"PICTURE TUBE RELIABILITY"

BY

PATRICK E. SULLIVAN

GENERAL ELECTRIC

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Picture Tube Reliability

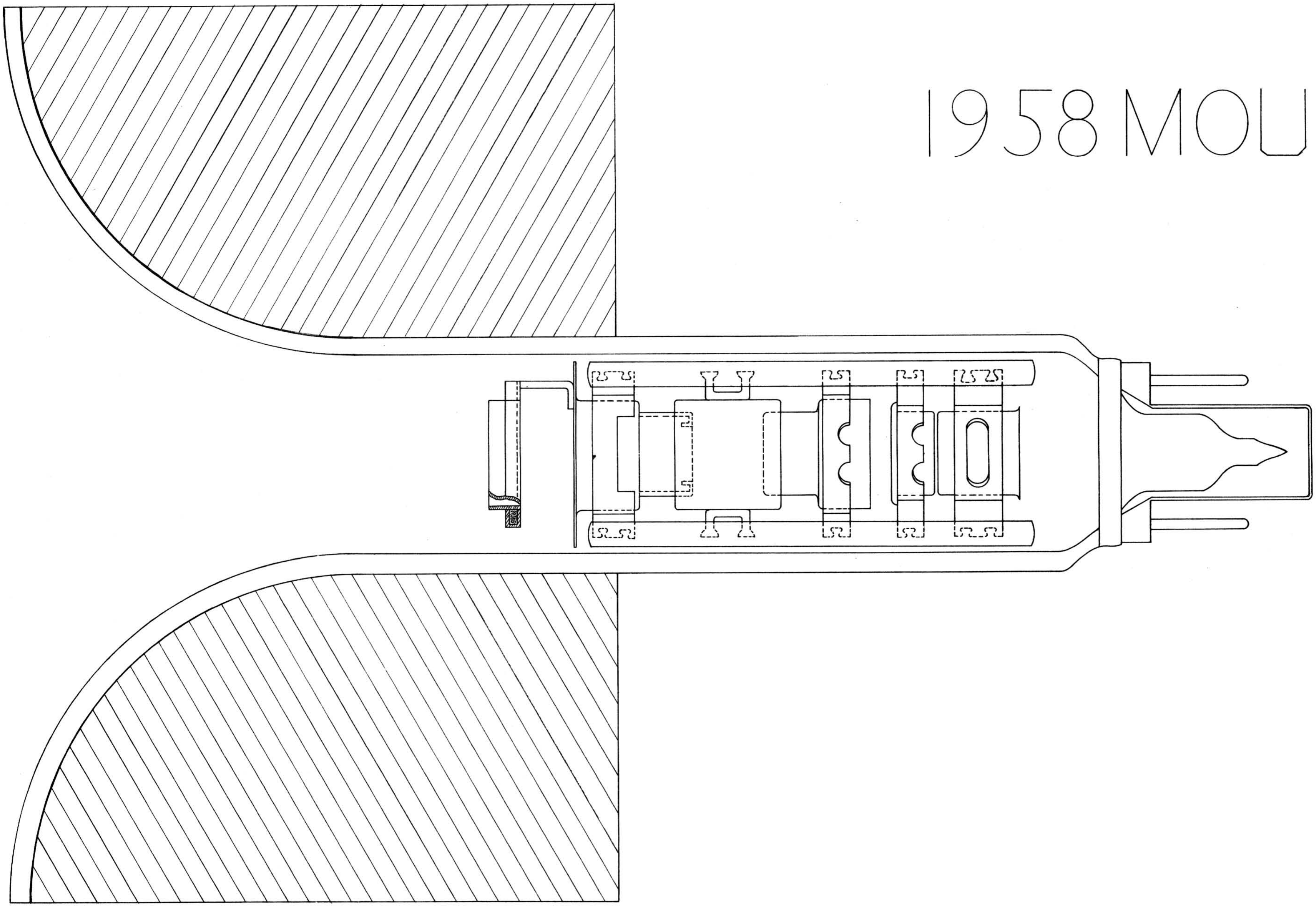
This is the first in a series of reports on picture tube reliability. This report will give the historical picture of our 110 degree picture tube manufacture, will relate the various 110 degree tube designs to reliability, will describe process changes, and make recommendations intended to promote better reliability.

Historical Information

The 110 degree line of tubes started production with a line of ion trap tubes in the 14", 17", and 21" sizes. The tube types were, 14AJP4, 17BRP4, and 21CZP4. In the last half of 1957, these three tube types were still experiencing a high rate of losses in the factory and we were being criticized for unusually heavy preship rejects on the Television Department's production line. These rejects were running over 8% on the Television Department's preline test operation. In addition, the Television Department was critical of our field return rate and of our life test results. Realizing that drastic measures were indicated in order to alleviate the condition, Mr. DeLong initiated an all out attack on all facets of the problem. To assist in the solution of the problem, the entire Product Engineering Section was assigned to various manufacturing engineering or process engineering duties. In a short time, however, Messrs. Schilling, Krackhardt, and Perkins were reassigned to Product Engineering work in order to design a new electron gun and new tube that would have much easier factory processing, much lower factory shrinkage, lower shrinkage in the customer's factory and assembly line, better warehouse reliability, and better life test. The whole purpose of this design effort was to design a gun having every desirable manufacturing feature incorporated in it, as it was well understood that a gun and tube that was easily manufactured would have greatest reliability. It is axiomatic in the vacuum tube business that factory shrinkage and tube reliability go hand in hand. This new gun was used in the 17CKP4 tube and the 21DEP4 tube. It is known as the 1958 gun or the DE gun.

I would like to point out some of the advantageous features of this 1958 mount. First, the design of the final lens (the so-called Einzel lens) has the low voltage focusing element larger in diameter than the high voltage third and fifth anodes. In addition, the fifth anode is formed with an outer skirt going almost completely out to the glass wall, and an inner formed aperture in the lower end so that getter being flashed from the top of the gun cannot find any straight-line path which will allow it to condense on the low voltage lens electrode. The getter material is barium, the same material as used in the cathode, and a material very prone to emit electrons. If barium deposits on the high voltage elements, there is only a reverse negative voltage which will not attract the electrons. If however, the barium is on the low voltage electrode, the electrons are pulled out by the adjacent high voltage electrodes. This initial flow of electrons triggers off an arc. Thus, this high voltage lens arrangement was designed to minimize the arc-forming ability of barium getter material on the low voltage focus electrode.

1958 MOUNT



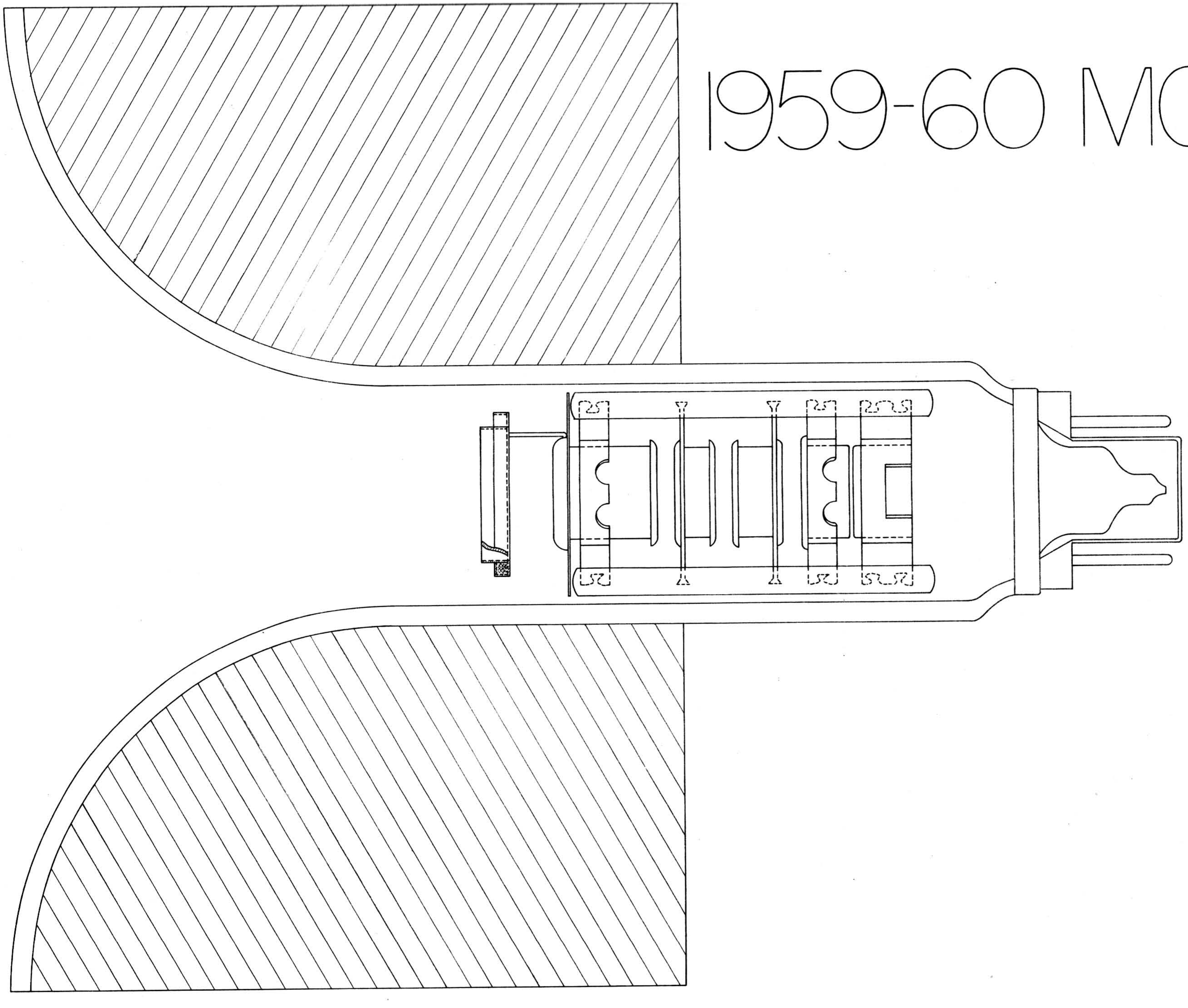
The second feature of this gun is the method of support of the electrodes in the glass bead. To each electrode is welded a wide strap. This strap has on its end a specially designed cut out or claw which will give maximum bite into the glass bead. With these wide straps, any tilting of the parts in the glass beads or any looseness of the parts in the glass beads is minimized. This gives maximum protection against changes in focus voltage or poor focus quality, both initially and throughout the life of the tube. In addition, the length of the insulation path along the glass bead is sufficient that under normal conditions the glass may easily be expected to withstand the voltages applied. The edges of the electrodes which might give rise to stray emission or corona discharge are rolled or otherwise polished in order to reduce sharp edges and thereby increase the high voltage tolerance. The gun was designed without an ion trap to give it better focus quality and the angle of the electron beam was designed to give maximum performance in the center of the tube consistent with sufficient depth of focus to give an acceptable picture at the extreme edges of the tube.

Early samples were made with an 0.025 inch first grid aperture. It was found that this small size aperture resulted in too close cathode to grid one spacing which gave poor reliability due to cathode-grid one shorts. This spacing was increased early in the design and the grid one aperture made slightly larger even though this gave slightly poorer spot size and resolution. The top springs which made contact between the bulb neck and the top electrode were designed to be quite long and with double contact to insure long life performance. The neck length was designed so that the springs would not attempt to contact the neck in an area of either our splice or the bulb vendor's splice. The getter was selected for maximum fill and for maximum barium yield. It was placed well above the other metal parts so that it could be flashed without unduly heating the remainder of the electron gun. The neck length was chosen so that the getter (which is the screen-most part of the gun) was far enough back from the yoke so as not to absorb power from the yoke and not to interfere with the electron beam while it was being deflected. As you can see, every effort was made to have an easily manufactured, low shrinkage, high yield, highly reliable, and long life tube. The results have well proven that we succeeded in our attempt and this gun and these tubes were the best that were ever manufactured by the Cathode Ray Tube Department, or for that matter, by any cathode ray tube manufacturer.

In the summer of 1958, the Philco Corporation announced their gas pump model and Predicta model television receivers. These receivers were quite shallow front to back and were made to exploit and capitalize on a Philco developed short neck tube. This tube was 1 1/2 inches shorter than our previous models and the Television Department requested that we supply these or similarly short picture tubes. After procuring samples of these tubes, visiting the Lansdale Tube Operation of Philco, discussing this design with their engineers, and examining the Philco life test, we concluded that this was not a good manufacturable or reliable design. While the Sylvania Tube Company finally succeeded in getting a passable tube, even our most recent data on Philco tubes life tested showed them failing in less than 500 hours. The Television Department believed that the Philco Corporation had such a reputation that they would not dare to introduce the tube and the set if it were as unreliable as we had described, and felt that G.E. must have a competitive product. We acceded to their urgent request and introduced a gun which is pictured here and known as the 1959 gun. A point by point comparison of these two designs would show that we abandoned practically every one of the features that made the previous gun so highly manufacturable and reliable. You will note that we no longer shadow the getter from the focus electrode. We no longer have wide straps on all the parts, and in fact, in order to achieve satisfactory insulation length along the glass bead, we abandoned the wide strap and designed a special claw which bit into the glass bead sideways. While this gave adequate insulation length along the glass bead, it subjected the bead to mechanical strains and has been the cause of a considerable amount of bead breakage. We have recently designed a narrow strap and are abandoning these claws in favor of a narrow strap in order to alleviate the bead breakage problem. This may lead to other problems with parts tilt and poor focus, but we now consider this a better compromise. The entire gun is mounted closer to the stem which results in the cathode being heated to a greater extent during the gun sealing process, which may contribute to worse emission life. The tubulation was made much shorter so that it would not protrude beyond the lead wires. This required a new design tipping oven, and in the early days of this production we were plagued with glass cracks in the tubulation or in the stem and we were plagued with leaks along the lead wires. This was finally alleviated when we ascertained that the socket used by the Television Department stuck out behind the tube by almost an 1/8 inch more than our base and the Television Department did not intend to use a shorter socket. On this basis we lengthened our tip by an 1/8 of an inch, again redesigned our tipping ovens and were able to greatly improve the shrinkage for glass cracks and leaky lead wires.

At the outset it was recognized that this new short neck tube would involve higher cost, higher shrinkage, less reliability, more field returns, and possible shorter life. During the last years manufacture of this gun we have made continual efforts to improve this quality. I have described our problem with the tip length. It should be noted that our tipping oven was redesigned and re-equipped on all our machines three different times in order to achieve lower glass losses and better reliability from air leakers. The lead wire length was redesigned twice, the method of making the stem was changed three times, particularly with relationship to the positioning of the dummy lead and the method of cutting off the unused lead so as to leave the minimum strain in the glass stem. Our gun seal equipment was completely redesigned in order to give better gun alignment and leave less strains on the neck due to heat cooling. Our procedures were changed to require that the electron guns be handled with tongs and a special tong design was developed by us for this purpose. The lead wire material was changed to minimize the breaking of the stem due to the material. The stem was redesigned early in the production of this tube in order to incorporate outer fillets which would add to the length of glass around the lead wire and thereby reduce the probability of leads along the lead wire. We incorporated a very rigid quality control stem leak test which is continued to this day. In our electron gun parts preparation, a hydrogen furance is reserved exclusively for the cathode. Our hydrogen furnaces are torn down for cleaning and repair each year. Charcoal traps and special chemicals dry our

1959-60 MOUNT



hydrogen before firing stainless steel parts. We have installed special temperature and humidity controls in our cathode spray room and more recently have installed a window so that visitors can be shown this operation or the foreman can supervise this operation without the necessity of entering this specially maintained room. Recently our cathode spray technique has been changed to place only one row instead of two rows of cathodes on a spray bar in order to get a smoother texture and better cathode. This has reduced our output per operator hour in half. We have instituted a blue ticket test so that each lot of parts received has a sample run through the factory on special test to insure than any malfunctioning of these parts is discovered before the lot is put into production.

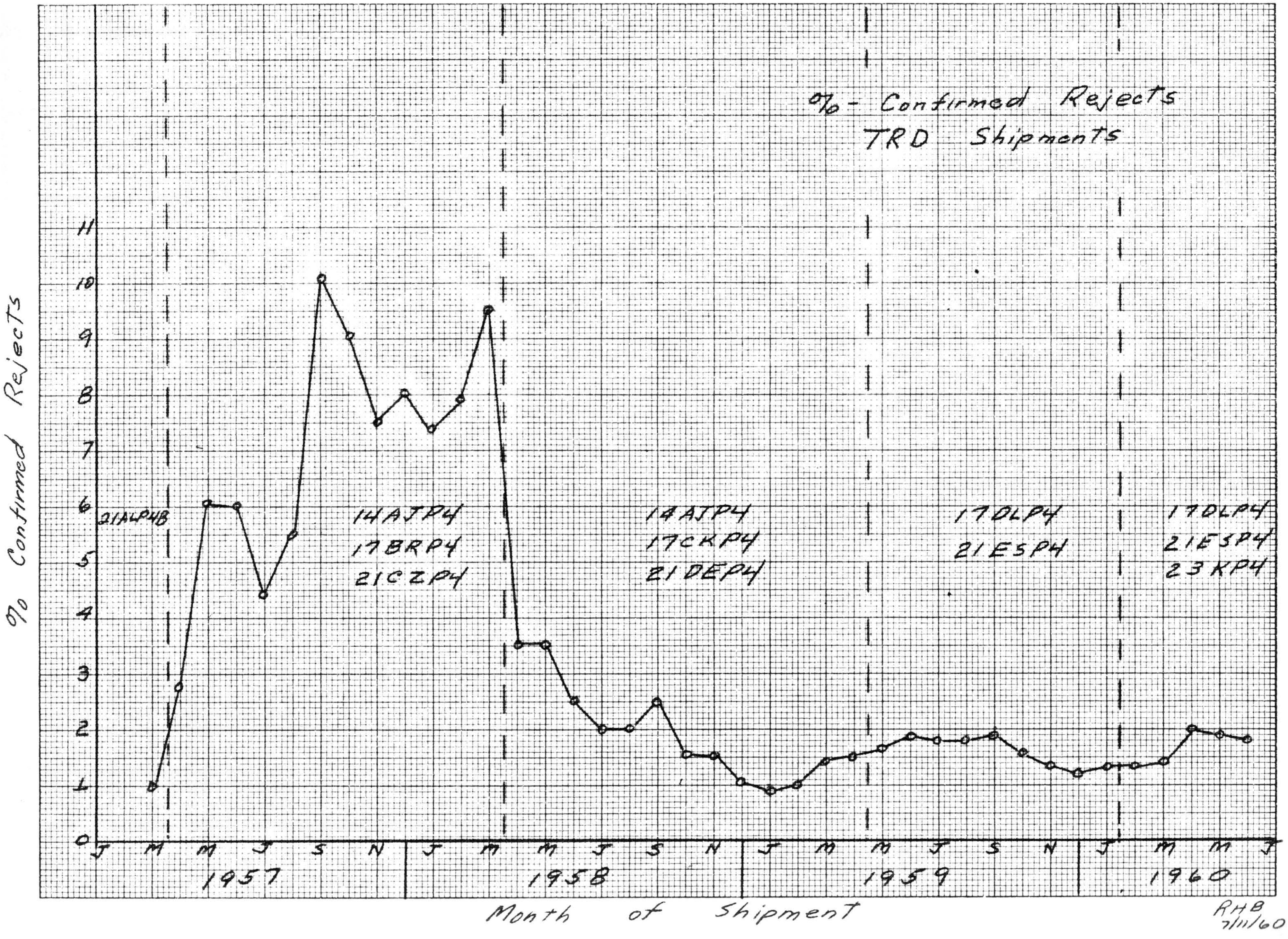
Many additional changes in processes, manufacturing equipment, design and procedure were made in order to improve the yield and reliability of this new gun and tube. Among these are a new phosphor for better phosphor adherence and less dusting and a new aluminizing filament to give better uniformity of aluminizing which gave better color uniformity, less blue edges, a better cross-over control, thus allowing higher bakeout and more getter flash. The vacuum on the aluminizing machines was improved. A new film lacquer produced by G.E. in Cleveland was developed and put into production. A new aluminum thickness control utilizing a "Q" coil shut-off was installed. An extra operator was put on each aluminizing machine to measure and control the corner thickness of the aluminum. A 100% inspection was put on the inside paint operation to check length and quality. Both Sylvania and G.E. phosphors were additionally improved by particle size control to give better color distribution. The G.E. phosphor was improved to make it tolerate a higher bakeout, and further improved to make it have better brightness. The water treatment system was redesigned and rebuilt to give even cleaner water and less screen defects, both initially and developing throughout life. Our screen bake process was increased both in temperature and time several times so that the overall change raised the screen bake from 22 minutes over 400 and reaching a peak of 415°C to a bake of 42 minutes over 400 reaching a peak of 426°C. We instituted an inside paint viscosity control and installed neck guides after inside paint on the dryers to reduce loose inside paint particles in the tube. A procedure of air flushing bulbs after bakeout and before gun seal was initiated to remove the gaseous products of decomposition. We instituted, at various times, neck cleaning procedures at filming, gun seal, screening, and other areas in an effort to improve the neck cleanliness situation and installed a two step trim at our spray film station to reduce loose particles of filming lacquer. We installed a hot tipoff on some exhaust machines to improve the residual gas situation and are extending this to all machines. A quality control test is now in use so that gassy tubes found at test are immediately reported to exhaust and result in removal of the buggy causing said gassy tubes. A better RF coil on the exhaust machines gives better gun de-gassing. We instituted quality control procedures for maintenance of proper RF heating, tipping, vacuum maintenance, and other vital tube making processes. We installed an automatic getter flash control, changed the getter design several times and finally changed to an exothermic getter whereby the flash, once started, proceeds to completion from its own exothermic heat. A new base which is attached to the tube by pressure of the nylon on the base pins instead of cement has greatly reduced cracked tips in the field. Our sparking techniques, voltages, and schedules have been modified five times in an effort to improve the high voltage tolerance of our tubes. Our testing is done at 3 kilovolts over the maximum voltage. An emission build-up test at preship weeds out the slow leakers. We installed steam heaters and a separate de-humidified air supply on our outside paint machine, and have just recently gone to a water base paint to eliminate peeled and loose paint on the outside of the tube. This new water base paint has necessitated the design and installation of a machine to wash the paint masks after every two tubes. We have recently changed the design of our spring clips from 3 springs with double contacts to two springs reaching upward and two springs reaching downward in order to improve our high voltage tolerance. We have instituted strict incoming inspection procedures to insure that our parts have no burrs. We are systematically eliminating all wood and fiberous material from our tube process areas, in order to eliminate loose particles falling into the tube. In our screen rooms, for example, we are replacing our wood platforms with steel and are installing rubber matting over all platforms. We have eliminated all paper and fiberous material from our tables, shelves, etc. in the mount room. We are using textolite tops and we are even anodizing our aluminum boxes to prevent aluminum scale from falling into the gun or tube. We have substituted plastic mount trays for the old wooden mount trays previously used. We have instituted a procedure of washing all of our incoming multiform glass. We have instituted a quality control inspection on the degree of fusion of the multiform beads. We have changed our glassing blocks to a new material, Viscotherm, so that no loose oxidized material will get into or on the gun. We have installed an aperture in the top anode of the gun in an attempt to prevent getter from splashing down into the gun. We have instituted new and strict cleanliness procedures in the mount room including a periodic check of the air supply filters and thorough cleaning of the ceiling panels at frequent intervals.

Results

It is very difficult to tie down specific results to any of these improvements that have been enumerated. As I have said early in this talk, the 1958 gun was the best gun ever used in cathode ray picture tubes by any manufacturer. I do not expect the present gun will ever have the same low shrinkages in the factory and the high reliability in the field. Recently, due to Television Department cut backs, we had occasion to run equal numbers of the 1958 tubes for replacement purposes and the 1959 tubes for original equipment. The shrinkage in the factory for high voltage defects which comprises arcing, stray emission, and anode leakages were twice as high on the 1959 tube as on the 1958 tube with all other procedures being equal.

The rejects on the Television Department line for this last year have been higher than on the 1958 product and the number of these rejects confirmed by our testing has likewise been higher. However, they are nowhere near as bad a situation as existed in 1957. On page 9 a graph shows the percent confirmed rejects being returned from the Television Receiver Department for the period 1957 to the present. You will note that the consistent improvement made throughout 1958, so that the January 1959 confirmed rejects were less than 1%, was interrupted, and we have not reached this low a figure since.

Our life test history does not bear out reports that this new tube type is significantly more unreliable. In fact, a perfect life test score of 375 was achieved in August of 1959 for the first time in Cathode Ray Tube history. On page 10 you may see a plot of this life test score from the beginning of 1957 to the present. The scoring system gives a greater weight to long life tubes and tries to factor in all aspects of life reliability. You will see that, with the exception of some short term dips and a very recent (as yet unknown caused) difficulty, our life test rating has consistently improved over the last three years. I believe this is a tribute to the zeal and attention of our manufacturing people because certainly this new design is much more difficult to achieve good life than the previous design. I believe tubes using the previous design would be even better, if such is possible. The life test chart just referred to was plotted from our tubes on our life test racks only. As you know, we are also operating life test on chassis. We do not use the same scoring system on the chassis life test, but it is significant to note that in 1957 we had 32% failures at or before 2,000 hours, in 1958 13% failures, and in 1959 10.4% failures.



% - Confirmed Rejects
TRD Shipments
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21DEP4
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Month of Shipment
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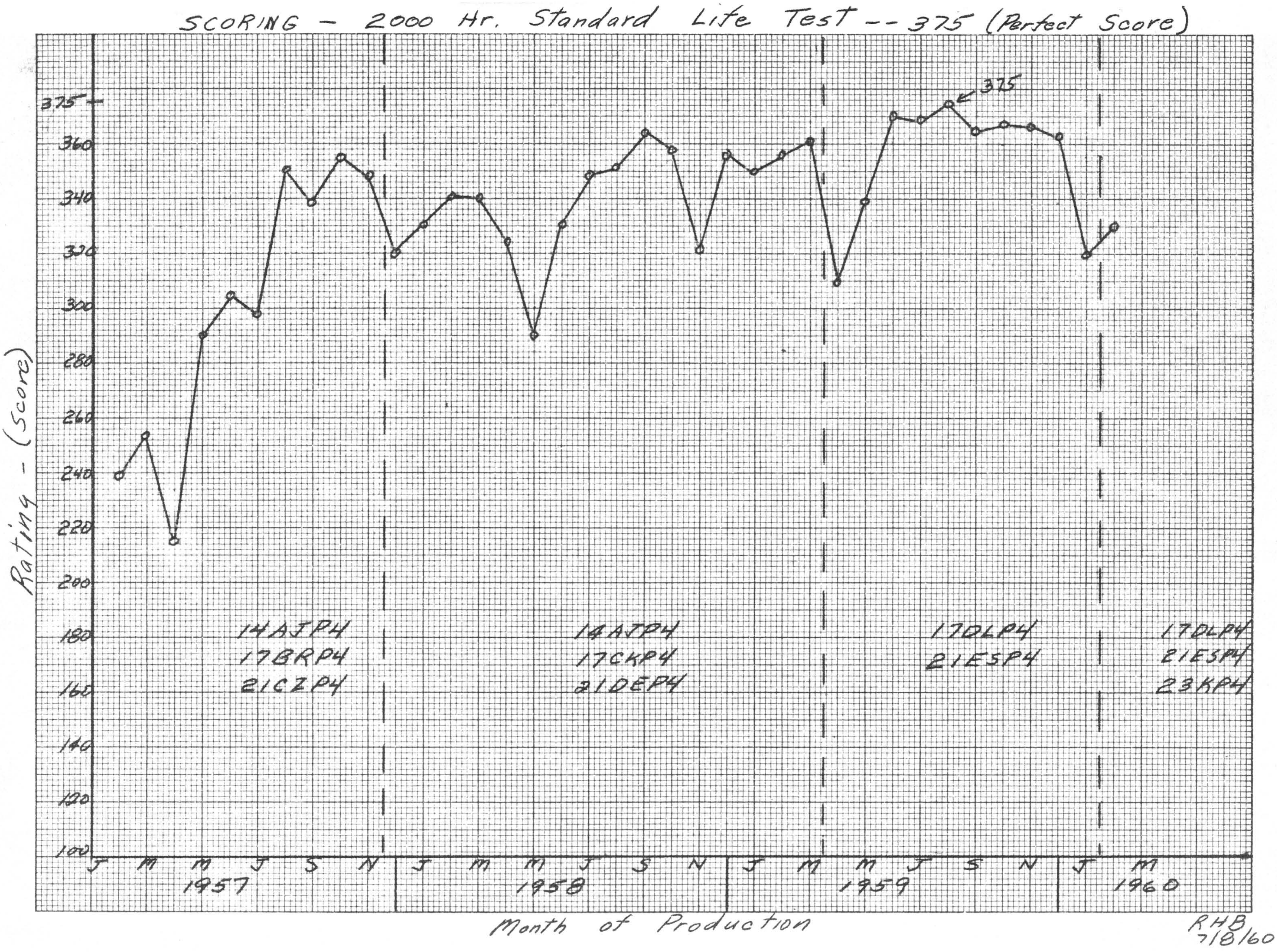
SCORING - 2000 Hr. Standard Life Test -- 375 (Perfect Score)
375
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Rating - (Score)
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17BRP4
21CZP4
14AJP4
17CKP4
21DEP4
17DLP4
21ESP4
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21ESP4
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1957 1958 1959 1960
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7/8/60

Recommendations

We are continuing to work on improvements in design and processing that will improve the reliability of the present tube types. I believe we have resolved all of the critical problems involving reliability except that of high voltage tolerance. Arcing causes not only customer dissatisfaction, but also causes direct failure of the tubes by burning out leads, cracking glass beads or generating gas. It also contributes to long term emission failure by either the arc attacking the cathode or the gas generated by the arc poisoning the cathodes. Thus, the main problem with reliability centers around the problem of arcing. The solution to the arcing problem is to be able to revert back to the Einzel lens as used in the 1958 mount. This will require approximately 5/16 inch additional neck length. If it is impossible to lengthen the tubes by this amount, the next recommendation would be to go to the TPF design which, by eliminating one of the electrodes, would shorten the gun sufficiently for us to use this old style Einzel lens. Another possible solution is to procure bulbs with an additional tubulation out the funnel in which the getter is located. This solution would seem to add too much to the cost to be really feasible. There is no question but what reliability has been sacrificed in favor of focus, contrast, resolution, cabinet depth, and possibly other performance or appearance features. I believe it is time to re-evaluate the compromises made between the various performance, value, reliability, and attractiveness features that go to make up the overall value of our product. I think you can see by todays presentation that improved reliability is easily possible if you are prepared to make the necessary sacrifices to achieve it.

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