Electrical Control for Varying Lighting Intensities

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Intensity control through new developments in apparatus is now available in economic forms and makes possible a variety of distributions suitable for producing visibility, comfort, and composition for different purposes.

BETTER Light—Better Sight" has become more than a slogan. The public is slowly awakening to the deleterious effects of bad practice in lighting, and illuminating engineers have begun to interest themselves in something more than the production and distribution of artificial illumination; namely, the protection of our eyes, and promotion of comfort in the process of seeing.

The primary aspect of this research deals with the levels of illumination desirable for various purposes. The tendency is in the direction of high intensities and the consequent increase in the cost of current. This paper investigates the available apparatus for the control of intensity electrically, not only from the standpoint of economy, but also for promoting comfort in seeing and flexibility in design.

The tendency to concentrate attention on the necessary brightness of the important object for the seeing of detail often obscures the contributing effect of less important areas which also lie in the field of vision. Good visibility is obtained only when areas, objects, and details are revealed in proportion to their importance, and inasmuch as the size of objects, a dominant factor in visibility, is not subject to much change, the brightness pattern projected to the eye of the observor determines chiefly their degree of visibility.

Except in rare circumstances the object, the direction of the beam, its color, and the source, in their physical makeup, cannot be changed easily once they are installed. It is possible, however, to alter the brightness and its by-products, color and distribution (chiefly re-

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sultant density), by controlling the lumen output of the source (through voltage or current regulation) from the highest burning efficiency to "out." In other words the most practical means of providing suitable control over intensity levels is by what is called electrical dimming.

Although the eye is a very flexible instrument and can see reasonably well over a relatively wide range of intensity levels from sunlight illumination on down to the rather questionable recommended foot-candle quantities, the problem of cost, and ultimately, appearance enter the calculations to such an extent that only future research may provide us with sufficiently exact figures to permit the specifying of wattages which will guarantee a completely satisfactory installation. For many purposes, also, it is desirable to have a variety of levels The engineer has discovered that the only safeguard he has is to provide a large factor of safety—more wattage than may be necessary. The objectionable "glare" that often results from such practice is probably not due so much to too much light as it is to bad distribution and balance. Under any conditions, in the owner's eyes it costs too much, and the engineer has weakened his position as an authority in this way, with the owner and his architect. If an economic means of varying the intensity of the various sources were provided, a balanced distribution of brightness levels suitable to the owner and the architect could be worked out.

The reactor and tube control made primarily for theatre switchboards (and recently applied to the color control for fountains, signs and show-windows) in spite of its cost has many advantages over the resistance dimmer or rheostat. It can handle large loads remotely from a small pilot dial. Its chief advantage from a commercial point of view is that it wastes little or no current when the load is dimmed.

The auto-transformer, thanks to its development for radio control, is the latest and most inexpensive dimming apparatus for small loads (2000 watts and under) to be used for lighting control.

From the standpoint of economy, where intensity control is specified or desired, the reactor and the auto-transformer have none of the objections of the old rheostat except that which is common to all three; when a lamp does not burn at its rated voltage, its lumen output efficiency is lowered. On the other hand the auto-transformer can be made to step up any voltage drop in the line at its high end. It is possible also to figure the point at which the current saving in a reactor offsets its extra cost compared to a resistance dimmer.

From the standpoint of comfort, when daylight fails or a storm comes up to reduce natural illumination below working efficiency, the photocell switch-on controller may be used to save the workers' eyes. If the artificial sources could be brought on in degrees of brightness corresponding to the speed and lessening of natural light or vice versa, there would be no shock due to quick change and there would be considerable saving in current consumption. A photocell with a series of relays set for different light values, each one actuating the intensity controller to bring it up or take it down to a predetermined balance point by a slow speed motor operation, would take the place of the single cell and contactor unit now in use.

It is conceivable that instead of wall switches small intensity controllers will be used so that the abruptness of switching on a light will not be present. Furthermore it will permit the selection of levels of illumination on walls, surroundings and working plane which correspond to the task at hand, particularly where a desk or bench is used for a variety of operations. In color work an intensity controller operating three circuits: red, green and blue, would permit the selection of any shade or tint desired. Where a variety of distributions is advantageous, different fixtures can be regulated to suit each purpose. In a lecture room, for example, there should be circulation lighting so that the audience can find their seats. When the lecture starts, this lighting can be taken down, and speaker and blackboard lights brought up. If lantern slides are used, note-taking lights and perhaps the speaker lights should be brought on and all others which would interfere with the pictures should be taken out.

Dimmers are used extensively in the theatre for the control of the lighting to provide visibility, comfort, composition, and atmosphere in terms of seeing for the audience. Efficiency and economy admittedly are of secondary consideration, but with the new appreciation of economy and comfort and perhaps a growing belief in the importance of good composition and a satisfactory atmosphere in lighting design, much can be learned from theatre practice. The use of dimmers for moving effects—sunsets, storms, color changes, and the like—is a small part of their value and obviously not applicable to anything outside the theatre in other than display work. A definite atmosphere and composition such as is conveyed to the eye as the curtain rises on a scene is the result of carefully balanced intensities from a number of instruments having different distributions and colors. With a dimmer controlling each circuit the designer can start with a dark stage and build in the lighting much as a sculptor puts clay on the framework of a figure, merely by bringing up the intensity of each source to the proper point. Obviously the great flexibility required to provide the proper lighting for many different scenes is not necessary or desirable in layouts outside the theatre, but almost any lighting problem can approximate a satisfactory solution by the judicious use of intensity-control apparatus.

HISTORICAL DEVELOPMENT

An excerpt from the *Journal für Gasbeleuchtung* or Gaslighting Journal, Munich, 1878: "But if we enquire further as to whether the electric rather than the gas light may prove suitable for street lighting as well as for lighting the average private home, our questions must be answered definitely in the negative. On the whole, we do not need in our private dwellings any light of such illuminating power as is given by the smallest electric lamp. The brightness of a good gas flame answers the general requirements; we can not use a much brighter source. The electric light would bring with it to the consumer the greatest annoyances. In order to turn on the light the motor-generator must be started, the candles[1] must be clamped in position, in short each consumer must be a skilled mechanic or employ one in order to maintain the lines and entire machinery in good repair. Indeed, that the entire light-generating equipment of a town can ever be placed in a single plant as are the gas works to-day, should not even be imagined. Each consumer, or at most, each group of several neighbors must have their motor-generator in common and manage it themselves. Now with gas lighting, the consumer need only open his valve and light the gas with a match; at any hour of the day or night he has light, and can burn it as long as he wishes without the slightest further trouble. Only think, that one of our larger cities would need about ten thousand electric lamps, that for these, motors of at least ten thousand horse power collectively and perhaps a thousand generators with their untold numbers of conductors would be necessary; that all these machines would be managed privately; it seems absurd, and justly so, that anyone would wish to believe in the possibility of electric light taking the place of gas, of supplanting it for general lighting, and, last but not least, of producing it far more cheaply than is at present possible."

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[1] Jablokoff Candles.

This article was written, of course, before incandescent lamps had come into use, before alternating current had brought with it the possibilities of transmission over reasonable distances. Yet it shows the resistance which people offer to the introduction of new equipment. When electric lighting came into being, companies and individuals alike refused to accept as possible or practical, ideas which are now commonplace. With these developments but without control, electric lighting is still seriously limited. Many new and practical methods have been evolved for the simple, safe, and economical control of intensity, yet designers and builders hesitate to use or recommend them either though ignorance of their value or fear of the seemingly high initial cost. Now that there is a solution to the problem of obtaining sufficient light easily and economically when and where it is wanted, attention should be turned to the control of that light.

The first intensity-control apparatus was of the resistance type, but differed widely from what is now known as a "resistance dimmer." It was called the "water barrel dimmer." A cask or jug of some dielectric material such as wood, stone, or crockery was filled with water to which had been added a very small amount of salt or acid. A stationary plate of metal rested in the bottom of the barrel and a movable plate was suspended from above and submerged in the solution. When the two plates were connected in series with the line and load, the solution acted as a resistance. By raising or lowering the upper plate, the amounts of resistance and hence the current flowing in the circuit could be varied. This apparatus gave very smooth even dimming, but unfortunately took up a great deal of space, was not reliable, had to be constantly refilled due to the evaporation, and when overloaded gave off a most unpleasant odor. It also had the great disadvantage inherent in all resistance dimmers of converting its voltage drop multiplied by the current into heat loss (commonly known as I^2R loss). These various factors brought about its replacement by more satisfactory equipment almost at once.

The carbon pile or carbon block rheostat has also been tried and found wanting. This dimmer consists of a number of plates or blocks of pressed carbon placed face to face in an insulated holder, with some kind of adjustable pressure device at one end. Carbon, being a good conductor, offers a relatively small resistance when the blocks are clamped tightly together, but when this pressure is relieved the resistance rises rapidly. The difficulty involved in maintaining exact pressures on the carbon, its changing resistance due to heat generation, the possibility of arcing between loose plates all decide against the use of this apparatus in lighting control circuits. Despite its cheapness and compactness, it falls definitely into the class of unsatisfactory control equipment, especially as it too, being a resistance unit, has the $I^2 R$ heat loss.

A dimmer which is still in fairly common use, but should not come under the classification of strictly modern control is the slider type of resistance dimmer, wound either in single or in multi-coil form. These dimmers consist of a coil or coils of resistance wire wound on porcelain tubes or sheets of some other insulating and heat-resisting substance such as an asbestos compound. In the single-coil form one terminal is connected to the last turn of the wire and the other to a metal rod fastened above the coil. Upon this rod or shaft slides a contact shoe fitted with an insulated handle. This shoe, making connection with the resistance wire below it through spring brass contacts, limits the number of turns or the amount of resistance in the circuit. In the two-coil slider dimmer, the principle is the same, but two coils of wire are used with but one slider. The terminals are attached, one to the end of each coil, and the slider with its spring contacts makes connection with both coils simultaneously. Thus, the current must flow through a portion of each coil of wire, but not through the shaft holding the moving shoe. Often rather than permit the shoe to rub directly on the wire, metal studs or taps are connected at various points along the coils; these offer a larger contact area and have less tendency to wear. While fairly smooth dimming may be effected with the slider-type dimmer it does not lend itself to group control, is not built in large capacity sizes, and in general is not calibrated to fit the acuity curve of the human eye. This last consideration refers to the ability of the eye to distinguish small changes at low intensities much more readily than the same changes in high intensities. Thus, an apparently smooth and even dimming change should vary slightly through the low intensities and continue more and more rapidly as the brilliancy of the lamps increases. These difficulties, however, do not prevent the slider dimmer from playing an important part in smaller American installations, while the Germans use a modified type with tracker wire control in their larger systems. This type of dimmer has also been used successfully as a preset in several control boards which are illustrated in the last section of this paper.

There is one other type of dimmer which was developed and discarded many years ago, yet from which has come the most modern light control apparatus. This is the reactance dimmer in its simplest form. Originally a coil of wire was connected in the load circuit, and a movable iron core which could be raised or lowered inside this coil varied the amount of reactance and hence the voltage across the dimmer. Theoretically, this was a great step ahead of the old resistance units, but practically the apparatus had many faults. It was heavy, bulky, noisy, and could not be operated easily or accurately. Yet, while it was forgotten for a time, this reactance principle is now being used in the newest theater switchboards, and in some of the largest lighting control circuits installed.

THE PLATE RESISTANCE DIMMER

The modern outgrowth of the slider-type dimmer is the plate dimmer. This, too, utilizes the resistance-wire principle, but here the wire is wound, not in coils, but in one or two multipointed star formations laid flat on a circular insulated base. This may be of stone or some kind of vitreous enamel set in a metal plate. At each "point" of the starshaped winding a tap is connected; when these are all in place more enamel or cement is poured over the wire thus embedding it firmly and preventing damage or loosening. In the dimmer having two concentric circles or rows of taps, the rotating arm and shoes make a connection from the outer ring to the opposite side of the inner, and the two sets of resistances are connected as were the coils in the double-coil slider dimmer. Where only one circle of contact points is used, it is split into two 180-degree sections, and the shoes and arm bridge these sections as they bridged the two circles in the former type. In either equipment there should be at least one hundred steps or taps in the winding to allow smooth dimming without "jumps" in intensity which are large enough to be noticeable.

When the soapstone base is used as a foundation for the resistance, the latter may be laid on both sides of the plate, giving the effect of two separate dimmers. In either round plate type the capacity is limited to 3600 watts per plate, though larger rectangular plates up to 6000 watts can be supplied. This limitation is necessary because of the heat generated—the I^2R loss which makes the dimmer's physical efficiency low. But there is another kind of efficiency than that given by measurable quantities. It is the ease with which the apparatus gives desired results—its flexibility, dependability, and safety.

In these terms the plate dimmers are far ahead of any of the apparatus mentioned heretofore. They give smooth dimming of rated loads, are easily assembled into groups or banks capable of being interlocked mechanically on master shafts, operation is relatively simple, and their life is long. Likewise, because the sizes of the wires may be decreased at the low end of the traverse, the units can be made to dim faster at the high end than at the low, compensating for the peculiarities of the human eye.

At the low end of the dimmer there are several blank taps on which the shoes rest at "black-out." Besides these when the dimmer is used in the hot line there are sometimes attached to the last live contacts a spring and lever called a "flipper switch" which produce a quick break in the circuit, thus preventing any loss of energy or arcing between contacts if the dimmer is not entirely turned off. Here, then, is a practical, safe, but relatively bulky and inefficient dimmer for lighting circuits. It has been in service for many years and is still manufactured in large quantities for all kinds of lighting control installations.

THE AUTO-TRANSFORMER

The second type of modern dimmer to be considered is the transformer or more particularly the auto-transformer. Although this method is the most obvious one for reducing the voltage in ac circuits, where perfectly smooth variable dimming is required, several factors enter which at first seemed to prohibit the use of such equipment. The simple transformer consists of two coils of wire mounted on an iron core in such a way that both coils have a common magnetic path. In this way the magnetic flux induced by one coil will pass through the second coil and induce a voltage in it. But this same flux passing through the coil inducing it induces in the coil a voltage or back emf (electromotive-force) which opposes the original voltage. If tho magnetism is not resisted or used in some way this back emf is almost equal to the original voltage, and only a very small current flows through the coil. However, when a load is placed on the secondary coil it will draw current which opposes or resists the inducing magnetism. This latter is slightly lowered and allows current to be drawn from the line making up for that drawn from the transformer.

Thus, a transfer of current may take place without any electrical connection, that is, by a magnetic flow alone.

As the magnetic flux which induces the voltage passes through each turn of wire in the coils, each turn acts in reality as a tiny voltage source, and all these sources in series give the total voltage across the coil. Therefore, by placing the load across a few or many of the turns, a small or large voltage may be obtained. The same is also true in the primary coil, but working from voltage to flux instead of from flux to voltage. The flux is proportional to the number of turns times the current, and the voltage of the primary is to that of the secondary as the number of turns of wire in the primary are to the number of turns in the secondary. Thus, by keeping the number of turns in the primary a constant, but varying the number between the secondary leads, the load voltage may be decreased or increased to almost any value.

The secondary coil is not always necessary. The primary induces the magnetism which in turn induces a back emf in it. If a load were placed across part of this coil it would draw current and current would flow from the line. Moreover, the voltage of the load would be in proportion to the voltage of the line as the number of turns between the load leads are to the turns of the coil between the line connections. This type of transformer is called the auto-transformer and is available for use in lighting control circuits.

All these principles have been known and understood for many years. The difficulty in using the transformer as a variable control occurs when trying to tap the coil through ordinary contact points and shoe. If the shoe touches but one contact at a time there will be an instant of "black-out" and an arcing as the shoe passes from one tap to the next. This is allowable in some work, but not in smooth flexible lighting control. Therefore, the shoe must touch a second contact before it leaves the preceding. As may be seen at once, this means the shortcircuiting of the coil or coils between the taps, and though the voltage across them may be small, the resistance of the shoe is negligible and the current flowing large. Some arrangement must be made for limiting the flow of this short-circuit current while permitting the load current to pass unimpeded.

Two types of transformer dimmers are being built for the control of lighting circuits, one in this country and one in Germany. Both use the tapped auto-transformer principle. The "Variac," manufactured by the General Radio Company of Cambridge, Mass., was designed primarily as a radio control unit, but is now being made in larger sizes up to 2000 watts capable of use in other types of work. The coil of the transformer is wound on a toroidal core, and a shoe bears directly on the windings at one end of this core. The shoe, rather than being made of brass or copper, is of carbon, and touches more than one turn at a time. The carbon offers sufficient resistance to the short-circuiting current to keep it at a relatively low value, while it permits an almost unimpeded flow of current to the load. The whole apparatus is not larger than $7\frac{3}{4}$ inches in diameter by $7\frac{3}{8}$ inches high.

In Berlin, Germany, the Siemens-Schuckert Company manufactures an apparatus called the "Bühnen Regel Transformator," System Bordoni (Bordoni Transformer Dimmer). This also is an auto-transformer, but it is built in a much larger form, and the windings are of heavy copper strips or plates. By spacing these with solid layers of insulation the side of the instrument appears like a flat commutator. For the shoe, a section not unlike the face of the winding is used, but in the width of three turns of the coil four sections of copper separated by strips of insulation are used in the shoe. To each of these strips or contacts is attached a resistance; these are connected together at the far end, and one terminal of the load is fed through the junction. With this system any short-circuit current must flow through two resistances in series, while the load current passes through four connected in parallel. The entire shoe and resistance portion of the circuit is hung in a sort of cradle which slides up and down over the face of the transformer. One transformer may in this way supply as many as thirty-two circuits, each operating at a different voltage and capable of being independently controlled.

The transformer dimmer will dim smoothly from full to out loads of any wattage up to its full capacity, an operation quite impossible with the resistance dimmer. Where a certain control unit is connected to a certain fixed load at all times this multi-capacity feature is not important; but in cases where flexibility is demanded it is of inestimable value. The transformer is one of the most efficient of electrical machines. Bordoni dimmers range in efficiency from 85 per cent upward. Variacs of 500-watt rating have a maximum power loss of 30 watts. The old I^2R loss of the resistance unit has been eliminated. While neither the Bordoni dimmer nor the Variac are at present built to any but a straight line dimming curve, gears or other suitable mechanical devices may be added to the control equipment so that their outputs correspond to the acuity curve. Costing less than a resistance plate dimmer of similar capacity, taking considerably less switchboard space, silent, of high efficiency and complete multi-capacity, the transformer dimmer would seem to be the answer to many of the simple as well as the more complicated lighting control problems.

THE REACTOR DIMMER

The present reactor dimmer has developed from the old straight reactance, through the resistance-reactor stage, to the tube controlled unit. The three parts into which this modern apparatus may be divided are: (1) the saturable core reactor itself, (2) the tube circuit with its auxilliary equipment, and (3) the switchboard pilot control. When one coil of a transformer is connected in series with the load and an ac supply, no current will flow through either the lamps or the coil. When it is desired that the lamps light, the back emf being generated must be reduced in some way. In the oldest reactors this was done by simply removing the iron core. It has been found simpler and much more efficient in all ways to saturate this iron core with direct-current flux from an additional coil. Such a saturation will prevent the building up of an alternating flux from the coil or coils in the load circuit and thus any back emf across those coils. In other words, the load current will flow through the reactor unimpeded. Varying amounts of direct current through the auxilliary coil will vary the alternating or load current from full to the black-out value for the lamps. The coil used for saturating the iron core is wound on a third center leg of the reactor, a large number of turns being used to reduce the amount of current necessary for proper operation. To prevent any induced alternating voltage in this coil, which would be large on account of the number of turns, the load or ac coils are connected so that the flux from one at any instant is equal and opposed to that from the other in the center leg of the reactor. In recent installations one other piece of apparatus has been used in this reactor circuit. The load coils, even when the reactor core is saturated, offer some resistance to the passage of current; that is, there is a voltage drop across the reactor in the load circuit. A booster transformer is used in series with the reactor and load which steps up the voltage on the lamp line to make it normal even with a voltage drop across the coils. Because this boost in voltage is not necessary at the black-out position, the transformer is sometimes connected with its primary in the lamp circuit. Thus, when the lamps are bright the booster transformer is operating; when they are out it is not used.

The next consideration in the reactance dimmer circuit is the means of providing some controllable source of dc for saturating the reactor core. In the first installations, such as the 7th Avenue Roxy Theater in New York City, dc was available from the city lines, and the simplest possible apparatus was used. Regular plate dimmers controlled the direct current flowing through each reactor's center coil. This small direct current could, however, control a large amount of alternating current, and a small resistance dimmer on the board could regulate a far greater load than had been possible previously. But there were still many difficulties in connection with this system. The plate dimmer did not permit mastering or presetting, the size of the control board was nearly as large as ever, and resistance losses still made the whole apparatus relatively inefficient. It was obvious that the resistance dimmer should be eliminated.

At present there are several methods used for supplying a variable direct current to the saturable core reactor, but the details are too numerous and complicated to be more than mentioned here. However, in each case, gaseous hot-cathode, full-wave rectifiers are used. With three-element tubes, the grid naturally controls the electron flow between annode and cathode, and regulating equipment is consnected in this gird circuit. Where individual full-wave triode tubeare used, conditions are quite different. Here the annodes of the rectifier are connected to a saturable core reactor whose center coil feeds through the outer windings of a second reactor. Thus, the alternating currents flowing through the annodes of the tube tend to induce a voltage in the center coil of the first reactor. Current in this coil is in turn regulated by a very small direct current flowing in the center coil of the second. This is obtained through the control apparatus from a full-wave, dry-disc rectifier.

The number of types of pilot control apparatus for saturable core reactors is almost as great as the number of control types for lighting circuits themselves; and, being used in low voltage low current systems, the disadvantages found previously do not always apply. Resistances, transformers, solenoids, inductors all find possibilities in pilot control work. These units are small enough to allow control handles to be placed on less than one inch centers, and as many as three or four circuit controls with five dimming presets and switches for each may be mounted in the space formerly required for one plate dimmer lever and switch.

By the addition of suitable apparatus in the control system the reactance dimmer is capable of taking any load down to 10 per cent of its rating, smoothly and evenly. This is not quite equal to the 100 per cent multi-capacity transformer dimming, but other factors give the reactance system added advantages. Single units are commonly built capable of dimming up to 10,000 watts of lamp load. Also, as the pilot controls carry only a small amount of current, a large number of these may be multiplied and mastered by a single small unit. In fact, even resistance units may be used for individual controls. For grand masters which take an entire installation on a single dial or lever, however, transformers, inductors, or other solenoid controlled tube-reactor units are used. Resistance pilots are generally installed only as intensity presets, and in other parts of the tube circuit as current-limiting devices. The other types of pilots being voltage rather than current regulators are used both as preset and as master controls.

TYPICAL ASSEMBLIES

The assembling of these control units in switchboards, centralized points of control, for manual or automatic operation is a relatively important aspect of the problem. Depending upon the function and the number of units involved, ease of operation, flexibility, master control, dependability, safety and dispatch comprise the principles governing the design and arrangement of parts. The following examples illustrate the tremendous advances in engineering practice in the more complex types of assembly.

The resistance plate dimmer was, of course, the first unit to be used in building up complete control boards. These early boards were merely dimmers and switches arranged on the face of an insulating panel. No particular regard was taken for safety or ease of control except that all the units were relatively close to one another and could be handled by one or a small group of operators rather than a number quite widely separated from each other. The appreciation of safety factors has brought about the "dead front" boards, and an ever increasing number of load circuits, to be controlled have necessitated closer spacing of dimmer handles and greater flexibility generally. With ordinary single sided plate dimmers, 4 inches between centers is the minimum spacing allowable; when double-sided plates are used 3-inch spacing of lever handles is possible.

In Fig. 1 is shown a typical ten-scene switching preset Major control board built by the Frank Adam Electric Company of St. Louis. The pilot switch and contactor principle is the same as that used in the Trumbull board described below, but each set of preset switches is mounted adjacent to the dimmer control lever with which it operates. With each is an individual rehearsal switch which is independent of the scene presets. The scene masters are assembled at the center of the board. There are three color banks each furnished with master interlocking handles—all capable of being controlled through a single slow-motion wheel.

Fig. 2 shows the face of the Controlite board installed in the Bushnell Memorial Auditorium in Hartford, Conn. This was built by the Trumbull Electric Company with Hyser pilot panel and Ward-Leonard resistance plate dimmers. It is an excellent example of the five-scene switching preset control board with the presets and master controls all mounted in a panel separate from the dimmer control levers. Four color banks, (red, blue, green, and amber) are employed; those dimmers to the far right of the master panel being the house controls, and the others connected to stage circuits. Interlocking of any dimmers on any bank may be accomplished, and geared action in either direction can be obtained by use of the slow-motion wheel. Each dimmer and circuit has five preset or scene preset switches and one rehearsal switch; each bank or color has master scene presets; and there are grand master preset switches for the entire board. By means of these any particular scene may be set up, and all the dimmers used in that scene thrown in by touching a single pilot lever. Each of these individual pilots controls a contactor which carries the load current. The master pilots are merely wired in series with their scene pilots and need no contactors. Each contactor is controlled by current routed first through the scene master, then through the scene selector, and finally through the individual pilot switch.

The last type of intensity control utilizing resistance plate dimmers is the motor-drive system which permits not only remote control switching but also remote control over dimmer movements. Fig. 3 shows the control panel for an installation having eight dimmer circuits. This particular unit was manufactured by Cutler-Hammer Inc. of Milwaukee, Wis., and is of the same type as their installation

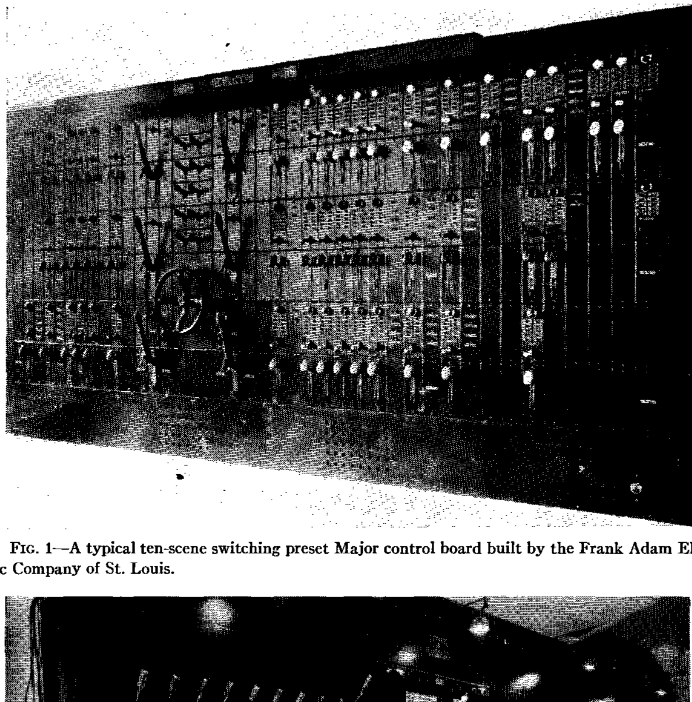

Fig. 1—A typical ten-scene switching preset Major control board built by the Frank Adam Electric Company of St. Louis.

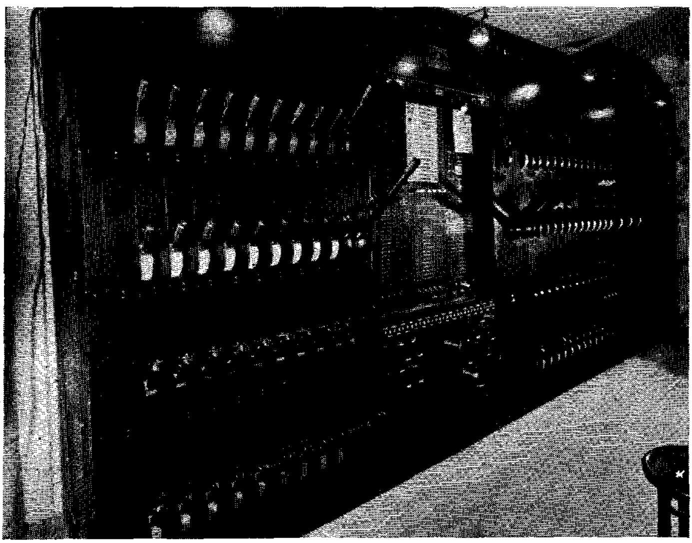

Fig. 2—Controlite board installed in the Bushnell Memorial Auditorium in Hartford, Conn. Built by Trumbull Electric Company with Hyser pilot panel and Ward-Leonard resistance plate dimmers.

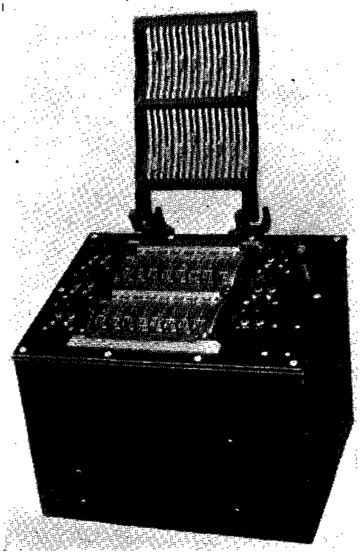

FIG. 3—The control panel for an installation having 8 dimmer circuits as manufactured by Cutler-Hammer, Inc.

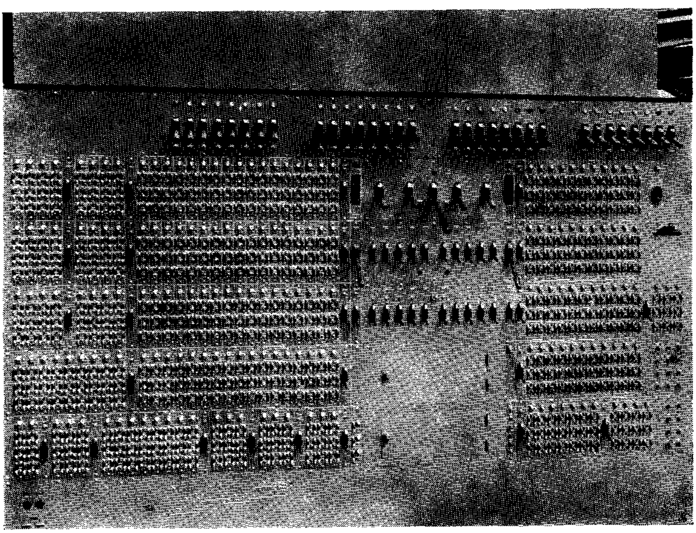

FIG. 4—A recent type of tube-reactor dimmer unit built by the Westinghouse Electric & Manufacturing Company utilizing the Hysterset circuit as installed in the Center Theatre in New York City.

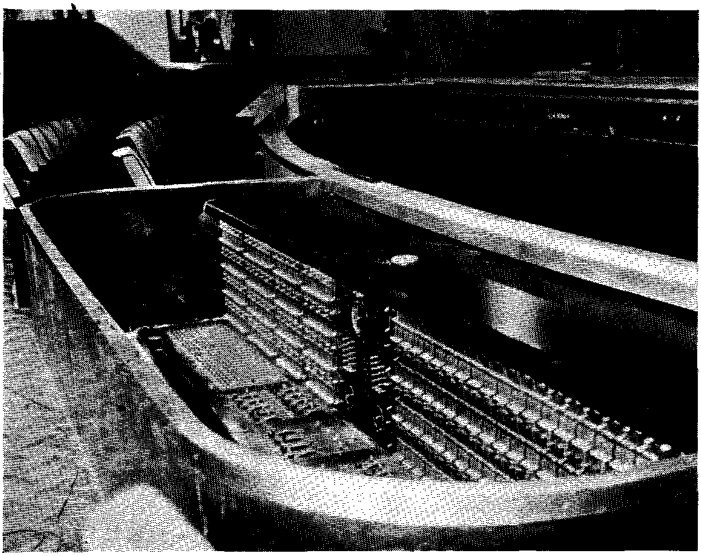

FIG. 5—The control board installed in the Radio City Music Hall, New York City, built by the General Electric Company, is a five-scene preset board controlling thyratron-reactor dimmers by means of small pilot solenoids and switches.

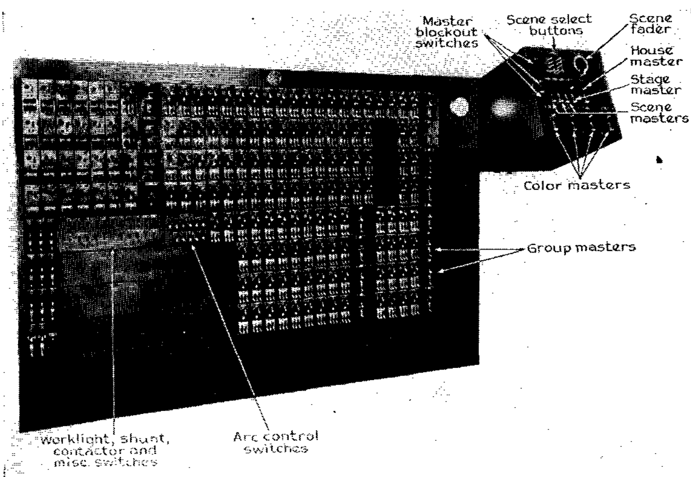

FIG. 6—One of the most recent types of thyratron-reactor control boards as installed in the Metropolitan Opera House, New York City.

for controlling lights in the fountains at Longwood Gardens, Penn. In the apparatus illustrated alternate levers control the position of each dimmer arm, that is, the final intensity of the circuit, while the others control the speed at which the dimmers move to the position preset. The presets are each a part of a resistance bridge circuit which starts the motor driving each plate as soon as that bridge is unbalanced. As the dimmer arrives at the position set, the bridge is again balanced, and the movement stops. The speed controls determine the rate at which the dimmer arm moves to a balance or to that position or intensity set by the presets. Switches on either side of the intensity and speed controls operate contactors used for blacking out one or more circuits, and switch presetting may also be accomplished. The slotted plate hinged at the back of the desk contains a number of stops which may be moved along each slot and clamped in place wherever desirable. When the plate is lowered over the face of the board and the lever at the right moved forward each preset lever is brought as far as the stop in its opening permits. By using a new template for each scene, quick presetting may be accomplished.

A few years ago a console-type control board was built by the Westinghouse Electric & Manufacturing Company for the Severance Hall in Cleveland. It contains all pilot controls for operating remotely the contactors and thermionic tube and reactor dimmers used in the installation.[2]

A later type of tube-reactor dimmer unit built by the Westinghouse Elec. & Mfg. Co. utilizing the hysterset circuit, is installed in the Center Theater in New York City. The control board is illustrated in Fig. 4. Each control unit consists of five scene preset dimmers, one rehearsal master, a pilot switch for each, and a single pilot lamp. The color sections are divided into groups with group masters for each, and variable auto-transformers are used as scene masters. The control levers for these and fader controls are in the central panel.

The control board installed in the Radio City Music Hall, New York City, and built by General Electric Company, is shown in Fig. 5. It is a five-scene preset board controlling thyratron-reactor dimmers by means of small pilot solenoids and switches. Each individual circuit control section includes five intensity preset levers, a rehearsal dimmer, switches for each, a pilot lamp, and a circuit master switch

[2] See I E. S. Transactions, Volume 26, pages 331–359.

for transferring from rehearsal to group master or scene preset. The central panel and horizontal desk contain master controls, faders, slow motion wheels, and a clock.

In the Metropolitan Opera House, New York City, one of the most recent types of thyratron-reactor control boards has been installed. A photograph is shown in Fig. 6. There are only three scene presets for each control unit, but the most efficient and compact equipment is used. When the transfer pilot switch on each unit is at the "rehearsal" or "group" position the first scene preset acts as a rehearsal dimmer. The third position of the transfer switch is "preset" allowing the individual units to be controlled from the master and fader panel. This is a separate section of the board extending up into the chief operator's box which is located behind the footlights like the prompter's box. Here are color masters, scene masters, and a grandmaster, besides a fader and scene selector switches. With one assistant operator to preset the individual controls, the chief can, by means of a few levers, control the lighting circuits over the entire stage and house.

DISCUSSION

A. E. Bailey, Jr.[3]: Electrical control for varying lighting intensities is a very well-chosen title for the paper presented. All-electrical control as such did not, until the past six years, play a prominent part in the varying of lighting intensities. Electro-mechanical control, if I may use the term in the broader sense, was the popular method used in dimming. This includes resistance dimming, either manual or motor operated, and also combined resistance-reactor control.

In order to control successfully, loads which in some instances amount to several kilowatts per circuit, we must appreciate that either we must use relatively large mechanisms or amplify the controlling means. The latter procedure was partly accomplished by the use of the saturable reactor and small resistance-type dimmers to control the direct current for saturation. Obviously, a separate direct-current supply was also necessary.

The advent of a practical electronic discharge device of the industrial type with means for controlling the amount of rectified current output solved among other things two very important problems. It provided a high ratio amplifier and at the same time furnished

[3] General Electric Company, Schenectady, N. Y.