responsible for corrosion may be produced by the electrolysis of soluble lime or alkali salts. Sodium chloride or ordinary table salt is used sometimes to thaw out street car switches in winter and occasionally finds its way into cable ducts where it is converted into caustic soda at the surface of the cable sheath as a result of current flow from the earth to the sheath. This type of corrosion also occurs in newly manufactured concrete conduits owing to the presence of free lime in the concrete.

It might be inferred, from this summary of the mishaps which may befall a lead sheath, that underground cables are a rather vulnerable point in the Bell System plant. As a matter of fact, the losses of cable due to corrosion are relatively small, thanks largely to care in the selection of conduit material, and to the skill and vigilance of the Plant Departments' forces. But when it is recalled that the Bell System has in service some 55,000 miles of underground cable, containing nearly thirty-eight million miles of wire, it is evident that no pains are too great to find the causes and so prevent corrosion of the protecting lead sheath.

High-Strength Aluminum Alloys for Diaphragms

By W. J. FARMER
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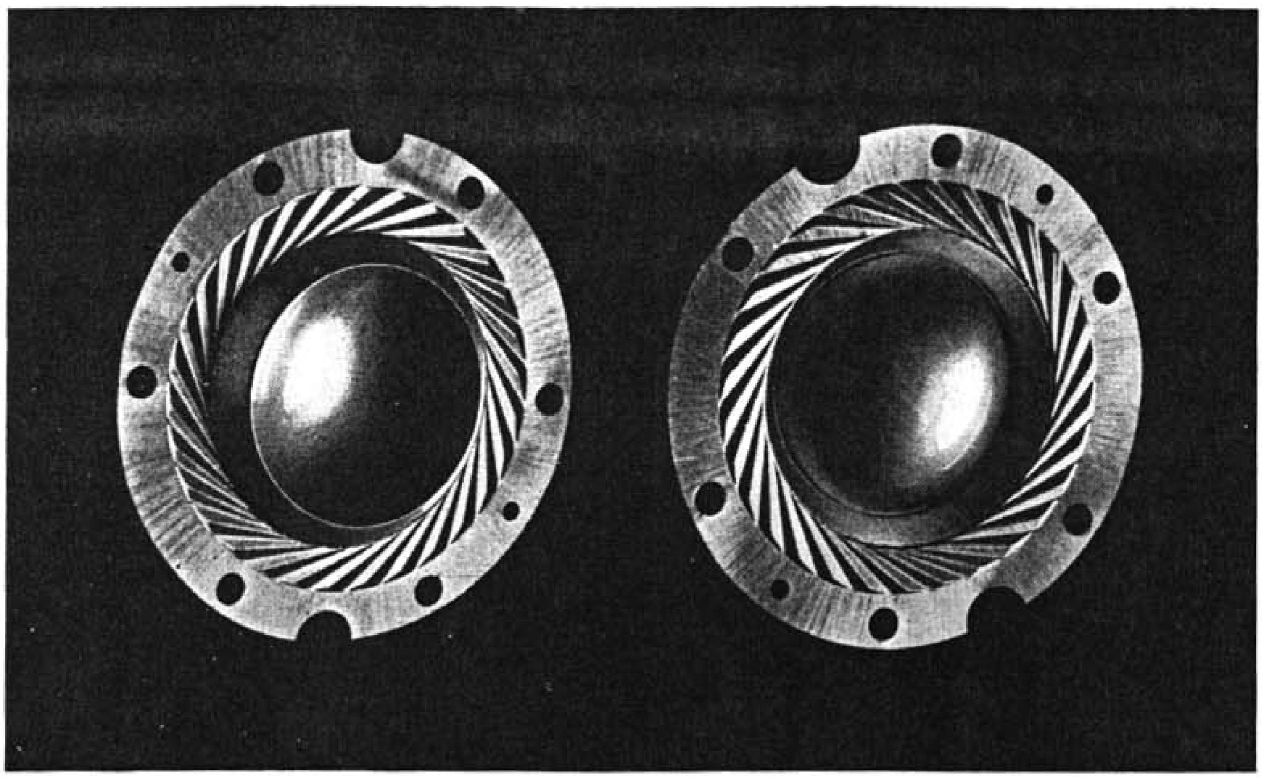
FOR the past ten years, aluminum alloys have to an increasing extent taken the place of steel, brass, bronze and other more common metals in many fields of industry. Used in the form of thin sheets, one group of the alloys has brought marked advantages to certain of the newer developments in telephone transmitters and receivers. There, used as diaphragms, they contribute prominently to high operating efficiency.

This group presents such a range of mechanical properties that those desired for almost any use can be secured by choice of an alloy of suitable composition, coupled with appropriate metallurgical treatment. Since strength, elongation and ductility can be controlled within wide limits, the necessary values in these respects can be secured in any cases but the most exacting. The greatest advantage, of course, is the low density, about a third that of steel. Another major advantage with most of the alloys, not otherwise found in nonferrous metals, is that parts can be increased in strength by heat treatment when they are in final manufactured form. Less important, manufacturing operations are facilitated by the low modulus of elasticity. It is about a third that of steel, so that the force needed for bending and other forming operations is about a third that which would be required

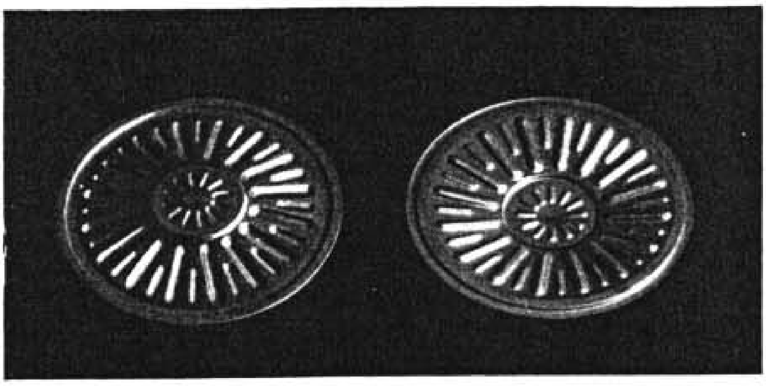


Formed diaphragm for a WE-555 Receiver, made of 17ST Alloy 0.002 *inch thick. It is used principally with sound-picture apparatus*

with steel parts of the same strength. The alloys are not immune to corrosion, but are much less subject to it than many of the materials which might be used in their stead. A quite different consideration makes them available for use in large quantity: the cost, although commonly considered high, is about the same as that of steel, when taken on the basis of volume rather than of weight. These facts, therefore, mean that there are available materials higher in ultimate tensile strength and in elastic limit than mild steel, with approximately one third the weight for a given part, and costing about the same per part.

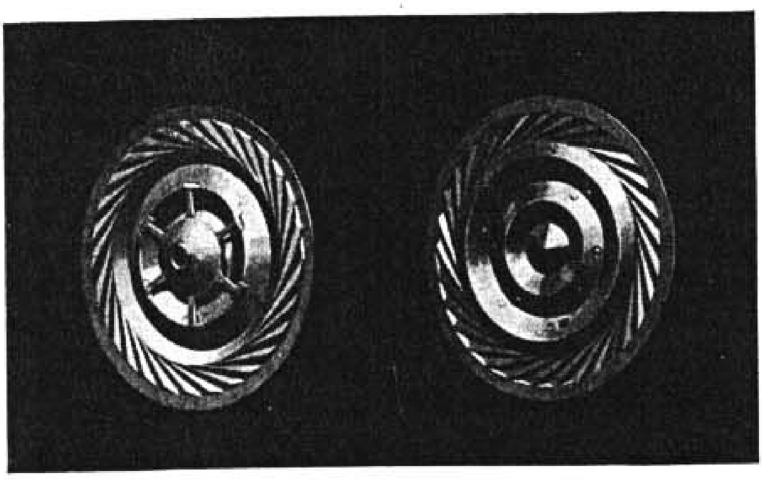
Many different compositions are available, but discussion will be confined to the two alloys commonly used in thin sheet form for diaphragms. These are the 17S or duralumin alloy and the 3S alloy. They are known by these numbers in accordance with the code adopted by the principal supplier, wherein each alloy is identified by a number followed by the letter S. That code reveals the chemical composition only; the temper and metallurgical treatment are given by a supplementary code consisting of one or more letters. These symbols do not tell the complete history, but only the processes revealing the current condition. Annealing is represented by O, and cold-working by H. W represents heat-treating followed by quenching only, T those processes followed by aging, and RT the more common sequence of heat-treating and quenching followed successively by aging and cold-working. The material for a particular diaphragm may therefore be 17SO at one stage of manufacture, after it has been annealed to facilitate forming, and at the end, when it has been hardened for use, be 17ST.

Duralumin is made up of approximately 4% copper, 0.25% silicon, 0.5% each of manganese and magnesium, and the remainder commercially pure aluminum. Although the total percentage of alloying ingredients is small, this material, whose density is very little higher than that of pure aluminum, can be brought by means of a tempering process to a tensile strength of 55,000 pounds per square inch with a substantial degree of ductility. The tensile strength may be raised by subsequent cold-working to at least 70,000 pounds per square inch; at the same time the property of ductility is almost entirely lost. Tempering may may be produced in various ways, but the usual method consists of heating the material to approximately 510° C., quenching it in water and allowing it to age at room temperature. Heating at this temperature for seven to ten minutes is usually sufficient for thin stock. The hardening proceeds very rapidly at first and then at a gradually diminishing rate until the maximum is reached at the end of five days. After heating and quenching, hardening may be carried out more quickly by maintaining the parts at 100°C. for a period of forty hours, a process known as artificial aging. When a part is to be made from heat-treated duralumin, there must be no delay between heat-treating and forming else the material will become so hard that it may fail in the course of the forming operations.



Diaphragm of handset transmitter; the material is 17ST Alloy

For use in several pieces of apparatus it has been necessary to raise the ultimate tensile strength of the 17S alloy to 75,000 pounds per square inch, and in special cases to as much as 85,000-95,000 pounds. This was accomplished by reducing the cross-sectional area about 90% through operations known as cold-working—swaging, drawing, rolling, and other cold processes. Material so handled, characterized by high tensile strength and elastic limit and by very small elongation, is specified as 17SRT. For other operations, annealed material is reduced 80% in thickness by similar cold operations. The material thus produced, 17SH, has an ultimate tensile strength of 45,000 pounds per square inch and negligibly small elongation.



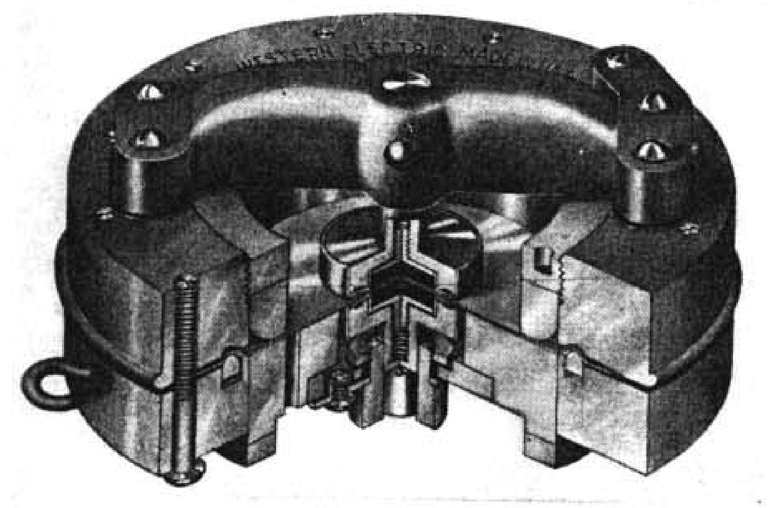
Reproducer for an Orthophonic talking machine, of 3SH Alloy; the spider is of hard commercially pure aluminum 0.014 inch thick

The other alloy extensively used, 3S, consists of commercially pure aluminum to which has been added approximately 1¼% manganese. In the annealed state it is about 25% stronger than annealed pure aluminum, and of slightly lower elongation. By cold-working its tensile strength may be brought up to about three times that of annealed aluminum, with a high ratio of elastic limit to ultimate strength. This alloy is therefore an extremely useful material in cases where severe forming is required. It does not, however, respond to heat treatment.

Both of these alloys may be rendered soft and ductile by annealing at approximately 343°C. at any time in the manufacture of parts if the hardness was caused by manufacturing operations carried out on formerly annealed material. Where the hardened condition was produced by heat treatment, as may be the case with duralumin, annealing requires heating for a longer time and at a higher temperature, followed by very slow cooling. Some of the deeply formed diaphragms are annealed a number of times in the course of production to remove the hardness resulting from the stresses of the forming operations.

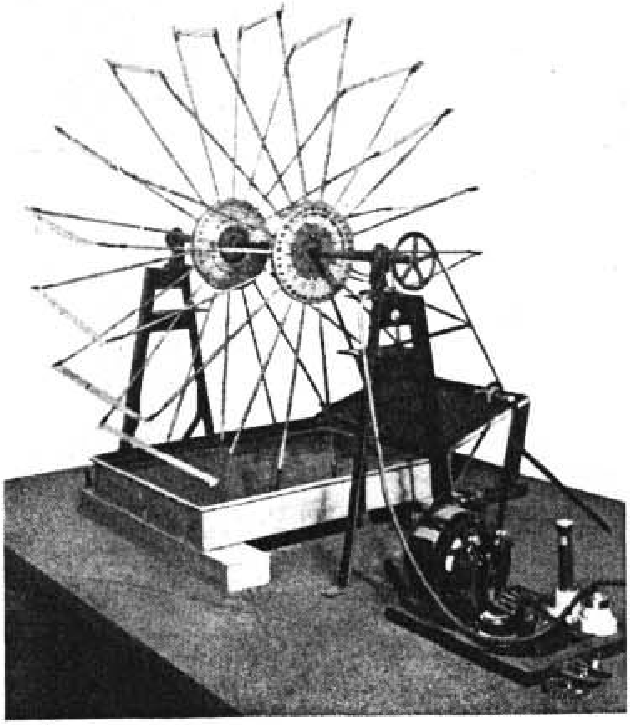
The alloys are received at the Hawthorne plant of the Western Electric company from the manufacturer in coils 0.020 inch thick. There they are rolled into ribbons of the thickness wanted, and generally just wide enough to make the blank for a single diaphragm. In all cases the material is buffed as it comes from the rolls. By this operation the resistance to corrosion is raised materially by the highly polished surface obtained. The thinnest material in use at present is a duralumin alloy for spacing washers of condenser transmitters; its thickness is only 0.00075 inch, about a sixth that of the paper on which the RECORD is printed. The most common thickness is 0.003 inch, and the thickest material commonly used is 0.005 inch.

Aluminum and its alloys are generally considered resistant to corrosion, and for thicknesses greater than 0.020 inch that is the case. In several pieces of apparatus the alloys are used in sheets 0.001 inch to 0.003 inch thick; obviously a very small degree of corrosion would be enough to reduce the cross-section of those parts by an extent sufficient to cause failure. Corrosion has therefore been studied intensively on pieces of apparatus and on the sheet stock as well. Since interest was mainly in objects 0.0017 inch and 0.003 inch thick, the tests were carried out on tensile samples cut from materials of these thicknesses. Several methods of corroding the alloys artificially have been



387-W Transmitter, for broadcasting. The diaphragm, which passes between the two carbon buttons, is a sheet of 17SRT Alloy, 0.0017 inch thick, stretched by the clamping ring tried, principally spraying with a salt solution, outdoor exposure tests on the roof and intermittent immersion in corroding solutions.

Our most dependable corrosion test makes use of a device resembling, on a small scale, the Ferris wheels of



Ferris wheel for corroding the aluminum alloys artificially

amusement parks. The device was developed by the Chemical Research Department. The tensile samples after measuring and cleaning are clamped into position at the circumference of the wheel, which is then rotated slowly and evenly for eighteen hours. They dip successively into the corroding solution at the bottom of each revolution and then drain and dry while completing the cycle; the corrosion occurs during drying. At the end of the corroding process the samples are removed and are broken in a tensile testing machine. Uncorroded samples from the same stock are also broken, for comparison. Protective finishes are appraised with the same piece of testing apparatus; coated and unprotected samples are exposed together, and then the ultimate tensile strengths of both groups are determined.

As rated by this machine chemically pure aluminum was highest in resistance to corrosion, and commercially pure aluminum second. Then followed a number of alloys, depending for their order on the treatment they had undergone as well as on their composition. The corrosion resistance is also determined in part by the surface. As might be expected, when it is smooth and highly polished it affords a considerably smaller opportunity for corrosion to start than does the somewhat rough gray surface commonly seen on aluminum cooking utensils.

Choice of the alloy for a particular use cannot be made entirely on the basis of corrosion tests, of course; mechanical requirements at times are such that a particular alloy and temper must be used regardless of its low resistance to corrosion. For such cases the problem of increasing the resistance to corrosion, in order to insure that the part will last through the life of the apparatus, has been studied in the Chemical Laboratories. Either one or two coats of varnish, sprayed onto a finished part, affords satisfactory protection but adds appreciably to the weight. Thin Bakelite varnish is also satisfactory for alloys whose mechanical properties are not changed by the baking operation.

An interesting effort to combine moderate mechanical strength with maximum resistance to corrosion is the Alclad alloy, developed and manufactured by the Aluminum Company of America. Sheets are made by rolling a slab made of duralumin or one of the other alloys in the center and aluminum on the outside. Thicknesses of the layers are chosen to give a finished sheet of duralumin 0.002 inch thick covered on each side with 0.0005 inch of pure aluminum. Users can secure Alclad 3S, Alclad 17S, or sheets made with other alloys in the center, to suit their needs. Particular care is needed, however, in heat-treating Alclad sheets, since there is a tendency, while the material is hot, for the copper to diffuse from the center layer into the aluminum and so to reduce the corrosion resistance of the protective layers. The material presents interesting possibilities where there is danger of corrosion and where the necessity for lightness makes it inadvisable to increase the weight with a protective varnish.

Although aluminum and its alloys are used elsewhere in the telephone plant, these high strength alloys in sheet form find their most important use in the solution of a basic problem, the transfer of vibrations between the air and the vibrating member of a transmitter or receiver. For the most efficient and faithful transfer of energy the difference in impedance of the two media must be reduced to a minimum and for that end the moment of inertia of the diaphragm, and hence its mass, must be made as low as possible. In high-quality transmitters, where the flatness of the frequency-response curve comes in part from the fact that the range of resonance of the diaphragms is brought near the upper end of the voice frequencies by the tension under which the diaphragms are held, the material must be of minimum density, yet strong enough to withstand stretching to the desired tension. Likewise in the diaphragms of dynamic receivers stiffness is as much an essential as light weight, and strength is needed on account of the handling during assembly. For these uses, and for many others, the sheet alloys by their combination of high strength and light weight, and by their ability to withstand difficult manufacturing processes, make possible results that could otherwise not be attained.

The Edison Medal

To Dr. Jewett has been awarded the Edison Medal for 1928, in recognition of his "contributions to electrical communication". This medal is awarded annually by a committee of twenty-four members of the A. I. E. E., for "meritorious achievement in electrical science, electrical engineering, or the electrical arts". Among previous Edison Medallists are Alexander Graham Bell, John J. Carty and Michael I. Pupin.