A SWITCHBOARD FOR ELECTRICAL TESTING.

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As the switchboard in use in the testing laboratory of the Central Scientific Company possesses some rather novel features, it was thought that a description of its arrangement and operation might be of interest to the readers of this magazine.

The testing laboratory of a scientific laboratory supply company is called on to make a large variety of tests, no small part of which are electrical. This fact is illustrated by the following representative list selected from the work done in this department during the last year.

Testing the operation, efficiency, and wattage of electrically heated and controlled drying ovens, incubators, water baths and thermostats.

Calibrating voltmeters up to 250 volts and ammeters up to twenty-five amperes.

Calibrating electrostatic voltmeters up to 30,000 volts by the use of high tension transformers.

Charging storage batteries.

Testing or operating lamps, induction coils, and A. C. or D. C. motors of various voltages.

Checking the resistance and current capacity of laboratory rheostats.

Checking the wattage and efficiency of heaters and heating elements.

Locating faults in the wiring of various electrical appliances.

Measuring the carrying capacity of resistance wires, coils, and fuses under special conditions.

Testing X-Ray, cathode ray, and other vacuum tubes.

Operating wireless and high frequency transformers.

For some time after coming to the Central Scientific Company the writer used portable meters and makeshift arrangements of rheostats and lamp banks in testing work. These improvisations were not without their value, for it was through this experience that the writer was able to determine the nature of the tests which the laboratory would be expected to make and what requirements the testing equipment would have to meet when the time should come to design it.

In the summer of 1916 the Central Scientific Company moved to its present commodious quarters on the Lake Shore Drive. This move made it possible for the laboratory to occupy a much

larger space than before, and provided an opportunity for the installation of some permanent electrical testing equipment. This equipment included a testing switchboard, a motor generator, and a distributing system.

The switchboard comprises two panels of heavy slate, each 34 by 36 inches, mounted side by side, one carrying the A. C. equipment and the other the D. C. equipment. These are mounted on substantial angle iron supports extending up to the ceiling, and located at a sufficient distance from the wall to permit easy access to the back of the board for changing fuses. In front of the board at standard bench height is mounted a hardwood shelf 16 inches wide running the full length of the board. This shelf makes it possible to do most of the lighter testing work right at the board.

As the building is located in the direct current district of Chicago, the power supply is a three wire 110-220 volt system. Alternating current is supplied by a motor generator. Two

FIGURE 1

advantages of this arrangement are that most of the testing work can be done with direct current, and that the generating of the alternating current in the laboratory gives a wide range of voltages and frequencies which would not otherwise be available.

The motor generator was built for this laboratory by the General Electric Company, and is of the double end two bearing type. The generator is a $1\frac{1}{2}$ K. W. three-phase, four-pole machine, giving 110 volts at normal speed. The motor is $2\frac{1}{4}$ H. P., 220 volt, compound wound, and is controlled by a combined starting box and speed controller, by means of which the speed may be varied between 900 and 2,700 R. P. M. This range of speed gives the generator a frequency of from 30 to 90 cycles, which is sufficient to meet all the requirements of this laboratory. The generator field is supplied from the 220 volt D. C. line, being controlled by a rheostat of comparatively high resistance, making it possible to vary the voltage through a range of over 30 per cent at any given motor speed. This variable speed feature of the motor also extends the voltage range, the extreme limits being about 40 volts at 30 cycles and 180 volts at 90 cycles. By means of appropriate transformers, any desired voltage can be obtained at any given frequency.

FIGURE 2

On the alternating current panel (see Figure 1) are mounted the starting and control box for the motor generator, the field rheostat, a 125 volt A. C. voltmeter, a 10 ampere A. C. ammeter, the control switches for the motor and generator, and three sets of terminals for the alternating current. The voltmeter is connected through a standard three phase voltmeter plug, by means of which it may be instantly thrown across any one of three phases. The ammeter is connected through a special switch which may be described as a double pole triple throw, having two pairs of blades and three pairs of clips, so arranged that either pair of blades can be thrown into the center pair of clips. As indicated in the wiring diagram in Figure 2, the ammeter is connected across the blades of one switch, while the blades of the other are short circuited. The switches are closed in the positions A, B, for phase 1, B, C, for phase 2, and

A, C, for phase 3. Thus either phase may be used separately, and the ammeter is always in circuit. For three-phase work the ammeter may be placed in whichever phase is desired, the third contact being closed with a removable clip.

On the direct current panel (see Figure 3), are mounted a 250 volt D. C. voltmeter, a 25 ampere D. C. ammeter, two rheostats, six switches, and the necessary terminals. A is the main switch, and serves to disconnect the whole D. C. panel. The switch D is thrown to the left for 110 volts and to the right for 220 volts. B, C, and E are for obtaining various combinations of the rheostats, their use being described below.

FIGURE 3

F reverses the polarity of the working terminals. Two field rheostats of the three plate type are used, each having a maximum resistance of 40 ohms and a maximum current capacity of 12.5 amperes. As each rheostat has about 65 steps, it is possible to secure sufficiently fine adjustments of voltage or current for calibrating meters. The connections of the rheostats are controlled by two switches, B and C, the wiring of which is shown in Figure 4. When B and C are both thrown to the right, which is equivalent to closing switch 2 in Figure 4, the rheostats are in series with each other. When B and C are thrown to the left, which is equivalent to closing 1 and 3,

they are in parallel. Either rheostat may also be used singly by throwing the corresponding switch to the left, i. e., closing 1 or 3, leaving the other one open. It is thus possible to obtain a maximum resistance of 80 ohms (with the rheostats in series), and a maximum current capacity through the rheostats of 25 amperes (with the rheostats in parallel).

FIGURE 4

The D. C. voltmeter is so connected that it measures the P. D. across the working terminals rather than the line voltage. These values are not the same when some of the resistance of the rheostats is in series with the load. The ammeter is also connected so as to read the current flowing in the working circuit, which may not always be the same as the current drawn from the line, as for example when the potentiometer connection described below is being used. The above arrangement of the meters facilitates measurement of resistance or wattage of rheostats, heating units, motors, etc.

Another type of work for which this board is well fitted is tracing out connections or locating short or open circuits in electrical appliances. To do this the two rheostats are connected in series with each other, and in series with the working terminals, providing sufficient protective resistance to prevent any injury to the meters or fuses. In fact, with all the resistance in circuit, less than one and one-half amperes will be drawn from the line in case of a short circuit. The testing terminals are then applied to various points of the wiring in the appliance under test, and the readings of the voltmeter and ammeter noted. In case of a short circuit or a connection having a very low resistance, the voltmeter will read practically zero, while the ammeter will indicate a flow of current. In case of an open circuit, the voltmeter will read the full line voltage, but the ammeter will read zero. In case the circuit is normal, i. e., includes more or less resistance, the readings of the meters will give an index to the amount of such resistance. The above arrangement replaces the old-fashioned test lamp, whose use was practically limited to determining whether or not a circuit was complete. The brightness of such a lamp gives at best a rather hazy idea of the amount of resistance in the circuit.

In certain kinds of low voltage work it is not practical to reduce the line voltage by means of series resistance, as for example when operating or testing battery motors, lamps, or coils. A bank of storage cells of sufficient size to provide a wide range of voltages is expensive, and requires no little attention. Provision has been made for this type of work by arranging a potentiometer connection of the rheostats. Throwing switch E to the left and switches B and C to the right, the two rheostats are connected in series, but the working terminals are shunted across the right hand rheostat. Under these conditions a reduction of the resistance in the latter rheostat will reduce by a corresponding amount the P. D. across the working terminals, and vice versa. Also a reduction of the resistance in the left hand rheostat will increase this P. D. By proper manipulations any voltage between zero and 220 may be obtained.

As will be noted in Figure 3, there are three receptacles at the bottom of the D. C. panel. The middle one of these is the working circuit, being connected through the switches, meters and rheostats. The right hand receptacle is connected directly to the 110 volt line and the left hand one to the 220 volt line. This arrangement makes it possible to use at the same time three different voltages. On both the A. C. and D. C. panels binding posts are provided to which connections may be made when it is not convenient to use the receptacles.

In connection with the switchboard a simple but efficient distributing system is used. Beneath the testing shelf is mounted a gang of six receptacles like those used on the board. From these receptacles circuits are carried to the dark room, the show room, and the various benches in the laboratory. Connections are made by means of flexible cords having a two finger type of plug on each end. It is thus possible to have instantly available at any part of the laboratory whatever current or voltage is desired.

LENGTH OF PATH OF LIGHT TRAVELED BY REFLECTION FROM MIRRORS.

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In Preston's *Light* we have given a problem which requires us to prove that when light from an object is viewed by an eye after successive reflections from two mirrors, the actual path traveled by the light is equal to the apparent distance of the last image to the eye.