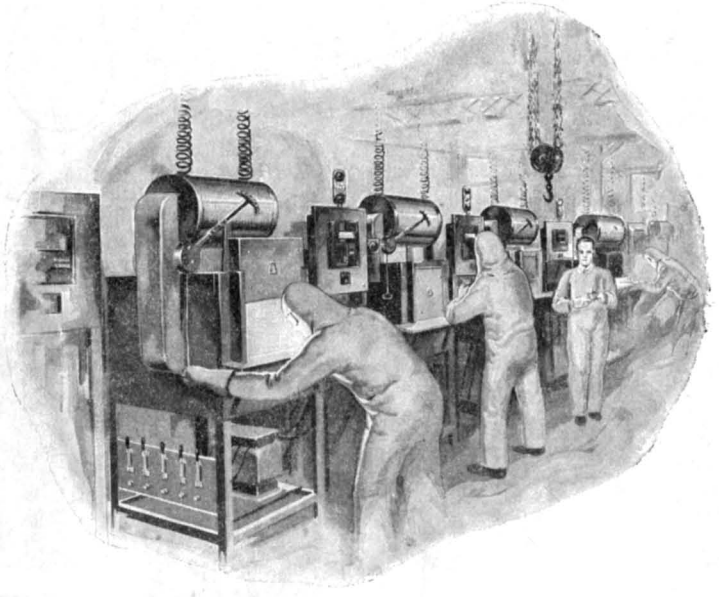
KUPROX

No Bulbs • No Liquids • No Noise

Technical Data AND Information of General Interest

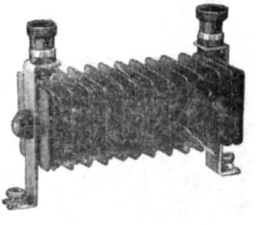
ENGINEERING BULLETIN 3482

December 1, 1927



A single KUPROX disc — a complete rectifying unit in itself. This piece of copper metal will permit an electric current to pass through it in but one direction.

KUPROX is manufactured from stamped copper discs, processed by heating to a temperature just under melting point. Nothing is added excepting oxygen from the furnace atmosphere. When cooled under the proper conditions each individual disc constitutes a perfect rectifying unit. Rectification is due entirely to electronic action. Since no chemical reaction or pressure phenomena whatsoever is involved, this property is retained indefinitely.



A complete full wave KUPROX rectifying assembly, for handling a higher current and voltage than is permissible with a single disc.

MANUFACTURED ONLY BY

The Kodel Radio Corporation

CINCINNATI, OHIO, U. S. A.

A Few Exclusive Advantages of Kuprox Rectification

Fig. 1
A single Kuprox disc—a complete rectifying unit in itself. This piece of solid copper Kuprox metal permits an electric current to pass through it in but one direction.

KUPROX is the ideal and perfect rectifier from every standpoint, fulfilling the dream of electrical engineers and scientists for ages. Among its many outstanding characteristics are

ABSOLUTELY DRY

KUPROX rectifiers contain no acids, oils, or liquids of any kind, consisting of solid metal plates only; no electrolyte of any kind, either dry, moist or wet, being employed.

PERFECTLY SILENT IN OPERATION

KUPROX rectifiers contain no moving or vibrating parts and are absolutely silent under all conditions of operation

REQUIRE NO ATTENTION

The KUPROX slogan "Install It—Forget it" means everything it implies. No adjustments, watering, inspection or replacement is required over extended periods.

CONTAINS NOTHING TO BREAK, OR GET OUT OF ORDER

KUPROX rectifiers contain no glass, filament, jars or other frail parts to break and will withstand the most severe handling without injury

HIGHEST OPERATING EFFICIENCY

KUPROX rectifiers, when used with a properly designed transformer develop a higher operating efficiency than any present known type of rectifier This fact, together with their total lack of attention or replacement, makes their installation ideal for all continuous service, such as trickle charging, etc.

UNFAILING OPERATION

The simplicity and permanency of KUPROX rectifiers insures absolute reliability under all normal operating conditions. Always ready for use, they will operate unfailingly so long as the A.C. supply circuit is uninterrupted.

LOW INITIAL COST

Considering life, operating efficiency and total lack of maintenance required, KUPROX rectifiers cost far less than any other known form of conversion apparatus.

UNIVERSAL APPLICATION

KUPROX rectifiers are available in types and forms applicable to nearly every commercial, radio or scientific requirement, for either the replacement of present types of rectifying apparatus or the total elimination of primary and secondary batteries of all sorts.

CREATES NO RADIO INTERFERENCE

KUPROX rectifiers do not interfere with radio reception in any way—a feature of growing importance.

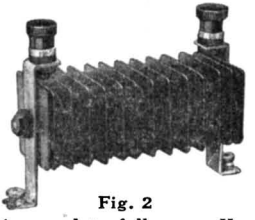


Fig. 2
A complete full wave Kuprox Rectifying Assembly for handling a higher current and voltage than is permissible with a single disc.

Principle of Operation

Considered from the standpoint of appearance and physical properties, KUPROX resembles a disc of sheet metallic copper. From an electrical standpoint, however, it differs from copper in that it permits an electric current to flow in but one direction, viz· from either or both of the outside surfaces (C1-C2, Fig. 3) to the small terminal extension (A) of the disc itself. Practically no current can flow in the reverse direction.

This peculiar behavior is due to a thin layer of copper oxide (B1-B2, Fig. 3), formed directly upon a sheet of pure copper (A) and coated on its outer surface with a thin copper film (C1-C2) The direction of current flow as previously explained, is from the copper films C1 or C2 through the intervening oxide layers B1 or B2 to the underlying copper plate A. If the positive terminal of a battery or other source of energy be connected to "A," and provided the critical voltage is not exceeded, no current will pass through the KUPROX disc upon completion of the exterior surface.

The rectifying properties of copper oxide were first made known to the world by the memorial researches of Professor Branley in 1874 The problem, however, of producing a commercial rectifier of this type appeared unsurmountable until the perfection of KUPROX, owing to the difficulty of establishing intimate and permanent contact with the copper oxide rectifying layer In the KUPROX patented process this is accomplished by first forming the copper oxide under proper heat and atmospheric conditions, and later reducing the outer surface of the oxide layer by chemical means into metallic copper. The resultant copper film, being formed from a portion of the copper oxide itself adheres to, and makes intimate contact with all of the exposed surfaces of the millions of individual copper oxide grains involved.

The advantages of this construction, even to the uninitiated, should be at once apparent over competitive constructions depending for contact upon a soft electrode under tremendous pressure. Due to the lower electrical resistance of KUPROX, a lesser number of rectifying discs is required for a given output, resulting in lower weight, less space and a higher efficiency Perfect contact is established throughout the entire oxide surface, by making contact with any part of the copper film. Inasmuch as there is no pressure phenomena whatever involved, initial operating characteristics are permanently maintained under all normal conditions of temperature and service.

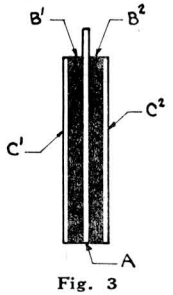


Fig. 3
Cross Section Individual Kuprox Disc.
A—Copper Plate; B1-B2—Rectifying Layer; C1-C2—Copper Films.

Electrical connection is effected with the outside copper films of each individual KUPROX disc by means of a stamped metal connector (B, Fig. 4), this connecting the outside surfaces of the disc in parallel. This connector contains a lug extention on one side arranged for soldering or spot welding to the copper tip of the adjoining disc. In this manner the required number of KUPROX discs, after assembly upon an insulated stud, are securely and permanently connected together for series, parallel or series parallel operation.

From the previous description it should be apparent that the slightest contact of the connecting washer B with the copper film of the KUPROX disc serves to effect perfect contact with the millions of copper oxide grains involved, due to this film being formed directly from the oxide itself and making intimate contact with the exposed surface of each individual grain thereof

No pressure phenomena whatever is, therefore, involved or necessary in the KUPROX construction eliminating all possibilities of increased electrical resistance due to expansion or other causes tending to reduce the original contact pressure.

To protect KUPROX Rectifying Unit assemblies from atmospheric oxidization or deterioration they are coated with a thin layer of moisture and acid proof enamel This also serves to protect them from acid spray if employed for battery charging purposes.

KUPROX is the only true *Metallic disc* rectifier existing at the present time and should not be confused with other so-called types of dry rectifiers. All of these (with the single exception of a copper oxide rectifier manufactured by a prominent Railway Signal Co.) are electrolytic in nature and consist of an electro-positive rectifying metal such as magnesium, together with an electro-negative electrode of aluminum, brass, iron, etc., with a *cake of compressed dry electrolyte* such as copper sulphide, interposed between, the entire assembly being bolted together under tremendous pressure to insure proper contact and rectification action.

Such rectifiers are essentially electrolytic in action and differ only from the well-known types of electrolytic cells in that they employ dry, instead of liquid electrolyte. They are, however, relatively short lived, and instead of consisting of but a single metallic disc, per rectifying element as KUPROX, contain, as before stated, *three* separate, co-operating discs per element, requiring the maintenance of tremendous pressure to effect rectification.

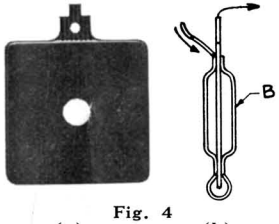


Fig. 4

(a) (b)

(a) Individual Kuprox Rectifying Assembly

(b) Cross Section View, showing Connector Strap.

KUPROX is the only *metallic disc* rectifier each individual disc of which, by and of itself, constitutes a *complete, independent* rectifying unit. *All others* necessitate the use of one or more separate co-operating electrodes and require that these component parts be compressed under enormous pressure to insure electrical contact and rectification. Basic patents owned or controlled by our company cover this basic principle of individual metallic disc rectifier construction in all its various phases.

Theory of Operation

While it can be truthfully stated that the underlying theory of all rectification is far from understood, careful investigation and extended research leads us to the conclusion that rectification in KUPROX is a *"point to plate"* phenomena, the underlying copper disc being the required extended 'plate' surface and the corners of the individual copper oxide grains representing the required 'point' contact. It is a well-known fact that wherever an extremely *fine* point is located near, *but not in actual contact with* a *flat* conducting surface of larger size, there is a tendency for current to pass more freely from the *point to the plate* than in the opposite direction.

This action is quite similar to that which would occur were a quantity of marbles poured through a conical funnel, held an inch or so above a table. The marbles would

flow out of the small end of the funnel quite freely provided the end of the funnel was held sufficiently far above the table surface, but their flow in the opposite direction would be seriously restricted, even though the direction of the gravitational attraction be reversed.

Letting each individual grain of copper oxide (it is estimated that there are several million such grains to the square inch of KUPROX) represent a funnel; the underlying copper plate, the table mentioned in the above analogy and the electrons of the electric current the marbles, the principle of KUPROX rectification may be quite easily understood. Here, however, the funnels or *electric valves* are of atomic size, each individual copper oxide grain containing millions of individual copper and oxygen atoms, the corner points of the copper atoms touching the flat surface of the adjoining copper atom with an oxygen atom interposed between. There are through literally billions upon billions of small electric "funnels" or valves in a KUPROX disc, each tending to obstruct the flow of an electric current in one direction, but permitting it to pass comparatively unrestricted in the opposite way

It should be apparent from the above explanation and previous description that KUPROX rectification is entirely electronic in nature and that no chemical reactions whatever are involved. Consequently unless a KUPROX disc is heated to a temperature that would permit a rearrangement of its molecular structure (this occurs at about 600° F.) there can be no deterioration, and KUPROX Rectifiers will function indefinitely

Physical Characteristics

The physical characteristics of KUPROX discs are much the same as copper. They withstand, without injury excessive vibration and rough handling. Bending, however, causes the oxide coating to break off reducing rectifying area only, but not otherwise affecting rectification properties. Immersion in water affects rectification but temporarily When thoroughly dried, original properties are completely restored. A coating of acid proof enamel applied after assembly effectively protects the individual discs from acid fumes and destructive atmospheric gases.

KUPROX Rectifying Discs may be readily manufactured in any desired size with an oxide rectifying coating on one or both sides of the underlying copper plate. It is obvious that for requirements necessitating a relatively heavy current the latter is preferable, since both of the rectifying layers may be connected in parallel, giving the effect of two discs in one. Where small currents at relatively high voltages are to be handled the single coated discs are desirable, since mechanical assembly is rendered much simpler, it being merely necessary to stack such discs in piles, the oxide coating of one disc resting against the underlying copper plate of the adjoining unit.

Connections between adjacent discs may be of any metal, commercial plate tin (tin-plated iron) being ordinarily used because of its low cost and the ease with which it may be soldered. In the later designs these connecting discs are somewhat larger than the rectifying plate, thereby serving to protect it from mechanical injury The required number of rectifying discs and connected plates are assembled upon an insulated stud and clamped together. Further protection from mechanical injury is afforded by enclosing within a housing or case of suitable design.

Extreme cold or heat does not in any way affect the physical properties of KUPROX. Unless properly designed for such purpose, KUPROX rectifiers operated at excessively high temperatures (above 140° F.) will increase slightly in electrical resistance with time. This increase in resistance is entirely a function of the maximum temperature attained, and no further increase in resistance will occur, provided the original maximum temperature is not again exceeded. Consequently the furnishing of a KUPROX rectifier for operating at excessive temperatures (200-250° F.) involves merely the use of slightly larger rectifying discs than where only normal operating temperatures are encountered.

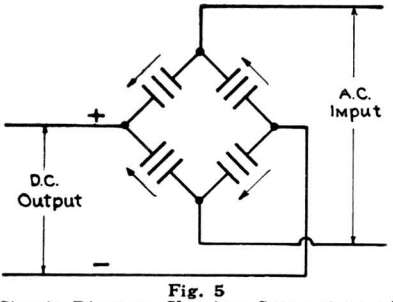
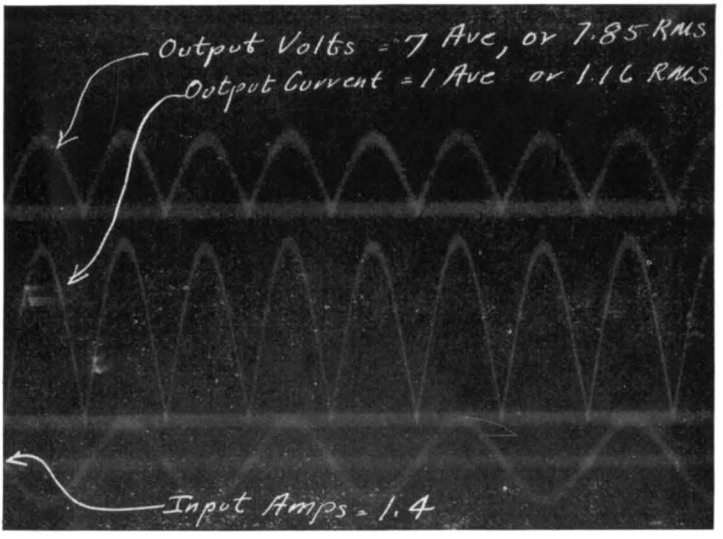


Fig. 5
Circuit Diagram Showing Connections of Twelve Individual Kuprox Discs for Full-Wave Rectification.

Electrical Characteristics



Oscillogram No. 6, illustrating the behavior of a full-wave KUPROX rectifier. This oscillogram forcibly illustrates the reason why KUPROX rectified current will operate all electromagnetic devices, such as telegraph sounders, relays, etc., perfectly, without the use of any filtering apparatus whatever. Note the perfect rectification obtained, which shows absolutely no leakage current whatever.

VALVE ACTION

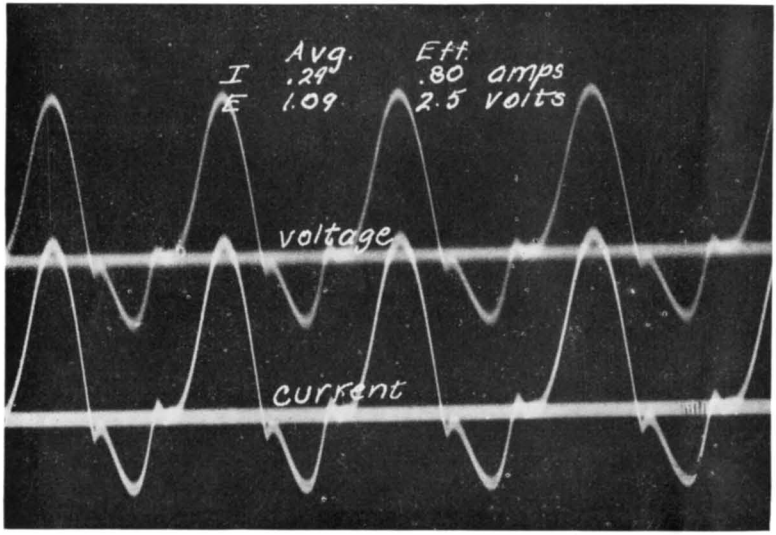
The valve action of KUPROX is practically perfect, as oscillogram No. 6 illustrated above, shows. Not only is there absolutely no reversal of current or voltage, but the slightest amount of inductance in output circuit, such as that contained in the conducting leads, has a pronounced filtering effect, and tends to maintain a minimum sustained current during reversal period. This inherent characteristic of KUPROX rectification makes the substitution of unfiltered, rectified A.C. power in many fields heretofore restricted to the primary and storage battery an accomplished fact.

As will be observed from the above oscillogram, wave form of the output current and voltage, is an exact reproduction of that of the line current. Rectification is not dependent upon electronic emission from a heated filament, or the puncturing of a rectifying film, and is therefore instantaneous. These ideal and perfect rectifying characteristics of KUPROX can best be appreciated by comparing oscillogram No. 6 above, with those of other well-known types of rectifiers appearing on the following pages.

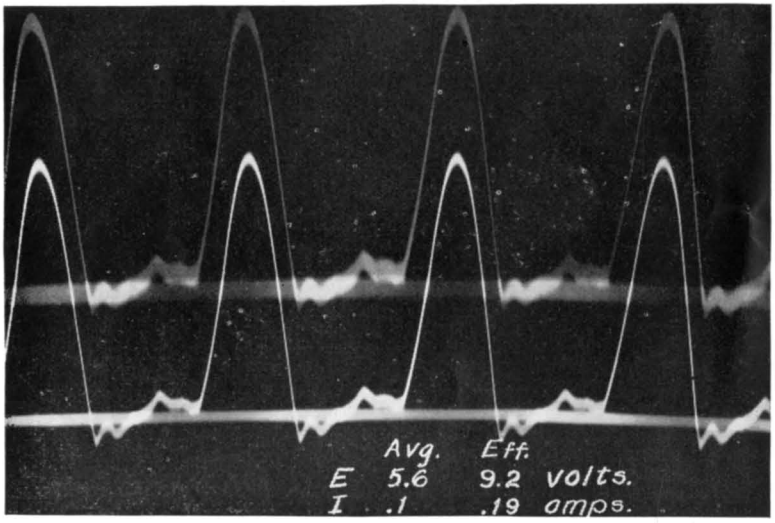
Owing to the comparatively few KUPROX rectifying discs required, full-wave rectification is quite easily obtained from a single phase A.C. supply source, by utilizing the well-known 'bridge'' rectifying circuit illustrated in Fig. 5 This circuit necessitates the use of but a single transformer secondary winding. Single or half-wave rectification may be readily obtained wherever desirable, by using the necessary number of KUPROX discs, connected in series.

EFFICIENCY

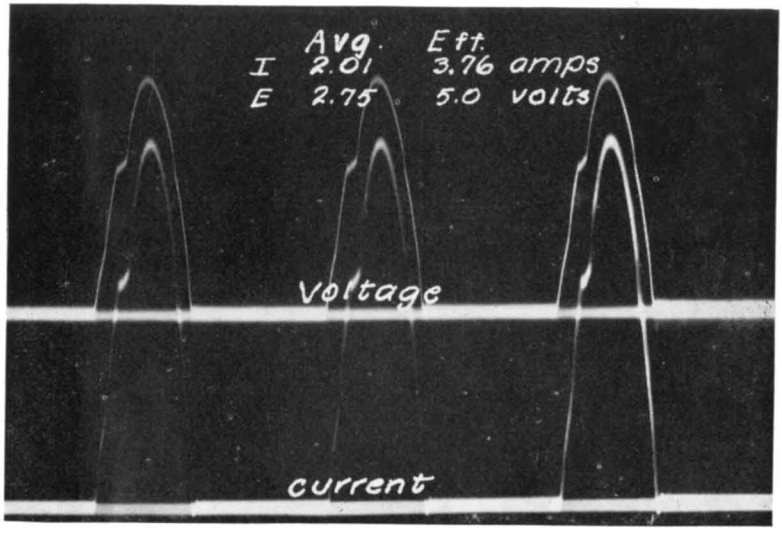
Due to the perfect rectification and extremely low resistance of KUPROX rectifiers, their efficiency is immeasurably superior to all competing types, averaging 57% under normal conditions. Curve No. 11 illustrates the efficiency of a four-disc, full-wave unit, at various current values, ranging from 10% to 300% of rated output. As will be noted therefrom, efficiency is practically constant between all current values of from 150% above and 70% under normal rating. This high initial efficiency is maintained indefinitely providing maximum operating temperature for which rectifier was designed is not exceeded.



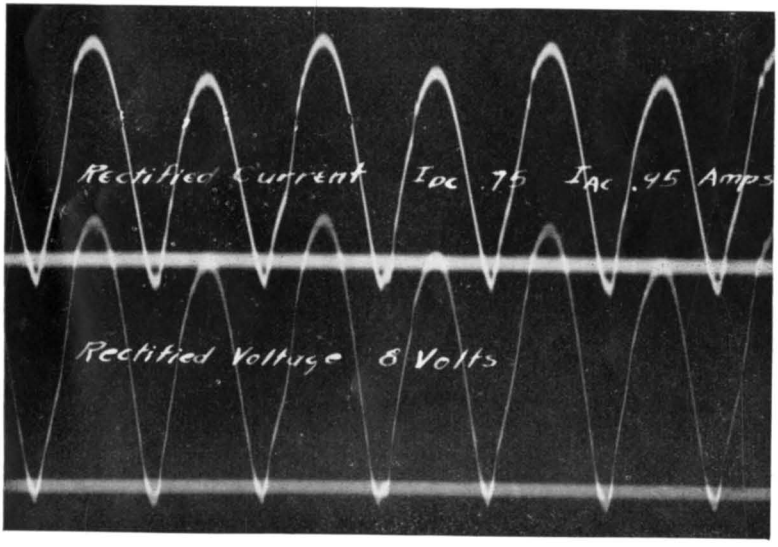
Oscillogram No. 7, covering the operation of lead-aluninum, ammonium phosphate rectifying jar. Note especially severe reverse current leakage and imperfect valve action.



Oscillogram No. 8, illustrating the behavior of a well-known tantalum-lead-sulphuric acid electrolytic rectifying cell, widely used in commercial work. While rectifying action is immeasurably better than the above, this rectifier too, is far from perfect in its valve action.



Oscillogram No. 9, illustrating the behavior of the familiar bulb type rectifier. While illustrating perfect valve action and showing practically no reverse current leakage, wave form is somewhat irregular.



Oscillogram No. 10, illustrating the behavior of a well-known dry electrolytic (magnesium-copper sulphide-aluminum-pressure) full-wave rectifier. Note imperfect rectification and severe reverse current leakage.

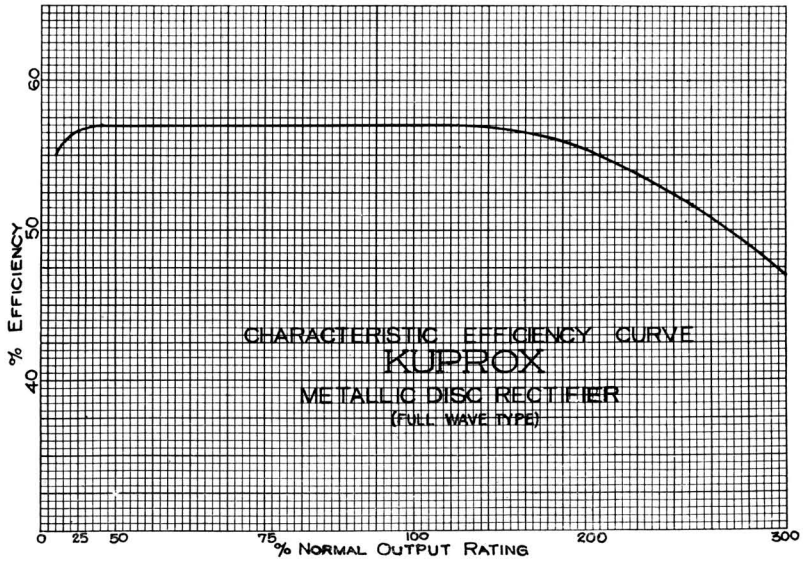


Fig. 11, illustrating the uniformly high efficiency of KUPROX rectifiers at various loads. This runs practically uniform at 57% for all load values between 10% and 150% of normal rating.

POWER FACTOR

The power factor of a full-wave KUPROX rectifier is approximately 100%, thereby permitting the use of transformers and supply circuits of minimum size and cost. The resultant saving in transmission lines and generating equipment on large installations, such as Railway Signal Service, is of great economical importance.

LIFE

The life of KUPROX rectifiers is indefinite, provided they are not severely overheated for extended periods. Rectification, as previously explained, is entirely electronic in nature, and involves no chemical reactions or other physical phenomena. Unless the molecular structure of the rectifying oxide layer be completely or partially changed, (and this can be accomplished only by prolonged heating at high temperatures), this property is permanent and unchangeable.

When subjected to an abnormal temperature (in excess of 180° F.) for an extended period, a gradual and permanent increase in electrical resistance occurs. This change is almost imperceptible at the lower temperature, but at 600° F. rectification properties disappear altogether. For each maximum temperature value attained there appears to be fixed and definite change in resistance, and thereafter, unless this maximum temperature be again exceeded, no further change takes place.

The continued operation of KUPROX rectifiers at their initial or rated output values involves merely the use of sufficient rectifying area and adequate means for radiation of heat developed. Where intended for use under adverse climatic conditions, such as in furnace rooms, tropical countries, etc., the pre-treatment of such KUPROX units at the highest operating temperature ever likely to be attained, will effectively stabilize their resistance characteristics, and insure continued operation at these excessive temperatures.

KUPROX rectifiers, properly designed for the service intended, will therefore continue to function indefinitely without any deterioration or drop in output, and will outlast any other type of electrical equipment if merely protected against mechanical injury

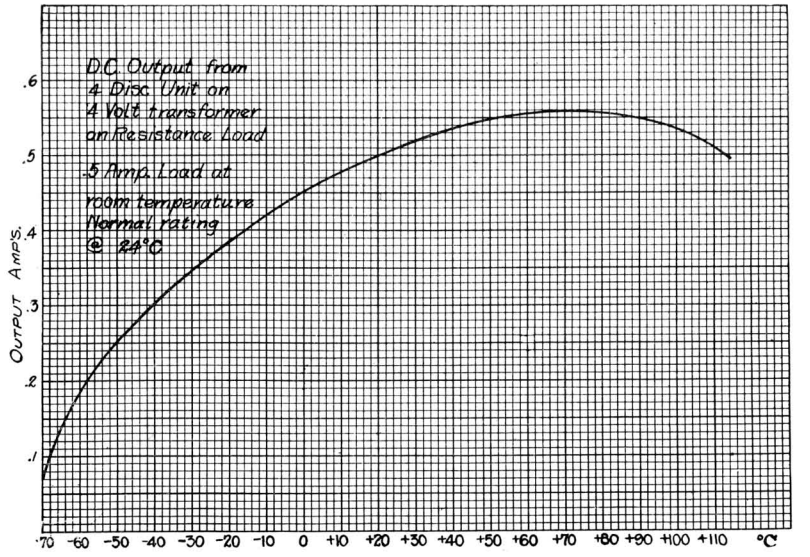


Fig. 12, illustrating resistance change with varying temperature. No allowance whatever is made in the above curve for natural increase in temperature while operating, temperatures shown being that of the individual rectifying discs themselves.

EFFECT OF VARYING FREQUENCY

KUPROX rectifiers operate with equal efficiency upon all commercial frequencies of from 15 to 1000 cycles. An investigation covering their behavior on the higher frequencies up to 10,000 cycles, is now in progress, and the results thereof will appear in the next edition of this bulletin.

EFFECT OF TEMPERATURE VARIATIONS

Any variation in operating temperature causes a corresponding slight change in the electrical resistance of a KUPROX rectifying unit. This effect, however, instead of resulting in an increased resistance with increase in temperature, as is characteristic with most metals, is negative, the resistance of KUPROX decreasing with increased temperature.

Curve No. 12 illustrates this phenomena, which averages —1 1% for each °C. change, compared to +.4% per °C. for pure copper. This characteristic is a decided advantage in most cases, as it counteracts the natural increase in resistance of transformer windings and circuit leads due to the heating thereof with use. Where undesirable, however, this negative effect can be completely counterbalanced by use of suitable ballast resistance, or similar device.

It will be noted from the above-mentioned curve that the maintenance of a given output at extremely low temperatures (—35° F.) is merely a function of design (disc surface) and therefore a matter of no serious commercial importance.

OVERLOADING

KUPROX rectifying units will withstand, without injury and increase in current value, which does not cause a rise in temperature exceeding 140° F.

Severe overloads, provided they are not continued long enough to cause excessive heating, are not injurious to KUPROX rectifiers in any way. Even momentary overloads of 1000% produce no permanent ill effects. For continued maintenance of output, rated current and voltage values assigned should not be exceeded, unless proper provision for dissipating the increased heat be made.

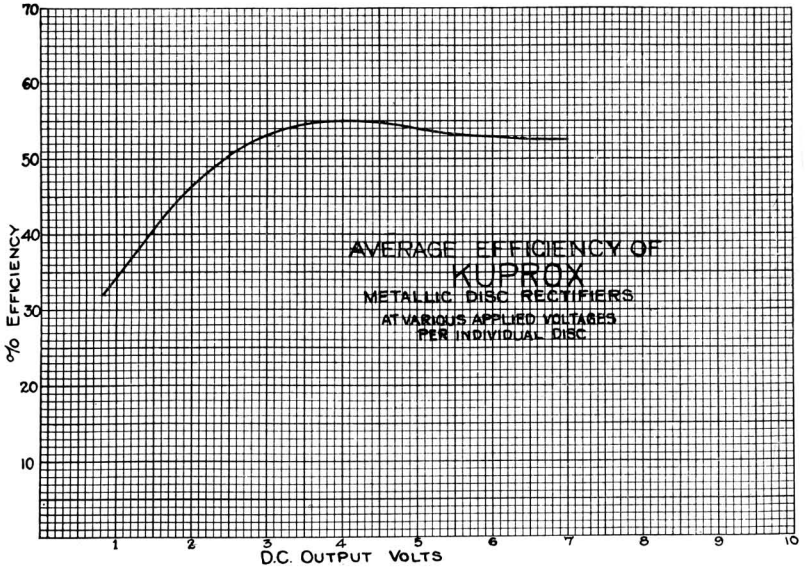


Fig. 13, illustrating operating efficiency at various applied voltages per KUPROX disc. Maximum efficiency is reached at 4 volts per disc, which is the normal operating disc voltage in all standard constructions.

CURRENT DENSITY

Like any other metallic conductor, the maximum current which can be carried by a KUPROX disc, depends upon the I^2R losses occuring therein, and the efficiency of heat dissipation employed. Consequently the maximum permissible current density for a given rise in temperature depends solely upon the method of heat dissipation employed, since the resistance per unit area is nearly a fixed quantity

Where no means of artificial cooling is employed, and using standard commercial spacing of $\frac{3}{8}$" it has been found that a current density of .2 amperes per square inch of rectifying area, will insure continuous operation with not more than 20° F. rise in temperature above surrounding air. With the help of additional radiating plates, forced ventilation, oil immersion and wider spacing, or a combination of these accelerators, this may be increased to many times this value.

Wherever a high output, combined with low initial cost is required, the artificial cooling means suggested above are entirely practical.

VOLTAGE RATING

This appears to be a fixed value for a given efficiency and ratio of rectification, and is entirely independent of rectifying area. Curve 13 illustrates the efficiency of KUPROX rectifiers, at varying voltages. As will be noted therefrom, maximum efficiency is developed with an applied potential of four volts per disc. This is the normal voltage rating of a single KUPROX rectifying disc.

In the event of applying an excessive voltage to a KUPROX rectifier, efficiency drops off rapidly resulting in the generation of considerable heat. This, however, will do no harm, so long as it does not produce an excessive temperature. In the event voltage is increased to approximately 70 volts per disc (nearly 2000% above rated value) rectifying film will puncture, temporarily destroying rectification properties. As soon as this excessive voltage is removed, the puncture will, in most cases, "heal," and original rectifying properties be restored.

EFFECT OF STATIC DISCHARGES

The effect of static discharges, surges and similar phenomena upon KUPROX rectifiers have been carefully studied, and providing the increased value of current passing there through is not sufficient to melt or fuse the copper plates or connectors, has been found to result in no permanent harm. Punctures of the rectifying layer, due to high voltage discharges, heal immediately upon the removal of such force, and in no way impair the operation of the rectifier thereafter.

Fields of Application

The term "rectifier" is thought by many to indicate a device, the usefulness of which is confined exclusively to the charging of storage batteries. While this is true of a large majority of known types of rectifiers, this is due to their limitations, either in capacity efficiency or adaptability and not beacuse of any restriction to this small important field.

As a matter of fact, battery charging represents but a small proportion of possible rectifier application. Wherever direct current is required for any purpose whatsoever and a commercial alternating power supply line is available, a rectifier of the proper type is either absolutely essential or can be used successfully and economically to replace any means of direct current supply at present employed.

In many instances at present, batteries of either the primary or storage type are believed necessary owing to the inability of present rectifiers to supply a perfectly steady and uniform direct current. The development of KUPROX—the perfect and final rectifier—has opened up entirely new fields for the application of rectified energy and is destined eventually to replace both primary and storage batteries, in many instances, together with all present forms of rectifying and converting apparatus.

At the present time rectifiers of various types are extensively used in the electrical and associated industries. Just a few of the many such applications, all of which can be better and more efficiently handled by KUPROX, are:

Electrochemical operation, such as the charging of storage batteries, electroplating, electrorefining, decomposition, etc.

The operation of electric arcs, both for series street lighting, as well as motion picture projecting, etc.

The operation of variable speed and heavy torque motors, such as employed in street railway, printing and other fields.

The rectification of high voltage current for dust precipitation, the operation of X-ray apparatus, etc.

For radio transmission, as well as supplying the required "A" and "B" current for operating receiving sets from a lamp socket.

In addition to the above well-known fields of rectifier application, KUPROX opens up fields which have been thought forever restricted to batteries, or similar uniform sources of current supply. Just a few of these many new fields of application are:

The operation of all electromagnetic apparatus, such as telegraph sounders, relays, electric hammers, bells, alarms, time-clock mechanisms, etc., without batteries of any sort.

The furnishing of current for telephone talking, ringing and similar circuits.

An electric valve permitting current to pass in but one direction. For example, as a reverse current relay and automatic cutoff, in auto lighting and starting systems, sub-station control equipment, etc.

The application of KUPROX rectifying current to such applications requiring an absolutely steady and uniform current supply is made possible only through the perfect rectification obtained. In addition to this superior rectification achieved, KUPROX possesses the advantages of simplicity, permanency high efficiency compactness, and reasonable first cost, and fulfills in every other respect the electrical dream of ages—an electrical conductor, preferably of metal, permitting electric current to pass in but one direction.

Patent Notice

As has been previously stated, the rectifying properties of copper oxide have been a matter of record since 1874 Various inventors, principally Garretson (U S. Patent No. 929582), Midgley (U S. Patent 756676), etc., have attempted, at various times, to make use of this basic principle in various ways. Because of these disclosures, the basic idea of a copper oxide rectifier is obviously unpatentable, invention being limited entirely to construction details, especially as to the method of effecting contact with the rectifying oxide layer.

KUPROX rectifiers differ only the previously disclosed types of Garretson and Midgley (both of which patents have expired) in the method employed to establish intimate contact with the copper oxide crystals. Instead of employing a separate impressionable electrode under heavy pressure, as these and other inventors had attempted, a thin outer layer of the oxide formation is reduced, through chemical means, back into metallic copper.

This revolutionary construction, perfecting as it does one of the oldest types of rectifiers known to the scientific world, is exclusively a Kodel product. Basic patents covering all phases of construction and processes, are pending in nearly every civilized country in the world, these being either owned or controlled by our Company It is the opinion of several nationally known Patent Experts, whom we have called upon to express a legal opinion in this matter, that KUPROX rectifiers not only do not infringe any existing valid U. S. or foreign patent, but that the various present pending KUPROX applications, when allowed, will dominate and control the dry rectifier field.

The above facts are mentioned merely for the benefit of prospective customers who might have been wrongly advised by our competitors, regarding the true situation in this respect.

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