another MRL Handbook... HB-10

Facts FOR CRYSTAL EXPERIMENTERS

By Elmer G.
Osterhoudt.

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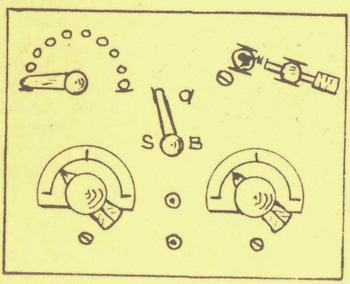

by
Elmer G. Osterhoudt
"With Radio since 1915," including:
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Radio Mechanic, Maximum, U.S.N.
Technician, Electrical Products Corporation
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F O R E W O R D

Hello - Crystal set fans, professionals, beginners, dabblers, newcomers and Old Timers! We are all in this thing together. The fact that you picked up this book shows some interest in the field of Crystal sets.

"Crystal sets" is a word many of the modern folks would like to forget. To the Old Timers, like myself, anything that uses a crystal and catwhisker - diode or Transistor - is still a Xtal set and nothing else. So, pardon us if we don't use the modern word "semi-conductor" because we feel more at home with the original - Crystal sets.

Millions are being spent in experimenting and plant expansion by companies building diode and Transistor units. Even the foreign countries are getting in the swim. As an example, Japan, for June, 1959, reports the following total output of semi-conductors: Diodes 2.6 million; Transistors 6.9 million; power Transistors 14,000; photo-transistors 2,700; rectifiers 23,000 and output increasing every day. Transistor set output is about 600,000 for the same period. Add to this the output of all the other countries and the U.S. and you have a sizeable business in semi-conductors. It is no longer "child's play!"

But, even with all the know-how - we do not actually know what takes place at the crystal/catwhisker contact, any more than we know what Electricity really is - we only have the many theories of explanation.

There is no more interesting field than small sets, with all their circuits - and crystals with all their varieties. One can spend a lifetime in this interesting field and still not learn all there is to it.

For easy experimenting, we suggest a "haywire" layout on your bench. No need to solder up for all experiments. Make up a bunch of red and black test prod wire leads, with an alligator clip on each end. Make them in 3-4-5-6" lengths. Clip them to something on the wall when not in use. Lay out your parts on the bench and clip them together with these leads. It just takes a few minutes to rig up a circuit. We do this quite often if we are not sure of a circuit. It is apparent many circuits may be improved by just juggling around the test leads.

WHY CRYSTAL SETS?

In order to properly build sets, and understand the more complicated theories of Radio, one must start from the bottom and work up. One must learn the 'why' of Radio (theory) as one advances- not that such and such happens if I "connect a wire here, etc," but why? If you learn the theory as you advance, you can immediately tell by looking at a circuit if it will work or not - and how well. The Crystal set is the best and only way to start. Many a fellow has quit Radio in disgust because he started with a 10-tube Bloop-a-dyne instead of first starting at the other end of the game and working up to it. If he did this - he would be more interested in Radio than ever.

Therefore, I can advise anyone that the best introduction to theory, Amateur Radio, commercial, broadcast work, receiving sets servicing, etc. is via the humble Crystal set. Don't think it is too easy - as here is a field in experimenting with Xtal sets that has never been touched by modern Radio principles. You can make a Crystal set almost as complicated as a tube set - if you have the knowledge, time and patience to work it out.

Recently there has been a tremendous revival of interest in Crystal sets, and they are now being built by beginners and professionals by the hundreds. There are many reasons for this, and my theories are these:

(1) During any depression, many Experimenters are forced to forget the multi-tube sets with all their 'frills and bills' and resort to other means of releasing their surplus Radio energy. They experiment with Crystal sets because it's cheaper.

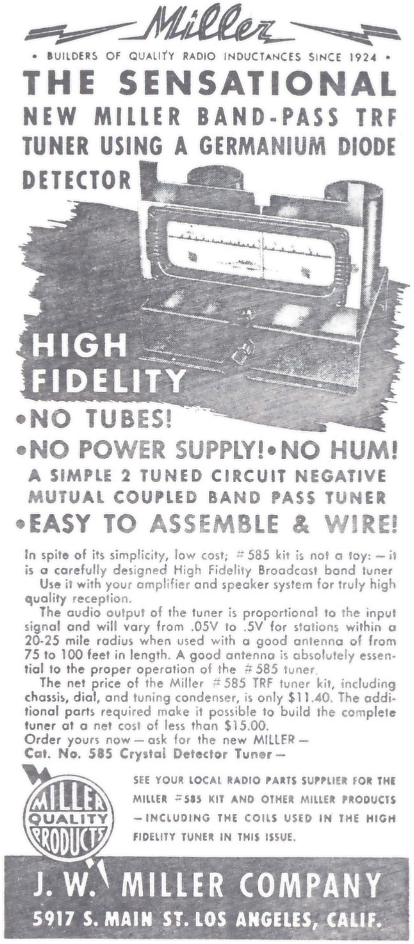
(2) Modern Radio magazines have advanced so far that if one can't swallow decibels, power-factor, and the various 'isms' used in them - they are lost. Especially the beginner, or the novice who likes to experiment for the fun of it, and not for the number of hieroglyphics he can make out of an equation. In other words, he must start with a complicated rig without understanding any of the principles involved. Learning it all in one 'gulp' is too much for him.

(3) Crystal set interest waned about 1924. With its revision, we can now apply the more modern techniques, circuits, Diodes and Transistor principles to Crystal set construction. In this way we can make a much better set now than we used to have.

(4) In comparison with the expense involved, there is nothing that affords so much amusement as a Crystal set. Many write in that they consider reception on a Crystal set as near to costing nothing as can be obtained.

So, fellows, start right with the Crystal set and you'll soon be building larger rigs with no trouble at all.

In Europe, and some other parts of the World, Crystal sets are used in the majority of cases. Engineers frankly admit that our modern multi-tube receivers cannot compare with the Crystal set in tone (fidelity). See Fig. 1, for a tuner running into a Diode crystal detector. See how they can be made into a modern piece of Radio apparatus. The oscilloscope shows voice reproduction from a Crystal is clearer than from any tube. Even with all the different kinds of tubes (some 15,000 types), the Crystal still surpasses them for clarity and faithful reception. Just listen to a station on a Crystal set and then listen to it on a modern Super-heterodyne and you'll see what we mean. In the latter, the base is either over-accented or there is none at all. The higher notes aren't the natural ones of the 'giver.' You can see how this works with a tone control on a tube set. You either have a high tone - or a low one. More Iron in transformers can



1. A Modern Crystal Set.

improve a tube set's reproduction immeasureably. If the bases are over-accented in a Crystal set - it is the fault of the transmitter. 'Clear as a Crystal' is really true.

Distances up to 25 miles are as good as a 201-A tube without regeneration. Under good conditions they may work over 4000 miles, in fact they have many times. They were used as standard equipment on Ships as late as 1923 - altho most Ops. carried a 1-tube detector and amplifier for convenience and reception of c.w. and arc stations. They are still carried for emergencies if the tube receiver goes out.

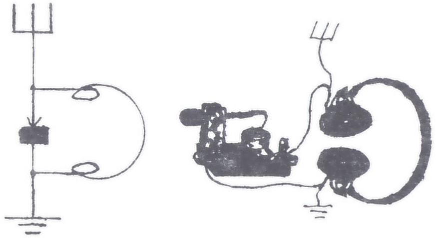
Almost every morning Australia used to be heard from Yerba Buena Island Navy station in S. F. Bay on a Crystal set. I have regularly heard old VAE, Estevan B.C. spark station off Los Angeles (1300 miles) on a Ship Xtal set - with receivers hanging on a knob of the set on my desk. This, of course, was under good conditions with a 300 ft. Aerial of 4 wires 75 ft. high, perfect ground on the steel hull, and at 9 or 10 p.m. But, nevertheless, it was heard - and many times, too. Ship operators have copied KPH, Bolinas, Calif., from the China Sea - a distance of 7600 miles, on ship Crystal sets. The Old-time Ops. can tell you what they used to do on a Crystal set but it's the new fellows coming into Radio who are skeptical and some consider it 'child's play.' We have sold hundreds of Crystal sets in the Miss. valley and the usual report is 1000 miles the first night. But much is to be done with them yet. A Crystal set has its place - and a mighty good one at that!

A Crystal set costs nothing to operate. No batteries are required unless using the Carborundum or Transistor types of crystals. A good crystal lasts at least six months - and, as they are cheap - we can say the cost of operation is nil. The original cost is also small. Many Fans, we come into contact with, have had a Crystal set operating for years at no expense. With a tube set - this is different. You can always use a tube, condenser or some other part - in fact, the average Serviceman can usually come up with a suggestion! If you build a Crystal set and decide to change the circuit - it costs practically nothing to do so. Usually the coil is the only part to be changed.

You won't burn out, or demagnetize a pair of phones on a Crystal set. They will be as good

10 years from now, provided you don't get hooked up to a lightning storm or your Aerial drop across a wet hi-line. Due to the heavy surges of DC in a tube set (mostly the Pentode output tube) phones have a tendency to demagnetize if their magnets are not made from good Cobalt steel. Or, if they get hooked the wrong direction in a set. See more on this in MRL HB-1 on Phones. In a Crystal set there is no such strong current to do any damage.

You may take a Crystal set anywhere - and it will stand a lot of 'booting' around before it becomes inoperative. Isolated spots, where there is no current as camps, resorts, beaches, etc. and if you have good operating conditions- your set will be OK. However, as discussed later, they seldom work good in canyons or near ore deposits or on the dry deserts. If a good tube set won't work - don't expect a Xtal set to work either. Give it a good Chance.



2. The Simplest Crystal Circuit.

Fig. 2 shows the simplest form of Crystal receiver that will receive signals. Just three parts are needed. An Aerial as a tuning inductance; a crystal as detector and rectifier; and phones to receive the impulses. If in a congested district, the stations will run together - but you will get music nevertheless. This is the principle used by the low-priced Crystal sets that are sold on the market.

Look at some of the old diagrams used by the early Telefunken and Marconi companies if you want to see if they can be made complicated. There was a mass of dead-end switches (for cutting out unused turns of coils)- various detectors (take your pick); large cabinets (some of them 3 ft. long); tuning and stand-by circuits; series-parallel types of switches; large tuning and fixed condensers (5 times as big as they are today); fuses (did you ever see a fuse in a Crystal set?) and numerous other parts. But the principles were just the same - tuning, inductance, crystal and phones.

Emergency Crystals and phones are hooked across the first tuning condenser in case the tube part breaks down or current goes off, Most land stations use ICW, that can be copied on Xtals.

Many Fans use Crystal sets near their beds so as not to disturb others asleep in adjoining rooms. There are thousands of them in use today for this purpose. One may lie down just as well with them. Sometimes one is awakened in the morning in case they went to sleep with them. Don't get choked on them!

Very little static is found on a Crystal set, due to lack of sensitivity and oscillation that are found in tube sets. During summer nights, when it is hot - you will get the same static and it will be more noticeable.

Where no current is available, unless you can lug batteries, etc. around - the Crystal set is very much appreciated. Hundreds are being used by prospectors, campers, etc. every night. Some of the distances covered are close to those made by a tube set. The usual deal is to throw 100 ft. of leadin wire over a tree and ground wire in a stream to get good reception.

During certain big Ohio river floods the following appeared in the Cincinnati Post: "Cincinnati Radio stations are reporting a rush for old Radio Crystal sets, use of which was abandoned by the majority of Fans years ago.

"Now, without electrical current, suburbanites, at home because of the general emergency holiday, and heeding the request of City manager Dykstra to stay at home and off the streets, are resurrecting old Radio Crystal sets, or buying new ones to keep tuned in on flood news from the Post's station, WCPO, or one of the three other local stations!" (Boy, what a long line - are you still with us?) hi.

Following from "Radio Craft," March, 1937:"And, believe it or not, there are still many of these Radio beginners who start in as did their fathers, with a modest Crystal set. The Crystal set still presents a tremendous attraction to tens of thousands of Radio beginners (and professionals!). If this were not so, it would be impossible, or at least difficult to purchase the crystal detectors these days. They are still sold, however, in great variety- proof of the popularity of the Crystal set. If you are within a mile or so of a powerful BC station,you can dispense with earphones, as a good magnetic type of loudspeaker, or a dynamic speaker with output transformer may bring in the locals good and clear."

Also in "Radio Craft," March, 1932:"Take for instance our present-day detector tube. It is woefully inedequate, with regard to quality, and compared to the Crystal detector, it is exceedingly poor. This has led a Western experimenter to substitute a crystal for a detector tube in his TV set, with astonishingly better results in the quality of the received image. (Ed. Used in practically all TV sets now.)The crystal detector is full of mysteries as yet unsolved by Radio engineers. The 'wise' Radio man may point out that great distances are freak reception. When it occurs hundreds of times, it is not freak reception!"

You never get ear-strain from listening to Crystal sets. It is not tiring to the auditory nerves. You may get "cauliflower ears" from too heavy phones - but inside they will be OK.

POCKET RADIOS.

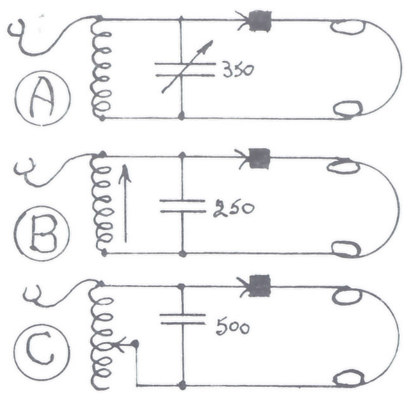
Let us differentiate when we discuss pocket Radios. There is first, the one we will discuss, that uses a Crystal and catwhisker - or crystal diode type, and having no batteries. Secondly, there is the type with several stages of Transistor crystals, fed by small batteries. Thirdly, we have the tube type- which has several tubes, fed by batteries.

In this discussion, we will deal only with the first, which uses but one Diode detector. We find lots of these advertised on the market, for which they claim wonders.

While they may be carried in the pocket,while riding or walking - they cannot be used as most people suppose, without an Aerial or ground connection. It must have at least a short pick-up to get energy from the air, as the small coil does not furnish this. Many of them advertise "no Aerial needed." Some may be used if you build up an Aerial around your body. Others may work a little from a whip Aerial, to be pulled out when it is played. A multi-stage Transistor pocket Radio,or miniature tube types have enough amplification that a built-in loop may be used. But enough power cannot be obtained from a single Diode detector with no Aerial.

All Pocket Radios that do not require batteries or tubes are Crystal sets and nothing else. There has been nothing invented yet that will give a lot of amplification without some external power being applied.

In Fig. 3-A is shown a simple circuit used in most Diode pocket Radios.A wire is clipped onto a metal pipe, light fixture, telephone, or any metal object - or even the water or gas pipe, - to get enough energy to make it work the phones. Some even rig up a phone in a box to make a speaker out of it- and advertise it as such. It is easy for the average Radio Fan to fit this coil, Diode and midget variable



3. Usual Pocket Crystal Radio Circuits. (A) Variable Condenser. (B) Loopstick. (C) Slider Tuning.

condenser into a box and receive signals. If you wish to use a Loopstick and a fixed condenser, then use Fig. 3-B. Fig. 3-C will let you use a slider on the coil to tune the stations. The latter is our MRL #19 Pocket Radio.

Some manufacturers say their Pocket Radios are "not cheap Crystal hookups." When you read the ad, you imply they are not Crystal sets, but what they really mean is they aren't "cheap" as you pay plenty for them! At first they used a fixed Iron pyrites crystal but now they use any type of Crystal Diode.

We get many letters saying: "contrary to your ideas, we get 700 to 1000 miles on our Pocket Radio." Yes, that may be possible - but do you do it without an Aerial or ground, as advertised? If you'll get far enough away from strong BC stations you can tune in a lot of DX on a Pocket Radio if you have an Ant. and ground. However, with a larger Crystal set, built with a low-loss Celluloid coil, standard .00035 variable condenser and the right circuit - it is a lot easier and better. Some concerns claim equal results but this is impossible.

Another well-written piece of literature, I have in front of me, says:"How would you like to have a guaranteed Pocket Radio, that you can take with you to camps, etc.?" After reading four pages of advertising - I can't find what the "guaranteed" refers to. Maybe it means it is guaranteed to be a Radio - which lets it get by.

Within the last few years a big firm, with thousands of dollars worth of advertising, from New York City, advertised to Hi-Heaven what was a Radio wonder. It turned out to be a simple Diode Crystal set - with more advertising than results. After thousands lost money on this scheme - the company was finally closed up. We gave personal advice to several of our customers to "lay off" - and build themselves a simple set for a lot less money and far better results than this scheme.

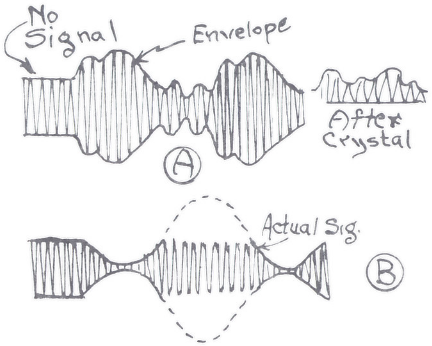
If you want to build a Pocket Radio - that is fine, but don't expect too much of it. It may cost a little more to build a good-sized Crystal set, but you will be far ahead in money and enjoyment.

Don't be fooled by large magazine ads, either. You might feel that because you saw it in a big magazine - it has to be right. Integrity, with the magazine, has nothing to do with it, when several thousand dollars a page is involved.The government won't prosecute unless there are lots of complaints. Few of us want to spend our life-savings to put some outfit on the right track. As a result,these trick ads keep coming - and the magazines keep printing them.

On several occasions we have been refused a little classified ad because we advertised "Short wave Crystal set." How else can you get several thousand miles on a Crystal set unless you go Short wave? We have hundreds of letters on file to prove that it has been done consistently. The same magazines took other ads that mentioned Short wave - and as soon as we wrote them, they took them out. But the magazines got the first ad in OK. These same magazines are full of trick ads for Pocket Radios, get-rich-quick schemes, etc. - so don't believe all you read.

DE-MODULATION and RECTIFICATION.

When I was in the YMCA Radio School, Los Angeles, in 1919, the subject of modulation was quite a bugaboo. A lot of meaningless junk - so we thought. But since then I have found that it is the whole backbone of Radio, and should be studied by everyone. It is really not as complicated as one might suspect if it is figured out.



4. (A) A Well-modulated Signal.
(B) Poorly Modulated.Mushy.

In order to de-modulate - we must have modulation to start. Fig. 4-A shows a carrier wave from a transmitter coming thru. The peak of oscillation is called the non-signalling amplitude on each side of zero. When sound waves are applied to this frequency, we get modulation, or an additional sound frequency added to the original steady carrier.

During conventional amplitude modulation (AM), the frequency of the carrier does not vary. You can prove this by listening to the steady squeal of a distant station on a tube set. In frequency modulation (FM) the carrier is varied in frequency.

The modulation of the carrier takes the form of the production of side frequencies or sidebands from the transmitter. The width of the modulated wave, or channel, above and below the carrier frequency, depends on the width of the tone wave impressed upon the carrier. The edge of this tonal wave is called the envelope. As we cannot hear DC, we hear the point where the current reverses, both in the carrier and the envelope.

If the tone wave is 1 KC. - then it will run 1 KC. above and 1 KC below the carrier. Good speech modulation is between 2.5 KC. and 3.5 KC. and called 100% modulation. A male voice has the greatest modulation. If too much modulation is imposed on the carrier- it may occupy more than 6 KC. band-width and interfere with other stations 10 KC apart.

If a buzzer, or audio oscillator tone is added to a carrier, there is very little modulation. Therefore, a much sharper-tuned transmitter. Any form of modulated carrier may be received by a Crystal detector.

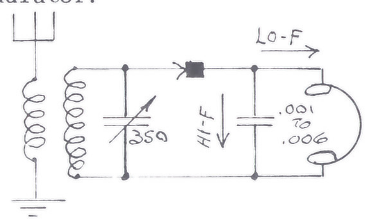
At Fig. 4-B we show a poorly modulated wave - where the tone is mushy. You've heard a lot of them. In this case the carrier will predominate.

In the U.S. and Canada, the BC frequencies are assigned evenly every 10 KC apart. Several stations may be assigned the same frequency, but time and location enter into their operation. If a station gets off its frequency, it will beat against that of another and cause distortion in both. RCA, and others, used to charge so much for monitoring BC stations, but I understand this is no longer done. No doubt the FCC does it for them - as a policing action.

In the receiver, we cannot hear the individual RF, or Hi-F oscillations coming over the Aerial, directly in the phones. They go too fast to vibrate the phones. Also, they would be too fast for our ears to hear anyway

as they respond to but 15 KC per second. The lowest BC frequency is 550 KC per second. Therefore, what we hear are not the tiny oscillations, but only the wave trains, groups, or envelope - corresponding to the microphonic audio frequencies.At the receiver, the carrier frequency beats against the side frequencies and this beat note is rectified by the detector. In certain systems only the modulated audio signal is transmitted, but it is necessary to have a steady carrier frequency at the receiver for it to beat against.

Rectification of the carrier and sidebands takes place in the detector. Because current passes in but one direction, only half the signal gets thru. This may be the zero to positive, or the zero to negative, depending on how the detector is polarized. Then you get the effect of sound waves in the phones from wave trains. The steady carrier is also rectified and finally dissipated by the hi-impedance of the phones, speaker or audio transformer. As a final result - de-modulation, or detection is said to take place. A Crystal, or other diode, is called a carrier rectifier, detector or demodulator.



5. Separation of Hi and Lo Audio Frequencies at Phones.

In Fig.5 you will see a simple Crystal circuit that shows the path of the wave trains. By putting a bypass condenser across the phones you lower the tone. This shows that the Hi-F goes thru the condenser and the lower frequencies go thru the phones. Lo-F won't go thru a condenser as easily as Hi-F. This is the principle used in tone controls on the outputs of tube sets.

One reason you get more volume on a tube detector than a crystal is because the latter rectifies only.The tube detector both rectifies and amplifies. Adding regeneration to a tube detector increases its output many times.

THEORIES OF DETECTION.

A detector is any device which renders Hi-F waves perceptible to any of the senses. A crystal is said to conduct "asymmetrically" (lack of proportion) or "unilaterally" (one direction). The sensitivity of a crystal depends on its one-way conductivity, or rectifying properties. Rectification takes place at the catwhisker contact. Unilateral activity is not perfect, as some current also flows in the opposite direction.

Crystal detectors are also "non-linear" - i.e., a certain increase in current does not increase the output in the same proportion. Other examples of non-linear resistances are Copper oxide rectifiers, vacuum tubes and electrolytes.

Crystal detectors are also "square-law" devices, i.e., the current varies as the square of the impressed voltage. Diode tubes are also square-law devices.Crystals are also "aperiodic" - no oscillation and untuned.

A crystal is more sensitive than the old Fleming valve - and as sensitive as a 201-A without regeneration. The more unstable a crystal,and the finer the catwhisker, the more sensitive it is, and the greater distances that may be covered. Likewise, the vacuum tube, when used as a detector, is also unstable. Hold your hand close to the detector tube of your big set and note the hand capacity. Also, if you remove the shield you will also get more DX - try it! Crystal detectors are sensitive if the contact is limited to one point. No increase in current is found by using several contacts. We have found it impossible to use Steel wool against a crystal for more contacts. Nothing happens. Two and three contact Transistor crystals are a different proposition as we are speaking of Diodes only.

We like to go off on a tangent now and then. The subject of large-contact rectifiers may be interesting in the study of unilateral activity. These are the large surface types as rectifiers, chargers, modulators, etc. for low frequency circuits, in contrast to crystal detectors with small contact points. Like crystals, they must also be disimilar metals or elements.

Before they came into existence, the electrolytic rectifier - or slop jar, was in universal use. If you spilled them - you were in a mess! When you pressed the key you'd get a gurgle when using an Electrolytic interrupter on a transmitter.

About the first solid rectifier, of large surface area, was the Kuprox, **or Copper oxide.** It consisted of a layer of metallic Copper alternated with one of Copper oxide. Usually one side of the Copper plate was left bright and the other was oxidized. This allowed current to flow only from the oxide to Copper. Lead plates were placed next to the oxide to get connection. A funny story comes to mind about a Los Angeles distributor who called in defective Kuprox units for credit. He sold 50 but was "lucky" to get 51 back! They're made up of several units in series, depending on the voltage. Its rectification is not as complete as a vacuum tube.

Selenium rectifiers are made from a Nickel-plated Aluminum or Iron base, coated with Selenium and sprayed with a low-temperature alloy. Selenium is very closely related to Sulfur and U can smell it when it gets hot. It is found in the free state or in Iron pyrites or other sulfide ores. (Note the connection with Iron pyrites crystals.) The base is negative and the alloy is the positive. Usually has a ratio of 100 to 1. Range may carry from a few volts and milliamps up to thousands of Amps. at high voltages. Selenium needs a small resistor in series to balance the load against high surges.

Silicon rectifiers are about the latest in large surface rectifiers, as they are not affected as much by temperature. They may operate up to 200 deg. C. and in the neighborhood of 1500 volts input. Silicon uses a much smaller rectifying area than the Copper oxide, etc., usually about 1/8 to 1/4" wide. Many are mounted directly on the chassis to form a heat sink. Silicon also requires a protective resistor. Low-power Silicon diodes have their contacts welded. Larger surface types usually have pressure contacts. For small meter rectifiers, Transistor power supplies, etc. ordinary Diodes may work OK, as well as small Copper oxide types.

The radiating fins on all solid rectifiers are to keep the heat down.

Copper sulfide was another type of rectifier. It used discs of Copper sulfide and Magnesium. It had a short life.

Another rectifier was granulated Silver and a metallic alloy, and separated by dehydrated Sulfuric acid (non-conducting), as Raytheon A rectifier, formerly used in A eliminators in 1926.

From the above descriptions, you can see the similarity between crystal detector materials and large surface rectifiers.

Nobody really knows what takes place in a crystal to make it rectify and detect. Various interesting theories have been advanced. There are so many mysteries as thermo-electricity, action at the contacts, atoms, molecules and peculiar actions of Electricity in general. For this reason, we are giving you some notes on allied subjects to make you decide for yourself.

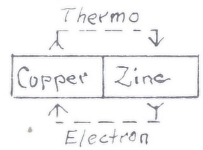
VOLTA EFFECT. Count A. Volta discovered the Voltaic cell, or the first Electric battery. Volt was also named after him. The Volta effect, contact potential or contact electrification is when two dissimilar metals touch each other, one becomes positive and the other negative. The neg. has more electrons and passes them over to the positive.

POSITIVE thermo-current --»

Bismuth - Nickel - Palladium - Aluminum - Tin - Lead - Gold - Silver - Copper - Zinc - Iron - Antimony.

«--electrons **NEGATIVE**

6-A. Polarity of Metals.



6-B. Direction of Activity.

In **Fig. 6-A** is shown a chart with POS. on one end and NEG. on the other. For instance, Bismuth is Pos. to Nickel and so on.

According to the electron theory - different substances give up their electrons with varying degrees of reluctance. Zinc gives them up easily, so a number of negatively-charged particles go over to Copper. Measureable voltage is found between the same substances with different structure, e.g., Lead and Lead oxide in a battery; cast Copper and electrolytic Copper, etc.

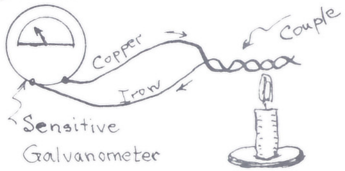
Volta discovered tiny voltages of .00025 to .0279 to be generated, as recorded on a sensitive galvanometer. Some metals, like Bismuth (pos.) and Antimony (neg.) produce the most voltage in the chart. From **Fig. 6-B** the electronic current flows from Zinc to Copper; thermo-electric current from Copper to Zinc.

Frictional Electricity is explained in a similar way, except a more intimate contact is necessary where the conductivity of the substances is small.

SEEBECK EFFECT. in 1821, Seebeck discovered that an Electrical current is produced by heating the junction of two dissimilar metals. Cooling one side may double the effect. This is known as the thermo-couple.

Very small currents are produced - ranging from .00025 to .03 v. but doubled by heating one side. Heating is said to tear off electrons from the negative metal and transfer them to the positive - thru wires and back to the negative metal. It is measured in micro-amps. or in milli-volts.

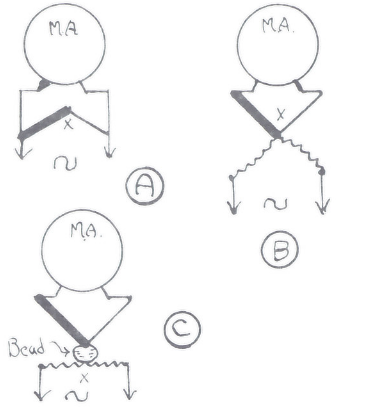
The contact between metals and electrolytes is greater, e.g., batteries, where there is a chemical action between. A battery was invented, for experiments, using a thermo-pile - and developed about 2 volts and current of 3 to 4 amps. Larger ones of 100 elements made 4½ v. and 4 to 5 amperes.



7. A Simple Thermo-couple Experiment.

Joints may be held by clamping or bolting or riveting. As in **Fig. 7**, the opposite ends run to the meter. One of the difficulties is that the thermo-couple is operated close to the burn-out stage and often has to be replaced. Few metals can withstand high and low temperatures for long, and it is the difference that makes the voltage. If ends are connected over a long period of time, current ceases to flow as the balance of electrons pass from negative to positive. Unit must be renewed.

Thermo-couples are used in thermostats, etc. and furnish just enough current to actuate a solenoid to control the regula-



8. Thermo-coupled Ammeters.
(A) Simple direct couple.
(B) Contact Thermo-couple.
(C) Bead Thermo-couple.

tor. Pyrometers use pure 87% Platinum alloy and 13% Rhodium. With 1000 deg. of heat, the Iron and Constantin couple produces less than 30 millivolts.

A thermo-couple is used in RF measuring instruments as they operate independent of frequency and up to 100 mc. Most meters use Constantin and Copper or Constantin and Manganin. **Fig. 8-A** is a simple couple, but more sensitive and easier to burn out. **8-B** works with a central couple with the resistors heating up the couple. More isolation but not as sensitive. **8-C** uses a glass bead and is still less sensitive, altho it has lower capacity effects. Meters use the D'Arsonval galvanometer as small DC flows thru it. Scales are hard to read at the bottom.

Various alloys are often used, but should be pure for best results. Some of the good thermo metals are Bismuth and Antimony German silver and Copper sulfide - Iron and Advance, Advance (Copper and Nickel), Alumel (Aluminum and Nickel), Chromel (Chromium and Nickel), Constantin (Copper, Nickel, Iron, Phosphorus, Silicon and Carbon).

Using a couple of Bismuth and Antimony it is possible to register a change of 1/millionth of a degree of temperature. The Bolometer, devised by Langley, uses a thin strip of Platinum connected in the arm of a Wheatstone bridge for fine tests.

The early Telefunken Company used a form of thermo-electric detector in one of their systems which is interesting. A small Copper cup is used for one connection. A fine Platinum wire rests in the cup, but was heated by an Alcohol flame. This developed an EMF at the junction. Incoming oscillations disturbed this current and actuated the phones. The cup was occasionally moved to find new spots. There is no doubt the imperfect contact had a lot to do with it.

PELTIER EFFECT. In 1834, Jean Peltier, France, discovered that when current was passed across the junction of two dissimilar metals the joint heated up; if passed from positive to negative and cooled it reversed. It is the opposite to Seebeck for in the latter - heat produces Electricity. In turn, this action develops a new current, called Peltier Electromotive Force. These tiny currents are due to molecular action at the junction and thruout the conducting wires owing to their non-uniformity in temperatures.

THOMSON EFFECT. To Prof. Jos. Thomson, England, is due much of the development of the modern Ionic theory of Electricity.

He found there is a tendency to increase or decrease the differences in temperatures when Electricity flows thru an unequally heated metal. In Copper, the current transfers the heat from hot to colder parts. In Iron it is transferred from cold to the hotter. In each case it tends to equalize the temperatures. There is no effect on Lead.

He also found that if one metal was heated on one end, and cooled on the other, that a very small thermo-electrical voltage was produced, which can be detected by a Galvanometer. The

same effect was noticed when he heated Iron and Copper at different temperatures and placed them end to end. This current is called the Thomson Electromotive force. The conductors may be thought of as composed of a number of little elements of volume at the junctions between which occur reversible heat effects. This is similar to the Peltier effects. If battery current is forced into the same circuit, there is a push or pull at the junctions, and the temperature of the joint will be raised.

Thomson believed that with rectifying detectors, that act without any applied voltage, that when a current is applied in any one direction, it heats up at the catwhisker junction. Reversing the current destroys the heat. Also that more current flows with the increase in temperature and decrease in resistance. The current, thus developed, is pulsating direct current and serves to energize phones.

CUMMINGS. In 1822 he discovered that when you heat one end of a bar and cool the other - and suddenly reverse the procedure - the current flow is also reversed. He also discovered "temperature inversion" - in 1823. This means that if there is any temperature for one junction, there is also the same for another. As one is made hotter, the current increases, decreases and reverses. Another complication that may disturb the detector.

Fleming suggested, before 1908, that a crystalline substance may contain valves that allow the current to flow in one direction only. This is nearest to the present Band theory of detection we now have.

BAND THEORY. This is one of the theories of crystal detection and rectification. Metals are good conductors, while insulators are poor. Semi-conductors, or Crystal detectors, have some of each property, as the name implies. Our Crystal detectors work good because Nature has thrown them together and mixed the conductors with the impurities. Impurities must be added to pure Silicon to make it a "P" type conductor. If added to pure Germanium it becomes an "N" type conductor, in the opposite direction. The usual additions are Aluminum, Antimony, Arsenic and Gallium - of about one part in 10 million, depending on the kind of characteristics desired.

Outside shapes of crystals may help the Chemist and Metallurgist determine a substance. The crystals may be classified into 7 fundamental systems of shape. They are (1) regular, or Isometric, as Galena and Iron pyrites; (2) Tetragonal, with 4 plane triangular faces; (3) Orthorhombic, with 3 unlike axes at rite angles; (4) Hexagonal, or 6-sided, as Quartz; (5) Monoclinic, dipping in one direction; (6) Triclinic and (7) Trigonal and many subdivisions of each. You may read further in your Encyclopedia if you wish.

Different substances that may crystallize into the same system are called Isomorphous. Others that may have several different crystal forms are called Allotropic. For instance, Carbon may go to the Diamond, in the regular system, or Graphite in the hexagonal. Sulfur may also form into two different shapes, etc.

Crystals are usually formed into orderly lines and planes unless pressure interferes. Plane surfaces are called Faces. An imaginary line drawn from one point to the opposite high point is called the Axis, like the Earth's axis.

When a monochromatic (1 wavelength) beam of X-ray is shot at the face of a crystal it will reflect its "grain" at a definite angle. During the War, while working at the Electrical Products Corp. plant, in Oakland, we shot Quartz crystals with X-rays to get the position of the cut. If they were cut wrong they would not oscillate. The naked eye cannot detect this "grain."

This grain is a mass of atoms built like a brick wall in three dimensions. It is called Crystal, or space Lattice, as you wish. It reflects the X-rays just as if there was a layer there.

Particles in the Crystal lattice are held together, in orderly fashion, by Electrical attraction. If this attraction is weakened by Electricity, heat, water, absorption, etc. the crystals fall apart.

Metals, insulators and semi-conductors all have their electrons arranged in bands, or levels. Each band may accommodate but one electron but there will be lots of levels of the same.

In metals, and semi-conductors some bands are filled, others partly filled and some empty. An applied Electrical field may force some of the electrons from the highest filled levels to the empty, or partly filled ones. This allows the current to flow thru. A filled band is called a Donator and an empty, or partly filled one an Acceptor.

In the Acceptor band there may be many "holes." When current is applied, an electron is taken from the filled band and enters the hole. The hole, that it left is now filled by another electron from another source. For this reason, the holes are called Current carriers. The impurities, that are added, help to make up the holes originally.

Insulators have a band structure of a filled level and above this a number of vacant, or forbidden bands. Because all bands of an insulator are full - they cannot take on more electrons. Conduction of current is now impossible as electrons must flow to carry the current.

Ductile metals, as Gold, Silver and Copper crystallize in packed atoms, called Face-center lattice. Ductility (state of being drawn out, as wire, etc.) depends on the ease with which each layer may pass over another layer of atoms.

Organic compounds form crystals of Molecules.

The Crystal lattice of Carbon, Sulfur and metallic elements are made up of uncharged atoms.

Most salts generally have the Crystal lattice made up of Ions.

So by electrons going from one hole to another, in but one direction, we get the explanation for current going in but one direction. As all semi-conductors will flow some current in the opposite direction, according to this - they must have certain bands "out of order." However, this is just one of the theories but seems to be accepted by most Scientists now.

Detection was first believed a product of thermo-electricity due to presence of heat at the contacts. Pickard demonstrated that it was not thermo-electrical, but due to rectifying properties of the crystals. He called crystals solid rectifiers in lieu of gas or electrolytic.

Prof. G.W.Pierce has made some lengthy experiments that showed there is no action occurring in crystals that could not be accounted for as inductance, resistance, etc. He has shown the heat at the rectification point of a crystal produced thermo-electricity at less than 1/500K of the rectified current. Thermo-current opposes the rectified current, as we have seen.

HALL EFFECT. In 1879, E.H.Hall a Harvard physicist, found that a minute transverse voltage was produced when a powerful magnet acts on a thin strip of metal, carrying a current. This was called the Hall voltage.

Ordinarily the electrons move lengthwise with the current but placing the magnet above and below the strip causes them to be shifted to one side, toward the negative side. This leaves a surplus of positive charges on the opposite side. This is called the Charge-carrier mobility.

Until recently it has been hard to find materials that produced this effect in easily measureable quantities. Now with the production of semi-conductor materials of Indium arsenide and Indium antimonide it has been made practical. Even so, the Hall voltage is in hundreds of millivolts. You can see the relation of crystal detector material when it was used.

Prof. Ruhmer used a flame detector for the first experiment leading up to the Fleming valve, in 1890. Ruhmer got signals from his flame detector but Fleming worked a filament and plate inside a vacuum tube. De Forest later came along and put a grid in it to control the trigger action. So even heat can enter into the detecting effect.

Some crystals have a pronounced capacity (condenser) effect, but with others it is almost neglible. Zincite, Chalcopyrites and Molybdenum have a capacity effect of about .001 mfd. Steel galena, Galena, Carborundum and Iron pyrites may run from .0001 to .0005 mfd. This may make you think why these crystals tune a lot sharper than Germanium diode crystals. Think about it!

Well, after reading all the above, you may wonder what it has to do with Crystal sets! Hi. It shows how they have been working all these years - trying to figure out what goes on at the catwhisker contact. But you can see there is a definite relation between thermo-electrical action, hot and cold, input and output differences in the signal and rectification, atomic re-arrangement and likeness to a tube detector. Still we get different reproduction in a crystal than we do in a tube.

SOME EARLY CRYSTAL DETECTORS.

More than being historical, the following will show how it interested important Scientists of the past. Like Edison's Electric lamp - thousands of combinations have been tried - with varying degrees of success. Just think of the time that has been devoted to the study of the lowly Crystal detector, or Diode. One valuable book we have "Crystal Rectifiers" by Mass. Institute of Tech. has 443 pages. You can see many other high-priced books on Semi-conductors - so there is still a lot to be done in this interesting field.

In this short space we will give some of the findings of some early Scientists. It is hoped you can find basis for some interesting experiments in these few notes.

First detectors of Radio waves were called Cymoscopes. They began with Coherers and other imperfect contact detectors, up thru thermal, magnetic, electrolytic, tube and finally to the Crystal detectors.

Braun, in 1874, first noticed the rectifying properties of the crystals when he used Tetrahedrite (see HB-3) with Silver catwhiskers, battery, potentiometer, pole-changing switch and galvanometer.

In 1906, Gen. Dunwoody discovered Carborundum could be used as a detector, altho it originated in 1891. It is not disturbed by jarring. Its best points are the rough ones caused by being next to the furnace wall. Its best operation is at 1 to 1.2 v. controlled by a potentiometer. An incoming voltage of .01 will vary the resistance about 4% at its most sensitive point. It has also been used as a powder in a glass tube, with brass plug contacts under pressure from both ends. Its sensitivity is about the same as the Electrolytic.

Pierce, 1907, discovered Titanium oxide with Silver telluride as a catwhisker and a small battery worked good as detector.

Dr. W.H.Eccles and Austin did a lot of crystal experimental work around 1913.

Pickard, afterwards, did a lot of work as he discovered Silicon would detect waves. He used Gold or Gold-plated catwhisker - but brass was next best. Silicon was not impaired by strong static charges. Much commercial Silicon contains metallic Calcium which may be attacked by air to form Calcium hydroxide to render it useless. Silica was also an impurity that had to be taken out. At present, the upper part of the melted ore is used for Xtals and the bottom rejected, thereby producing Silicon 99.9% pure.

Pickard also discovered the Perikon detector. It may be many combinations - but essentially it is made of two different crystals - with one as the catwhisker. The contact is usually heavy - made by adjusting screws to proper sensitivity. His Zincite (oxide of Zinc) in contact with Copper pyrites (sulfide of Copper) was considered twice as sensitive as Silicon. It could be used with or without a battery. Other combinations were Bornite, Iron sulfide, Silicon, Molybdenum sulfide, etc.

We understand Pickard obtained a patent for"any mineral effect" - called thermo-electric. All mineral effects are not thermo-electric- so it has been proven.

Roland Brownlie used to make fine Crystal detectors for the Navy, etc. One of his Perikon detectors used to sell for $15 to $20. The famous Dr. Pickard gave all his data to him when he had finished experimenting with Crystal detectors.

The early German Telefunken Company used various crystals in their ship and shore stations. Galenas were early used but they knocked out easily. They used a Graphite (pencil lead) as a catwhisker, with a very light contact. Also a catwhisker of Platinum wire, or a pointed piece of Tellurium. Iron pyrites, with a Gold or Gold-plated wire worked very good. "Moly" - or Molybdenite was also used by them. It was held between two brass contact plates and the catwhisker touched the third side. Moly may be cleaned with sandpaper.

The Hozier-Brown detector, of England, used a pressed pellet of Peroxide of Zinc between a blunt lead contact and a plate (!) of Platinum - with an adjustable battery around it.

Many combinations are still being tried. Recently, at John Hopkins' University,a tiny strip of Columbium nitride was frozen to 465 deg. below zero F. and it made an excellent detector. Most metals' resistance increases with increase in temperature - except some alloys that remain constant. The resistance at absolute zero is practically nil.

From 1925 to 1940 the Crystal detector was used mostly in the laboratory for detecting and the monitoring of UHF power. A combination of Silicon crystal with a catwhisker of Tungsten or Moly was the most sensitive.

Southworth and King, 1939, developed a Crystal detector for microwave work using Silicon and Tungsten as a c/w. Surface was polished so c/w would move easily and was found to hold its adjustment for several weeks.

A "high-burnout" red-dot crystal was developed by G.E. of England, where Silicon powder was mixed with very little Aluminum and Beryllium. This started the addition of impurities which made crystals more sensitive.

Boron doping is used considerably in Silicon diodes.

THE CARE AND OPERATION OF CRYSTAL DETECTORS.

The following requirements of a good detector may not be amiss at this time. (1) as much surface as possible should be exposed for adjustment; (2) Xtal must be firmly mounted to get a good Electrical contact; (3) the position and pressure of contact must be adjustable; (4) it must rectify with very small changes in potential (sensitive); (5) it must not jar out easily; (6) be unaffected by atmospheric conditions; (7) should be easily replaceable.

Too much heat applied to, or near a crystal tends to reduce its sensitivity.Some Fans prefer to mount their loose crystals in a cup instead of heating them. Tinfoil can also be used to pack around it for a better contact. In the early, more elaborate stands, the cups had 3 setscrews

that were used to screw up on the crystal hunk.

Hugonium, or Wood's metal, is used to mount the most sensitive crystals. However, most concerns use soft solder without rosin flux, as it's more easily to obtain. We use Plumber's lead and pour them into molds.As it cools instantaneously, it does not affect the crystal. Wood's metal may be made by melting 2 parts of Lead in a crucible.Add 1 part of Tin; 4 parts of Bismuth and 1 part of Cadmium and stir. While Lead melts at 327 deg. C. this Wood's metal melts at around 70 deg. C., or can be melted in hot water (see HB-3). A mold may be made and the Wood's metal poured into it.Quickly push the crystal down in the liquid, and just far enough to leave a little "holding" edge around it. A wooden mold may be made by clamping two pieces of hardwood in a vise. In the crack, drill a 7/16" hole ¼" deep. Place them in a clamp to pour - and then remove the clamp and the crystal will drop out.

Another soft metal may be made by melting equal parts of fine lead wire and tinfoil,and adding a little Mercury. If too much Mercury is added - it will have no holding properties.

Notice how easily plain Galena knocks out of adjustment, but on the other hand - how sensitive it is. Iron pyrites and Silicon are more stable but lack the DX properties of plain or Steel Galena.Steel galena has a lot more points than plain Galena.

We believe there is nothing to equal a good piece of plain Galena. Its best points are near the edges of the cubes, or in cracks in the cubes.The lightest touch is required - and we find a long, fine catwhisker is the best.

Steel galena is next best but is more practical as it has more points and less easy to knock out. It takes a little heavier adjustment than plain Galena.

Iron pyrites and Silicon take a heavier touch than Steel galena. Fixed pyrites and Silicon were used in older Pocket Radios - but the newer Diodes are now in use.

Carborundum may take up to 5 lbs. pressure from a heavy brass catwhisker, and with a battery in series with it, is the most stable of all. In proportion, it is not as sensitive to weak DX stations.

Diode crystals now have their catwhiskers welded to the crystal on the most sensitive spot. They form their catwhiskers into the form of an "S."

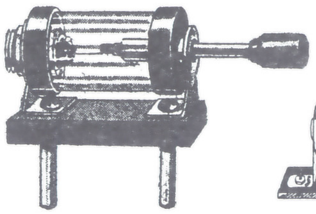
Any metal, that doesn't corrode, may be used as a c/w. It's queer - that in the order of the sensitivity - they are also expensive, and freer of corrosion. For example, in their order of sensitivity,- Gold, Gold-plated, Silver, German-silver, brass, Copper, Iron, etc. In many of the old ship sets the spring c/w was Gold-plated to save money. Corrosion, or oxidation, is the bugaboo of good catwhisker contacts. It is a good idea to file or sandpaper the c/w point now and then to remove corrosion or burned surfaces, which prevent good DX reception. NEVER scrape, or sandpaper a crystal if you want to use it again. Molybdenite is the only one we know you can do this and not hurt it. If you raise your c/w instead of sliding it - it is also better.

Also, always cut the catwhisker off straight with a pair of scissors and not with diagonal pliers. The latter gives a wedge shaped cut which isn't good.

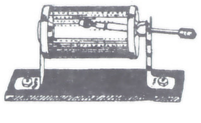
A glass-enclosed stand is OK for local reception,but for real DX it is hard to adjust. We used to have some good ones made in the USA, but Fig. 9 will show a few suggestions from Australia and Argentina that are good.

With all commercial stands you will find a heavy c/w wire, and why they do it I don't know. We use a very fine wire that we wrap around this heavier one, after soldering the latter to the adjusting arm. You won't get any good DX with the heavier.

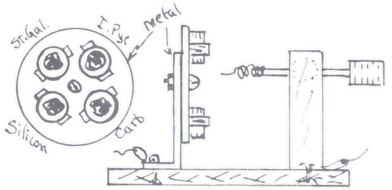
Crystals should not be touched



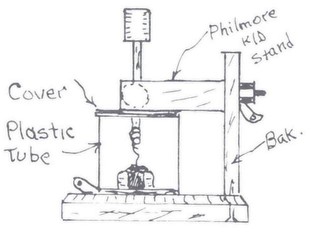
Argentina Enclosed Stand.



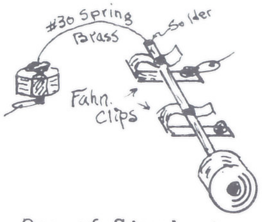
Australian Enclosed Stand.



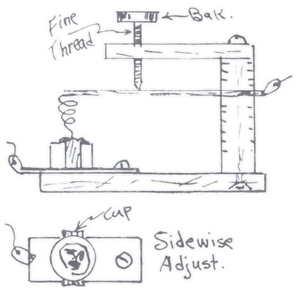
A Selective Crystal Stand.



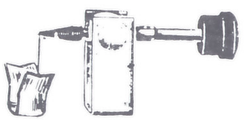
Making an Enclosed Stand from Philmore Knocked-down stand.



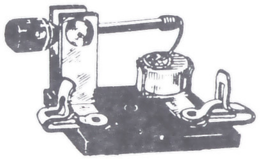
One of Simplest Stands for the Finest Whisker Adjustment.



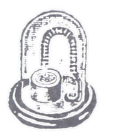
Another Fine Crystal Stand with sidewise Adjustment.



Philmore Knocked/down Crystal Stand.



Philmore Assembled Crystal Stand.



Philmore Enclosed Crystal Stand.

9. An Interesting Variety of Crystal Stands.

with the fingers as the natural oil on one's body will rub off on the crystal. This oil makes a resistance at the point. If a Crystal set is used around the kitchen, where grease and steam combine, it will soon lose its effectiveness. Sometimes the washing of a crystal in Ether, water or Alcohol will help remove the grease. When handling a crystal- always touch the sides.

Inasmuch as a crystal may be cleaned - I firmly am convinced that, for best reception, it is best to renew it every 6 months.

Even crystals, that have been enclosed, do not have the sensitivity of a new one - unless the new one is inferior.

A very loud signal, or heavy burst of static may destroy the sensitive point of contact between crystal and catwhisker. It just requires re-adjustment. In spark transmitter days the Xtal was automatically shorted by the change-over switch when sending.

Some circuits use the crystal in series with the Aerial and ground. Besides being very broad tuning - the crystal is affected

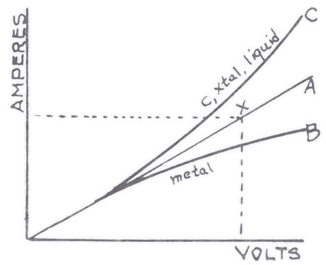
by heavy static surges and soon loses its sensitivity. I have heard of several Fans who used this type of circuit and soon complained of the crystal getting weaker. It is worse in the tropical climates and Lower Cal. and Florida, where the static is usually on a rage. While there may be more lightning storms up north - the occasional surge is not as bad as the constant rush. Close lightning strikes may damage any tube or crystal so this can be foreseen. A lightning arrester may prevent this.

On old ship sets, where the spark transmitter raised havoc with the crystal it was necessary to have a buzzer tester. It induced oscillations into the Aerial by a few turns of wire. As stations were few then - we'd have to press the buzzer button for a quick adjustment. Now we have so many BC stations operating that we don't need it. For a little buzzer kink - for a higher pitched tone - put some paper between the armature and poles.

CRYSTAL EFFICIENCY AND THE CHARACTERISTIC CURVE.

When a current flows thru a circuit, it heats up the circuit - and changes the Electrical resistance of that circuit. If the change in resistance was even voltage and amperage - then we'd have a straight line (A) in Fig. 10, and it would be linear.

But with metals, we have the line (B) which slopes downward -



10. Effect of Heat on Resistance.

and shows an increase in resistance with an increase in temperature - and this is called non-linear. If you will make a scale of volts and amps. and extend the dotted lines over and down - you will be able to experiment with this graph. You will see a reduction in amps. as the temperature increases. By figuring Ohm's law $\frac{E}{TR}$ you will see there is an increase in resistance. Make several check-points and see how the resistance changes.

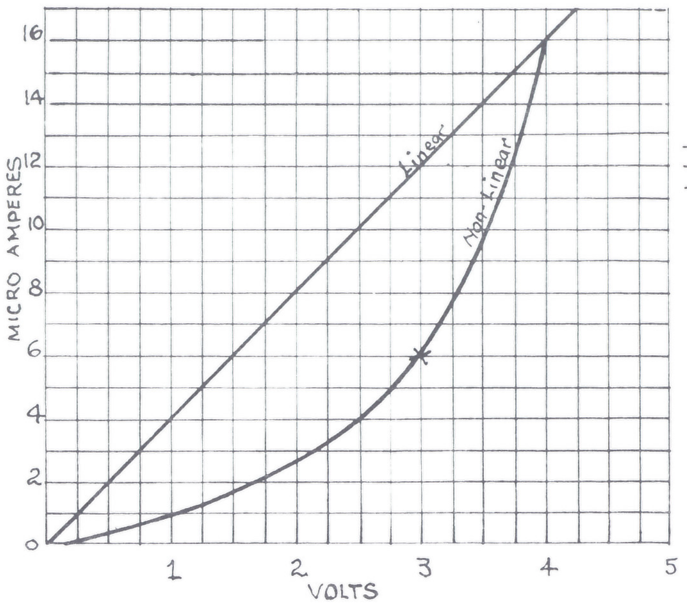
If we go to Carbon, crystal, mineral or liquid, at (C), you can see the resistance decreases with rise in temperature. The graph may be figured in the same manner as for metals.

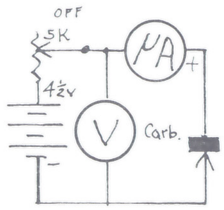
It has been said we can rig up an old Carbon lamp and compare it with a modern metal Tungsten filament type - to check the way temperature affects each type.

The effective resistance of one type of crystal may be 1000 ohms - while another may be 100K in the same direction. The value of applied voltage divided by current is the apparent resistance of the crystal. This is altered from point to point on the surface contact, as well as the characteristic curve of the same crystal. In the above line (C), we find the current increases faster than the voltage - which means the resistance decreases as the temperature increases. It is this change in resistance that causes the crystal operation. No explanation has been found for this phenomenon.

Often some battery current may be added to a crystal to make it operate better. Some crystals are slow to conduct at zero potential. In a Perikon detector, it was found that it had a 25K ohm resistance at zero potential but was brought to efficiency if .05 to .1 volt of DC was added. Silicon may operate better with .15 to .2 volt added. You may try other types if you wish.

Apparently the more stable the crystal, the more we can use current to help it along. For





11.

Apparatus for making a Characteristic Curve.

instance, with plain Galena, anything but the smallest current will make it inoperative. But on Carborundum, we can use a heavy catwhisker for a heavy contact point and from 1 to 10 volts DC, depending on the individual crystal. All Perikon detectors use a battery.

A crystal may operate without a battery, but when used, the direction of the current must be poled with the crystal. In Carborundum, the positive usually goes to the crystal side. If we reverse it, we get distortion and weak signals. The direction of the received current and the direct current output are always in the same direction. Be sure to try all crystals in different directions, as certain polarities are preferred. The only exception is Transistors. Be sure to hook them in the RIGHT direction FIRST- or they may be ruined - once the electronic structure is reversed in polarity, it will break down the Transistor.

In Fig. 11 we find apparatus for making a characteristic curve of a Carborundum crystal. It uses a micro-ammeter, voltmeter and control of battery current. As crystals are non-linear - we don't get a straight line - but a curved one as shown on the graph. If the crystal was linear, it would give a sharp click in the phones, like a short circuit, when connected or disconnected to a crystal circuit in operation. But, instead, we get a fluctuating sound in the phones when the circuit is disturbed. It must have a good slope and not follow Ohm's law - to be a good detector and rectifier crystal.

Now we line up some graph paper as shown in Fig. 11. We begin our readings by setting it at 1 volt and making a cross on the graph. Then for 2, 3, 4 volts, etc. When you have covered the range - connect the crosses with a French curve and note the type of slope you get. This may be done with any crystal- altho the Galenas may require very little battery to energize them.

Let's take a theoretical input

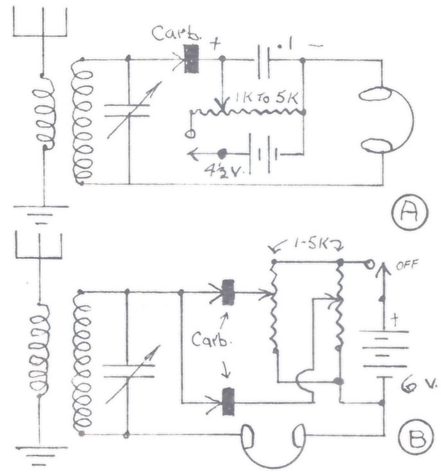
voltage of 1. If we start on the 1-volt setting, and add our input voltage - we get 2 volts total. Looking on the chart we see there is only a 1.5 micro-amp. "jump" in the total signal. But, if we go up to the cross at 3 v. and add another input volt - we get a "jump" of 10 micro-amps - which represents the most sensitive voltage point. If the line was straight there would be no sensitivity to input voltage. You must have the "jump" to make it sensitive. This curve is approximate - and will vary with different crystals under test. We get a sensitive voltage adjustment between 1 and 4 for the most of our Carborundums. In the past we have not been operating Carborundums under highest efficiency with a bias of only 1½ volts. We suggest you experiment with higher voltages.

For the fellow, who doesn't want to go to all this trouble to measure a Carborundum - just find a weak DX station and bring up the proper adjustment of voltage and catwhisker for volume.

Most crystals are tested for sensitivity by an Ohmmeter. They are tested for "forward" and "backward" resistances. The one with the biggest difference is considered the most sensitive. Certain characteristics are then looked for in the manufacture of crystal Diodes - and when they are found - the price goes up!

In about 1927, the Carborundum Company was putting out a superhet, that used the fixed Carborundum and a bias battery as the second detector between the last I.F. and the first audio tube stage. Due to so much current feeding across the circuit - it was usually used without a bias battery. It cut down the oscillation of a tube second detector and gave better reproduction of music. Many crystal diodes are now used as second detectors, especially in TV rigs, where the best fidelity is desired.

Fig. 12-A shows a single Carborundum unit with an adjustable

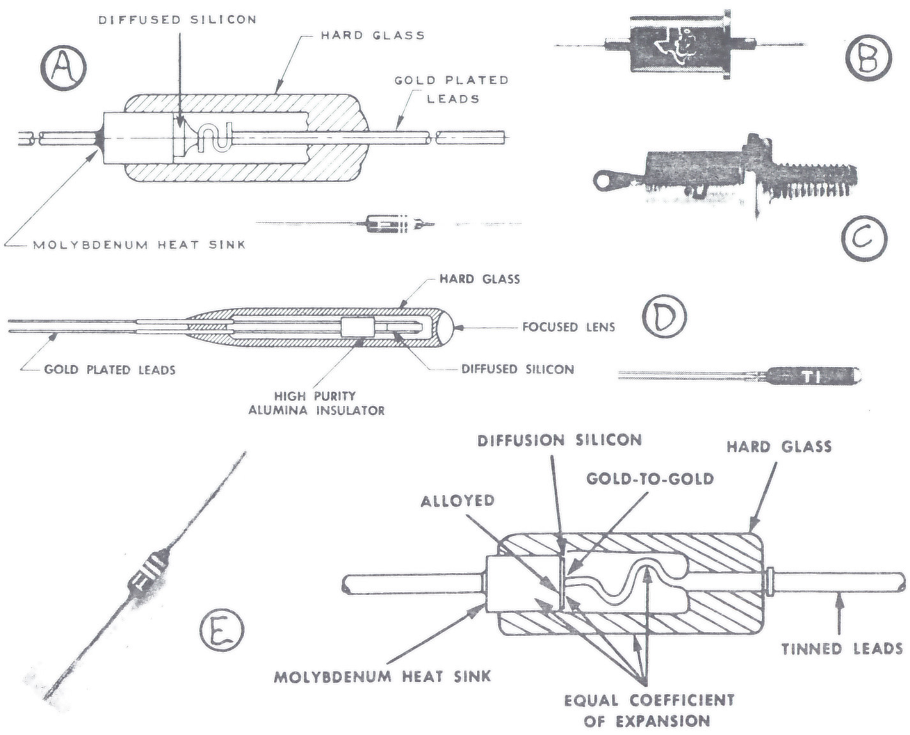


12. (A) Current Bias Adjustment for a Single Carborundum.
(B) For a Dual Carborundum.

bias voltage. On some crystals it may be necessary to reverse the polarity of the crystal. On Carborundums we found the ones with rough surfaces the best and these take the current in the conventional manner. But if we singled out ones with smooth faces - it seemed they took a reversed voltage - with the negative going to the crystal.

Fig. 12-B shows a dual crystal hookup which has certain advantages. The new Mercury cells may be used, if desired, as they may furnish about 4.5 volts per cell - altho less battery may be used with some crystals. Be sure to switch off the battery when not in use to preserve it. A volume control may have a switch to do this. We do not see too much difference between 1000 ohm and 5000 ohm controls, altho the latter will run your battery down a lot less.

The above Carborundum circuits apply equally well to adjustable and fixed. The adjustable gives you a lot more leeway in finding sensitive spots. Vary the adjustment of both potentiometer and the catwhisker on DX.



13. Some Modern Crystal Diodes by Texas Instruments, Inc.

SOME MODERN CRYSTAL DIODE APPLICATIONS.

Selenium rectifiers have their just place in the Radio field. But to get higher voltage operation, many units must be stacked in series. This occupies a lot of space.

With Silicon rectifiers, one junction is sufficient, unless very high voltages are required. For half-wave, lightly loaded rectifiers, Silicon has an average forward to reverse ratio of 99% against Selenium of 68%. Due to lower leakage (reverse) current in Silicon, they heat up less. Less leakage also allows them to be used at higher frequencies. In some of the higher voltage Silicon rectifiers several fins may be added for a heat sink to keep them cool.

In the following descriptions, diffused means "spread out,"i.e. the contact is broadened. Grown crystals are formed by dipping and raising a "seed" crystal from a crystalline solution, for a long period of time.

The above Silicon rectifiers by Texas Instruments are very interesting. Cuts show the actual sizes of the diodes.

(A) is a mesa computer diode, 1N914, of diffusdd Silicon, that handles 100 v. at 75 ma. Note the shape of the catwhisker.

(B) is a grown junction Silicon rectifier, 1N589, carrying 1500 v. at 50 ma. Note the very sturdy construction.

(C) is another grown junction, high voltage Silicon rectifier, 1N1130, carrying 1500 v. at 300 ma. Note it is stud-fastened to the chassis.

(D) is a photo-duo-diode of diffused NPN Silicon, 1N2175, and carrying 50 v. at 1250 ma. Note the focused lens on the end of the diode.

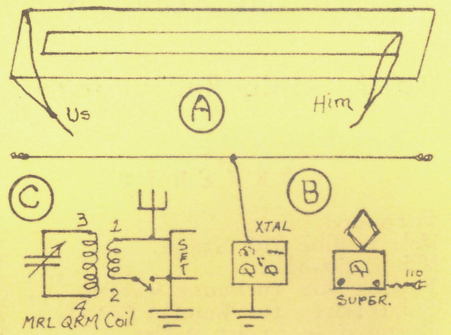
(E) is a diffused Silicon, hi-power glass diode rectifier, 1N649, carrying 600 v. at 400 ma. It has a 2 million to 1 forward to reverse ratio, which is practically perfect rectification. Note the shape of this catwhisker in comparison to (A).

RESONANT CIRCUITS.

The power of two resonant circuits is amazing. Tune a station in on your set. Then set a resonant circuit, consisting of a coil and condenser, tuned to the same station - alongside your set, and see the results. You may have seen it work in an apartment house, where your signals may bloop in and out, due to some other tenant hitting the same station with his set. This gives a boosting effect - or often called bandpass.

Fig. 14-A shows a 4-wire Aerial we made in Los Angeles. Because it was on the landlord's property, we decided to give him the two inside wires. We sold him a Reinartz regenerative (and it proved to be a good transmitter, as we found out). We were always tuning him in - or he was tuning us, altho the wires were separated the usual 30" apart.

A case in our Labs., Fig. 14-B, we found very noticeable. We put an AC-DC superhet. with a loop Aerial, on a table underneath our outside Aerial wire. We hooked a #2 Crystal set to our Aerial leadin and to ground. Altho the Aerial was 30 ft. above the Superhet. - it doubled its volume when we hit the same station on the #2 Crystal set. Another set may work as well, or even better if it is a regenerative tube set.



14. 3 Types of Resonant Circuits.

Recent experiments, Fig. 14-C, we have been making with our QRM coils. On our little 2-tube AC regenerative we were pressed to separate a loud local, KOBY, from KFBK, Sacramento, 90 miles away, and only 20 kc on the dial. With the QRM condenser set on KFBK we were able to knock out KOBY sufficiently to read Sacramento. Without this resonant circuit it was impossible on the direct-coupled set, with no TRF ahead. Its effect was so noticeable that it was almost impossible to tune in other locals on other frequencies unless the QRM condenser was moved to the station desired. Its volume was then boosted materially. The switch is effective if you want to set the condenser on one station and tune the rest of your dial.

The same resonant circuit idea is effective on Shortwaves if you use plug-in coils. Our type RF coils work OK. As the impedance of the secondary of the QRM coil is close to that of the Aerial-ground circuit there is little loss in shorting. Because the circuit gives a boosting effect, this shorting is more than offset by the gain received.

So, from the above experiments - if you want all your sets to work efficiently - tune them all to the same station. Hi.

This boosting circuit is not new - as it was used by many early types of Radios.

another MRL Handbook...

5½ x 8½
24 pages
12 drawings

HB-9. "MRL Radio Notes No. 1."

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We used, as a basis for this Handbook, MRL Radio Builder #34, which is out of print. All items were completely done over and in most cases, greatly enlarged. We also made all articles as up-to-date as possible.

This Handbook should be in your library, along with all MRL Handbooks and literature. They are all written to "we" can understand them!