from the rheostat, but obviously the closer the better. The location selected must be such that space is available to remove the tube bundle for cleaning. The clearance required is indicated on the outline drawing of the heat exchanger. In order to make the most efficient use of the sump tank on the smaller rheostats having built-in sumps, the heat exchanger should be located entirely below the level of the top of the sump tank. This will prevent draining of the electrolyte back into the tank when the pump is shut down and more of the tank capacity can be used for excess electrolyte. Replenishing of the water will then be less frequently required and changes in electrolyte concentration due to evaporation will be retarded. For the larger rheostats using a sump pit of ample capacity, this point has less importance.

Piping. A schematic diagram of the minimum piping requirements is shown in Fig. 7. Only iron pipe and fittings should be used in locations where contact with the electrolyte solution is to be expected since this solution attacks brass and bronze. The piping between the pump, heat exchanger and rheostat should be as short and have as few fittings as conditions will permit. The shutoff valve between the pump and the heat exchanger provides a means to limit electrolyte flow to prevent possible overloading of the pump motor while all piping is new and losses are low.

Provide a drain for the heat exchanger so that it can be drained before the tube bundle is removed. A connection must also be provided to the drain trough below the rheostat cells so that the cells may be drained for inspection of the electrodes, etc.

Due to physical properties of the electrolyte, a very tight piping job is required if leaks and seepage are to be prevented.

Wiring. Connections should be made as shown on the wiring diagrams furnished with the rheostat and associated apparatus. Make certain that wire sizes and insulation class are adequate and that they are in accordance with any special requirements indicated by notes on the diagrams. Conduits should be of ample size to accomodate one or more spare wires for all control circuits and such wires should be pulled in during installation. While making connections to the electrolyte pump motor, try it out and use phase connections resulting in correct pump rotation as indicated by rotation arrows mounted on the pump.

Cleaning. After all the work of installation has been completed, the rheostat should be cleaned out with water. Remove any floating objects or other foreign matter from the sump pit to prevent possible damage to the pump. Sweep and flush out the sump pit, also flush out each electrolyte cell by opening its drain valve and hosing down the inside walls. Replace the covers over the top of the cells.

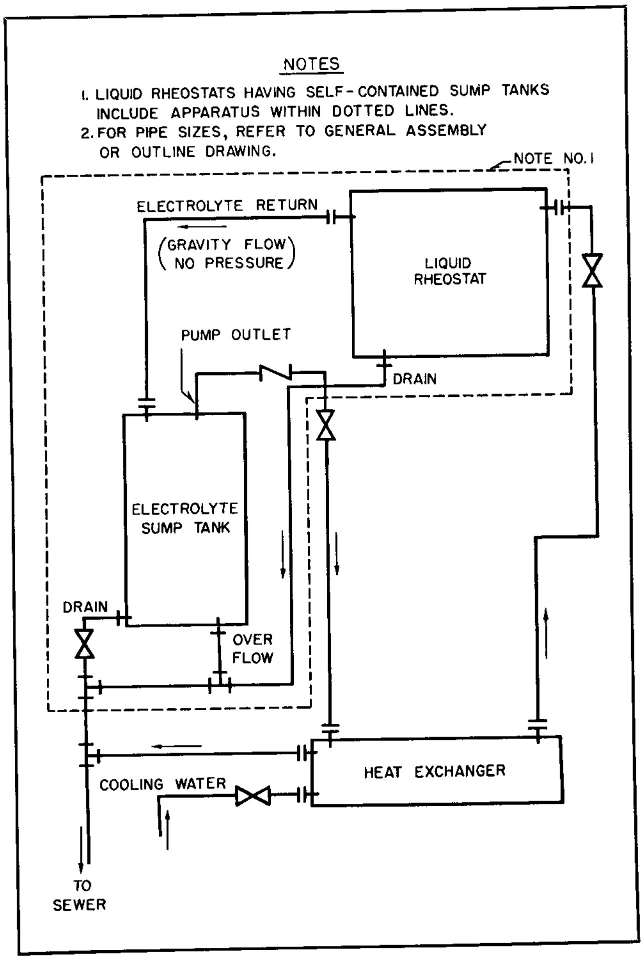

FIG. 7. Typical Pipe Connection for Liquid Rheostat Installation

TESTING AND ADJUSTING

Leaks. A thorough inspection for leaks should be made after water has been added to the system. Do not tighten any of the bolts holding the cells against the tank at the top nor those holding on the bottom plates unless leaks at these points are discovered. These joints have been tested at the factory and normally will not require field adjustment.

Electrolyte Pumps. The electrolyte circulating pump should be properly lubricated in accordance with the manufacturer's instructions before water is added to the rheostat. Oil-lubricated bearings should be filled with oil through the filler gauge and kept filled to within 1/8-inch of top of gauge as measured when the motor is not running. Grease-lubricated bearings are packed at the factory and require occasional addition of small amounts of grease. Such bearings should not be overfilled.

The pump should be set so that the cover plate fits squarely over the hole in the sump pit cover and is thus supported evenly at all points around its edge. The pump shaft must be plumb; this can be checked by placing a spirit level on the pump half of the flexible coupling and checking the level at positions corresponding to a full revolution of the pump.

The pump motor should also be mounted with its shaft vertical and in true alignment with the pump shaft. To align the motor with the pump, set the motor in position and place mounting bolts in the holes loosely. Remove rubber bushings or bolts from the coupling halves and adjust the motor half of coupling so that it has 1/16 inch clearance from the pump half of coupling at the nearest point. Place a straight edge across the flanges of the coupling at points 90 degrees apart and shift the motor until the flanges line up perfectly. See that coupling halves are evenly spaced at all points, placing shims under the motor mounting if necessary to maintain this alignment. Tighten bolts maintaining the alignment. Replace fittings removed from the coupling.

After the pump is operating with water in the tanks, measure the load on the pump motor. If the load exceeds the motor nameplate rating, the delivery head is lower than estimated and flow should be restricted as required by closing the valve in the pump discharge pipe.

Electrolyte Level. To determine the minimum operating level for electrolyte in the system of a rheostat having a self-contained sump tank, first fill the cells up to the overflow pipe, then start the pump and continue filling slowly until the water entering the cells at the bottom no longer carries air bubbles with it. This will indicate that the pump is completely submerged. Note the level of electrolyte on the glass gauge while the pump is still running. Mark the low level at a point about three inches above the level on the gauge to provide some margin of safety.

To establish the high operating level point, continue to fill the rheostat with the pump running until discharge from the sump tank overflow is evident. Stop the pump and let the excess water drain through the overflow. Restart the pump and note the level on the gauge to which the water drops. Mark the high operating level at a point approximately an inch below this gauge level.

When a separate pit is used, a similar procedure can be followed in determining the high level point to which the pit should be filled.

Electrode Operating Mechanism. All bearings in the electrode positioning motor and on other parts of the electrode operating mechanism should be checked to see that they are properly lubricated and free to rotate. Turn the motor by hand throughout the full range of operation to make sure there is no appreciable variation in torque required at different electrode positions which indicate friction or binding.

Observe the operation of the limit switches which function to stop the motion of the electrodes at the extremes of travel. These limits have been set at the factory and should not be changed unless they are obviously out of adjustment. The minimum spacing between moving and stationary electrodes should not be less than 3/8 inch.

Other contacts on the limit switch are required as indicated by the wiring diagram. The cams for these switches have been given a tentative setting at the factory which may require further adjustment during installation to yield the best results. Changes can be made in both length and position of any cam without disturbing the setting of other cams. To release the cams so that they may be rotated, loosen the large clamping nuts at either end of the cam shaft. The split cams can then be rotated at will to give the point of operation and length of cam surface necessary.

Speed of the operating motor is varied over the operating range so that the rate of change of ohms between electrodes approaches linearity. The speed is determined principally by adjustment of the resistors in the armature circuit. Adjustment of these resistors can be made to change the rate of electrode movement if necessary. At installations where the current drawn by the main motor must be limited during acceleration or deceleration, this feature is automatically insured by having the speed of the electrode positioning motor sufficiently slow. Depending on the gear ratio in the speed reducer between the positioning motor and the operating mechanism, the range of electrode speeds for covering the full travel is adjustable from eight to ten seconds minimum to approximately two minutes maximum.

Protective Devices. Standard equipment for the liquid rheostat includes two protective devices which should be connected into the customer's alarm system. Both devices function when there is danger of excessive temperatures in the rheostat which might cause boiling of the electrolyte. Boiling does not injure the electrolyte or the rheostat; it does, however, make the resistance between electrodes vary which will cause phase unbalance in the secondary of the main motor with which the rheostat is being used, possibly resulting in damage to equipment. The recommended maximum electrolyte temperature is 160 degrees F. or less.

The indicating thermometer measures the temperature of the electrolyte as it leaves the cells. This thermometer contains electric contacts which operate when 160 degrees rising temperature is reached. The most likely cause of excessive temperature is failure of the cooling water flow and this should be investigated first, including valves in the cooling water piping. Also, the temperature of the cooling water should be checked and the heat exchanger cleaned if necessary.

A similar situation occurs in case there is a failure in the electrolyte circulating system. The second protective device is a liquid level relay which operates whenever the level of electrolyte in the rheostat falls below a predetermined depth. This relay is of the induction type having two windings on its coil. The secondary portion of the coil has its circuit connected to a plug which is located on top of the tank over the cells. A rod from this plug extends down toward the electrolyte and, when the level is correct, the tip of the rod is immersed. The circuit is completed through the electrolyte to the frame of the rheostat and back to the coil which has one lead connected to the rheostat frame. If the electrolyte level drops, the tip of the rod is no longer in contact with the electrolyte and the circuit is interrupted so

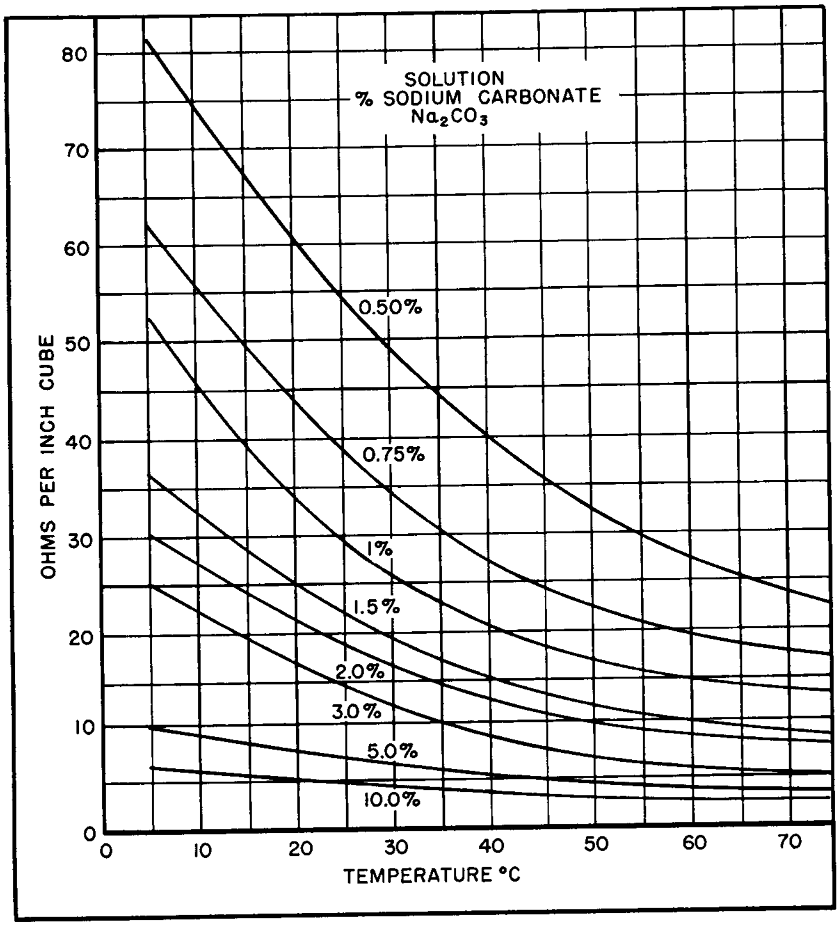

FIG. 8. Curves Showing Resistance of Electrolyte as a Function of Density and Temperature

that the relay operates. Most likely causes of low electrolyte level are failure of the pump or need for replenishing the water in the electrolyte. Valves in the piping should also be checked.

Both of the protective devices have contacts rated for 110-volt low energy, non-inductive circuits. They may be used to operate a light or a bell, the drop of an annunciator, or another relay. The flow relay has two contacts, one normally open and the other normally closed; the appropriate contact can be selected for the alarm circuit.

Electrolyte. Distilled or rain water is preferable to ordinary tap water for preparation of electrolyte. Impurities in the water may result in increased electrode wear. Of all common impurities, chlorine is probably the most harmful to the rheostat. ***Never under any conditions, should ordinary salt (sodium chloride) be put into the electrolyte.***

Any good grade of commercial sodium carbonate (soda ash) is suitable for making up the electrolyte. Electrolyte is not supplied with the rheostat. The sodium carbonate preferably should be completely dissolved before it is added to the water in the tank. The quantity required can be determined on a weight basis by use of the information below.

The percent density of the electrolyte solution is normally selected after consideration of two conditions: the maximum speed of the main motor which determines the minimum resistance to be reached in the rheostat, and the amount of starting inrush on the main motor which can be tolerated which determines the maximum resistance requirement. For a fan type load where torque varies with the square of the speed, the inrush current will be below 100 percent if the resistance in the rheostat is great enough to reduce main motor speed to at least 60 percent of rated. For a constant torque type load the rheostat resistance must be large enough to reduce main motor speed to 50 percent, if inrush is limited to 100 percent. The resistance per phase in the rheostat can be determined from the following equation:

$$R = \frac{r \times s}{A} \text{ when}$$

R = total resistance per phase

r = resistance of electrolyte in ohms per inch^3. (see Fig. 8)

s = distance between electrodes in inches

A = nominal area of electrode x .85

Fig. 8 shows the resistance per inch cube for a variety of densities and also how the resistance varies with temperature. In determining the maximum desired resistance, the resistance value should be used for hot electrolyte since cold electrolyte will always cause a lower inrush current. Calculations for determining the minimum desired resistance must make allowance for resistance in the main motor secondary and also resistance of the conductors between the motor and the rheostat. The minimum value of "s" in the equation should not be less than 3/8 inch. The maximum value can be determined by measurement although this figure is usually shown on the wiring diagram accompanying

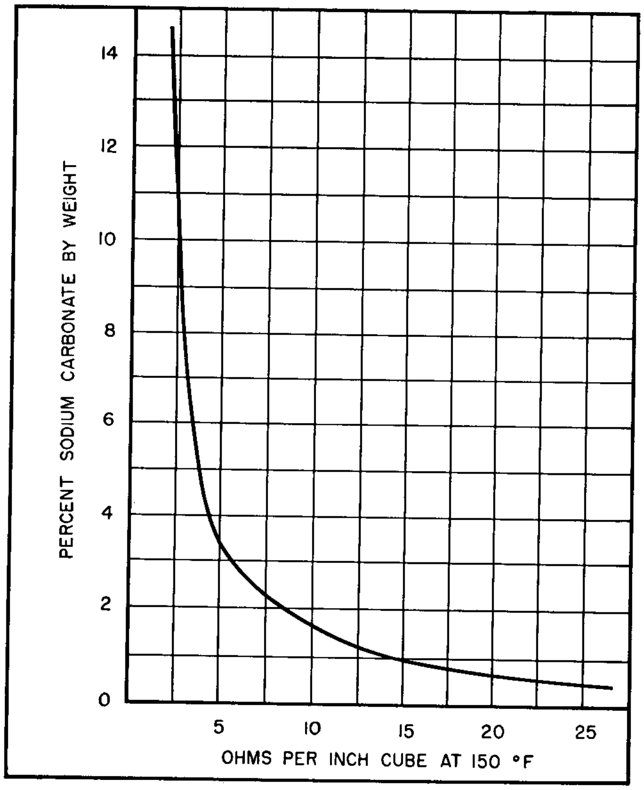

FIG. 9. Variation of Electrolyte Resistance with Concentration of Sodium Carbonate

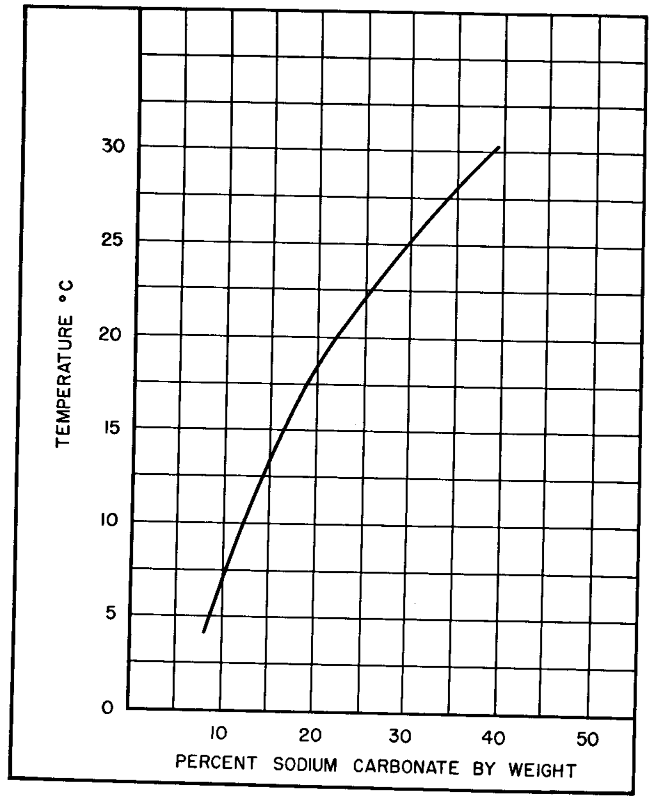

FIG. 10. Approximate Solubility of Sodium Carbonate

the liquid rheostat. The approximate strength of the solution can be determined by this means and when operation is begun the final concentration can be arrived at by draining of some electrolyte and adding a slight amount of concentrated solution or water as required. The percentage strength of the electrclyte is based on relative weights of water and sodium carbonate.

Two other curves are included in this leaflet for general information. Fig. 9 is a curve showing how the resistance of the electrolyte solution varies as the density is changed. It can be noted that as very concentrated solutions are approached, the addition of large amounts of sodium carbonate has small effect on the resistance. Fig. 10 shows how the solubility of the sodium carbonate is affected by temperature. Care must be taken to be sure that the concentration is never permitted to get strong enough to result in the formation of crystals of sodium carbonate at low temperatures when the rheostat is not in service. Such crystals may freeze the electrolyte pump so that it is necessary to remove and clean the pump before it can be started again.

When the rheostat is placed in operation and the electrolyte reaches operating temperature, its motion will wash off paint and other protective coatings used to prevent rusting during shipment and installation periods. This matter will appear as scum on the surface of the tank above the cells or in the electrolyte sump. If should be removed frequently as long as it continues to form. Should spots of this matter lodge permanently on the current carrying surfaces of the electrodes, it may interfere with current distribution and cause uneven wear on the electrode surfaces.

Electrodes. Rheostats of the smaller sizes have their moving electrodes suspended from a common copper neutral bar by specially flexible copper cable. The top end of the electrode cables are soldered into slotted copper blocks which, in turn, are bolted through the slots to the copper bar. Each moving electrode may be adjusted up or down by loosening the bolts and sliding the block. The electrodes are adjusted at the factory for equal spacing and no further adjustment should be required until it becomes necessary to replace worn electrodes or cables.

The larger rheostats have rigid supports for the moving electrodes and generally require more accurate phase balance than do drives on which the smaller rheostats are used. It is possible to make minor adjustment in the electrode spacing without loosening the electrical connections. The electrode and its supporting conductor is supported from two

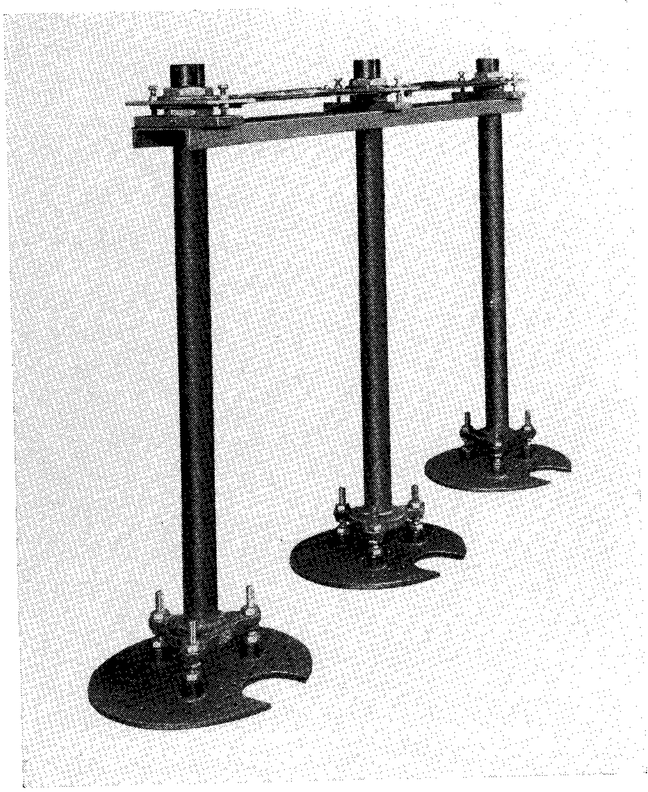

FIG. 11. Moving Electrode Assembly Showing Bolts for Adjusting Electrode Position

bolts equipped with lock nuts. If the lock nuts are loosened, the electrode can be raised or lowered by turning the bolt in the required direction. (See Fig. 11).

If there is any unbalance in the phases, it will be most pronounced when the electrodes are at minimum separation. This setting has been made at the factory, but may require final adjustment by actual test during installation. If there is any question concerning unbalance, the relative currents into each rheostat cell should be measured. Since only relative readings are required, several alternate methods suggest themselves. A direct current ammeter shunt may be used with a rectifier type millivoltmeter. A current transformer, rectifier and d-c ammeter can be used. A comparison of lesser accuracy can be made by comparing the swings of a d-c ammeter connected to the current transformer directly without using the rectifier. Rotor frequency at speeds corresponding to minimum separation is usually of the order of two cycles per second or less.

The procedure for balancing the phases is outlined briefly as follows:

Lower all moving electrodes (by hand after the limit is passed) until the moving electrodes are resting on the stationary electrodes. Non-conducting spacers have been fastened to the upper surface of the stationary electrodes so that the metallic surfaces of the two electrodes do not come in physical contact. Measure the resistance of the three phases and then raise the moving electrodes approximately 1/8 inch, again check resistance and adjust spacing by adjustment as described above if necessary. Move the electrodes up and down again to approximately the same position and again check balance. Repeat this sequence with slightly wider separation working up to a total separation of approximately 3/4 inch. By this time a balance will be reached which maintains itself consistently.

A similar procedure can be followed when replacing worn electrodes. The electrodes are counterbalanced by a weight to reduce the torque requirement on the driving mechanism. The counterweight is adjusted so that the electrodes tend to separate when motive power is removed and the reduction gear not connected.

Flow of Electrolyte. Motion of the electrolyte causes some erosion of the electrodes and it is desirable, therefore, to keep the flow rate to the minimum which will supply adequate cooling. After the installation is complete and operating under normal rated load conditions, the flow of electrolyte should be throttled by the valve in the pump outlet until the steady state electrolyte temperature, as indicated by the thermometer, is between 140 and 150 degrees F.

MAINTENANCE

Occasional addition of water to the electrolyte solution replacing losses by evaporation; less frequent cleaning and flushing the electrolyte system and replacement of worn electrodes represent generally the only maintenance required. Periodic inspection of bearings is also desirable, however, wear is very gradual due to the slow rate of motion characteristic of the electrode positioning mechanism. The purity of the water used to make up the electrolyte will be an important factor in determining the frequency for draining and cleaning the electrolyte system since impurities in the water are concentrated as evaporation occurs and these impurities may be corrosive, causing appearance of crust or deposits. It is for this reason that use of distilled water is recommended.

Starting-up. Do not actually operate the main motor and rheostat together until after all tests and adjustments which can be made without the motor have been completed. When starting, it is recommended that several observers be stationed to assure that no obviously dangerous or damaging conditions are permitted to develop.

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BUFFALO PLANT • MOTOR AND CONTROL DIVISION • BUFFALO 5, N.Y.
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