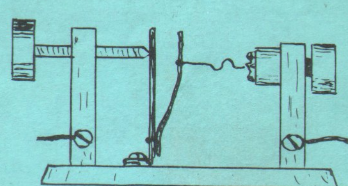
another MRL Handbook... HB-3

CRYSTAL DETECTORS

By Elmer G. Osterhoudt



CONTENTS.

by

Elmer G. Osterhoudt

"With Radio Since 1915," including:

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Technician, Electrical Products Corporation
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FOREWORD.

This is a complete revision of our original Handbook "Crystal Detectors" as published in 1938. As the original was mimeographed - its stencils have long since worn out, because so many have been sold.

Since 1938 much has been done along the line of Crystal detectors by the large Labs. No firm has been too large, or too proud to dabble in this re-generated field. The Engineers have found enough intricacies to write many large technical books on the lowly detector, but put forth under the guise of Diode and the Transistor. From the looks of the progress already made, we have only touched the surface. After reading and studying this Handbook, you will see the multitude of combinations that "might" be used to convert Radio signals.

The original small section on Oscillators, or Vibrators has purposely been omitted as they do not come under detectors. In its place we have simmered down volumes of data on Diodes and Transistors, trying to brush over lightly, a few interesting peculiarities of these detectors.

Much of the material contained herein is all we can obtain on the subject. Scientists may find other minerals that can do even a better job than those described. Many differences of opinion exist, relative to merits of certain crystals. Nature is hard to predict in the outcome of any conglomeration she may concoct.

Daily we are finding more uses for the lowly crystal detector as use in computers, hearing aids, electronic organs, bias supplies, sensitive DC relays, TV and receivers.

Detection at UHF is the same as at low frequencies, and they are used more in the former. A Crystal Diode may replace a tube for modulation, detection, rectification, and now, amplification in the Transistor. Crystals used as mixers have the highest signal-to-noise ratio that can be obtained in some bands, and used on frequencies over 300 mc.

We are especially indebted to Mr. Robert Darneal, A.B. (Chem.), Ph.D. (minerals), Stanford Univ., for many helps, theories and the samples submitted.

It is my hope the reader will find a little more enjoyment in the "Art of Catwhisker Setting."

A great amount of investigational work has been done with crystals as detectors. This was because for a long time they were the best detectors available, until the tube came along.

Until 1920 we used to search for information, in the very few books to be had. A lot of this information was considered a trade secret, and only a few of the common minerals as Galena, Iron pyrites and Silicon were known to the average Dabbler.

During the 1920's there was an increase in activity because everyone was building some kind of Radio, and the crystals came in for their share. Scientists, to get their name in print, gave forth with lots of good data.

There was a distinctive lull in the 1930's - with only a few of us in the game. However, during World War 2 the big Labs. got interested in promoting high frequency work as Radar, TV, and other forms of HF because they found crystals could do a lot of things tubes could not.

Crystal detectors are point-contact rectifiers, in lieu of large-area-contact rectifiers, as Selenium, Cupric oxide, etc. Tubes may be called "vacuum diodes" against Crystal diodes. Like tubes, crystals can modulate, detect, rectify, amplify and convert signals.

Crystals have lower input and output capacitances than tubes, which is important in high freq. work. Crystals can also operate at higher frequencies than tubes and do it better.

CRYSTALLOGRAPHY.

This is the science of the study of crystals, but having more to do with shapes than with their Radio qualities. Each kind of crystalloidal compound has the property of forming into certain well-defined shapes, or crystals, on cooling or evaporation. These shapes may help determine the composition, unless the mass has been crowded, in which case the crystals will be of distorted shapes. A colloidal solution, i.e., Glycerine, will not form into crystals but remains in solution.

There are many ways of forming crystals. One method is by use of Electricity. Usually they form from cooling, or evaporation, of a certain liquid. For instance, table salt forms on the evaporation of salt water. Most Radio crystals are used as formed in the natural state. Others, like Silicon, may be furnace products or put together by fusion. Some may be of Volcanic origin. Other crystals are of thin flakes, like Galena, or in large crystals like Iron pyrites. Many are natural ores combined with Sulfur, oxides, etc. They may even be composed of a large number of elements, or compounds, merely thrown together.

Some detecting material may be formed by fusion, in a massive or amorphous state, as we would melt solder. The same material may also be crystalline, depending on its origin and condition of formation. Consequently, it is hard to find two crystals with identical sensitivity, due to variance in combinations.

The greater part of minerals are formed by solidification, from fused rock material, or from igneous rocks. Examples: Silicon, Iron, Aluminum, Magnesium, etc.

Some are formed by crystallization from a solution, as evaporization of water and forming salt crystals, as Boron, etc.

Also formed from crystallization of volcanic vapors, etc. as Sulfur, Tellurium, Arsenic, Sulfides, Boric acid, etc.

The most important minerals are found in veins, therefore, our best crystal detector material. These include Iron pyrites, Chalcopyrites. Galena, Chalcocite, Bornite, Marcasite, Arseno pyrites, Stibnite, Tetrahedrite, Sphalerite, etc. The sulfides form most of the important vein minerals, and most of them work as detectors.

As temperature of formation increases with depth, many of our detectors have been classified by amount of heat during their origin:

The low (50-150 deg. C.) include pyrites, Marcasite, and Stibnite.

Medium (150-300 C.) as Galena, Sphalerite, pyrites, Chalcopyrites, Bornite, Arseno-pyrites, Tetrahedrite, Enargite.

High (300-500 C.) as Gold tellurides, Molybdenite.

Another classification may be made, according to type of veins in which crystals are found:

Gold-bearing quartz veins contain sulfides, pyrites, Chalcopyrites, Arseno-pyrites, etc.

Gold-Silver-Copper veins are mostly Copper sulfides, as Chalcopyrites, Tetrahedrite, Bornite, Chalcocite, pyrites, Cuprite.

Silver-Lead veins have sulfides as Galenas, Argentite, Tetrahedrite, Sphalerite and the pyrites.

Lead-Zinc veins have Galenas, Sphalerite, Marcasite, Chalcopyrites, Anglesite, Cerussite.

Copper-Iron veins may have the pyrites, Chalcopyrites, Bornite, Tetrahedrite, Marcasite, etc.

Minerals combining with Oxygen, to form oxides, are Silicon, Carborundum, Cuprite, Zincite, Pyrolusite, Anatase, etc.

Carbonates may be Cerussite.

Borates as Colemanite, Boron, Ulexite.

Sulfates as Anglesite.

ANATASE. TiO_2

Also called Octahedrite and Rutile. Brookite, with the same formula, is similar in looks. It is a mineral compound of Titanium dioxide, resembling Silicon.

Is a crystalline formation, having a metallic lustre of a black, or brown color, resembling that of Iron.

Found in Arkansas in large black crystals. A new plant is now in operation in Henderson, Nev., producing some 3600 tons of Titanium per year. Also found in Calif., Florida and Virginia. While widely distributed, it is not at all concentrated.

Radio. Large polished metal plates may be used for contacts. A battery increases its sensitivity, like Carborundum. No further information on its use as a detector of Radio waves.

Other uses. Titanium is a light metal, about half as heavy as Steel. Is extremely hard and very strong, and like Silicon, is used to toughen Steel. Titanium resists the terrific heat of jet engines. Also used in guided missiles, rockets, pigment in paint, marine pumps, propeller shafts, armor plates, and the new Atomic energy program.

Titanium melts at 1800 deg. C.

ANGLESITE. $PbSO_4$.

Lead sulfate. One of the more important ores of Lead. It is a white substance.

Galena may be crushed and then roasted in a furnace, where it takes on Oxygen, during combustion. This goes into Lead sulfate and Lead monoxide.

Lead sulfate is a chemical compound formed upon discharging a storage battery. Lead oxide, PbO, is changed into Lead sulfate by the Sulfuric acid.

Radio. No information on its crystal use, except that it has been used as a detector. It has a high resistance.

Lead melts at 327.5 deg. C.

ANTIMONY. Sb.

Antimony is abundant in its Sulfide, Sb_2S_3, or Antimonite. Some ores reported in Western states.

It has a metallic appearance, and a crystalline structure. Some are large beautiful crystals.

Antimony is tin-white color, hard and brittle. It is more metallic in appearance than Arsenic and Phosphorus.

It is melted at about 600 deg. C. with Iron. This separates the mass into Antimony and Ferrous sulfide, FeS. (See its similarity to Iron pyrites, FeS_2?)

Radio. This is probably used in its natural ore stage of Stibnite, Sb_2S_3. It may also be used in combination with Germanium, to give "impurity" to the latter. It is a poor conductor of electricity, so therefore, the reason. Stibnite is affected by light rays, similar to Selenium.

Other uses. Most of Antimony is used in the mfr. of bearing metal and storage battery plates and to harden Lead, babbitt metal, etc.

Antimony melts at 630 deg. C.

ANTIMONY-ALUMINUM. Sb plus Al.

Antimony is somewhat abundant in its Sulfide, Sb_2S_3, or Antimonite. Antimony crystallizes into large, beautiful crystals. It also combines with Sulfur (see connection between Galena, Iron and Sulfur?) Antimony has been used since 2000 B.C. and the U.S. produces 30,000 tons of it annually.

Aluminum is not free in nature but is in combination with Oxygen and Silicon in clays. But it is the World's most abundant of metals, making up 1/12th of the Earth's surface. (Why hi prices?)

Radio. At present writing, a new compound of these two metals has been made to replace Germanium in Diodes and Transistors. The claim is made that it is as sensitive, and the compounds cost but 50¢ per pound. Germanium costs $135. It is being developed by Bell Labs., National Bur. of Standards, and the Battelle Memorial Inst. in Columbus, Ohio. It has been found the new combination can stand a higher temperature, which has been one of the faults with Germanium, when used on projectiles, etc.

In this connection, we have the theory again, of the "poor contact" rectifier. Antimony is a poor conductor of Electricity; Aluminum a good one.

Antimony melts at 630 deg. C.
Aluminum " " 660 " "

ARSENIC. As.

Arsenic is seldom found free in Nature, but is usually associated with the Sulfur compounds of Iron, Sulfur, Lead and Copper. Whenever we find Sulfide ores of these metals, we usually find Sulfur compounds of Arsenic. The common ore is Mispickel, an Arsenical from Iron pyrites, FeAsS, usually found in England and Silesia.

Most commercial Arsenic comes from dust that collects in the flues of smelters of Gold and Lead.

Arsenic often acts like a metal, but really is not. It forms in a dark, gray crystalline solid. It resembles Phosphorus in many ways, and can be broken up into pieces, similarly.

Radio. Arsenic is a good conductor of Electricity. The Xtals are rare, but can be used as detectors. Almost any Iron pyrites has some Arsenic in it. (See connection between Iron pyrites?) Some Arsenic crystals have been used with Silicon as a Perikon detector.

Other uses. Free Arsenic is used in the mfr. of certain Bronzes and other alloys, lead shot, drugs, etc. Arsenic makes shot harder and rounder.

I once had a pal at Sea, who used to work in the Copper mines of Butte, Mont. While still under 20 years old, his teeth had to be removed, due to Arsenic poison he contracted in the mines.

Arsenic ignites at 200 deg. C.

BORNITE. Cu_5FeS_4.

Called Copper pyrites; double Sulfide of Copper or Sulfide of Iron and Copper, of various proportions. It is one of the commonest Copper ores, which looks like brass or Gold. It is crystalline in character, and is Copper red, or brownish in color - on a fresh fracture. They carry about 55% of Copper. Crystals may also be dark red, bluish-gray, brown or purple, and rapidly tarnish on exposure to the air. Copper is the ore that occurs native in large masses.

Some Bornite is found in U.S.

Radio. The combination of Bornite, in contact with Zincite, is called the Perikon detector. In use, it is generally tapered to a point, and used as a catwhisker for Zincite. It may be used with or without a battery, but one is preferred for volume. It takes less battery than Carborundum. This used to be a very stable detector, and as such, was furnished as standard equipment on the old RCA and Marconi tuners on ships in the Spark transmitter days. Many a one I've juggled around on shipboard!

Copper melts at 1083 deg. C.
Iron " " 1530 " "

Boron. B.

Non-metallic Boron is never found free in Nature, but only as Oxides of metals. Boron is a greenish-brown, amorphous powder and in highly lustrous crystals.

It is about .001% of the crust of the Earth. Occurs as Boric acid and salts of condensed Boric acids, as Ulexite, Colemanite, Rasorite and Borax.

98% of the World's supply is from Death Valley and the Mojave deserts of Calif. and Nevada. It also occurs in Tuscany. (Incidentally, in Death Valley, about every 7 yrs. the midsummer temp. reaches 180 deg.F. on the desert floor.)

Radio. Melted pellets of Boron were used as crystal detectors in 1943, to which were added "selected impurities" in varying amounts. Some of the pellets showed sensitivity, but not sufficient to be practical.

.001% of Boron added to Silicon will increase its sensitivity a lot.

It is probable some of the associated crystals of Boron may be used as detectors, also.

Boron melts at 2000 deg. C.

CADMIUM SULFIDE. CdS.

In the natural state this occurs in the rare ore of Greenockite. Cadmium is associated in small quantities with almost all Zinc ores, in a ratio of about 200 Zinc to 1 of Cadmium.

As a result, most commercial Cadmium comes as a byproduct of Zinc smelting. (Note that Germanium comes from the same furnace.) The U.S. produces about 4½ million pounds per year.

Cadmium metal resembles Zinc. It is silver-white, tinged with blue. It is softer and more workable than Zinc and becomes very brittle when heated.

Radio. Since 1951, G.E. has been growing Cadmium sulfide crystals in the Lab., from a fraction of a mil. to several mils. in cubical sizes. G.E. has found them to be semi-conductors that can amplify X-ray energy a million times. When excited by X-radiation they release currents of electrons that can operate various mechanisms. They are said to be 1000 times more sensitive than Photo-electric cells and the advantage of requiring low-intensity X-rays. They claim over a million times more sensitivity to X-rays than oxidation chambers, generally used for X-radiation. Another report claims Cadmium sulfide Xtls to equal Germanium and Selenium.

G.E. experiments sorted out canned fruit that contained foreign matter. Also, with this Xtl amplifier, it threw out cans that were partially filled. Penetrating a metal can is a good trick, if you can do it!

Cadmium is used to test storage battery cells by testing between positive and Cadmium and between negative and Cadmium. The point is that the electro-chemical action may have some bearing on Cadmium sulfide as a semi-conductor.

Other uses. Cadmium is one of the constituents of low-melting alloys, like Wood's metal, for mounting crystals.

It is also used as a yellow paint pigment. Also used in electroplating Iron and Steel tools, auto parts, etc. against rusting, which is better than Zinc. Also to plate articles that will later be plated by Silver, to get a better bond. Also used in some solders. Alloyed with Silver, it retards tarnishing; with Gold it has greenish-tinge.

Cadmium melts at 320.9 dg. C.

CALCIUM SULFIDE. CaS.

Called Sulfurated lime. Is a crude mixture of Calcium sulfide with sulfate. Obtained by heating to redness, in a crucible, a mixture of Calcium sulfate, charcoal and starch, until contents have lost their black color. By de-oxidization action of the coal and starch, the sulfate is converted into sulfide.

Also, by heating pure Lime and Sulfur in the dry states, we get sulfide, or sulfurated Lime. It becomes luminous for awhile, - when exposed to strong light. Been used in luminous paints.

Radio. Has been used as a Xtal detector. Probably used between plates in the dry state. No information as to whether battery is required. Its connection with Sulfur and the luminoscity may give some clue to its semi-conductor use.

Other uses. Calcium is never found free in Nature. Is a white silvery metal, when freshly prepared, but combines with Oxygen and Nitrogen and tarnishes with a gray and yellow surface, and is then called Quicklime. Has a crystalline structure. Is harder than Barium, and is malleable & ductile. Has been used in deep-sea sounding devices, mixture in storage battery plates; in production of other metals; purification of Lead, etc. Would have many other uses if not for its high cost.

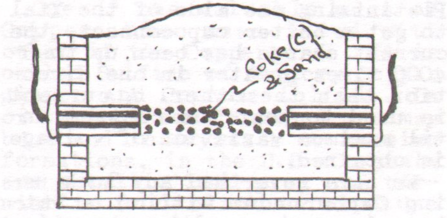
Calcium melts at 810 deg. C.

CARBORUNDUM. SiC.

Also called Crystolon, Silica carbide. In 1891, while experimenting with sand for the production of artificial diamonds, Dr. Acheson, at Monongahela, Pa. discovered Carborundum.

Carborundum is a synthetic crystal, or Silicide of carbon, or Silicon carbide. The two elements are not combined chemically, but are run together by heat in a furnace. The crystals can stand a red heat.

It is made by heating coke, sand, sawdust and salt in an e-



Carborundum furnace.

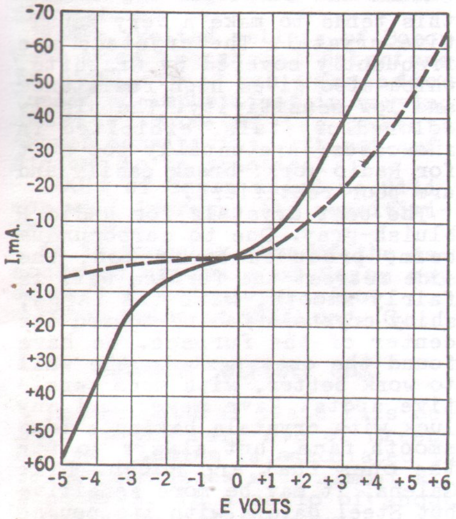
lectric furnace of the resistance type, using Carbon granules as conductors. It is heated to 3000 deg. C. for 36 hrs. after which the furnace is opened. Gorgeously colored Carborundum Xtls in shades of iridescent dark blue and green are removed. The crystals are diamond-shaped, and excel the Ruby in hardness, being next to the Diamond. They will scratch glass. The Carborundum plant uses 25,000 H.P. of electrical energy for furnaces, etc.

Radio. Not until 1906 did Gen. Dunwoody use Carborundum as a crystal detector. Because it contains coke, and other impurities this tends to make a very sensitive crystal. The crystals are frequently covered by Graphite, which also gives high resistance and low-sensitivity. The highly colored crystals, exhibited in showcases, are usually too soft for Radio work; break easily and are poor rectifiers.

The best crystals for Radio R bluish-gray. Due to carborundum being produced by fusion, the side nearest the furnace wall is fairly smooth, with the large, shiny crystals facing toward the center of the furnace. We have found the ones next to the wall to work better, with more sensitive spots. Have never had any luck with crystals having a long smooth face, but always go for the ones that are rough. Like Galena, it may be more sensitive but Steel galena, with its roughness, is more practical.

Some of the crystals react positively; some in reverse. We have found the ones with the crystal toward the positive side of battery are best, and they usually turn out to be rough. By Platinizing one side of the Xtal to get a better cup contact, the current change has been up to 3-4000 times greater in one direction than the other. A current is used to heat the contact until maximum variation of voltage is obtained.

We have never had any luck using Carborundum without a battery in series, altho reception may be had on loud stations over short distances without it. The general method, at one time, was to connect a potentiometer across the battery, to give the Carborundum the correct voltage. Because this tends to run the battery down, and the adjustment is not critical, we prefer to hook a flashlight cell in series with the crystal and phones. Try reversing polarity - the wrong direction will give fuzziness. It is a good idea to connect a S.P.S.T. switch in series, so U can disconnect battery when not in use. Pulling one phone tip out will accomplish the same thing.



Carborundum characteristic curve.

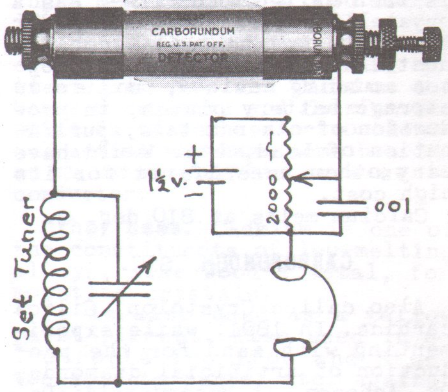
Here are some tests made by the Carborundum Co. with different voltages in series:

Volts D.C.	Micro-amps. Ahead	Rev.	Ratio of Rectification
10	100	1	100:1
20	800	20	40:1
27½	2000	120	50:3

You can see, with too much v. the Carborundum is not as sensitive. Any crystal that starts to detect at 1½ v. is very good. On diagram, where curve starts upward abruptly is the most sensitive detecting point - in this case 1½ to 2 volts.

Cromium works good as a catwhisker. A Steel phonograph needle is also good. Heavy spring brass is also very good, and is usually what you find on all fixed crystals. Up to 5 lbs. wt. may be used on a Carborundum c/w contact, thereby making it a very stable detector. Polished metal plates have also been used. A light contact may be best for DX reception, altho it won't be as stable. We have had some very good DX reports on Carborundum.

Various types of fixed Carborundum crystals have been sold.



Carborundum Stabilizer Unit.

The one sold by the Carborundum Co., in the 20's, was made like a cartridge fuse, with a heavy open coil steel spring for pressure. We used to slam these down on the cement to readjust them!

Others were made inside a metal cap, with a hole for adjusting the brass c/w wire. The old Advance Co., of Los Angeles, in the 20's, made thousands like this, but with a Bakelite "pillbox" with brass bottom. We used to pry off the bottom and re-adjust them! Our present type is an open mounting for ease of adjustment sidewise, of the heavy .020" spring brass catwhisker.

Other uses. For practical purposes, the crystals are crushed and cleaned with Sulfuric acid. They are then mixed with a binder, and made into abrasives, grinding stones and wheels, and emery paper. The first Carborundum was 40¢ per carat - or $880 per pound. Over 1½ million lbs. are produced per month. at the Niagara Falls' plant.

Corundum. Many have asked the difference between Carborundum & Corundum. Carborundum is Silicon carbide, while Corundum is crystalline Alumina, Al_2O_3. Corundum is glued to cheap cloth to make emery paper.

Silicon melts at 1420 deg. C.
Carbon vaporizes at 3500 C.

CERUSSITE. $PbCO_3$.

One of the principal Lead ore sources, and may be valuable if found in quantities. It is the natural state of Lead carbonate. Commonly found with Galena, and which it oxidizes to a sulfate. Is often found in Stalactites in caves.

Crystals have a pearly lustre of gray, or grayish-black in color, sometimes tinged with blue, or green, due to presence of the Copper salts. May be also adulterated with Barium sulfate, Gypsum or Lead sulfate. The crystals may be very brilliant.

Found in various parts of the U.S. The more common name is White lead, of paints.

Radio. Was widely used by the early Marconi company. No further details.

Lead melts at 327.5 deg. C.

CHALCOCITE. Cu_2S.

One of the valuable ores of Copper. Also associated with other of the Copper ores. It is called Sulfide of Copper, Copper glance and Cuprous sulfide. Is of various combinations and may be found in crystals or massive formations, in the U.S. Crystals are metallic lead-gray and tarnish to dull black on exposure to the air.

It may also be formed when Copper is heated with Sulfur.

Radio. Has a ratio of about 2:1 of rectification in a crystal set, which is fairly low.

Copper melts at 1083 deg. C.

CHALCOPYRITES. $CuFeS_2$.

Another of the important, and common ores of Copper, similar to Chalcocite. Also called Copper pyrites, or "Peacock ore" due to its color, when it tarnishes. Also Sulfide of Copper and Iron.

Occurs in scattered veins with Iron pyrites, in the older Geological rocks. Has a brass-yellow metallic lustre. Always found with lots of impurities as Nickel and Cobalt sulfide, Arsenical sulfide, Gold, Silver, etc. It sometimes occurs in crystal form but usually in the massive.

Found in various parts of the U.S. as Arizona; Calif.; Colo.; Ellijay, Ga.; Mont.; Utah; etc.

Radio. Has been used as a Perikon detector, using Zincite as a tapered catwhisker. It has a low rectification of about 2:1.

Copper melts at 1083 deg. C.

CUPRITE. Cu_2O.

Another of the important Copper ores. Is a native oxide of Copper. Also called Cuprous oxide, red oxide of Copper, or suboxide of Copper.

It may occur in the massive state, or in crystals. In the latter state it may be long, thin needles called Chalcotrichito, and with a sub-metallic lustre. Also may be found in ruby red, octahedral crystal form.

Is occasionally found as a furance by-product.

Radio. Very little information is obtainable as to its use as a detector, except that it is not too valuable. The furnace by-product form is less sensitive than the natural crystals. Ultra-violet rays affect its sensitivity to quite a degree.

Copper melts at 1083 deg. C.

DIODES, see later.

ENARGITE. $3Cu_2S.As_2S_5$.

This is a sulfo-salt, usually small crystals, also in granular or massive states. Metallic gray black to iron-black. May be even streaked with grayish black.

Found in Montana, Colo., Utah, Calif., Alaska, etc.

Radio. No details on use as a detector, but it contains all the necessary elements to detect.

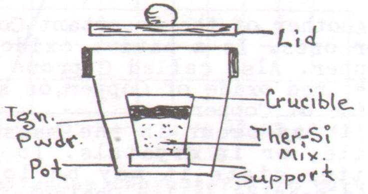
Copper melts at 1083 deg. C.
Arsenic ignites at 200 deg. C.

FERRO-SILICON. Fe_2SiO_4.

Called a ferro-alloy. It is ordinarily made in the electric furnace.

When the Silicon, in pig iron, runs over 8% it is classed as a Ferro-silicon. It usually contains 12-14% Silicon. If a higher content of Silicon is used, it becomes too costly. The idea, in certain Steels, is to have less Carbon, so this is where Ferro-silicon comes in.

Radio. In 1911, Radio crystals free from Carbon, were being made by the following process:



Use an earthen flowerpot, and in the bottom place a Hessian crucible. In this put ½ lb. of a black Thermit powder (then 50¢). Also 1/8 lb. ignition powder (then 50¢ ½ lb.) Ignite with a taper and place a lid on it. The burning is over in one minute. After 5 min. pick it up with tongs and plunge into water. Then, break the crucible. The alloy is in the form of a button in the bottom. Throw the slag away. The formula for the amount of Silicon is

$$X = \frac{Tp}{200}$$

where X equals amount of Silicon sought; T equals amount of Thermit; p equals % of Silicon. So, for 30% Silicon, we use 100 gm. of Thermit

$$X = \frac{100 \times 30}{200} \quad 15 \text{ gm. Silicon}$$

By varying the amount of Silicon in this compound, we may get varying degrees of sensitivity. This is a project for the fellow with a Chemical Lab. and not for the dining room table!

GALENA. PbS.

This is the most important Lead ore of commerce, and found extensively in the Rocky Mts., England and Spain.

Also called Lead sulfide, sulfide of Lead, Lead ore, or Lead glance. Sulfur is Sanskrit for "Enemy of Copper."

Galena is the most widely distributed of the metallic sulfides. It occurs in beds, or in veins, in the crystalline rocks. Pieces have been found that were 12 inches across.

It has been found in association with Zinc, Copper, Arsenic, Antimony, Bismuth, Tin, Selenium, Silver and others. Because many of these impurities are carried with it, may be a reason for its high sensitivity. When pure, it contains about 86% of Lead.

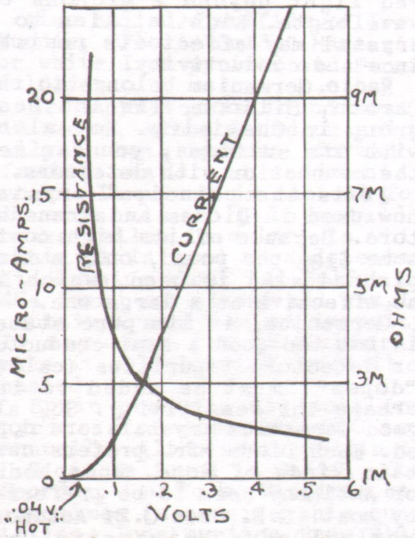
Galena is characterized by its weight. It has a pure Lead color - with metallic lustre similar to Silver. In the native state it forms in cubical, or octahedral crystals that may easily break off in squares.

Galena crystals have also been obtained as a furnace by-product but are not very sensitive in this form, probably because they are too pure.

Radio. Galena is the most used of all the old type crystals, as it was the most sensitive. Steel galena is almost as sensitive, but has the advantage that it doesn't "knock-out" of adjustment as easily as Galena. The best points are near the edges, probably where most impurities exist. It has been suggested one grind off a corner of a Galena crystal and use it for contact point with catwhisker.

In 1910, a Galena/galena crystal set was invented in Australia, which consisted of a Galena Xtal as contact. The results may have been due to difference in resistance between the two crystals at the points.

Galena requires a very light, stiff and clean catwhisker with very little pressure. One of the fine, plated Copper wires is OK. Also a brass spring or Platinum wire. A pointed piece of Tellurium crystal will also work. A Graphite rod and Plumbago (black lead pencil) have also been used for a catwhisker.



Galena characteristic curve.

No battery is used as it destroys sensitivity. It is very sensitive to heat, so be careful when mounting, to use Wood's metal, or other low-melting point alloys. It is better for long distance reception as strong signals destroy its sensitivity.

Galena should be renewed often as it loses its sensitivity when exposed to the air. Small pieces are better than large ones, as too much resistance in the latter. It passes a positive current better than a negative, at a ratio of 10:1.

Other uses. Used in a powder form to glaze pottery. Its principal use is for Lead.

Lead melts at 327.5 deg. C.

GALENA, STEEL. PbS plus Ag.

Also called Argentiferous galena or granular Galena. "Argentite" means Silver. (Ag)

This is the massive state of Galena, in comparison to the crystalline plain Galena. Steel galena resembles a piece of broken steel rod, and therefore, its name, altho there is no Iron or Steel in it. Under the microscope the crystals look like Galena.

Steel galena often contains so much Silver it is profitable to mine it just for the latter. It may be associated with Silver sulfide ores, as well as other impurities found in plain Galena and similar ores. Silver is the whitest of metals, so may be the reason for the light lustre often found in Steel galena. Steel galena usually contains 86.6% of Lead; 13.8% Sulfur; 1% Silver.

Radio. Steel galena is the most popular crystal now in use, with the Crystal Dabblers. Very little specific information can be found about it. It is next in sensitivity to plain Galena, but offsets this difference by its ease of adjustment. It seems to be alive with sensitive spots. Probably due to so many "edges" where "hot" spots are found.

Silver is the best conductor of Electricity. So, when mixed with Lead and Sulfur there is this difference in conductivity that makes a good rectifier.

German silver wire seems to be the best catwhisker, altho ones specified for plain Galena may be used. The contact need not be as light as plain Galena. Once a distant station is tuned in, it is best to readjust the catwhisker to the weaker station, as apparently a different resistance at the point of contact is needed for DX stations. It will then be sensitive to all long distance stations. Our best DX records have been made with our Steel galena crystals.

Steel galenas make the set tune sharper than Germanium diodes.

Heat also reduces its sensitivity, like plain Galena, but possibly Steel galena can stand more heating.

Lead melts at 327.5 deg. C.

GALENA, SYNTHETIC. Pb plus S.

We have had several Fans write in telling us how they make up their own crystals. This is a mixture of Lead and Sulfur, or synthetic Galena.

Melt a piece of Lead the size of a pea, or Lead shavings in a crucible, over a gas flame. Cut the heat down enough to just keep the Lead melted. Next slowly stir in 1 gram of powdered Sulfur. Cover it if the fumes R too strong. A few filings of Ag (Silver) may be added. When it cools you have a black mass. It may be used as is, or broken up into pieces. Some prefer to melt it directly into a crystal cup.

Radio. Some lots are better than others, but is seldom as sensitive as natural Galena or Steel galena. The holes in the rough surface are the most sensitive spots. It may deteriorate and fall apart eventually. Uses the same kind of catwhisker as the Galenas.

Lead melts at 327.5 deg. C.

GERMANIUM. Ge.

A fairly recently discovered element, as it cannot be found in old Chemistry books.

It occurs in small amounts in Sulfide ores, but generally is a product of Zinc refining. Like Tin and Lead, it forms two oxides GeO and GeO_2, which can act as an acid or a base. Germanium is then produced by removing the oxide with a Carbon.

In June, 1952, Germanium was found considerably in a coal seam in Northern West Virginia. At present prices, a ton of this coal contains $35 worth of Germanium. Chemists are working on a method of extraction from coal of which W.Va. has some 100 billion tons still unmined.

It is a metal of a gray-white color and metallic lustre. Is brittle and durable, and in many Germanium compounds it resembles Silicon and Carbon. It is insoluble in water, HCl, or dilute Alkaline hydroxides. Is soluble in HNO_3 and fusel alkalies. Its stability is unaffected by air, and oxidizes at 600 deg. C.

Even tho Germanium may be an inch thick, it has been found to transmit infra-red (heat) light rays over a broad portion of their spectrum. Pure Germanium & Silicon metals have been prepared that transmit 50% of infrared light beyond 2 microns of wavelength. Light applied to a crystal may affect its resistance and conductivity.

Radio. Germanium belongs to the Carbon, Silicon, Tin and Lead group in Chemistry. So, along with its sulfides, you can see the connection with detectors.

It is the principal crystal now used in Diodes and Transistors. Because of its high cost, some $135 per pound, only a tiny pinhead size is used, which is as effective as a large one.

Germanium, in its pure state, is not too good a semi-conductor or detector. Impurities (called "dopes") must be added to increase the sensitivity. So, all good Germanium crystals are doped. Each Diode mfr. prefers certain kinds of dope. Phosphorus or Antimony seem to be preferred by most. G.E. uses 0.2% Antimony while Purdue University uses 0.25%. Bell Labs. uses 0.1% of Tin. Purdue has also made tests with Nitrogen, Vanadium, Arsenic, Columbium, Tantalum, Bismuth and Iron, but with less success than Phosphorus and Antimony.

Researches during World War 2 showed some semi-conductors may be made positive or negative.

Under tests it has been found 0.35 v. D.C., in series with the doped Germanium crystals increased sensitivity. Further uppage of voltage reduced it.

Range of frequency use has been to 100 meg/c. Mostly used in the 2nd detector, or discriminator circuits, where it has a more favorable characteristic of operation than a tube.

For a catwhisker wire, a .003" dia. Platinum-ruthenium has been the best. G.E. welds the wire to the crystal with 250 m.a. of DC, which cannot be done with a Silicon Diode crystal.

Other uses. Germanium takes the place of Rock salt in optical work, as latter absorbs moisture too readily. Germanium is also harder. It can be ground finer than present materials.

Germanium melts at 958 deg. C.

IRON PYRITES. FeS_2.

Also called disulfide of Iron, Mundie, "Fool's Gold," Marcasite or white Iron pyrites and Ferric sulfide.

Iron pyrites is found mostly in veins, altho found occasionally in both igneous (formed by fusing heat) and sedimentary rocks. It occurs in cubical form in crystals of pale metallic brass-yellow in color, in which state it is used as a detector. It contains about 54% Sulfur and 46% Iron, and almost all samples contain Arsenic as an impurity. It may have enough Sulfur to make it self-burning, once it is heated.

Spain produces the most Iron pyrites, of some 350,000 tons annually. Altho scattered in the U.S. it is found in Calif., Col. Georgia, New York, Virginia, etc. sometimes in considerable quantities. Iron pyrites from Ellijay, Ga. is fair as a crystal. This Georgia's crystalline belt is about 100 to 150 miles wide.

In Leona Heights, Oakland, Cal. there is an Iron pyrites mine that produces 25,000 tons annually. We have had some of this as samples, and it is very poor as a detector.

Radio. Iron pyrites is usually more sensitive on weak signals than Carborundum. It is good for distance reception, especially on short waves. Reports of 4000 miles have been received from some of our Fans, on short waves using adjustable catwhisker.

For a long time it was the principal fixed crystal, as it is very stable, and holds its adjustment well. If it became inoperative, the catwhisker was moved sidewise until the maximum signal was obtained.

It is also recommended where an induced current is used, as in a Reflex set, or as a 1st or 2nd detector stage for a tube set. The Galena's points would burn off under these conditions, as any amount of current makes a Galena inoperative. Even with a Reflex set, the Iron pyrites seldom needs adjustment. When we used to build dozens of Harkness Reflex sets, in Los Angeles, in the 20's, they would be out for months before the catwhisker had to be re-adjusted.

Most Pocket Sets used to have a fixed Iron pyrites crystal, but most of them have now gone over to Germanium diodes.

A Gold catwhisker is the best, and was the kind used by the early Telefunken Company. The Gold point was usually mounted on a German silver spring - to save money, as well as provide a rigidity to the contact. Brass & Copper are next in efficiency. An increase in sensitivity has been noted when using an Antimony catwhisker.

A light touch is not normally needed on this crystal, as with Galena. However, Iron pyrites obtained from Ellijay, Ga. works better with a light catwhisker. For a fixed crystal, a heavy brass spring wire is bent into a slightly inverted "V" shape. One side is soldered to a binding post screw and the other touches the crystal. It has been used considerably on shipboard, since a heavy contact is required.

While Iron pyrites does tarnish, it does not become inoperative as quickly as Galena.

Iron pyrites from different sources varies in sensitivity. It is usually hard to get good specimens, even tho it is considered plentiful.

Other uses. Commercially, Iron pyrites is used mostly in the mfr. of Sulfuric acid. Also for blue Vitrol, vermilion paints, settings for rings, bleachings, fertilizer, insectides, Alum and fulfate of Iron.

As to Fool's Gold - if you are panning for Gold, and get down to the black sand, and find some "color" - pull the pan around in the shade. If it is Gold, it will still glisten. Iron pyrites only glistens in the Sun. Also, Iron pyrites is harder and more brittle than Gold.

Iron melts at 1530 deg. C.

IRON PYRITES, SYNTHETIC. FeS.

Ferrous sulfide. It is claimed it is easily made by heating Sulfur with Iron filings - when the elements combine to form a black mass.

Radio. Do not know how good they are as Radio detectors.

ISERINE. $((FeTe)_2O_3)$

This is a combination of Tellurium and Iron. Tellurium is considered a rare element, and may occur native, but mostly in combination with Sulfur compounds. It belongs to the Sulfur group of metals. Found with Iron pyrites as well as a by-product of pyrites' burners.

Tellurium is a white, lustrous metal, or metalloid, closely resembling Sulfur or Selenium in its chemical reactions.

Radio. This combination has been used as a detector, but no further details. However, as Tellurium is closely allied with Selenium, Sulfur and Iron pyrites, there is a suspicion that it would work OK.

Tellurium melts at 452 deg. C.
Iron melts at 1530 deg. C.

LEAD PEROXIDE. PbO_2.

Also called Lead dioxide. it is not a natural ore.

Lead Oxide (Litharge) is obtained by exposing Lead to a current of air, which oxidizes it to a yellow powder, called Massicot. At a high temperature this fuses to Litharge, in the form of reddish-yellow crystalline scales. By further heating, this gives off Lead peroxide, which is a reddish-brown, or chocolate powder, plus a red powder (Minium), or Red Lead of commerce.

Lead peroxide may also be produced as a deposit on the anode when acid solutions of Lead salts are electrolized.

Radio. Lead peroxide is a conductor of Electricity, which differs from most oxides, which offer high resistance.

It is a detector of the Electrolytic type. We find two combinations have been used. A lower contact plate of Aluminum and an upper contact of a brass adjusting screw. Lead peroxide powder is placed between. Should be kept moist at all times to prevent "crackling."

The other method is an electrode of Platinum (pos.) and one of Lead (neg.). Pressure is regulated by a setscrew adjustment for pressure on the powder placed between. The detector requires 2 volts to operate it.

Other uses. Lead peroxide is Lead compound used to form the positive plates of storage battery cells.

Lead melts at 327.5 deg. C.

MOLYBDENITE. MoS_2.

Sulfide of Molybdenum, or Molybdenum disulfate is the ore. Molybdenum is the pure metal. "Molybdenum" is Greek for Galena

- altho it resembles Lead, it has no connection with Galena.

It occurs in Granite, Limestone and other rocks, in varying proportions, with Sulfur compounds. Usually is found in foliate masses, or scales resembling Graphite, but differing from the latter in its bluer color. We have received samples of rocks, showing Molybdenite in tiny veins. It may crystallize in soft, non-elastic plates. Pure Molybdenum looks like freshly cut Lead, or a bluish-gray, metallic lustre.

The U.S. produces 85% of the World's supply, or 27 million pounds annually, with a value of 15 million dollars, with Russia coming next. Norway is also a big producer. In 1947, the Molybdenum producing areas, in their order were Utah; Colorado; Hurley & Questa, N.Mex.; Miami, Ariz.; McGill, Nev.; Bishop, Cal.

Molybdenite ores are roasted with Ammonium hydroxide to remove the sulfide, to produce the pure Molybdenum.

The powdered metal can then be pressed into a rod and electrical current passed thru it, and this will form a wire of Molybdenum. The resistance of the rod is sufficient to cause arcing between the particles (like Carborundum furnace) and weld it into the wire. Afterwards, it may be rolled into sheets, or drawn into wire.

Radio. "Moly" was used by the early Telefunken Company. It is a good crystal on strong signals and may be interchanged with Iron pyrites. It is not as sensitive as the latter. One peculiar fact about "Moly" is that its surface may be cleaned with sand paper, which would ruin other crystal's sensitivity. The resistivity of "Moly" is high.

Almost any metal may be used for catwhisker. Copper has been used. Also a flake of "Moly" crystal may be used for contact. Silver powder has been used, and later, Silver wire. A "Moly" wire has been used successfully with Silicon crystal. Contact may also be a polished plate of any metal. Two polished brass plates are also alright.

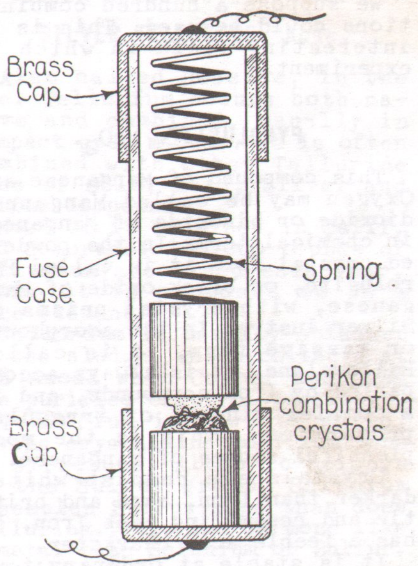
A battery of 2 to 4 volts will increase sensitivity of "Moly." May be connected the same as for Carborundum.

"Moly" is also sensitive to infra-red light, and responds quicker than Selenium. High resistant crystals are more sensitive to light; also when using low temperatures.

Other uses. 70% of Molybdenum goes to the Steel industry. It is used to harden and toughen Steel. Also used to make supports in Electric lights; some parts of Radio tubes; points of spark plugs and Electrical furnace resistors.

Molybdenum melts at 2620 C.

PERIKON.



In the course of experimenting with crystal detectors, a favorite combination of zincite and copper pyrites is very often found. This combination is usually sensitive practically all over the surface and gives excellent results. When such a combination has finally been found it can be mounted in a very stable form by following the illustration shown above. A burned out fuse of the tubular type is used as the case. The brass caps are removed and the interior cleaned out thoroughly. The base of one of the crystal mountings is soldered to one of the caps which is replaced on the tube. The other crystal is then placed in the tube so that the two will come in contact with each other. A fairly stiff spring is then inserted and the other cap replaced. —P. W. Streeter.

This is a coined word. "Perikon" is used to signify any type of crystal detector which uses one crystal for a base and another for a catwhisker contact.
Most of these combinations work better with a battery. It may be because of poorer contacts than obtainable with catwhisker contact points.
Many combinations have been used. Pickard developed a Perikon using Zinc oxide, ZnO, and Chalcopyrites.
The most common Perikon to be used on Ships was Zincite and Bornite, which was standard equipment for years. Other combinations are Silicon and Arsenic crystals; Zincite and Chalcopyrites;Antimony and Iron pyrites; Bornite and Chalcopyrites; and even Galena and Galena, as used in Australia.
We suppose a hundred combinations could be used. This is an interesting field in which to experiment.

PYROLUSITE. MnO_2.

This compound of Manganese and Oxygen may be called Manganese dioxide or binoxide of Manganese in chemical terms.In the powdered crystal form it is called Pyrolusite, or black oxide of Manganese, with crystal prisms of Silver lustre. In the amorphous, or massive form, it is called Psilomelane. It is always accompanied by Iron compounds, and is a complex mineral of irregular proportions. This is the most plentiful source of Manganese.
Crystals are reddish-white, darker than Iron, hard and brittle and resembling cast Iron. It has a feeble acid character.
It is stable at ordinary temperatures, when it is black. Upon heating, it easily gives off Oxygen and red oxide of Manganese. (Remember H.S. Chemistry?)
Sources are Russia, Africa, India, Brazil and a small amount in Georgia and Western U.S.
Radio. Detector developed by the early Telefunken Company, in 1901. About as sensitive as the Electrolytic detector, which is not too "hot."
Other uses. Generally used for making Chlorine and Oxygen.Black oxide of Manganese powder (Pyrolusite) mixed with Plumbago (Graphite) was used as a depolarizer in the Leclanche cell. This has been replaced by the present dry battery. The mixture in the latter is Pyrolusite, crushed coke and Graphite, tamped around a Carbon rod (positive). One could try some of this powder between a couple of plates, with a battery in series as an experiment.
Manganese melts at 1230 deg.C.

SILICON. Si.

Also called Silicum. "Silicon" is Greek for flint.
Silicon does not occur free in Nature. Its compounds are very abundant. Next to Oxygen, it is the most plentiful of all - and includes 87% of the crust of the Earth.
The most abundant compound of Silicon is Silica, or Silicon dioxide, SiO_2. This is found in Sandstone, quartz (see connection between oscillators?), rock crystal, flint, ruby, and the sand of the seashore.Some quartz - or rock crystals, that come from Brazil, are several hundred pounds each.
Silicon has crystalline, as well as amorphous forms. Latter is brown powder,that really contains minute crystals, resembling the diamond in structure. They are hard enough to scratch glass. It has a white, silvery, metallic appearance and resembles Steel in color. Is smooth-looking and rather brittle.

Silica can be reduced by highly heating powdered Aluminum, or Magnesium, with it to form a pure Silicon. The Aluminum melts at 660 deg. C. and dissolves the Silicon (see connection between adding Aluminum to Silicon to make better crystals?). Upon cooling, the Silicon separates as metal-like crystals and the Aluminum is dissolved in an acid solution.
Another method for fused Silicon, is by use of the Electric furnace, where a mixture of Magnesium and sand is subjected to a high temperature. It is then treated with acids and molten Zinc until the pure Silicon remains.
Silicon can be treated with Carbon to make Carborundum, SiC.
Radio. Pickard discovered the use of Silicon as a detector, in 1906, being the first commercial crystal to be used, to any extent. It was popular until about 1920. During World War 2 it came into prominence again, in the manufacture of Diodes.
It is a fair conductor of Electricity, which helps its use as a semi-conductor. In combination with high-frequency tube sets, it has operated down to 10,000 megacycles. It is rather sensitive, for general use,being similar to Iron pyrites, in sensitivity and stability, but not as sensitive as Steel galena.
There were several kinds of impurities (dope) tried with Silicon. Aluminum or Boron, added to Silicon have greatly improved its sensitivity. Also 0.4% Aluminum and 0.2% Beryllium have been added to Silicon with success. Boron, as low as .001%, is sufficient to increase its conductivity and sensitivity immeasureably. Beryllium and Aluminum additions also make the crystal tougher and harder.
The best catwhisker used in Silicon diodes is Tungsten. A British company prefers Molybdenum wires 2 to 8 mil. in dia., with conical points. A catwhisker of Molybdenum seems to be the next best in efficiency. An Antimony wire is also very good. Before the Diodes came into being, the best wire was a Gold one, with Brass next in order. Others used Copper, Carbon or Tellurium as contacts. Nobody has succeeded in welding a catwhisker to Silicon, as with the Germaniums. Sensitivity is helped by using a light contact. Silicon has also been used in Perikon detectors. A Silicon and Silicon have been used. Also, Arsenical crystal compounds have been used with Silicon crystals.
While it has not been advised to use a battery in series, the Scientists, using doped crystals - found that by using 0.1 v. DC. the sensitivity was improved,but beyond this the curve drops.
Other uses. Commercial Silicon is generally used to harden the Steel of commerce. Spring Steel contains Silicon and Manganese. Silicon Steel, used for cores of transformers and magnets, contains about 5% Silicon. It promotes sound castings, free from blowholes. Small quantities added to Copper deprives it of Oxygen and improves it for Telephone and Telegraph wire, as it toughens and hardens it.
Silicon melts at 1420 deg. C.

SILVER TELLURIDE. Ag_2Te.

Also called Hessite, in the ore. Tellurium occurs both native and combined, usually in compact gray masses. It is often combined with other Telluride ores of Gold, Lead, Silver and Sulfur compounds.
Most of it is mined in Calif. and Colorado. 200,000 pounds of Tellurium are mined each year, altho it is supposed to be a rare element.
Tellurium is usually obtained in the sludge, which collects at the anode when Copper and Lead are purified electrolytically.
Tellurium is a white solid, having crystalline modifications in structure. Altho it belongs to the Sulfur group, Selenium resembles Sulfur more than does Tellurium.Tellurium is more like a metal than Selenium or Sulfur.
Radio. You can suspect some detector possibilities when we mention Sulfur (Galena) so often - along with its electrolytical action. Also, its resemblance to Selenium (area contact rectifiers). Also it conducts Electricity,when under the influence of light, altho not as effective as Selenium.
Hessite crystals were used a-

gainst Aluminum, which surface was kept clean by Petroleum. The resistance at the point of contact was 1000 to 3000 ohms D.C. It is called a thermo-electric detector in Radio use.
Silver melts at 960.5 deg. C.
Tellurium " " 452. " "

SPHALERITE. ZnS.

Zinc blende, mock lead, Black Jack, or false Galena. Crystals often distorted, or rounded. May also be massive. May be various colors from white to yel-brown. Some varieties phosphoresce when scratched.

May also contain Iron and Manganese besides Zinc and Sulfur. Most common mineral of Zinc, and closely allied with Galena. Found in many places in the U.S.

Radio. No record of detector action, but the formula, and its association in veins may give some action.

Zinc melts at 419.4 deg. C.

TETRAHEDRITE. $3Cu_2S.Sb_2S_3$.

A Copper-antimony sulfide is distinguished by its deep black color on fracture. May be granular or massive state, similar in construction to Sphalerite.

Is most common member of the sulfo-salt group, and usually is found in Copper or Silver veins in Colorado, Arizona and Nevada.

Radio. No record of its use as a detector, but the formula is very suspicious, as it contains most active elements in good detectors.

Copper melts at 1083 deg. C.
Antimony melts at 630 deg. C.

TRANSISTORS. See later.

ZINCITE. ZnO.

Red Zinc ore or red oxide of Zinc. This is an impure native state. Crystals occur with other Zinc minerals, and mixed with sulfides of Iron, Copper, etc. It is a valuable ore when found in quantities.

In its native state it is a translucent, deep red, thru reddish-brown to orange-yellow in color. It consists chiefly of Zinc oxide and some oxide of Manganese, to which its color is supposed to be due. It usually occurs in the massive, or granular state, like Steel galena.

Pure Zinc oxide is a brittle, amorphous, white, tasteless, powder, insoluble in water at ordinary temperatures. It turns yellow when heated. Then back to white on cooling, to make Zinc white, as used in paints. It does not take a high polish.

Zincite is also a product of the Zinc furnace, but is not as sensitive in this state.

Radio. Zincite was one of the first detectors, and for a long time was sold under the name of Perikon, when operated with Bornite. The Electrolytic detector was 13.2% efficient and the Zincite was 13.4%.

For a wire-type catwhisker, Steel seems to be the best. Other contacts are Copper and Tellurium, which may be adjusted by a Steel spring.

Used as a Perikon, it was a standard part of the equipment on Ships for years. I used to use them on the old RCA receivers, in the 20's. It has always been a very stable detector when used with Bornite or Chalcopyrites as contact. Many used to prefer it to Galena. The two minerals were mounted in separate cups and brought into contact with a spring, with adjustable tension.

Strong signals usually made it insensitive, so it was usually shorted during transmission of signals. It may require a battery, when using a metal catwhisker. It usually takes less current than Carborundum.

Zincite has also been used in the Lossev oscillating crystal circuit.

Zinc melts at 419.4 deg. C.

QUICK REFERENCE CHART

Here is a quick checklist of the detectors we have attempted to cover. The Perikons, Diodes &

Transistors are covered separately, as they may be different combinations. However, their ores are covered in this list.

In many cases it may be found a battery of about .1 volt works better than none, which may depend upon the crystal. They may be tried with and without a little battery boosting voltage.

CLASSIFICATION OF CRYSTALS.

Name	Formula	Chemical	Active element	Battery
Anatase	TiO_2	oxide	Titanium	yes
Anglesite	$PbSO_4$	sulfate	Lead	?
Antimony	Sb	element	Antimony	no
Antimony-Alumin.	Sb plus Al	compound	Antimony-Aluminum	no
Arsenic	As	element	Arsenic	yes
Bornite	Cu_5FeS_4	sulfide	Copper-Iron	yes
Boron	B	element	Boron	no
Cadmium sulfide	CdS	sulfide	Cadmium	no
Calcium sulfide	CaS	sulfide	Calcium	?
Carborundum	SiC	carbide	Silicon	yes
Cerussite	$PbCO_3$	carbonate	Lead	?
Chalcocite	Cu_2S	sulfide	Copper	yes
Chalcopyrites	$CuFeS_2$	sulfide	Copper-Iron	yes
Cuprite	Cu_2O	oxide	Copper	?
Enargite	$3Cu_2S.As_2S_5$	salt	Copper	?
Ferro-silicon	Fe_2SiO_4	alloy	Iron-Silicon	?
Galena	PbS	sulfide	Lead	no
Galena, steel	PbS plus Ag	sulfide	Lead	no
Galena, synthet.	Pb plus S	sulfide	Lead	no
Germanium	Ge	element	Germanium	no
Iron pyrites	FeS_2	sulfide	Iron	no
Iron pyr. synth.	FeS	sulfide	Iron	no
Iserine	$((FeTe)_2O_3)$	oxide	Iron-Tellurium	?
Lead peroxide	PbO_2	oxide	Lead	yes
Molybdenite	MoS_2	sulfide	Molybdenum	yes
Pyrolusite	MnO_2	oxide	Manganese	?
Silicon	Si	element	Silicon	no
Silver telluride	Ag_2Te	salt	Silver-Tellurium	yes
Sphalerite	ZnS	sulfide	Zinc	?
Tetrahedrite	$3Cu_2S.Sb_2S_3$	sulfide	Copper-Antimony	?
Zincite	ZnO	oxide	Zinc	yes

TRADE NAMES.

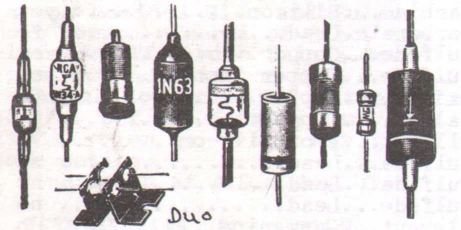
Even tho we have but 5 types of crystals now in general use, e.g., Carborundum, Germanium, Iron pyrites, Silicon and Steel galena, they may be sold under various names. Altho this list is far from complete, it may aid you in deciding which to buy.

You will note that Steel galena is the most represented. Often the same brand may vary from 1:2 to 1:10 in ratio of sensitivity. As most ores are mixtures, the ratio cannot be guaranteed. It is not the fault of the seller, but another trick of nature.

Trade name	Crystals
A-1	Galena; St. Galena.
Ajax	Steel galena.
Argentite	" "
Canadian	" "
Diodes	Germanium; Silicon
Ferron	Iron Pyrites.
Foote	" "
Goldite	" "
Hertzite	Steel galena.
Lenzite	" "
Magic	" "
Magnetite	" "
Melomite	" "
Midite	" "
Million point.	" "
Missourite	" "

MRL..........Carborundum; Iron pyrites; Silicon; Steel galena.
NAA..........Galena
Nevadium..... "
Permanite.....Steel galena.
Philmore......Iron pyrites; Steel galena.
Pyron.........Iron pyrites.
Radiocite.... " "
Rubyite.......Steel galena.
Silver bell...Galena.
Silverite.....Silicon.
Sparkite......Steel galena.
Texas......... " "
Transistors...Germanium.

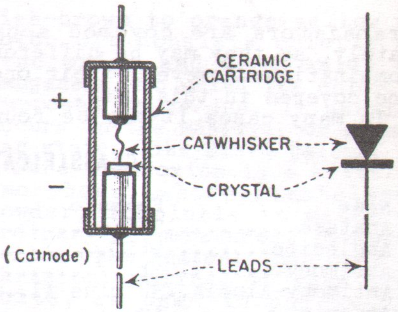
CRYSTAL DIODES.



Also called "semi-conductor Diodes." As far as that goes, any crystal detector may be called a Diode. However, for the present, we will limit it to the tiny, fixed crystals now in use.

Due to extensive work done in the large Labs. during World War 2, the crystal was found to be much better for some circuits than a tube. Consequently, the Silicon and Germanium crystals were put to use. Instead of the clumsy pre-war crystals, these were fixed in Ceramic and other mountings. An advantage of using a Diode is its small size, small catwhisker and no vacuum required. This also gives a more natural frequency than a large Xtl. Because the catwhisker point is so small, it offers very little capacity effect, which is detrimental in micro-wave tuning, in contrast to a tube.

The catwhisker is shaped like an "AC curve" as it stays in adjustment better. The idea is not new, as we find it in Drakes' (1927). Microscopes, and other sensitive devices are used to



CRYSTAL RECTIFIER AND STANDARD SYMBOL

set the catwhisker. G.E. welds the catwhisker to Germanium with 250 m.a. of DC, which cannot be done with Silicon. The cavity of the Diode is then filled with Paratac wax 80%; Opal wax 20%, which melts around 90 deg. C.

Diodes may be divided into two classes. First is the high-sensitivity type as Silicon. This will rectify from low audio frequencies up to 10,000 megacycles which makes it most effective in micro-wave equipment as H-F detectors, mixers for FM converters and micro-wave receivers. Above 420 mc. the crystal mixer has many advantages over the noisy tube. Silicon averages about 10:1 in resistance between backward and forward current. In a 1N21 the forward resistance may be 100 against 10M to 100M ohms in reverse.

The other type is the high-back-voltage type, represented by Germanium. This is the most popular in use as a general rectifier and second detector. The 1N34 replaces the 6H6 and 6AL5 tube Diodes. Germanium is limited to below 100 mc. because its rectifying properties fall off. It rectifies at about 100:1 ratio of backward to forward current.

Germanium is not damaged by high currents, while Silicon may be affected. The lowest resistance reading of a crystal shows its polarity. Researches during the War showed that some semi-conductors could be made posi-

tive or negative, but most of them are definitely unilateral.

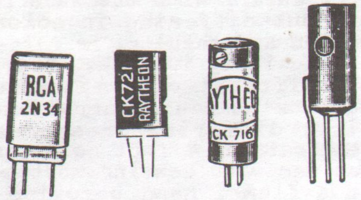
However, for Crystal sets most Diodes work OK on the frequency range required. Due to the impedance of most Diodes, they tend to broaden out the signal, in comparison to Steel galena, Iron pyrites and Carborundum. Apparently Germanium is the worst.

Manufacturers may combine two in one mounting and call them Duo-diodes. Others put 4 1N34's together and call them Varistors which are used in bridge rectifiers.

At this writing, Diodes to replace tubes were being made at the rate of several hundred thousand per month.

Germanium melts at 958 deg. C.
Silicon melts at 1420 deg. C.

TRANSISTORS.



Called the Germanium triode. They are of two types, the Point contact and the Junction type.

The Point-contact type is a block of Germanium with two catwhiskers, or electrodes placed very close together, and brought out to leads. One is called the Emitter (G in tube) and the other the Collector (P in tube). The bias voltages may be interchanged and the device be made to work in the opposite direction. This cannot be done with tubes, the nearest to it is the space-charge detector.

The Junction-contact type is an area-contact type. It is made from three blocks of Germanium, sandwiched together, with leads welded to each block. This requires less power to operate it than the Point-contact type. The sensitivity is so great that if a piece of wet paper is placed between copper and Silver coins enough current will be produced to energize it. Or, the energy expended by a Flea jumping every minute will keep it operating. Often the heat from the body is enough to work it, as Germanium is sensitive to light and heat. It has high efficiency with low distortion value.

A new Tetrode Transistor is now being made. Besides the base, Emitter and Collector, another contact, also with a bias battery, has been added. The unit uses three electrodes welded to a Germanium bar.

Entering the Emitter, the signal is amplified 100 times at the Collector. Be sure to hook Transistors up correctly, as the reversal of polarity will ruin them. The audio transformers, in between stages, are reversed, - the larger winding now being the primary. Distant lightning will also ruin them.

Transistors are noiser than tubes, usually producing a hissing sound. They draw more plate current than tubes, but no filament battery. Some work better as amplifiers; some as detectors (just like we used to juggle the old 201-A tubes around!). They are not too good on frequencies above the BC band, but this will be overcome.

Transistors are now being used in multi-tube Computers. One of these rigs has 6000 tubes. There are thousands being used in telephone repeater stations. The field of pocket Radios is much benefited. At present, 4 major companies are producing over 8000 Transistors per month.

MOUNTING CRYSTALS.

Often in manufacture, many crystals are mounted in too hot a mixture of Lead. Heat usually impairs sensitivity, possibly by molecular disturbance in the Xtl itself. For this reason they should be mounted in some form of low-melting-point Alloy.

A crystal may be held in a clip, or screwed up in a crystal cup. In the latter, it may be packed with tinfoil.

To increase contact surfaces,

a crystal may be mounted in a pool of Mercury and tinfoil, as no heat is involved in mounting.

Chuck Cole, Elyria, Ohio, says he found more DX and stations tuned sharper,if the crystal was mounted dry. Reason may be due to so many positive and negative contacts when the crystal is set in metal. The higher resistance lessens the shorting effect on the coil and tuning condenser.

One fellow uses Plumber's Lead wool to pack his crystal in cup.

However, for ease of manipulation, most all crystals are now mounted. Altho conductivity of each metal in an Alloy is greater than the Alloy, it is not detrimental in operation.

When metals are melted together, they form an Alloy, or mixture. If Mercury is added, it is called an Amalgam. Bismuth and Cadmium lower the melting points of Alloys,and impart fusibility. Bismuth and Antimony prevent the shrinking of the Alloy because they expand on cooling, which is the opposite to most metals. The Arsenic and Antimony make the Alloys brittle. Tin and Lead impart hardness and tenacity.

Eutectic mixtures. If two or more metals are combined into an Alloy in equal proportions, the one having the highest melting point will crystallize first. If combined in certain proportions, they will crystallize at the same time, and at a lower temperature. This correct proportion is called an Eutectic mixture,and the degree the Eutectic temperature. Therefore, Eutectic Alloys are best for mounting the crystals due to low melting pt.

Each metal added to the Alloy will change the melting point of the others. For instance, Wood's Metal is composed of Lead 327.4 deg.; Tin 231.9; Bismuth 271; Cadmium 320.9 but the Alloy has a melting point of 71 deg. C.

A recent Eutectic Alloy, with the lowest melting point, has been discovered by Colgate University. The approximate composition is Bismuth 42.34%; Lead 22.86%; Tin 11%; Cadmium 8.46%; Indium and Antimony 15.34%. It melts at 47 deg. C. (116½ F.)

Most low-melting-point Alloys are used in fire sprinkler systems or for babbitt metal.

To change Fahrenheit to Centigrade, subtract 32 from F. and multiply by 5/9ths.

FORMULA vs COLOR.

You have probably noticed several compounds having the same chemical formula, but called by different names. Steel galena looks like a piece of broken steel rod, but has the same formula as plain Galena, which has layers, or cleavage. Anatase, Brookite and Rutile may all have the same formula, but different crystalline structure, just like Diamond and Graphite differ.

Another instance, familiar to adult "jelly makers" is cane and beet sugar, with the same formula, but differing in color and action and results.

Especially in rocks, there may be different colors, caused by various molecular arrangements. Also, differing pressures and temperatures affect color,as you can see when heating most metals in a flame. Lead peroxide is a good example of color changes.

LARGE vs SMALL CRYSTALS.

In the old Crystal set days it was considered better to have a small crystal, as the large one offered too much resistance. We believe the larger ones offset this by having more hot spots, & greater ease of adjustment. Personally, we have never been able to find any noticeable difference between the small or large. The proper manipulation of the catwhisker is the most important if good results are to be obtained. Each crystal has its own degree of sensitivity. In the manufacture of Diodes, the catwhisker is adjusted by a microscope to the tiny crystal.

CRYSTAL SHAPES.

Radio crystals are usually formed in well-defined shapes.

However, if the crystal mass has been crowded just before cooling - the shape may be altered.

Others may appear in the massive state, altho under a microscope, small crystals are discernible. (Steel galena).

Salts of Lead and Copper may sometimes form crystals 20" across, and brilliant as gems,but too soft for jewelry use. Carborundum, while hard enough to scratch glass, cannot be cut or ground, because it is too brittle and breaks up.

POOR CONTACT RECTIFIERS.

Nearby transmitters produce mysterious effects on metal objects. Loose joints in a stove may produce arcing that sounds like music from the stove.

Poor Aerial joints will sometimes act as detectors, and give music when phones are connected in series,altho NONE of our FANS ever have ANY loose joints!

Catwhiskers, drawn across a crystal cup may sometimes produce music, caused by crystal dust, dirt, etc. making a poor contact with the catwhisker. If the debris is removed,no further detected signal is received.

When Nature throws a lot of different metals and non-metals together it results in a hodgepodge mass. The word "massive" is well used! They are not welded together as we'd solder a joint. Some nearby particles may have a good bond - others may be held together loosely. It is the latter type that form our semiconductors, rectifiers, or poor contact detectors. We must have a resistance built up in a ratio of forward to backward current. This makes the current flow many times easier in one direction than the other, i.e.,unilateral.

Consistent with the fact that impurities are added (see Germanium, Silicon, etc.) to pure metals, in order to increase the sensitivity, this tends to show we need a poor contact, or heterogeneous mass, to produce a good crystal, and not the chemically pure form.

Impurities (dopes) in semiconductors should come from a neighboring family of atoms. For instance,in Germanium a trace of the closely related Silicon has no effect. But, small additions of Arsenic or Gallium can change the conductivity enormously. Impurities in hi-quality Selenium, Germanium or Silicon should not exceed 1 part in a million. Aluminum or Boron added to Silicon are best. Phosphorus and Antimony are best for Germanium. The good dopes added to Germanium are worse for Silicon and vice versa.

The semi-conductors are made up of a poor and a good conductor of Electricity. In Galena, Lead is good; Sulfur poor. Aluminum is good; Antimony poor. Iron in Iron pyrites is good; Sulfur none.

So, to get the best detectors, some impurity must be added to the chemically pure.("CP" should mean "commercially pure.") No doubt, in our Radio Fan work, plenty will get in!

SENSITIVITY TO LIGHT WAVES.

Photo-electrical effects have been noticed during experiments with Silicon and Germanium diodes by several Scientists. A slight variation in reading was noticed when a strong light was applied near the contact. Experiments of this sort may be made with some Diodes having a glass enclosure. This may help to explain some of the mysteries of semi-conduction,and what happens at the contact point. So far it is mostly all theory. The amount of change is proportional to the difference in both light and the forward voltage applied. There is no doubt that because Thorium is Radioactive, and it is related to Germanium, there is some connection in Radioactivity.

7000 mile reception on a Crystal set, by Commercial stations, in the 1920's. Present Xmtrs, with increasing power are making it easier for the Crystal Fan to cover greater distances.

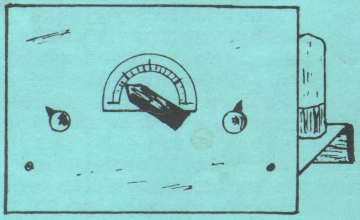
another MRL Handbook...

#4 - MRL 1-TUBE D.C. ALL-WAVE RECEIVER.

CONTENTS.

SOME OF THE QUESTIONS ANSWERED IN HANDBOOK 4. Pages given.

What is the logical method for learning Radio? Ans. on page 3.
How is this set good for the learning of code? p. 3.
How does the small set field work into a large Hobby? p. 3.
Why is this set called the single circuit tuner? p. 3.
What are the advantages? p. 3.
How do we substitute a standard variable for .00014? p. 4.
How does this combination select the range of coils? p. 4.
Why is the Antenna condenser the most important part? p. 9.
What is the purpose of the insulated extender to panel? p. 9.
How does distance between the plates of the Antenna condenser affect the set? p. 10.
Why is heavy wire used for RF circuits in this set? p. 10.
On what bands is it most important to be careful? p. 10.
What is our new method of systematic wiring? p. 12.
What special care should be used around sockets? p. 12.
Why do we make the grid leads short as possible? p. 12.
What does size of regeneration condenser tell you? p. 13.
Why are celluloid coils preferred? p. 13.
What are two methods of finding range of condensers? p. 15.
Why is tickler of 20 m. coil interwound with secondary? p. 15
What band works best? p. 15.
Why does it take 2 coils to cover the broadcast band? p. 15.
How does splitting the BC help the Hi-Frequency end? p. 15
What lengths of Aerial are to be used in City? Country? p. 15.
What is life of batteries? 16.
What effect does reversing the A polarity have on SW? p. 16.
How far should one get on this set? 7½ pages of reports.



Circuit originally developed by us in 1940, but many little changes have since been made to make it a real DX'er. Distances up to 12,000 miles are recorded on 7½ pages of reports. Easy, full-scale layouts, where sheets may be removed and placed directly on parts for marking. Easy to assemble and wire with our new systematic wiring plan. Complete conventional parts list. All coil winding data from 20 to 830 meters. Plenty of theory, as needed. Uses 1C5 or 1Q5 tubes; others if desired. 1 flashlight cell; 22½ B. Hundreds have been sold to Engineers, Teachers, etc. of higher learning, as well as Beginners able to run a soldering iron. We have left nothing out to prevent its being tops in performance. Same size as this Handbook, but 18 full-size drawings. Same source & price.