ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

Semiannual Progress Report No. 4

SHOCK ON ELECTRICAL COMPONENTS IN TRACK-LAYING AND WHEELED VEHICLES

July 1, 1955 to December 1, 1955

H. S. Bull

Project 2145

DETROIT ARSENAL, DEPARTMENT OF THE ARMY
CONTRACT NO. DA-20-089-ORD-36543
CENTER LINE, MICHIGAN

January 1956

ensm

UMR0926

no. 4

FOREWORD

This is the fourth semiannual progress report on a research program being carried on in the Department of Electrical Engineering, The University of Michigan, under the supervision of the author.

Most of the work reported here represents the labor of Mr. Harris Olson, who has devoted all his time to this research. In addition, the project has benefited from the expert counsel of Professor Jesse Ormondroyd of the Department of Engineering Mechanics, and from the generous cooperation of the Chrysler Corp., the Electric Auto-Lite Co., the General Electric Co., the Tung-Sol Electric Co., the Westinghouse Electric Corp., and members of the SAE Impact-Tester Panel

TABLE OF CONTENTS

ENGINEERING RESEARCH INSTITUTE • UNIVERSITY OF MICHIGAN

LIST OF FIGURES

LIST OF FIGURES
(concluded)

ENGINEERING RESEARCH INSTITUTE · UNIVERSITY OF MICHIGAN

ABSTRACT

This is the fourth semiannual progress report covering the period from July 1 to December 1, 1955. The accomplishments may be summarized as follows:

1. Five impact testers of the Arsenal type have now been modified in accord with project recommendations and work has begun on studies of comparative performance of these machines.

2. Sufficient lamp mortality tests have been completed on the rotary-drum impact tester to indicate that it is a reliable testing device for miniature lamps.

3. A method of mounting miniature lamps on the rotary-drum tester has been devised that gives accurate positioning and low energy loss.

4. Additional theoretical studies of lamp impact testing on the rotary-drum tester have been completed.

5. A group of modified type 1251 lamps has been tested, with the results indicating that the structural modifications gave some improvement in life, but not as much as was anticipated.

6. Two changes in the instructions for modification of the Arsenal-type tester are included in an appendix to this report.

OBJECT

The objects of this research project are:

1. to determine practical means of increasing the operating life of incandescent lamps used on military vehicles, with particular reference to their resistance to vibration and mechanical shock;

2. to study the presently accepted method of impact-testing vehicular lamps and to determine practicable means of improving the tester and correlating the results obtained by the several testers now in service; and

3. to design, study, and evaluate a new and smaller impact tester which may possibly supplant the impact testers now being used.

CONCLUSIONS AND RECOMMENDATIONS

1. Five impact testers of the Arsenal type have been modified to comply with project recommendations and a testing program is underway to determine the correlation of these machines by comparison of lamp mortality curves taken under presumably identical conditions on each machine.

2. Lamp mortality tests performed on the rotary-drum impact tester indicate that it is a reliable machine with several outstanding advantages over prevailing types of testers. Several improvements of the tester components and studies of possible changes in operating procedure are contemplated.

3. Sample lots of modified type 2416 and type 1251 lamps have been received and tested. The results indicate that a rather drastic redesign of the 1251 may be necessary if marked improvement in its resistance to impact is to be achieved.

I. CONTINUED STUDY OF THE MODIFIED IMPACT TESTERS (ARSENAL TYPE)

A. STATUS OF EXISTING MACHINES

Early in 1955 detailed drawings and explanatory instructions for the modification of the Arsenal-type impact tester were sent to the seven other laboratories possessing these machines. It seems appropriate at this time to report briefly on the status of this modification program.

1. Detroit Arsenal Tester.—This machine was loaned to The University of Michigan for research purposes and was the first to be modified. Modification was completed in July, 1954, and data on its performance after modification may be found in the Project Progress Report 2145-12-P for January, 1955. To date, this machine has been operated nearly 800 hours since being modified.

2. Electric Auto-Lite Tester.—This tester, located at the Lockland plant near Cincinnati, was modified in the latter part of 1954. The difficulties encountered in completing this modification and typical data obtained on test lamps after these difficulties were surmounted are discussed in the Project Progress Report 2145-18-P for June, 1955. It is now being used for routine mortality testing.

3. General Electric Tester.—Modification of this machine, located at Nela Park, in Cleveland, was begun late in 1954 and quite consistent operation in routine lamp testing was achieved by March, 1955. Comparison of typical mortality curves obtained on this machine with similar curves for the Arsenal and Auto-Lite machines shows fairly close agreement (p. 11, 2145-18-P).

4. Tung-Sol Electric Tester.—Modification of this machine, located in Newark, was completed in August, 1955. Performance tests so far completed seem quite satisfactory and it is doubtless in regular use for production testing.

5. Westinghouse Tester.—This tester was modified in August, 1955, and preliminary evaluation tests seem to indicate satisfactory performance.

6. Chrysler Tester.—The tester owned by the Chrysler Corp. has not yet been modified, although the necessary parts have been completed and assembly is planned for the near future.

7. Guide-Lamp Tester.—This machine, located at Anderson, Ind., probably will not be modified.

8. Bureau of Standards Tester.—This tester probably will not be modified, because of the little use it receives.

B. PERFORMANCE OF TUNG-SOL TESTER

The results of mortality tests on six racks of lamps including both 12- and 28-volt types are now available, with the tester completely modified and operating under the following conditions:

Speed - 700 rpm
Lift force - 16 lb for .0015-in. lift
Anvil drop - .041 in.
Test cycle - 15 min cold
30 min hot
15 min cold and
repeat for 9 cycles, with lamps inspected at the end of each 60-minute cycle.

The results of these tests are shown in Figs. 1 and 2 and indicate a very satisfactory consistency in tester behavior. Records were also kept of the exact location of failed lamps on the test rack for these six runs and the results are shown in Fig. 3. It will be noted that roughly 40% of the 46 failures

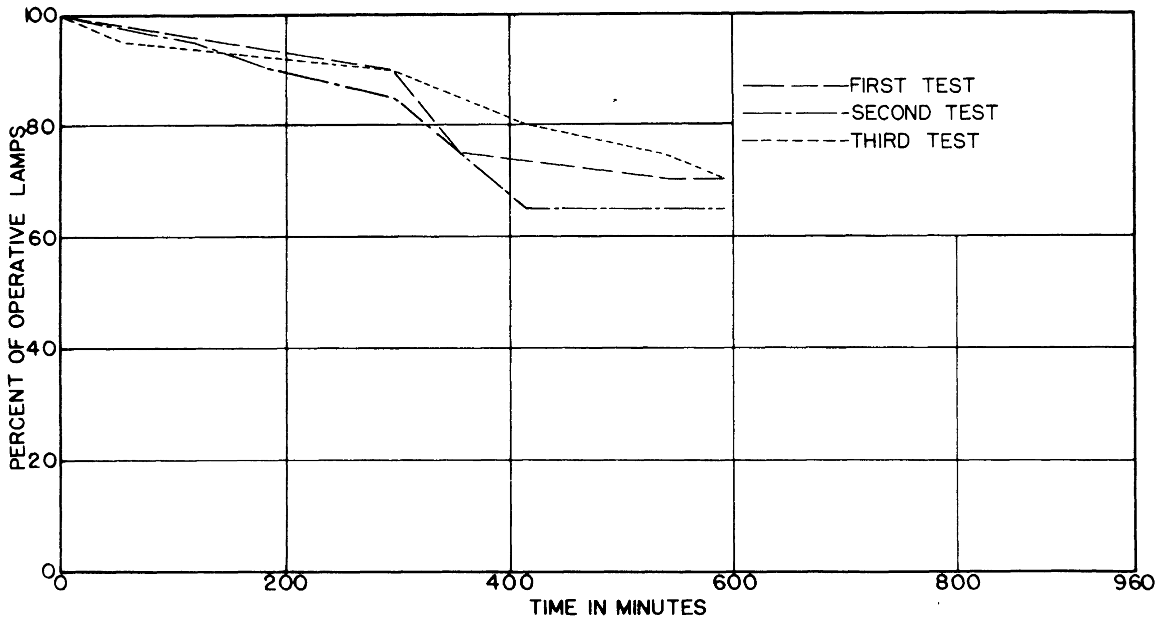


Fig. 1. Mortality curves of three racks of type 67 lamps operated on the Tung-Sol modified Arsenal-type impact tester.

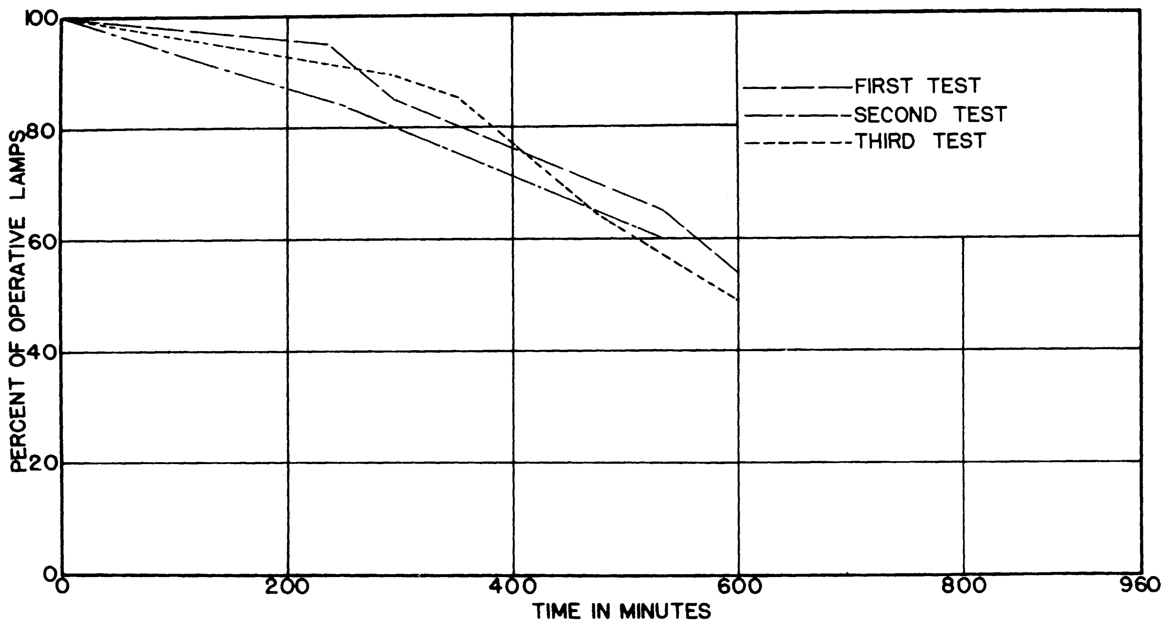


Fig. 2. Mortality curves of three racks of type 1251 lamps operated on the Tung-Sol modified Arsenal-type impact tester.

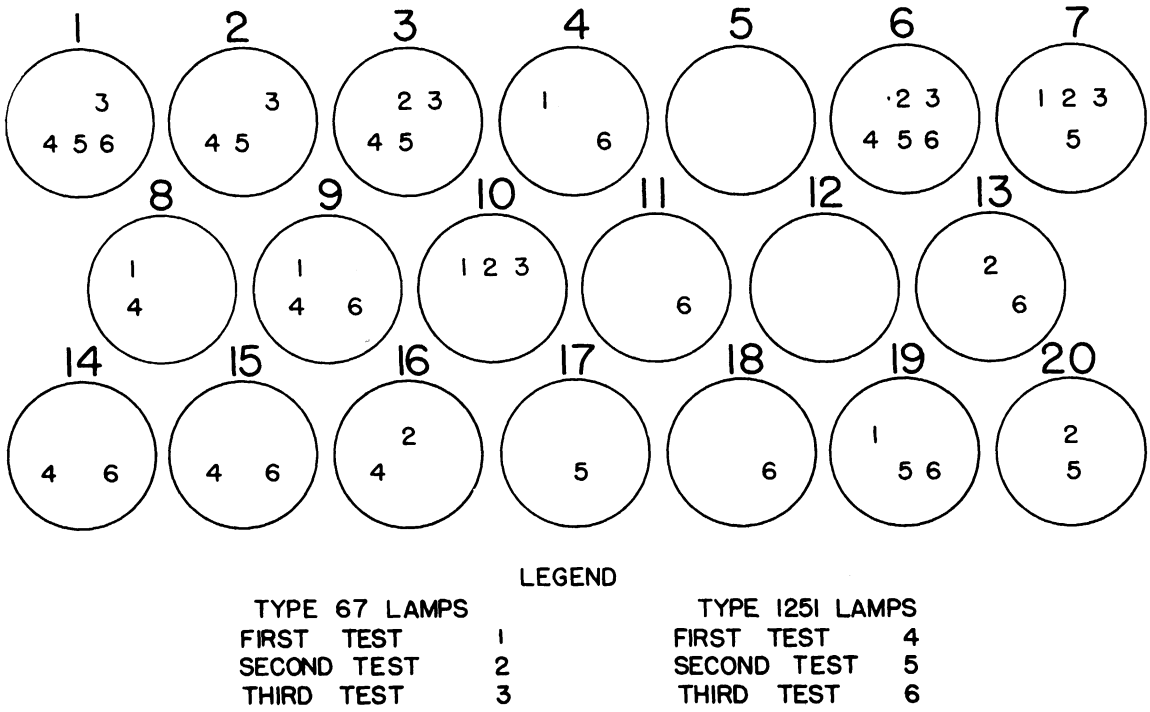


Fig. 3. Distribution of filament failures in terms of socket location for six racks of lamps tested on the Tung-Sol modified Arsenal-type impact tester.

occurred in sockets 1, 3, 6, and 7, while two sockets showed no failures and three sockets only one failure each. These observations are presented merely as a matter of interest, since the number of tests is too small to permit any definite conclusions to be drawn. However, the accumulated operating experience with the Arsenal tester reveals a somewhat similar situation.

C. PERFORMANCE OF WESTINGHOUSE TESTER

The Westinghouse Corp. has provided the project with the results of a series of lamp mortality tests performed on their Arsenal-type tester, including tests completed before the tester was modified. A total of 193 type 67 lamps were tested before modification with the tester operating at 900 rpm, and with hot and cold cycling in conformance with Federal Specification W-L-1116, Amend. 7, which is 15 minutes cold, 30 minutes hot, and repeat the cycle seven additional times. The steepest curve in Fig. 4 shows the average mortality obtained from the various runs in this series. A group of 199 lamps of the same type and lot was then subjected to a similar test, except that the tester speed was reduced to 700 rpm, with the average results as shown in the middle curve of Fig. 4. As would be expected, the slower speed brought about a marked reduction in mortality rate.

After the tester was modified to conform to the recommendations previously referred to, a group of 40 lamps from the same lot as the previous runs was tested under the following cycling conditions: 15 minutes cold, 30 minutes

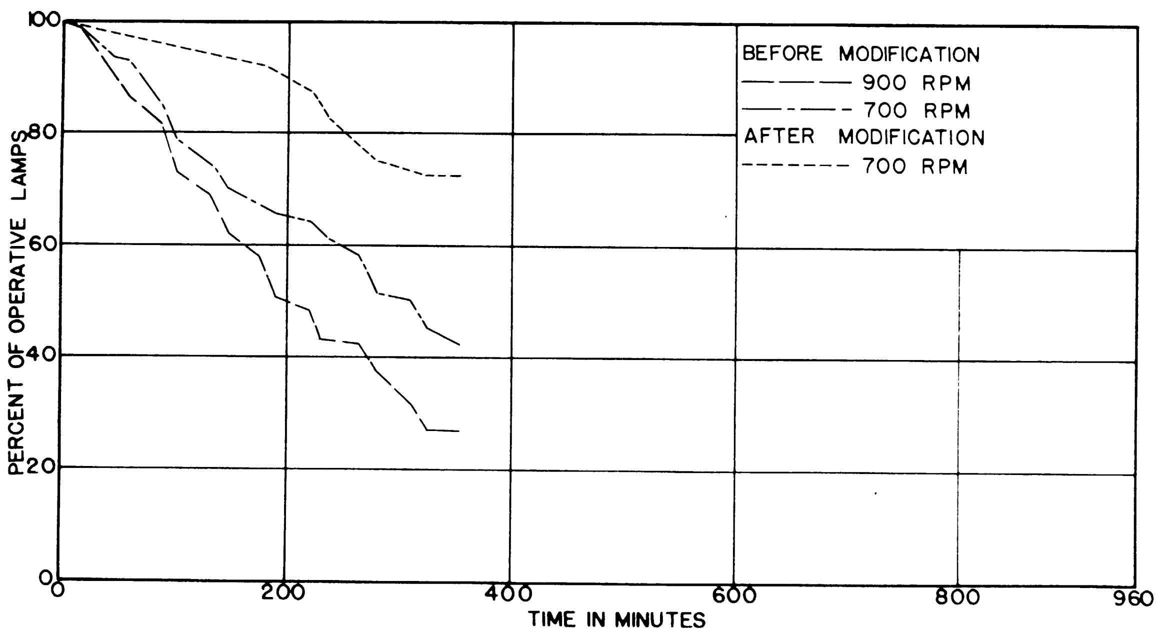


Fig. 4. Average mortality curves of the Westinghouse impact tester before and after modification.

hot, and repeat seven times. The results are shown in the upper curve of Fig. 4, and indicate a still further reduction in mortality. Data on individual rack tests are not at present available, thus preventing an analysis of deviations, but smoother and more consistent tester performance is expected after modification.

Figure 4 indicates a drop in the mortality rate in each successive test. This can be explained quite readily since the original arm structure had been strengthened and stiffened at the corners so that the force required to separate the anvils was about four times the normal amount. When the speed was reduced, the number of impacts for the same number of cycles was reduced, thus decreasing the mortality rate. The mortality rate was further reduced when this additional force was removed from the arm during modification. The arm now has an opening force equal to the recommended value.

D. PROPOSED CORRELATION STUDIES

The SAE Impact-Tester Panel, in a meeting at The University of Michigan on November 17, 1955, agreed that correlation tests of all the modified impact testers were desirable. Plans were formulated to supply each of the interested laboratories with a group of 100 type 1251 single-filament lamps (made by Tung-Sol) and a companion group of 100 double-filament lamps, type 1034, made by General Electric. Each type was to be part of a homogeneous lot thoroughly mixed before packaging. The following test conditions were agreed upon:

1. The single-filament lamp shall be cycled 25 minutes on and five minutes off for a total of 16 cycles (eight hours), or until 75% have failed, whichever occurs first.

2. For the two-filament lamps the operation shall be 20 minutes with the minor filament on, five minutes with both filaments on, and five minutes with both filaments off for a total of 16 cycles (eight hours).

3. The test voltages shall be 28 volts for the type 1251 and 14 volts for the type 1034.

4. Inspection for possible failure shall be at least once per cycle; said inspection to be during the cold portion of the cycle.

5. Testing shall be in lots of 20 at a time.

The type 1251 lamps were distributed to the six laboratories participating in the test program and the results are now being collected in preparation for study. The type 1034 lamps have not yet been distributed.

II. CONTINUED EVALUATION OF THE ROTARY-DRUM IMPACT TESTER

A. SUMMARY OF PREVIOUS RESULTS

A description of an enlarged rotary-drum impact tester and the results of initial tests to indicate how well it may be expected to perform were included in the progress report for June, 1955, pages 18-25. These tests, although somewhat inconclusive because of the meager amount of data then available, indicated that the rotary-drum tester can be considered just as reliable as the Arsenal tester. Mortality curves obtained on several groups of type 2416 lamps showed that a given percentage of failures could be secured with the rotary tester in considerably less time than with the Arsenal tester. In addition, it had the advantage of being relatively cheap in construction cost, seemed likely to require much less maintenance, and was very quiet in operation. Mention was also made in the same report of the need for improved lamp-holding devices.

B. IMPROVED LAMP HOLDERS

The only component of the rotary-drum tester that seemed unsatisfactory was the lamp holding unit. Accordingly, efforts were expended to improve this device.

Figure 5 shows the rotary-drum tester ready to test a group of lamps having S-8 bulbs, supported by an improved type of lamp holder. The design features of this holder may be more clearly perceived in Fig. 6, which shows the following holder components quite clearly: the frame, ground strip, bearing, pivot leaf, and connecting cables. Proper alignment of lamps having slight differences in base and bulb shape is accomplished by varying the length of the pivot leaf and by raising or lowering the center of the bearing rod. A simple jig is provided to hold the lamps in place while the leaf is soldered to the base.

Lamp holders of this type have been completed for lamps with G-6 and S-8 bulbs and plans are completed for holders accommodating G-3-1/2 and RP-11 bulbs. With minor variations, these holders can be made adaptable to any of the other common miniature bulb types.

C. ADDITIONAL MORTALITY TESTS

To meet the need for more data on tester performance for comparison with previous runs on the rotary-drum tester and on the Arsenal tester, several

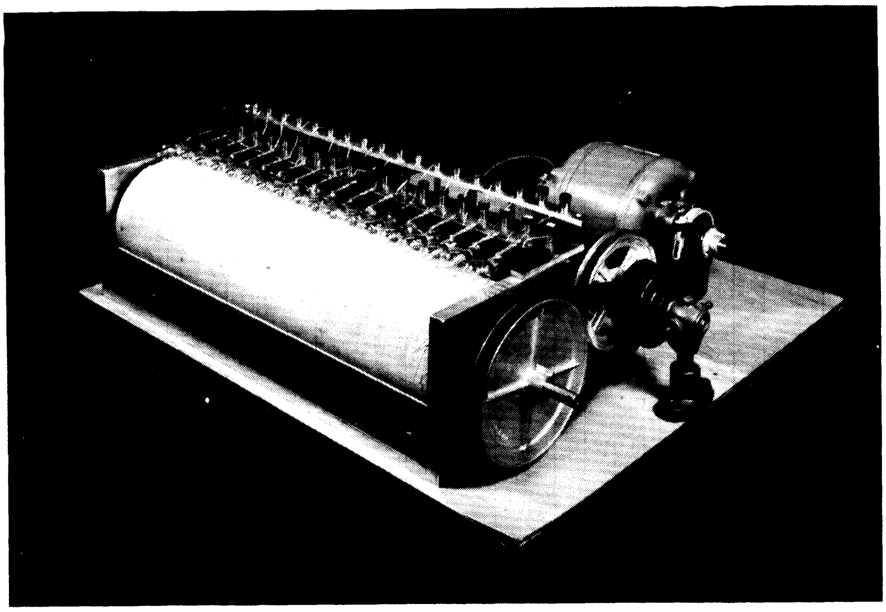


Fig. 5. Overall view of the rotary-drum tester loaded with a group of lamps having S-8 bulbs supported by an improved lamp holder.

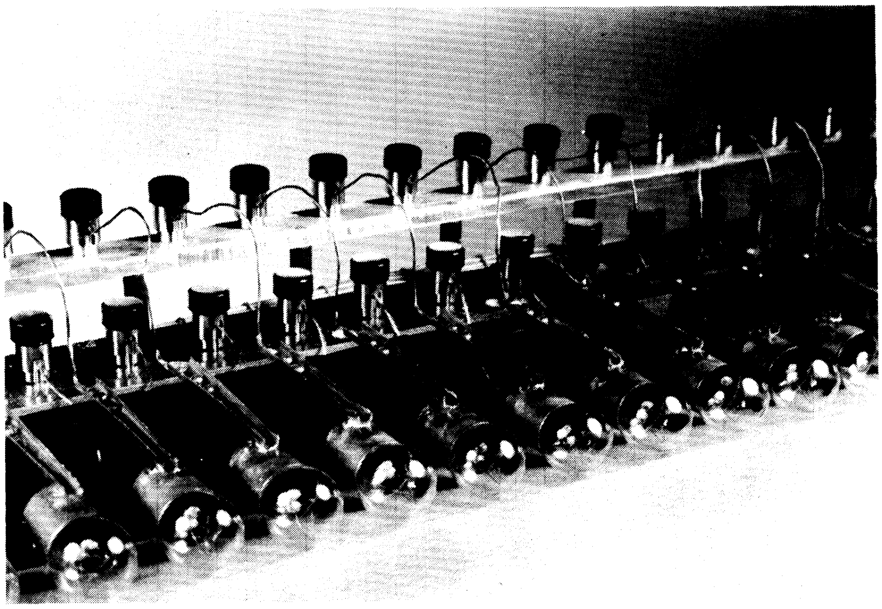


Fig. 6. Design features of the improved lamp holders for a G-6 bulb.

additional groups of lamps were subjected to mortality tests. The first of these was a homogeneous group of type 1251 lamps, supported in a manner similar to that of the lamps shown in Fig. 6, and impact-tested for 240 minutes or until 100% failure. The drum speed was adjusted to give 700 impacts per minute and the cam offset was 0.063 in. The operating cycle was set at 25 minutes on and five minutes off, with a neon lamp switched in series with the test lamp to give a visual indication of filament failure during the five-minute-off period. All lamps were watched closely during each cold cycle, when the likelihood of failure was the greatest, and were given a frequent visual inspection during each hot cycle. The results of five runs, each consisting of 20 lamps, are shown in Fig. 7. It will be noted that the spread was very narrow until the 50% mortality point was passed. About 33% of the failures were due to entanglement and shorting of the filament segments; the remainder were due either to fatigue or to sawing action at the support wire.

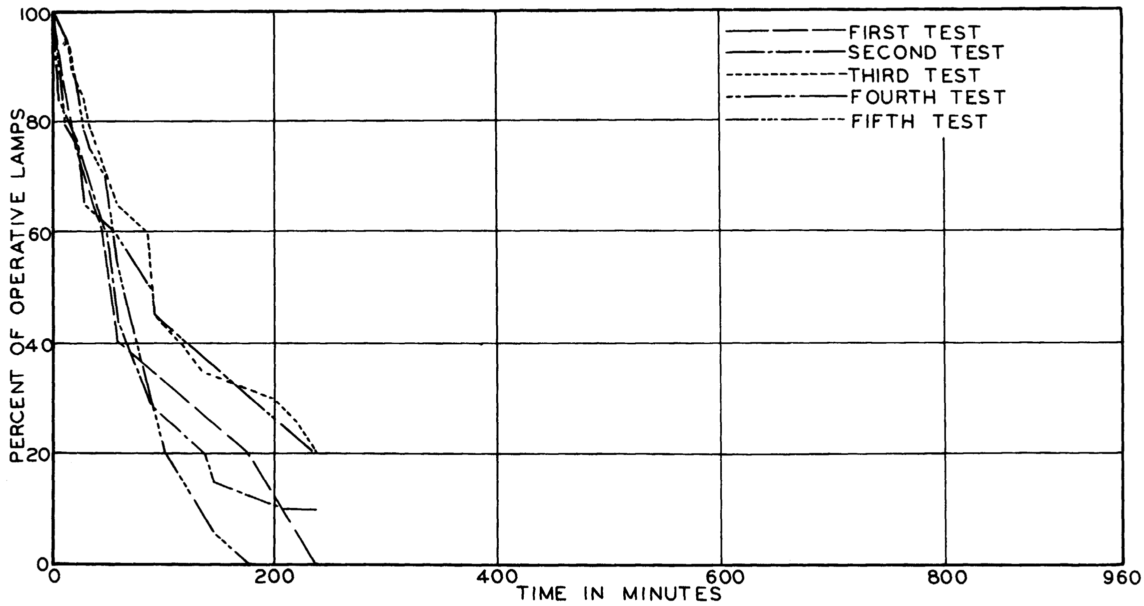


Fig. 7. Five mortality curves of type 1251 lamps furnished by Company "A" tested on the rotary-drum impact tester.

Figure 8 shows the results of impact tests on a second group of type 1251 lamps obtained from a different manufacturer in which the same test procedure was followed. The spread of the curves is slightly greater, but no marked differences in mortality rate can be observed. In this group, about 25% failed as a result of entangled filament sections, with the rest showing fatigue failure.

For a third series of tests, a type 1683 lamp with an S-8 bulb was selected, primarily to see whether or not a change in bulb size would affect the consistency of tester performance. Tester speed, cam offset, and operating procedure were exactly the same as in the previous tests.

Figure 9 shows the results obtained in four test runs. A modified G-6 lamp holder was used for the first three tests, while a regular S-8 holder was employed in the fourth test. The spread of the various runs is about the same as observed in the previous tests, but the mortality rate is considerably

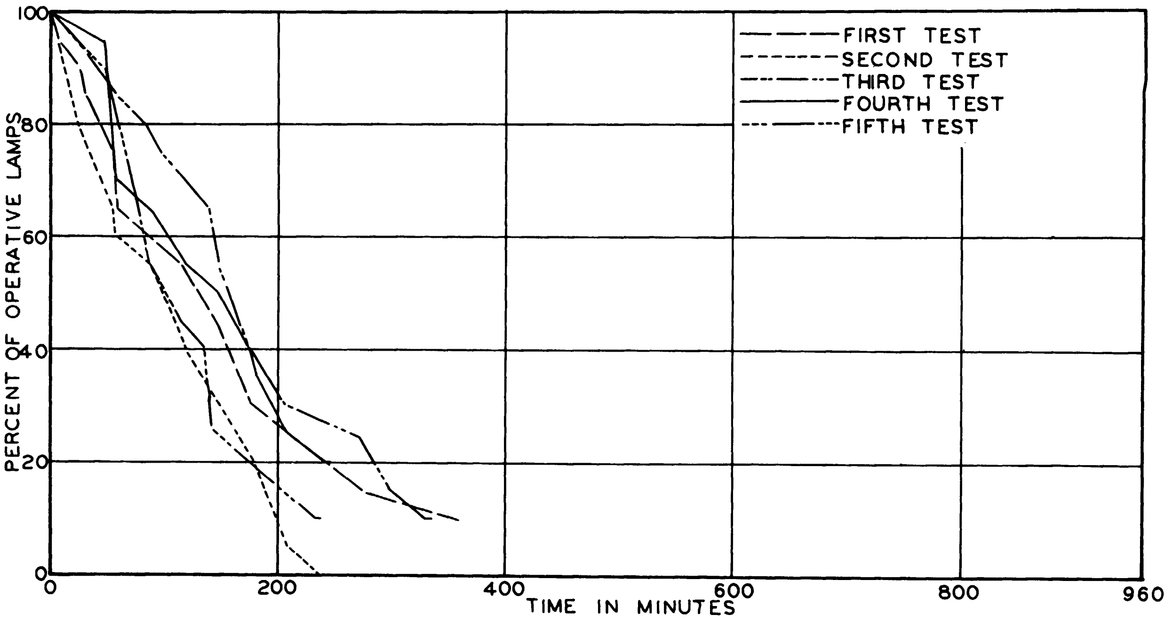


Fig. 8. Five mortality curves of type 1251 lamps furnished by Company "B" tested on the rotary-drum impact tester.

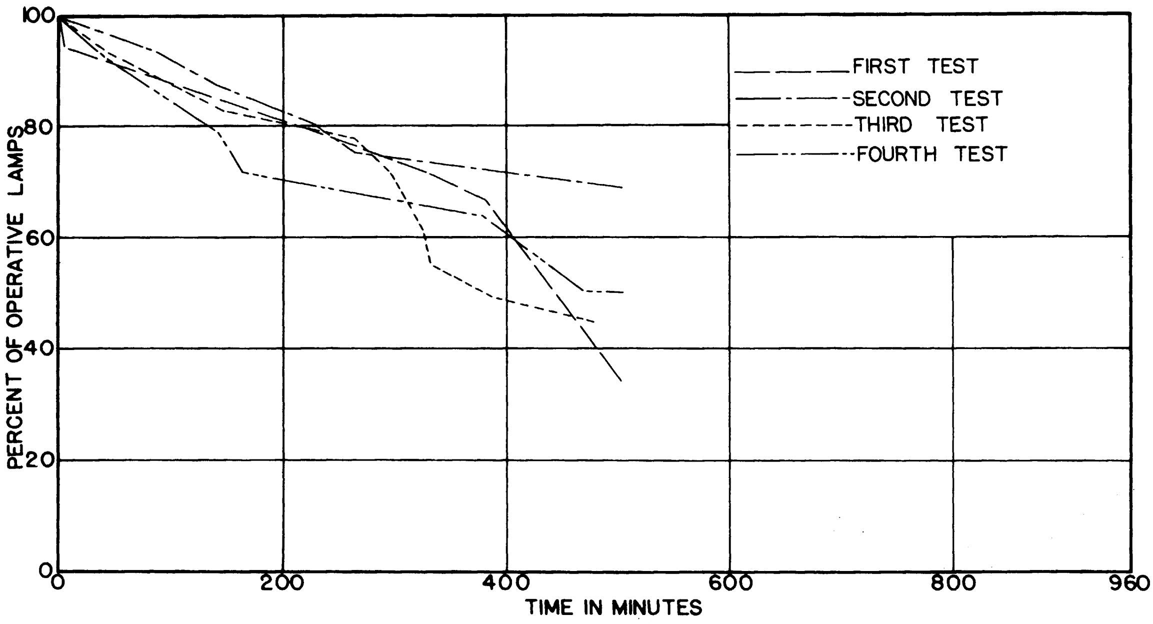


Fig. 9. Four mortality curves of type 1683 lamps of the same origin tested on the rotary-drum impact tester.

less. This is in accord with the results obtained on the Arsenal tester with the same type of lamp.

To evaluate further the revised S-8 lamp holders, a group of type 1203 lamps was purchased for use on the rotary-drum tester. These had an S-8 bulb, a 21-cp, c-2v filament and a single-contact bayonet base. Impact tests of these lamps, mounted in the S-8 holders, were conducted under exactly the same test conditions as in all the previous tests, and the resulting mortality curves are shown in Fig. 10. The spread of these curves does not differ much from that found for the other tests, with an average mortality rate somewhat less than that obtained with the type 1683 lamp.

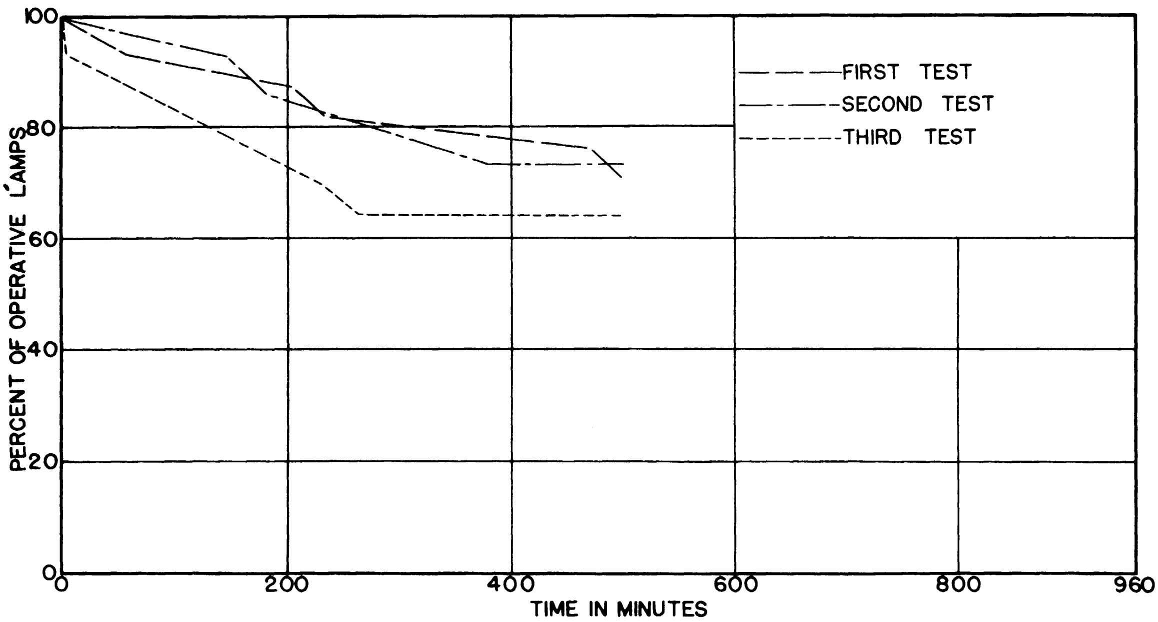


Fig. 10. Three mortality curves of type 1203 lamps of the same origin tested on the rotary-drum impact tester.

Although the total number of lamps tested to date on the rotary-drum tester is quite small, it is encouraging to note that the spread between successive runs on the same type of lamp is quite narrow, and we may conclude that this type of impact tester has proved to be a reliable means of determining lamp ruggedness.

D. ADDITIONAL HOLDER DESIGNS

The accumulated experience with the rotary tester has indicated clearly that inconsistent results are in large measure due to faulty lamp holders. Consequently, more effort is being expended in devising and testing new forms of lamp holders that will suspend the lamps more freely and be more easily modified to accommodate various lamp sizes.

1. For bulbs having a candelabra bayonet base (single filament), efforts have been made to improve the brass spring-clip mounting shown in Fig. 9 of the progress report for June, 1955.

2. Studies have been made of a machined lamp-holder yoke intended to replace the brass spring clips just referred to.

3. A pivoted metal receptacle has also been proposed for the same purpose.

4. Spring-steel clips that encircle the lamp base have been tried.

5. Use of commercially available sockets for bayonet lamps has been proposed.

6. The possible use of mechanical clamps as a means of attaching the lamp to a support arm has also been proposed.

All these schemes have been discarded as being impracticable, and the method finally chosen as most likely to yield consistently good results employed a soldered connection between the brass lamp base and a brass supporting strip, giving a simple, rigid and yet light-weight mounting assembly. Details of the first of these mounts are shown in Fig. 11, where the support

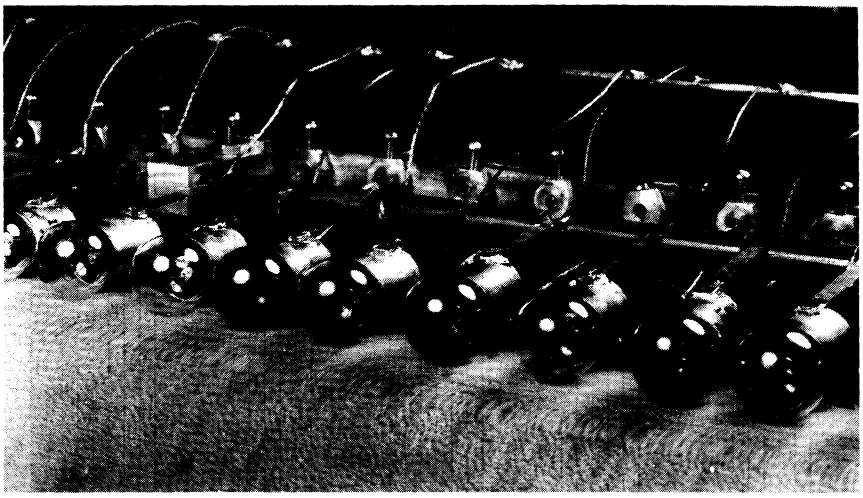


Fig. 11. Original pivoted leaf mount
used on the rotary-drum tester.

is in the form of a flat strip, .015 x .125 in., with the bearing end curled to form an eye enclosing and resting on the steel bearing rod. Two racks of type 1251 lamps supported on the rotary tester in this manner were given mortality tests in accord with the usual testing procedure and the results, shown in Fig. 12, agree closely with previous tests of the same type of lamp.

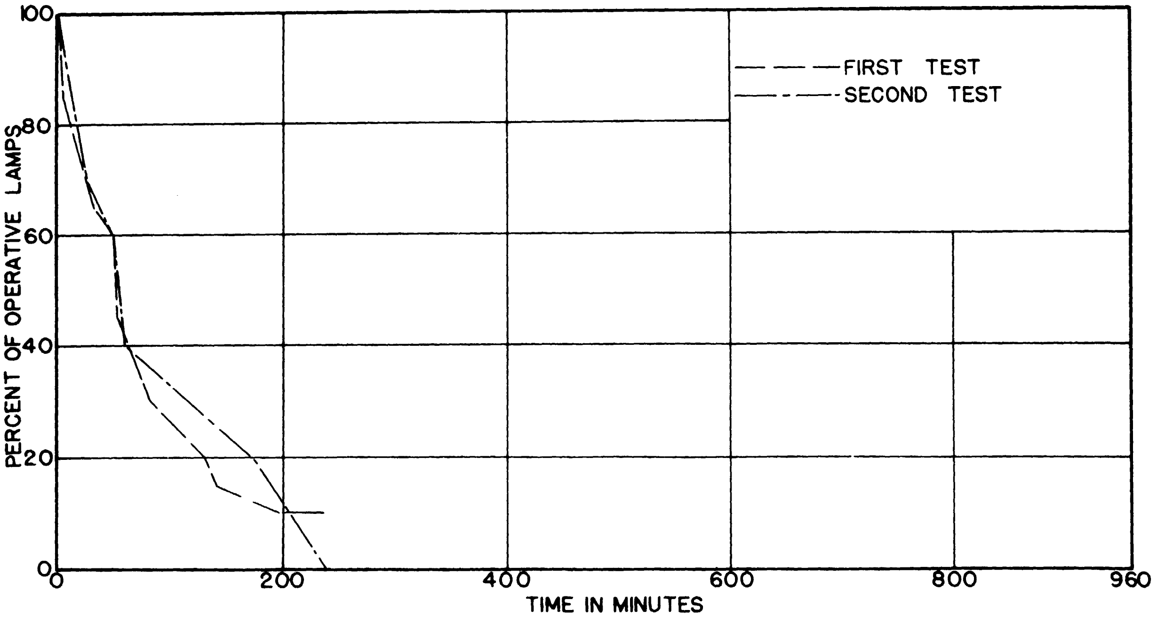


Fig. 12. Mortality results of the two tests of type 1251 lamps operated on the rotary-drum impact tester with brass-leaf support.

An improved design which eliminated the metal-to-metal contact at the bearing rod was then devised in which the brass supporting strip was attached to a bakelite block pierced to receive the bearing rod. The block served as a combination spacer and bearing, giving better alignment and smoother operation. Figure 13 shows the improved mount and Fig. 14 gives the results of mortality tests on two racks of type 1251 lamps obtained with

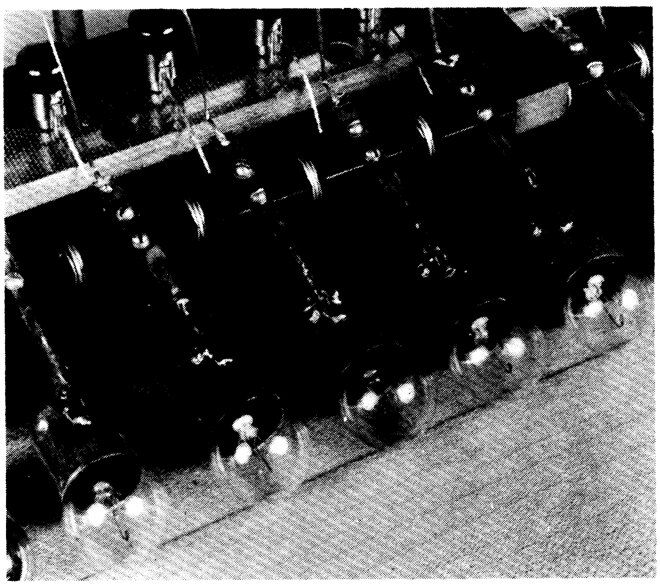


Fig. 13. Improved pivoted leaf mounts used on the rotary-drum tester.

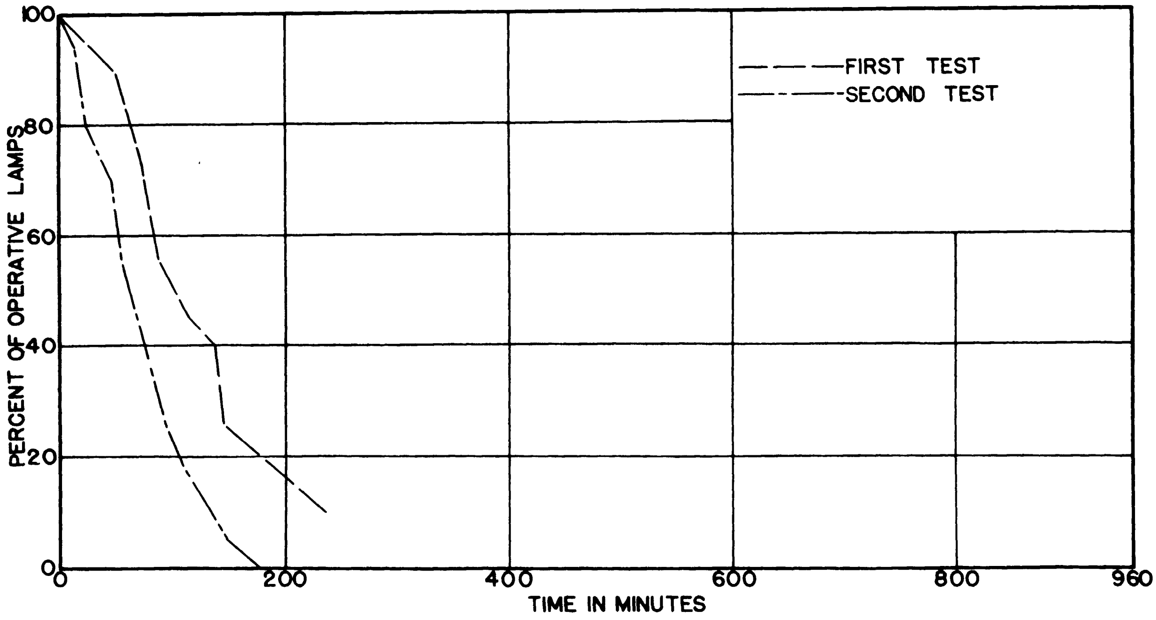


Fig. 14. Mortality results of the two tests of type 1251 lamps operated on the rotary-drum impact tester with the improved bakelite bearing blocks.

this improved support. The observed performance correlates well with previous test runs.

Operating experience with this type of mount indicated the need for somewhat closer tolerances in the dimensions of the bakelite blocks. Accordingly, a set of bearing blocks was built to closer tolerances and used in testing three racks of type 1251 lamps. The results are shown in the first three curves of Fig. 15.

A second set of blocks duplicating the dimensions of this set was built and used in testing one more rack of type 1251 with results as shown in the fourth curve of Fig. 15.

High-speed photographs taken of the tester in operation with these improved lamp mounts indicated that the flat brass strips supporting the bulb bases were bending considerably. Accordingly, the long edges of each strip were bent to produce a channel section similar to the mounting strip shown in Fig. 6. A test run using type 1251 lamps supported on channel strips gave results as indicated in the fifth curve of Fig. 15. Apparently this change in mounting-strip design had little or no effect on lamp mortality, but it did greatly stiffen the arm and more than doubled the natural frequency of the mounts.

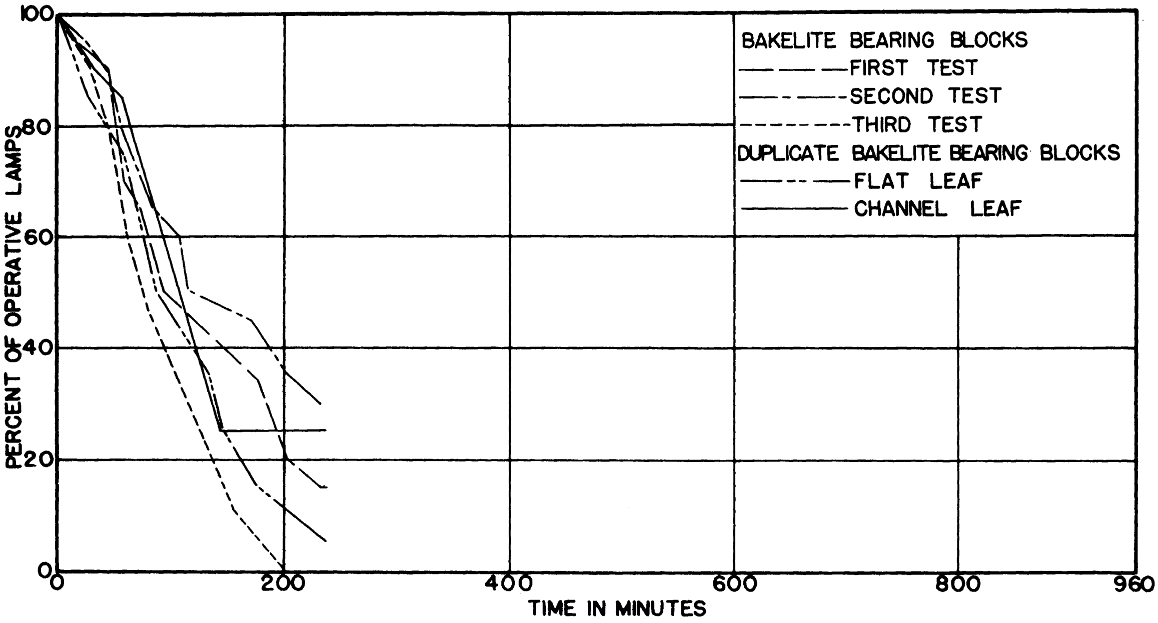


Fig. 15. Five mortality curves of type 1251 lamps tested on the rotary-drum impact tester to evaluate three different sets of lamp mountings.

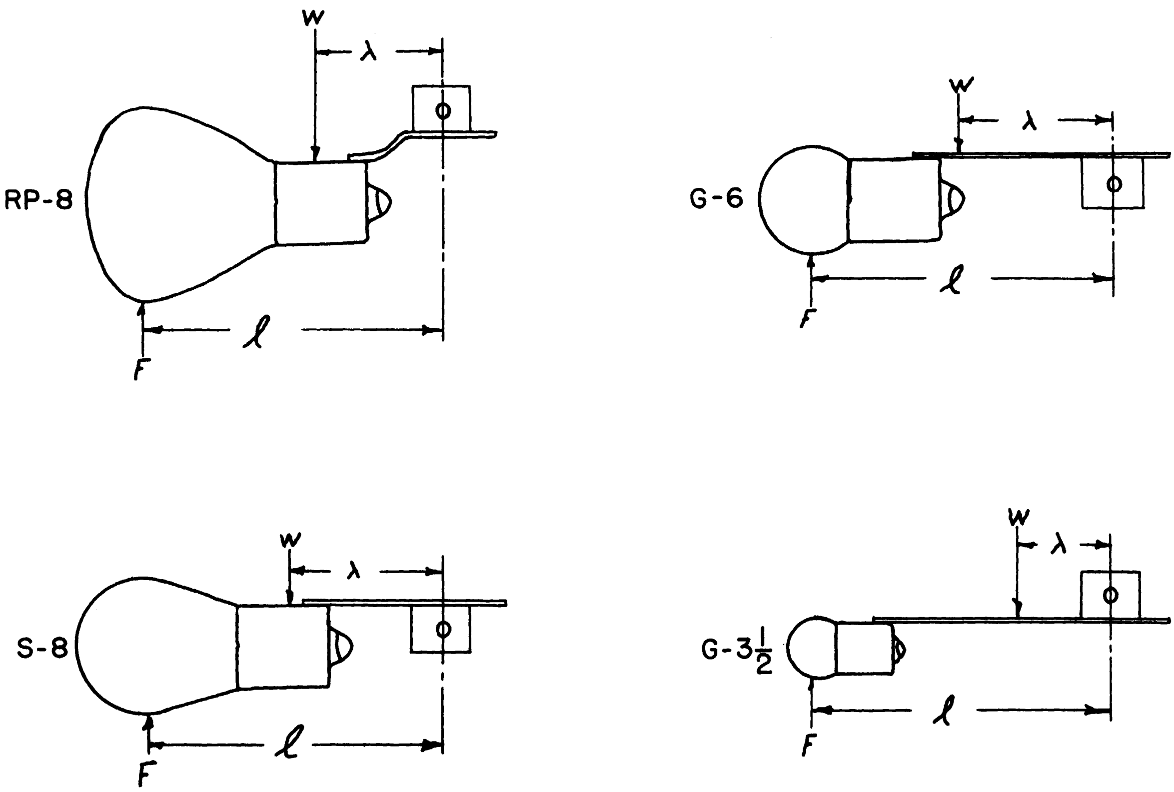
E. THEORETICAL STUDY OF IMPROVED LAMP MOUNT

Since a mount consisting of a brass supporting leaf soldered to the lamp base at one end and attached to a bakelite bearing spacer at the other appeared to operate smoothly and gave consistent test results, it seemed appropriate to subject this basic design to a theoretical analysis. The accompanying sketches show four common bulb types with symbols which are defined below:

ℓ = distance from pivot to impact contact,
λ = distance from pivot to center of gravity,
W = weight of assembly,
F = force to hold assembly in horizontal position, and

$$\lambda = \frac{F}{W} \ell \quad .$$

The velocity of impact is the most important factor in producing filament deflection which leads to free oscillation and ultimate failure. The velocity of impact depends on the offset (cam depth), h, and on the physical properties of the assembly considered as a pendulum which rotates around the pivot. The velocity of impact is also a function of the speed of drum rotation. This is shown experimentally by the fact that the character of filament failure changes from fatigue failure at low speeds (175 rpm) to plastic sagging



at high speeds (311 rpm), although the offset, h, remained constant. Impact velocity is discussed here only for normal operating conditions of 175 rpm and h = .063 in.

For a horizontal pendulum which is permitted to fall freely through a small angle, h/ℓ radians, the equation of motion is

$$\frac{W}{g} K^2 \theta_{''} = W\lambda \;,$$

where

- W = weight of assembly,
- K^2 = radius of gyration of assembly around pivot,
- $\theta_{''}$ = angular acceleration of assembly, and
- λ is as already defined.

Then,

$$\theta_{''} = \frac{g\lambda}{K^2} \;,$$

angular velocity, $\theta_{'}$, $= \frac{g\lambda}{K^2} t$, and angular displacement, θ, $= \frac{1}{2} \frac{g\lambda}{K^2} t^2$.

At the instant of impact, $\theta = h/\ell$ and $t = t_1$:

$$\therefore \quad \frac{h}{\ell} = \frac{1}{2}\,\frac{g\lambda}{K^2}\,t_1^{\,2}$$

and angular velocity, $\dot{\theta}_1 = \frac{g\lambda}{K^2}\,t_1$

$$\dot{\theta}_1^{\,2} = \left(\frac{g\lambda}{K^2}\right)^2 t_1^{\,2}$$

$$\therefore \quad \frac{2\,\frac{h}{\ell}}{\dot{\theta}_1^{\,2}} = \frac{1}{\left(\frac{g\lambda}{K^2}\right)}$$

and

$$\dot{\theta}_1^{\,2} = 2\,\frac{h}{\ell}\,\frac{g\lambda}{K^2} \; .$$

The linear velocity of the point of contact is $\ell\,\dot{\theta}_1 = V_1$

$$V_1^{\,2} = \ell^2\dot{\theta}_1^{\,2} = 2h\ell\,\frac{g\lambda}{K^2} = \frac{\ell\lambda}{K^2}\,2gh$$

$$V_1 = \sqrt{\frac{\ell\lambda}{K^2}}\;\sqrt{2gh}$$

$$t_1^{\,2} = \frac{2K^2}{g\lambda}\,\frac{h}{\ell} = \frac{K^2}{\ell\lambda}\,\frac{2h}{g}$$

$$t_1 = \frac{V_1}{g\,\frac{\ell\lambda}{K^2}} \; .$$

The length ℓ was chosen to be two inches.

Pendulum swing tests of assemblies similar to those shown in the sketches determined values of λ and K^2. The results for normal conditions are shown in the table below.

Bulb	W grams	F grams	cycles/second	λ inches	K inches	ℓ inches	$\frac{\ell\lambda}{K^2}$	$\sqrt{\frac{\ell\lambda}{K^2}}$	Velocity in./sec	t_1 sec
RP-11	13.2	5.66	2.5	.858	1.16	2	1.270	1.127	7.8	.016
S-8	12.53	5.81	2.5	.937	1.21	2	1.275	1.129	7.8	.016
G-6	9.62	4.08	2.32	.848	1.242	2	1.100	1.047	7.27	.017
G-3-1/2	6.28	1.96	2.38	.625	1.041	2	1.158	1.074	7.46	.017

The surface velocity of the drum at 175 rpm is about 50.3 in./sec. The bulb should hit the drum surface at a distance from the drop-off of about 50.3 x .017 = .855 in. Experiments indicate that the average impact distance is .8586 in. when operated at 175 rpm. The impact point varied directly with the change of drum speed.

F. CONNECTING WIRES

The wires used for making electrical connections to the lamps should be as light and flexible as possible to avoid restraining the free movement of the lamps. Since soldered connections are used and the wires are widely spaced, uninsulated wire is preferable. Stranded or braided wire seems necessary to give adequate current capacity with maximum flexibility. The best for the purpose that has so far been discovered is either Belden No. 8127 or No. 5570. Each of these is equivalent to No. 25 AWG and therefore has ample current capacity for the present application, although not quite as flexible as desired. The search is being continued for more suitable wire.

G. EFFECTS OF CHANGING DRUM SPEED AND OFFSET

The lamp mortality tests thus far discussed in connection with the operation of the rotary-drum impact tester have all been obtained with so-called normal drum operation; that is, with a drum speed of 175 rpm, giving 700 impacts per minute, and a .063-in. offset.

It now seemed desirable to obtain some information on the tester performance at other speeds and with other values of offset. Accordingly, four test runs were planned, one with the normal offset and three others with quite different offsets, as tabulated below:

h - inches	Velocity, in./sec
.031	5.11
.045	6.16
.063	7.27
.078	8.13

A constant drum speed of 175 rpm, with presumably identical lamps, type 1251, was used, and the results appear in Fig. 16. As would be expected, the larger offset resulted in more rapid failures, while smaller offsets produced less severe impact conditions and a lower mortality. The nature of the predominating type of failure also changed. Small offsets produced fatigue failures largely; large offsets increased the number of failures due to plastic deformation of the filament. A more complete study of these relations is being carried out.

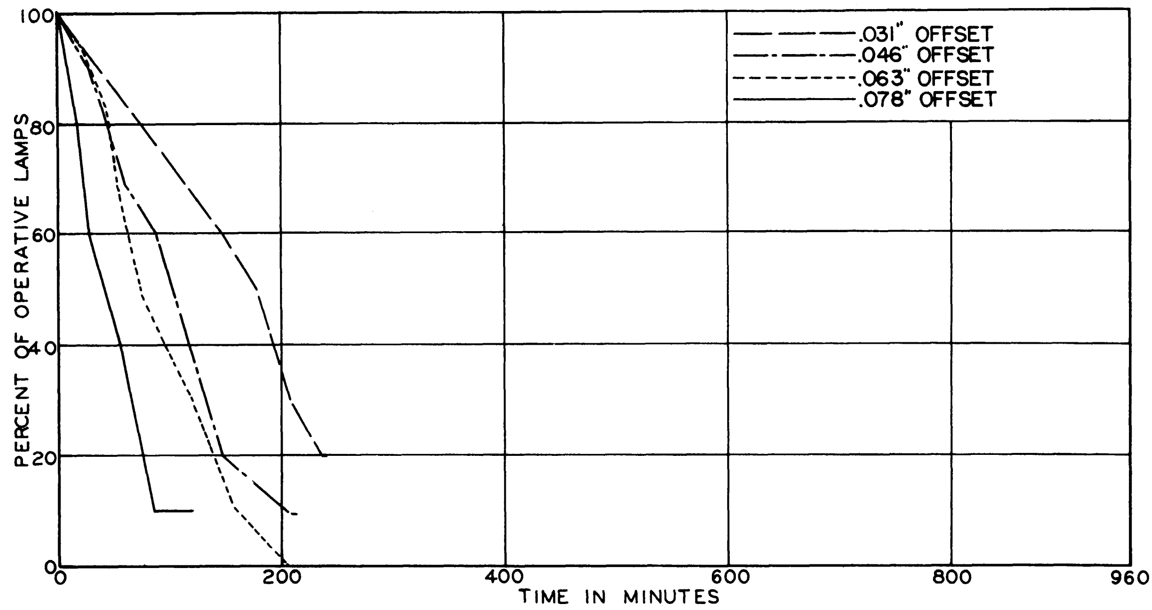


Fig. 16. Comparative mortality tests of type 1251 lamps completed on the rotary-drum impact tester, using four different cam settings.

In order to obtain some evidence as to the effect on lamp mortality of using different drum speeds, three runs were taken with a constant offset, using speeds of 175, 216, and 311 rpm. The results appear in Fig. 17 and follow the expected trend. The higher the speed, the greater the mortality in a

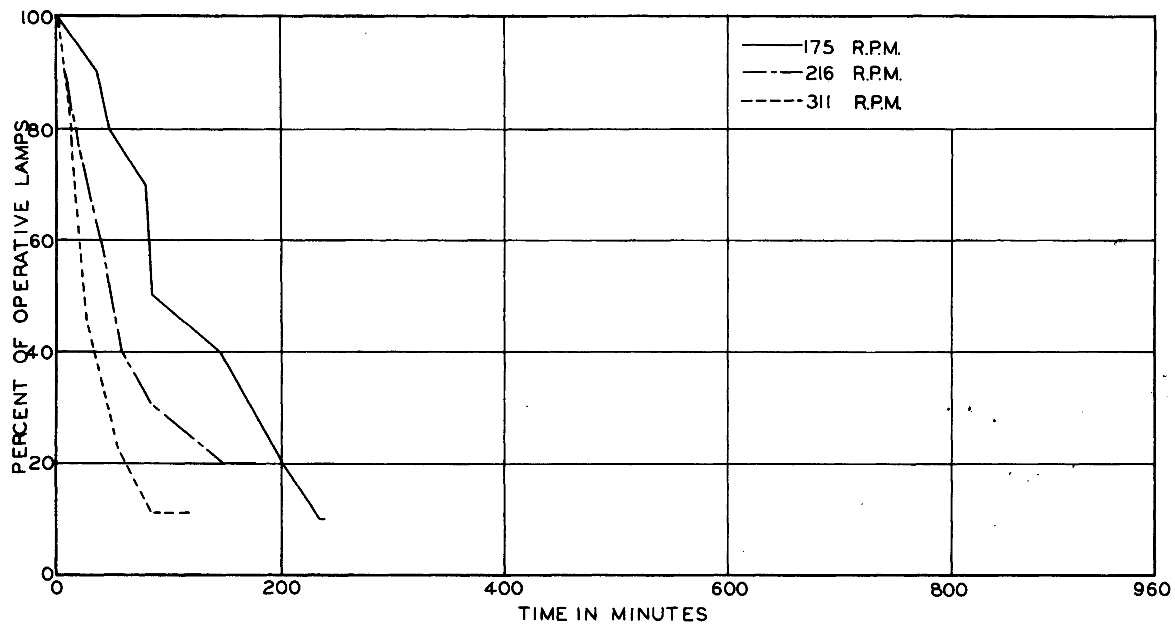


Fig. 17. Comparative mortality tests performed on the rotary-drum impact tester while operated at three different drum speeds.

given time. Here again the more severe tests produced increased numbers of lamps failing by plastic deformation.

H. COMPARISON OF ARSENAL AND ROTARY-DRUM TESTERS

Some early comparative data on the relative performance of these two radically different types of impact testers were presented on pages 23-26 of the progress report for June, 1955. This comparison will now be extended and will include some comments on relative ease of operation and maintenance and relative cost.

Figure 18 shows the range of mortality tests on ten racks of type 1251 lamps obtained from manufacturer X and distributed equally between the Arsenal and rotary-drum testers. Standard testing procedure prevailed; that

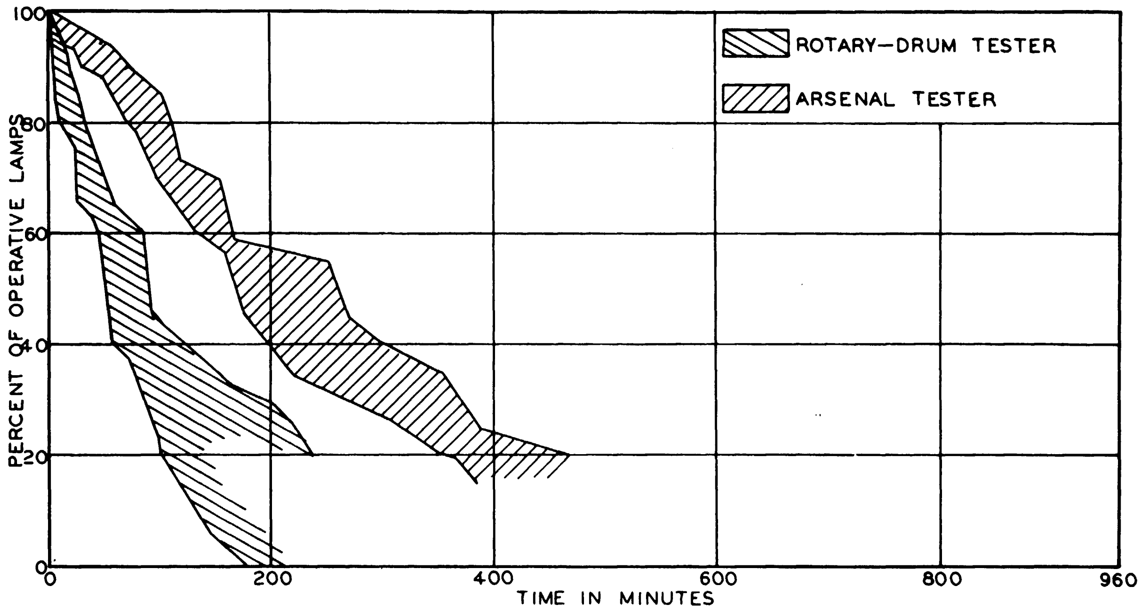


Fig. 18. Comparative ranges of mortality tests completed on the rotary-drum impact tester and the Arsenal impact tester using five lots of type 1251 lamps from source "X" for each grouping.

is, cycling in each case was alternately 25 minutes on and five minutes off, with frequent observations of lamp condition during each hot cycle and almost continuous observation during each cold cycle when the neon indicator lamps were in the circuit. Normal speeds and cam settings were used. It is quite evident that the rotary-drum tester was more severe and caused greater mortality than the Arsenal tester, although the character of failure was the same for each tester.

Ten additional racks of type 1251 lamps obtained from manufacturer Y were then tested in exactly the same manner, five racks on each tester, and the results are shown in Fig. 19. The mortality ranges obtained were very close to the previous series, with the same type of failure predominating.

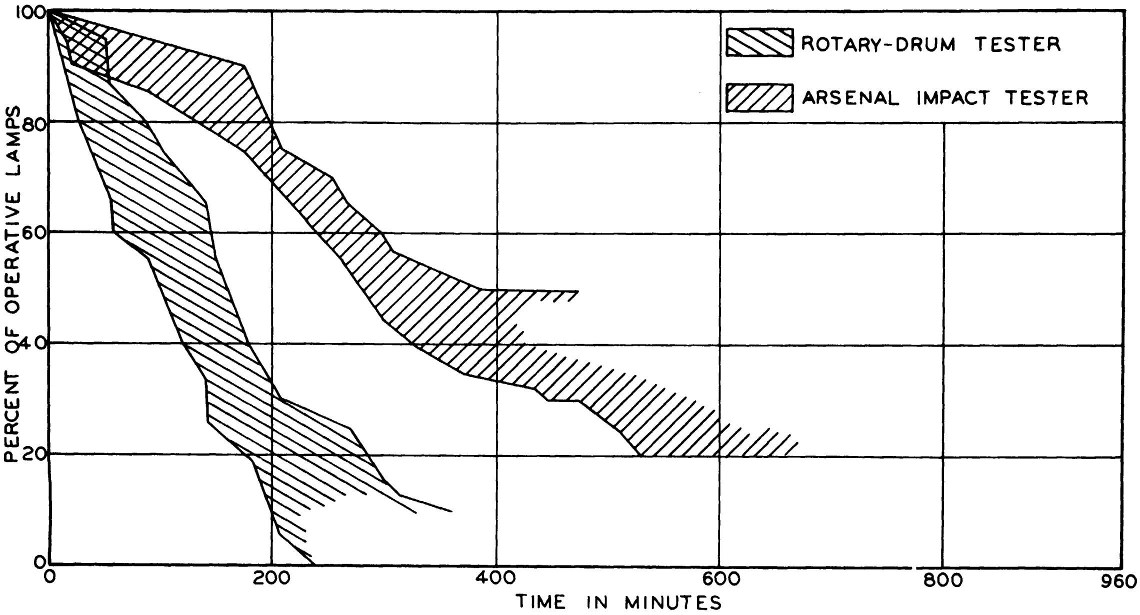


Fig. 19. Comparative ranges of mortality tests completed on the rotary-drum impact tester and the Arsenal impact tester using five lots of type 1251 lamps from source "Y" for each grouping.

Further comparative tests were completed, using several lots of type 1683 lamps. These are of interest chiefly because previous experience has shown that it is very difficult to produce impact failures in this lamp. The results are shown in Fig. 20, where it will be noted that the rotary-drum tester produced more failures in a given time than the Arsenal tester.

The simplicity of the rotary-drum tester reduces maintenance to a minimum and makes it possible to change lamp racks rapidly. Only six screws need to be removed and replaced and two electrical connection plugs reinserted to ready a new rack for testing. While one rack is undergoing testing, a second rack can be very quickly prepared, since a simple jig is available to align and hold the lamps while soldering the holder to the base. The entire process of mounting 20 lamps with a G-6 bulb, including all soldering usually requires 20 to 25 minutes, a much shorter time than is required to prepare and load the Arsenal tester. It is likely that two racks of lamps could be prepared and given a complete mortality run in one working day unless the lamps were unusually rugged.

The almost complete lack of noise associated with the operation of

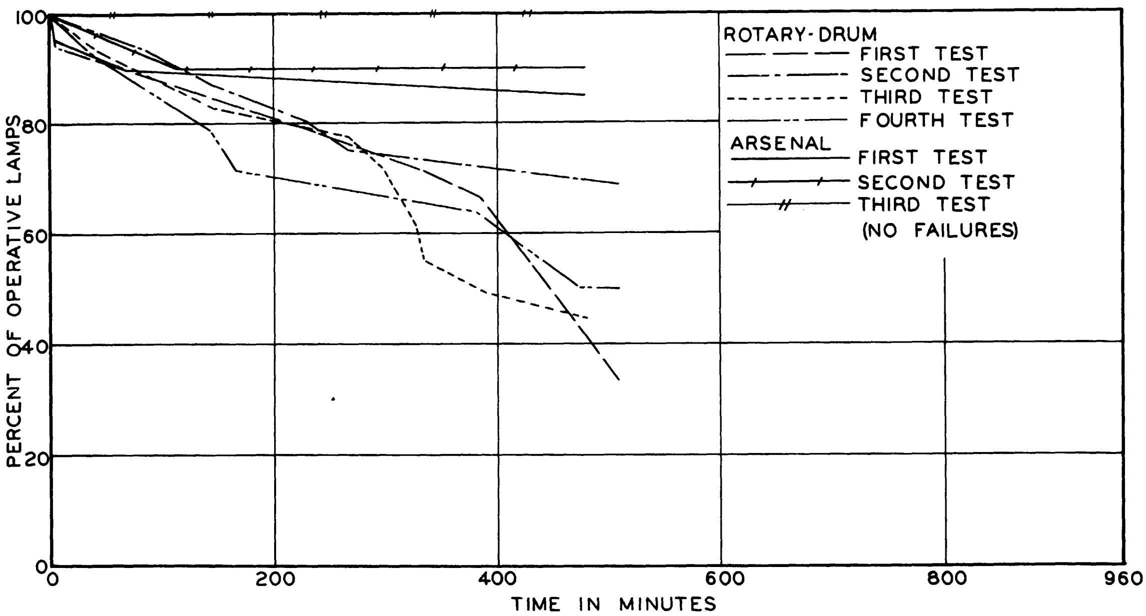


Fig. 20. Comparative mortality tests of type 1683 lamps completed on the rotary-drum tester (four tests) and the Arsenal impact tester (three tests).

the rotary tester has already been mentioned. Its initial cost is so small that many testing laboratories might wish to have several available if a heavy testing schedule is anticipated.

I. FUTURE PLANS FOR THE ROTARY-DRUM TESTER

So long as lamps with brass bases require impact testing, a strong case can be made for the present type of lamp holder where connection to the base is made by soldering. If, however, the lamp companies decide to change to an aluminum base, it may be necessary to devise some form of clamp for the lamp-base connection. Studies of various clamp designs are contemplated.

It is probable that the rotary-drum tester in its present form cannot be employed as a practicable means of impact testing PAR lamps or other forms of integrated lamp housings. It seems appropriate to give some study to possible modification of the tester components that will permit it to be used in impact tests of large lamps.

III. FURTHER STUDIES OF EXPERIMENTAL LAMP DESIGNS

A. TYPE 2416 LAMPS

On pages 10 and 12 of the second progress report, January, 1955, some tests were reported in which a few type 2416 lamps were provided with short auxiliary coils slipped over the ends of the filament. Although these lamps showed evidence of improper gas content, their resistance to impact seemed to be superior to standard production samples and the manufacturer was requested to furnish additional samples for further tests. Unavoidable delays hindered the fulfillment of this request until too late for the test results to be reported in the next progress report. These results will now be discussed.

Careful examination of these lamps with an optical comparator showed that the physical structure of the filaments was apparently identical to the standard production type, except for the addition of slip-on coils. The slip-on coils were composed of tungsten wire with a diameter of about 75% of the filament wire diameter and coiled with many more turns per inch than the primary filament coil.

Two racks of these lamps were placed on the Arsenal impact tester and operated at the manufacturer's recommended voltage. The major filament was tested for 32 cycles (25 minutes on, five minutes off), followed by 16 cycles for the minor filament. Figure 21 presents the results of these tests. Fatigue accounted for all but one of the failures; the filaments showed little evidence of distortion at the end of the test.

Comparison of these tests with others on standard 2416 lamps made by the same company does not show that sufficient benefit is achieved by the addition of slip-on coils to warrant their use. The desired ruggedness in this lamp seems to depend more on close control of the filament winding and mounting processes to secure uniformity and symmetry in secondary coil spacing. In view of the additional fact that the commercial demand for this type of lamp is rapidly shrinking, further study of possible design modifications does not appear to be justified.

B. TYPE 1251 LAMPS

The 1251 lamp, with a G-6 bulb, a 3-cp, 2c-2v supported filament and butt-seal construction, has been used extensively in impact tests on both the Arsenal and rotary-drum testers. As a consequence, numerous failures have been observed, and all failed lamps have been carefully inspected for the purpose of

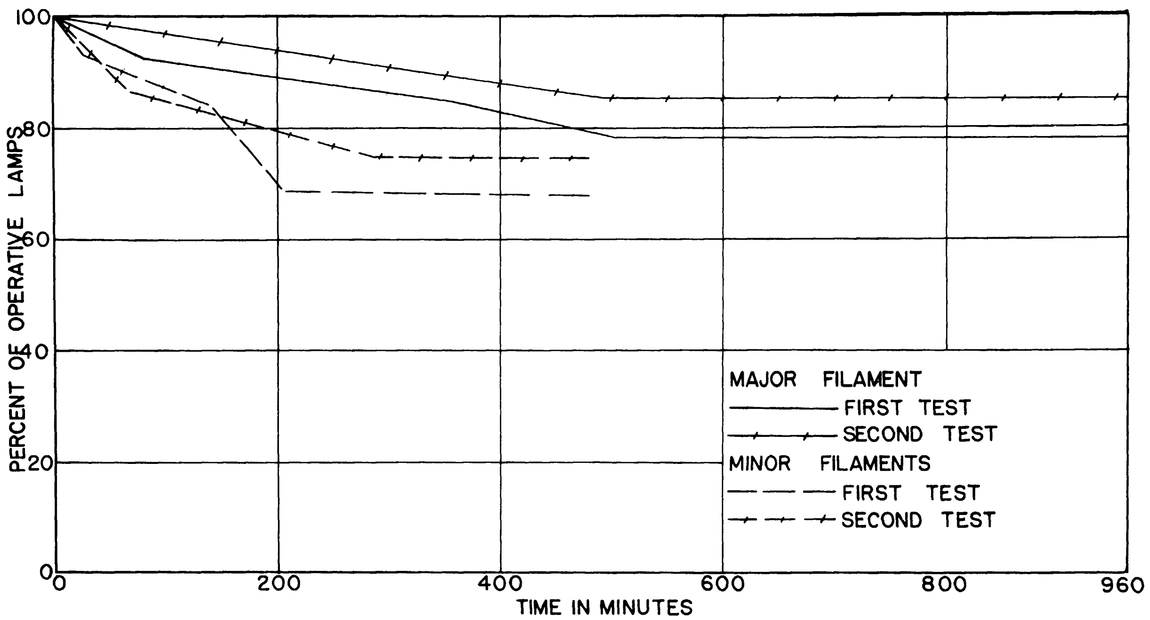


Fig. 21. Mortality tests of major and minor filaments of type 2416 lamps with slip-on coils on the ends of the primary coils.

determining the probable cause of failure. A list of the most common types of failures follows:

1. Entanglement of the two filament segments with consequent shorting.
2. Fatigue breakage at one of the eight transition spots in the two filaments.
3. Sawing action of the support wire upon the filament.
4. Escape of the filament from the hook of the support wire, with consequent entanglement and shorting.

These observations were transmitted to the lamp companies and it was suggested that improved resistance to impact might be attained in this type of lamp by expanding the lead tip spacing to a maximum, closing the hook of the support wire and shortening the coil length to a minimum.

One manufacturer responded by providing a group of lamps for test in which the first two of the above suggestions were carried out, and several racks of these experimental lamps were given mortality tests on the rotary-drum and Arsenal testers. The usual procedure with regard to cycling, hot- and cold-cycle observations, and standard tester settings was followed.

Figure 22 shows the results obtained on three tests, using the rotary-drum tester. A definite reduction in mortality appears to have been achieved by the improved mounting of the filament, although some sawing action at the central points of support could still be observed and there was some evidence of shorting of filament segments.

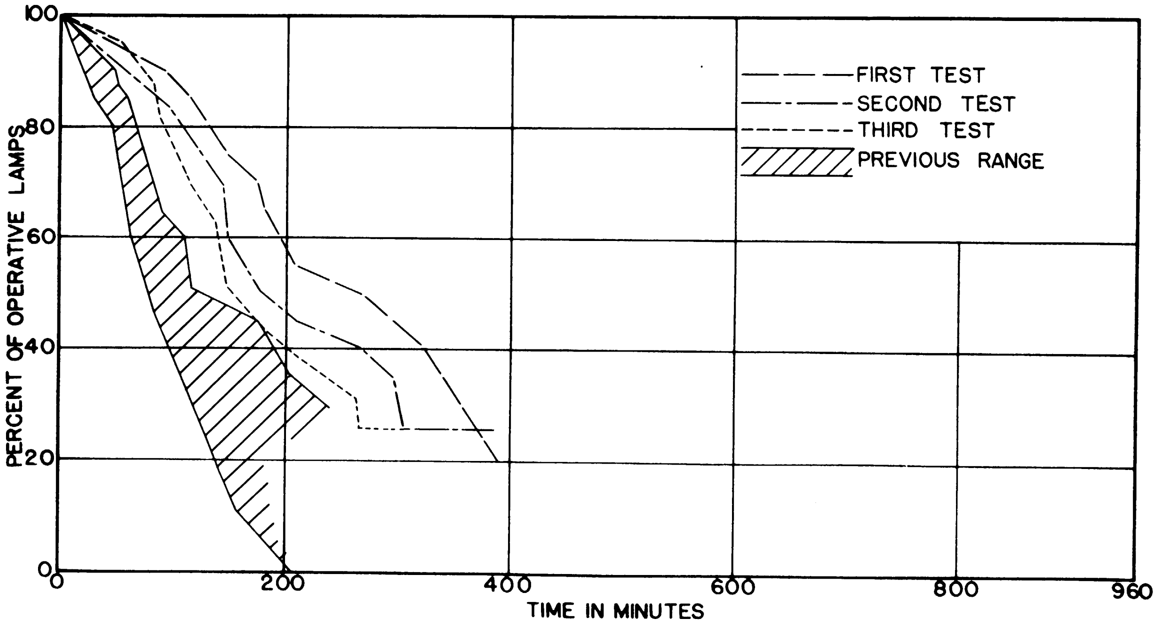


Fig. 22. Comparative mortality rates of regular and special 1251 lamps of the same origin tested on the rotary-drum impact tester.

Two racks of these lamps were tested on the Arsenal machine, with somewhat inconsistent results, as evidenced by the two divergent curves of Fig. 23. The mortality rate indicated by the second test is quite comparable to the results obtained by the manufacturer on his own modified tester. No other comparative runs are at present available.

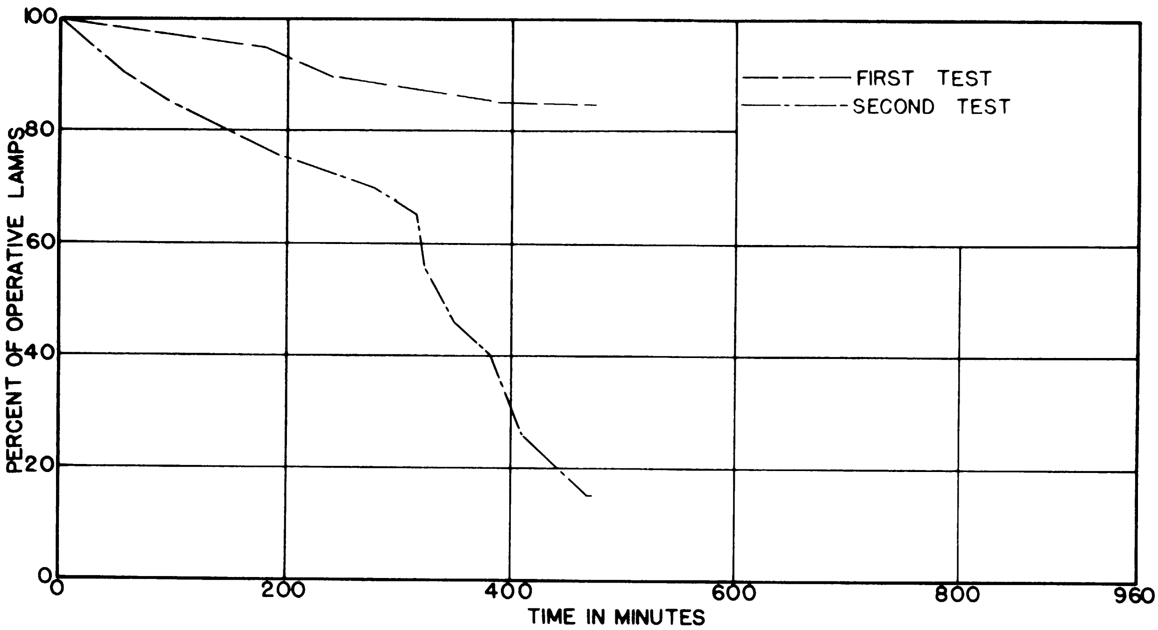


Fig. 23. Mortality rates of special type 1251 lamps tested on the Arsenal impact tester.

The results of these tests suggest that the possibility of changing the bulb shape of type 1251 merits investigation. A different bulb might permit:

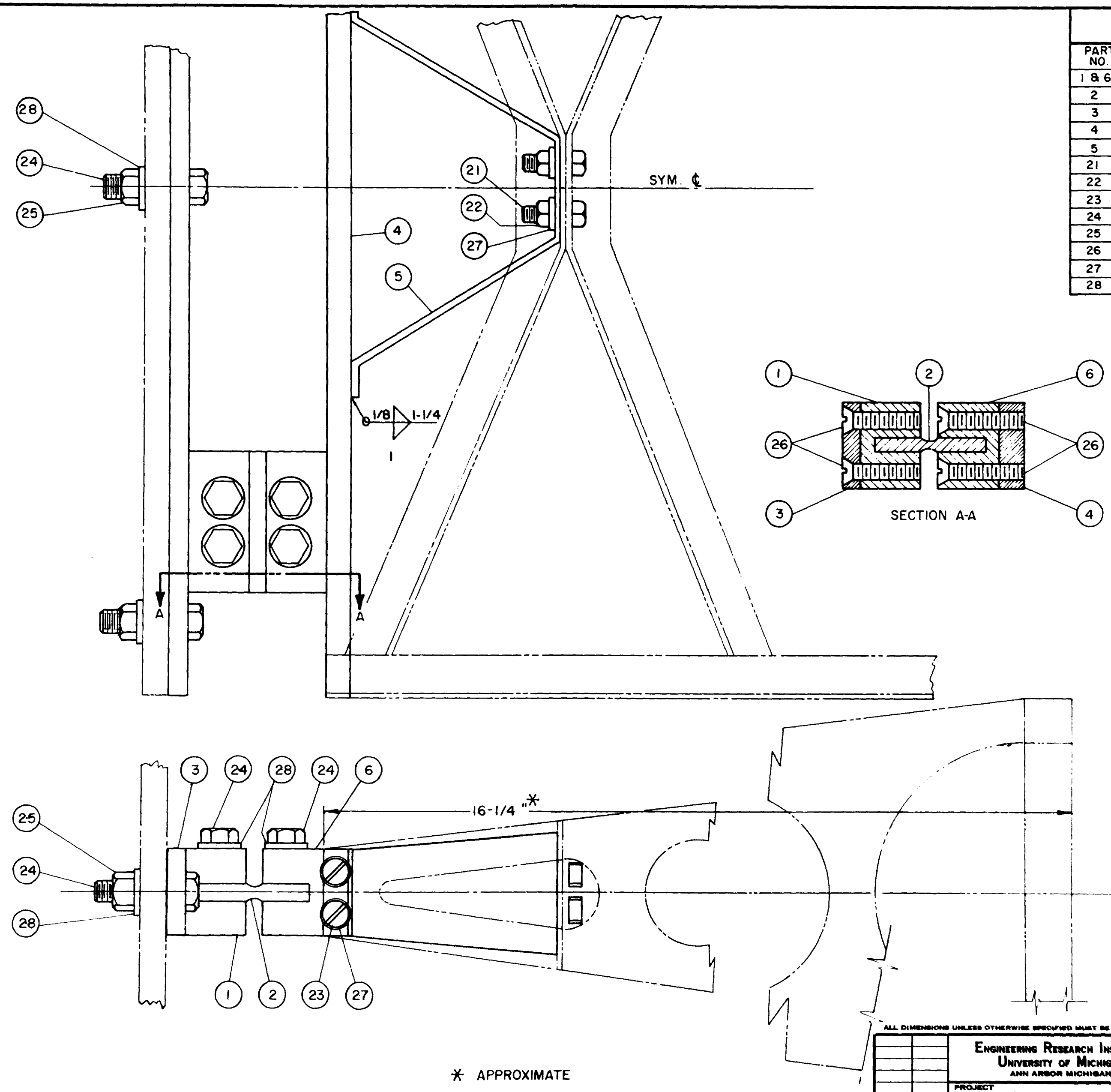
1. A greater spread to the support leads.
2. A possible redesign of the entire method of filament support that might eliminate the central support wire.
3. A possible increase in filament diameter, thus increasing its resistance to impact, even though this might result in an increase in watts rating and in candlepower output.

APPENDIX

A. An addition should be made to the list of operations needed to complete the modification of the Arsenal type of impact tester as presented on page 4 of the progress report for June, 1955.

4. Remove and discard the clamp (part no. 91) that was used to retain the lamp-holder plate in the yoke.

B. The drawing for the elastic hinge assembly shown on page 6 of the above-mentioned progress report requires a minor correction. The corrected drawing is shown on the following page.



BILL OF MATERIAL

PART NO.	QUANTITY	DESCRIPTION
1 & 6	2 Each	Clamp-7/8 x 1-1/4 x 2 C.R.S
2	2	Hinge -3/16 x 1-5/8 x 2 C.R.S
3	1	Rear Plate-1/4 x 1-1/4 x 14-5/8 C.R.S
4	1	Forward Plate-3/8 x 1-1/4 x 14-5/8 C.R.S
5	1	Brace-1/8 x 1-3/4 x 10 C.R.S
21	2	Cap Screw-1/4-28-3/4
22	2	Nut-1/4-28
23	4	Screws-12-24-3/4"
24	11	Cap Screws-5/16-24-1-1/4
25	3	Nuts-5/16-24
26	16	Flat Head Machine Screws-1/4-28-1-1/4
27	6	Lock Washers-1/4 Nom. I.D
28	11	Lock Washers-5/16 Nom. I.D

NO.	CORRECTIONS	DATE	CK.
1	SYMBOL ADDED	1-13-56	

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64" DECIMAL ± .005" ANGULAR ± ½°

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR MICHIGAN

PROJECT 2145

CLASSIFICATION

DESIGNED BY
DRAWN BY
CHECKED BY
APPROVED BY
SCALE
DATE 3-1-55

TITLE Modified Elastic Hinge Assembly for Incandescent Lamp Impact Tester

DWG. NO. C-

ISSUE DATE