

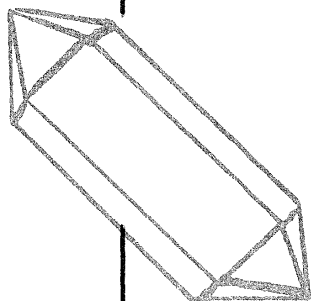
P R O C E E D I N G S

C H I C A G O

C R Y S T A L

C O N F E R E N C E

11-12 JULY
1944



ERRATA NOTICE

- Page 17 Paragraph 4, 4th line: 5000 KC should be 5 KC.
- Page 18 Paragraph 5, 1st line: 1942 should be 1943.
- Page 109 Eleventh line down: The word "specified" should be "specifies."
- Page 109 First remarks on the page by Mr. Balter: Delete the sentence "There is the mere fact it doesn't wash up as much as one that is jarred a little bit." Second sentence in these same remarks should read, "I think the only thing to do is submit some samples which we will put in our test chamber and see if they do age."
- Page 112 Paragraph 9 (Mr. Balter's remarks), second sentence should be: "You can have a temperature controlled box which need not be larger than a foot square."

PROGRAM FOR CHICAGO CRYSTAL CONFERENCE

NORTH BALLROOM

THIRD FLOOR STEVENS HOTEL

11 AND 12 JULY 1944

CHAIRMAN: Col. L.J. Harris, Director, SCIA

TUESDAY 11 JULY

9:00 A.M.	National Anthem
9:10 A.M.	Introductory Remarks Col. Lester J. Harris Director, SCIA Mr. William Halligan The Hallicrafter Co. Mr. P. W. Galvin Galvin Mfg. Corp.
9:55 A.M.	Crystals in Combat Major General Roger B. Colton, Chief, Engineering & Technical Service, OCSigO
10:25 A.M.	Break
10:35 A.M.	Minutes of Dayton Conference of 7 and 8 May 1944 Mr. N. J. Laub Chicago SCIZ
11:05 A.M.	Questions and Announcements
11:25 A.M.	Lunch - Boulevard Room
12:25 P.M.	Effects of Proper Cleaning Methods Mr. H. Waesche, Engineer, Crystal Section, ARL
12:45 P.M.	Survey of Problem of Stability of Quartz Crystal Units Dr. K. S. Van Dyke Chief Physicist, Crystal Section, Engineering & Technical Service, OCSigO

Crystal Conference (Cont'd)

1:35 P.M.	Break
1:45 P.M.	Studies of the Deterioration of Crystal Units al the Humidity and Holder _____ Techniques for Fabricating Stable Crystal Units. Mr. Virgil Bottom Physicist, Crystal Branch, Camp Coles Signal Lab.
2:35 P.M.	Break
2:45 P.M.	Preparation Developments
3:05 P.M.	A Mechanical Means of Mr. L. A. Faber James Knight Co.
3:25 P.M.	Questions (During this period questions will be received pertaining to any or all of the 4 preceding talks)
4:25 P.M.	Break
4:35 P.M.	Basic Factors in Crystal Pro- duction Mr. H. G. Human Crystal Products Co.
5:00 P.M.	this time the general adjourn until 8:00 July.
5:05 P.M.	Proper Packing Methods for Crystals Capt. M. L. Wexler, O/C Packaging Section, Storage & Issue Agency (This meeting will be held pri- marily for the prime contractors and Government representatives; however it will not be closed to anybody who wishes to attend)
5:50 P.M.	Adjourn

Crystal Conference Cont'd

WEDNESDAY 12 JULY

8:00 A.M.	National Anthem
8:05 A.M.	Roll Call Col. Lester J. Harris Director, SCIA
8:10 A.M.	Crystal Holders Lt. J. J. Maguire O/C, Equipment Section Crystal Branch, Camp Coles Signal Lab.
8:40 A.M.	Questions
8:55 A.M.	Principles of Quality Control Major C. R. Brearty O/C, Quality Control Section, SCIA
9:25 A.M.	Break
9:35 A.M.	Quality Control Applied to Crystal Inspection Lt. L. Jacobson O/C, Sampling & Inspection Records Subsection, SCIA
10:20 A.M.	Questions
10:40 A.M.	Crystal Testing Equipment Capt. E. F. Mitchell O/C, Crystal Branch, Camp Coles Signal Lab.
11:10 A.M.	Questions
11:30 A.M.	Lunch - Boulevard Room
12:30 P.M.	Crystal Specifications Capt. E. F. Mitchell O/C, Crystal Branch, Camp Coles Signal Lab.

Crystal Conference (Cont'd)

1:15 P.M.

The general assembly will disband and all persons present will arrange themselves into three groups:

- a. One group will discuss DC-34 & DC-35 Crystals in Dining Room No. 1
- b. One group will discuss FT-243 Crystals in the North Ballroom on the 3rd Floor.
- c. One group will discuss CR-1 and DC-11 Crystals in Dining Room No. 4.

Each of these groups will be conducted by a chairman and a discussion board as indicated on the following sheets. It is expected that questions arising from Captain Mitchell's talk on Specifications will be presented for discussion in these group sessions rather than in the general session.

4:30 P.M.

Farewell & Adjourn

Col. Lester J. Harris
Director, SCIA

(All persons will reassemble into the North Ballroom for this session)

INTRODUCTORY REMARKS

Col. Lester J. Harris

Director, SCIA

During the past few months Allied Armies have met with successes which two years ago a large group of people ardently insisted would never be possible. In any time of great strife there is always this group of individuals who like all opportunists are quick to grab at the most meager of facts and use them to justify all kinds of fantastic predictions.

These opportunists operating without advance planning have been quick to realize in their unthinking way that the wave of success which has accompanied Allied Forces in recent weeks can only mean an ultimate Allied Victory. In this they are correct; unfortunately however, the enthusiasm with which they have viewed the successes has caused them to jump to other conclusions which are wholly unwarranted.

a. They viewed the success of the African campaign and concluded therefrom that the so-called 'soft under belly' was ripe for successful and immediate conquering.

b. The fall of Stalingrad to them was conclusive proof that the Russians would be in Berlin in a matter of a few days.

c. The invasion of France by Allied Forces has been hailed by these warped imaginations as the trigger which will collapse the German Reich, as instantly as the trigger of a gun fires a bullet.

These are the conclusions of those who would have you believe that the war is over.

Let us pause to contrast these conclusions with the real situation, and as we prepare to make this comparison we will be wise to conclude without question that the war is not won nor will it be won by the type of wishful thinking which I have just outlined.

a. It is true we were successful in North Africa; it is true that by virtue of tremendous sacrifice, brilliant leadership and months of grueling hard work we were able to subdue the German Forces in North Africa.

b. It is true that we attacked the allegedly 'soft under belly' but fortunately for all of us, when this attack was planned our leaders quite intelligently reckoned with the fact that surrounding this presumably soft spot was an armor of steel and exactly as they expected the allegedly soft and mushy tenacle, Italy, which was attacked developed into a hardened and tempered bayonet.

In other words, wishful thinkers who predicted an early end to hostilities as a result of success in Africa, have since been forced to admit that perhaps they were overly optimistic, in like manner the hasty conclusions that gave rise to a wave of optimism at the fall of Stalingrad have also been forcefully invalidated by subsequent events.

Today we find ourselves once again faced with a powerful minority who, because of the attractiveness of their opinions to the general public are finding it quite easy to convince their friends that the invasion of Europe is the signal which will result in the hasty collapse of the entire German cause.

a. They draw their conclusion in spite of the fact that a few days ago the closest advance of any of the Allied forces was still around 600 miles from Berlin.

b. They draw this conclusion in spite of the fact that our enemies were still able to hold a geographically small island for 24 days against the best that the Allies could bring to bear against them. I refer to the island of Saipan whose capture in the first 14 days of combat cost the United States 9,752 casualties. In other words, an island in which the first 14 days of combat created casualties at the rate of 696 men per day, and Saipan is still 1500 miles from Tokio.

It should be now obvious that this war is not over. It should be equally obvious that any action which non-thinking optimists take to convince the public that it is over, can only result in increasing the amount of sacrifice and suffering which we must endure before the war is finally over.

The question then arises, "What can we here at this conference do to effectively assist in reducing the suffering which must be endured until an Armistice is signed?"

The answer to that question is found in the basic underlying purpose for which this conference is called.

a. We can make a tremendous effort to understand those with whom we must deal in order to deliver at the time they are needed our quota of crystal units. It is for the purpose of achieving this understanding that this conference was developed.

It is hoped that this conference will make clear:

a. The reasons why crystals must be etched to final frequency.

b. The reason why crystals must be inspected in accordance with Quality Control Techniques.

c. The reasons why specifications must be vigorously enforced,

d. And the reasons why many other alleged obstacles must be overcome if this war is to be won on schedule.

Let the keynote of this meeting then be, "The war is not over but through cooperative effort which results from complete understanding, the war will be won."

INTRODUCTORY REMARKS

Mr. William Halligan
The Hallicrafters Co.

Colonel Harris, General Colton, Mr. Galvin, Officers, Ladies and Gentlemen of the Signal Corps and Assembled Crystal Manufacturers: When I saw my name on the program to talk to you today, I assumed that I might be required to recite on Crystals, Quartz Crystals, their manufacture and so on, so to smarten myself up, I thought I would consult the Enclyclopedia, and I read, "Quartz crystallized in a * * * rhombohedral effect of the hexagonal system". That kind of threw me, so I thought that because I can do better with pictures, I would look at some of the pictures on the page, and under the pictures I read this inscription: "The two crystals shown in Figures 4 and 5 are "anantio morphus", that is they are "non supposable!". That is pretty tough.

"The basis is striated parallel to their edge of inception with R and this serves to distinguish R and X, and thus, in the absence of X faces, to distinguish left handed or right handed crystals."

Now, obviously, I didn't read any further, the going was entirely too rigid. So I came to a couple of conclusions. I am going to leave it in the hands of Hans Sauer and Fred Kahn who are doing a swell job.

I was reminded of the picture a couple of years ago confronting General Colton and the Signal Corps, when they had the task of constructing out of ashes, an industry to produce millions of crystals, which, as you folks here know, this industry has done.

I think General Colton can tell, or could tell if he chose to, about the difficulties that confronted him when he had this problem put into his hands.

He had no trained personnel to make crystals. Quartz, itself, is a very critical item, as we all remember. We had no equipment with which to make crystals, and out of this has been created into what, to my mind, is truly a miracle of American incentive and industry.

I think this crystal industry is probably the outstanding contribution or activity in the whole war effort. It was not alone the Signal Corps that did this. They were very expertly helped by the Contractors, and I specifically want to pay some tribute to the Galvin Manufacturing Company who did, in my opinion, a primary job in creating this crystal industry.

I think the Hallicrafters job was a very slow second, although I feel very proud of what we have done. As I recall after Elmer Wavering and his mighty men swept across the country there was very little for the Hallicrafters.

Introductory Remarks (Cont'd)

But I might say that Elmer and his crew did a very, very marvelous and thorough job. Somehow we survived and I think we have contributed, as I say, in a secondary way.

Now about these meetings we are attending here. Colonel Harris has told you the nature of them. Our Mr. Sauer has rather outlined to me what we can expect, and I look back on the few years of this crystal activity, and I know lots of us, - most of us, - felt pretty much frustrated at all these Signal Corps specifications, and it seemed to us every possible impediment to our progress, everything we wanted to do, was hindered. They seemed to throw things at us. But, looking back with a lot of satisfaction, we seemed to survive all of these difficulties, and I know whatever you might encounter at these meetings, - you might feel some modicum of resentment to, - live it down.

Do your best. Get in and put the same sincere effort behind it we have, and we intend to.

There were some things Colonel Harris mentioned in his talk just a moment ago. He mentioned France and Saipan. It just so happens, - if you will indulge me a little bit, - I got a letter from my brother, a doughboy in France, telling me of some of the vicissitudes of that kind of operation, and my own son is in the neighborhood of Saipan. He has been out there a long time. In both places the going is very, very tough.

I don't need to tell you it is my personal determination to knock the living hell out of this thing to get the crystals out and the other equipment we are required to get out. I think you can see from the personal angle I have on the war, I am going to do just that. I look to you folks to do the exact same thing.

Thank you very much.

INTRODUCTORY REMARKS

Mr. P. V. Galvin
Galvin Manufacturing Corporation

Colonel Harris, General Colton, Members of the Military, Crystal Manufacturers: Elmer Wavering informed me there was going to be the prospect of doing some crystal business down here this morning. I got down here reasonably early, but I found Bill Halligan had all of the orders.

There were no orders left for me so I want to make a few remarks to you, and bow out. But I do welcome this opportunity to meet with this group for the first time. I know quite a number of you, and I know about most of you. I know about those of you that are in our crystal picture.

To you in particular, and to all in general, I want to extend my gratitude for the fine support that you have given us in aiding us in discharging our responsibility that we took on when we went into the serving of the war effort.

I hearken back to the time when we first got into our war effort, and were exposed to the crystal problem. There was no crystal industry of any consequence at that time, just a small little industry, from a volume standpoint.

I remember one of the first contacts I had in the matter was a rather natural, normal one, with George Wright. In our conversation I told George Wright that in a conversation I had with General Colton that it was an expectancy that in quite the immediate future there would likely be 650,000 crystals.

On the basis of the amount of crystal business that George had been doing up to that time, - and he was no small manufacturer in the crystal business back at that time in '41, - he asked me if it would be possible to get a guaranteed letter from President Roosevelt that there was going to be 650,000 crystals bought; that he would have to take that kind of a letter back to his Treasurer before they would ever think about expanding into that tremendous, great business.

Well it came to pass that about 90 days after that General Colton placed an order for 1,200,000 crystals in our laps, and I looked and blinked and started to ask the General how he thought we ought to go about that, and quick on the trigger as he always is he said, "Wait a minute, you are industrialists; you are going to answer this question. Go along as industrialists and take this thing and work it out yourselves, and see how good industrialists you are."

So we were literally dropped into the crystal business in that fashion. I look back and think our policy has been a wise one. Truly we didn't get a lot of crystal manufacturers together, but we got a lot of American ingenuity together.

Introductory Remarks (Cont'd)

I think that if a lot of you fellows had looked in the dictionary before you went into the crystal industry and found what Bill Malligan did, you would have shied off. You would have been afraid to go into the crystal business, but you went into it because you didn't know any better, - most of you. You had better stay in it, and had better get into it deeper.

There is going to be a trend I can see woven through this meeting, - probably there is a good reason for it. We Americans are a funny race of rascals; we are extremists, - extremists in every direction. It is possible that there may be too extreme a swing toward this so-called postwar planning.

Well as I see the problem for you fellows you must do a little postwar dreaming and thinking, but don't let it take a minute of your active efforts away from this job. The very fact that there is this type of conference at this time, indicates the momentum of our task.

Many of you fellows have come a long way in learning a lot about the crystal business. We all have come a long way in learning a lot about the crystal making business, but there is a lot more that we will have to learn about the crystal business, because I don't think everybody, or hardly anybody knows all there is to know about the crystal business. We are all learning together, the laboratories and ourselves, and it is these meetings that are going to put us all together in the best possible position to serve the using arm. Fundamentally, that is our objective.

If we make the crystals for them, we must continue to seek to make better crystals. We are learning to make better crystals. We are going to have to learn to work with better inspections. We counsel conservatism on everybody's part, including the laboratory. Let's all work out these problems together, and continue to do a good job in serving the Armed Forces.

I thank you.

INTRODUCTORY REMARKS

Major General Roger B. Colton
Chief, Engineering & Technical Service

Colonel Harris, Ladies and Gentlemen: It is a great pleasure to be here. When we started in the crystal business, we started other people in the crystal business. Some two and one-half years ago, I think that about as many crystals had been ground in this country as there are people in this room. Not far different.

No one believed originally that we could get out enough crystals, - but you did get them. You people here are the people, for the most part, who made the crystals. I have a very warm spot in my heart for all of you.

Some of you made lamp shades; some of you, I believe, ran garages, and some, I believe, even cut tombstones. Those who cut tombstones, knew more about rocks than I did.

In the last two and one-half years we have learned a lot about crystals, even the old timers who thought that they knew all about them, and we have more to learn before all of our problems are solved.

For instance I am reminded that I was reliably informed that one of the questions before the house was, "an obvious scratch". Is that correct Major? The main thing is, we got the crystals, and we are still getting them, and by and large they are doing the job that they were meant to do.

Our decision to go into crystal controlled radios for widespread tactical use has been more than justified by the results obtained. The Army had radio before they had crystals. Now the Army has communications. That's the difference. Crystals gave us communications.

The advantage of precise and constant frequency control, together with the ease of reading, have given a reliability to our radio communications, which make them second to none in the World.

The chief disadvantage in the crystal control are those incident to supply, which you people have solved, and distribution, which is the job of the Signal Corps, which it has undertaken and on the whole, has done fairly well.

In this connection, General Forrest's famous remark about getting there, "fustest with the mostest" does not mean much applied to crystals, unless they are for the right radio sets and on the right frequencies.

Furthermore, they have to work when you get them there, so if you think you have your troubles, remember the Army has had its troubles and its difficulties and problems too in distributing the millions of crystals to the different theatres for the right sets, on the right frequency, and at the right time.

Introductory Remarks (Continued)

When Major Marks and I were in England and Italy last spring, we personally checked on the signal corps equipment, not only the major signal corps equipment, but the various components and especially crystals.

In general, I found that the supply was adequate. I found some bad crystals that I wish I had not found, but the supply of good ones was, in almost all cases, enough to make up the result of somebody's carelessness.

On the Anzio Beachhead, and from Africa to England, every theatre commander I talked to, and I talked to Colonel Theodore Roosevelt, General Eaker, General Clark, General Bradley, General Huebner, all of those people who are now fighting in Italy and in France. All of these commanders were full of praise for Signal Corps equipment. However, we must remember that that theatre is quite different from some of our other theatres, in the Southwest Pacific and China, Burma and India, where high temperatures and humidity are prevalent. We have received reports that we can expect more defective crystals under our present standard, which is the reason we are increasing our standard, - one reason.

Not all of these failures are due to aging. Some of them must be attributed to such things as wrong frequency stamped on, careless assembly, plain dirt, - I could tell you some of the other things that make the crystals break down, but we will skip them. You all know them.

Consequently, while you are discussing your problems in the Inspection Agency and laboratories, just remember that a defective crystal in the Burmese Jungle is no help to anybody, and may, in fact, be the cause of the loss of life and the loss of tactical advantage.

Improvement in the general quality of crystals is not just somebody's dream. It is a military necessity. Two and one-half years ago, we were faced with the necessity of getting out crystals in unheard of quantities, and it was far better to have a large number, - an adequate number, - if not such good crystals, than to have a large proportion of our radio sets without crystals at all. That phase is passed.

You gentlemen have now demonstrated your ability to build crystals in quantity by actually doing so. I believe that you have also demonstrated to yourselves your ability to make these crystals, high quality crystals.

I hope and believe that you gentlemen all feel a personal responsibility for every radio set that is imperfect due to a defective crystal, as I do, and as all of the members of the Engineering and Tactical Services of the Signal Corps do, and as I am sure all of the members of your Inspection Agency does. If the set fails it is our fault. We cannot escape it. It is our fault.

If a crystal is not exactly on a frequency, communications will fail at extreme range. And if a set isn't on the exact frequency, communications will fail at extreme range.

Introductory Remarks (Continued)

Some of you, who are radio engineers, may dispute that, but if you will think it over, when you are working on a radio net, if one of the sets of crystals is not exactly on frequency, communication fails, at extreme range. If it is too badly off frequency, communication, of course, fails at all ranges. Of course you can still talk over the radio set, but nobody is there to hear you, so you might just as well not have any crystal in your set.

Of course if a crystal loses its activity or badly shifts its frequency in the process of aging, communication is never established by that crystal. I am glad to say that failures of this kind have not been very large under actual field conditions, but gentlemen, a few failures of communications mean the loss of a few battles, and I am sure that neither you nor I wish to lose even a few battles.

Even a few battles lost means many lives lost, even though we win the war in the end. The crystal industry is now one of the most cooperative of all the industries with which I have to deal. The teamwork between the crystal industry and the Signal Corps is splendid. I am confident that it will continue to be splendid.

MINUTES OF DAYTON CONFERENCE
OF 7 AND 8 MAY 1944
Mr. N. J. LAUB
CHICAGO SCIZ

Mr. Nick J. Laub of the Chicago Signal Corps Inspection Zone reviewed briefly, the minutes of the Signal Corps Conference held at the Signal Corps Inspection Agency Headquarters, on the 7 and 8 May 1944, for the purpose of discussing various problems arising in the inspection of Crystal Units.

Some of the problems discussed at the Dayton Conference were:

1. Installation of Sampling Procedures designed to comply with requirements of Quality Control procedures being applied to acceptance tests as conducted by Signal Corps Inspectors.

2. It was decided that the use of different sample groups may be used for the various acceptance tests listed in Specification No. 71-3046, except that the same sample group must be used for the drop, vibration, seal, and immersion tests, and in the order listed.

3. A new standard test oscillator, AN/TSM-1 for use in inspecting CR-1 Crystal Units, is to be distributed in the very near future by the Laboratories. The new test set is of an improved design and free from many of the prominent defects of the older type. The correlation of the new oscillator will be maintained by the Camp Coles Signal Laboratory, and not the Aircraft Radio Laboratory. The test sets are to be shipped directly to the inspector-in-charge at each plant manufacturing CR-1 Crystal Units.

4. At the termination of each pilot run, on all types of Crystal Units, a conference will be held between the pilot run engineer, the contractor or sub-contractor, the Signal Corps Inspector in Charge and if possible, the Zone Crystal Coordinator. The Inspection Instructions, manufacturing procedures, and applicable specifications will be reviewed and discussed at the meeting, and an agreement, among all those concerned, must be reached before termination of the pilot run.

5. Crystal activity may drift when the crystal is inserted into a test oscillator for measurement. It was agreed that such Crystals will be acceptable providing the activity does not drift below the specified minimum activity requirements.

6. Clarification of the term "Rework" was established. The term "Rework" as it applies to the repair of a Crystal Unit, means the making of physical changes of the quartz crystal, its holder, or other parts that will effect the conditions for which the Crystal Unit was rejected.

7. The interpretation of the requirements of the Mechanical Visual Inspection Clauses of the various specifications were clarified. It will be acceptable to accept more than one defect in a given sample lot, providing that no specific defect occurs more than once within the sample

Minutes of Dayton Conference of 7 & 8 May (Continued)

lot. The presence of any defect more than once within the sample lot automatically requires rejection of the crystals represented by that sample lot.

Questions submitted to Mr. Laub at the close of his speech were:

1. Is the new test oscillator to be used only as a reference test oscillator?

Yes, it will be used only to check the correlation of the working test oscillator.

2. How does a contractor obtain a test oscillator when it is required to be used in manufacturing preproduction samples of a new type?

The test sets may be obtained by requesting the Signal Corps Inspector to forward his request through the proper channels to the Laboratory.

3. What becomes of sample Crystal Units forwarded to the Laboratories for various tests?

The samples that have been tested by the Laboratory are to be returned directly to the inspector-in-charge at the plant where the Crystals are manufactured.

EFFECTS OF PROPER CLEANING METHODS
MR. H. WAESCHE, ENGINEER
CRYSTAL SECTION, ARL

Colonel Harris, Ladies and Gentlemen:

1. My talk was to be the effect of Crystal Cleaning. What I would like to do is give a resume of how we got into this cleaning of Signal Corps test. Some of the things we found out made it necessary for the Laboratory to have the Crystal Wash Test.

2. Now to start off by going back and giving a resume of the things that happened in the Crystal Industry. Cleaning was somewhat overlooked in the rush to get crystals with more obvious requirements emphasized with such things as X-Ray Orientation Methods, securing of manufacturing equipment, conservation of quartz overshadowing all other factors in spite of a few voices in the wilderness calling for greater emphasis of what then seemed like minor details involving greater quality control. The industry, of course, responded magnificently with production miracles, despite the inexperience of the majority. However, as time went on, quantity was not enough and the pendulum began to swing toward the direction of quality even if it meant reduced production; dependable crystal units were more important than - just crystal units.

3. In July - September, 1942, a handbook was issued, based on manufacturing procedures of that date for manufacturing quartz oscillator plates, by the Office of the Chief Signal Officer. It was recognized that cleanliness was important to prevent aging. It was recommended that carbon tetrachloride and water rinse with "lint-free" towels for drying and final drying with clean compressed air should be used. This was also to apply to the case and electrodes. Aging was recognized by all, some heated the blanks to cure it, some just finished the unit a few hundred cycles low and allowed them to go to a higher frequency, of course the activity dropped but that was just one of those things.

4. Then between December 1942 and April 1943 one manufacturer independently investigated some crystal units from their own stock and other sources and discovered that by washing some crystal units, changes as high as 5000 kc were obtained. Further investigation showed that the crystal units could readily be manufactured so that a maximum change of plus 800 cycles would result if the oscillator plate was washed and re-assembled, provided the crystal had been washed with soap and water and dried on a towel without rubbing. The crystals which changed frequency by several kc. turned out to be those which had been rubbed with towels during the final drying. The same manufacturer attempted then to show that a crystal would have a greater frequency drift with age, but to their consternation the frequency stability was greater than with non-towelled crystals. This situation led to a feeling of false security in spite of the fact that it was known that any moisture reaching the plate would immediately destroy the loading effects and the crystal unit would shift in proportion to the loading to a higher frequency. But then, the crystal unit was inside a case and besides the specifications for crystal units completely ignored such conditions.

Effects of Proper Cleaning Methods (Continued)

5. In April 1942 reports reached the Aircraft Radio Laboratory, then about to embark on its CR-1 Program, that certain manufacturers were using a "Lint-Free" cloth, which when rubbed on the dry quartz plate would set the frequency most anywhere desired - that is within reason. Also cigarette ashes, starched towels and other media could be and obviously were being used to attain the same results in varying degrees. The Aircraft Radio Laboratory immediately advised the Contracting Officer that they did not consider this an acceptable manufacturing practice based on their requirements and simultaneously this was confirmed independently by data submitted through Signal Corps Inspectors at the Company referred to previously. These Signal Corps Inspectors requested an interpretation from the Laboratory because the specifications did not specifically cover loading practices. The Laboratory immediately invoked the good workmanship clause of the DC-11 and CR-1 Specifications and requested, through the Contracting Officer, that all loading by means of towels or otherwise be declared unacceptable.

6. As of this time, cleaning and aging were not too well tied together. A report of a Signal Corps Conference of 10 May 1943 refers to disturbed surface layers of quartz and their effect on aging, but there was little or no reference to aging resulting from loading and/or dirt. Some mention was made of cleaning solutions.

7. Soon after this, Supplement No. 3 to the latest Signal Corps handbook, entitled "Salvage of Quartz and Reclamation of Blanks" was issued. A paragraph in this publication by the Chief Signal Office stated that a thorough cleaning of crystals would improve their stability and activity. A cleaning solution, that later proved inferior to the toothbrush, soap and water method, was recommended but it was a step in the right direction but, apparently like other cleanliness recommendations, was unheeded by all but a very few manufacturers.

8. Late in June 1943, the Aircraft Radio Laboratory embarked on its CR-1 Pilot Runs. These were now new ventures, both for the Signal Corps and the manufacturers. One thing among others the Aircraft Radio Laboratory was determined to have clean crystals, and they never relaxed on that point. When the Aircraft Radio Laboratory Field Engineer arrived in Chicago, he found a kindred spirit in a Signal Corps Roving Inspector for Crystals, who was determined to wash crystals with a toothbrush. The Aircraft Radio Laboratory Field Engineer thought this was a good idea but a big jump to introduce too suddenly. However, this inspector was quite convinced, had done considerable experimental work which showed that the crystal units, which had been properly cleaned, could be expected to shift not more than plus 350 cycles when scrubbed with a toothbrush and soap and water. The Aircraft Radio Laboratory Field Engineer felt that the step toward a cleaning test should be made gradually and that, after all, the main thing to eliminate was "loading" the crystal to adjust the frequency. To this end, a compromise test was set up in the preliminary Signal Corps test procedures, requiring that the Signal Corps Inspector merely dip the crystal in water, carbon tetrachloride, alcohol, benzine, after having measured the frequency before dipping. After reassembly the crystal must not have changed more than 500 cycles. The Signal Corps

Effects of Proper Cleaning Methods (Continued)

Inspector was still for the toothbrush and actually he knew what he was talking about, but compromised on the dipping test.

9. This procedure was short lived. The CR-1 production was behind schedule and Pilot Run complications, which appeared to be slowing down production, resulted in a conference in Chicago, 10-13 July 1943 between CR-1 manufacturers, representatives of the Chicago Signal Corps Inspection Zone, the Office of the Chief Signal Officer and Camp Coles. At this conference interpretations of the CR-1 Specifications were gone over and the ground work laid for revised Inspection Instructions. The question of cleaning test was introduced and opposition from the manufacturers was great. Other Signal Corps Agencies, other than Aircraft Radio Laboratory, concurred with the manufacturers in that a crystal unit should not be opened for cleaning and that if it operated satisfactorily in Signal Corps tests, it should be acceptable regardless of loading or dirt. Consequently, all tests of this nature were deleted from the Inspection Instructions. The Aircraft Radio Laboratory Engineers were not convinced that some control over cleaning should not be exerted. The representative inspector of the Chicago Signal Corps Inspection Zone, having gone to Kansas City, was definitely not convinced. Consequently, in all plants where Pilot Runs were in progress and in subsequent Pilot Runs, representative crystals were subjected to water or other dip and if they shifted in frequency a kc. or more the plants final cleaning processes were not approved until the crystal plates could pass this Pilot Run test. Finishing and cleaning procedures were approved. It might be stated that one Chicago CR-1 manufacturer also realized the importance of cleanliness and preferred to voluntarily rework several thousand crystal units when it was found that a large percent of his crystal units shifted after dipping even though he could have objected strenuously.

10. For the next two months all was relatively quiet on the crystal cleaning front. This was merely the calm before the hurricane.

11. On 9 August 1943 Aircraft Radio Laboratory received report of certain defective crystal units from the using forces.

12. On 30 August 1943 the same report was again received.

13. On 11 September 1943 a letter was issued to all manufacturers by the Office of the Chief Signal Officer warning manufacturers of loading crystals, which was a serious business and prosecution could result.

14. On 24 September 1943 one manufacturer reported that if he must clean his crystals as the Signal Corps wanted that he would have his production reduced by 50%.

15. Meanwhile an Aircraft Field Engineer was sent to investigate reports from the using forces that many air force crystals were not usable. His investigation resulted in his return to headquarters and investigation of Depot "S" stocks followed. A large quantity of Depot Stock was found to be defective because of aging. In some cases 80 to 90 percent of a lot of units was defective. All Aircraft Radio Laboratory Field Engineers were

Effects of Proper Cleaning Methods (Continued)

armed with toothbrushes and the first crystal washing test, as incorporated in a letter to the Contracting Officer dated 25 September 1943, was put into immediate effect by Aircraft Radio Laboratory Field Engineers, although time was allowed for the manufacturer to adjust his procedures to comply. Actually, except during Pilot Runs, this letter acted only as a lever to change the CR-1 manufacturers over to better cleaning methods for gathering information on just what could be attained in production. A tentative limit of 600 cycles change was allowed after scrubbing with a neutral soap and water and toothbrush. A second procedure, dated 28 February 1944, was issued and the cleaning test was armed by rejection limits slightly more lenient than in the original letter at the higher frequencies. Also, in the new letter, a detergent soap was specified. This was done because the original test, whereby the first procedure had resulted, had been performed using the soft water of New York City. It was discovered that ordinary soap and other water would tend to load the crystal. The detergent soaps appear to have corrected this condition. Simultaneously, with the development of the cleaning procedures, the Aircraft Radio Laboratory became aware of the probability that the cleaning of crystal units alone did not cure aging. It vastly improved the unit, but if moisture should happen to reach the plate, then aging would be accelerated. Checks during Pilot Runs of crystals, which had been etched to final frequency versus those not etched to frequency as well as controlled lapping procedures suggested that etching and controlled lapped crystal units were superior relative to aging characteristics. A check at one of the contractor's plants, where records on etched and unetched crystal units had been kept, suggested that etching would improve its use. All CR-1 manufacturers were, therefore, encouraged to etch and to clean the crystal thoroughly as well as use controlled lapping methods. These suppositions by Aircraft Radio Laboratory were confirmed by letter by experimental evidence from Camp Coles. That Laboratory likewise confirmed that cleaned crystals were less subject to aging but not free of this characteristic if the crystal unit was subjected to high humidity.

16. In order to check on crystal quality being manufactured after October 1943, Aircraft Radio Laboratory selected samples of all the stock of CR-1 received at the Depot and subjected them to special tests to determine their aging. As a part of these tests some crystal units were washed. Almost no dead crystals were encountered. At the present time, all Depot Stock is tested in Signal Corps Standard Test Sets for activity only, before shipment.

17. Frequency is one of the most important things. Etching and cleaning maintain frequency regardless of conditions. (Mr. Waesche cited several illustrations: "We have tested one thousand nine hundred and 41 (1,941) crystals of various CR-1 plants, and out of this only 13 failed in 6, 7 and 8 megacycle range. We have washed something like three hundred and fifteen (315) CR-1 crystals from various manufacturers. Presumably these crystals I am referring to were all put into the Depot after approved washing technique had started. Average for crystals of 5 and 6 thousand kc. range was a change of 230 cycles. For 64 units 7000 kc. change was 386 cycles.) We do not expect to use cleaning to

Effects of Proper Cleaning Methods (Continued)

offset etching, or any other requirement. Cleaning was just an intermediate measure until we could get a test by Camp Coles to put etching into effect. In spite of the fact that the picture here presented is much rosier, it behooves none of us to relax on the problem of cleanliness.

SURVEY OF PROBLEM OF STABILITY
OF QUARTZ CRYSTAL UNITS

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1. It is clear to everyone that we use quartz crystal units in the belief that they are stable, that their frequencies remain constant both during our immediate use of them and for a long period thereafter. In addition to this stability, it is true, there are a number of other features which are definitely contributory to their acceptability as frequency determining elements of radio circuits. Among these may be mentioned, the space factor, the ease of switching from channel to channel, and the speed of netting. But valuable as these other features are, there stands out, in any consideration of the question of building the radio circuit around a quartz crystal, the assumption that the quartz crystal unit, and above all, the quartz itself, is stable.

2. In the general stability problem, whether it involves the constancy of the quartz, or the effect of circuit variations on the frequency of oscillation, the blame for instability must be placed variously where it belongs on the several elements, quartz, holder, circuit, design, etc. For convenience, we shall divide the problem into two parts, one specific, the other more general. Stability during any one operation of a crystal unit in a single circuit requires that a crystal's properties shall not change by its own self-heating, that it start to oscillate each time in the same mode of vibration and continue so, and that the crystal have great stabilizing power in over-riding circuit fluctuations. The broader problem requires identical performance under different operating conditions such as different temperatures over a whole range of ambients, or when plugged into different circuits, and in its oscillation next year as compared with today. The last of these, which concerns the permanency of the crystal unit, will be recognized as the so-called aging problem which has caused concern to so many of us over the past year. This matter of permanence will be our major topic for consideration. The others are listed to place the aging of crystal units in its proper setting as but one of the factors in the general problem of generating constant and precise frequencies.

3. It may shock some of us to recall that there was a day when some people thought the quartz crystal to be almost too fixed and too permanent a device. It was new to have a radio frequency circuit element which one could not tune or adjust and the amateur of the mid '20's fretted particularly with the problem of over-grinding. Perhaps some of you recall cartoons and wisecracks in QST of that time illustrating difficulties of putting quartz back onto the crystal after it had been ground off. Lowering the frequency of a crystal after it has once been cut has always been a problem. In answer to the early prayer of the amateur's cartoons we have Dr. Frondel's recent discovery of a way to produce a moderate downward adjustment of the frequency. As is familiar to you all, by X-ray treatment he changes the internal properties of the crystalline quartz, as if making it less stiff in its elasticity, so that it selects a lower frequency.

Survey of Problem of Stability of Quartz Crystal Units (Continued)

4. During the past year we have become particularly conscious of what some assumed to be a natural tendency of a quartz plate to move upward in frequency with age; the quartz to become elastically stiffer, as it were. It is true that in many crystals the frequency does rise as time goes on, but it is not in this case a property of the rock which is changing but its surface which is sloughing off. Sad experience teaches us that certain precautions in preparing this surface are essential if the frequency of a quartz crystal is to be the fixed thing we had thought it to be.

5. In considering the permanence of a crystal unit it will be well to defer those effects which are due to the presence of the holder until after we have discussed the permanence of the quartz plate itself. As has just been indicated, the key to permanence of the frequency determining piece of quartz is now known to be its surface. The careful study of this problem at Camp Coles Signal Laboratory and the correlated as well as independent studies in other laboratories and plants all furnish overwhelming evidence of crystal surface disintegration, and they lay the blame for disintegration on the process of preparing surfaces by abrasion and the action of water vapor on surfaces so prepared. It seems obvious from the general trend of the findings that we shall not have stable crystal surfaces, and thus crystals which are permanent in their frequency and activity, until the method of finishing used is one which arrives at the final surface by dissolving away the quartz instead of chipping it away. The experiments are so conclusive as to convince the Signal Corps that the conditions to be satisfied in its radio circuits can be achieved only by etching quartz plates to frequency. Thus the Signal Corps is out to buy not just quartz crystals but etched quartz crystals.

6. As indicated, there have been many who have participated in the experiments and tests to run down the causes of aging. Many, in addition to those who have worked directly with Camp Coles, have conducted special experiments at my suggestion and I wish to acknowledge for all of us all of this help with very real appreciation. Some probably feel that the Signal Corps is seeking perfection when it is critical of such small frequency changes as they find to occur after the better abrasive treatments. Figures such as Mr. Waesche has just read might be used to defend the stability of lapped crystals, particularly where scrubbing has followed the abrasive. I should like to comment that Mr. Waesche's figures are presumably indicative of rather even temperature and moderate humidity conditions of storage. Such conditions do not prevail all over the world and moisture absorption in the phenolic holder and its re-emission into the crystal cavity can produce very destructive conditions within for any lapped crystal plate. The test is not only whether crystals will stand up in the depots but whether they will stand up under the temperature and humidity cycles which are to be found anywhere our equipment has to go. The small frequency changes which carefully lapped surfaces undergo when stored in our relatively dry buildings are going to be multiplied too many times for comfort when such crystals meet tropical climates. All of the tests certainly point that way.

7. It is the common experience to find manufacturers insisting

Survey of Problem of Stability of Quartz Crystal Units (Continued)

that their own units do not age. In many cases they have performed careful experiments and I do not question the sincerity of their conclusions. Where there is a divergence of views I think the reason is probably to be found in the differing definitions of stability. We have been forced to a severe definition and test for permanence of surface layers. Disintegration can proceed for a time without loss of material or change of frequency, and activity measurements alone are not as dependable in indicating the progress of cracks as is frequency in indicating loss of material. Accordingly, stability against disintegration is being judged in the light of stripping tests before and after exposure to aging influences in order to detect material which may be more loosely bound to the surface after exposure than before. Those who differ with us neglect this severe test. However, it is our common experience that activity losses while a lapped surface is exposed but untouched are continuous and that ultimately the crystal becomes dead. For a dead crystal there is no cure in the field but cleaning and the extent of the deterioration then becomes apparent in a large frequency change.

8. It is learned, and here the basic experimental work done in the Bell Telephone Laboratories is acknowledged, that for about one-third of a micron down from the surface of a prepared crystal blank the base rock property is destroyed in lapping. X-rays prying into the crystal plate show a disturbed surface layer which is out of line, in the crystal lattice sense, and different from the solid rock below. In the Signal Corps' experiments, and there is pretty good scientific confirmation elsewhere, the full depth of that disturbed layer appears to be susceptible to the destructive effects of water vapor. This layer appears to be completely removable by etching and the remaining quartz to be uniform solid rock. This solid rock is our goal and we shall feel much more secure when we have reached it.

9. To repeat, to secure crystal plates which are solid and undisturbed quartz throughout we have merely to introduce a proper etching technique into their finishing. Our conviction that there are also economies in this method of finishing helps to support us in the decision to require it. The problem which we face today is no longer one of finding a way to make surfaces which are suitably permanent but rather one of working out together the manufacturing procedures which will provide the stable surface without introducing other and unforeseen elements which will interfere with performance.

10. So much for the permanence of the quartz plate. With progress in clearing up difficulties in one place it is perhaps natural to find new ones showing up elsewhere. In the present instance frequency instability of the crystal unit is not all resultant from disintegration of the crystal surface. An equally serious cause of frequency and activity changes is also the loading of the surface with foreign material. Here the principal offender is the phenolic holder as commonly used. These phenolics have the property of absorbing water under conditions of high humidity and then at a later time, perhaps at a higher temperature, giving this up again. The water absorbed from without the holder is released within to condense on the quartz plate, causing loading as well

Survey of Problem of Stability of Quartz Crystal Units (Continued)

as the surface disintegration effects just discussed. Plated units of the wire mounted type, which do not have pressure electrodes to shield them, are particularly susceptible to this loading. The corrosive action of vapors which are released by phenolics, including ammonia among others, is particularly effective both in causing loading and in completely disintegrating the internal connections. Our experience with phenolic holders and the extreme sensitiveness of crystals to surface effects leads me to the belief that until crystal holders are made of other than phenolic materials, and are hermetically sealed as well, we shall always have cause for concern about frequency stability when temperature and humidity conditions change over extreme ranges, and that we shall not be justified in counting on long life for our crystal units.

11. Dr. Van Dyke concluded with a brief blackboard discussion of differences now existing between individual crystals made in the same lot and all satisfying the same formal specification, and showed how differences in the active piezoelectric capacitance could cause crystals which are adjusted for identity of frequency in one set to develop appreciably different frequencies in another. The crystal unit in the using circuit is called upon to develop a high impedance. In order that the oscillation may be sustained the piezoelectric part of the reaction of the crystal must be in parallel resonance with the dielectric part, the latter supplemented by circuit capacitances. The frequency of oscillation is automatically that at which this parallel resonance obtains. When crystals producing different piezoelectric reactances are placed within a standard holder of fixed dielectric capacitance, the frequencies at which parallel resonance, and therefore oscillation, occur are different. At least five-fold variation in the piezoelectric reaction is found among crystals of the same general size, shape and cut as they are being produced in our plants. This variation is controllable only by so adjusting the fine detailed dimensions of the crystals that each has the same vibration pattern. The aim is to have all parts of the crystal cooperating in the vibration for maximum activity, or maximum piezoelectric reaction. Where the piezoelectric response differs greatly from one plate to another these crystals, although giving identical oscillation frequencies in, say, a standard test circuit, would give considerably different frequencies in another circuit. The problem becomes particularly serious when manufacturing tolerances for a radio set permit sizable variation of capacitance across the crystal. This is an illustration of instability of the more general type; such crystals have an almost unpredictable scatter of frequency in military equipment.

STUDIES OF THE DETERIORATION OF QUARTZ CRYSTAL UNITS
WITH SPECIAL REFERENCE TO THE EFFECTS OF TEMPERATURE AND
HUMIDITY ON THE QUARTZ PLATE AND HOLDER - TECHNIQUES
FOR FABRICATING STABLE CRYSTAL UNITS

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Summary: A study of the aging of quartz crystal units, extending over a period of more than six months has been carried on at CCSL. Most of the factors involved in the deterioration of quartz crystal units have been isolated and investigated. The principal cause of aging is deterioration of the surface of the quartz plate. Data is presented to show that this is largely eliminated by etching. Various pre-aging techniques have been investigated and found to be of very little value.

The effect of the holder has been studied. Loading of the crystal plate by materials emitted by the holders has been found to contribute to the aging of crystal units. Corrosion of the metal parts of the holder by the by-products from the phenolic causes many failures. Both effects are reduced by re-curing the holders.

Some notes on adjusting the frequency of oscillator plates by etching are added.

Introduction: It has been recognized for several years that high frequency quartz crystal units undergo spontaneous changes of frequency and activity with time. This phenomenon is called aging. Nearly every amateur radio operator has at one time or another found it necessary to "clean" his 40 meter crystal in order to get it to operate. This is typical of crystal aging.

Until the war, no large quantity of high frequency crystals had ever been produced. However, since 1941 large numbers of high frequency crystals have been made for military purposes. Most of these were satisfactory when originally tested but after a few weeks or months in storage, a very large proportion were found to have deteriorated to the point where they were unusable. This led to an intensive study on the part of the Signal Corps, with the cooperation of many manufacturers, to determine the cause of and the remedy for aging.

The most obvious result of aging is a decrease in the activity of the unit. Usually after a period of storage it is found that the Q of a crystal has decreased. It can be shown from the theory of the equivalent network for a crystal (Fig. a) that a necessary condition for oscillation is

$$\text{that } Q > 2 C_0/C$$

where $Q = \omega L/R$ and C_0 is the parallel capacitance across the crystal.

Studies of the Deterioration of Quartz Crystal Units (Continued)

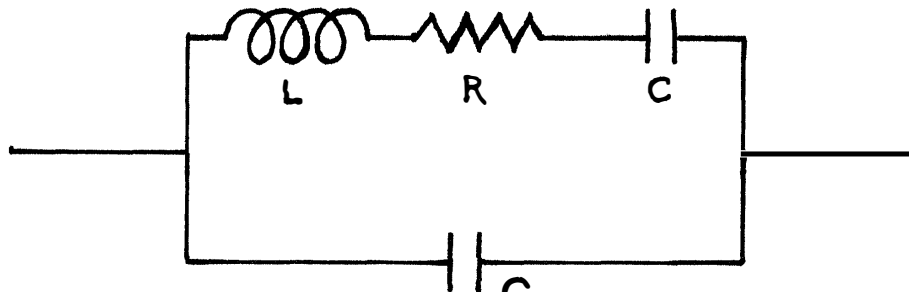


Figure a.

The effect of aging is to cause a decrease in the value of Q . When the Q of the crystal falls below the limiting value set by this relationship the crystal can not oscillate or is "dead." Obviously the larger the parallel capacitance C_o the higher is the Q required of the crystal.

This explains why a much higher rate of failures was experienced among DC-11, DC-16 and DC-26 crystal units than among the FT-243's. The capacitance in parallel with the crystal in the SCR-522 is 32 mmfds while in the BC-659 and BC-620 it is 15 or 20 mmfds. Many crystals will operate in the latter sets even when "dead" in the former.

Nearly every crystal which has failed because of aging can be restored to normal activity by cleaning but the result is invariably an increase in frequency. This increase is usually much greater than the tolerance and the crystal unit is therefore useless. If the dead crystal is observed at grazing incidence a white dust or powder can be seen on the surface. It can be made more apparent by marking in the dust with the corner of a card or the finger nail. Dissipation of energy by these loosely held particles causes the Q of the crystal to be lowered. When the dust is removed the Q of the crystal returns to normal but the frequency is increased.

In checking depot stocks it was found that crystal units made by different manufacturers varied in the proportion of failures. A study of manufacturing processes was made to try to isolate the causes of the failures but the results were not satisfactory. The processes in use were so variable that it was not possible to determine the factors which caused the differences in the proportion of reject units.

Aging phenomena are not limited to quartz crystals. Many foods are aged to improve the quality. Here the changes are probably chemical often produced by the action of bacteria. Rubber and photographic films are susceptible to aging. Aging in the former is greatly accelerated by ultra-violet light while in the latter it is due to radiation from radioactive elements and cosmic rays. Since slow physical and chemical changes are constantly taking place in most things, aging is the rule in nature rather than the exception.

It was formerly believed that crystalline silicon dioxide was perfectly stable. Quartz is almost inert chemically; reacting only with a few chemicals and then only very slowly. Its solubility in water is

Studies of the Deterioration of Quartz Crystal Units (Continued)

extremely low. But it is now known that the surface of the quartz plate is not stable and that under some conditions, a sort of weathering takes place. While the amount of quartz which is affected is exceedingly small, the delicacy with which measurements of frequency can be made permit these changes to be observed with great accuracy. The frequency of crystals in the 6 - 9 mc/sec ranges is exceedingly critical with respect to thickness. If it were possible to remove one layer of atoms from an 8 mc/sec BT plate it would raise its frequency by about 10 cycles and this is easily measurable. To increase the frequency of the same plate by 1 kc/sec it is required to reduce its thickness by only .04 microns or .0000016 inches which is less than 1/10 of the wave length of visible light.

1. Aging in high frequency crystals.

Aging is most serious at high frequencies where the crystals are quite thin. From the laws of standing waves we have

$$f = K/t$$

Where f is the frequency and t is the thickness.

$$df/dt = -K/t^2$$

For a BT crystal $K = 2.54 \times 10^{15}$ cm sec⁻¹

and at 8 mc/sec

$$t = .0318 \text{ cm}$$

hence $df/dt = -2.54 \times 10^{15} / (.0318)^2 = -2.5 \times 10^8$ sec⁻¹ cm⁻¹

or 2.5 cycles/sec per Å unit change in thickness. (The minus sign means that the frequency increases as the thickness decreases.) Hence to change the frequency of an 8 mc/sec crystal, 1 kc/sec, it is necessary to reduce its thickness by 400 Å or about .1 the wave length of visible light. Since 10,000 Å equals one micron, it follows that a decrease of 1 micron in the thickness of an 8 mc/sec crystal produces a frequency of 25 kc/sec. The same change of thickness on a 1 mc/sec crystal produces a frequency change of less than 500 cy/sec. Fig. 1 shows the relationship between frequency and thickness for BT plates. It will be shown later that aging is caused by the deterioration of the surface of the quartz plate causing it to become, in effect, thinner.

2. Nature of the phenomenon.

A freshly lapped 8 mc/sec BT crystal ordinarily increases in frequency by 300 to 500 cycles in the first 24 hours. If a freshly lapped crystal is operated in a good oscillator and its frequency beat against a primary standard using a good interpolation oscillator and cathode ray oscilloscope for measuring the deviation, it is found that the frequency

Studies of the Deterioration of Quartz Crystal Units (Continued)

increases at the rate of several cycles per second per minute, for the first few hours. Very often the increases are not steady. The frequency of the crystal will remain constant for a few seconds or even minutes and then suddenly jump several cycles. These changes are not to be confused with those which occur as thermal equilibrium is being established which are as often negative as positive.

After the first few hours the rate of increase of frequency becomes very much less. The rate of increase is dependent upon the humidity. The higher the humidity, the greater the rate of increase. The crystal may continue to increase in frequency indefinitely or after a time the frequency may become practically constant or even decrease. After a few days the plate is covered with a fine white powder.

During this time the activity usually decreases. The rate as well as the amount of change is somewhat dependent upon the lapping procedure used but no lapping procedure has been found which produces crystals which do not deteriorate under humid conditions.

Occasionally crystals are observed in which the frequency continuously decreases. A few have been observed in which the frequency decreased at the rate of several hundred cycles per week. This was due to loading of the crystal plate by materials emitted by the phenolic of the holder and the neoprene of the gasket. It is largely prevented if the holders are soaked in hot carbon tetrachloride and then baked. High frequency plated crystals nearly always decrease in frequency when exposed to elevated temperature and humidity. It is impossible to separate the aging of the quartz from the effects of the holder when the crystals are mounted in phenolic holders. To circumvent these difficulties crystal plates have been subjected to various conditions independent of any phenolic holder.

In a group of crystals which have been subjected to identical treatment, a wide variation of behavior is usually observed. The frequency of a high frequency shear type crystal plate does not change in a strictly uniform manner as its thickness is changed. There is a "fine structure" due to the coupled modes and their effect on the main mode. Even though two crystals have the same frequency, it does not follow that the removal of the same small amount of quartz from each will result in the same frequency change. With respect to activity the differences are even more marked. In rare instances, the removal of a very small amount of quartz from the surface of a crystal has been observed to cause the frequency to decrease.

The activity of a crystal unit may increase with time or it may decrease. The frequency likewise may either increase or decrease. Sometimes the loading from the holder almost balances the loss of quartz by aging. All these inter-related and complicated effects make the interpretation of aging data quite difficult. A statistical study is almost always required.

Studies of the Deterioration of Quartz Crystal Units (Continued)

3. Effect of water vapor.

The exact mechanism by which the surface deterioration takes place is not known. However, water vapor plays a very important part. Crystals sealed in glass holders show no tendency to change frequency even when sealed in immediately following lapping. Quartz plates stored in test tubes over silica gel do not become covered with the white dust which is characteristic of crystal aging. On the other hand, crystal plates in phenolic holders show the effects of water vapor within a few hours after being exposed to a warm humid atmosphere. Control groups maintained at the same temperature but at low humidity are not affected.

Freshly lapped plates held at high humidity exhibit the characteristic dust within a few days.

There is no doubt that water vapor plays an important part in the aging of lapped crystal plates.

4. The disoriented layer.

It has been known for many years that lapped surfaces of crystals are covered with a layer in which the atomic planes are disoriented with respect to the body of the crystal. Davison of Bell Telephone Laboratories has shown that quartz is no exception to this. The presence of this misaligned material can be shown by relatively simple experiments. A lapped plate is placed in a beam of monochromatic x-rays so that reflection is obtained at the Bragg angle. A photographic film is placed at the proper place to receive the diffracted beam. Leaving the film and the collimating slits unmoved, the crystal is turned a few degrees away from this position. The crystal continues to reflect the beam at the Bragg angle. The only explanation for this is that there must exist on the surface of the crystal, blocks of quartz of considerable size in which the atomic planes are not parallel to those in the main body of the quartz. Some of these blocks are turned away from the main body of the quartz by as much as 5 degrees. The misaligned material may be removed by etching. When the crystal has been etched sufficiently to remove a layer $1/4$ to $1/2$ micron* thick x-ray evidence of misaligned material largely disappears. Figure 2 is an x-ray diffraction photograph showing the evidence for the misaligned material.

Evidence for the instability of the misaligned material is found in the very high initial rate at which it is attacked by reagents used for etching. Fig 3 shows the characteristic change of frequency of a

*It must be emphasized that these measurements are made by observing the frequency change and computing the corresponding change of thickness assuming ideal plane surfaces. Since the irregularities in the surface following lapping are of the same order of magnitude as the calculated change of thickness, it is not possible to speak of a layer of such a thickness except by definition.

Studies of the Deterioration of Quartz Crystal Units (Continued)

crystal plate with time as a result of etching. The rate becomes constant after the frequency has been increased by approximately*15 kc/sec. This corresponds to the removal of a layer of quartz to an AVERAGE depth of some .3 micron* from each surface of the crystal.

5. Scrubbing of Crystal Units:

Some changes of frequency and activity of crystal units have in the past been due to the presence of foreign material on the surface of the crystal at the time of assembly. Aging, however, is inherent in the nature of abraded surfaces, and the effects of foreign materials is secondary.

After a lapped crystal plate has been thoroughly cleaned by the use of water followed by some solvent such as carbon tetrachloride, it is still possible to increase its frequency from 1 to 3 kc/sec by scrubbing it with soap and a toothbrush. If this scrubbing is done under carefully controlled conditions, it is found that the rate of removal of quartz by the brush is not uniform. The rate of removal is very great at first and soon reaches the point where the rate is very small. It was formerly believed that the removal of this loosely bound surface material would prevent subsequent aging but such is not the case. Scrubbing largely eliminates the very rapid initial aging but has little effect upon the long term aging of the crystal in the presence of water vapor.

Crystals which have been thoroughly scrubbed are, after a month at moderately high humidity, covered with quartz dust. When this dust is removed the frequency of the crystal rises again. The process can be repeated a number of times with the same crystal.

The rise of frequency resulting from each cleaning operation becomes less and it appears that the crystal plate would ultimately reach a frequency at which it would remain stable.

Many crystals which have been scrubbed at the time of manufacture have been rescrubbed after a period of shelf life and in every case, the frequency of lapped crystals increased far out of tolerance. The presence of quartz dust also indicates that the surfaces of these crystals have deteriorated.

On the other hand crystals which have been etched sufficiently to remove all x-ray evidence of the misaligned surface layer never exhibit

*It must be emphasized that these measurements are made by observing the frequency change and computing the correspondence change of thickness assuming ideal plane surfaces. Since the irregularities in the surface following lapping are of the same order of magnitude as the calculated change of thickness, it is not possible to speak of a layer of such a thickness except by definition.

Studies of the Deterioration of Quartz Crystal Units (Continued)

the quartz dust on the surface nor can their frequencies be changed appreciably by scrubbing after long periods of shelf life or artificial aging at high humidity and temperature.

6. Pre-aging Techniques.

A number of methods for pre-aging crystals have been tried. In Great Britain boiling the crystal in sulphuric acid has been favored as a pre-aging technique. In this country the one most favored has been to bake the crystal at a temperature close to the curie point for several hours. Neither methods has much value. It may be stated as axiomatic that the value of any pre-aging technique is in proportion to the change of frequency which it produces in the crystal. Unless the potentially loosened quartz is removed no pre-aging technique has any value. If scrubbing be considered as pre-aging it is undoubtedly the best pre-aging technique known. One fault with pre-aging is that, if effective, it produces unpredictable changes of frequency and therefore precludes close adjustment of frequency.

7. Effect of lapping procedure.

No lapping procedure has been found by which stable crystals can be finished, but it is possible to vary the nature of the aging phenomenon by the lapping procedures. For example, crystals finished with a fairly coarse abrasive such as 600 mesh silicon carbide do not change frequency as rapidly as those lapped with optical finishing powder. But they lose activity much faster. On the other hand crystals lapped with a very fine abrasive increase in frequency more rapidly but do not decrease in activity so much. There are slight differences in the behavior of crystals lapped with silicon carbide and aluminum oxide abrasives of the same mesh size but these differences are extremely difficult to isolate because of the numerous other variables. The weight and material of the lapping plates have slight effects but again the variables are so numerous that to isolate a single factor is very difficult. There is no evidence that the speed of lapping has any effect on the aging characteristics.

Oil used as vehicle for the abrasive results in a grinding speed approximately double that obtained with water or soap and water. For this reason and others, most manufacturers prefer oil as a vehicle for lapping. There is no significant difference in the behavior of crystals lapped with any of these vehicles. A number of other specialized materials have been used and no differences have been observed in the aging characteristic of the crystals. From the result of these experiments it is believed that the aging of quartz crystals is inherent in lapped surfaces and it is highly improbable that any lapping procedure can be found which will produce crystals which will not age seriously.

It was once believed that microscopic cracks produced in the sawing operation might be responsible for aging but such is not the case, at least for the sawing procedures in use in the industry. Aging of the

Studies of the Deterioration of Quartz Crystal Units (Continued)

crystal plate can be prevented by etching away the material disturbed in lapping but if the etched surface is lapped, even with the very lightest of pressure, the misaligned layer reappears and the crystal ages just as before. A group of thirty-five BT plates lapped to 8.4 mc/sec with 125 aloxite were then etched 100 kc/sec with ammonium fluoride. Five of the crystals were retained as controls and the remainder divided into 6 groups of 5 crystals each which were then lapped by various procedures. The crystals were all thoroughly scrubbed with soap and toothbrush, rinsed in boiling distilled water, air dried and mounted in FT-243 holders. They were artificially aged for a period of one month at a temperature of 50°C and a relative humidity of 75%. They were then opened and rescrubbed exactly as before. The results are summarized in the following table.

- Group 1. Controls - not lapped.
- Group 2. Lapped 10 kc/sec with aloxite 125 on glass by hand using water.
- Group 3. Lapped 10 kc/sec with aloxite 125 on metal by hand
 kc/
 kc/sec with aloxite
 lap using soap
 kc/sec with aloxite 50 on glass by hand using
- Group 7. Lapped 10 kc/sec with aloxite 50 on metal by hand using water.

Group	Original Ave. Act.	After 30 Days		Ave. of.	Ave. of.
		Ave. Act.	Ave. of. (c.p.s.)		
1		.51	-24	51	
2		.27	72804		74480
3		.34	1662		73059
4		.30	1985		73104
5		.32	1873		73064
6				46	72897
7		.32	1210		72760

6 and 7 w
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crystals, except
 limits permitted by current specifications.

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experiments have been made with
 show the presence of misaligned quartz
 that they are susceptibe to aging.

Studies of the Deterioration of Quartz Crystal Units (Continued)

8. Theory of aging.

No adequate explanation of the deterioration of the surface of a quartz plate has been advanced. The facts are that all lapped quartz surfaces deteriorate when subjected to moisture. Every lapped quartz surface, even when highly polished is covered with a layer of misaligned quartz extending to an average depth of $\frac{1}{4}$ to $\frac{1}{2}$ micron.* This layer can be removed by etching after which the crystal is practically immune to aging. There can be little doubt that the misaligned material is associated in some way with the quartz which ultimately weathers from the surface. This could be a simple physical process due to progressive cracks in the quartz or to thermal shocks. That water plays an important part in the aging process is certain but the mechanism by which the quartz is loosened is not known at present. Perhaps some chemical reaction between the finely divided quartz on the surface and the carbon dioxide of the air or the ammonia or phenol from the holder is responsible.

It is well known that silica in finely divided form reacts quite readily with water at elevated temperature. It seems not unreasonable to expect that the reaction might also take place at a much slower rate at lower temperatures. It is possible that the reaction of water with the quartz in the sub-microscopic cracks in the surface results in swelling which causes pieces to break off. The particles of the powder range in size from one to ten microns and are quite clearly fragments of quartz. This hypothesis will also explain why aging is prevented by etching. The acid attacks the finely divided quartz and rapidly reduces the surface area. At the same time the acid tends to reduce the surface to a series of natural atomic planes. It has been shown by Joffe that a crystal of sodium chloride is much stronger if it is etched by water than if merely cleaved. This suggests that a surface formed under conditions approaching equilibrium such as obtained during etching is much more stable than one which is fractured.

However, further study is needed to explain the mechanism of aging and a complete understanding of the phenomenon will require considerable research.

9. Remedy for aging.

Since aging is dependent on water vapor, the most obvious solution to the aging problem is to eliminate all moisture. Crystals sealed in glass tubes have changed very little in frequency or activity over long periods of time. By sealing pressure mounted crystals in glass tubes it has been found that there is no difference in the behavior of lapped and etched crystals when water is completely eliminated. However, it is not possible to eliminate this factor in phenolic holders. Phenolics used for crystal holders are highly transparent to water vapor and the humidity inside the holder is never far from the humidity outside. Thus, if phenolic holders are to be used, the only alternative is to remove the layer of material responsible for the aging and this must be done by etching.

*See footnote to paragraph 4.

Studies of the Deterioration of Quartz Crystal Units (Continued)

Controlled experiments with etched crystals show very clearly that the surfaces of etched crystals do not disintegrate under the influence of water vapor. Many groups of crystals have been prepared by known techniques and observed under various conditions over considerable periods of time. A few of these are listed in Table II.

The results on the higher frequency crystals are especially significant. It is almost impossible to finish crystals by abrasion in the frequency ranges above 11 mc/sec and keep them active for more than a few days when exposed to water vapor. Yet etched crystals above 12 mc/sec have been kept at moderate humidities for more than 3 months without serious deterioration. These results were obtained using holders which were recured by soaking in hot carbon tetrachloride followed by baking at 160°C for at least one hour. If this precaution is not taken, the crystals decrease in activity and frequency due to loading from the holder. It is believed that most of the changes of frequency and activity of etched crystals are due to this effect. The powdered quartz which invariably accompanies aging of lapped crystals is never found on the surfaces of crystal plates which have been etched by the amounts indicated in Fig. 4 or more. Where controls are indicated in Table II the crystals were given identical treatment except that hand finishing was substituted for etching to frequency.

TABLE II

<u>Nom. Freq.</u> kc/sec	<u>No. of Units</u>	<u>Lapped With</u>	<u>Etched</u> kc/sec	<u>Stored</u>	<u>Time</u> (days)	<u>Change Freq.</u> (c.p.s.)	<u>Average Change Activity</u>	<u>Controls</u>
U 10,870	7	95 aloxite	25	75%RH 50°C	95	-46	-2%	±8158 cps -25%
V 11,160	5	125 aloxite	25	75%RH 50°C	90	±65	-3%	all dead
Q 10,230	4	50 aloxite	20	75%RH 50°C	103	±66	-2%	none
A 8,880	9	125 aloxite	50	75%RH 50°C	80	±129	-3%	none
C 8,390	5	125 aloxite	100	75%RH 50°C	33	±45	-5%	±1 to 4 kc/sec
M 8,600	5	125 aloxite	600	Room Cond.	120	±56	-6%	none
E 8,450	10	303 $\frac{1}{2}$ Emery	30	75%RH 50°C	85	-85	0%	none
G 8,310	10	125 aloxite	5	98%RH 50°C	124	-134	-10%	none

Studies of the Deterioration of Quartz Crystal Units (Continued)

TABLE II (Contd.)

	<u>Nom. Freq.</u> kc/sec	<u>No. of Units</u>	<u>Lapped With</u>	<u>Etched</u> kc/sec	<u>Stored Time</u> (Days)	<u>Change Freq.</u>	<u>Average Change Activity</u>	<u>Controls</u>
O	9,180	6	800 SiC	15	75%RH 50°C	110	-108	0% \neq 849 -15%
A	11,500	6	125 aloxite	100	75%RH 50°C	85	\neq 517*	-10% all dead
P	9,100	5	125 aloxite	30	75%RH 50°C	105	\neq 56	-6% all dead
O	12,320	5	125 aloxite	40	75%RH 50°C	95	-202	-9% none
J	9,250	10	125 aloxite	40	75%RH 50°C	30	-136	-8% \neq 1500 cycles -40%
H	8,320	10	125 aloxite	10	75%RH 50°C	120	-150	-5% none
J	8,320	10	125 aloxite	10	75%RH 50°C	120	-135	-3% none

10. Other factors in aging.

The term aging is used to cover all changes in frequency and activity which occur with time. When aging was first recognized it was variously attributed to the holder, the electrodes, dirt, etc. The quartz plate was last to be suspected. Nevertheless, most aging is due to the lack of stability of the quartz surface.

There are, however, other factors which cause changes of frequency and activity in high frequency oscillator plates and these properly come under the term aging. The most serious of these factors is loading of the crystal by substances emitted by the phenolic holders and the neoprene gaskets. Nearly all thoroughly etched crystal plates decrease in frequency when placed in phenolic holders. Unless the holders are well cured these decreases are of the order of 50 to 500 cycles per month on crystals in the 8 mc/sec range. The crystals can be restored to their original frequencies by cleaning. This is not to be confused with the aging which results from deterioration of the surface of the quartz plate. When such crystals are rejuvenated by cleaning the frequencies are always increased.

* Includes rescrubbing twice.

Studies of the Deterioration of Quartz Crystal Units (Continued)

It has been found that loading of the crystals is reduced somewhat by baking the holders before assembly. Holding the holder and gasket at 160°C for one hour has been found to be fairly effective although a lower temperature for a longer period of time might be equally good or better.

Another factor which contributes to aging is the variation of the electrical characteristics of the holder with humidity. The electrical resistance between the pins varies by a factor of 10⁴ in holders made of wood filler phenolformaldehyde plastics of the type almost universally used for crystal units.

The activity of a crystal unit can often be increased by 10% by baking the holder prior to assembly. A number of manufacturers have found that their proportion of crystals rejected in the temperature tests is lowered very considerably by recurring of the holders.

During humidity tests the activity of the crystal unit decreases because of the electrical losses in the holder associated with the absorption of moisture.

Serious corrosion of the internal metal parts of crystal units often occurs. While the corrosion is much greater at higher temperatures and humidities, some units fail under ordinary room conditions for this reason. A number of corrosive substances are emitted by phenolics. Among these are ammonia, urea, phenol and sulphur dioxide. The corrosion results in instability due to poor electrical contact. Complete failure may follow because of flakes of corrosion which find their way between the electrodes and crystal plate. In extreme cases complete failure may result from breakage of the contact plates or springs.

A phenomenon known as "corrosion fatigue" or "season cracking" results from the action of ammonia on brass. The ammonia liberated from the phenolic attacks the brass at points of stress and very rapidly causes the contact plates to break. The reaction is accelerated by increasing the temperature and humidity. At a temperature of 50°C and a relative humidity of 75% approximately half of the FT-243 holders with brass contact plates fail within a period of one month. Brass contact plates should never be used in phenolic holders.

There are several other factors which cause variations of activity and frequency. When successive measurements are made at different temperatures variations are observed in the activity and frequency. These conditions are due to the change of temperature and do not represent a permanent change in the crystal. However, when a crystal unit has been carried to an extreme of temperature, it usually does not return to the same activity or frequency when returned to room temperature. These effects are due to changes in the amount of moisture and its position within the holder. There is good reason to believe that there is a layer of water on the surface of every crystal. This serves to load and thereby affect its frequency. The amount of water on the crystal is affected somewhat by its recent history and causes the frequency of the

Studies of the Deterioration of Quartz Crystal Units (Continued)

crystal to exhibit a sort of hysteresis affect as the temperature is changed. While this cannot be classed as aging, it does make the interpretation of aging data somewhat difficult.

The electrodes have often been suspected of contributing to the aging problem but except for corrosion, no evidence exists at present which would indicate that such is the case.

Conclusion: The aging of crystal units is very troublesome, especially in the higher frequencies. The principle factor is the deterioration of the surface of the quartz plate. This can be largely overcome by etching. Most of the other factors are associated with the phenolic holder. To obtain a crystal unit with the best stability it will be necessary to mount an etched blank in a glass or metal holder, hermetically sealed and free from any phenolic parts whatsoever.

Notes on etching: Crystals should be etched to frequency by at least the amount shown in Fig. 4. This should preferably be done by a mass etch technique to insure that every plate is etched by the minimum amount. Adjustment to frequency by further etching should follow this.

Crystals sometimes lose activity when etched by these amounts. Two factors are involved in this case. The activity of a crystal at a given frequency depends critically upon its dimensions. If the crystal has good activity and its frequency is changed by etching or grinding, it may be necessary to change the edge dimensions also to have good activity again. Conversely if the crystal plate has poor activity at the original frequency and dimensions, it may have good activity at the new frequency. Obviously, etching does not affect the edge dimensions of the crystal appreciably.

However, if the surfaces of the crystal have been harshly treated, the crystal loses activity when etched. Scratches and irregularities in the surface are attacked by the etchant more rapidly than the remainder of the crystal and cause it to become pitted. This always results in lowered activity. The edges of the crystal must be smooth before etching or serious loss of activity occurs. If the surface of the crystal is properly prepared it may be etched by 4 times the amount shown in Fig. 4 without appreciable changes in activity except for those associated with dimensional relationships. (See Table II)

After a crystal has been etched, its frequency can be increased several hundred cycles/sec by scrubbing it with soap. In the etching process, several fluoro-silicates are produced. Some of these are only slightly soluble in cold water. These are deposited upon the crystal and can be removed only with some difficulty.

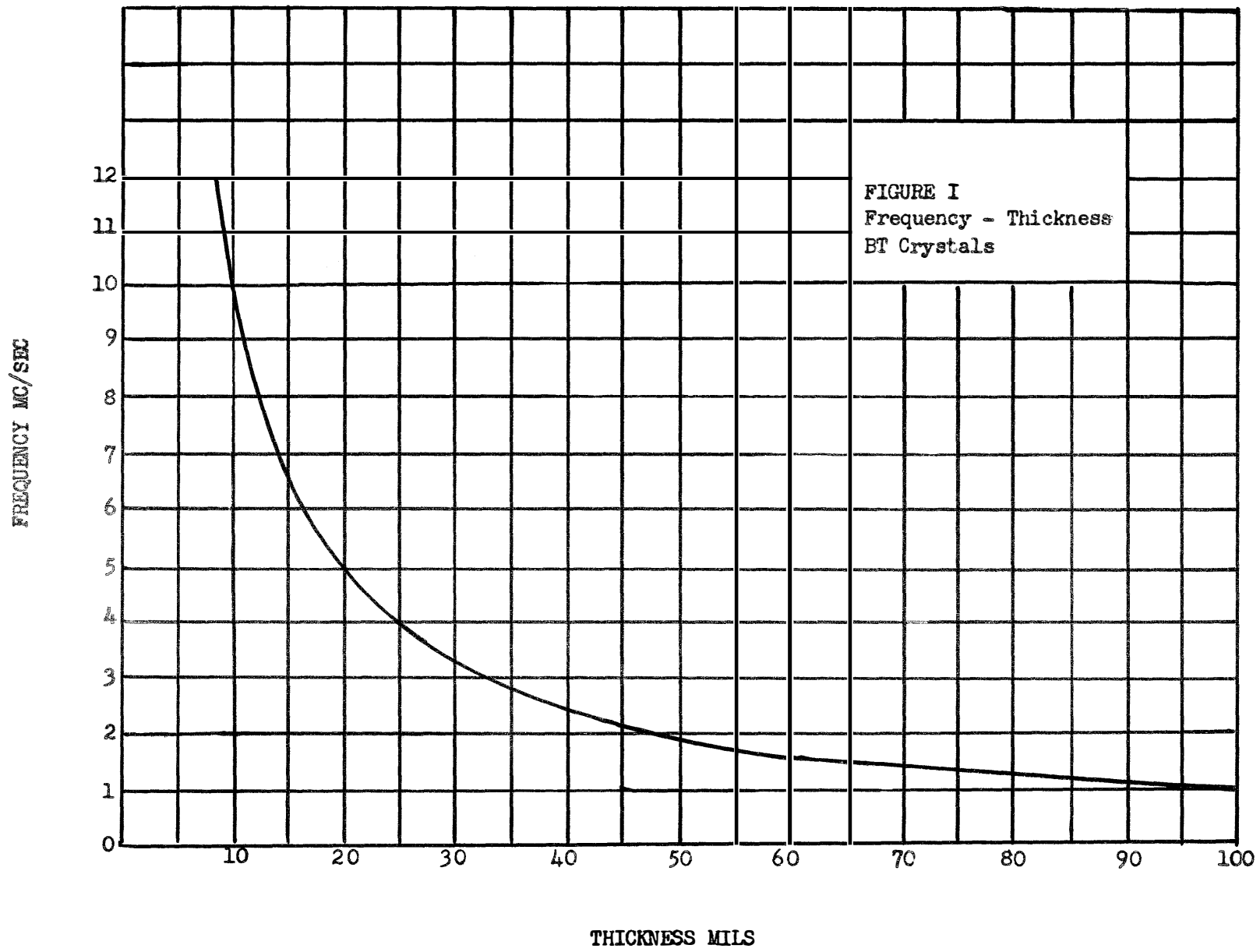
One method of cleaning the crystal after etching is to scrub it thoroughly with soap and a toothbrush followed by a thorough rinsing in boiling distilled water. A mechanical process whereby the crystal plate is sprayed with boiling water is also being successfully used.

Studies of the Deterioration of Quartz Crystal Units (Continued)

When a crystal plate has been properly lapped, etched by a sufficient amount and thoroughly cleaned, it is not possible to change its frequency by further cleaning, even after many months at high humidity. This is the final test for the effectiveness of any technique for preventing aging.

It is not necessary or desirable to use sodium bicarbonate as a neutralizer following etching with the ammonium-di-fluoride compounds. These compounds are more easily dissolved in water than is sodium bicarbonate. The crystal should be thoroughly rinsed, preferably in running water when being tested and should be given the final wash in boiling distilled water before assembly. After cleaning it should not be touched with the fingers.

Copper is the best metal for making etching machines. For individual positions, a small dish dipped in hot wax or paraffin to protect the glass or enamel may be used. Although ammonium-di-fluoride compounds are relatively safe the operator should never put his hands into the solution and good ventilation should be provided. A quantity of soda or lime water should be on hand for use in case of emergency. The hands should be thoroughly washed with plenty of soap and water after work and before eating. Cleanliness is very important.



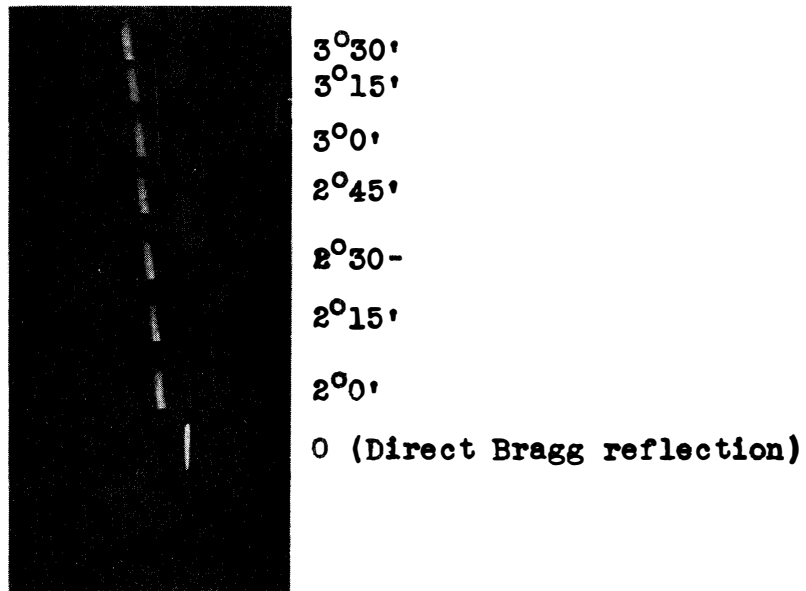


FIGURE 2.

The disoriented layer on the surface of a BT quartz plate lapped with 600 SiC. The persistent line is due to reflection of the copper $K\alpha$ line from the surface when the blank is turned from the Bragg angle by the angle indicated. The broad line at the left is due to background radiation.

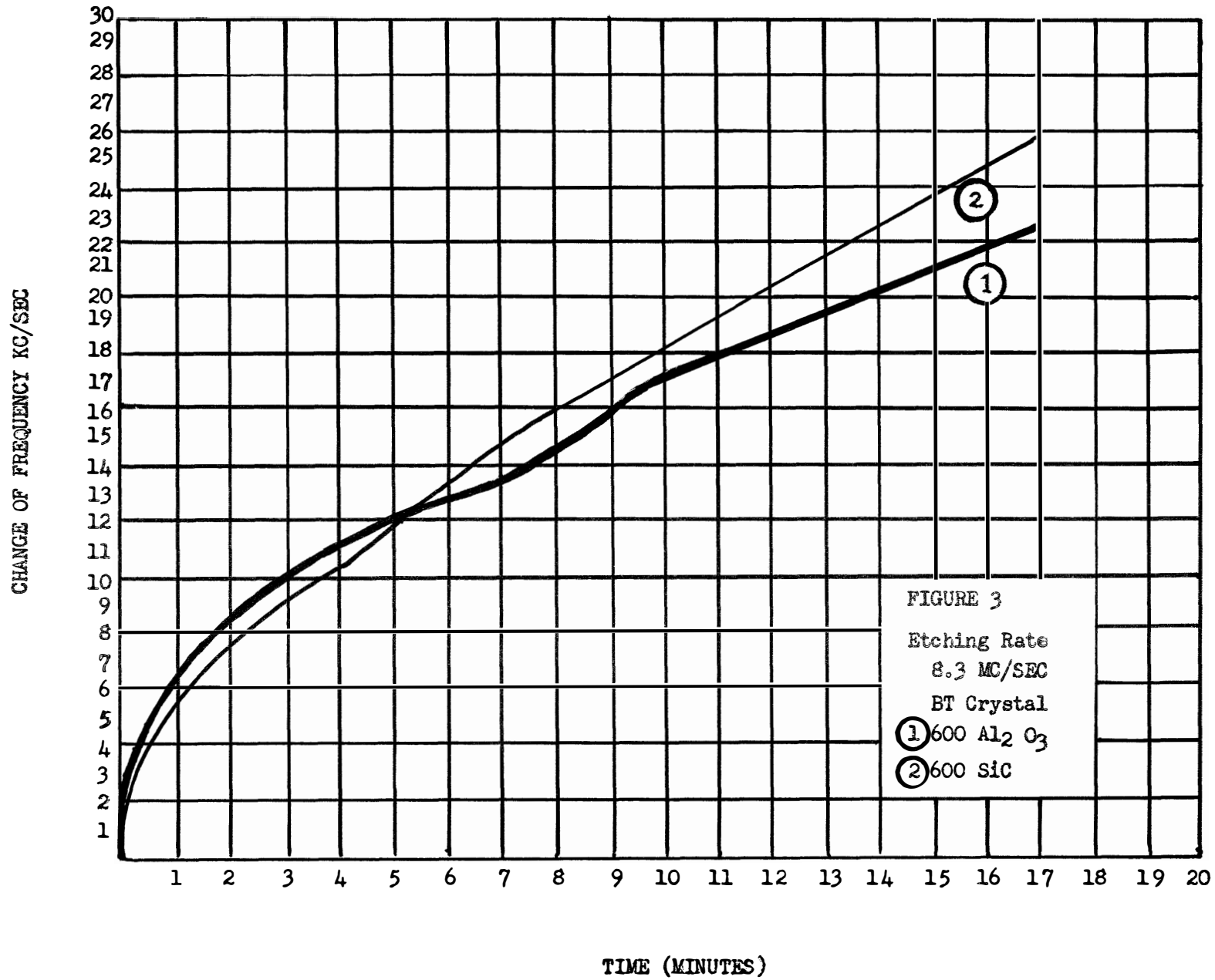
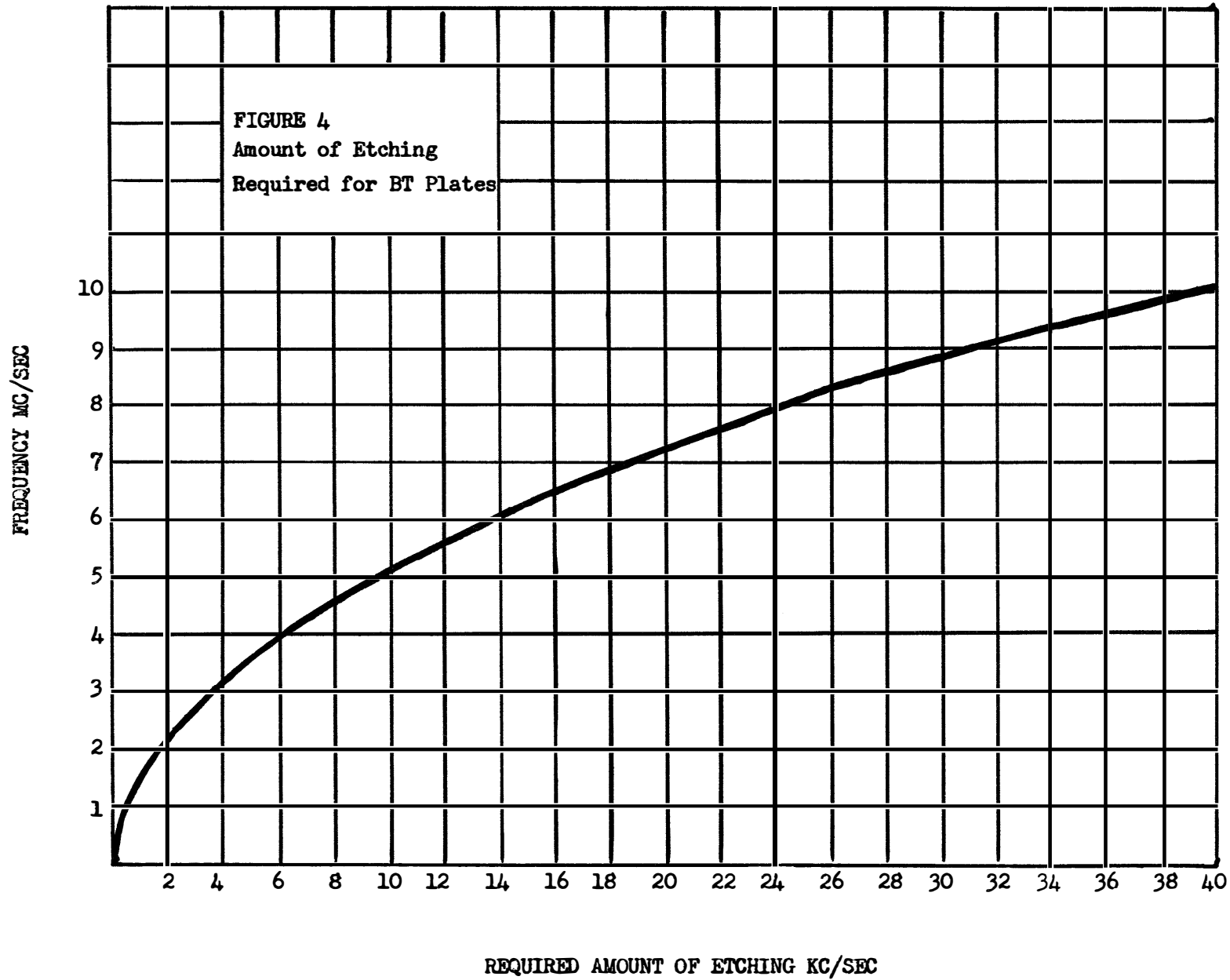


FIGURE 4
Amount of Etching
Required for BT Plates



30m

MILLING AS PREPARATION FOR ETCHING

Mr. Frank M. Lund

Precise Developments Company

1. I don't want to talk about milling as a frequency device but only as pre-etching procedure as used in our plant.

2. First, we didn't have good luck with it. I won't go as far as to say the abrasives suggested at the time were not practicable as there was a great deal of trouble with changing these particular units. That is still one principle objection to milling.

3. We have made perhaps a 150,000 crystals that were milled. Our prime original motive was the fact that ever since we have been manufacturing crystals we have been plagued with chips on edges of crystals which required a great deal of inspection and hand labor to eliminate them. When they got over to the finishers they were using an abrasive process for finishing. If there were any tiny chips which our inspectors passed, the finishers spotted them and then sent them back. We started to use milling as a means of eliminating these chips. It did such an excellent job I hope we never have to throw it out. We got into this etching process early. One of the biggest difficulties in etching was the instability of time. There was no determinable means of predicting how much quartz it would remove from the crystal in the first few minutes of operation. We built a machine and of course that was designed strictly on the basis of time. We had to place a crystal in it so that it would ride down tracks certain lengths of time, stay in acid certain lengths of time and come out a proper frequency. It wouldn't do that with any lap process we were able to devise. So we thought about pre-etching of all of these crystals before putting them into the track. This proved to be a tedious process. About the same time we swung into milling. This process completely stabilized the timing in the etching procedure. The variations between different crystals were so small that they could be ignored. Also the method of lapping did not affect the timing as long as the crystals were processed in the milling machine.

4. Crystals that have been placed into the etch immediately after lapping do not have finished surfaces that are as free from crevices as those crystals that have been subjected to the milling process before etching.

5. The milling process is not adequate as a frequency finishing process because the crystals come out of the milling machine with their surfaces concave. Inasmuch as the lapping process is furnishing crystals that are very flat and parallel it has been necessary to remove the high corners that are evident after the milling process. This is accomplished by machine lapping the crystal for approximately 8 minutes in garnet. This procedure enables us to remove the high corners without affecting the rest of the surface. Garnet is the only soft abrasive that we have been able to use successfully. Crystals that have been through these two processes are easier to control in the etching process.

Milling as Preparation for Etching (Continued)

6. The main purposes of milling are: To remove chips and incidental scratches and to stabilize the surfaces of the crystal. These two big factors are satisfactorily achieved in the milling process.

7. We have not had much trouble in loss of activity of crystals during the etch process since we have started using the milling process.

8. Recognizing the limitations of milling and using it only as a conditioning process we have found it to be one of the best processes we have installed in our plant.

A MECHANICAL MEANS OF ETCHING

Mr. L. A. Faber

Stanley Knight Corporation

1. I am glad to have this opportunity to tell you about a simple, but efficient etching machine, and I hope you understand that I am not even suggesting that any of you adopt the system that I am going to describe. We have been using this machine for several months and it does work. It can be, and will be, improved, but at least it is a start in the right direction. We are finishing all of our production by machine, except the very final step, which is still done at a finishing position by hand. We have been unable to succeed in washing crystals clean enough by machine at the mounting positions. If the problem of washing can be solved and done automatically at the etching machine or in a succeeding stage, I am sure that crystals could be finished ready to put in the casing without having to go to an operator for final adjustment.

2. We are attempting to pre-dimension crystals in production and have succeeded quite well, so that when a crystal comes from the etching machine and is given to the finisher she is not permitted to touch the edges, and if the activity is low the crystal is sent to another department to check dimensions, and for other imperfections. If the dimensions are incorrect they are corrected, and sent back to the operator for final adjustment of frequency.

3. We have improved our system throughout, the same as have all other manufacturers. I think in most cases etching is proving practical, after the first few difficulties are overcome. Etching will not cure all troubles, and it must be remembered that the crystal must be given careful and correct treatment prior to etching to frequency in order to give performance as a finished product.

4. I think it can be said, in general, that the crystal industry knows very little about crystal finishing, and I think in a matter of a year or two we will look back at our present methods and wonder how we succeeded in doing as well as we do. To give you a brief outline of our complete procedure is in order, because the treatment of the quartz prior to etching is important. I realize our "neck will be way out" to use the vernacular, when I get through, and I want to say right now we do not recommend the following procedure to anyone, although we are using it, and our results at the present time are the best we have been able to attain. This is our procedure:

a. Wafers are cut .020" thicker than our lowest frequency requires, angles are held to within 15' on Z. 30' on X and AT within 20'. This may sound loose to many of you, but in actual practice we hold the angles closer than mentioned above. We X-Ray about 100 blanks out of each 2000 after they are lapped and 80% of them are within 15' on all angles. The wafers are cleaned and etched with Quartz-Etch, inspected for twinning, and the "X" line is put on by X-Ray.

b. After the blanks are diced they are lapped with No. 500 abrasive to pre-determined thickness, at least .002" thicker than the

A Mechanical Means of Etching (Continued)

lowest frequency we make. At this stage all blanks are etched and inspected, then they are sent to a squaring position where they are squared to pre-determined size, depending on what frequency we expect to finish. From this position they are sent to a tumbling mill and are tumbled from 10 to 24 hours using garnet and No. 400 abrasive and water mix to round the corners and remove the sharp edges and small chips. They are then sent to a radio lapping position which, by the use of abrasive of the aluminum oxide type #800 grit and finer, they are lapped to within 20 to 100 kilocycles of finished frequency. After the radio lapping operation has been performed they are washed for about 3 to 5 minutes in etching solution and then given to the department which calibrates them into frequency groups. These groups are given to the intermediate etching position which, by using our etching machines, finishes them to within 5 kilocycles, or closer, of finished frequency. The crystals are then sent to the finishing positions and, in many cases, can be mounted directly in the holders, after they are washed. The finishers are not permitted to edge grind crystals at the finishing position in order to obtain activity, consequently when they find a crystal that, as it comes into exact frequency, loses activity, that particular crystal is laid aside, and later sent to a dimension checking department which inspects and corrects the dimensions for maximum activity before it is returned to the finishing line. Each of our finishers have individual small etching tanks in which they may adjust the frequency slightly, if necessary. All of our crystals, of course, are scrubbed with soap and water, rinsed with hot water from the tap, and then rinsed with distilled water before they are put in the holders.

5. I have pictures of the machine that we use in our production. A variable speed turntable, 4-ft. in diameter, rotates with its edge over a circular tank. There are hooks at the edge of the turntable on which hangers to hold the crystals are placed. A track assembly, consisting of 20 individual tracks, each one 6 inches longer than the preceding one, is placed so as to completely encircle the acid tank. The hangers, with the crystals in place, are then hooked on the turntable and the lower end of the hanger is placed in the proper track and as the turntable moves the lower end of the hangers holding the crystals falls off the end of the track into the acid. Due to the varying track lengths, and variable speed turntable, the time the crystal is in the acid can be regulated. When the crystals reach the end of the acid tank they rise over a partition and then fall into the washing tank. The water in the washing tank is kept very hot by an immersion heater, and a small stream of clean hot water is allowed to run into the tank to maintain cleanliness. After the crystal is washed it climbs another barrier and goes through a heated tunnel to be dried. As the crystal comes out of the tunnel the operator removes them and checks them for frequency. If they are overshoot it is slowed down. By having the same operator check the crystals in and check them out, it is possible to control the frequency quite closely. One operator at our plant consistently does 1,000 in 8 hours.

QUESTIONS AND ANSWERS
EFFECTS OF PROPER CLEANING METHODS
MR. H. WAESCHE
ENGINEER, CRYSTAL SECTION
AIRCRAFT RADIO LABORATORY

1. Q. Will you discuss the possibility of the quartz plate being loaded by material applied from the nylon toothbrush while the plate is being scrubbed?

A. There will be no possibility of the quartz plate being loaded while it is being scrubbed with a detergent and water. However, there is a definite possibility of loading the crystal plate if the toothbrush is dry. It is also possible that a loading condition might exist in a locality having hard water due to precipitation materials formed, but none as far as actual loading from the toothbrush is concerned.

QUESTIONS AND ANSWERS
STUDIES OF THE DETERIORATION OF QUARTZ CRYSTAL UNITS
MR. V. BOTTOM
PHYSICIST, CRYSTAL BRANCH
CAMP COLES SIGNAL LABORATORY

1. Q. Why don't we have a performance specification for required amount of etching?

A. The Signal Corps tries to avoid specifying manufacturing procedures. The only performance test we have is a Laboratory test. The only two possible ways of making this sort of test are:

1. X-Ray diffraction test for presence of material.
2. The other test and the only test for aging phenomenon is to let it age.

In other words shut down crystal acceptance for two months and hold your crystal for one month and then accept them if they pass the test. So an exception had to be made and specify a definite manufacturing procedure.

2. Q. In the proposed etching procedure, why is it required that the minimum frequency change be obtained in one continuous etch?

A. I think a mass etch is a desirable thing unless per chance one could avoid this by tumbling as a prelude to etching. That I have not investigated. Take a group of crystals and etch each of them by a given amount of time under given conditions, your frequency condition will vary enormously. But if you etch all of these crystals at once by this length of time, than for a given concentration, the change of frequency is accurately proportioned to time. What we believe is the best procedure is to get rid of this uncertainty by a mass etch. Etch all crystals by amount of time to remove a given amount and adjust frequency from thereon.

Questions and Answers (Continued)

3. Q. Have you employed different etching agents?

A. Yes, we have tried all of the common hydrofluoride compounds and they are all acceptable as long as they produce good crystals.

4. Q. How about loss of activity on etching?

A. Two reasons, one is you change frequency and you must readjust dimensions to have good activity. Second; in a case where the activity of the crystal is not restored by edge grinding, it is because the crystal was poorly lapped or improperly lapped prior to etching. Rough edge is extremely sensitive to etching. The crystal will lose activity very seriously.

5. Q. Will all holders go through immersion test after baking?

A. As far as we know baking has no beneficial effects on holders except to drive out objectionable gases.

6. Q. Where does ammonia come from?

A. Phenolics are very complicated things. I don't know the chemistry of them. Try this simple experiment. Take a holder, pulverize and place in a test tube** and you will detect the odor of ammonia. Ammonia is certainly one of the by-products of the chemical reactions which take place in these holders.

7. Q. Does etching make the plate more susceptible to fracture?

A. It has been proved that the etching of crystal surfaces may increase the tensile strength to as high as 70 to 80 percent of its theoretical tensile strength.

** Heat the tube.

BASIC FACTORS IN CRYSTAL PRODUCTION

Mr. H. G. Human
Crystal Products Company

Colonel Harris, Ladies and Gentlemen:

1. I would like to preface my remarks by insisting that I expect to contribute little to existing information on crystal production. The thesis I would like to develop is the idea, that it's not what procedures are used in fabricating crystals, be it in sawing, lapping or cleaning or etching, but how well those procedures are performed.

2. We are pretty well agreed, I think, that the difference between a good plant and a mediocre plant is not the difference in the amount of technical skill a plant can muster among its personnel, but rather the difference lies in logical and intelligent orderliness of procedure and the excellence in which those accepted procedures are exploited and carried out.

3. I would say that the entire successful operation of a plant, however, is predicated on several basic factors. If those are met the operation is bound to be successful. The first is intelligent, open minded and aggressive supervision which reflects itself in satisfied employees. The two coupled together breed an overall "Esprit de Corps" which is the greatest single asset to any kind of production. A second factor is the proper distribution of the right people in the critical stages of operation. That is extremely important. That goes for supervision as well as line operators. A third factor which is really the result of the first two is the complete exploitation of best practices in our possession. As I've said before, in this stage of the game it's no longer a question of a lack of technical knowledge or adapting new methods, that assimilation I grant should go on constantly, but having those practices in operation carried out 100%.

4. We've all had the experience of trying to duplicate a seemingly desirable production feature we saw successfully used in other plants. Yet, so help us when we brought them back home, they didn't work for us. The difference is, I believe, that the wrong set of immediate employees were trying to put them into operation. It's not the gadgets and the elaboration of equipment that makes either for good crystals or for quantities. Plant cleanliness and the most efficient logical traffic of crystals in the line of production are both requisites for successful operations that are automatically accomplished by adequate supervision and management.

5. Although in our plant we have consistent inspection at every stage of production, using approximately 20% of our employees, I will mention only the particular stages on which we feel that greater emphasis pays the greatest dividends.

6. Foremost, of course, is incoming inspection of holders and component parts. I believe that is a common procedure. In the preparation of blanks, emphasis is placed on the inspection of the undiced

Basic Factors in Crystal Production (Continued)

wafers for electrical and optical twinning and on mechanical blank inspection after the semi-final lap. In order to avoid giving finishers or etchers even slight flawed crystals which is a waste of time and money we make another thorough inspection following our mechanical beveler.

7. The department, however, that receives greatest attention is the final inspection and mounting. This is the stage that sets every plant's excellence of production. Ours is housed in a separate air conditioned room, well lighted by fluorescents, in addition to individual spot lights for close inspection. The inspectors are equipped only with finger cots, running water and air jets. No towels are used and blanks are wetted for oil detection. Inspectors have neither activity nor deviation meters. They can concentrate solely on inspection. Crystals come to them mounted in cases, less bolts, springs and gaskets. Here each unit is dismantled and every component inspected for defects and flaws. Electrodes and air gaps are inspected and cases examined for cleanliness. Each inspector has an assistant we call a capper. She inspects and inserts pre-washed gaskets and springs and bolts the case.

8. Here is an 8 hour shift, each inspector with her assistant turns out about 250 units. Attached to each inspection shift is a quality control operator whose job it is to spot check constantly. She washes about 60 crystals a day with an abbreviated sash brush and Orvus soap. She checks samples from each inspector. Since each unit bears not only the final finisher's number but also the inspector's number, it is simple to check back on workmanship.

9. This department contains the cream of the crop of former finishers whose judgement is dependable and whose reliability is established. There is little point in exercising extreme care in all proceeding operations if this final precasing inspection is ill-done.

10. Our rejects from this department run 10%. This includes frequency and activity rejects at room temperature, the final operation before leaving the inspection room. No crystals are accepted for the hot and cold boxes unless the activity is 20% higher than the CES-1 required minimum. In the BC-659's for example we require .65 Ma. before accepting them for temperature run. The 10% rejected go immediately back to the final finisher for correction.

11. Crystals coming from the final inspection department are successively routed through the starting test, hot and cold boxes, final tightening, glyptaling, varnishing and cleaning, mechanical inspection, room check for frequency and activity and the drop test.

12. Rerunning lots of 1000 crystals periodically through temperature boxes representing Signal Corps temperature run rejects is time consuming and to avoid an excess of that sort of thing we allow a strong 10% margin of safety above the CES-1 minimum. As a further safeguard we make activity checks every 1°C instead of every 2°C. I can assure that such a practice, in spite of small increased rejects

Basic Factors in Crystal Production (Continued)

and slightly increased testing time, pays dividends not only in consistent Signal Corps acceptances but in better quality crystals.

13. Our 100% mechanical and electrical pre-Signal Corps inspection is one of our most exacting operations. Inasmuch as stability in frequency and activity is the essence of acceptance tests we give all crystals a severe drop test. They are sharply tapped twice at each of three different angles and activity and frequency variations noted before and after each of the taps. It entails four readings for each crystal but you can be quite certain you're submitting crystals that will pass inspection. On this test we reject 6%.

14. Crystals are submitted three days before shipment is made to allow an even flow through Signal Corps acceptance tests. A lot of 3000 for example is submitted Monday morning by 8:30. The 90 crystals selected for the acceptance test are run through the temperature box and vibrated on that day. On Tuesday all other tests are completed. On Wednesday they are stamped for acceptance, the date stamp applied and lacquered and shipped that night. Each day, then the Signal Corps performs tests on three days shipments involving from 8,000 to 10,000 crystals.

15. Our records for the first three weeks in June show that our final finishing inspectors rejected 10%. These crystals as mentioned previously are immediately corrected by the operators who submitted them. 2% were rejected in the starting test, and 23% in the temperature boxes checking every 1 degree. An additional 8% were rejected by our mechanical inspectors including crystals that were accidentally dropped, prong scratches and other miscellaneous causes. A final 6% were rejected by our electrical inspectors including drop test and 3% of course are made unshippable through the immersions acceptance test. On paper this represents an accumulative loss of 50%. In reality however, most of these throw-outs are easily repaired with an overall loss of blanks amounting to approximately 15%. The rejected crystals are tabbed according to reject causes, corrected and thrown back into the regular traffic for testing. We have found that for consistent acceptance for shipment none of the standards and procedures we have set up are too severe and over the long haul it is the most economical way to operate.

16. Crystal production under the new specifications is far removed from wishful thinking. Wishful thinking here is a vice that is an expensive indulgence. You either do or you don't. There is a comparatively small area for argument. The only way we can operate is to set up certain correct rigid procedures that will assure a high consistence of Signal Corps Acceptance. It is absolutely necessary to initiate promptly whatever procedures and changes are necessary. Our first week of operation under the new specifications found us with 38% Signal Corps rejected lots. The following week it went to 6% and then 5%. We are having today well under 5% Signal Corps lot rejects. To effect that reduction involved many changes. It is necessary in crystal production to make frequent changes. It is imperative too, that those changes are made quickly and effectively for economy's sake. Whether it includes 100 or 1000 employees the problem involved is only relatively different. All changes are distasteful to

Basic Factors in Crystal Production (Continued)

workers. Changes can be costly if based on insufficient data or if conclusions are prematurely reached and if they are not made decisive and clear cut. If changes are initiated a mere order to employees is not adequate. Workers must make changes not only on the basis of how but why. A good dose of employee-public relations can be thrown in here to excellent advantage. Changes must be sold to the employees to be thorough and effective. We are convinced at Crystal Products at least that whether it be alterations or what have you, for solid cooperation and loyalty it takes a heap of selling, but the selling must be based on facts for permanent production results.

PROPER PACKING METHODS FOR CRYSTALS
Capt. M. L. Wexler
O/C, Packaging Section, Storage & Issue Agency

1. The following information was gathered:

a. New packaging specifications have been written covering crystal units:

- (1) U. S. Army Signal Corps Spec. #71-2-545
- (2) U. S. Army Signal Corps Spec. #71-2-546
- (3) U. S. Army Signal Corps Spec. #71-2-547
- (4) U. S. Army Signal Corps Spec. #71-2-548

b. Upon issuance of instructions by the Contracting Officer crystals are to be individually unit packed in accordance with above specifications and Method II of U. S. Army Specification #100-14A.

c. Unit packages are to be marked in accordance with specification #72-6-15.

d. Intermediate packages are to be marked in accordance with specification #72-6-15.

e. Shipping containers are to be marked in accordance with specification #72-6-16.

f. Set up box as outlined in above specifications is to be used for unit and intermediate packaging. Folding boxes are not acceptable.

g. Cellophane packaging will not be permitted with crystal units.

h. Gross weight of box should not exceed 70 pounds. Net weight of contents should not exceed 50 pounds.

i. The above information and specifications are to be applied to all current and future contracts when the Contracting Officer requests it.

j. Action has been taken to secure copies of above-mentioned specifications from the Storage and Issue Agency.

k. Authorization will be obtained from the Contracting Officer to put the above specifications into effect.

THE FOLLOWING QUESTIONS WERE ASKED AT
THE CONCLUSION OF CAPT. WEXLER'S TALK

1. Q. It was mentioned here today that practically all crystals received in the Depot are rechecked for activity and frequency or activity alone. That would require breaking the vapor proof seal.

Proper Packing Methods for Crystals (Continued)

A. This is incorrect, they are spot checked only.

2. Q. Why is it necessary to limit size and weight of container?

A. Container sizes are limited so that the standardized package will fit into its allocated space within the master container for the end item of which it is a component. Container weights are limited so that they will be one-man borne and to facilitate warehousing at depots and other points. Crystals packed as components should also be unit packaged so that if the need arises for a crystal which is not in stock it may be taken from a set and shipped without processing and also as added protection until they are placed in operation.

CRYSTAL HOLDERS
LT. J. J. MAGUIRE
O/C, EQUIPMENT SECTION, CRYSTAL BRANCH
CAMP COLE SIGNAL LABORATORY

1. It is planned that all crystals supplied for use by the Signal Corps will be hermetically sealed. It is clear that if this is to be accomplished in time to help in our "all out effort" the crystal industry will have to voluntarily shoulder a whole series of new engineering and technical problems.

2. It is realized that the crystal manufacturers are currently faced with many problems, some of which it is hoped will be resolved at this meeting. In asking again the cooperation of the industry in order to convert to hermetically sealed holders, the Signal Corps is mindful of the many important discoveries by the industry which have made possible the vastly improved quality of crystals currently being supplied over those which were supplied one year ago. The Signal Corps is also fully cognizant and appreciative of the past cooperation of the crystal manufacturers in so quickly eliminating the brass contact plate and brass pins when it became apparent that they were contributing causes to failures of crystal units in the field. It is with these accomplishments fully in mind that the Signal Corps has the confidence to ask that the entire crystal industry convert over to hermetically sealed crystal units.

3. In a first effort to get this conversion under way, we will present at this meeting a few development models of hermetically sealed crystal units. These units are, it will be seen, not all adaptable for quantity production. Some of these units, may be modified in various ways to make them suitable for quantity production.

4. Due to the urgent requirement of the using arms for the hermetically sealed crystal unit which will adequately perform under all conditions of temperature and humidity we do not feel that it would be justifiable to immediately standardize on a hermetically sealed holder at the expense of supplying the numbers required by the using arms. It is the intention of the Signal Corps to adopt any available designs which appear adequate for immediate production and again postpone standardization until such time as an adequate supply is available. As this conversion gets under way, we ask you manufacturers as rapidly as a new design, or improved design, occurs to any of you, to refer it promptly to the Signal Corps so that it can speedily be considered on its own merits and also for its possible piecing out of an integrated program of conversion. Many of the holder manufacturers and a large number of crystal unit manufacturers have already submitted models and drawings of hermetically sealed crystal units. All these ideas are under active investigation by the Laboratories and it is hoped that an even greater number of ideas will be presented. In this discussion on crystal holders I would like to limit consideration to the designs of hermetically sealed crystal holders immediately available and to those which it can be anticipated could be fed into production during the next two months.

Crystal Holders (Continued)

5. The papers of Dr. Van Dyke and Mr. Bottom have covered fully the observed failures of Crystal Units due to the moisture absorbing characteristics of phenolic holders and it is not considered necessary to refer to these conditions, except to the extent that they appear in the hermetically sealed holders under consideration.

6. In limiting this discussion to two assembly designs of a metal hermetically sealed holder for Crystal Unit FT-243, it should not be inferred that the Laboratory is not interested in the development of other improved hermetically sealed holders for the FT-243 Unit and other Signal Corps Crystal Units now in production. As mentioned previously all ideas and suggestions will be most welcome.

7. Preliminary designs of metal, glass and ceramic holders have been submitted, but progress has not been rapid enough to permit more than mention that these types are under investigation.

8. The only type of FT-243 hermetically sealed holder which we are able to present to this meeting is one whose development has been closely followed by the Laboratory and one which it is believed will prove practical and lead into current quantity production without delay.

9. The holder is simply a two piece metal container with solid Kovar pins led in thru glass sleeves in a Kovar header and with a cover which fits down into the header and is then soldered completely around. An opening in the top of the cover permits evacuation, filling with a dry gas and a second solder seal.

10. The internal cavity can be adapted for plated crystal units by merely the welding of clips to the tops of the soldered pins, or for the electrode sandwich by the insertion of a ceramic split liner and spacing block.

11. Both adaptations of these holders are available and prompt quantity production is anticipated. Models of both these types are available here for your inspection.

12. A motion picture showing a simplified method of assembly, evacuating and sealing this holder has been prepared. Since there was very little time between the date at which these holders were available and this meeting, no effort could be made to adequately cover all details of this process. It is felt, however, that this film would be interesting in that it would present a clear idea of this holder assembly and its possibilities for large scale production. (A 15 minute motion picture film was shown at this point.)

PRINCIPLES OF QUALITY CONTROL
Major C. R. Brearty
O/C, Quality Control Section
Signal Corps Inspection Agency

1. You have heard that we have a quality control program in Signal Corps Inspection. It may be felt that there is something mysterious about it, or possibly that it is somewhat theoretical or highbrow. We hope to show today that it is neither and that it is an intensely practical program for Government inspection. It is a program which affects the way in which Signal Corps Inspection is conducted on all kinds of products. It is my purpose here to tell you just what the general program involves and where it is aimed. I have said that it affects the way in which Signal Corps Inspection is conducted. Naturally it is aimed at a certain ideal way - an ideal relationship between the contractor and the Government at the Government inspection point. I shall try to define this relationship a little later.

2. In the past, considering the whole field, Government inspection has been many different kinds of things. At times and at certain places it has been a kind of battle ground - a war within a war - which is of course not as it should be. There is actually a departure from our ideal in each case where a contractor's inspector passes a piece of equipment and the Government inspector rejects it. We know we cannot expect to eliminate all cases like that, as there are human beings on both sides of the fence. However, we believe that we can go a long way in approaching our ideal if, on both sides of the fence, before and after the presentation of equipment to the Government inspection, there is a common understanding as to what constitutes a defect, a common understanding as to what constitutes acceptable quality. This means a common understanding of a defect, a common understanding as to which defects are more serious, a common understanding as to how effective a job must be done in removing these defects, that is, what the Government inspection uses as a measure of acceptable quality in terms of proportion of defects remaining in the product presented.

3. Arriving at a common understanding on acceptable quality is a highly essential part of our program. From that alone, come the most important benefits of our program. For this reason, I am going to elaborate a little on how we achieve these understandings.

4. Our common understanding as to what constitutes a defect, and the relative seriousness of defects, is reached in consultation between the Signal Corps and contractor personnel, during which an analysis is made of the probably effect of the defects on field use of the equipment. In any cases where this analysis shows that the Signal Corps has been making rejections for certain imperfections which have no effect on field use, the Signal Corps will be ready to correct its practice so that these items no longer are causes for rejection. Likewise, if it is found that the contractor personnel had been omitting to look for and eliminate certain defects which are shown by this analysis to have an effect on field serviceability or life, it will be expected that the contractor will correct his inspection practices accordingly. The result of this step is a list of standard defect definitions supplemented by samples where necessary.

Principles of Quality Control (Continued)

5. Next we come to the question of standardizing on number of defects, that is, how many defects can there be as a maximum in a given amount of product which will be acceptable to the Government? When expressed in just that way in number of defects per given amount of product, we call it our "Acceptable Quality Level". There are other ways of expressing it. For example, in the case of an electrical characteristic it might be expressed in terms which involve the average of the measurements of that characteristic and the spread, that is, amount of variation. In any event, however, our acceptable quality is determined from two primary considerations. First, what can the field live with in terms of number of defects without causing an appreciable effect on overall operation and maintenance of equipment. Second, what can the processes produce - the manufacturing processes which are normally employed for the equipment and the manufacturer's inspection, as practiced by the average manufacturer of a good quality product in the industry concerned. Of course, we have no means of knowing this on an entirely new product or an old product under an entirely new specification. In such cases, our procedure is to begin by inspecting a large proportion of the product until we get the information needed, in the meantime, using some kind of temporary acceptance basis until our acceptable quality level can be established from factual information.

6. The Acceptable Quality Level is thus determined by considering these two factors: Field needs and the capability of manufacturers. If we are lucky, the two factors will give us the same result or, still better, it will be found that the manufacturers are capable of giving us a better product than the field must have as a minimum. If we are not so lucky and there appears to be no way of improving the output, a suitable compromise must be reached, based on realistic consideration of practicalities, and consideration of the quantity as well as quality that we must supply to the field.

7. Common understanding on these things has been found by experience to place us a long way on the road towards our ideal set up. It enables the contractor to instruct his own personnel definitely as to the defects they should inspect for and eliminate and how they should apportion their effort, on the more serious and less serious defects. This enables the contractor to assume the responsibility for presenting an acceptable quality of product to the Government inspection position and enables the Government to limit its inspection to a mere verification that an acceptable level of quality is being maintained. This can normally be done by the use of sampling plus a quality control analysis of the results with the amount of Government inspection dependent on the amount of assurance needed and the evidence that the levels are satisfactory. This defines fairly well our ideal set up, the objectives of this program.

8. Restated, our objectives are these: Through common understanding of acceptable quality, and through definite assumption by the manufacturer of responsibility for maintaining that quality level, to reduce the impact of Government inspection to a minimum. To make the Government inspection merely a tool to verify that the quality level is being maintained and furnish information to the manufacturer which will aid in maintaining that level.

Principles of Quality Control (Continued)

The less often Government inspection causes any action such as rejection of quantities of material, the closer we are to our objective. Our aim is a smooth flow of material through the Government inspection position and on to shipment to the points where it is needed.

9. Insofar as possible we want to lift the Government inspection out of the manufacturing processes, out of the assembly line, and place it only at the point where the manufacturer is ready to present a production which he has screened and is maintaining normally at the quality level agreed upon.

10. You probably will want to know a great deal about the kind of Government inspection we employ under this program, at our inspection position. That varies from one product to another, so I am going to leave most of that to the next talk which concerns the application of this program specifically to crystals. A few things should be pointed out at this time however. First, we use sampling wherever we can, except on operating tests on completed units of radio or telephone equipment. We employ where we can sampling procedures of a type which is being standardized for the Army Service Forces. In some cases we develop special procedures for special cases, based on fundamental sampling theory. The procedure used depends considerably on what is found feasible as an acceptable quality level. This brings out the point that the proper inspection procedure can not be determined until we have found what quality level is feasible. This means that if a sampling procedure is incorporated in a new specification at which time there has been no opportunity to determine what level is feasible under the new requirements, quite likely it will not be the most efficient procedure and may not even be workable if it turns out that the quality which can be produced can not pass the acceptance criteria which were set up. For this reason, for purposes of this program, we advocate either omitting definite sampling procedures from a new specification or leaving them subject to change after the product has been analyzed. Possibly the manufacturers may feel some objection to not having a final sampling procedure tied down in the specification originally. However, it will be recognized that the manufacturer has considerable to gain if the procedure is determined later, taking into consideration the realistic aspects of production and inspection.

11. In closing my own remarks, I want to say that we are quite proud of the accomplishments of our quality control program so far, on various kinds of products. One of its biggest accomplishments is that it makes for a consistent inspection, day after day, by both the contractor personnel and the Government personnel. We have accomplished a smooth flow of productions to shipment in cases where such results were not thought feasible before on the products concerned. Both we and the manufacturer have felt highly gratified by the results.

"EXTRACT"
QUALITY CONTROL APPLIED TO CRYSTAL INSPECTION
Lt. L. J. Jacobson
O/C, SAMPLING & INSPECTION RECORDS SUBSECTION, SCIA

(Editor's Note: The following talk was presented at the conference almost entirely as a blackboard demonstration; consequently the original steno-typist's notes were in many cases meaningless because of their repeated reference to information that was shown on the blackboard.

As a result of the conditions outlined above, it has been necessary to edit the steno-typist's notes appreciably in an effort to make the following information reasonably complete to attendees of the conference without the use of drawings and other illustrative tools which were used at the original discussion.)

1. In discussing applications of quality control techniques to the inspection of crystal units, it would be well to take time to review the overall objectives of the program - covered in Major Brearty's talk - define some of the expressions and terms we will use; describe some specific applications to crystal unit inspection and try to analyze - in some detail - the problems facing us in the light of the new specifications which are now, or soon to be, applicable.

2. Let us place ourselves, for the moment, outside of the shipping door of our plants. Take the position of the men in the field service, on the receiving end - the ultimate consumer of these crystal units. Thanks to your efforts, the ultimate consumer of crystal units is in regular receipt of thousands and thousands of crystal units. This ultimate consumer has a rather sound, even if rough, method of measuring quality. If, in a large bulk of crystal units, very few were found which did not operate as intended, the bulk would be described as a "good quality lot." If, in a large bulk of material, many defective units - units which did not operate as intended - were found, the shipment would be called a "poor quality lot." This measure of quality used by the ultimate consumer is quite effective. That is: many defectives signifying poor quality; few defectives signifying good quality.

3. It is safe to assume that the man in the field is not immediately concerned with whether the crystal unit failed to operate as intended because of a mechanical rupture in the case; because of mis-calibration; because of moisture leakage; or because there wasn't any quartz plate in the holder. Deficient operation is deficient operation. Reasons for deficiencies are usually not of immediate interest to the man in the field and the analysis is left to us who have the time to worry about reasons. We have the responsibility for measuring and controlling the number of defective units being shipped to the field and for knowing the specific contribution of each and every cause to the overall percentage of crystal units which don't operate as intended. We are responsible for investigating, understanding, and controlling these reasons for failure. It is from this point of view or approach that "quality level" is best defined.

Quality Control Applied to Crystal Inspection (Continued)

4. The "quality level" could be measured as the percentage of crystal units being supplied for field service - averaged over a period of time - which will not operate as intended. The ultimate consumers' "acceptable quality level," would be the maximum percentage of defective crystal units permissible, for effective field use. For the manufacturer and Government's inspector, the "acceptable quality level" could be defined as the poorest quality, in percent defective, which a contractor be permitted to present, continually for Signal Corps acceptance and which the Signal Corps will continually accept.

5. If quality is to be evaluated by measuring the percentage of defective or non-conforming units being shipped to the field from the manufacturing plants, it is essential that we all know what a non-conforming or defective unit is. Before developing some methods for measuring quality, let's consider some practical aspects of determining when a unit does not conform to specification requirements.

6. The basic statement of the Government's requirements for crystal units is contained in the contract and its specifications. It is recognized that crystal specifications have been subject to extensive revision and have been modified to keep pace with - or lead the development of - the industry. There is little doubt - in fact this conference has already supplied an abundance of evidence - that further revisions and changes in standards and requirements will be made as the needs of the field require them. Nevertheless, at any given time, for any contract, the existing specification is the best available expression of the Government's minimum needs. The specification usually describes the minimum requirements of a crystal unit through the medium of performance or acceptance tests. If the specification is an adequate statement of field needs - and neither the contractor nor inspector can assume otherwise - then it follows that any crystal unit which passes each and every requirement of the specified acceptance tests will be satisfactory for field service. The first practical question on hand is how to conduct acceptance tests.

7. Note: At this point a detailed discussion of typical or illustrative acceptance tests prescribed by either AWS C75.11 or Spec. 71-3046 was made using blackboard illustrations. The points covered in this part of the talk were concerned largely with the sequence to be used in performing acceptance tests and the significance of the sequence of testing used in measuring non-conformance. In outline, the following points were included in the discussion.

a. The 10 or 12 acceptance tests currently prescribed are supposed to be done (according to present specification) in the order listed in the Specification. This is recognized to be difficult in many cases because of the length of time required to complete all acceptance tests on the same sample.

b. It is desirable to break down these acceptance tests so that as many as is possible can be done concurrently on different samples. The Laboratories have under consideration a breakdown of tests.

Quality Control Applied to Crystal Inspection (Continued)

c. The listing of acceptance tests in the order in which they should be performed is an engineering problem. A sequence of testing which makes performance tests as close an approximation as possible to actual field service conditions is desirable. The following illustrative sequence of 4 acceptance tests to be done in the order listed was discussed in detail:

(1) Drop - vibration - seal - internal inspection. In this sequence, the internal inspection test is made on the crystal unit which has already experienced drop, vibration, and seal tests. The crystal is internally inspected under most severe conditions in that the results of internal inspection following the three previous tests already mentioned, might be significantly different than the results of an internal inspection test performed on crystal units which have not gone through the rigors of a drop, vibration, and seal test.

(2) It was pointed out that if several acceptance tests bore an engineering relationship to one another and that if one test did not have proper meaning unless the crystal unit undergoing that test had been subjected to another preceding it, then all acceptance tests which must be performed in sequence could well be grouped as a "basic group test" and a crystal unit which failed to meet one or more of the specified requirements of the acceptance tests in the group might well be considered as a single non-conforming unit for the group test.

8. We have now developed our definitions of "acceptable quality level" and a basis for establishing "basic group tests." For each "basic group test," the percentage of units in any lot or sample which are non-conforming or defective can be measured. Over a period of time our as-simulated inspection records would show the process average - the percent defective for each "basic group test." Similarly, the process average in percent defective for all basic group tests taken together can be determined, by adding together the individual percent defective of each basic group test. Before discussing some of the specific quality control acceptance techniques and sampling schedules which could be used in crystal inspection, we should pursue this subject of non-conforming or defective units a little further. Before we measure quantities of defects we must have a common understanding of what a "defect" is. It would be silly to develop statistical methods of measuring quality levels, prescribe group tests, etc., if we don't know a defect when we see one, or conversely we don't know a good unit when we see one. General Colton said yesterday that he understood that a major question on the floor was "what is an obvious scratch." Until this question and others of a similar nature are resolved to mutual satisfaction of the contractor and inspector, measurements of quality will be seriously affected by the vagaries of individual opinion and judgment.

9. In cases where conformance or non-conformance of a crystal unit to the requirements of an acceptance test is determined by meter measurements - activity, frequency, stating time, few problems exist. Nearly everybody will read a meter with sufficient accuracy so that unanimous opinion on whether or not a crystal unit is on proper frequency or develops

Quality Control Applied to Crystal Inspection (Continued)

proper activity can be obtained. If acceptance tests covering mechanical, visual, and internal inspections are to be given equivalent status with electrical or temperature tests in determining acceptability of a crystal unit, then it is essential that an equivalent degree of clarity in defining a defect should be developed for these former tests as is now available for the latter. The contractor is entitled to know what a conforming or non-conforming item is for these visual tests if he is expected to adjust his processes, including his own inspection so as to present crystal units substantially free from defects. The contractor is also entitled to know that the Signal Corps inspector is using the same definitions of defects. The Inspection Agency realizes the necessity for establishing uniform acceptance criteria for Crystal Units at all inspection points and for all personnel. Perhaps insufficient attention has been paid by contractors, inspector in supervisory levels, and Signal Corps laboratory organizations to clearing up these questions involving workmanship standards. It is a job that belongs to all of us and should be started immediately. Several suggestions of immediate practical value might be tried.

Note: The subject of establishing physical standards for defects in visual and mechanical inspection was discussed with the use of blackboard illustrations. The program inaugurated by the Inspection Agency and the Laboratories to develop and issue defect standards was discussed. The contractors were requested to take the initiative in cooperation with resident inspectors in compiling examples of visual defects which were especially troublesome at their own plants. The role of the Zone Crystal Coordinators and Agency Coordinator in compiling and standardizing these standards were described.

At this point in our discussion we have covered the principle lines along which we would arrive at an "Acceptable Quality Level"; the organization and use of acceptance tests for measurement of quality performance and how to establish workable standards for defects to be used in connection with the acceptance tests which require judgment decisions. With this background we can discuss the procedure for arriving at a value for the "Acceptable Quality Level"; the definition of the contractors' responsibility in production of material equal to or better than the "Acceptable Quality Level" and the responsibility of Government inspection in developing sound inspection acceptance procedures to protect the contractor from unjust rejection - rejection of good material - and to protect the using services from unjustified acceptances - continuing acceptances of material containing defectives in excess of the minimums established by the "Acceptable Quality Level." To review - an "Acceptable Quality Level" from the point of view of the manufacturer and inspection, is the maximum percent defective that the contractor can continually submit for acceptance and which will merit continual acceptance by the Signal Corps. The acceptable quality level to be established for the crystal industry will depend on the practical balance between two significant factors.

a. What percentage of defective or non-conforming units can be supplied to the field and still meet their needs for effective operation.

Quality Control Applied to Crystal Inspection (Continued)

b. What level of quality can present mass production processes be reasonably expected to deliver. Let us consider the second factor - the simpler one to evaluate at the present time - and review a method for determining what quality level can be reasonably expected from a number of representative crystal manufacturers.

10. A simple method for establishing a tentative acceptable quality level for the crystal industry might be based on a thorough analysis of the production performance at some 10 or 12 plants. If, for a representative period of time, we found that these 10 or 12 producers were delivering material of reasonable uniformity from day to day, then the process averages based on inspection results of these manufacturers would be a rather accurate estimate of the quality of material being shipped to the field from these plants. The Signal Corps would not be taking an unreasonable stand if in the initial stages of its quality control program it established for the industry a quality level based on the average process performance of these selected plants. It might develop, and should be expected, that the acceptable quality levels based on the production performance of these selected plants would be significantly better than the quality currently being delivered by the rest of the industry. Requiring the rest of the industry to conform to such a standard may place a demand for improvement and better control of the current processes - including contractor inspection - at all other points. It can be seen that from a sensible evaluation of inspection records that a grading of contractors in the order of their quality of performance can be established and would be an extremely valuable piece of information for the Signal Corps. By a series of successive steps involving; firstly, establishing a tentative acceptable quality level based on performance of some 10 or 12 manufacturers; secondly, prescribing equivalent performance for the rest of the industry; thirdly, measuring the performance of all plants on a comparative basis - a thoroughly reasonable acceptable quality level should be developed for the entire industry. Developing an acceptable quality level would allow the Signal Corps to specifically require of the manufacturer that his production processes consistently deliver material not worse than some predetermined and specified percent defective.

11. For illustration, let us assume acceptable quality levels of 1% for any one group test and 2% for all tests taken together was established. It would be the responsibility of the manufacturer to control his processes to the point where uniformly and consistently, material would be presented for Signal Corps acceptance which would not be significantly worse than 2% defective for all grouped acceptance tests taken together; and of that 2% no more than 1% could be contributed by any single acceptance test. This is one simple but effective method of stating the contractor's responsibility in the production of good quality material. (It might be of interest to point out that our preliminary investigations to date indicate that no manufacturer for any type of crystal is meeting quality levels which I have used for illustration.) When we speak of production process which must be so controlled as to consistently deliver material equal to or better than the AQL, the inspections performed by the contractor at every stage in the process are considered as much a part of the production process as the production tools and methods in use.

Quality Control Applied to Crystal Inspection (Continued)

maximum, none of the 5000 should be accepted. There appears to be little justice in returning two lots and accepting three if the quality of all 5 is substantially the same. This is an illustration where discrimination between good and bad quality lots leaves much to be desired and where ineffective discrimination places an unjust penalty on the contractor producing an acceptable product and allows acceptances of batches of unacceptable quality presented by poor quality producers. The using forces loses both ways.

14. Let us assume, for purposes of illustration, that a contractor consistently produces material which is 50% defective for some characteristic and consistently presents material of this level for Signal Corps acceptance. It is quite conceivable, though the illustration is for an extreme case, that common methods of sampling now in wide use would reject submissions of material containing 50% defective in the order of 75% of the time. Nevertheless, due to chance causes, 25% of all submissions are accepted. Operation under this system, while materially reducing the flow of material from that contractor's plant may still allow 25% of the shipments to be made whose quality may not appreciably better than 50% defective. It may be recognized that under systems of sampling inspection in common use the material shipped out the back door may not be substantially different than the quality of material submitted for Signal Corps acceptance. That is as it should be - provided material presented for acceptance is of the proper quality level. However, the major deficiency of the common sampling methods now in use is that they attempt to judge the merit of each independent lot submission by means of a small sample without any regard for evaluating the overall quality level and uniformity of material being presented for acceptance. If a contractor is operating at a process average of 10% defective, there is little justification for utilizing the same sampling schedules at his plant as are being utilized at the plant of a contractor consistently producing material at a 2% level. Systems in common use specify an identical inspection load and use the same acceptance criteria at different plant locations regardless of the quality levels being maintained at these locations.

15. In general, it might be stated that good quality producers suffer most from the vagaries of arbitrary sampling schedules and it follows that the injustice of such schemes gives little protection to the using service. The Signal Corps Inspection Agency, based on extensive work done by the Army Service Forces, has available the means for setting up sound sampling schedules based on predetermined statements of acceptable quality level and designed to give both contractor and the Government maximum protection against vagaries of chance. In a nutshell, the effectiveness of statistical inspection tools is based on the principle that production processes are controlled to a point where a high degree of uniformity of production is obtained - day in and day out. The samples selected from independent lot submissions cumulatively added together give a more accurate picture of this overall consistency and level of the process. This line of action calls for a continued analysis of inspection records and by such analysis to obtain accurate information on the uniformity and level of quality.

Quality Control Applied to Crystal Inspection (Continued)

16. We would propose the use of a double sampling scheme for most acceptance tests in crystal unit inspection. Such a scheme would operate, briefly as follows: A sample from each lot of material presented for acceptance is chosen and thoroughly inspected. The allowable number of defects for this first sample is predetermined, and on the basis of the first sample one of three actions is taken. The lot of material is accepted as being consistent with the acceptable quality level; the lot is returned for rework and reinspection because the sample shows the lot to be significantly worse than the acceptable quality level; if neither of these two actions is conclusively indicated - a second and larger sample is chosen. Upon inspection of the second sample acceptance or rejection of the lot is made on the basis of the number of failures found in the combined first and second samples inspected. We would also propose the use of flexible sampling schedule to operate roughly as follows: Where a contractor is comfortably meeting the AQL without a lot to spare, normal sampling would be used. Where the process average is significantly better than the AQL, a reduced sampling schedule would be used. Where the process average is found to be appreciably worse than the AQL, a stricter sampling would be used. It is by the use of a flexible system which applies a sampling schedule whose rigor is adjusted to the production performance at each plant that effective discrimination between good and bad quality is really obtained. The pay-off, reduced sampling schedules, is given to the good quality producer and the rod, so to speak, is applied through the medium of stricter sampling schedules to the poor quality producer.

17. We find that control chart techniques of analyzing data are applicable to the wash test. We have also found at many plants that the washing process shows a high degree of consistency at good quality levels. The use of control chart techniques as an acceptance tool for the wash test would normally result in a reduction in inspection effort. It might also be pointed out that the use of control chart techniques for this acceptance test helps solve many puzzling questions that confront both the contractor and Signal Corps inspectors. The specification may state, for example, that a maximum change in frequency after wash should be 600 cycles. By definition, a frequency change of 599 cycles would be acceptable, but a frequency change of 601 would warrant rejection. This may not be the intent of the specification, but a rigid interpretation of presently specified requirement leaves us no recourse, but to accept 599 cycles and reject 601. Actually we have not made use of all the information made available by our inspection wherein 10 discrete readings of change in frequency are made for each lot of material presented for acceptance. No use is made of these 10 readings except to look for those single values in excess of specification requirements. Proper analysis of accumulated data for wash test by control chart methods would give us a very accurate picture of the quality level and degree of control of the process.

Note: Blackboard demonstration on use of frequency distributions and the development of control chart limit lines were used here. Blackboard drawings of operating characteristics of proposed

Quality Control Applied to Crystal Inspection (Continued)

statistical sampling schedules and sampling systems in current use were drawn. The documentation of the contractor's responsibility by statement of AQL and the responsibility of the Signal Corps inspection to provide adequate assurance to the contractor that only justifiable rejections are made while affording the Government protection against acceptance of defective material was demonstrated by the operating characteristics of proposed sampling schemes.

18. To review, the overall objectives of a quality control program are:

a. To give the contractor a clearly defined and documented statement of his responsibility for the production of material of acceptable quality.

b. To give the Signal Corps inspector an equally well defined method of inspection so that accurate measurements of the degree with which the contractor has met his responsibility can be made.

c. To establish for both the contractor and Signal Corps a common understanding of acceptable quality for all acceptance tests.

d. To utilize the Signal Corps inspection position only as an effective tool in the measurement of quality and for all cases where the contractor discharges his responsibility to guarantee the smooth, uninterrupted flow of material through the Signal Corps inspection position to the field.

e. To establish uniform acceptance criteria at all Signal Corps inspection points throughout the crystal industry.

Colonel Harris' organization in cooperation with other Signal Corps agencies represented here today, is inaugurating a program for the clarification of mutual problems facing the manufacturers and Signal Corps inspectors, and for the introduction of quality control acceptance inspection methods wherever possible. You people will be called upon to give us the utmost in cooperation. Where necessary we will call for increased effort on your part to obtain greater uniformity in production and contractor inspection. It may be necessary to require - in some of the initial phases of our work - an increased number of samples to be chosen and tested by the Signal Corps inspectors. I feel free to make the categorical statement, that without this cooperation of the contractors in this mutually beneficial program no reasonable success will be achieved. It is not the policy of Colonel Harris' organization to require people to take different approach on inspection by means of a directive. You are entitled to - and will receive - as complete a statement of our objectives and purposes as is possible when we come to ask you to do some special work to help us get this program under way.

CRYSTAL TESTING EQUIPMENT
CAPTAIN E. F. MITCHELL
O/C CRYSTAL BRANCH,
CAMP COLES SIGNAL LABORATORY

1. I shall talk on crystal testing equipment, but limit myself to consideration of those items of test equipment which are peculiar to crystal testing.

2. The two items of special equipment used in testing crystals are test oscillators and seal test equipment. Let us consider the seal testing equipment first. Heretofore we have generally tested the seal of crystals by immersing them in a container of water, placing the water in a vacuum chamber, and reducing the ambient pressure. Although this method does show up most units that have bad leaks in them, it has several weaknesses:

- a. It is not reproducible.
- b. It does not show all leakers.
- c. It is possible by the application of this test to introduce a bit of water into the holder and yet have the crystal unit pass the test. At some later date, after the crystal units have been accepted, it is reasonable to expect that this drop of moisture will cause the crystal unit to fail.
- d. Because of its semi-destructive nature it is usually applied only as a type test.

3. Although this test has been unsatisfactory in several respects it was, until about a year ago, the only seal test we knew how to apply. About that time there was developed, by Bell Telephone Laboratories, an equipment for actually measuring the rate at which air will leak out of a crystal holder if the unit is subjected to a reduced ambient pressure. To do this several units are placed in crystal sockets in a vacuum chamber, the pressure reduced to below one inch of mercury and through an external switching arrangement a DC potential of about 1500 volts is alternately applied to each unit. When the pressure within any unit is reduced to 10 inches of mercury absolute that unit will permit so much ionic current between the electrodes. By determining the length of time required for the pressure inside the holder to drop to ten inches of mercury with an external ambient of less than an inch we gain an idea of how rapidly the unit leaks. It is of course necessary to calibrate the various designs of units for this test. Furthermore theoretically each frequency would have a separate calibration, for the frequency of the unit determines that of the oscillator plate and, therefore, the spacing of the electrodes is determined by the thickness of the oscillator plate and hence (for any given cut) by the frequency. However, it is feasible to group many frequencies under one calibration.

4. Various troubles may be encountered in attempting to apply this test. If the edges of the electrodes are burred the test may be invalidated. Certain care must be taken in inserting the crystal units in the sockets within the vacuum chamber, otherwise arcs may occur between

Crystal Testing Equipment (Continued)

crystal holder pins. Certain units will pass the specified amount of current at room temperature. This is probably due to inclusions contained in the oscillator plate possibly rutile needles (titanium dioxide). Such units of course cannot be tested for adequate seal in this manner.

5. However, with a little use and investigation, it is believed that this type of test can be made applicable to substantially 100% of the production of any given type of crystal unit. It is now being successfully used in at least three plants on crystals as widely divergent in characteristics as pressure mounted BT cut units and plated CT cut units. This is a test which can be rapidly applied, is non-destructive, there being no danger of so affecting the units that a failure will occur sometime after the test, and can, therefore, be applied to all units (except those few units which pass DC through the oscillator plate itself). Furthermore, it is believed that the results obtained by this method will be far more reproducible than results obtained by an immersion test. Practically all present crystal specifications require that crystal units be tested by this method as soon as the equipment is available.

6. The other item of test equipment used in the testing of crystals is the test oscillator. Let us see what is required of the crystal test oscillator. It has always been generally known by crystal people that a given crystal unit does not have a unique frequency but that its exact frequency at a given temperature is determined by the circuit in which it operates. It is the shunt capacitance which the oscillator circuit presents to the crystal which exactly determines the frequency at which a crystal unit will function. It has not always been so well understood that the relative activity of a crystal unit is also determined by the characteristics of the oscillator circuit in which it is used. However, I believe this is now generally recognized. The particular characteristic of the oscillator circuit which effects the relative activity of the crystal is that characteristic of the oscillator circuit which permits a particular crystal to oscillate with a certain amplitude of vigor. This can be thought of as the effect of the oscillator circuit on the RF voltage which the circuit places across the crystal or the RF current which the circuit causes or permits to pass through the crystal. This characteristic is frequently not critical and probably it is sufficient for a given crystal simply to have the current which passes through it be below some certain level. Nevertheless this fact should not be completely ignored in discussing, specifying or using test circuits. Let us then say that the following two conditions are required and sufficient of a test oscillator:

a. It should present to the crystal unit the same shunt capacitance as the "use" circuit.

b. It should drive the crystal unit as hard as does the "use" circuit.

Crystal Testing Equipment (Continued)

7. In starting off fresh it would of course be possible to achieve the same end result by a different approach. We could then choose to test the crystal in any circuit selected and require that any new equipment designed to use such a crystal should look to the crystal the same as the selected test circuit. However, in most cases, we have been prevented from doing so since the various equipments which were to use crystals were designed without reference to any particular crystal or crystal test oscillator.

8. It has become necessary in the procurement of crystals to select some suitable test oscillator. In procuring crystals for operating a particular piece of equipment the most obvious answer to the question of what test oscillators shall be used is to agree to use the actual equipment in which the crystal will operate. This is a very reasonable solution and is workable and many crystals have been bought in just that manner. However, the use of the radio set presents certain difficulties. In the first place, it is necessary to select and maintain an average or a minimum set as a standard set and make all other sets used as test oscillators agree with that set. This is not easy. Moreover many radio equipments are too large and cumbersome. One other difficulty is the fact that it is frequently not feasible to vary over a wide range the temperature of a crystal unit while it is inserted in a radio set, nor is it feasible to vary the temperature of a complete radio set. It, therefore, may become necessary in using a radio set as a test oscillator to provide a jig which had leads from the crystal socket of the equipment to a crystal socket contained in a temperature box. This, of course, adds to the capacity across the crystal and may easily destroy the frequency correlation. It is possible to avoid the difficulties peculiar to the use of a radio set as a test oscillator by designing a simple crystal oscillator which looks to the crystal the same as does the "use" circuit. This test oscillator may be designed with leads going into a temperature box as part of the oscillator circuit. Thereby frequency correlation with the radio set is obtained. Usually a simple one or two tube oscillator, both inexpensive and small, can be correlated sufficiently well to a complex radio set circuit. Such oscillators are already used in specifying and testing of Signal Corps crystals. I believe that they have generally been referred to by the industry as "Signal Corps Black Boxes". I doubt that this name was applied because they were painted with black enamel. It is virtually impossible to define the effect on a crystal unit of one of these so called "black boxes". If they are to be used the only way of giving numerical value of activity is to establish a series of standard oscillators, making sure that the characteristics of the control oscillator do not change, and relating the characteristics of all other oscillators in use to the primary standard. However, this is a difficult task and will of necessity always be a potential source of arguments.

9. Despite the difficulty in using such test sets as a means for specifying crystal performance many millions of adequate crystals have been procured for the Signal Corps on just such a basis. The problem may

Crystal Testing Equipment (Continued)

not be serious if the activity required of the crystal is not critical to either party. By that I mean if the value of activity specified is not difficult for the manufacturer to produce and contains a sufficiently large safety factor that a crystal unit with an appreciably smaller activity will operate the equipment adequately. However, when we are faced with the problem of providing crystal for equipments which require a crystal as good as it is practicable to produce in quantity the problem becomes very acute.

10. If the simple black box is to be used, it is required that the Signal Corps design a black box for each radio set for which crystals are procured, standardize and maintain a series of standard oscillators to which the test oscillators in the various manufacturing plants can be referred, and constantly check calibration. This is awkward and impracticable. It was, therefore, considered advisable to provide universal or at least adjustable test oscillators which would have such controls on them as would enable the oscillator to be adjusted to simulate to the crystal any of a number of equipment. If a test oscillator is to be termed universal it must be capable of presenting many varieties of capacitance to the crystal and it must also be capable of oscillating a given crystal with various degrees of amplitude. The design of such an instrument appears to be very complicated. However it is quite easy to design an equipment which has adjustable capacity but which can cause any given crystal unit to oscillate with one degree of vigor.

11. Two such oscillators have been designed, one or the other of which is now used in specifying the majority of Signal Corps crystal units. I refer of course to Test Set AN/TSM-1, a Signal Corps equipment developed out of the old Western Electric "D" Specification Oscillator, and to Galvin's Model CES-1 Oscillator. The AN/TSM-1 employs a Miller circuit and the CES-1 employs a Pierce circuit. Currently work is going on at the Laboratory to convert specifications for various crystal units into terms of performance in one or the other of these equipments. It is believed that all the crystals the Signal Corps requires are capable of being so defined except some units which are used as filter crystals and crystal units of the type housed in Holder FT-241-A.

12. There are words which have similar dictionary meanings and which have been used synonymously by crystal people. I refer to the words correlation and calibration. Allow me to give my definition of these words:

a. Correlation is the act of establishing known electrical relationships between two pieces of equipment such as:

- (1) A radio set and a Standard Crystal Test Set or
- (2) Two standard crystal test sets or
- (3) A standard crystal test set and a production test set.

b. Calibration is the act of adjusting any crystal test set such that it becomes a device with which measurements of crystal quality may be made in terms of a previously established scale.

Crystal Testing Equipment (Continued)

13. Although the design of adjustable test oscillators is not difficult, the problem of maintaining calibration is extremely difficult. This difficulty is increased as the number of sets to be simulated is increased and probably the increase is much out of proportion to the ratio of the number of sets simulated. Therefore, it has been necessary to provide some adequate means of calibrating the various sets. The original method of calibration was to take crystal units and insert them in a standard which might be a radio set or a test oscillator and then in the test set being calibrated, and adjust the test set being calibrated so that it gives the same indication of activity for a given crystal as did the standard. This method is weak since if a crystal is operating near the temperature of an activity dip, the activity can vary materially over a short period of time due to changes in temperature. Furthermore, we know that crystals change in their activity with time. We now understand that this is caused by aging and feel that we can prevent it by proper manufacturing processes. However, a few months ago this was not the case; hence, the maintaining of standard crystals to be used for calibrating was impracticable. Further it is desirable to calibrate at the specified minimum level of activity but it is usually difficult to get crystals of such activity. The activity of a crystal unit can be knocked down artificially by putting a resistance in series or parallel with it or by dirtying or grinding the face of the oscillator plate. The first method is most convenient, but may not give too accurate results. The second method is not convenient; however, it may give better results.

14. The scheme of using calibrating coils or artificial crystals was envisioned and such a coil was provided for the Western Electric "D" Specification Oscillator. However, this method, as first applied was weak in one respect, namely that the test oscillator was calibrated at an indicated level of activity several times the minimum level of activity specified for the crystals whose performance was defined in terms of operation in the test set. This means that extreme care must be taken in fabricating the test oscillators so that each unit is as nearly as possible exactly like all other units. Further care must be taken in handling them so that this similarity is not destroyed. However, Camp Coles has recently evolved a method of calibrating the AN/TSM-1 wherein the equipment may be calibrated at any selected level of activity. This means that when used for testing crystals for procurement it can be calibrated at the minimum specified level of activity. The test sets, which have recently gone out to the Signal Corps Inspectors at all plants manufacturing CR-1's, are provided with calibration coil and instructions for calibration in this manner. We feel certain that this method of calibration will provide standards at each crystal plant which will give within $\pm 5\%$ of the mean at the passing level of activity. This is actually superior to the tolerances of the meters used in these equipments. These meters have an accuracy of $\pm 2\%$ of full scale value or ± 0.02 ma. at all parts of the scale. Although this estimate of $\pm 5\%$ sounds very sanguine, Laboratory data taken with various units and various calibrating coils indicates that such a degree of accuracy can be anticipated.

Crystal Testing Equipment (Continued)

15. The scheme employed in this method of calibration has been extended to the CES-1 and we plan to provide artificial crystals for use in calibrating these equipments to simulate various radio sets. These artificial crystals are currently being tried out by Signal Corps personnel and we have sent instructions to Galvin to see if they can use a coil which they have fabricated in accordance with our specifications. It is hoped that by use of such artificial crystals we can eliminate the necessity for such great care in fabricating and maintaining test oscillators. This would permit the checking of calibration at plants or at the Laboratory without carrying standard oscillators from place to place. Furthermore, it will be possible to specify completely a test set. This is so because the artificial crystals can be completely defined by a drawing, which gives the value of the total resistance and reactance which the artificial crystal has at any one frequency. Hence to define completely a test oscillator, it will be necessary only to give a schematic and possibly the layout of the test oscillator and define its calibration with reference to its performance with a standard artificial crystal inserted in the crystal socket. Let us hope that this can be reduced to acceptable specifications very rapidly for once it has been accomplished, one of the greatest ambiguities in crystal specifications will have been removed.

16. I believe that when we have accomplished this we will have provided a completely usable and adequate test set for specifying and procuring crystal units. However, such a method of specifying and testing crystals will not satisfy the Laboratory for crystals will still be defined in terms of their performance in some arbitrary circuit and it is obviously desirable to specify a crystal in terms only of itself. I believe that it is possible to do this but because of the fact that certain characteristics of crystal units vary one with the other and not in a straight line relationship, the problem is extremely trying. However, we are now pursuing an investigation of measuring and specifying crystals in absolute terms and of course if we can achieve that goal we will then use such definition of crystal units in specifications. The day is, I am sure, at least six months off.

CRYSTAL SPECIFICATIONS
Captain E. F. Mitchell
O/C, Crystal Branch
Camp Coles Signal Lab.

1. In discussing crystal specifications I shall limit myself to specifications applicable to Signal Corps types. In general, the earliest specifications were contained bodily in equipment specifications. Such a specification is fairly easy to write. Essentially all that is needed to be said is that the crystal shall enable the equipment to meet all other specification requirements.

2. If an individual or organization desires to specify crystals for only one piece of equipment, this may be an entirely adequate specification. However, it has several weaknesses. In the first place, when specifications are written in this manner it usually means that a radio engineer writes a crystal specification. The probability is that that radio engineer knows very little about crystals and how to specify them. I know whereof I speak, for long before I was in the Crystal Section, and when I knew even less about crystals than I do now, I once wrote a crystal specification. It was for the DC-12 to be used in Radio Set SCR-284. That specification was not a good crystal specification, however I believe it was not the worst crystal specification ever included in an equipment specification. I believe that in general equipment engineers do not know what can be reasonably expected of a crystal in the way of temperature and frequency characteristics. Further, they do not know how to specify the activity of a crystal. They may give tolerances which are either ridiculously wide or which are almost impossible for a crystal manufacturer to meet. Another weakness in writing crystal specifications in such a manner is that it completely disregards the problems of standardization, for if equipments are built to a performance specification and the crystal specification is that the crystal shall enable the equipment to perform satisfactorily, we may end up not only with a different crystal for each different type of equipment but also with very many circuits slightly different for the same type equipment as manufactured by different companies. Therefore the crystals will be different. In the initial procurement of equipments, this is not particularly serious, but if we are called upon to procure replacement crystals for those equipments, it may prove serious.

3. I know of one noteworthy, horrible example; a case with which some of you are quite familiar. This is the case of Frequency Meter Set SCR-211 which is a very well engineered piece of equipment, however original specifications were performance specifications and the crystal was required to operate the Frequency Meter adequately. The result was that of the first thirteen models of the equipment each required a crystal which was slightly different from the others. In recent months this has caused a very serious problem for the Signal Corps because it has become desirable to get replacement crystals for some of these units already in the field. The problem of providing specifications and test sets is so serious that it appears that some of the frequency meters will be thrown away simply because the crystal

Crystal Specifications (Continued)

circuit and crystal unit were not standardized early in the game. All present and future models of the equipment have been standardized electrically as well as physically and this problem will not obtain with this equipment in the future.

4. The next step in the evolution of a modern crystal specification is the writing of a general crystal specification, which general specification is made subsidiary to an equipment specification. With this scheme particular tolerances or the circuit in which the crystal is to be tested are specified in the equipment specification. This is a step forward for it enables the crystal engineer to control the crystal specifications for the most part and to guide the equipment engineer through the crystal problems which are peculiar to that equipment. However, this method also ignores the problem of standardizing crystals and crystal oscillator circuits. Such a specification may require that the crystal will behave so and so in the radio set, in a test oscillator simulating the radio set, or in both. This is the form of specification which has been used in procuring the greatest portion of crystals for the Signal Corps for this war.

5. Another step in the evolution of the crystal specification has been the writing of entirely independent crystal specifications. American War Standard for Crystal Unit CR-1 is an example of such a specification. Signal Corps Specifications No. 71-3021 covering "Crystal Units with Wire Mounted Silver Plated CT and DT Cut Plates", and No. 71-3046 covering "Pressure Mounted Quartz Crystals" are other examples. I firmly believe that it is highly desirable to have all crystal specifications in a completely independent form. However the problem of preparing an adequate independent specification for crystals for equipment in existence is a sizeable one, for a test oscillator has to be selected and then limits have to be determined for specifying the crystal in terms of its performance in the selected test oscillator. Correlation between these limits on the test oscillator and adequate performance in the equipment must be assured. Once this job is done, however, it makes the problem of specifying, procuring and manufacturing crystals simpler. Furthermore such a specification is a necessary prerequisite to any effective and extensive program for crystal standardization. For so long as crystal performance is defined in terms of operation in specific equipments, it will be virtually impossible to bring the various equipment engineers together on crystal requirements, because to tell an engineer at Camp Coles Signal Lab that a certain crystal unit which is proposed as a standard behaves so and so in a certain piece of Army Air Forces equipment means almost nothing to that CCSL engineer. In the preparation of the American War Standard for Crystal Unit CR-1, technicians of the OCSigO, ARL and CCSL worked hand in hand. Specification No. 71-3046 covering "Pressure mounted Quartz Crystals" is based on that AWS and vigorous attempt was made to have these specifications as similar as possible. I believe that considerable success was achieved in that effort. Those three groups together with the Signal Corps Inspection Agency will continue to strive towards standardization of all crystal specifications.

Crystal Specifications (Continued)

6. I believe that specifications for crystals for the use of the Army Air Forces and for crystals for the use of the Army Ground Forces can be almost identical. The only striking difference between the service conditions imposed by the two sets of services is that crystals for Airborne equipment must be capable of repeatedly going through rapid pressure cycles in which the ambient pressure varies between full sea level atmosphere and the pressure obtained at great elevations. Concurrent with these pressure cycles, the units are called upon to meet rapid temperature cycles in which the temperature is varied from way below zero to as high as 90°C. Ground Forces crystals may be required to experience the same sort of extreme temperatures, however they would hardly be called upon to meet rapid temperature cycles. In normal service, Ground Forces crystals are not called upon to meet large changes in ambient pressure. However, even Ground Forces crystals may at times be transported by air and at such times they will be called upon to meet almost as extreme conditions as are Airborne crystals. Therefore it strikes me that crystals for Ground Forces equipment should be capable of meeting the same conditions as are crystals for Airborne equipment.

7. Hence the Signal Corps is committed to a program designed at furnishing one crystal specification for all crystal units. So far the current specifications for substantially all Signal Corps types have been reduced to four--American War Standard for CR-1, SC Spec. No. 71-3046, Spec. No. 71-3021 and Spec. No. 71-1355-B. The various tolerances on the several units may differ, but the same sort of requirements will be made applicable to all units. We are further committed to reducing the number of test sets used in crystal specifications to a minimum. As pointed out before, it is believed that substantially all our crystal units can be specified in terms of either Test Set AN/TSM-1 or CES-1.

8. Now let us consider specific questions which have been asked with regard to specifications:

1 Q What effect does deterioration of brass contact plates have on aging of crystal, and what has been done to eliminate the problem?

A Deterioration of brass contact plates causes crystals to go dead because the stem of the contact plates becomes so corroded that the electrical circuit is broken.

Specifications have been amended to prohibit the use of brass contact plates. Changes in present contracts are being negotiated to prohibit their use.

2aQ Is etching going to be part of the specifications?

A Yes. It will be a part of all future specs for pressure mounted units. Although it is contrary to Signal Corps policy to specify manufacturing methods, we know of no other practical way of

Crystal Specifications (Continued)

specifying the thing we want in this case.

2bQ If so, how soon will that requirement become effective?

A As soon as possible - exact date to be determined at this meeting.

2cQ How much etching will be specified?

A Enough to increase the frequency of a 4 mc AT cut plate by 10 kc or of an 8 mc BT cut plate by 25 kc.

3 Q Has a satisfactory test been devised to determine a properly finished crystal?

A No. None which can be written into a specification and conveniently applied by inspectors.

4 Q Can edging of crystal be applied at any stage in the etching procedure, or after etching has been completed?

A Yes.

5 Q If edging after or during etching is permissible, will the edging procedure be specified now or in the future?

A Any edging procedure may be used which does not employ a loose abrasive and which does not abrade the major surfaces of the oscillator plate in any manner.

6 Q What is required or recommended pre-etching technique?

A No special pre-etching technique is required. This is in accordance with the SC policy of not specifying manufacturing methods except where absolutely necessary.

7 Q What cleaning method after etching will be specified?

A No cleaning method after etching is specified. However the units must be capable of passing the presently prescribed scrub test except that the cleaning procedure required under that test is changed so that a carbon-tetrachloride rinse is not required. However, the oscillator plate must be rinsed in some degreasing agent.

8 Q Will any other method of finishing besides etching be satisfactory? Will the milling method be satisfactory?

A The Signal Corps knows of no other method of finishing which produces units as stable as does the etching method. The

Crystal Specifications (Continued)

Signal Corps does not believe the milling method is satisfactory. However if it can be conclusively proven to the Signal Corps that some other method produces oscillator plates as stable as does the etching method, such a method will be acceptable.

9 Q Is standardization of crystal holder design and material is contemplated? If so, when will standardization become effective? And what type of holder is contemplated?

A Standardization of crystal holder design and material is contemplated. The Signal Corps is committed to a program of housing all AT and BT cut oscillator plates in hermetically sealed holders. The first part of the program will be to get all units so housed. Standardization will then be attempted. It is desired to have all production hermetically sealed by 1 January 1945. Standardization should be effective 1 July 1945.

10 Q When will Seal Test Equipment be available?

A Seal testing equipment will be available as follows:

a. Equipment to test crystal units housed in Crystal Holders FT-241, FT-243 or the Holder of the CR-1 Unit, will test 44 units at a time; Priced at about \$725. Delivery starting about 1 August.

b. Equipment to test any Signal Corps type crystal for which the hermetic seal test is specified, will test 110 units at a time; priced at about \$800. Delivery starting about 1 August.

11 Q Which governs inspection? Inspection Manual 9A, Contract, or Specifications? And in what order?

A First, the contract, second the specifications mentioned in the contract, and third the inspection manual.

12 Q Are not type test limits too stringent considering errors in meters, variations in test sets, variations in ambient temperature, and inherent defects in crystals?

A The Signal Corps considers that the type test limits set forth in the American War Standard for the CR-1 and in tentative Signal Corps Spec. 71-3046 dated 6 March 1944 are not too stringent. However the following are too stringent with the exception that Par. E-11 of tentative Signal Corps Spec. 71-3046 shall be made to read: "After the test specified in F-15, there shall be no resultant electrical or mechanical damage to the crystal unit. Marking shall be legible but discoloration or running of the marking is not to be considered as mechanical damage. The d-c resistance between the pins of the unit shall not be less than 100 megohms, when measured as specified in Par. F-15." This changes the present specification by eliminating the need for determining changes of frequency and activity of the test, and further states that discoloration or running of the markings is not cause for rejection of the unit. Furthermore because of the present criticalness of production and inability of several manufacturers to meet the needs of the Armed

Crystal Specifications (Continued)

Forces, the Signal Corps is forced to make certain waivers in some cases.

13aQ Why was 90°C chosen for immersion test when units are only required to operate up to 70°C?

A Because units may encounter temperatures of 90°C under service conditions either while operating or while idle. Any permanent damage to the crystal as a result of such temperatures may ruin it for further use; however, failures shown up in the temperature run are only temporary.

13bQ If 90°C is required should there be a requirement on permanence of nomenclature?

A The nomenclature should be legible after the immersion test even though the coloring material used in the lettering has run or disappeared.

14aQ What is opinion of Laboratory on corrosion?

A Any corrosion is bad; the laboratories feel that there should be an absolute minimum of it in Signal Corps crystals.

14bQ How much corrosion is excessive?

A We of the Crystal Branch leave the decision as to what is excessive corrosion up to specialists in that problem.

14cQ What steps can be taken to insure that units will pass the corrosion test?

A The use of stainless steel of 18% nickel silver pins and of stainless steel or nickel plated brass screws, will go a long way toward permitting units to pass the corrosion test.

15 Q At least three units or 10% of units tested for activity in temperature cycle, should be permitted to allow production to proceed. Will this be allowed?

A No, this cannot be allowed since under such a plan the Signal Corps might accept an appreciable number of units which even at the time of acceptance would not operate the radio equipment. However as pointed out above the Signal Corps may grant certain waivers under present contracts in order to keep production up.

16 Q What happens when a unit fails one of the Acceptance Tests? Is it carried over to other tests? Not considered in other tests? Or replaced after a failure in one test?

A Under the present American War Standard CR-1 and

Crystal Specifications (Continued)

Tentative Signal Corps Spec. 71-3046 all units are required to be subjected to all acceptance tests. However we now feel that this is not necessary but do feel that the following method is the most lenient that can properly be applied.

Sample Selection and Test Routine. Each of the Acceptance Tests shall be performed on thirty crystal units, selected by the inspector from each lot of 1000 units or less submitted by the manufacturer, except that only 10 units shall be subjected to the Immersion or alternate Immersion and Seal, Cleaning Test, and the Internal Inspection Test. Different groups of 30 units may be used for the various tests, except that Drop, Vibration, Seal and Immersion Tests shall be performed on the same group in the order listed. However if a unit fails the Drop Test, it will be replaced by a unit similarly selected at random, for the Vibration Test.

If it is agreed by manufacturers represented here that this is in fact a relaxation and will not be the cause for increases in price, a change to this method need not be negotiated by the Contracting Officer and the inspector will be instructed to apply such a procedure immediately.

17 Q Is a destructive test, such as Drop Test, advisable or necessary?

A Destructive tests, in general, should be kept to a minimum although they cannot be completely eliminated. The Signal Corps does not consider that the eight inch "drop" test is destructive. If it be a destructive test, then the subject units are so fragile that they cannot be considered satisfactory for military use.

18 Q What can be done to clarify internal inspection test procedure?

A The Signal Corps Inspectors will work out with manufacturer's standard defect boards. Then the Signal Corps Inspection Agency and the Signal Corps Laboratories will correlate these boards.

19 Q When units of paragraph F-6h are re-tested and re-submitted to Inspector, does the Inspector again perform all Acceptance Tests on all units? And if so, why?

A Yes, the Inspector again performs all acceptance tests on all units. This is necessary since the inspector does not know the history of the units between the time he returned the units to the manufacturer and the time they are again submitted to him.

20 Q Paragraph 98-e(2), page 63, of Inspection Manual 9A is interpreted to mean that a receiver must be used in making

Crystal Specifications (Continued)

the tests outlined and that a comparison oscillator or a deviation meter may not be used. Is this interpretation correct and if it is correct why can't a comparison oscillator or deviation meter be used?

A Paragraph 93-3-2 states that signals from a crystal test set and from a comparison oscillator be fed into a receiver for determining frequency deviation. If the comparison oscillator has been accurately correlated to the standard crystal test set, the desired method will be satisfactory since a deviation meter is nothing more or less than a receiver with a special device connected into the output for measuring frequency. However equipment for checking correlation consisting of a receiver capable of being tied with WWV multivibrator, a standard crystal test set and an audio oscillator must be available for checking correlation. It is to be checked at the minimum passing point for activity and at the maximum allowable frequency deviation. If the manufacturer will supply the above equipment, and can demonstrate to the satisfaction of the Signal Corps inspector that the above equipment is in correlation, there is no objection to using the deviation meter method. Once the correlation of the equipment has been demonstrated, however, it will still be necessary for the Signal Corps inspector to check his zero standard at least once a day before testing.

21 Q Is the binding of upper or lower contact strips, or both, of sufficient seriousness to warrant rejections?

A If units contain contact strips which are so large that they bind on both sides they should be rejected. If the contact strips are properly sized but are so displaced that they bind against one side of the holder, this is a sign of poor workmanship and should be corrected.

22 Q Just how serious is an "off center" spring and is there any definite pressure required?

A The "off center" spring is not particularly serious, but is a sign of poor workmanship and should be prevented. The spring force specified in applicable specifications is required in each case.

23 Q What is the effect of gaskets being less than flush to side of holder, say 1/32"?

A There is probably no serious effect if the gasket of a given unit departs from flush with the side of the holder by 1/32". However, if it does so this is one evidence of poor workmanship and should be corrected.

24 Q Can definite limits be set for permissible drift

Crystal Specifications (Continued)

in activity and frequency of the crystal units?

A No limits of drift are stated under contract specifications. The unit should at all times throughout the temperature run stay within the specified tolerance for frequency and activity.

25 Q Are pencil marks on plated crystals harmful?

A Pencil marks may not be particularly serious, but if they are accidental they are a sign of poor workmanship, and should be prevented. If they are placed on the plates as a normal manufacturing process, the Lab should be advised of this and furnished with sample units for test.

26 Q How objectionable are small chips, and small areas that have been chipped and plated over, on plated crystals?

A The degree of objectionableness of small chips and small areas that have been chipped and plated over is hard to determine. However they are examples of poor workmanship and should be held to a minimum. It is suggested that the proposed Standard Deviation Boards to be set up include at the plants that are manufacturing plated crystal units, examples of such units. These should include samples showing good and bad units with regard to chips. The inspector and manufacturer should get together on what they feel would be good plated units. Later the SCIA and Laboratory can correlate such boards between the several manufacturers that are delivering such unit.

27 Q If the contractor is not at present polishing electrodes, what procedure is Signal Corps Inspector to follow?

A Polished electrodes are not required by specification. Therefore if the contractor is not polishing electrodes, the Signal Corps Inspector need take no action.

28 Q How much of a blow should be used in tapping crystals for check of activity and activity drift?

A With the exception of the crystals housed in holder FT-241-A, no tap test is specified for crystals under current Signal Corps contracts.

29 Q Could definite arrangements be made to have the Standard Oscillators sent directly to the Signal Corps inspector at each crystal plant?

A Test Sets AN/TSM-1 are currently being shipped to the Signal Corps Inspector at the Crystal Plants. At such time as the Laboratory has an additional number of good test sets of other types, they will be handled in the same manner. The following method of handling the matter is proposed.

Crystal Specifications (Continued)

A reference standard crystal test set is one which is furnished to the Signal Corps Inspector in Charge at the plant of the manufacturer for use in correlating production test oscillators.

One reference Standard Crystal Test Set of the type specified on Crystal Specification Sheet, will be furnished in accordance with the applicable Crystal Specification Sheet. It is to be used only as a reference standard for correlating production test oscillators and equipments. The crystal manufacturer shall make no changes, however small, including changing of tubes or recalibration of the Reference Standard Crystal Test Set without consent of the contracting officer, or if the prime contractor supplies the Reference Standard Crystal Test Set, consent of the prime contractor is necessary.

30 Q Is brownish discoloration due to rust stain on the interior of the tube shield or cover harmful to the plated crystals?

A The brown discoloration is rust and is likely to cause failures if particles of iron oxide should fall between the electrodes and the crystal plate. Therefore, units with this discoloration should not be accepted. Furthermore, this discoloration is an indication of poor workmanship or poor materials and as such should be prevented.

31 Q Will limits other than of $2\frac{1}{2}$ to 6 pounds be acceptable for spring force used in crystal units, if it can be determined that the units meet electrical requirements?

A The limits on spring forces mentioned in specifications, must be complied with, even if it can be demonstrated that the units meet the electrical requirement. However, the Signal Corps will entertain a discussion of the propriety of the specified limits as the exact value chosen is slightly arbitrary. This discussion must be limited to the general case and not the product of only one manufacturer or to only one contract.

32 Q When are preproduction samples required? Will approval given on a group of samples for one type, as the BC-659, hold for another type as the BC-620?

A Both the American War Standards for the CR-1 and Spec. 71-3046 require that crystal units in the grades and types called for in the contract, be submitted prior to production. For crystals housed in the Holder FT-243, a type is interpreted to mean a unit for operation in a particular radio set. That is crystals for the BC-659 and for the BC-620 are different types. A manufacturer who may be able to meet the requirements of one radio set may not necessarily be able to meet the other. Therefore, under the specifications, preproduction samples of each type of crystal for each radio set is required.

33 Q Is the glyptol that is used on the threads of the case assembly screws used as a locking agent, or as a corrosion protection?

A Glyptol is used now primarily as a locking agent; however, it does offer corrosion protection and it would be wise when using it to completely cover the metal parts. However, failure to completely cover the metal parts should not be construed as non-compliance with specifications.

34 Q Due to the fact that acceptance of FT-243 Crystal Units is to be made on the basis of acceptance test listed in specification 71-3046, is it necessary that each unit be inspected for activity and frequency at room temperature?

A The specification does not require that each unit be inspected for activity and frequency at room temperature. However the specification does imply that the government inspector will check "the manufacturer's production test in order to assure himself that the tests meet the requirements of the specification". Subjecting all units to room temperature for activity and frequency is one method whereby the inspector may assure himself that the units meet activity and frequency requirements.

35 Q With reference to F-16 of referenced specifications, "Cleaning and Internal Inspection", it is requested that the question as to what constitutes an acceptable finished surface of the quartz plate be clarified.

A Originally the Signal Corps was afraid to accept crystal units in which the blanks were badly chipped, scratched and fractured, for fear that such defects might have some effect on the aging characteristics of the unit. However now that we have carried on investigations on aging to the point where it is known that units which are etched to final frequency will not age materially, we are no longer governed by this fear. To determine compliance with the requirements contained in Par. C-9 in tentative SC Spec. No. 71-3046 and in the corresponding paragraph of the AWS for the CR-1 it is planned to set up Standard Defect Boards on which will be shown units which should be rejected for chips, scratches, fractures and cracks. As pointed out above, however, the Signal Corps will now accept units which are much worse in this respect than were formerly accepted.

36 Q When will an up-to-date copy of Signal Corps Spec. 71-3046 be issued which will contain all the latest deviations?

A A new issue of Spec. No. 71-3046 will be prepared which will include changes in methods and changes in specifications agreed upon at this conference. The exact date of issue cannot be stated; however those changes which are a relaxation of the present specification will be effected through changes in Inspection Instructions as soon as this can be done.

37 Q Reference is made to Par. F-15a of Spec. 71-3046 dated 6 March 1944, which substitutes a modified immersion test in lieu of the hermetic seal test when the manufacturer does not have the proper facilities. Is it intended that the manufacturer will have to perform this test as a production test on each crystal unit

Crystal Specifications (Continued)

submitted to the Signal Corps inspector?

A It is not intended that the manufacturer will have to perform the modified immersion test in lieu of the hermetic seal test as a production test on each crystal unit, but rather that it will be applied as an acceptance test.

38 Q In Par. F-14 of Spec. No. 71-3046 what is the meaning of "The frequency of the applied vibration shall be varied at a uniform rate between approximately 10 and 55 cycles per second, the cycle of frequency excursion being between one and two minutes"? Does this imply a sinusoidal or linear variation?

A What is intended here is that the frequency shall be varied at an approximately uniform rate in a linear manner. However this is not critical. The specification will be changed to read, "shall be varied at approximately a uniform rate".

39 Q Will the new print on FT-243, CR-1 and DC-34 Holder be general, or will it cover all present variations in design?

A So far as the FT-243, and DC-34 are concerned the new print will be general until such time as a standardized design is determined for hermetically sealed holders. The same applies to the CR-1.

40 Q What allowance is made for a drifting crystal when encountered in a type test where it would drift beyond the type test tolerance but still not drift beyond the production tolerances?

A Test procedure set up to measure changes of activity as a result of a particular type test should be such that the before and after tests are performed under the same circumstances, thereby eliminating the affect of this drift. This may in some cases require that the manufacturer provide special test equipment capable of being used in such a test technique. Air conditioned rooms of equipment for soaking at some particular temperature near room temperature may suffice.

41 Q Are rutile needles cause for visual rejection?

A No.

42 Q Can Laboratory-built seal test equipment be used if it is proven adequate?

A Yes. However it is likely that difficulty may be encountered in proving that it is the equivalent of items available on the market. It is not enough that the equipment be capable of making the test, but it should make the work of the inspector making the test at least as easy as other items now available.

43 Q Are all oscillator plates required to be etched or

does this pertain only to oscillator plates above 4 megs?

A Eventually it is planned to require that all oscillator plates be etched. However the immediate requirement is directed only to those plates above 4 megs. However, if one type of crystal unit has frequencies extending from below 4 mc to substantially above 4 mc etching is required. The DC-34 and DC-35 do not now have to be etched. All FT-243's do have to be etched.

GROUP DISCUSSION OF DC-34 AND DC-35 CRYSTALS
CAPTAIN E. F. MITCHELL - CHAIRMAN

THE CHAIRMAN: The meeting will come to order. I think we are now, very definitely, to the place where it is only a matter of questions from you folks, but I'm happy to entertain suggestions from you.

MR. ORMONT (Keystone): In the March specification, part of the type test has provisions for temperature run to be made by the Signal Corps and inspected as part of the acceptance test. In view of the fact that the correlations may be off and only one failure is permitted, I would like to suggest that we have a tolerance allowed. In other words, on the crystal disk we may not catch it, or we may catch one or two that might dip.

... Off the record discussion ...

THE CHAIRMAN: Let me point out that we need the thing we specify. If you can give it to us, fine. We do know this; unless we have continuous, recorded runs, dips will occur which may or may not be caught by the person checking those crystals. It may be rerun and caught on the next run. There is that possibility. You have not attempted to work under this specification?

MR. ORMONT: We have run several runs through on this specification, probably half a dozen.

THE CHAIRMAN: Do those half dozen runs represent six thousand units?

MR. ORMONT: Oh no, no, no! We simply took, for instance, what we are currently running which are under the old specification and applied the March specification to them.

THE CHAIRMAN: What did the older specifications --

MR. ORMONT: We didn't have that included.

THE CHAIRMAN: So far, I don't think it is a question for discussion.

MR. ORMONT: We can leave it either way.

MR. WALLACE (Indiana): I agree that it is a real problem.

MR. LEUCK: We have a file on that. On the previous contract, our inspector was instructed to make exactly the same type of careful job of running the temperature run. He could pick one up very easily.

THE CHAIRMAN: What eventually happened?

MR. LEUCK: We got a clarification of the rules with an inquiry in this type test. We didn't get an answer.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. WALLACE: The way the temperature run is made, according to the new specification, at 2 degree interval, it is impossible to have the inspector follow the same logical way that the original operator ran. There may be a lag of a degree or an increase of a degree. As a result, you might just dip out and you have to throw out all your crystals.

MR. HENDERSON (Higgins): In the rerunning temperature we have found that just about ten per cent will be found and will be caught in the dip.

THE CHAIRMAN: Are you talking about DC-34 and DC-35 or crystals in general?

MR. HENDERSON: I am talking about DC-34 crystals. However, I have found the same thing in 243. It shouldn't be put beyond the additional one out of thirty being run.

THE CHAIRMAN: But it would be, of course, taking the full ten per cent. Let me ask this question. Is it implicit, in this discussion, to lower the requirements? What can you do to evade this difficulty we are faced with? It is a fact that we have a test here which is not reproducible. There is no argument. We do have such a test. The only way to avoid it is to specify continuous measurement of activity. We don't want to ask it because, obviously, it is impractical. You are suggesting we lower the limits on the rerun. That isn't the way the specifications are written. What have you done to raise your production limits?

MR. ORMONT: Practically every one of our crystals which go in for a run have requirements of 11. We start not lower than 14 to 15 or 16. Our rejection limit is about $12\frac{1}{2}$. If they go below $11\frac{1}{2}$ at any temperature, they are rejected. However, I still say I have seen it, and many times, that crystals will go to as low as .06 and will not be caught by the operator, and will be caught later on the rerun.

THE CHAIRMAN: I appreciate that.

MR. ORMONT: Frankly I don't know what the answer is. I thought I'd bring it up and see what could be done about it.

MR. HENDERSON: It seems we are all, more or less, in the same boat. With what we are working with at the present time, we are not confronted with temperature runs. The older specifications we are now using are still anticipating that, and what we are doing is attempting to train our operators to watch for erratic operation which is a cause for rejection even though they don't catch the activity reading before the rejection point. One that is habitually erratic during the cycle of the wheel is a cause for rejection, and while we have eliminated it one hundred per cent, we have yet to go a long ways.

THE CHAIRMAN: Do you use as the rejection point, the specified

Group Discussion of DC-34 and DC-35 Crystals (Continued)

minimum or a higher point?

MR. HENDERSON: A higher point.

... Off the record discussion ...

MR. HERBERT HOLLISTER (Hollister): Even if we had a check every minute, we would not catch them. We find if we have an operator watch for the creeping of a meter, hands up or down check, every minute, we can practically stop this trouble. She then stops the wheel and observes whether the crystal is coming into or going out of the dip.

MR. WALLACE: I think all of us who manufactured 34's and 35's would be really happy if we knew the dimensions; if it were worked out so we didn't have extreme dips. That's a logical solution. We don't want to manufacture something to change the specifications, but in order to maintain production we don't know the answer as to why they don't dip out dimensions. Most of us haven't done enough work to know what the dimensions should be or how dips occur. If we knew more about it, or could get information we'd be glad to stick without any questions.

MR. V. BOTTOM: If we had the information, we'd be glad to give it to you. Pre-dimensioning is not a simple matter. We at the Laboratory and many of you men know how to find dimensions that will work. You can tell a man, write it out on paper, and give it to some manufacturer who goes home and tries it, and the next week he will call you up and say, "I can't make it go." Pre-dimensioning supposes you are going to do certain things; you are going to hold certain tolerances. Some of you can't hold those tolerances. You make random corrections and it is easier for you to do it that way than to hold the necessary tolerances that you have to do in order to get pre-dimensioned crystals out. You just can't say, "Here are the dimensions. Take them and use them."

MR. HOLLISTER: I think when you introduce pressure and some variation of spring pressure, you again come in out of the rain and you are anxious to get out of them.

MR. BOTTOM: I think we are all perfectly willing to admit there is more about pre-dimensioning that we don't know than we do know. If we get any more information than we have at the present, you will get it. I am sure you can't get it any place at the present time -- a set of figures to which you can make crystals. There are other causes of activity dips than just plain dimensions. Bad electrodes will cause excessive rejections in the temperature run. The springs may be too weak; the crystals not flat. Improper air gap spacing and air resonances play a part in this phenomena. Dimensions are only one factor in it.

MR. RALPH HUKILL (Quartz Laboratory): We have worked out twenty-four dimensions out of a possible forty-five. We will go ahead and work

Group Discussion of DC-34 and DC-35 Crystals (Continued)

out the others, and the people who have the same frequencies we have will do the work we have already done. It would save a lot of work if we could pool this information.

THE CHAIRMAN: A fine suggestion, and I suggest that you give us the information and also give the prime contractor the information. He can operate with his people faster than we can.

PACIFIC RADIO CRYSTAL: Each finisher has a heated holder that is constantly kept at 70 degrees, which brings the crystal to minus two or three KC when given a heat check. Then the operator begins a correction and by the time she has brought the crystal into frequency, she usually has all the dips out of it. We have very few rejections, practically none, in the type test.

MR. ORMONT: It has never been required heretofore. The temperature run was not part of the type test.

THE CHAIRMAN: It has been known for a good while, hasn't it? If there is something you can do to beat this and you are not doing it, I think you are negligent. It is pretty generally used.

MR. BOTTOM: Let's discuss what one can do. There are several tests one can use for the crystal to find out if there is likely to be any rejection for instability. You can throw a greater capacity across the crystal. You can't always tell whether a crystal is going to be a stable crystal or not, but you can throw out a lot of them you know aren't going to be. Another thing, if the operator has the type of holder to increase the pressure on that crystal, a lot of unstable crystals are going to show up immediately.

MR. ORMONT: We do that.

MR. BOTTOM: Increasing the shunt capacitance on any crystal will decrease its apparent activity. Some stop oscillating at one value of shunt capacitance and some at another. The greater the value of the critical shunt capacitance, the better is the unit. A crystal is less likely to have an activity dip and therefore more likely to go thru the temperature run if it will operate into a high capacitance.

Some crystal plates are very sensitive to pressure. If the activity drops badly or the frequency shifts when pressure is applied, it is poorly dimensioned.

The third suggestion of a quick temperature run is a simple means of eliminating many potential failures.

By these three tricks many of the "duds" can be eliminated at the finishing position. There may be other tricks as well.

MR. HOLLISTER: There is one simple rule. Until the finisher realizes this, he will be juggling back and forth with these humps but not controlling them. Z grinding will raise the hump up in temperature and X grinding will lower it. Therefore you do stop somewhere before

Group Discussion of DC-34 and DC-35 Crystals (Continued)

you get to frequency, and if a hump is as high as 60 or 70 degrees, you can bring Mr. Hump down where he causes the trouble so you can move him out.

MR. HUGO: We tried the cart before the horse procedure. We took strong crystals and instead of shipping them to the armed forces, dismantled and measured them and tried to duplicate them, and that way we found some dimensions which seem to stand up over several different cases. We eliminated some of these three steps of yours.

MR. LOUIS PATLA (D. X. Crystal Co.): You can cut down your rejections from about 35 per cent to 12 per cent. Many people are inclined to overlook the fact that it is harder to do, but I believe that it is the one thing which will go a long ways to cut down temperature box rejections.

MR. BOTTOM: Dimension X, or rather, parallel to X, is a critical one. I am aware of that because of flexure vibration. I don't mean X dimension. It has to be kept quite close.

THE CHAIRMAN: Are there any other comments?

MR. BOTTOM: We have, at the lab, prepared a memorandum on which two or three people have been complimentary enough to say that it did them some good on the methods of finding dimensions. We have given it to a number of people who have asked for this information. If the memorandum is of value to anyone, we can supply it. I am sure you can tell anyone how to do a thing in simple phrasing.

MR. ? (Monitor): We had considerable trouble in reproducing the same results in the temperature runs on not only the 35'S but on others. Realizing the equipment might be off correlation, we tried to run a number of crystals through the temperature runs, over and over, and we found that we do reproduce pretty fairly the same results on the same crystal if the reading is taken closely enough. I found the temperature correlation one of the important factors, and so we are following a process of taking a rejection, that is when a dip or crystal has a tendency to look like it is right near the rejection point, to eliminate the possible error in the equipment, we have tried to test the crystal in the test standard and check it to see. It will, quite often, be found that there is a slight variation in voltage which causes that trouble.

THE CHAIRMAN: We have here a test which is not reproducible. By that I do not mean that these temperature dips are not reproducible, but simply that when you test at degree intervals you do not get the same play in dips all the time. If a dip is due to the oscillator plate, it is reproducible.

MR. LEUCK: Those dips that we have noticed are not really bad and are of very short duration -- a matter of ten or fifteen seconds. I am speaking of the DC-34 temperature dips if you are making a half

Group Discussion of DC-34 and DC-35 Crystals (Continued)

hour run. In a thirty minute run, it would be a fraction of a degree, possibly a half or a quarter of a degree. It is very possible to have the crystal perform perfectly ninety-nine per cent of the time, and dependably, but you will have that dip there one or one-half per cent of the time. They might be ninety-nine per cent good or ninety-nine and one-half per cent good.

MR. ORMONT: Might I suggest this? I think the point is important, but I also think all of us should gather some data on it. I think that we should take the results of at least half a dozen type tests. In other words, six thousand crystals are not the number of failures in this particular case. If it becomes alarming, perhaps then we can take some steps to modify or correct, if possible. I mean, there is no specific data available now, but we do know or, that is, we think it is a point which will come up.

THE CHAIRMAN: How near are we to operating under this specification? I don't know. Will the whole thing evolve upon us at once? Or will it be gradual?

... Off the record discussion ...

THE CHAIRMAN: I think the suggestion on the first few experiments with them is very good, but we may be able to get some dope out of it which will enable us to make an engineering solution.

MR. ANDERSON: We are within a few days of going under that spec. If it is the opinion of some of the fellows that you can take a group of crystals made up under the old spec, you can gradually eliminate at least fifty per cent of the lot because of activity variation.

MR. APPLEBAUM (John Mech. Ind.): We age crystals the old-fashioned way to eight cycles to accomplish that same result. It doesn't help considerably. The dips still do occur. It appears that the age of dips on DC-34, under the present high minimum activity limits are far greater than on any other class of crystal.

THE CHAIRMAN: This morning when I was talking about crystals with critical activity requirement, I was talking specifically about the DC-34. That's why I can hardly ask you to make this production fifty per cent higher than the specification. That's why I am extremely hesitant about lowering the limits in any respect, when actually I need that activity. We knew the crystal was going to be hard to make. Therefore, we are going into the program gradually. I suggest that we see what happens when your plant is ready to go.

MR. MOSSHART (Elec. Products Co.): We wrote up a rather extensive procedure of operation. How closely are we holding to that procedure?

THE CHAIRMAN: The manufacturing procedure?

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. MOSSHART: The written one.

THE CHAIRMAN: You are not bound by that, but we would like to be advised when you change it, partly because we think sometimes we can avoid pitfalls for you and partly because of the process of learning for us.

MR. APPLEBAUM: In the higher frequency of 34, would there be any objection on the part of the Signal Corps to use the BT cut instead of the AT cut, and too, could we reduce the etching time, or the distance, because it does alter the surface? It reduces the surface to a rougher surface which, in turn, reduces the activity.

THE CHAIRMAN: We have not asked that the etching be required, but you can get your production rolling on this basis without worrying about the etching. I have done that purposely because the aging of these units is not as critical as the aging of higher frequency units. You know we will want it in the end and will go into it of your own volition in a way best calculated to fit into your production schedule. The DC-34 isn't as critical as higher frequency units. That isn't pertinent. You can finish crystals if you have them. In the meantime, I suggest you find out what to do when we do ask for etching.

MR. APPLEBAUM: We considered we are required to etch them a minimum of five KC, and we have in there only AT cuts. We have made some experimental runs with the BT, especially the 3900 and 4000 KC channels which are particularly difficult for us.

THE CHAIRMAN: Are you ready to go into the new specification or not?

MR. APPLEBAUM: I am talking about operating under the old specifications.

... Off the record discussion ...

THE CHAIRMAN: You should immediately alleviate this condition.

MR. ORMONT: I assume that when we start on the new contract there will be a new pilot run?

THE CHAIRMAN: Yes.

MR. ORMONT: I wanted to bring up one subject. During the last pilot run the very small matter of bevel crystals came to the fore and was slightly clarified after a fashion, and I just wanted to bring it up again now so we will know what to expect.

THE CHAIRMAN: You can expect the same thing you had the last time. Again, a sharp bevel is something hard to define. If it is a knife bevel it is a weak unit.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

QUESTION: What happens to a beveled crystal when it is etched?

MR. BOTTOM: The same thing that happens to any other crystal. The bevel does not appear to make a difference. The quality of the surface is important not the geometry of the surface.

MR. ORMONT: We have done a little bit of experimenting as far as etching is concerned. We haven't been able to eliminate scratches and we wonder if there are any suggestions along those lines.

MR. BOTTOM: Scratches are ninety-nine per cent a problem of your housekeeping. There are plenty of manufacturers who do not have scratches at all. There are people making crystals without scratches.

MR. ORMONT: We have isolated special crystals, cleaned them and still do get scratches. The point is, I don't know how the Signal Corps inspector is going to interpret the scratch clause. We will eventually go into etching.

THE CHAIRMAN: When you do go into etching, the interpretation of the scratch clause will be less rigorous than it has been in the past. We interpreted very rigorously, because we felt that there was a connection between those scratches and aging. We now feel that if you are performing the etching we require, the crystals will be, for practical purposes, aging free. Rejections of lots of the crystals, based on those scratches, will be exceptions, and if you are showing a true effort to do housekeeping you need not worry.

MR. HANDWERG (Galvin Manufacturing Corp.): We passed over this one point now, that is the rejection of the temperature run and type test. It is checked for activity by the inspector for acceptance. We know the problem of short dips. Is it your thought, though, that we will grow into this thing gradually on the new specification and be granted a preliminary waiver on requirement six? There is only one rejection that the spec calls for as the spec now stands.

THE CHAIRMAN: I was suggesting that you not be granted any waivers on information developed the first two or three runs.

MR. HANDWERG: In other words, the spec stands?

THE CHAIRMAN: Yes. I think we got the meat out of that discussion. I don't know what the answer is going to be, but I hope we can get some definite indication out of the first pilot runs before the rest of you are ready.

MR. ORMONT: I understand they are holding up the registering of proper nomenclature on this present contract. As much as we are ready for a pilot run, we haven't been able to order cases because of that. I wonder if you know how soon it will be?

THE CHAIRMAN: I was not aware of such a problem.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. ORMONT. With the code numbers coming off, the manufacturers' name will be going on. Nobody has decided the size of the manufacturer's name to be printed on the case, so we are all waiting.

MR. HANS SAUER (The Hallicrafter Co.): I suggest a DA smaller carrier.

THE CHAIRMAN: If it jibes with the old FT-243, it presumably will be the larger. My guess is that it is acceptable.

MR. HASLEY (Wenkstern Hasley): I have tried several times to get holders for samples with code letters on, and then was told that the code letters wouldn't be acceptable; that we have to have our name on. So, I have gotten McKinzie & Wright Stamping Company to make up a die with our name, "Wenkstern and Hasley Company", on it. I told him he didn't need to spell out "Company" and he got it all on one line between the screw holes. It looks pretty nice.

MR. ORMONT: The main point, however, is that still our company, as well as several others, are ready.

THE CHAIRMAN: How about pre-production samples? Don't hold them.

MR. HENRY (Henry Manufacturing Co.): How about holders that already have the code name on them?

CAPTAIN E. A. BELL (Signal Corps): Those holders you have, go ahead and use them.

... Off the record discussion ...

MR. APPLEBAUM: Does the prime contractor's name or the subcontractor's name appear?

THE CHAIRMAN: The manufacturer's name.

MR. ORMONT: When do we expect to get the pilot run?

MR. SAUER: Pre-production samples are going to be worked on this week at Hallicrafter. After that time, you can notify us and we will state when the pilot runs are going to be in. As soon as we have available personnel, we will start.

THE CHAIRMAN: We are awfully anxious to find out how the first pilot runs go.

MR. W. SCHEPPELE: As soon as you get approval on the pre-production samples, without waiting for the pilot run, automatically we will begin to accept crystals. When the pilot run is started we will accept crystals up to midnight of the day the pilot run is declared. From then on, they are not accepted without approval from the engineer.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

THE CHAIRMAN: May I point out one thing in connection with what just has been asked as to pilot runs and production? We need crystals and we can make this arrangement. If you take advantage of that, and I'm not suggesting that because maybe you wouldn't like it. I'm only suggesting that you take advantage of it in that way. Otherwise, if you take advantage by starting your production before you get pre-production approval, on the theory we are going to have to take the crystals, we are both going to get into trouble. Let's get pre-production samples in and see if you are doing the job. We have had this happen. Even before pre-production samples were approved, we have known people who have built up a tremendous volume of units. It's heart-breaking to either or both of us sometimes.

MR. ORMONT: We can't actually make crystals anyway until we find out the story.

THE CHAIRMAN: Are there any other problems?

... Off the record discussion ...

MR. ANDERSON: We can, after the pre-production samples are approved, make crystals and submit them to the Signal Corps for inspection and ship them to the prime contractor in anticipation of the pilot run at some later date?

MR. SCHEPPELE: That's right. At the time you receive approval of the pre-production samples, you may, at the same time, receive a telegram giving the date of the pilot run. If the date of the pilot run is in the future, you may go ahead and make the crystals and we will accept them until that day the pilot run starts-

MR. ORMONT: In testing some of the units in this new immersion test up to ninety degrees, we ran into the problem of these stainless steel screws, or rather nuts, corroding. We took the problem up with Sauer and he gave his interpretation on the fact that where the corrosion can be wiped off with a rag, where it is loose corrosion, they would be acceptable. Now, I thought it might be a point to bring up here.

MR. HENRY: There are different types of stainless steel. Is there any specific type required?

MR. ORMONT: Yes, 18-8 is required in the specification.

THE CHAIRMAN: If it is really stainless steel, we are going to have to work out the answer.

MR. ORMONT: I took it up with several people. It is really stainless steel. It seems as though it is kind of uncommon.

THE CHAIRMAN: We will say it is okay.

MR. WALLACE: In your previous talk in the other room, you

Group Discussion of DC-34 and DC-35 Crystals (Continued)

warned us that we weren't to use, if possible, any more holders with brass contact plates. I happen to have 15,400 holders with brass contact plates, and wonder whether we should junk those holders or use them up in the next two months.

VOICE: Sell them to Hitler! (Laughter)

MR. HANDWERG: I'd like to add that the DC program moved a lot slower than we expected. Our suppliers have a substantial quantity of holders manufactured months ago which have brass contact plates. Now, where they are buying current production holders, you are supplied with phosphor-bronze. What are we going to do about that?

MR. BOTTOM: Is it feasible to change them?

THE CHAIRMAN: Gentlemen, the technical answer is clear-cut. If you can get replacements you should get them. The actual monetary answer is not so clear. I suggest that you get all the facts you can as to how many you have, if you can get replacements in time, and I think you probably can. Address the problem to the contracting officer. Get complete information on this and address a letter to the contracting officer stating, "We have this many holders being changed, but there will be an increase of so much."

MR. HANDWERG: We talked this over. We only confined the recommendation to 243 holders.

THE CHAIRMAN: When was that?

MR. HANDWERG: We wired a letter to our suppliers on 243 about two weeks ago. As yet, we have nothing specifically clear. We will clear the thing and have the information in your hands before the end of the week.

THE CHAIRMAN: Can we depend on you, Hans, for it?

MR. SAUER: Surely.

THE CHAIRMAN: About the possibility which is always present, you may have to use some or all of the holders. Maybe you can't get replacements. Although I said that baking was not the answer, it is a partial answer.

MR. BOTTOM: We know, perfectly well, baking out does partially alleviate this problem. I am not sure I know the best way to bake them. The holder manufacturer will know better how to get this material out. It is the ammonia that does the dirty work. You can bake it out at 160 degrees Centigrade. You have to do it in a pretty well ventilated oven or furnace or the contact plates will get black while doing it. If we have to use these things in the tropics, we ought to do all we possibly can to make it as nearly failure-proof as possible. Baking is the least we can do to recure these holders.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

I have baked them an hour and it reduces the defect at least fifty per cent.

MR. ORMONT: We can get specifications from the holder manufacturers for that.

MR. BOTTOM: That's the place.

MR. ? (Howard Mfg.): I think this is the first thing that came up on brass contact plates. In our plant we are using phosphor-bronze on all 34's. As far as baking, we found in quite extensive tests, that baking does make a great deal of difference as far as the gas is concerned, and we run over them in schedules from an hour on up, and we find that it takes about a twenty-four hour cure in baking in order to get the job done at 250 degrees Fahrenheit in electric ovens, closely controlled. It is slightly under blistering point. As far as our tests have gone, there is no more ammonia gas left in the holders when they are done. If it is a gas oven it won't work. The electric oven will. We have also found in some of the ovens we have used that during the first length of time in baking there was some corrosion shown on phosphor-bronze plate.

MR. BOTTOM: It is really discoloration. That's not serious. These brass plates will break from corrosion. They may be bright and shiny and still broken in two.

MR. HOWARD: As far as the pins are concerned, they will be nickel-silver.

MR. BOTTOM: Do you think it would be safe for the manufacturer to bake them twenty-four hours at 250 degrees in an electric oven that is ventilated?

MR. HOWARD: Yes, that would probably answer it. It is a question of having to be tested. Further, when we carry the test on in respect to hydrotropic tests, we find a great improvement there also.

THE CHAIRMAN: Just in case I haven't emphasized this, I want to do this. This one single thing scared me more, in our findings, than anything else. These other failures are relative. This is the gradual degradation of performance. This thing that we are talking about is that the unit is suddenly no good at all. They have used these units in places where there is a warm climate and conditions are aggravating. I am going to ask you to do what you can to help us control it. The first thing to do, if you can, is to avoid the use of brass contact plates. Do so by getting the data we discussed and presenting it to the contracting officer. A letter has already gone out. The second thing is this. If you get caught with units which have brass contact plates and which you have to use, bake them. I don't know what it will mean to you, but I think you have enough ingenuity to do that for us.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. HANDWERG: Do you want to specify any particular baking procedure? What are you going to recommend? Do you want the crystal manufacturers to bake the holders they now have in stock?

THE CHAIRMAN: If it is determined they are going to have to use them.

MR. HANDWERG: Make a recommendation so we can follow it.

THE CHAIRMAN: Bake it 250 degrees Fahrenheit for twenty-four hours.

MR. BOTTOM: These units are subjected to 60 degrees Centigrade for a period of 10 days. During that time half of the group of twenty of them were dead.

THE CHAIRMAN: If you can arrange for new holders, or holders with some other contact plates, that's what we want. This is to be used as a last resort in case you have to use the holders with brass plates.

MR. HOLLISTER: Do I understand that the holders purchased from this date forward will be baked by the manufacturer?

THE CHAIRMAN: I believe Howard's are.

MR. HOWARD: Yes. They are baked. From now on, they will not have brass. They will be all phosphor-bronze and nickel pins.

MR. HANDWERG: When did your shipment start? I have indication that some holders went out the early part of July with brass plates.

MR. HOWARD: I don't believe we have a problem at the moment. I do know there has been an order in that stipulated brass plates.

MR. HANDWERG: If we sent holders back to you for baking, do you have the facilities for a mass job?

MR. HOWARD: No, we don't. We might be able to arrange for it, however.

VOICE: We find in a 90 degree immersion test, the holders become highly discolored. Also the nomenclatures, or rather the ink in the depression seems to come off rendering it illegible and it looks like very poor workmanship. What should be done about that?

THE CHAIRMAN: The running of the markings should not be considered as a failure. Special instructions will go out as to that effect. For our specification we are going to require that the marking be legible after the test. This can be achieved if you are using the engraving process, which all of you are. Is that correct?

VOICE: It's hot stamping with white ink.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

THE CHAIRMAN: If all the ink is out, you can still read the thing?

VOICE: Afer a fashion.

THE CHAIRMAN: Is it capable of being read?

MR. ANDERSON: If we are going to deep run them together, it is so hard to read in the case of hot stamping.

THE CHAIRMAN: I don't know who cares what happens to the ink or the writing.

MR. ORMONT: What about the discoloration of the holder?

THE CHAIRMAN: We'll anticipate that.

MR. JIM KAY (Industrial Engineering): In our holder we bake it before, and we have found that twenty-four hours isn't necessary. In our different tests, it seems that after 120 degrees Centigrade for four hours we can't tell any difference in the various tests from four hours on. I thought you specified twenty-four hours in your specification.

THE CHAIRMAN: Actually I haven't written any specification. If you want to appeal to the contracting officer, you can.

MR. KAY: We use 120 baking Bakelite.

THE CHAIRMAN: I expect the material you used is pertinent in how much baking is needed. What is needed for one holder is not adequate for another holder. Do you have any with brass contact plates?

MR. KAY: No, stainless steel. We have always had stainless steel.

THE CHAIRMAN: Maybe you need more baking.

MR. KAY: I thought you were going to specify twenty-four hours, and we can tell no difference after four hours.

THE CHAIRMAN: The matter doesn't pertain to your holders. I think if the twenty-four hour basis would be used it would be desirable. I am scared to death I am being overly conservative about something to cause the crystal unit to fail at the moment the company commander is talking back to a battalion or regiment.

MR. APPLEBAUM: Why not suggest a test that they might run to determine whether or not the holders are defective.

THE CHAIRMAN: We are going to try not to use them.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. ORMONT: Everybody seems scared of holder manufacturers for some reason or another.

... Off the record discussion ...

THE CHAIRMAN: We are talking about units in your plant with brass contact plates. The only thing we are specifying for future production is that the contact plates be made of phosphor-bronze, stainless steel or copper. We haven't specified a bake and it hasn't been suggested here that we do. If you are doing it, I suggest you don't discontinue it. We will try to arrange for other people to do it also. The thing we are talking about is these holders which you have in your stock, and which you may have to use to keep up your production. If you have brass contact plates, the answer is bake them for twenty-four hours at 120 degrees Centigrade. You are still not complying with the specification we want which is that they will not have brass contact plates. But this is something you can do to help us take care of a serious situation. Is that a complete answer to this problem? Maybe you will get new holders.

VOICE: We will probably put in new plates.

THE CHAIRMAN: I hope you can.

MR. HANDWERG: Is it your thought to review the specification in detail?

THE CHAIRMAN: I just thought maybe some of the questions would come up. There are points in there which showed you how we plan to take care of them. Frankly, I doubt if it is necessary.

MR. HANDWERG: Let's see if a lot of these men have seen the March 6th Specification or not. I guess practically all of them have.

THE CHAIRMAN: Let's not start reviewing this then if they have seen it.

MR. ORMONT: Has the laboratory available a chart indicating the thickness to come off low frequency crystals -- etched off? Is that available?

THE CHAIRMAN: I will permit you to take one sheet out of this specification to look at.

MR. BOTTOM: We are fairly sure, today, that we know the basic facts about this aging, and this chart shows the amount of material that must be removed from a crystal in terms of frequency change following the lapping procedures in common use today, to get crystals substantially or completely free of aging. The chart shows the required amount of change of frequency in the vertical side and the nominal frequency of the crystal along here for both AT and BT crystals. Every single crystal ought to be etched by this.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. HENDERSON: How much quartz is to be removed?

MR. BOTTOM: It is difficult to say what is to be removed. It amounts to a removal of half a micron from an ideally plane surface.

THE CHAIRMAN: May I emphasize this? Please don't come to us with the story your crystals don't need to be etched this much. Maybe they don't, but what does it cost you? What is the difference between etching 15 and 25 KC? We know if you are going to etch them 25 KC, they will be okay. Since it isn't a difficult thing once they get into the etched bath to remove that specified amount, let's do it.

MR. BOTTOM: This is the minimum that we can tolerate.

MR. APPLEBAUM: There is a later specification from the Signal Corps, dated later than the March 6th specification, which might ultimately be succeeded by this, in reference to the old style alternate test of twenty-four inches of mercury. There is a Signal Corps specification pertaining to DC-34 and 35 dated later than the March 6th specification.

THE CHAIRMAN: What is the contractor being asked to bid on?

MR. SAUER: The March 6th.

THE CHAIRMAN: I don't care how many specifications are out; those are the ones we are talking about.

MR. APPLEBAUM: We are definitely speaking about the new specification 71-3046.

VOICE: Do the new specifications require lock washers?

THE CHAIRMAN: They do. Does the above apply to pre-production samples?

MR. HANDWERG: Make the samples up without if it is going to delay, then correct the condition.

THE CHAIRMAN: Do your subcontractors have a copy of the specifications?

MR. HANDWERG: Yes.

THE CHAIRMAN: A lot of these questions here you are asking me, you could have settled in your own mind before you came here if you had read that specification. I am saying this, gentlemen, there are so many points you asked which need never have been asked. I commend to you the reading of that specification like a Bible because it is your Bible and our inspectors' Bible. It is your Bible and you can answer so many questions by reading it so that you can save our time at these meetings.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

MR. LEUCK: You referred to the drop test. I think you misinterpreted me. We anticipate drop test troubles, and on this last contract drop tests were included and we were trying to solve the difficulty, and we found we should increase the tension of the spring and eventually put on ten pound spring pressure. After we had done that, we found we could drop them eight feet instead of eight inches and not break them.

THE CHAIRMAN: Now you are talking about military equipment. There is a potential broken holder by virtue of spring pressure. When we selected two and one-half to six pound pressure, we thought we were safe on both ends, although a two and one-half minimum is pretty low. We thought we were encompassing most of current production. If you are using stronger springs, or want to use stronger springs, there is no objection providing there is no danger of bulging the holder. I don't know how we can give a complete answer to that as to whether or not the holder will bulge, because obviously different holders will be different in that characteristic. We'd like to have samples. I think, probably, ten pound pressure is better than six, providing it doesn't endanger the holder. As far as this one characteristic is concerned, get us one batch of holders.

MR. SAUER: The same answer came up on distortion of the holder.

THE CHAIRMAN: Maybe we are anticipating trouble.

MR. SAUER: It doesn't look bad to us because the crystals will take quite a bit of abuse.

THE CHAIRMAN: I'd like to get ahold of some of those units and see what they look like. If one submission from one crystal manufacturer shows that it's all right, we can extend it to the same holder used by the other crystal manufacturers.

MR. HOLLISTER: What effect did it have on the activity by using increased spring pressure?

MR. LEUCK: As far as we can tell -- where 35's are concerned we can tell a lot. It didn't affect either one of the DC-34's or DC-35's.

THE CHAIRMAN: Is there anything else?

WYNN PRECISION COMPANY: In the specification here, it has on production test, "sealed or alternate test". As it stands now, we are supposed to give an immersion seal test hundred per cent production.

THE CHAIRMAN: It does not give this impression in the inspection instructions. The combined seal immersion test is applied as an acceptance or type test.

MR. SCHEPPELE: Wasn't your inspector notified of that?

Group Discussion of DC-34 and DC-35 Crystals (Continued)

WYNN PRECISION COMPANY: No. He asked me to bring up that question.

THE CHAIRMAN: I don't understand how it fits in your activity drifts.

MR. LEUCK: We are referring to the activity drift in the change of temperature.

THE CHAIRMAN: The thing I discussed yesterday was only because I had been asked questions about it. I was asked what drift was acceptable. Any drift was acceptable provided the unit remained within frequency tolerance throughout the temperature run or under any type test applied. There is no requirement as to drift.

MR. LEUCK: What I am getting at is over a period of time, through a type test --

THE CHAIRMAN: You mean will age? Possibly. On low frequency units aging which will occur during a type test, during a period of a few hours, will not be very serious. In other words you can't account for variations in activity during the period of the type test.

MR. LEUCK: If you are talking about --

THE CHAIRMAN: We are talking about units four megacycles and below; units presumably being tested at least three or four days after being manufactured.

MR. LEUCK: That's right.

THE CHAIRMAN: You can not explain changes in activity or frequency by saying the units are aging.

MR. HOLLISTER: I am wondering if it isn't confusing that the trouble occurs because of the change occurring in the new type of test which is covered in the new specification. Obviously you have small dips which are legal, but which can cause failure in the type test. For instance, you start a vibration test in an ambient temperature of 68 degrees in Colorado in the mornings. By the afternoon when that type test is concluded, that room temperature may have gotten up to 81 degrees and if you've got dips in there, you may have a failure. In the new specification it is recommended -- I think that the status of it is that such measurements be made in constant room temperature.

THE CHAIRMAN: It is a possible answer. This is a more complete answer to your problem. In several type tests performed on successive days, the inspector should immediately, before the first type test, measure the unit for room temperature, frequency and activity. I suggest you suggest it to him and I'd go to some coordinator with it.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

WYNN PRECISION COMPANY: There are only ten units in the immersion acceptance test.

THE CHAIRMAN: I think it calls for thirty, but I'm proposing only ten. As I said once before, we need only ten of these. All the inspector knows isn't what I said up here. He wasn't here. I think you can say that it is, obviously, unreasonable for him to take your word for it. Maybe he knows you are honest but maybe doubts your ability to understand things. It is obviously unreasonable to expect the inspector to take your word for what happened at this meeting. Furthermore, it is definitely contrary to his instructions, and it should be. There is a channel of information which goes out to that inspector. He can act only on that information which he gets through those channels. Action on any other information is violating his instructions, and he is assuming a technical responsibility which he does not have. He is wholly misbehaving. As a result of these conferences we arrive at certain decisions and attempt to implement them as rapidly as possible. You can laugh at army paper work. I do. You can swear at army paper work. I do. But it isn't just army paper work. It is work incidental to any organization. I am quite sure other organizations have worse paper work than we do. When you have any huge organization you are going to have that always. With us it can not be avoided. The opposite of that is chaos. If there is no paper work you are going to have chaos. You have it in your own organization. The smaller the organization the less the need for it and the more rapidly you can act. As a result of this conference, we are going to make certain changes in the inspection instructions. I don't go back and write inspection instructions. Other people in other laboratories are going to write them. They are going to write, I hope, pretty much what I ask them to. First I have to phrase it, then it has to go through two or three offices. They will get it and probably rephrase it. There is a certain form which they have been told to use -- certain matters of policy. It will take time. In the meantime you will chafe. There is nothing we can do about it. We have got to accept that. Don't go back to your inspector and say, "Captain Mitchell said so and so. The contracting officer said so and so." All we are interested in are the inspection instructions which he gets. If it is too slow, call the contractor and get him to worry us a bit. Don't expect it this week or next. Some of these cases where we are relaxing the requirements which are written into the specification which you bid on, it is unreasonable for you to expect us to hurry too much. If, in the meantime, we get something really hot and we feel we have to take care of it, we may be sidetracked. We will do everything we can. I am expecting information from Major Dempsey and his people and from people here from the inspection instruction section. We will act fast on it, and we will get the instructions out to you as rapidly as we can.

MR. HENDERSON: On some of the specifications, accuracies in the test of .002 per cent and 10 per cent -- It seems to me that with non-temperature controlling equipment and meters with an accuracy of two per cent of full scale, that you are rather loading your inspectors with laboratory measurements and with equipments and training highly

Group Discussion of DC-34 and DC-35 Crystals (Continued)

insufficient for using them. I actually, while not the best engineer in the world, have done some laboratory work on radio equipment. I don't feel safe in saying to myself, "I am sure I am right".

ARMBREWSTER (Signal Corps): I'd like to answer that. We have to work pretty close on equipment supply via subcontractors. We found many cases where the subcontractor is working with pretty close tolerances to the Signal Corps specification. The crystals were getting darn near the borderline cases. In those instances prime contractors has written the suppliers and asked them to tighten up on their specifications more rigidly than the Signal Corps specifications. If the subcontractor will take that into consideration as he goes over the Signal Corps specifications and write his own specifications which are a lot more rigid, I think he will find out he will get a lot less rejections back from Glavin and Hallicrafter. We have daily conferences about shipments involving twenty thousand crystals. It is a tough decision to make on the acceptance of those.

THE CHAIRMAN: I point out what we are asking you to do in terms of what we are talking about. On frequency measurement we specify a tolerance of .001 per cent. That sounds awfully close, but what is the frequency tolerance permitted of the units? The frequency tolerance is .02 per cent, and all we are asking of the greatest accuracy that can be achieved in your plant is that it be five per cent of the overall tolerance. That isn't a very great accuracy to request. It may be difficult to make, but consider the theory of measurements to use a yardstick to measure a yard. You want something close to plus or minus ten per cent of a yard. If we widen up materially we are seriously kidding ourselves that we are getting .02 per cent tolerance of crystals. I can't draw any other similar comparison. Yes, I can. On activity. Instead of ten per cent of the tolerance here --

... Off the record discussion ...

THE CHAIRMAN: Let's see if you are talking now about the same thing in our specification. As far as frequency is concerned the contractor will furnish test equipment with an accuracy of plus or minus .001 per cent. And you are now talking about the difficulty of making that measurement. Well, that specification doesn't say all frequency measurements will be accurate to that extent, but that the ultimate capability of it, if he uses great care, is that he can make measurements that accurate. I think you were interpreting it that way.

MR. HENDERSON: I realize that, Captain. What was really in my mind was this. I realize that this is only a start and that I would like everyone concerned to realize that they are approaching the limits of equipment now available and operators of available equipment.

THE CHAIRMAN: That phrase was first used more than a year ago now. I don't know exactly what you men have in your plants, but I don't think it is particularly too tough to ask that measurements be

Group Discussion of DC-34 and DC-35 Crystals (Continued)

made in that extent. Your argument about meters being two per cent meters may or may not be applicable in type tests. You are interested in reproducibility, and in fact, talking about reproducibility rules out meter inaccuracy on two per cent meter which is calibrated within two per cent. If you use the same instrument you will have eliminated most of the meter error.

MR. HENDERSON. I realize that it has also been stressed to use the same equipment.

THE CHAIRMAN: It behooves the inspector to do that.

MR. HENDERSON: Conversely, however, to them the same equipment means the same physical equipment. However, that same piece of physical equipment can be entirely different.

THE CHAIRMAN: Good equipment wouldn't be.

MR. HENDERSON: I speak of the CES-1 test oscillator.

THE CHAIRMAN: As far as CES-1 is concerned, if that is the thing limiting the accuracy of your measurements, then six months or a year from now we can ask for tighter specifications. As far as the whole extent of that point, it is not so much a point of greater accuracy as it is the ability of the operator to read an interpretation between the markings of a few microamperes. I would like to see a meter with a bigger scale which can be read directly by marking. Can we get better meters in those sets? I don't know the answer.

... Off the record discussion ...

THE CHAIRMAN: We'll look into it. Thank you for the suggestion. This shouldn't be governing in this case, but just let me point something out to you so you can have a better understanding of some of the problems we face. Probably the same sets we use are standard for you and will be issued in the field. Maybe we could do something else, but the first answer to the procurement problem, probably is to use the same thing. When we start shipping to the field, we are severely limited in what meters we can use. Two different test sets could be designed with one for the field.

QUESTION: Why not have the meter calibrated for two and one half millimeters rather than for five?

THE CHAIRMAN: It is simply a question of the availability of the instruments. If you get up close to the center of it, you can read it better.

MR. ANDERSON: On frequency measurement, Hans pointed out that with fifteen or sixteen cycles on low frequency there is little difference. We can prove it. We have the equipment capable of reading accurate .0001, but it takes someone who has had experience to read it.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

THE CHAIRMAN: I realize the problem. Equipment, if it is used carefully, is capable of reading to that accuracy. Supposing I ask you to provide the equipment to measure .001 per cent?

MR. ANDERSON: Would we hold the crystals until we were able to meet that spec?

THE CHAIRMAN: Obviously not.

MR. SCHEPPELE: Are you having trouble with the inspector reading that?

MR. ANDERSON: No.

MR. SCHEPPELE: If you are having any trouble contact this office.

MR. ORMONT: On low frequency are one-hundred cycles allowed?

THE CHAIRMAN: It says you shall furnish the equipment capable of furnishing .001 per cent.

MR. HOLLISTER: The matter of meters, in a similar problem, came up a few years ago. At that time it was specified that a meter be used not larger than would read seventy-five per cent, full scale, at the range that meter was working in.

MR. BOTTOM: I think it might help some to justify this statement of required accuracy. In a lot of plants the Signal Corps inspector has nothing to measure the frequency with except the crystal, you have given him, and told him, that it is on frequency. I have been in plants where the Signal Corps inspector had nothing better than that to measure your frequency with.

VOICE: Another serious thing is this. The crystal placed in a standard 34 or 35 standard will drift more than in the air in making a reading.

THE CHAIRMAN: They wouldn't have the same drift. We try to take a reading immediately when it is put in, or wait until it settles down. Take it under similar circumstances each time. There is a real reason why that test set does that, because the radio set does it. The intent of the specification is that before and after measurements will be taken under the same conditions and at the same ambient temperature, calibrated the same way, and if a drift is due to self-heating, measurements should be taken at the same amount of time after initial insertion. I don't see how you can put all that into the specification. These are all problems. Probably some of the inspectors won't appreciate them immediately. Most will.

VOICE: I have seen cases when we want to get a stable reading. There is a slight movement. It should be close to thirty cycles, and if he watches it it will be thirty cycles.

Group Discussion of DC-34 and DC-35 Crystals (Continued)

QUESTION: Suppose it is twenty-eight cycles?

THE CHAIRMAN: Somehow we have the understanding that the reading must be taken under the same set of conditions. I feel confident that you can help us do that.

WYNN PRECISION COMPANY: On immersion tests it takes quite a time and we change shifts. We got one reading, and due to the different correlation of two inspectors there was a little difference there even if the crystal hadn't changed any.

THE CHAIRMAN: They probably have a characteristic way in which they take a reading.

MR. SCHEPPELE: That's really something you have to settle with your inspector. That's a local problem.

THE CHAIRMAN: The ideal answer is obviously for the same man to take it.

MR. SCHEPPELE: Has that caused you any rejections?

WYNN PRECISION COMPANY: We have had some on immersion. We don't know if that was the cause.

... Off the record discussion ...

MR. LEUCK: The same man will vary, and consequently another man will vary even more.

THE CHAIRMAN: The meeting is over.

The meeting adjourned at 4:15 P.M.

GROUP DISCUSSION OF FT-243 CRYSTALS
LT. R. L. SNYDER - CHAIRMAN

THE CHAIRMAN: We are now passing out a specification which is only a proposed specification and it may look different in a couple of weeks or a month. I don't think we are going to have time to go through the specification in detail. There are several things that have been changed in the acceptance test. One is the number of rejections allowed on the temperature runs. I think everybody is interested in that.

I will let Mr. Brewster explain that change in the paragraph on activity and temperature run. That will be a separate paragraph.

MR. BREWSTER: (Galvin): We now have two conditions prevalent in 243 Crystals that cause rejections. One cause is sharp dips. The other is miscorrelation of equipment.

Sharp dips may occur at a single temperature and may dip down quite deeply. Correlation errors or failures may fail over quite a number of temperature check points, but very slightly below the minimum.

... Mr. Brewster illustrated this point with two diagrams drawn on the blackboard ...

MR. BREWSTER: What we at Galvin are requesting for our subcontractors in order to allow production to proceed is that we be allowed two such crystals as this and one crystal like this (indicating). Two crystals with a quick dip below minimum and--that is, two crystals with quick dips at any two temperatures and one crystal with a gradual sweeping dip covering three temperature test points going slightly below the minimum.

I believe that about 90 per cent of the crystals meet the activity requirements of the March 6 specification. That is from the standpoint of the type test rejections. In other words, if the March 6 specifications were adhered to from the standpoint of activity requirements through the temperature run, at least 10 per cent of the crystals would be lost.

THE CHAIRMAN: In other words, by all the manufacturers, not one particular manufacturer?

MR. BREWSTER: Well, to go further, there is first of all this condition that some manufacturers are not using these waivers. However, their production quantities which they are shipping is substantially lower than it has been previously.

The other condition is that the balance of the plants that are on schedule or close to schedule are using the waiver. Now, there may be 5 per cent of the plants that are not using the waivers who are on schedule.

Group Discussion of FT-243 Crystals (Continued)

THE CHAIRMAN: I think, gentlemen, to get down to this, which is supposed to be an informal discussion, if you will note this proposed specification, the double asterisks denote changes from March 6 specifications. Suppose we start from the beginning.

QUESTION: Do you also propose one activity failure as it exists is one?

THE CHAIRMAN: Not below 10 per cent.

SAME QUESTIONER: One that actually fails in activity?

MR. BREWSTER: My proposal was we be allowed one crystal that falls to 10 per cent below the minimum activity requirements and two crystals which fall to 50 per cent below the minimum activity requirements, but not at two successive two degree temperature test intervals.

SAME QUESTIONER: That would be in lieu of one complete failure as the specifications provide?

THE CHAIRMAN: That is a deviation from the present specifications.

SAME QUESTIONER: Wouldn't we be allowed one of those?

THE CHAIRMAN: The way the specification reads now, you can have one dead crystal completely. We are eliminating that.

QUESTION: Suppose you have one dead crystal and then these others? Then what?

THE CHAIRMAN: We want no crystal to fall below 10 per cent.

MR. BALTER: Under the present specifications what you say is acceptable, but under the requested deviation you are not allowed any. If you have one dead unit, the submission is rejected. In other words, we would rather take two units or three units which fall a little below rather than take one unit which is completely dead at some point.

QUESTION: Isn't there a possibility there you have one crystal which has two dips and is 50 per cent below? Well, how about if you had one crystal that went to 50 per cent below? That is your regular allowance. That is according to your specifications.

MR. BREWSTER: If it goes 50 per cent below, but not at two successive temperature test intervals.

... Off the record ...

QUESTION: Under the present specifications you allow one complete failure to be dead. My suggestion would be to retain that and if we want further flexibility we can be allowed one additional failure which can be in either of those two categories or no dead ones. Two of

Group Discussion of FT-243 Crystals (Continued)

one category and one of another. In other words, there will be 1, 2, and 3 failures.

MR. BALTER: The thing we are trying to get away from is the one failure allowed.

QUESTION: According to this, it wouldn't have to be a complete failure. It could go down to 75 per cent minimum and then back up again. Suppose it dipped 75 per cent, what then?

MR. BALTER: It has to be rejected. That is right.

SAME QUESTIONER: Are the inspectors still going to make the 100 per cent check at room temperature?

MR. BALTER: No, that is not in the specification.

QUESTION: Mr. Brewster's thesis seems to be a crystal with a narrow dip or 10 per cent below the minimum limit is a crystal which will not prevent the equipment from working normally. Why consider those as rejects at all?

MR. STANLEY: Under the present specifications if the dip is below the rejection minimum, as soon as it passes the rejection line it is out and that is trying to take that into consideration.

SAME QUESTIONER: But, according to Mr. Brewster's argument it seems to me that certain of these dips do not inhibit the normal operation of the equipment and if that is true, then I don't think that should be considered as a rejection because it actually will work the equipment.

MR. BALTER: The Radio Set will not operate if the Crystal is at a temperature where a dip occurs. It may not stay there very long it is true, but it will not operate the radio.

SAME QUESTIONER: Why reject it at all?

QUESTION: There is something I think we forgot in this discussion. That is, that the problem was, we would let the temperature run and not get any dips and if we ran it the second time, they would occasionally show up. I think that is our really big problem, the fact we have the big dips we occasionally miss because they are within the 2 degree range and the second curve is something that comes by small differences by day to day, which you might occasionally get in a crystal that goes 10 per cent below.

Group Discussion of FT-243 Crystals (Continued)

Because of these small differences which are really hairline things, we are knocking out a whole raft of crystals and no one is getting any place fast. I think the object is to settle on something whereby we have a compromise and still not lower the activity standards or try and get away with passing crystals that are really dead. None of these crystals we are talking about would not work in a set.

THE CHAIRMAN: I think that is what Frank is trying to do, to compromise on correlation of the equipment with the 10 per cent below, allowing one reject on 10 per cent below and compromising with those that have excessive activity dips by allowing two to go 50 per cent below is reasonable.

SAME QUESTIONER: This seems to be a good compromise if the Signal Corps wants to go along with it.

THE CHAIRMAN: Dropping that 10 per cent below may not solve your borderline cases. You may have to raise your production above your minimum in order to keep to the one going 10 per cent below.

... Off the record ...

QUESTION: He is restricting it to two of one kind or one of another. Why not have three altogether?

THE CHAIRMAN: We are defeating our reasoning in back of that, by allowing three that could go down 50 per cent then.

QUESTION: Do you figure out it takes .42 to operate that regular size 659 in accordance with the operating characteristics of the set as defined by the Signal Corps? Since then have you done any work to find out the minimum possible operating conditions?

MR. BREWSTER: In answer to your question, we have not.

SAME QUESTIONER: If not, we don't really know what we are talking about.

MR. BREWSTER: We know .42 will operate the equipment to the Signal Corps requirements.

QUESTION: You are down 10 per cent?

QUESTION: .23 is a sharp dip. If this is true, what Mr. Brewster is talking about, the Radio Set is inoperative in a sharp dip. I am thoroughly against allowing those dips because I don't think at any time should the set be out of operation.

PREVIOUS QUESTIONER: I agree with him. Since we put through that waiver there has only been one case I know of. We are testing now at .46.

Group Discussion of FT-243 Crystals (Continued)

THE CHAIRMAN: You set your standards up?

SAME QUESTIONER: There has only been one case where the Signal Corps, checking at .42 have found a crystal that went out and that was at 70 degrees and they recalibrated the temperature and found out it was 72 degrees instead of 70. That has been our experience on that particular one.

MR. BREWSTER: In specific answer to your question, I would like to point out that you had the advantage of a number of Signal Corps personnel in your plant. I would like to summarize to this extent that a condition did exist where equipment was improperly correlated, and after the equipment was properly correlated, corrective measures were suggested and taken by the manufacturer to improve the quality of his product over what he had previously been delivering and he states now that it has materially increased the quality of his product so he apparently does not need the waiver.

SAME QUESTIONER: I still think we should have the waiver although we should manufacture or attempt to obtain that in our own quality control, but as far as the Signal Corps is concerned to avoid having submissions going back into our lap which throws a monkey wrench into the machinery for the next couple of days--

MR. BREWSTER: We are perfectly in agreement with you and we feel that if you and your inspectors keep up the work you have done, some time in the future you will have your plant so well organized and your test equipment so well correlated that progress will be made in eliminating these dips to the extent that this will no longer be a problem.

SAME QUESTIONER: In working out a new specification we will eliminate the plan.

MR. BALTER: The point is, operating under the waivers, you are asking the Signal Corps to take three dead units per thirty samples out of a thousand-- You say we are supposed to take 10 per cent dead units which means we could conceivably take one hundred dead crystals out of every thousand we accept.

This waiver we are referring to as far as the Scranton meeting goes, says we will accept three units which fall below specification limits. Since this is a sample, we are going to take units which are 10 per cent defective. Three out of thirty failed and may have gone completely bad.

SAME QUESTIONER: I am predicating this whole thing on the fact that you have your own quality control setup to a point where you know you are not going to get those, but at the same time, who can tell?

MR. BALTER: Now, we are back again to the inherent defects. Personally, I think the feelings of the Laboratory are, there are

Group Discussion of FT-243 Crystals (Continued)

no such things as inherent defects--dips that appear one time and don't appear another time. Let's not argue that now. That is a highly debatable point. We want an answer which is going to be effective immediately. An answer that will permit production as you want and which will give us better assurance that we are not taking a hundred dead crystals per thousand--

SAME QUESTIONER: Let's put it this way: Go ahead with it and we will tell you what we think of it.

MR. BALTER: We are willing to allow a general reduction of the limit of 10 per cent for the temperature run. That is to take care of correlation. If any one unit falls below 10 per cent on the temperature run, those submitted are rejected. However, recognizing the fact there are some mysterious factors we don't know about and which come in, we will take two units which fall not below 50 per cent of the minimum acceptable limit, at one temperature test point, and that way, we are getting away from accepting any totally dead units and have reasonable assurance that all units will operate their radio sets then.

QUESTION: I ask there should also be allowed one failure which goes below the 50 per cent dip because you are going to have them in submissions from day to day and I don't care who it is, they are not making crystals that good.

MR. BALTER: We have figures which show that 80 per cent of the manufacturers submitting crystals to Galvin are operating without these waivers.

MR. BREWSTER: At reduced production. That is what we are trying to do, to help you out to try and get the production.

SAME QUESTIONER: The way it is now, you are allowed one failure completely. Under the new specification, if two crystals fall below 10 per cent of the minimum you would be rejected.

MR. BALTER: If two crystals fell below 10 per cent in a slow curve.

SAME QUESTIONER: How are you going to tell that?

MR. BALTER: The distinction is going to be made whether the unit fell below 10 per cent on two successive readings. If it does that, it is a reject. If it goes below 10 per cent on one and not below 50 on another reading, that is not a reject.

... Off the record ...

QUESTION: How about this compromise--instead of allowing two dips, allow one dip on the 50 per cent and one dip on the 10 per cent and then one dip below that.

Group Discussion of FT-243 Crystals (Continued)

MR. BALTER: No, we are back to one dead crystal again.

SAME QUESTIONER: It doesn't have to be dead. It could be 50 or 55 or 60% below. All I want is the one crystal that would be a dud as far as these limits are concerned and a fighting chance for the others.

MR. STANLEY: We are doing a lot of bickering over something here. Under the principles of type testing, you are type testing a group to guarantee production temperature runs. The Laboratory has said under the type testing they will accept a certain amount of defective crystals because you are not going to get every one right. You know that. So, I am inclined to agree with these gentlemen that we should allow one that fails in activity plus these deviations here. These are much more than I expected to be given by the Laboratory.

QUESTION: By failing do you mean completely dead?

MR. STANLEY: I mean anything below the 50 per cent limit.

SAME QUESTIONER: In other words, a dead crystal?

MR. STANLEY: In making the temperature run it is very easy for the inspector in inspecting the wheel or the box to make a bad crystal that registers zero activity. That crystal is going to be thrown out.

MR. BALTER: Well you shouldn't have that condition and in very few cases do you have it.

QUESTION: It seems to me in discussing the dead crystal, we are getting away from the primary purpose of this particular type test. After all, the temperature run is not designed to determine how many crystals are dead. It is to determine the activity requirements between a certain temperature range. This is my thought: If one crystal is found to be dead in that particular type test, it should not be necessary to take that whole lot of a thousand and run them back through the temperature test, but test them at room temperature and see if any of them are dead. I think maybe the assumption is the whole lot is being rejected because of the dead one that got in there, but you go back and take your thirty crystals and check them and if you find another dead one, you would be pretty well hooked, wouldn't you?

THE CHAIRMAN: Gentlemen, I don't think there should be any dead ones in there.

QUESTION: I think they are going around in circles for one reason: We don't hold ourselves up as an example, but I want to say this, we make it a point, and this is something I have been arguing with my inspectors about, I have been wanting the inspectors to make it a part of this specification or the one we are working on now, a provision that every crystal should be put in your vibrator and vibrated. That is, rigidly clamped down and vibrated for five minutes at 50 to 60 cycles. We have been consistently doing that. Mr. Brewster can tell

Group Discussion of FT-243 Crystals (Continued)

you that on the new specification, without the relaxation, we have turned out some eleven or twelve thousand crystals and I say this, which is the gospel truth, that we have not had one dead crystal go through our heat run, let alone, be found by an inspector. I think that would cure the whole situation if the boys had to do that.

I want to say another thing about correlation. We had one case where we started on the correlation of the equipment we were running 10 per cent rejects, and we knew we should run 45 per cent. We were too good. Everybody was happy but me because I said we can't be that good, and we took and made up special crystals, some that were at the passing point, other below the passing point at various stages. We ran them through the CES-1 test oscillator.

We first took the crystals that were at passing and put them on the units that were supposed to be correlated and found they read perfectly. But, we took these low crystals and ran them through the heat run--which were low on the CES-1--and in some cases they ran 6.56. Now, we took the insides out of these machines and we really pulled them apart. We took out the condensers, fixed the condensers, and all kinds of wiring, and we made those units coincide with the CES-1, and in doing that, we found we could take the CES-1, put these low crystals in it, take it out and put them in the heat run, and the inspector could see where they dropped to a certain point in the CES-1, they dropped to the same point in the hot run box.

Now, I would like another provision in the specification to take care of that because I know other factories are not aware of that fact that the specification should be changed to the point where each inspector would have a series of those crystals--I don't mean erratic. I mean crystals made at a low standard of activity so that could be checked in your plant and you are not going to have all the trouble in operating that you do now.

MR. BALTER: Well, certainly every plant so far is correlated.

SAME QUESTIONER: I want to differ with you there. This happened after an engineer was there and had okayed my equipment.

MR. STANLEY: May I give an experience here, too? This was in the case of a plant on the Pacific Coast. The inspectors have run type tests on 1050 crystals through the temperature cycle. There have been five lots out of thirty thousand crystals rejected or have had the red dot put on them because of activity failures under the old specification, and the failure of every one constituted a quick dip. There wasn't one that stayed low. That is the gist of the whole thing, as I see it.

MR. BREWSTER: Gentlemen, we have gone all around this thing and I would like to say this: That I haven't put up this suggestion without giving it very careful consideration. We ran hundreds of crystals through at Galvin during the past two or three weeks; crystals that

Group Discussion of FT-243 Crystals (Continued)

were made to the new specifications, and I have gone back over those charts in trying to analyze what causes failures and it has been my feeling that these things which are brought up here today will allow about 98 per cent of production to proceed on the basis of tests and re-run tests, which we have made at Galvin.

Now, if anyone else has studied the problem and made charts and feels that they have sufficient information to propose an alternate suggestion, I am sure the Signal Corps will be glad to consider it. If there aren't any concrete suggestions to this immediate problem of the number of rejections allowed and the temperature runs, I would suggest that we request a showing of hands to get an indication of which direction we should travel.

QUESTION: I would like to raise a point here. Suppose you have three dips, sharp dips, and none of the others were rejected, what is your decision?

MR. BREWSTER: That condition would occur very rarely. What I am bringing out is that accepting crystals on the basis which has been outlined here today, on the basis of our figures and our investigations, that we will get 98 per cent of the production it is possible to get.

SAME QUESTIONER: I mean, instead of having two crystals that dipped twice, suppose we had three that dipped twice and none that dipped once?

MR. BREWSTER: Under that condition, you would have a shipment rejected. But, that occurs very infrequently according to the records which we have made.

QUESTION: How about two rejections for any size?

MR. BREWSTER: What you are allowed now is that the Signal Corps inspector will accept any crystals which go down to 42 and you may have in there crystals which are completely dead or which fall a percentage beyond 42. We and the Signal Corps feel that that is somewhat too lenient and in a meeting which we had last night, we talked this situation over and we have requested that the waivers continue. The Signal Corps wanted to take them out completely. We arrived at this solution which was what we felt was necessary in order to get production.

Now, in answer to your question that the 42 on the 659 will allow that crystal to proceed. I mean the lowering of that limit must be a certain figure, but that figure is not applicable to the other contracts that will be affected by the specification and by the waiver so that what we want to do is arrive at something that will apply generally to all the crystals of all types.

THE CHAIRMAN: Suppose we go through the specification here

Group Discussion of FT-243 Crystals (Continued)

and note the changes that have been made?

QUESTION: I would like to mention, in the past year and a half or so, I have witnessed temperature runs of hundreds of thousands of crystals with the readings recorded on charts. The charts are on file now at Galvin Manufacturing and I have seen runs time and time and time again when a crystal exhibited an activity reading of zero in one spot. These happened to be CR-1 crystals.

I am very inclined to believe those crystals were not defective crystals as much as a bad contact or something that occurred in the equipment, and I am hesitant to allow or to feel that something of that nature will be the cause for rejection of a thousand crystals.

THE CHAIRMAN: My only suggestion is that there happens to be two more conferences going on that are probably discussing the same thing, and this original proposal right here is one we talked about last night and everyone agreed with it. Now, if there is anything else that comes out of the other conferences--

QUESTION: I would feel much better if a lot of the chance were taken out of it. If there is a dead crystal, let's put a second alternative to it where the inspector selects another lot and checks them instead of rejecting that entire lot.

QUESTION: Wouldn't it be possible to have the inspector authorized to re-run that same lot?

THE CHAIRMAN: I think we will probably say the inspector may re-run the crystals if the cause of the failure can be traced back to any particular reason and you can eliminate those particular failures as you resubmit the lots. As we go through this, I think you will see that?

... Off the record ...

QUESTION: Mr. Brewster named all the steps. Undoubtedly he conducted the tests under his correct supervision and correct control. They were undoubtedly done by girls experienced in that and on good equipment. We are talking about taking an inexperienced girl and giving her a temperature run box which she has never used before, and it takes some time before she learns how to do it. Basing statistics on the number of rejections made by experienced operators and people who are well qualified--

THE CHAIRMAN: I think Frank has based this temperature compromise on testing units--not the ones we got a year ago, but the ones coming in under this Specification.

MR. BREWSTER: That is right and it is not only that condition. The reason we made the runs at Galvin was to determine how the crystal units failed, what percentage failed, and for what cause. These per-

Group Discussion of FT-243 Crystals (Continued)

centages do not indicate the number of failures on crystal units coming in by any means. They indicate failures in plants that are now manufacturing crystals and of the rejections encountered by the Signal Corps inspectors. That is based on a letter sent to our subcontractors and based on the information therefrom.

THE CHAIRMAN: Shall we get back to this problem again? Shall we go through the specification now?

F-1a is merely a rewording of that paragraph.
F-2a is Reference Standard Crystal Test Set.

I don't seem to have the first pages here. We will start with C-9a, Finishing Treatment of Quartz Plate. This specified the crystal will be finished to final frequency by etching.

... Off the record ...

QUESTION: Is the use of the quartz aggregate in the cleaning procedure considered other abrasive as stated in C-9a?

MR. BALTER: There is the mere fact it doesn't wash up as much as one that is jarred a little bit. I think the only thing to do is submit some samples which we will put in our test and see if they do age. That is the only way we are going to approve it, and until such time as that is done, I don't think they will be acceptable.

QUESTION: You do not consider scrubbing with a toothbrush abrasive, however?

MR. BALTER: No.

... Off the record ...

QUESTION: Is it permissible to use hand abrasives on the surface of the FT-243 under four megs?

THE CHAIRMAN: Under the new specifications, all crystals ordered under the new specifications will have to be acid etched.

... Off the record ...

QUESTION: The clarification of scratches and chips was asked by the floor. We would like to have this as quickly as possible.

THE CHAIRMAN: The Inspection Agency is working on that problem and they are setting up standards.

QUESTION: Has the Laboratory ever produced any conclusive evidence of the seriousness of scratching?

Group Discussion of FT-243 Crystals (Continued)

THE CHAIRMAN: These standards that are set up may be much lower than they were previously due to etching requirements.

SAME QUESTIONER: Do you mean more obvious scratches will be permitted after etching?

THE CHAIRMAN: That is to be discussed.

... Off the record ...

QUESTION: Presuming this standard of scratching will be attained, from the ten crystals that will be opened, if more than one has a rejectionable, obvious scratch or chip, is that subject to rejections?

MR. STANLEY: That is right. If it is defined as a fault, it will be; if it is an obvious chip as set up.

QUESTION: On the matter of scratches, I understand the matter has been taken up between your laboratory and ARL and that the effect of scratches on an etched crystal is yet to be determined, but it is being worked on.

THE CHAIRMAN: Yes, and there is an indication that the limit may be lower.

SAME QUESTIONER: We aren't sure yet what the effect of a scratch on the etched crystal is, and it is very obvious that scratches show up on etched crystals which would not show up on one finished with a coarse abrasive. That applies to crystals finished with a fine abrasive also and the thing is being studied and it is being discussed.

THE CHAIRMAN: General Requirements. D-1. The only change in that paragraph is the omission of preproduction samples. It is a matter of clarification.

The next change is E-9a. That is a clarification on the hermetic seal test equipment.

MR. BREWSTER: We had a little discussion on that and it was pretty well agreed by the laboratories, I believe, that crystal samples approved for one type radio set--could stand approved for other models. The only contingency which would be involved would be the correlation of the electronic equipment, and for that reason, perhaps a pilot run might be required. But, other than that, we were unable to find any other change which would be required.

QUESTION: Will preproduction samples be required from all manufacturers before they begin under the new specifications?

THE CHAIRMAN: That is right. That is what it says.

... Off the record ...

Group Discussion of FT-243 Crystals (Continued)

QUESTION: If we all submit them at the same time, what will happen to production in the meantime? It is going to take them a long time to get them checked.

THE CHAIRMAN: Galvin and the laboratories are working on them.

MR. BREWSTER: I think I can say you fellows will be pretty well assured that production is not going to be held up if we can possibly avoid it. We are working on a number of different ways in which we can expedite approval of the preproduction samples and also expedite the pilot run prior to the first submission of samples under any specification.

... Off the record ...

THE CHAIRMAN: Does anyone else want to say anything?

FLOOR: It is all very well and good to say the manufacturers are not going to suffer any loss of production because of the delay in testing preproduction samples. As long as the contracting officer requires that production, that is true enough. There are going to be waivers made. But, on the other hand, from the legal standpoint, the manufacturer is on the spot plenty. Assuming the contracting officer decides the particular amount you were working on wasn't particularly important and no emphasis was made to expedite the testing and approval of samples and the pilot runs, I can see this coming up: What happens to the manufacturer, twiddling his thumbs waiting for the stuff to come through?

THE CHAIRMAN: The only thing I can go back to is the previous statement. I don't think we will discriminate against any manufacturer. The first ones in will be the first ones tested, and we are going to try and test all of them as quickly as possible.

... Off the record ...

THE CHAIRMAN: Are there any comments on the drop test? I believe you all heard Captain Mitchell's comments.

QUESTION: You can't read 38 cycles in the first place, and you are going to get that in change of temperature by the time it is dropped a couple of times.

THE CHAIRMAN: That is true, but in the higher frequencies, I don't believe you will find that. In the 34 and 35 program, we have been allowing .003 as the deviation on that. The .002 as indicated here, was changed to .003. Is your problem on the 34 or 35?

SAME QUESTIONER: It is BC-611 and DC-37.

THE CHAIRMAN: How do the rest of the contractors feel on that drop test, the ones making BC-611?

Group Discussion of FT-243 Crystals (Continued)

... The majority of the contractors agreed that point was not bothering them ...

MR. BREWSTER: I would like to say one thing; I understand that problem. I think that is a problem of the whole industry. That is, when the tolerances of a test approach by 50 per cent or less the degree of accuracy which you have in your equipment for measuring the results of that test, then naturally your test is no longer a test on the unit, but becomes a test on the accuracy of your test equipment. I would suggest that through all of these tests, drop, vibration and cleaning and everything else, that a minimum be established which is flat without regard to frequency which will allow for the measuring equipment.

SAME QUESTIONER: I was going to suggest we use 100 cycles or .002 per cent, whichever is the most.

THE CHAIRMAN: I know this is a problem on some of them.

SAME QUESTIONER: Getting back to the 243, it will come up on the 34 and 35, but you are dealing in two different masses. We haven't experienced the trouble in the 34 as we have in the smaller blank in dropping, because you've got two mass problems, so it is definitely not a 34 or 35 problem, but an FT-243 problem.

MR. BREWSTER: Will you recommend at the general meeting following this one that that was our conclusion and arrive at some sort of a compromise agreement?

MR. BALTER: I think you are overlooking a number of facts. One is, there shouldn't be an appreciable temperature change in a crystal that is picked up and dropped five times in a matter of thirty seconds or a minute, and if there is, there is no good reason why the temperature of the crystal cannot be regulated and it should be tested to take care of that.

SAME QUESTIONER: If the Signal Corps will do this, we will be glad to do it; You make arrangements with the War Production Board to release air conditioning equipment to air condition that room. That is the first thing. Secondly, you will allow us to write off, during that contract, the cost of air conditioning the room. Air conditioning is a big advantage because we tested crystals in air-conditioned rooms and found the crystal units met requirements.

MR. BALTER: Air conditioning is a solution, but it is not the only solution. You can have a temperature control box which need not be larger than a foot square.

SAME QUESTIONER: You are still bringing your crystal out into the room which has a different temperature.

MR. BALTER: If there is any change, I don't think it is

Group Discussion of FT-243 Crystals (Continued)

appreciable. Secondly, the other conditions can be remedied. We can have the inspector drop the crystal and then read it immediately afterwards.

THE CHAIRMAN: I think there will be quite a discussion on the 34 and 35's on that and whatever they have on lower frequencies should also apply to FT-243's.

MR. STANLEY: I think the solution is an air conditioned box. That is what we are doing on the Coast. I think that is the only solution outside of what was suggested. I think we will settle for a box.

THE CHAIRMAN: There has been one change from the specification as you now have it. ARL has 200 megohms. This may be changed to 200 megohms too. That is E-11. The frequency and activity requirements on that test have been eliminated.

... Off the record ...

QUESTION: If shipments are rejected, what is then done?

THE CHAIRMAN: The cause is determined and then they are reworked as defined by Captain Mitchell in his talk.

... The means of reworking rejected shipments was then discussed and the subject was put aside to come up in the following meeting ...

THE CHAIRMAN: The next change is, we have taken internal inspection and made it a separate paragraph. It was confusing as we had it before. It was cleaning and internal inspection. It is now a separate paragraph.

MR. BALTER: Before it was cleaning and internal inspection, and therefore only one failure was allowed. As it is now separated you are allowed two failures under each section.

... Off the record ...

THE CHAIRMAN: We are going to define a scratch or chip but it will take time. In the meantime these are in effect. If two crystals out of the ten fail that would be cause for a rejection. Likewise, if the inspector feels the blanks are scratched more than they should be, a thousand crystals are rejected. I wanted to bring that question up as it has been asked many times.

MR. BREWSTER: In regard to that I would like to say that our subcontractors have all been notified by letter that if such an occurrence happens that a shipment is rejected because of internal inspection, we in turn will request through Colonel Harris' office that a zone coordinator be sent out to the plant or that a pilot run engineer be sent to straighten out the situation and they have promised us twenty-four hour service on it.

THE CHAIRMAN: F-6. There has been a change there. "Acceptance

Group Discussion of FT-243 Crystals (Continued)

Tests. Acceptance tests shall be performed by the Signal Corps Inspector, and shall be the basis of accepting crystal units as meeting the requirements of this specification, or rejecting them as failing to do so."

F-1a is clarification.

F-2 refers to the standard crystal test set and is clarification on the distribution of the test set.

F-2b is--

QUESTION: I notice that reads, "The crystal units may be subjected to all tests."

MR. BALTER: That is at the option of the inspector.

THE CHAIRMAN: The next paragraph is F-6b. Failures.

F-7, Etching Test. Oh, by the way, we should go over F-6a. It is not marked with the double asterisks. That is sample selection and test routine.

QUESTION: What is the total amount of crystals taken for the test? How many tests have you done? There are ten. In other words, they could take three hundred crystals.

MR. BALTER: No, the same units must be subjected to both seal and immersion.

SAME QUESTIONER: You are still talking about an appreciable quantity. Frankly, I don't think they will.

MR. STANLEY: That operates in your favor. You are not performing destructive tests on them and the only thing we fought to get in before, was to expedite the shipment because it takes ten hours if you take one group and run them through whereas you can take the group and run them through as specified here and it doesn't take that long.

THE CHAIRMAN: F-7, no comment.

... Off the record discussion on the effect of surface moisture and humidity ...

QUESTION: Could we be allowed to blow a fan over the crystal or allow it to be wiped off?

QUESTION: Could the units be permitted to stand more than thirty minutes?

MR. BALTER: Well, the purpose of this is to provide a standard test. If you permit them to stand longer, you will evaporate the moisture that has been absorbed. If you want to wipe them with a towel at the end of thirty minutes, I think that is permissible.

Group Discussion of FT-243 Crystals (Continued)

MR. BREWSTER: You can't wipe it all off. The same thing applies to a plate of glass on a desk.

QUESTION: The one thing we all want to know is when we have to start out etching procedure and I think in a few minutes we should decide that.

QUESTION: In paragraph 15-a, do I understand we can put it in and take it out and dry it?

THE CHAIRMAN: No.

SAME QUESTIONER: It doesn't say we can't.

... Off the record

MR. BALTER: There is one change at the end and that is in H-5c. We also skipped over a previous paragraph on the standard test sets and that is that these three echelons of standard crystals have changed somewhat. In that, the reference standard crystal test set is going to be furnished the Signal Corps inspector.

THE CHAIRMAN: I think we had better get around to the etching.

... Off the record discussion ...

QUESTION: What did Galvin get as a result of their telegrams?

MR. BREWSTER: The results of our telegrams was that a lot of you could be etching your crystals without interfering with production, by about September 15, with the exception of one or two companies who I haven't heard from.

Now, it is our opinion, from speaking with members of the Signal Corps and speaking with manufacturers who are now etching, that it will take considerably longer than this time because of the lack of available equipment, the engineering time that is required to establish pre-etching technique in the blank, the investigation of various fluids and their effect on etching in your own particular process and various other engineering angles of getting etching into operation.

Therefore, it is the request of Galvin Manufacturing that etching be not required until at least the first of October. We have done everything possible to have our subcontractors etching before that time. Many of the crystals that you are getting now are etched and a larger percentage of them will be etched in the very near future, and we hope to have time to work into this thing gradually. The earliest possible date would be October 1, and we would like to have more time than that if the Signal Corps can possibly allow it.

Group Discussion of FT-243 Crystals (Continued)

THE CHAIRMAN: Well, I think we should set a date like October 1 if there are several companies that have not gotten into etching at this time.

... Off the record ...

... The meeting adjourned at four twenty-five o'clock ...

GROUP DISCUSSION OF
CR-1 ()/AR AND DC-11-() CRYSTALS
CAPTAIN J. E. FOX - CHAIRMAN

1. Captain J. E. Fox of the Aircraft Radio Laboratory called the meeting to order at 2:30 P.M. An outline (copy attached at the end of these proceedings) of the topics to be discussed was presented to the various representatives.

2. During the introductory remarks given by Capt. Fox, attention was called to the fact that the conference time had been considerably shortened, and that it would therefore be necessary to dispense with that part of the discussion dealing with contractual and inspection matters. As a consequence, the discussion was limited to the Signal Corps Acceptance Tests performed under A.W.S. Specification C75.11 - 1944.

3. The initial discussion concerned the sequence of acceptance tests as presented on pages 3 and 4 of the outline. In answer to questions concerning the sequence of tests shown page 3 of the outline, it was pointed out that:

a. It is necessary to run acceptance tests in the parallel arrangement similar to that shown on page 3 of the outline in order to complete Signal Corps tests the same day as the production lot is submitted. Crystal unit lots of thirty, when subjected to each test in rotation, as presently listed in the A.W.S. Specification requires approximately 14 hours for completion. Under such circumstances, the manufacturer would have to wait two days before knowing whether or not his submission was acceptable.

b. It is also necessary to subject crystal units to the arrangement of tests shown on page 3 of the outline; (See Test No. 3) in order to more nearly approximate actual service conditions.

c. It is also necessary to group acceptance tests in the manner shown on page 3 of the outline in order to accomplish the first steps in a logically planned quality control program.

4. It was agreed that the Wash Test (Test No. 7, Page 3 of the outline) could follow the Immersion Test (Test No. 6, Page 3 of the outline), and thereby save from destructive test the ten additional crystal units otherwise required. It was shown that the Wash Test could not be included in Test No. 3 since the time required to complete the acceptance tests would then prevent finishing tests the same day as started.

5. The sequence of tests shown on page 3 of the outline has one disadvantage in that it is possible to find in any one of the tests a crystal unit which may be a reject for a reason other than that for which it was tested. For instance an activity failure might be found in a group of units just previous to Drop Test thereby causing room for disagreement as to whether or not it should be counted

Group Discussion of CR-1 ()/AR and DC-11-() Crystals (Continued)

a reject for the particular test.

6. The sequence of acceptance tests was revised as shown on page 4 of the outline to eliminate the above described condition. Under this sequence, the entire acceptance lot is first subjected to mechanical inspection and room temperature test to eliminate chance rejects from occurring in later tests. It was pointed out by some representatives that the present method now used in some plants requires a replacement crystal to be selected when a crystal unit is found defective under test, when such defect is not a result of the test itself.

7. Discussion pertaining to sequence of tests was suspended at this point since further time could not be devoted to this item. However, it was decided that the final decisions and conclusions would be forwarded to the manufacturers concerned.

8. The individual acceptance tests were then taken up in the order listed in the outline.

9. Mechanical and Visual Inspection as covered on page 5 of the outline was discussed first.

a. It was pointed out by representatives present that in addition to the defects listed in the outline, that defects listed under Pins should also include "flats*" and "poor plating*", and that defects listed under Case should also include "scratched*" and "gate removal*".

b. It was also pointed out that the crystal holder dimensions shown in Figure 1 of the A.W.S. Specification should be corrected to agree with previous Signal Corps Drawings SC-B-5999-A and B since these drawings were the basis under which the present CR-1 phenolic holder was designed. It was agreed that a deviation would be allowed in this respect.

c. Representatives present were informed that defect standards for external and internal inspection of crystal units would be set up in each contractors plant as rapidly as possible in order to achieve uniformity of inspection in each individual plant as well as between the various contractor's plants.

10. Spurious Frequency Test covered on page 5 of the outline was discussed at some length, and it was generally agreed that the present form of test for spurious frequencies was somewhat inaccurate and not adequate for the purpose. Further investigation will be conducted by Aircraft Radio Laboratory and the manufacturers in an effort to develop a definite and adequate test for the purpose. In the meantime, the requirement will still be left in the specification and the present test now in use will be continued, but rejection of

*See footnote on Page 5 of attached outline.

Group Discussion of CR-1 ()/AR and DC-11-() Crystals (Continued)

submissions will not be made by the Signal Corps Inspector on this basis.

11. Drop Test, Vibration Test, Seal Test, and Internal Inspection were discussed in the order listed on pages 6 and 7 of the outline.

a. In the general discussion of these tests, information was requested as to whether or not a controlled temperature box could be used in the performance of the Drop and Vibration Tests. It was agreed that temperature boxes could be used for the purpose provided that the use of such equipment did not seriously delay the completion of tests in the required time. Attention was also called to the fact that the proposed method of handling such tests, as covered in the outline, eliminated for the most part any questionable rejects caused by temperature variation.

b. In relation to Paragraph c(2), it was pointed out that erratic changes in activity due to drop or vibration test might also be caused by dirty electrodes and contact plates. Apparently several instances of this sort have occurred where electrodes have been lapped and placed into holders without being sufficiently cleaned.

12. The Full Load Test described on page 8 of the outline was covered in some detail. From the results of this discussion, it was concluded that:

a. Increasing the voltage across the crystal unit by 20% over that imposed by the low coil of the Standard Crystal Test Set would result in a loss of high activity crystal units due to fracture since such units would have to be production tested at higher voltages in order to meet the Signal Corps tests.

b. A full load test based on the voltage developed across the crystal unit by the low coil of the Standard Crystal Test Set would be satisfactory.

c. Aircraft Radio Laboratory would investigate the voltage imposed on Crystal Unit CR-1 ()/AR in present Signal Corps radio sets now in production and development, and that such development as found necessary would be initiated to obtain a complete answer to this problem.

d. In the meantime, production tests will proceed with Signal Corps full load tests based on the voltage developed across the crystal unit in the low coil of Standard Crystal Test Set as measured at room temperature.

13. The remaining tests covered on pages 8, 9, and 10 of the outline were not discussed in this conference due to the lack of time. However, an open discussion held after the conclusion of the main meeting brought up a few additional problems for consideration.

a. It was pointed out by one manufacturer that the present

Group Discussion of CR-1 ()/AR and DC-11-() Crystals (Continued)

immersion test had caused a lowering of frequency in some Crystal Units FT-243 placed under test in his plant although such effect was not noticed in Crystal Units CR-1 ()/AR made at the same time. Since the phenolic of the FT-243 unit was apparently at fault, it was suggested that this condition be referred to the Camp Coles Signal Laboratory for final comment.

b. It was also pointed out that high humidity conditions were causing some difficulty in temperature runs at one plant, resulting in some good crystals appearing as rejects. This condition, according to the manufacturer, was due to moisture absorption by the various phenolic insulators used in the temperature box. Silica jell as well as various other means had been tried to remedy this condition with no great success. According to the manufacturer, continuous temperature run recordings of rejects obtained under the above conditions showed that most of the reject units were good. The manufacturer suggested that all Signal Corps temperature run rejects be subjected to additional continuous temperature run tests in order to definitely determine the exact condition of such units. It was suggested by Aircraft Radio Laboratory that the manufacturer use better electrical insulating materials in the temperature boxes as a means of minimizing such conditions. The use of continuous temperature run equipment as a final check was taken under consideration, though it was pointed out that the use of such a test would extend Signal Corps tests way beyond the time requirements allowed. Further investigation of this condition will be carried out by Aircraft Radio Laboratory before a final decision is reached.

14. At the conclusion of the conference, it was decided that since the time allotted was insufficient to thoroughly discuss the various problems covered in the outline that Aircraft Radio Laboratory would forward at a later date to the CR-1 and DC-11 manufacturers concerned an analysis of the final decisions and conclusions obtained.

FAREWELL AND ADJOURN
COLONEL LESTER J. HARRIS
DIRECTOR, SCIA

THE CHAIRMAN: I would like for just a few minutes to ask Major Swinnerton to say a few words before we adjourn.

MAJOR SWINNERTON: Thank you, Colonel Harris. I have three things I want to say and I will try and say them briefly. You haven't had much pressure from any direction that I am aware of on the conservation of raw material. That is, quartz. You are going to get some shortly.

The second thing is that the Crystal Section of the Office of the Chief Signal Officer is proposing to issue, I hope within the next thirty days or sooner, if it can be done, a supplement to the manual on the subject of etching to frequency.

The third thing I have in mind is to voice the appreciation of the Office of the Chief Signal Officer and the Quartz Crystal Section to the Inspection Agency, and that means you, Colonel Harris, and all of the assembled manufacturers here. We wish to express our appreciation of the cooperation that has gone into making this conference possible. (Applause)

THE CHAIRMAN: It has been a swell time. We have had a lot of fun. We have done a lot of things and you anticipated the roll call this morning and you didn't get it and you were disappointed. All we did was hang that over your heads. If you weren't here, you were to be marked absent. That was all there was to it. All of you were here, including myself and it was bad, because I missed my breakfast. I didn't have a thing until noon. That wasn't good.

I hope you will all go back feeling like it has been a wonderful thing and the success, if there is a success, I think, was due to the work of Mr. Wavering, (Applause) Mr. Sauer, (Applause) Miss Hooker, (Applause) Lieutenant Rittenhouse, (Applause) and all the rest of them. All I did was to read what they told me to. I had a swell time doing it and let's work together and let's cooperate and let's get the job done.

... The meeting adjourned at four forty o'clock ...

OUTLINE USED IN GROUP DISCUSSION OF
CR-1 ()/AR AND DC-11-() CRYSTALS

1. Organizations to be represented.

- a. Crystal Manufacturers, Crystal Units DC-11 and CR-1 ()/AR.
- b. Dayton Signal Corps Procurement District.
- c. Aircraft Radio Laboratory.
- d. Signal Corps Inspection Agency.

2. Purpose of Conference.

The purpose of this conference is to hold an open discussion concerning contractual relationships, inspection problems and Signal Corps Acceptance Tests performed under the A.W.S. Specification C75.11 - 1944.

3. Object

The object of this conference is to obtain uniformity of test, uniformity of product and improved quality control for Crystal Units CR-1 ()/AR and DC-11 ().

4. Schedule

1:15 P.M. - 1:45 P.M., DSCPD

Open discussion of general contractual matters and specific problems relating to prime and subcontractor's responsibilities.

1:45 P.M. - 2:15 P.M., Signal Corps Inspection Agency

Open discussion of Signal Corps inspection methods, quality control program and problems relating to inspection.

2:15 P.M. - 4:00 P.M., Aircraft Radio Laboratory

Open discussion of Signal Corps Acceptance Tests performed under the A.W.S. Specification C75.11 - 1944.

4:00 P.M. - 4:30 P.M.

Open discussion.

NOTES

1. Responsibilities of Signal Corps Organizations Participating in Conference.

- a. The Dayton Signal Corps Procurement District is responsible

Outline Used in Group Discussion (Continued)

for issuing contracts for crystal units for the Army Air Forces and for passing final approvals on any technical or other changes in the contract which might affect the cost of the units or which might cause delay in delivery.

b. The Aircraft Radio Laboratory is responsible for setting up the technical requirements and specifications necessary to meet the military characteristics requested by the Army Air Forces. Other functions include conducting pilot runs, development and investigations of manufacturers' requests for technical deviations.

c. The Signal Corps Inspection Agency and its Zones are responsible for testing the production crystal units and for the maintenance of the quality level required by the specification as well as the quality levels and requirements established during the pilot run.

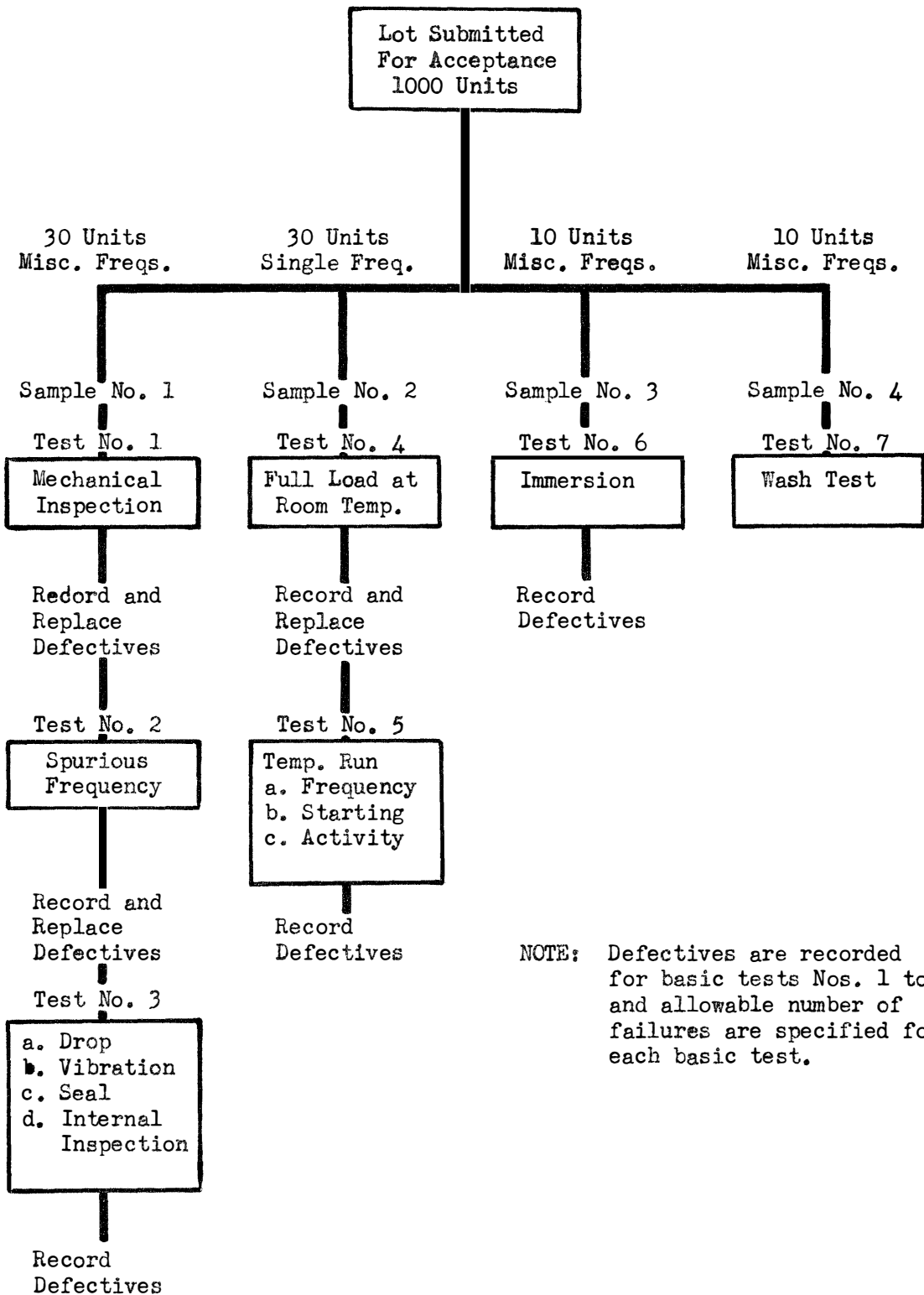
2. Problems pertaining to Signal Corps Acceptance Tests for Crystal Units CR-1 ()/AR, and position of Aircraft Radio Laboratory in respect to such tests.

a. Aircraft Radio Laboratory is endeavoring to obtain a good production crystal unit of the CR-1 ()/AR type which can be subjected to quality control methods of inspection by the use of accurate sampling procedures. To attain such an end, it is necessary that the production crystal units be of uniform quality and that the tests be of a uniform nature. The conference discussion is intended to provide for an exchange of ideas between the Signal Corps and the Contractors as well as between the Contractors themselves relative to the improvement of manufacturing methods, increasing the accuracy of acceptance tests and modification of present tests as based on experience with the A.W.S. specification in plants to date.

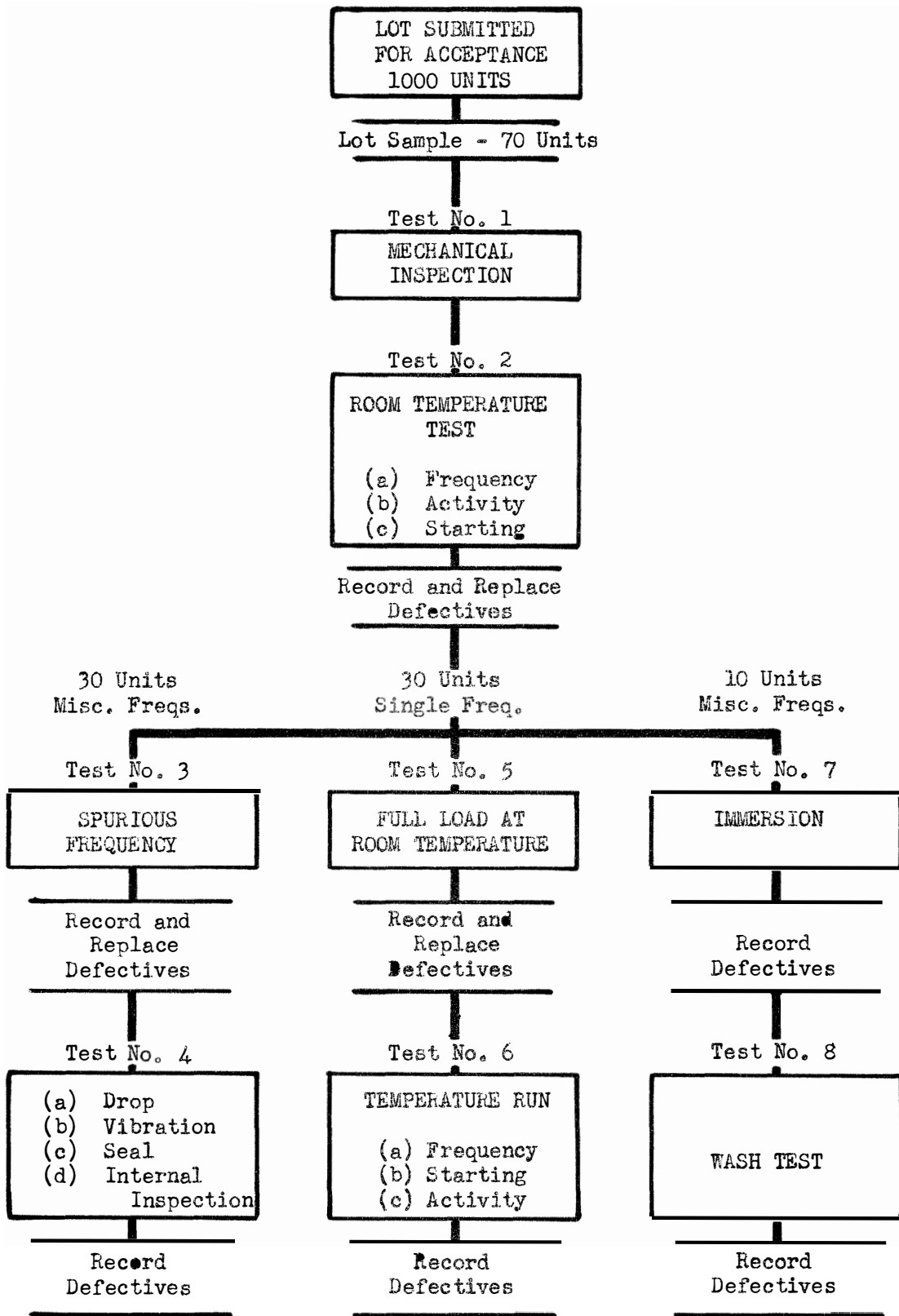
b. In order to expedite the progress of the conference, since the time allotted is short, the Aircraft Radio Laboratory has outlined below a description of the various acceptance tests, difficulties experienced in tests, and corrective measures proposed. It is desired that the contractors and manufacturers consider carefully these proposals since comments and questions will be solicited during the conference.

c. The desirability of manufacturers offering sound constructive criticisms cannot be emphasized too strongly. Such comments and criticisms by the manufacturers and the Signal Corps will materially aid and assist in the formulation of satisfactory acceptance tests during the short time available.

PROPOSED ACCEPTANCE TESTS FOR CRYSTAL UNIT CR-1 ()/AR



NOTE: Defectives are recorded for basic tests Nos. 1 to 6 and allowable number of failures are specified for each basic test.



Outline Used in Group Discussion (Continued)

INSPECTION DETAILS

1. Mechanical and Visual Inspection (External inspection of crystal unit)

a. This test as now performed under the American War Standards Specification C75.11 - 1944 is unsatisfactory in that inspection is subject to varying opinion judgments by the Signal Corps Inspectors. This results in non-uniformity of inspection between plants and between inspection zones.

b. To correct the above condition, it is proposed that models of representative defect standards be established. Sufficient models of each type of defect will be selected to establish a graduated range of bad, borderline, and good units. These models will be photographed and used as a basis for setting up other similar models in the various plants during the pilot run.

c. Defects to be considered under Mechanical and Visual Inspection are as follows:

Pins:

Bent, loose, corroded*, out of tolerance

Case:

Warped*, cracked, chipped*, porous*, blistered*, out of tolerance.

Gaskets:

Undersize*, oversize*, torn*.

Nomenclature and Frequency Marking:

Illegible*, Incorrect, Incomplete, poor protective coating over marking.

Screws:

Corroded*, loose or missing, badly burred*, screw wells not sealed*.

d. One test failure will be allowed for each type of defect found in the thirty units inspected. Two test failures of the same type will reject the lot.

2. Spurious Frequency Test:

a. It has been the experience of Aircraft Radio Laboratory that the test for spurious frequencies in crystal units is not an adequate test for the purpose. Present methods of testing have inherent difficulties in that the test may or may not repeat depending on the

*Models will be selected for those defects marked with an *. Defects not so marked are self-evident.

Outline Used in Group Discussion (Continued)

particular temperature at the time. Investigation will be carried on to determine whether or not an accurate and definite test can be developed for the purpose. In the meantime, the test will be carried on in the normal manner by Signal Corps inspection personnel. The results of the spurious frequency tests will be forwarded to Aircraft Radio Laboratory, and where conditions indicate that a manufacturer is not doing a good job, investigation will be made by this Laboratory.

b. Comments are invited from manufacturers as to causes of failure and corrective action normally instituted or carried out in plant procedure.

3. Drop Test
Vibration Test
Seal Test
Internal Inspection

a. It has been found desirable to consider drop test, vibration test, seal test, and internal inspection as a group test since the results of such tests bear a definite relationship to each other. The test will be made on thirty (30) crystal units of which not less than ten will be opened for internal inspection.

b. Present methods of running the drop test and vibration test provide results which are not always uniform due to the fact that some crystal units exhibit room temperature activity dips which may cause either sharp or slow changes in activity well in excess of ten percent of the initial value.

c. It is proposed that the drop and vibration test be made in the following manner:

(1) Cull out all crystal units which obviously exhibit unstable activity value at room temperature, and replace with stable units to obtain test group of thirty (30) units. Measure the frequency and activity of the units, run drop test and vibration test, record activity and frequency in each case, and mark crystal units, having changes in activity and frequency in excess of ten (10) percent and .002 percent respectively.

(2) Open marked crystals after seal test and if any units contain the following defects, it shall be recorded as a definite drop test or vibration test failure:

- (a) Air gap less than .0003 inches.
- (b) Spring pressure less than $2\frac{1}{2}$ lbs.
- (c) Foreign material in holder cavity or between electrodes*

*Reference defect standards will be established.

Outline Used in Group Discussion (Continued)

(d) Poor electrodes*

(e) Oscillator plate undersize, oversize, having chipped or rounded corners, or badly out of square*

(3) Two rejects will be allowed for drop test and vibration test combined.

d. Seal test will be made by ionization or water immersion method until sufficient ionization equipment is available, after which all seal tests will be made by the ionization method. The test will be made on thirty (30) crystal units and one test failure will be allowed.

e. Internal inspection has not been satisfactory when left on an opinion basis. Therefore, defect standards will also be set up for this inspection in the same manner as for the external inspection of the holder. One test failure of each type will be allowed. The minimum sample will be ten units although more may be taken if drop and vibration test cull out more than ten units. Defects are listed below:

Gaskets:

Soiled*, torn*, improperly mounted*.

Interior of Case:

Contains obvious moisture, oil or wax*, contains loose or foreign particles*, loose or broken contact plates, corroded contact plates*.

Chase or Interior Fittings:

Broken or cracked, porous*, rough edges or flash*, soiled*, electrodes bind or chase binds in cavity - improper dimensions*.

Oscillator Plate:

Undersize or oversize*, fractured*, foreign material on plate including pencil marks*, rough edges, edge chips or scratches**, excessively beveled edges*, corner chips not rounded.

Electrodes:

Insufficient air gap, poor lands*, corroded*.

f. Under the above group test of drop, vibration, seal and internal inspection not more than two test failures will be permitted for drop and vibration test combined, not more than one test failure for seal test, and not more than one test failure of any one type under internal inspection.

**Will not be cause for inspection reject where etching requirements are under effect. Signal Corps inspector will record data and forward to Aircraft Radio Laboratory for any necessary action.

* Reference defect standards will be established.

Outline Used in Group Discussion (Continued)

4. Full Load Test:

a. Present full load test under A.W.S. Specification C75.11 - 1944 does not provide adequate test conditions for crystal units having frequencies over 7.8 megacycles as related to the equipment in which the crystal unit must operate.

b. It is proposed to run an overload test at room temperature based on increasing the voltage across a crystal unit in the Standard Signal Corps Test Set AN/TSM-1 by 20 percent (based on the low coil) over that obtained by the same crystal unit oscillating at peak activity in the same test set. Test will be made on crystal units of every frequency manufactured.

c. Thirty crystal units will be tested and one test failure will be allowed.

5. Temperature Run (Activity, Frequency, Starting)

a. The initial results obtained on early pilot runs under acceptance test temperature runs based on the A.W.S. Specification C75.11 - 1944 was highly unsatisfactory to both the manufacturers and the Signal Corps. Since that time the corrective action taken by most manufacturers has brought quality level to an acceptable value. Corrective action found necessary at the time included the following:

(1) Improved temperature correlation of temperature boxes and continued maintenance of such correlation with especial reference to temperature and points.

(2) Improved activity and frequency correlation of oscillator circuits and continued maintenance of such correlation.

(3) More uniform operation of temperature boxes by supervision of operators and by use of automatic reject mechanisms.

(4) Setting manufacturing levels for frequency and activity to values sufficient to insure acceptance in Signal Corps tests.

b. Other factors which have been, or which might be responsible for rejecting good crystals or passing bad crystals during a temperature run are as follows:

(1) Non-stable oscillator due to tubes or components.

(2) Sticky activity meter.

(3) Poor voltage regulation tubes in temperature test oscillator.

(4) Unstable crystal standard in temperature test

Outline Used in Group Discussion (Continued)

oscillator or crystal standard not warmed up sufficiently before temperature run.

(5) Production crystal units under test having some drop test or vibration test failures present. Vibration of crystal on temperature wheel may cause activity or frequency failure during temperature run.

(6) Bad humidity conditions in temperature box and use of insulating material having high moisture absorption properties.

(7) Poor contact resistance at temperature box contacts or variation of contact resistance.

(8) Use of altitude test immediately prior to temperature test.

(9) Variation in activity and frequency readings due to poor line voltage regulation in plant and due sometimes to merely switching heat "off" and "on" in temperature box.

(10) Non-etched or only slightly etched crystal units are apt to exhibit activity and frequency changes during the temperature run.

(11) Production crystal units which contain drop test failures may change their activity between production test and acceptance test due to normal handling in plant.

c. It is proposed that acceptance test for temperature run allow two test failures in each group of thirty (30) units tested per one thousand (1,000) unit lot.

(1) Under the acceptance test two of the thirty (30) units under temperature test may fall as low as .20 ma for frequencies below 7.8 mc (.18 ma for frequencies above 7.8 mc) and the remaining twenty-eight (28) crystal units may fall as low as .25 ma for frequencies below 7.8 mc (.20 ma for frequencies above 7.8 mc). Any that fall below the above requirements shall require rejection and retest of the submitted lot.

(2) Under the acceptance test two of the thirty (30) units under temperature test may exceed frequency tolerance by two hundred (200) c.p.s. The remaining twenty-eight (28) crystal units shall not exceed the tolerance limits. Any that exceed the above requirements shall require rejection and retest of the lot.

d. Acceptance tests will be made using a tuned plate oscillator, correlated equivalent to Standard Crystal Test Set AN/TSM-1, for the temperature test. Measurements of both activity and frequency will be made at half activity.

Outline Used in Group Discussion (Continued)

6. Immersion Test:

a. The immersion test as set up in the A.W.S. Specification is inherently a destructive test, that is, it results in a crystal holder which is no longer usable. The test also results in damage to the nomenclature. Pilot run data also shows that frequency and activity readings are apparently of no value in this test.

b. It is, therefore, proposed that only ten units per one thousand (1,000) unit lot be selected for this test and that no requirements be established as to adherence of nomenclature under these conditions. Test requirements will be based on a resistance measurement entirely.

c. One test failure will be allowed in each ten (10) units tests. A failure is defined as any unit in which the resistance drops below two hundred (200) megshons.

7. Cleaning Test:

a. The cleaning test as now covered in the A.W.S. Specification C75.11 - 1944 will apply. The frequency increase of the crystal unit after subjection to the cleaning test shall not exceed .006% of its nominal or rated frequency.

b. None of these units will be subjected to internal inspection.

