V - CUT CRYSTALS—CRYSTAL UNITS

Silica (SiO_2) is the general classification to which belongs the crystalline substance "Rock Crystal," more commonly known as "Quartz," from which, because of its unusual properties, the familiar quartz oscillator crystal is manufactured.

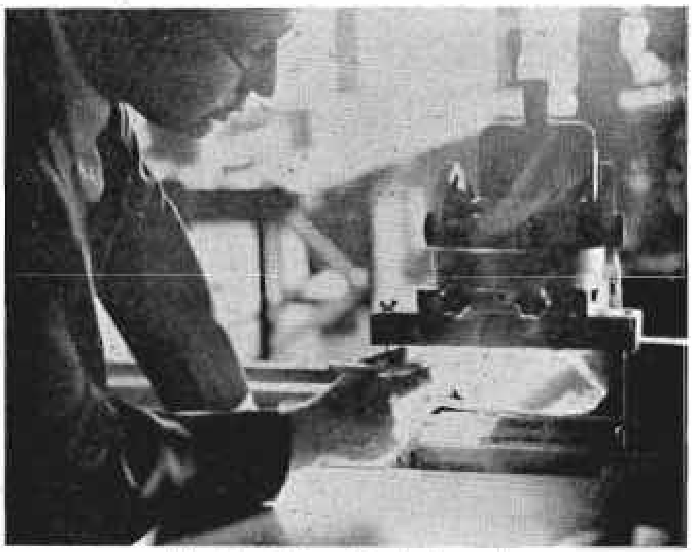
Raw Quartz or Rock Crystal as it appears in nature can be found on all continents. The more perfectly formed crystals required for scientific purposes are obtained from Brazil. The crystals are mined in a primitive fashion in the interior of the country, after which they are transported to the coast by pack animals. The ideal natural crystal consists of a six-sided prismatic body capped at each end by an apex. However, the usual crystal as we get it consists of a portion of the body and only one apex. This is due to mining procedures, in that the larger specimens are generally found protruding from clusters of smaller crystals bound by other rock formations. The usual method then is to break the crystal near the base of the protruding part. Selection of the finer pieces starts at the mine and continues all along the line of shipment, so that only the best optically clear crystals are received at the laboratory.

A fine specimen of "Mother" Quartz Crystal.

Because of the regular growth and formation of quartz crystals there exist certain axes of symmetry. First, one axis of three-fold symmetry, and second, three axes of two-fold symmetry. The axis of three-fold symmetry called the principal, optic, or "Z" axis, is an axis around which the crystal can be rotated in steps of 120° without distinguishing a change of appearance at these positions. The three axes of two-fold symmetry are axes about which the crystal can rotate 180° to restore the original pattern. These axes pass through the edges of the crystal and are normal to the principal axis.

A good example of a bad specimen.

Examining a piece of rock quartz.



Precision cutting of natural quartz.

Determining preliminary cuts.

Crystal Characteristics

With respect to the quality of rock crystals it is essential for specimens to be reasonably free from defects such as cracks—foreign particles—"ghost crystals," which are well defined crystals appearing within the specimen—veils and needles, appearing as such because of microscopic air spaces—twinning—and impurities. Twinning in quartz crystals consists in a broad sense of two principal types. The first type, called stress-strain, is thought to have been caused by rapid temperature changes creating non-uniform temperature gradient which set up strains in the crystal line structure. The second type of twinning is called 180° twinning, in which the crystal structure is altered within by a reversal of form.

The uses of raw quartz are numerous and diversified—from jewelry to abrasives. It may be cut and polished for ornaments, prisms and lenses, and can be fused and drawn into threads for delicate instruments. But of most importance is the application of the piezo-electric property of quartz for pressure gauges, supersonic wave generators, and of special significance, for the control of radio frequencies, to which in recent years a great deal of consideration has been given. This characteristic of piezoelectricity as exhibited by quartz crystals is both interesting and phenomenal. It is an example of inter-conversion of mechanical and electrical energy in that when subjected to stresses, electrical charges appear on certain surfaces of the crystal, and conversely when placed in an electrical field, the specimen becomes mechanically distorted. In 1920 Cady discovered that quartz plates, because of the piezo-electric characteristic, could be employed to control the frequency of a self-oscillating circuit.

During the early stages of investigative work on crystals, it was found that when compression took place along the two-fold axes of symmetry, electrical charges appeared on surfaces normal to these axes. Consequently, the three axes of two-fold symmetry were designated as the electric or "X" axes. Furthermore, it was discovered that elongation or compression at right angles to an electric axis and in the same horizontal plane, also produced electric charges on the same surfaces. These new axes of which there are three, by virtue of the three electrical axes, were designated as the mechanical or "Y" axes.

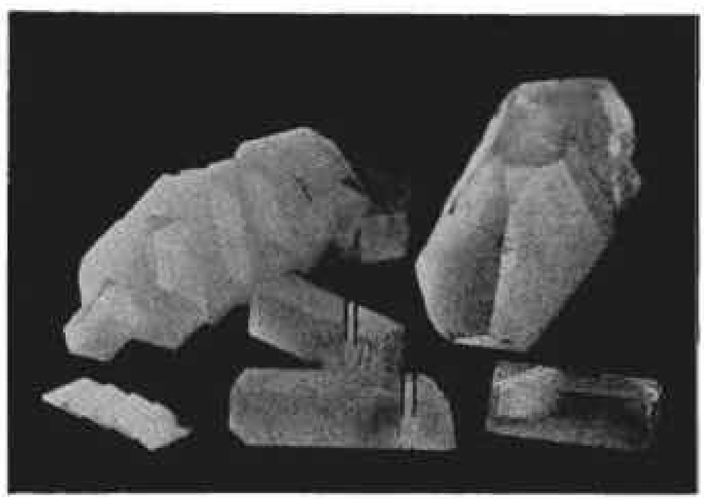
Interference patterns made by light falling on the lapped crystal as it rests against an optical "flat" assure flat plates.

Crystal Cuts

Piezo-electric elements are cut and ground into various shapes such as long rods, flat discs, and thin plates. Thin plates are used most frequently in oscillating circuits. The plates are cut from the raw quartz in a wide variety of angles, the more common type of cuts being the "X" cut and the "Y" cut. The "X" cut quartz plate is an orientation about the optic or "Z" axis, the major surfaces being normal to an "X" axis, parallel to a "Y" axis and parallel to the "Z" axis. The "Y" cut crystal has its major faces normal to a "Y" axis and parallel to the "X" and "Z" axes.

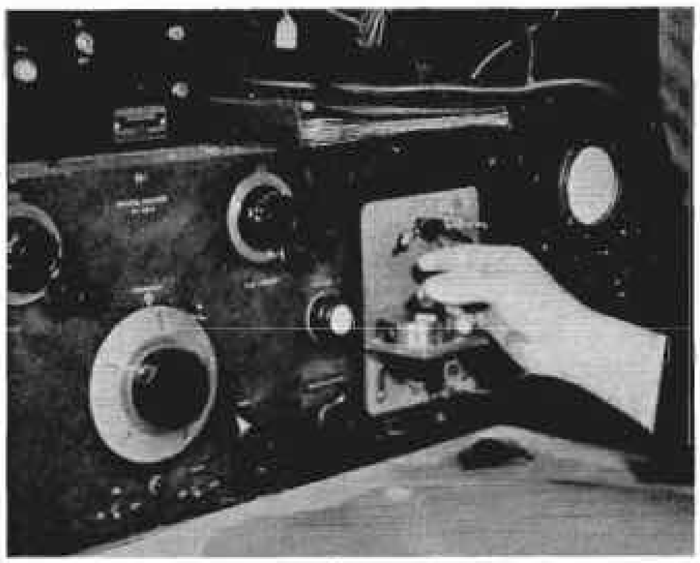
Examining blanks for imperfections normally invisible.

The "X" cut crystal, in size, is usually one inch by one inch and anywhere from fifteen to three hundred mils in thickness, depending upon the frequency desired. The temperature coefficient of this cut is negative by about twenty cycles per megacycle per degree Centigrade. That is, as the temperature of the crystal is raised, the frequency drifts lower at the rate of twenty cycles per megacycle per degree rise in temperature. The "Y" cut is similar to an "X" cut crystal in size, but the temperature-coefficient is about plus eighty-five cycles per megacycle per degree Centigrade. In a like manner, as the temperature of the crystal is raised, the frequency rises at the rate of eighty-five cycles per megacycle per degree rise in temperature.



Illustrating the various cuts.

X-Ray Spectrometer Equipment



Testing filter crystals.

Natural quartz compared with the AVA-37 Holder.

V-Cut Crystals

In recent years the search for zero temperature-coefficient crystals became quite active and of considerable importance. As a result of this search, RCA has developed the "V" cut quartz crystal. Unlike the other types of low-temperature-coefficient crystals, the "V" cuts are oriented away from the optic or "Z" axis and are not parallel to either the "X" or "Y" axes. The "V" cut type is a cut which assures minimum variation with temperature change, high output and a relatively great thickness in order to minimize the possibility of fracture. For broadcast service the temperature-coefficient is less than 1.5 cycles per million per degree Centigrade.

Manufacturing V-Cut Quartz Crystal Oscillators

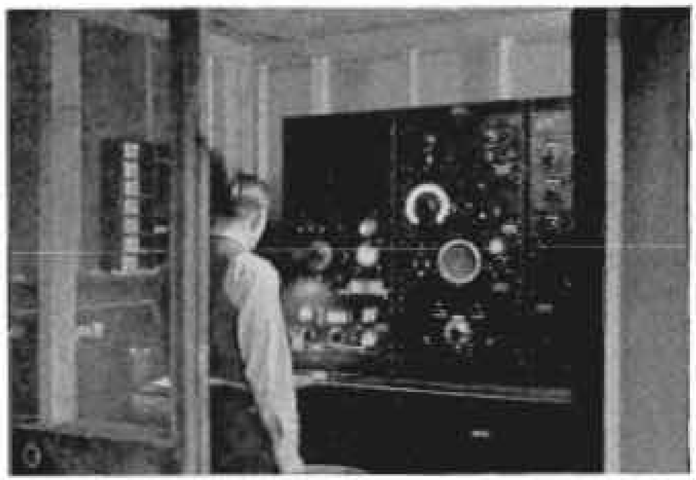
In the manufacturing of RCA V-cut quartz crystal oscillators only the highest grade of raw quartz is used. The specimen of raw quartz, commonly called the mother crystal, is first examined very carefully. It is coated with cedar oil, which brings out the defects more clearly, and removed to a dark room, where it is examined with elaborate optical equipment. In certain cases, a microscope is used to disclose the more obscure defects. After inspection the specimen is mounted horizontally and cut into sections approximately one inch thick. The cut faces of each are normal to the optic axis. The section is then checked for stress-strain and 180° twinning. Strained areas are masked and the clear areas are laid out into bars, which, as a convenience in cutting, may include some of the twinning portion blocked out in the section. The next step is to set up the bar and tilt in a direction such that the blanks may be cut at the specified angle.

The orientation is determined accurately by an X-ray method in which the angle between the principal face of the blank and a known atomic plane is measured. Following this a reference face is made which is usually a hand grinding procedure, giving reasonable flatness for final X-ray measurements. If these measurements indicate the crystal orientation to be outside the predetermined limits, the blank must be re-ground until the tilt has been sufficiently altered to bring it within the limits. The surface of the reference face is then improved by light grinding and polishing, and with the aid of optical flats a high degree of flatness is obtained.

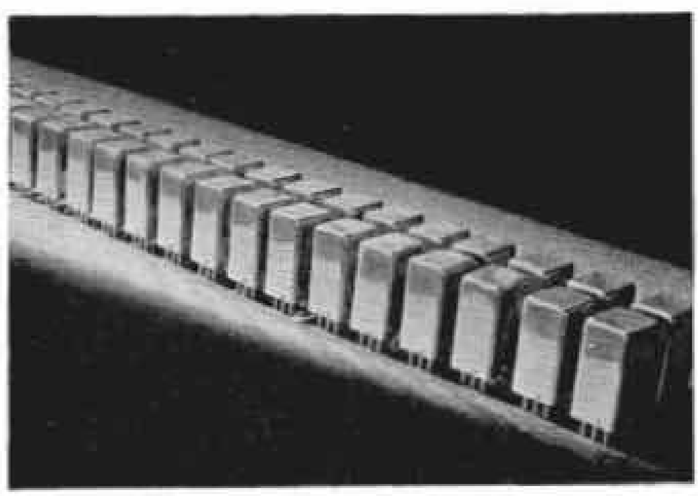
Once the reference face has been established all other dimensions are referred to it. Excess quartz may be removed by machine lapping or grinding, but when the blank reaches the final finishing stage it must of necessity be larger than required for the frequency specified. The reason is obvious, as no way has yet been found to add quartz to a blank and still have it function as an oscillator. The only salvation for an over-ground crystal is to set it aside as a blank which sometime might be suitable for a higher frequency crystal.

The final finishing is essentially a hand-grinding job. The operator must form the crystal to meet specifications as to frequency, activity, and temperature coefficient over a specified temperature range, which might be anything from −50° C. to +100° C. Many less expensive crystals are tested only from room temperature to +50° C. The crystal must be free from spurious oscillations, double frequencies and frequency jumps. The usual specifications call for a frequency temperature-coefficient of two parts per million per degree Centigrade, or better. In the final testing of the crystal, it is essential that the complete assembly of holder and crystal be checked over the specified range, as the mechanical assembly of holder parts may also have a temperature-coefficient affecting the performance of the unit. The recent tendency in final testing has been toward the use of automatic recording equipment.

Sealing off the AVA-37 Holder.



One of the many similar banks of crystal test equipment.



TMV-129-B Holders nearing completion.

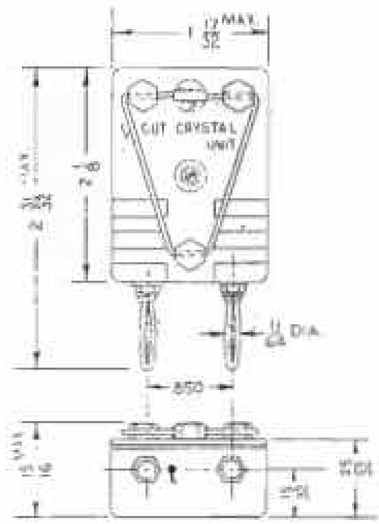
Crystal units are generally pre-cooled and then placed in an oven, where they gradually reach the upper temperature limit required by the test. During this test, the frequency drift and oscillator grid current, as well as the temperature, is recorded automatically. The temperature-coefficient of the crystal can then be readily computed over the entire temperature range or any part of it, while the oscillator grid current gives an indication of the crystal activity over the same range. Having passed such tests, the units are then sealed and shipped.

A more recent development in the piezo-electric art is the production of "V" cut crystals having specially contoured faces, which makes it possible to provide much thicker and stronger crystals for a specific frequency. This is of particular importance in the frequencies ranging from 7,500 Kc. as high as 20,000 Kc., where ordinary crystals would be too thin to be manufactured commercially. However, it is necessary to use tuned plate circuits with this more rugged type of crystal.

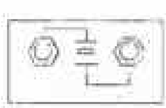
Facilities have been provided to manufacture a precision product, and all the steps have been geared to this high precision from the selection of raw quartz to the final crystal calibration. For this reason the RCA Mfg. Co., Inc., particularly welcomes the opportunity to furnish crystals to meet the most rigid specification. RCA has furnished all the crystals to meet its own stringent requirements for a number of years and has recently expanded its facilities to offer this service to others. Thus this service includes a wide experience with circuits in addition to unusual manufacturing and test facilities.

The organization has made every effort to standardize on a few types and mountings of crystal holders. By maintaining a relatively few active designs, the economic advantages of quantity production are realized and confusion in selecting the proper unit minimized. Since the holder influences the characteristics of the crystal, RCA prefers to furnish the complete unit; certain holders, however, are available for separate sale. The inconspicuous, yet all-important crystal unit, is truly a precision product of RCA.

Model AVA-10 Series



RED DOT OR RING.



END VIEW SCHEMATIC

The RCA type AVA-10 series of crystals and crystal units have been developed to provide high quality at a low cost. However, nothing has been sacrificed in furnishing rugged construction to withstand the stringent requirements encountered in aircraft and commercial services. This is substantiated by the service these units are rendering in the field.

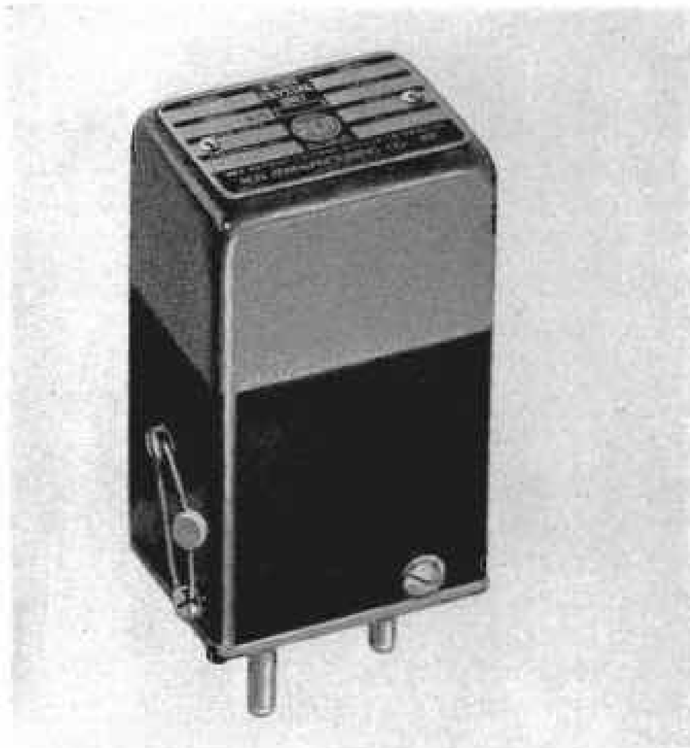
The holder body is moulded ceramic steatite with two terminals spaced at 0.850 inches, and each electrically connected to a crystal electrode of nickel silver. The crystal mounting is of the pressure air gap type and means for adjustment are provided so that optimum operating conditions are obtained. After final adjustment the holders are sealed against dust and moisture.

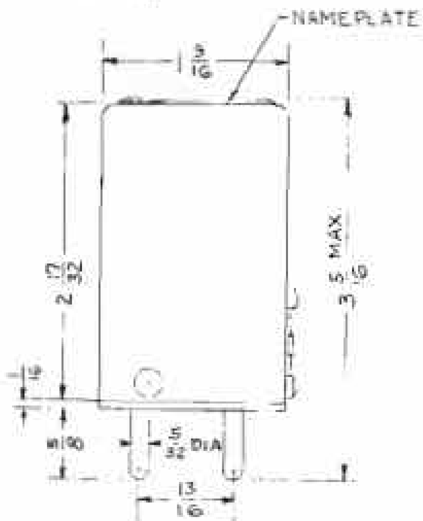
The AVA-10-B is provided with electrodes for crystals operating in the range of 1,715 Kc. to 10,250 Kc., while the AVA-10-C contains two electrodes specially designed for crystals operating from 10,250 Kc. to 20,000 Kc. The AVA-10-D and AVA-10-E are similar to the AVA-10-B and AVA-10-C respectively, differing only in temperature operating range.

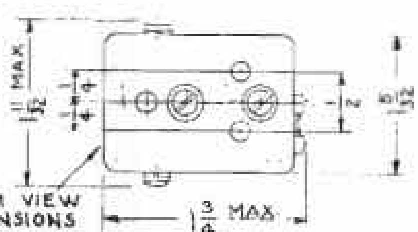
Model AVA-11 Series

Designed to meet the requirements of commercial aviation and police equipment, the RCA type AVA-11 series of crystals and crystal units incorporate design features resulting from years of experience in this field.

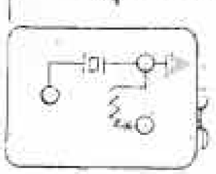
They are characterized by small physical dimensions, correspondingly light weight and extreme ruggedness. The metal cover serves as a very effective shield which makes it practicable for use at high frequencies. The electrodes are of nickel silver and mounting of the crystal is of the pressure air gap type. A 6-volt or 12-volt heater, controlled by a bi-metallic disc type of thermostat is provided to maintain the crystal temperature above the dew point and to limit the temperature range through which the crystal must operate.







BOTTOM VIEW PIN DIMENSIONS



BOTTOM VIEW SCHEMATIC

The AVA-11 and AVA-11-A holders cover the range from 1,715 Kc. to 10,250 Kc., and are identical, except that the former has a 12-volt heater unit while the latter incorporates a 6-volt heater. The heater terminals, as well as the electrode terminals, are brought out through the holder base in a three-prong arrangement, one prong being common to one electrode and one side of the heater.

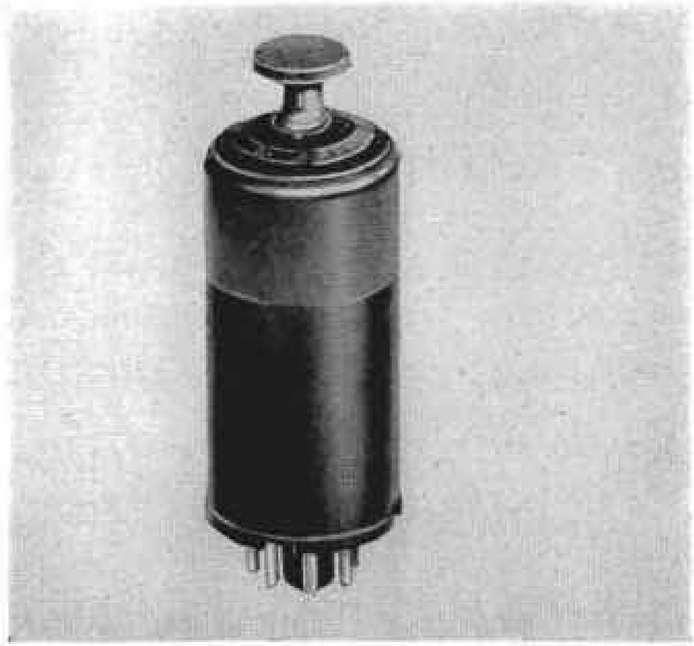
The AVA-11-C covers the frequency range from 10,250 Kc. to 20,000 Kc. and contains a 6-volt heater. This type is designed primarily for police service. The AVA-11-D holder is designed for the frequency range from 1,715 Kc. to 10,250 Kc., contains a 12-volt heater as does the AVA-11, but also includes an electrode terminal on the side of the holder case.

The use of RCA "V" cut low temperature-coefficient quartz crystals in this type of holder makes for a precision product in every respect.

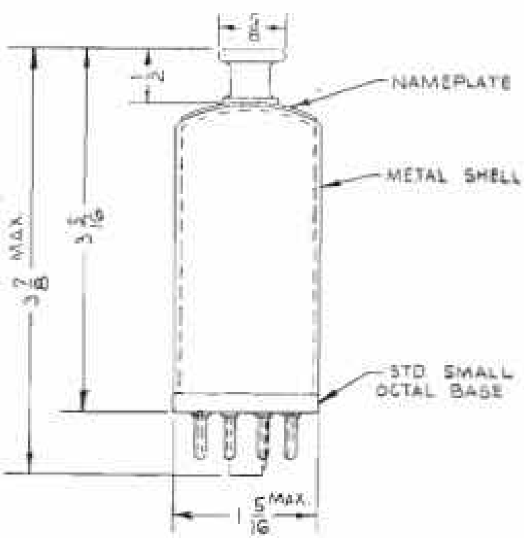
H. T. Neher

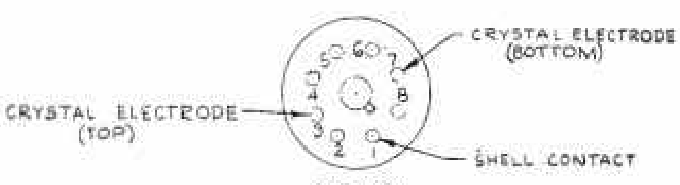
Model AVA-37 Series

This series of crystals and crystal holders is a recent achievement of the RCA laboratories. This type provides all the benefits of the standard low-temperature-coefficient "V" cut quartz plate, plus the new feature of mounting this element within an hermetically sealed, gas-filled metal envelope. The benefits obtained are of paramount importance where reliability of operation and stability of performance are essential under adverse conditions of dust and humidity.



Since the crystal element is mounted in an air-tight chamber filled with an inert gas, it is impossible for dust particles or moisture to come in contact with the crystal or its electrodes. This valuable feature insures remarkably long, trouble-free service, a requirement of particular importance in the aviation and police services. The complete unit is small, no larger than an ordinary metal tube which it closely resembles, and is provided with a standard octal type base for mounting in an ordinary tube socket.



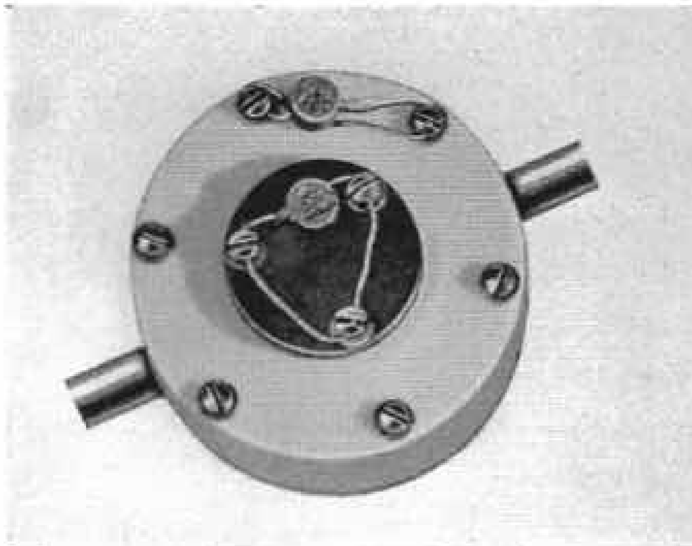


In this holder the crystal mounting is of the pressure air gap type, permitting the holder to be mounted in any position. The entire construction is extremely sturdy, amply able to withstand the most severe type of vibration or shocks liable to be encountered in any type of radio service. This holder has already been awarded a certificate of adoption by the Civil Aeronautics Authority, and it is fully anticipated that this new type holder will be in great demand when its distinctive features are fully recognized, particularly in view of the low price made possible by quantity production.

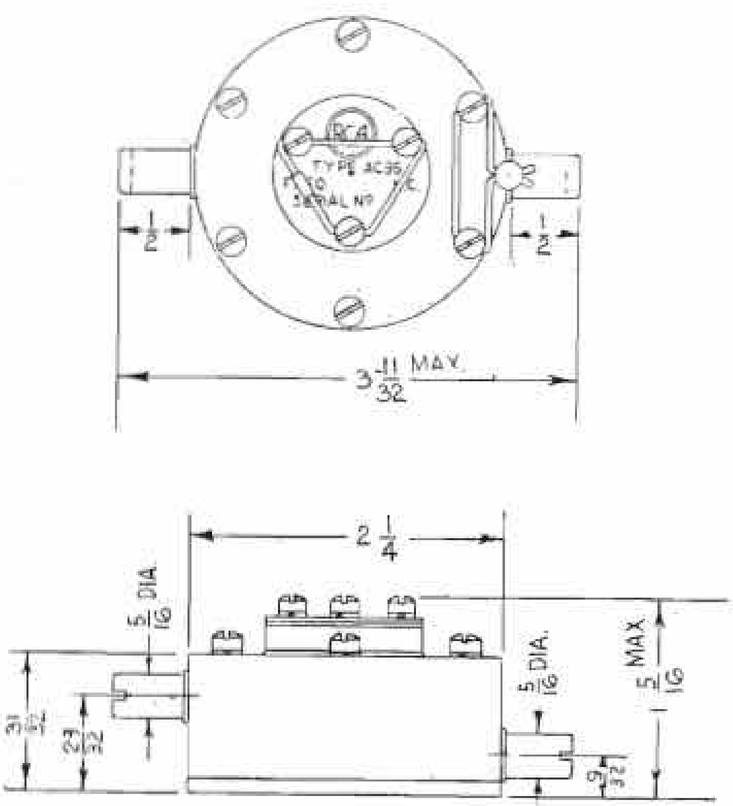
This unit is manufactured in two frequency ranges. The model AVA-37 covers the frequency range of 1,715 Kc. to 10,250 Kc. Model AVA-37-A covers 10,250 Kc. to 20,000 Kc.

Model AC-95 Series

The RCA type AC-95 crystals and crystal units were designed to function in the low frequency range between 200 Kc. and 400 Kc. The crystals employed in this series, as in the others, are "V" cut low temperature-coefficient plates.



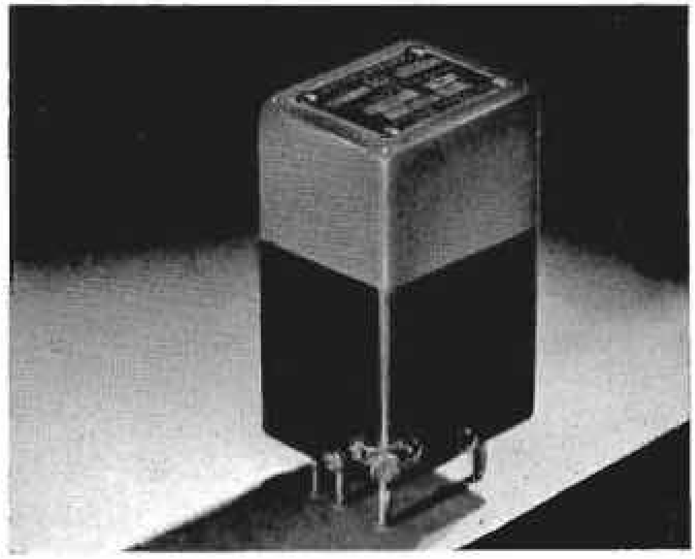
The holder bodies are of ceramic steatite, approximately two and one quarter inches in diameter by seven-eighths of an inch high. The monel metal bottom plate serves as the lower electrode and is connected to the lower of two side terminals, each of which is one-half inch long by five-sixteenths inch in diameter. The upper side terminal is connected internally to the top electrode.



The AC-95-A holder has the same external appearance as the AC-95, but internally is designed to provide a pressure air gap mounting for the "V" cut crystals which may thus cover the frequency range from 1,715 Kc. to 10,250 Kc., or even up to 20,000 Kc. if desired. The electrodes of this holder are made of nickel silver, similar to those employed in other RCA holders for this same frequency range.

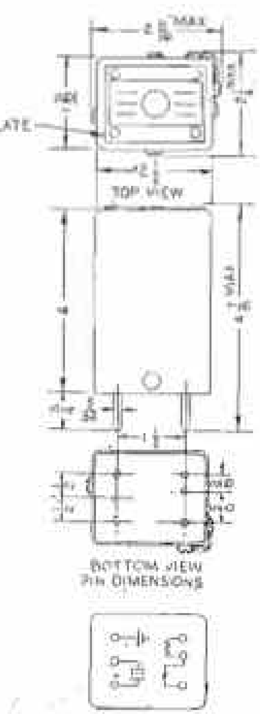
In the AC-95-B holder the crystal mounting is of the fixed air gap type, the holder itself being of the same general appearance as the two types just described, but differing in the size of nameplate on the top surface. This crystal unit is designed to cover a frequency range from 200 Kc. to 2,000 Kc.

Models TMV-129-B and TMV-129-C



This series of crystals and crystal units is designed to provide frequency control for all transmitters operating in the frequency range from 200 Kc. to 3,000 Kc. It incorporates many patented features which provide a precision and quality of radio frequency control far in excess of the rigid requirements of the Federal Communications Commission for broadcast purposes. These units are widely used throughout the world and are particularly popular in the United States.

The 129-B holder is a shielded, self-contained unit of the plug-in type and contains a 15-watt, 115-volt heater element and a bi-metallic, compensated thermostat. The heater element and thermostat employed in this series are not just commercial articles adapted to a special application. On the contrary, the temperature control specifications of this holder are so rigid that RCA engineers have designed a special heater winding which surrounds the crystal chamber on all four sides. It is very carefully insulated and shielded, and is energized directly from a 115-volt source (either A.C. or D.C.) through the controlling thermostat. The thermostat itself was especially developed for this application. No relays are used in this circuit, thereby reducing the possibility of failure. The crystal temperature in the holder is maintained at approximately 60 degrees Centigrade.



The crystal mounting is of the fixed air gap type and the electrodes are of monel metal. Connections to the two electrodes are brought out to two contacts of a special six-prong base which also provides connections to the metallic shields, heater winding and thermostat.

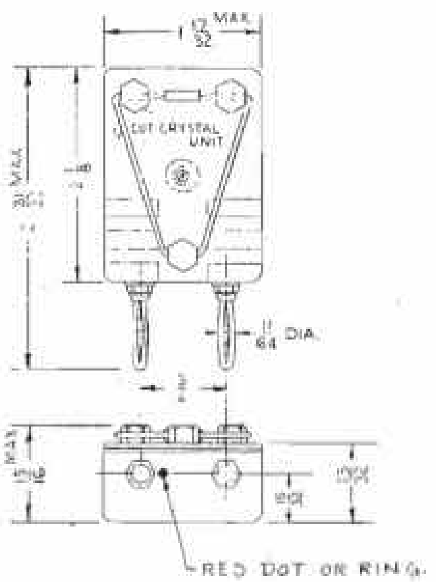
The RCA Type TMV-129-C differs from the TMV-129-B only in the type of crystal mounting employed. The pressure air gap type of mounting for use between 3,000 Kc. and 20,000 Kc. is used in the TMV-129-C. This type holder is a new product of RCA to extend all the benefits of the TMV-129-B throughout the high frequency range, thus providing precision frequency control up to twenty megacycles.

The material and workmanship of the TMV-129-B crystal unit is of such a high standard that RCA does not hesitate to guarantee that the assigned frequency will be maintained within ten cycles when used in the RCA UL-4292 oscillator. That is a degree of precision far exceeding any practical requirement.

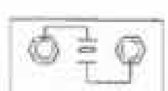
Model TMV-135 Series

Amateurs have found these crystals and crystal holders excellently suited to their purposes. Commercial operators have also obtained excellent results with their use. This series is identical with the AVA-10 series, except that the two terminals are spaced three-fourths of an inch in accordance with standards set up for amateur use.

The holder body is of ceramic steatite, electrodes are of nickel silver and the crystal mounting is of the pressure air gap type. As in the more expensive type RCA holders, this unit uses the RCA "V" cut, low temperature coefficient crystals which are available for the 160, 80, 40, and the 20 meter amateur bands. Although primarily designed for amateur application, this holder is also extensively used for commercial purposes wherein the grinding tolerances and temperature-coefficient specifications are more rigid than required for amateur service.



The TMV-135 holders may be mounted in any position and may be used in a variety of oscillator circuits, so long as the radio frequency voltage and current do not exceed the guarantee ratings. Each crystal is carefully tested for accuracy, activity and stability before it is sealed into its holder.



BOTTOM VIEW
SCHEMATIC

The TMV-135-C is identical with the TMV-135-E, except for the electrodes and the crystal. In the higher frequency ranges special crystals are employed and differently shaped electrodes are used to provide maximum output. High quality at low cost is provided in this series of crystals and crystal units.

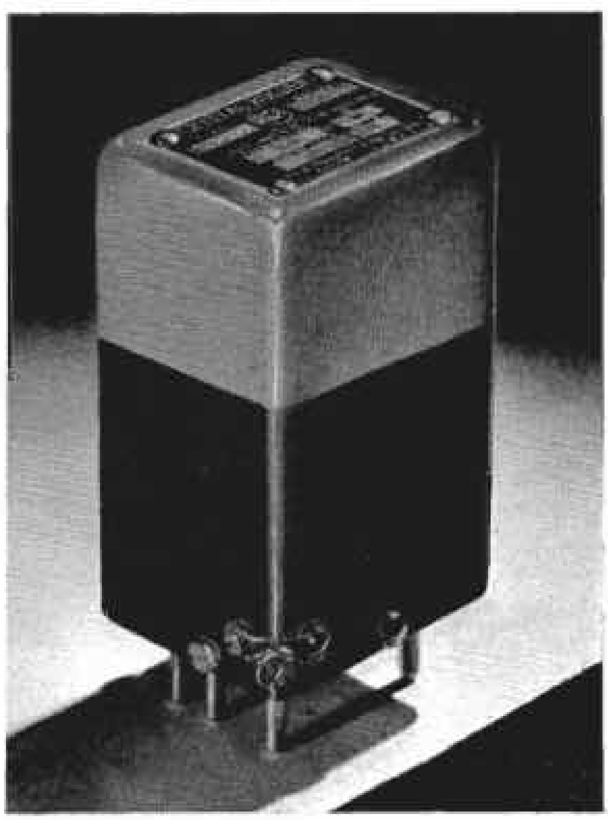
Crystals and Holders for Special Applications

A recent development of the RCA Manufacturing Company, of prime importance to the manufacturers of superheterodyne receivers, is the production of crystal units for intermediate or high frequencies. These units are the product of years of crystal research and manufacturing experience. Stability and a high "Q" factor are the most important characteristics of these units. Other outstanding features are their performance and simplicity.

These holders consist essentially of two similar moulded sections with an "X" cut or a "V" cut quartz crystal plate. The plate is inserted as the two halves are placed together and sealed. For intermediate frequencies the pocket formed by sealing the two moulded halves of the body together is just large enough to permit the crystal freedom of motion in any direction.

The complete units are so small and light that they may be mounted securely by the two leads which form the connections or by their electrode extensions. In performance, the use of RCA "V" cut quartz plates in these sealed holders provides high-quality, inexpensive crystal units, free from frequency "jumps" or "creeps."

Special types of crystal holders are constantly being designed and manufactured for special applications, and RCA will welcome the opportunity to submit designs and recommendations for crystals, crystal holders or complete units for any application in transmitters, receivers or test equipment.



SPECIFICATIONS OF STANDARD CRYSTALS AND HOLDERS

Type	Frequency Range	Temperature Range	Accuracy	Heater	Elec-trodes	CRYSTAL Mounting
AVA-10-B	1,715 Kc.—10,250 Kc.	0° C.—+50° C.	Within 0.01% of specified freq.	None	Nickel Silver	Pressure Air Gap
AVA-10-C	10,250 Kc.—20,000 Kc.	0° C.—+50° C.	Within 0.01% of specified freq.	None	Nickel Silver	Pressure Air Gap
AVA-10-D	1,715 Kc.—10,250 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	None	Nickel Silver	Pressure Air Gap
AVA-10-E	10,250 Kc.—20,000 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	None	Nickel Silver	Pressure Air Gap
AVA-11	1,715 Kc.—10,250 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	12 V. bi-metallic disc thermostat	Nickel Silver	Pressure Air Gap
AVA-11-A	1,715 Kc.—10,250 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	6 V. bi-metallic disc thermostat	Nickel Silver	Pressure Air Gap
AVA-11-C	10,250 Kc.—20,000 Kc.	−40° C.—+55° C.	Within 0.01% of specified freq.	6 V. bi-metallic disc thermostat	Nickel Silver	Pressure Air Gap
AVA-11-D	1,715 Kc.—10,250 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	12 V. Bi-metallic disc. thermostat	Nickel Silver (side	Pressure Air Gap terminal)
AVA-37	1,715 Kc.—10,250 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	NONE	Nickel Silver	Pressure Air Gap
AVA-37-A	10,250 Kc.—20,000 Kc.	−40° C.—+55° C.	Within 0.015% of specified freq.	NONE	Nickel Silver	Pressure Air Gap
AC-95	200 Kc.—400 Kc.	−10° C.—+60° C.	As specified	NONE	Monel Metal	Micrometer Ajustable Air Gap
AC-95-A	2,000 Kc.—10,250 Kc.	0° C.—+60° C.	Within 0.01% of specified freq.	NONE	Nickel Silver	Pressure Air Gap
AC-95-B	200 Kc.— 400 Kc. 550 Kc.—2,000 Kc.	−10° C.—+60° C.	Within 0.01% of specified freq.	NONE	Monel Metal	Fixed Air Gap
TMV-129-B	500 Kc.—3,000 Kc.	60° C.	Zero beat *	115 V. 15 W. thermostat A.C. or D.C.	Monel metal	Fixed Air Gap
TMV-129-C	3,000 Kc.—20,000 Kc.	60° C.	As ordered depending on type of service	115 V. 15 W. thermostat A.C. or D.C.	Nickel Silver	Pressure Air Gap
TMV-135-C	1,715 Kc.—10,250 Kc.	+10° C.—+50° C.	Within 0.01% of specified freq. for commercial use	NONE	Nickel Silver	Pressure Air Gap
TMV-135-E	10,250 Kc.—20,000 Kc.	+10° C.— –50° C.	or within 0.1% foramateur use	NONE	Nickel Silver	Pressure Air Gap

*Zero beat implies that the crystal is calibrated in the actual circuit in which it is to be used. For this, a trimmer condenser is used for fine adjustment of frequency.