RP 366

QUARTZ PLATE MOUNTINGS AND TEMPERATURE CONTROL FOR PIEZO OSCILLATORS

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ABSTRACT

In this paper are described a number of representative types of mountings for rectangular and circular quartz plates to be used as frequency standards. Unless the movement of the quartz plate in the holder is restricted, the frequency will change with each slight jar. A satisfactory holder for mounting a long rectangular quartz plate to oscillate in its extensional mode may be made by clamping the plate centrally perpendicular to its length between two keys, one in the face of each electrode. The electrodes are spaced by quartz washers. A plate mounted in such a holder will be constant in frequency to 1 part in 300,000. Such a mounting has not been found satisfactory for frequencies above 100 kc as the damping caused by the pressure of the keys is too great.

A very satisfactory holder for mounting a cylindrical quartz plate for "thickness oscillation" may be made by clamping the plate between three screws, mounted radially 120° apart in a ring so that they press into a V-shaped groove cut around the cylindrical surface of the quartz plate midway between the faces. The electrodes are spaced on either side of the quartz plate by pyrex washers. Mounted in such a way, the plate has been found to be constant in frequency to 1 part in 1,000,000 in a portable frequency standard with the addition of temperature control of the oscillating circuit. Some discussion is given the subject of temperature control of the piezo oscillator.

CONTENTS

I. INTRODUCTION

During the past few years an extensive study of certain phases of piezo oscillator construction and performance has been made at the National Bureau of Standards. The piezo oscillators have come from two chief sources—those sent in for calibration and those built at the bureau to serve as frequency standards. There has been no opportunity for long-continued observations on the former class of piezo oscillators, but the latter have yielded information of considerable value based on measurements which were made daily over a period of a year. These piezo oscillators differed in the manner of temperature control, method of mounting the quartz plate, type and number of tubes used, and type of oscillating circuit. Each of these factors affect the frequency constancy of the piezo oscillator. The material presented herewith deals chiefly with the quartz plate mountings and temperature control units, and is given with the hope that it may be of assistance to those interested in constructing piezo oscillators of greater reliability or in judging the probable merits of a given piezo oscillator.

II. THE QUARTZ PLATE AND ITS MOUNTING

At the present time piezo oscillators are in use which range in frequency from 25 to 5,000 kc. The quartz plates commonly used in covering this range of frequencies are rectangular bars, circular disks, and thin rectangular plates. Mountings for these plates differ greatly in outward appearance but the principles involved are much the same. The mounting must be so made that: (1) The air-gap will not change with ageing of the component parts, (2) the air-gap changes in a definite, predictable manner with variation in temperature; and (3) the unessential electrical capacity is minimized. The freedom of the quartz plate to move about between the electrodes must be restricted as much as possible without damping the desired mechanical vibration of the quartz plate. Any forces which tend to damp the vibration should be constant. The particular use for which the piezo oscillator is intended should determine the type of mounting. If the piezo oscillator is to be used as a primary standard, it will probably be kept in one position, protected from shock as far as possible, and be in continuous operation so that its frequency may be measured in terms of standard time. If the piezo oscillator is to be used as a secondary standard, it should be built so that it may be moved from place to place wherever it is needed and maintain a constant frequency over relatively short intervals of time. The frequency will change abruptly with a shift in the position of the plate within the mounting, and will drift more or less slowly with changes in damping depending on the magnitude of and rate at which the damping changes. It is very difficult, if not impossible, to maintain a constant damping factor for a quartz plate holder for an extended period of time. Therefore, it would appear that primary standards should use a mounting which possesses a minimum amount of damping, maintained, of course, as constant as possible. For secondary standards, the type of holder which allows a minimum of shifting in the position of the quartz plate is to be preferred.

The usual commercial piezo oscillator utilizes a rectangular quartz plate. The extensional mode of oscillation is customarily used for frequencies below 200 to 400 kc. For frequencies above this limit, the "thickness mode" is employed. These quartz plates are usually "Y cut" or "30° cut" quartz plates.[1]

A simple type of holder, which is often used for rectangular quartz plates, consists essentially of two brass electrodes with a celluloid or bakelite ring to limit the shifting of the quartz plate.[2] The upper electrode may be adjustable as to air gap or may rest on the quartz plate. (See fig. 1(*A*) and (*B*).) In another holder are used pins of bakelite or hard rubber mounted in the lower electrode to hold the quartz plate in place. The frequencies of piezo oscillators that incorporate mountings of this type change considerably when jarred, due to the shifting of the plate between the electrodes, and the varying of the damping as the plate touches the pins or a supporting ring, at different points. The constancy of frequency for a quartz plate mounted in this way is ordinarily 1 part in 10,000 to 30,000.

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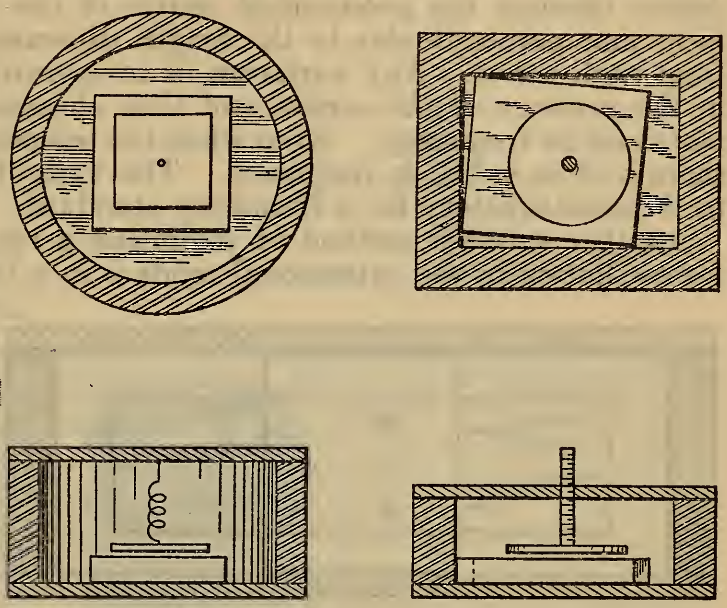
[1] Walter G. Cady, "Piezo-Electric Terminology," Proc. I. R. E., vol. 18, p. 2136; December, 1930.
[2] A. Hund, "Uses and possibilities of piezo-electric oscillators," Proc. I. R. E., vol. 14, August, 1926. R. C. Hitchcock, "Mounting quartz oscillator crystals," Proc. I. R. E., vol. 15, p. 902, November, 1927.

If the two faces of the quartz plate are cleaned thoroughly, platinum electrodes may be sputtered directly on them. Connection to each electrode may be made by a piece of tin foil which is held in place by amberoid cement. The quartz plate may then be suspended by threads in a suitable position. A plate mounted in this manner will oscillate readily, but the frequency will drift continuously, usually toward a higher frequency. The sputtering on the surface of the plate changes the decrement and frequency of the plate. A quartz plate mounted in such a way gives a constancy of frequency of 1 part in 20,000 during a period of two or three months.



a b

FIGURE 1.—*Types of simple quartz plate holder*

For rectangular plates which have one dimension large with respect to the other two, generally termed bars, there are other methods of mounting which may be used. In order to hold the quartz plate in position, a slot may be made in each edge of the quartz plate, midway between the two ends. These points are approximately at rest when the plate is oscillating in its extensional mode. Two screws are mounted on the lower electrode in such a way that they engage in the slots, and thus hold the quartz plate in position as it rests on the lower electrode. (See fig. 2.) The screws are made to fit the slots very neatly, and are adjusted as tight as possible without producing binding at any normal temperature. If the electrodes cover only the central portion of the quartz plate the damping is considerably reduced. A quartz plate mounted in such a holder will be constant in frequency to 1 part in 300,000.

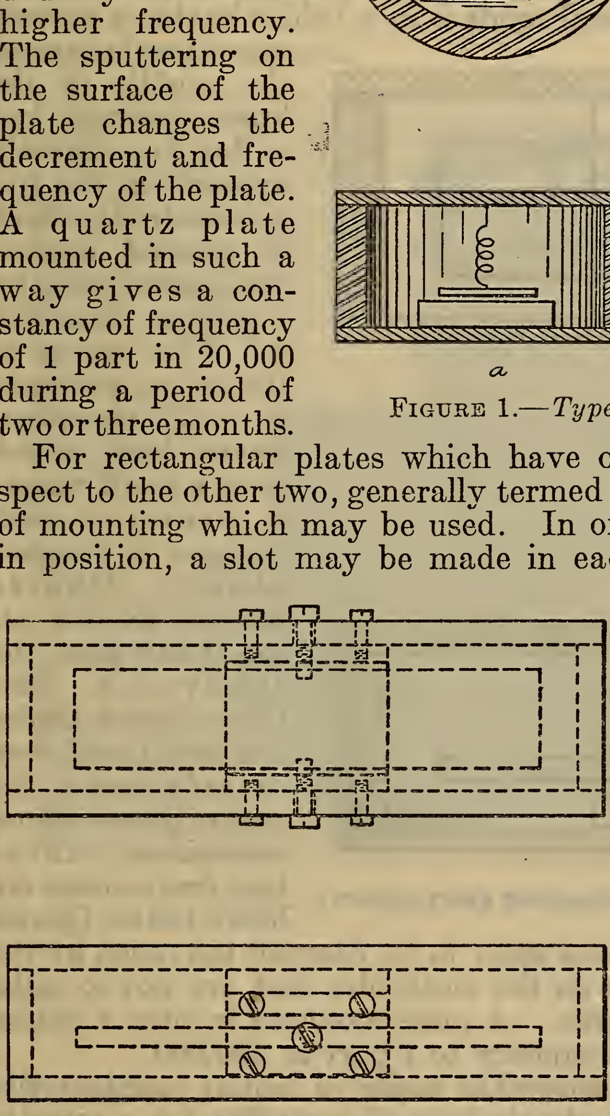


FIGURE 2.—*Mounting for long rectangular quartz plates*

In another piezo oscillator tested, the quartz bar is clamped between screws that project through the electrodes. The screws are

located at the vertices of an equilateral triangle; three screws in each electrode are so placed that each screw is directly opposite a screw in the other electrode. (See fig. 3.) The position of the points of support with respect to the quartz plate must be such that a line drawn through the geometrical center of the plate, parallel to the faces and perpendicular to the length dimension, is equally distant from each screw. Any variation in temperature causes a variation in the pressure of the screws and thus changes the damping of the plate and its frequency. Even when the temperature is held constant there is often a drift in frequency. This type of mounting has proved to be unsatisfactory for a frequency standard.

Another suitable method of mounting a rectangular quartz plate for oscillation in the extensional mode is in a holder having a narrow raised portion across the middle of the lower electrode, and a flat key directly opposite in the upper electrode, which is pressed against the quartz plate by a spring. (See Fig. 4.) The spring in the upper electrode is a stiff phosphor-bronze helix, which gives a small change in pressure with changes in temperature. Quartz spacers fix the air gap between the electrodes. This type of plate holder has been found very satisfactory for quartz plates whose extensional vibration frequencies are below 100 kc. Quartz plates giving higher frequencies seem to be damped too much by the width of the pressing surfaces on the electrodes and are not so satisfactory as frequency standards. A plate mounted in such a holder has been found constant in frequency to 1 part in 300,000.

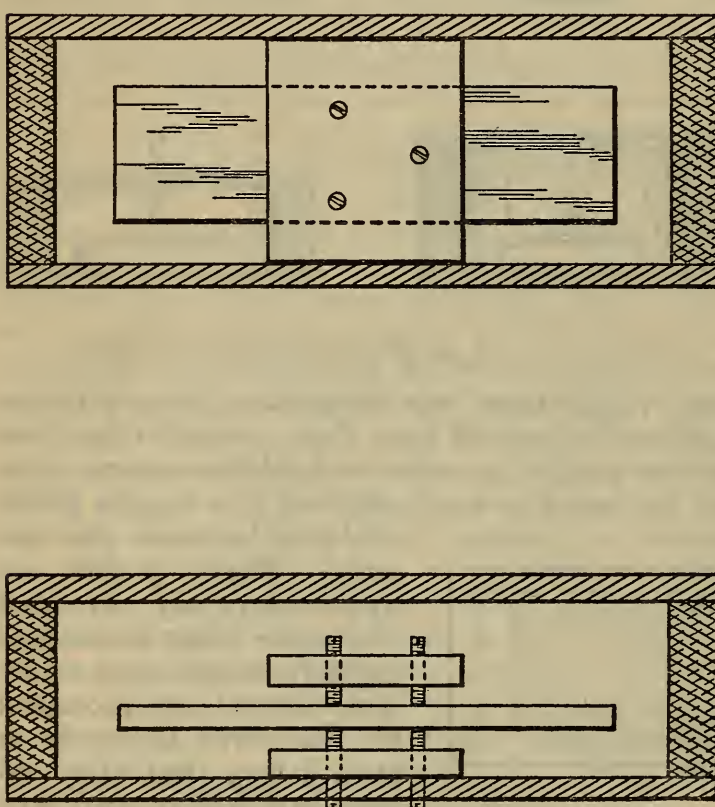


Figure 3.—*Mounting for long rectangular quartz plates*

A circular quartz plate is somewhat easier to mount satisfactorily than a rectangular plate. A simple type of mounting for a circular plate utilizes a piece of pyrex tubing, slightly larger in diameter than the quartz plate, to serve as the spacer between the electrodes as well as to hold the quartz plate in place.[3] (See fig. 5.) This type of mounting is found more advantageous for a "thickness mode" rather than for any other mode of oscillation as there is less variation in damping for this mode. The pyrex ring must be of such a size that

[3] V. E. Heaton and W. H. Brattain, Design of a Portable Temperature-Controlled Piezo Oscillator, Proc. I. R. E., vol. 18, p. 1239; July, 1930. B. S. Jour. Research, vol. 4, p. 345; March, 1930.

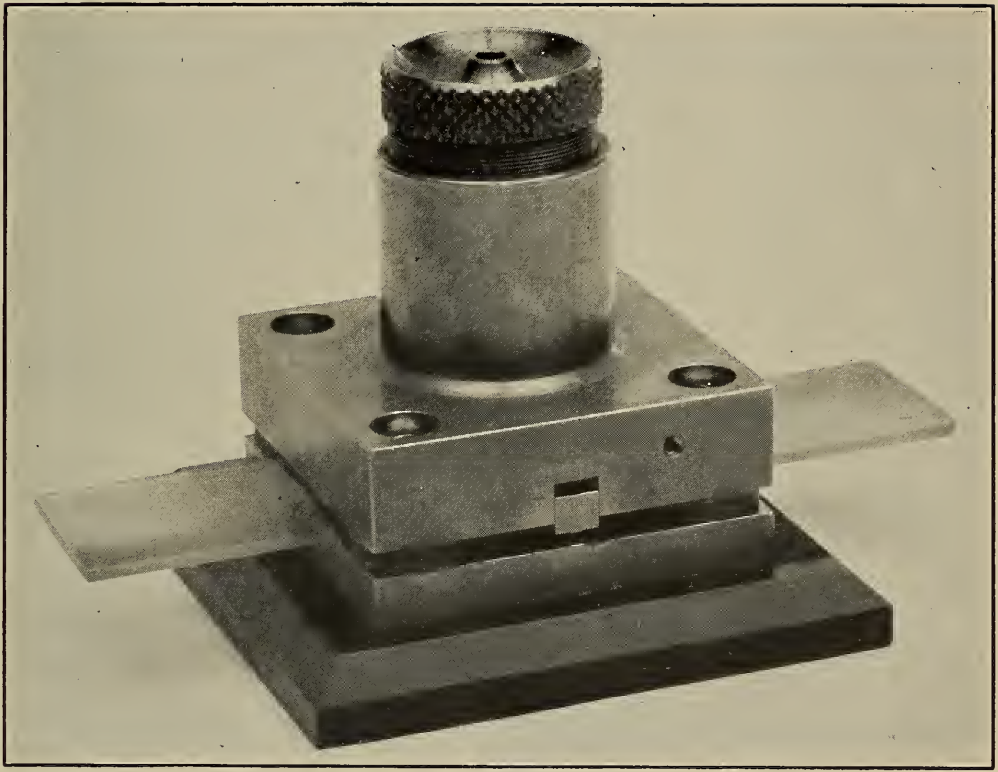


FIGURE 4.—*Mounting for bar-shaped quartz plates*

it will not clamp the quartz plate at any temperature at which the piezo oscillator will be operated. The greatest possible constancy of frequency of a plate in such a holder is 1 part in 200,000 for a portable standard as the quartz plate is able to shift slightly in the plate holder as well as rotate.

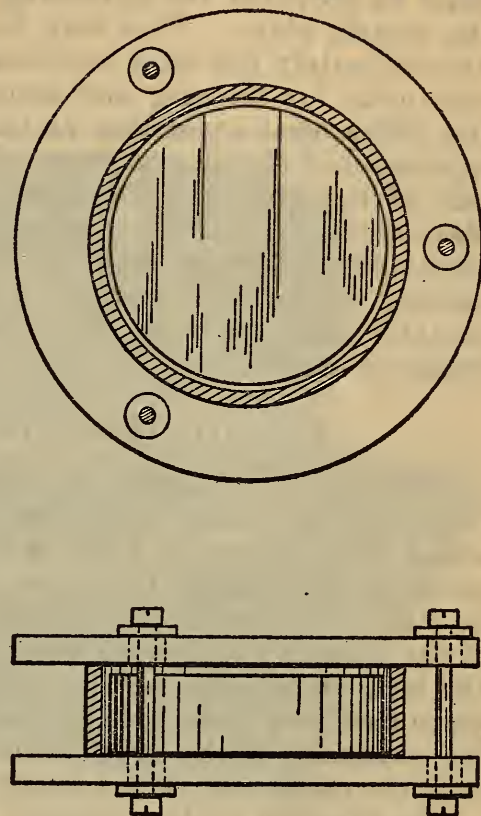


FIGURE 5.—*Simple mounting for cylindrical quartz plates*

Another dependable method of mounting a circular quartz plate involves the cutting of a tapered hole along the axis of a "30°" or Y cut disk. The hole is cut so that the diameter decreases from both faces toward the center. The damping is small when the quartz plate is mounted on a horizontal rod of bakelite, or similar material, passed through the hole.[4] (See fig. 6.) It has been found that the temperature coefficient of frequency may be greatly reduced for such "doughnut-shaped" plates by suitably proportioning the various dimensions. A pyrex ring serves as spacer for the electrodes. If the quartz plate moves so as to come in contact with either electrode, the decrement is increased. Therefore, such a mounting is not reliable as a portable standard, although in a fixed position the piezo oscillator is reliable to 1 part in 1,000,000 with the extension of temperature control to the oscillator circuit. If the temperature and barometric pressure of the air surrounding the quartz plate and if filament and plate voltages of the oscillator tube are maintained very accurately at a constant value, the accuracy of such a piezo oscillator is 1 part in 10,000,000 according to Marrison. Experience obtained at the bureau with similar piezo oscillators verifies this statement.

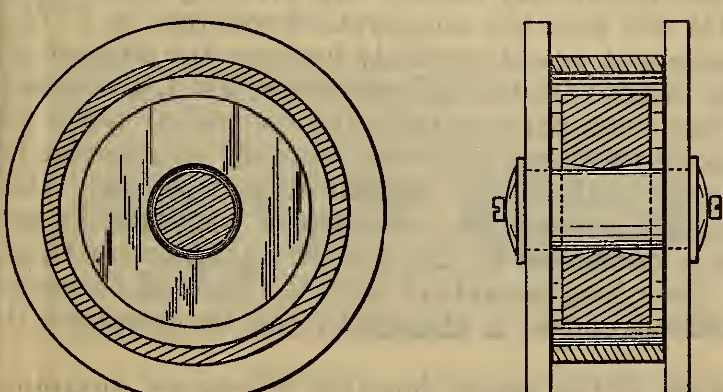


FIGURE 6.—*A satisfactory quartz plate mounting for a stationary frequency standard*

It is possible to mount a cylindrical quartz plate so that it will be reliable as a portable standard. About the cylindrical surface a V-shaped groove is cut halfway between the two plane faces of the quartz plate. The quartz plate is

[4] W. A. Marrison, A High Precision Standard of Frequency, Proc. I. R. E., vol. 17, p. 1103; July, 1929 Bell System Tech. J.; July, 1929.

then mounted within a ring of metal by three screws, 120° apart, whose tapering points fit in the groove in the quartz plate so that it is gripped only at the bottom of the groove. (See fig. 7.) Some means must be provided for equalizing the expansion of the mounting and the quartz plate. This may be done by choosing a metal having approximately the same temperature coefficient as quartz or by using one metal for the ring and another for the mounting screws so that the differential expansion of the two metals will be the same as the expansion of the quartz plate. The electrodes are mounted on either side of the ring, pyrex washers serving to space them. In such a plate mounting the decrement is very small and there is no opportunity for the quartz plate to shift. A quartz plate mounted in this manner will hold its frequency constant to 1 part in 1,000,000 as a portable standard with the extension of temperature control to the oscillator circuit.

III. TEMPERATURE CONTROL

The proper control of temperature in a piezo oscillator is just as important as proper mounting of the quartz plate. A thermostat, which operates heater units, is used to control the temperature of the medium surrounding the quartz plate mounting. This medium may be either liquid or air. A liquid bath is less satisfactory on account of the difficulty of keeping the liquid away from the quartz plate, and the lack of portability.[5] A large air bath increases the bulk of the piezo oscillator, but does not add excessive weight and does increase the constancy of the temperature. The air bath in no way interferes with the oscillation of the quartz plate.

The simplest control consists of a small box of wood or of similar material, containing a thermostat, the quartz plate mounting and a lamp or electric heater. The constancy of temperature depends on the type of thermostat used and the relative locations of the various pieces in the temperature-controlled space. The room temperature will probably affect the temperature at which the quartz plate is maintained. If the thermostat and heaters are properly located, a good bimetal thermostat will hold the temperature constant to 1° C., whereas a mercury thermostat would probably increase the constancy by a factor of 10. The reasons for the difference are: First, a bimetal thermostat ordinarily has some parts outside the controlled space so that the heat may be conducted out while the mercury thermostat is usually mounted entirely within this inclosure; and second, the variation of temperature necessary to cause the thermostat to go through one heat cycle is much less for the mercury thermostat than for the bimetal type. Over long periods of time the bimetal thermostat shows an aging which causes a change in the temperature it maintains.[6]

Mention has been made of the proper location of heaters, thermostat, and the quartz plate mounting. If these three elements are located without any consideration or knowledge of probable results, the temperature may be found to vary several degrees within the so-called temperature-control cabinet, assuming that heat is applied to the thermostat and quartz plate by conduction through air alone.

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[5] R. C. Hitchcock, Mounting Quartz Oscillator Crystals, Proc. I. R. E., vol. 15, p. 902; November, 1927.
[6] W. A. Marrison, Thermostat Design for Frequency Standards, Proc. I. R. E., vol., 16, p. 976; July, 1928.

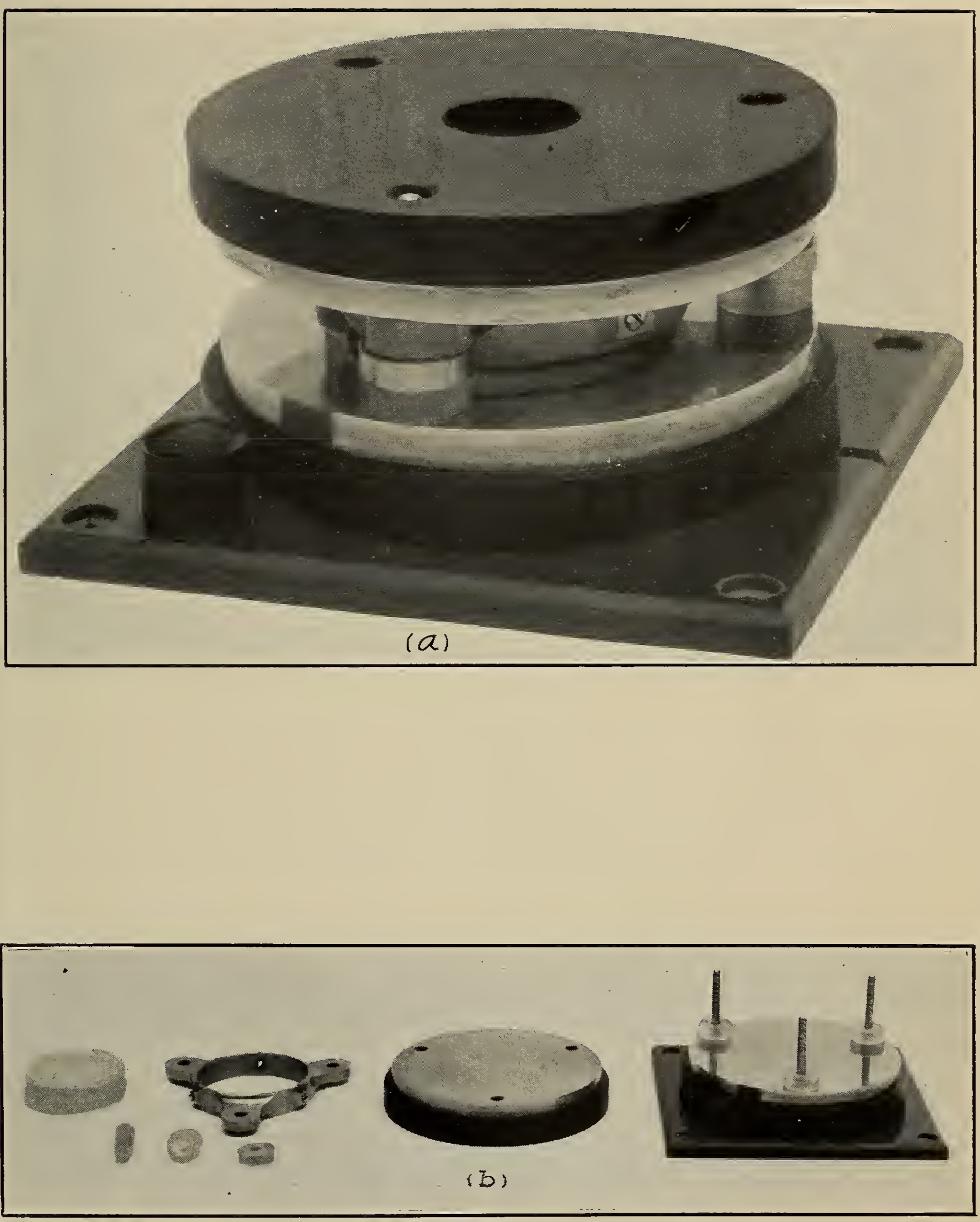

FIGURE 7.—*Mounting for cylindrical quartz plate*

a, Assembled; *b*, disassembled.

However, if the heater unit warms a large metallic body which carries the quartz plate mounting and the thermostat, the metallic body acts as a heat reservoir and distributor and effectively reduces the temperature variation required to actuate the thermostat, with a resulting reduction in temperature change of the quartz plate. Such a system, if suitably designed, using a bimetallic thermostat may be expected to hold a given temperature much better than indicated above for such thermostats.

Another method of improving the temperature control of the quartz plate consists in placing the plate holder inside a heat-attenuating box. This box may consist of a single layer of metal, wood, or other material. It is better, however, to make the compartment of alternate layers of metal and felt or asbestos, using metal as the outside layer. The metal should be brass, copper, or aluminum so as to distribute the heat readily over the entire surface of the attenuator. The poor heat conductor between the metal walls slows down the heat transfer to the plate holder.[7] Such an attenuating cabinet of 3 or 5 layers of material may reduce the variations of temperature inside to 1 per cent of that in the temperature-controlled compartment.

Still better control may be obtained if the thermostat is placed in a well in the outer layer of metal in the attenuation box. Variations of room temperature then have a negligible effect on the temperature of the quartz plate as long as the heaters are not overtaxed.

If portability is not required, the temperature-controlled compartment may be made larger with a fan to force the air to circulate about the attenuating cabinet containing the plate holder. This arrangement is very little superior to the smaller box described above in which heat is supplied on all six sides of the attenuating cabinet.

In any temperature control system, the thermostat operates more satisfactorily if it controls the heater current through the agency of a relay rather than directly. Either direct current or alternating current may be used for the heater current. If direct current is used, a potential divider will supply the necessary current for operating the relay. If a. c. is used, the relay may be operated on the output of a small rectifier.

Where great constancy of frequency is required, the oscillator circuit also must be maintained at a constant temperature. It is very desirable to have a double temperature-control on the quartz plate, putting the oscillator circuit in the outer temperature-control compartment.[8] The quartz plate is mounted in an attenuating box in the outer wall of which is placed a mercury thermostat. This attenuator is in a constant-temperature compartment whose walls are of alternate layers of metal and insulating material and whose temperature is controlled by the thermostat in the wall of the quartz plate attenuator. This temperature-control unit is then placed within another compartment, whose temperature is controlled by a thermostat of either the mercury type or bimetal type. This outer compartment has walls of insulating material. In the outer compartment are placed the oscillator tube, and coil. The inner compart-

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[7] V. E. Heaton and W. H. Brattain, Design of a Portable Temperature-Controlled Piezo Oscillator, Proc. I. R. E., vol 18, p. 1239; July, 1930. B. S. Jour. Research, vol. 4, p. 345; March, 1930.
J. W. Horton and W. A. Marrison, Precision Determination of Frequency, Proc. I. R. E., vol. 16, p. 137; February, 1928.

[8] J. K. Clapp, Temperature Control for Frequency Standards, Proc. I. R. E., vol. 18, p. 2003; December, 1930.

ment operates at a temperature a few degrees above that of the outer one. The outer compartment contains enough heaters to maintain a constant temperature, regardless of room temperature. Such a unit will maintain a constant temperature at the quartz plate under all conditions except for small drifts in the operating temperature of the thermostat.

WASHINGTON, July 8, 1931.