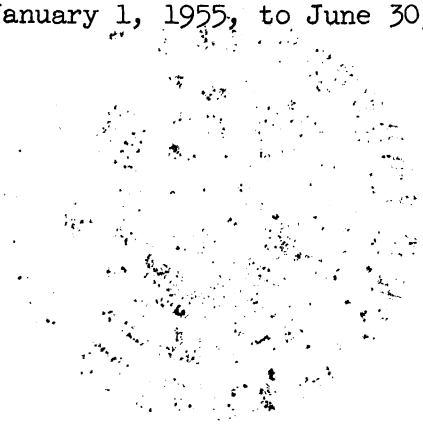
ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

Semiannual Progress Report No. 3

SHOCK ON ELECTRICAL COMPONENTS IN TRACK-LAYING AND WHEELED VEHICLES

January 1, 1955, to June 30, 1955



H. S. BULL

Project 2145

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

June 1955

ongm
UMR0926
no. 3

FOREWORD

This is the third semiannual progress report on a research program being carried on in the Department of Electrical Engineering, 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 Professor David Ragone of the Department of Chemical and Metallurgical Engineering, and from the generous cooperation of the General Electric, Hudson, and Westinghouse lamp companies, and the Electric Auto-Lite Company.

TABLE OF CONTENTS

		Page
FOREWORD		ii
LIST OF FIGURES		iv
OBJECT		v
ABSTRACT		v
CONCLUSIONS AND RECOMMENDATIONS		vi
I.	CONTINUED STUDIES OF THE ARSENAL IMPACT TESTER	1
	A. REVIEW OF PREVIOUS WORK	1
	B. CONTINUED WORK WITH AUTO-LITE TESTER	1
	C. PRINTS AND SPECIFICATIONS FOR THE MODIFIED ARSENAL TESTER	4
	D. MODIFICATION OF GENERAL ELECTRIC MACHINE	9
	E. COMPARATIVE PERFORMANCE OF MODIFIED MACHINES	11
	F. ANALYSIS OF LAMP IMPACT TESTING	11
II.	THE DESIGN AND EVALUATION OF A SMALL IMPACT TESTER	17
	A. BASIS FOR DESIGN	17
	B. DESCRIPTION OF PRESENT FORM OF SMALL TESTER	18
	C. OPERATING PROCEDURE	21
	D. PRELIMINARY PERFORMANCE TESTS	21
	E. INITIAL EVALUATION TESTS	22
	F. POSSIBLE MODIFICATIONS	26
	G. WORK IN PROSPECT	27

LIST OF FIGURES

Figure		Page
1	Mortality curves of five racks of lamps operated on the Auto-Lite impact tester.	2
2	Mortality curves of three racks of lamps operated on the Auto-Lite arm mounted on the Arsenal base.	2
3	Mortality curves of two racks of lamps operated on the Auto-Lite arm mounted on the Arsenal base.	3
4	Mortality curves of two racks of lamps operated on the Auto-Lite impact tester.	3
5	Mortality curves of four types of lamps operated on the General Electric impact tester before and after modification.	10
6	Comparative mortality curves of the Arsenal, Auto-Lite, and General Electric modified testers.	11
7	Principal structural features of the rotary-drum impact tester.	19
8	Three-contact lug-base lamps mounted on the rotary-drum impact tester.	20
9	Type 1265 lamps mounted on the rotary-drum impact tester by means of spring brass clips.	20
10	Relationship of filament deflection and lamp drop for lamp No. 256 on the rotary-drum impact tester.	22
11	Comparative tests of 2416 lamps (major filament).	23
12	Comparative tests of 2416 lamps (minor filament).	23
13	Comparative tests of 2416 lamps (major filament).	24
14	Comparative tests of 2416 lamps (minor filament).	25
15	Comparative tests of 1253 lamp.	25
16	Comparative tests of 1265 lamp.	26

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 a new and smaller type of tester and subject it to performance tests.

ABSTRACT

This is the third semiannual progress report, covering the period from January through June, 1955. The accomplishments may be summarized as follows:

1. Work has continued on the task of smoothing the performance of the Electric Auto-Lite tester and obtaining operating data in the form of lamp mortality curves to be compared with similar test data obtained on the Arsenal tester.

2. The General Electric tester has been modified to conform to all the changes made in the Arsenal and Auto-Lite testers.

3. Intercomparison of performance data obtained on all three modified testers has begun.

4. Further theoretical studies of lamp impact testing have been completed.

5. A small impact tester of the rotary-drum type has been built and subjected to preliminary evaluation tests.

CONCLUSIONS AND RECOMMENDATIONS

1. Further evidence has been obtained to strengthen the belief that the structural modifications of the present form of the impact tester have definitely improved the reliability and consistency of its performance. It is recommended that other companies having testers of the Arsenal type be encouraged to modify their machines in like manner.

2. Preliminary performance tests of the new rotary-drum tester are very encouraging. The results thus far obtained justify further intensive effort directed toward the development of structural refinements in the tester itself, and in the lamp holders and other auxiliary devices associated with it.

3. Further work needs to be done in modifying the physical features of lamp filaments in the hope of obtaining increased life without serious loss of efficiency.

I. CONTINUED STUDIES OF THE ARSENAL IMPACT TESTER

A. REVIEW OF PREVIOUS WORK

In the January, 1955, semiannual progress report on this project, certain modifications in the structure and operating specifications of the Arsenal impact machine were described. Some evidence in the form of lamp mortality data was presented which indicated that the modified tester showed marked improvement in the consistency of behavior and in correlation of data on successive runs with similar lamps. Consequently, steps were taken to carry out the same modifications in the tester operated by the Electric Auto-Lite Company, and comparative tests were begun to determine the degree of correlation between lamp mortality data obtained on the two machines. The results of initial tests available at the time the January report was written indicated that the correlation with the Arsenal tester was not quite as good as was hoped for, and that the spread between successive runs using identical lamps on the Auto-Lite tester was greater than desired. A need for structural adjustments and additional test runs was evident.

B. CONTINUED WORK WITH AUTO-LITE TESTER

The Auto-Lite machine was carefully inspected and several minor adjustments were made. Lamp testing was then resumed and three runs were completed in the Cincinnati laboratory. To facilitate further testing the hinged arm was then removed, brought to Ann Arbor, and installed on the base of the Arsenal tester in the project laboratory, where two more runs were taken. The results obtained in these five runs are shown in Fig. 1. The drop distance and the force required to lift the arm from the anvil were somewhat different for each of the five runs but the indications obtained from the Statham accelerometer were almost equal.

Figure 2 shows the results obtained in tests of three more racks of lamps using the Auto-Lite arm on the Arsenal base; in Fig. 3 are shown the results of two more tests which were taken under the same operating conditions so far as possible but using lamps obtained from a different manufacturer.

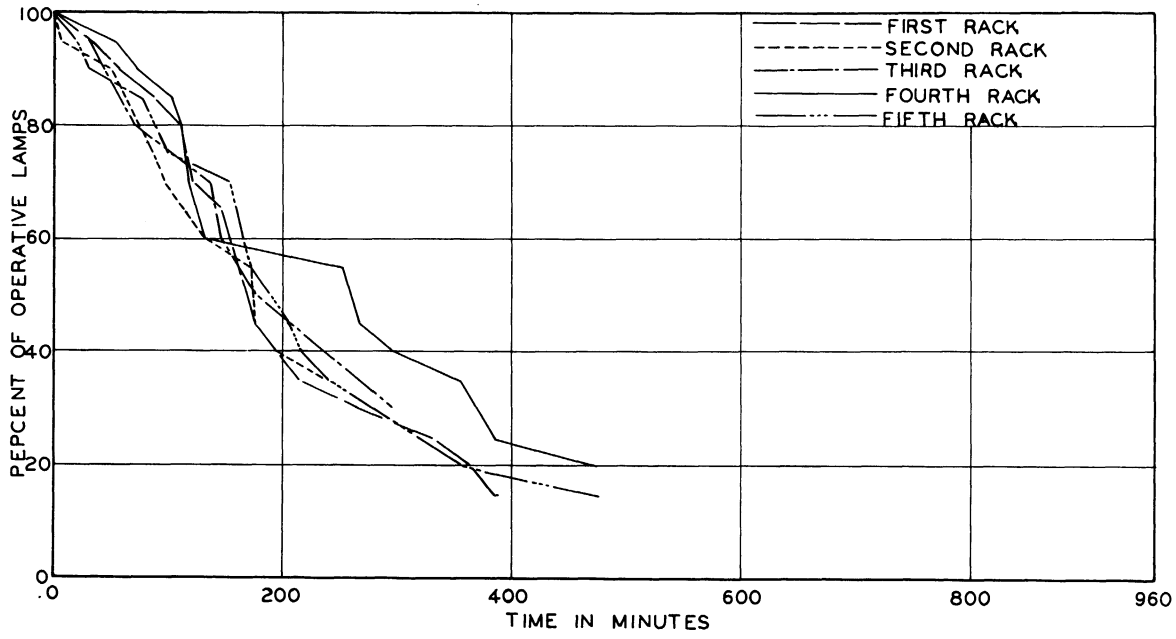


Fig. 1. Mortality curves of five racks of lamps operated on the Auto-Lite impact tester.

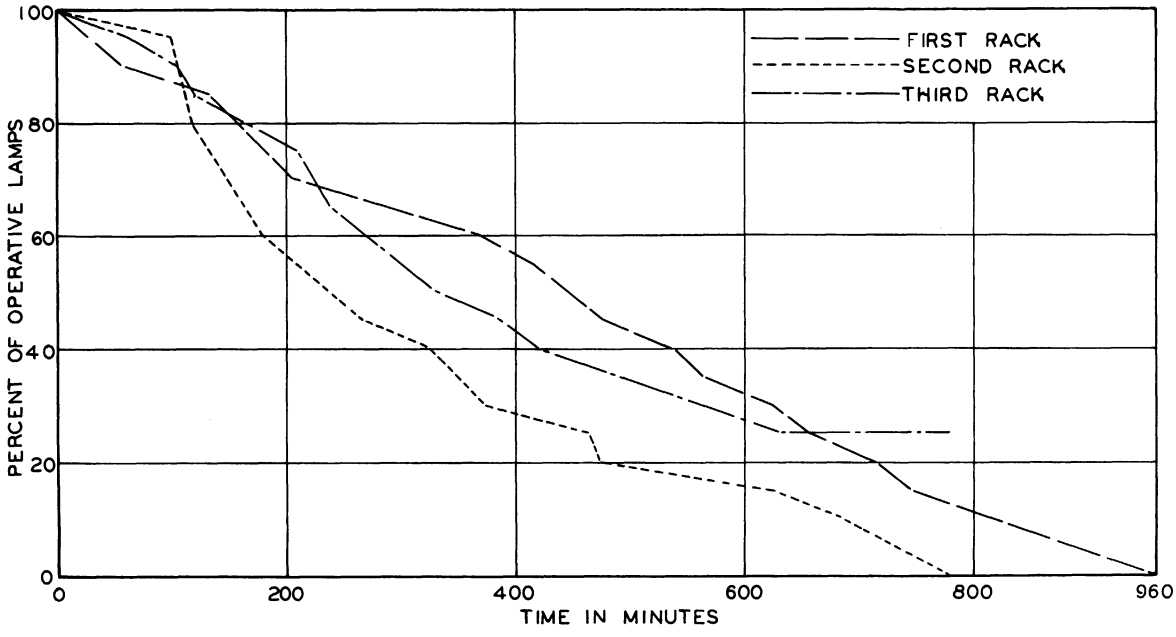


Fig. 2. Mortality curves of three racks of lamps operated on the Auto-Lite arm mounted on the Arsenal base.

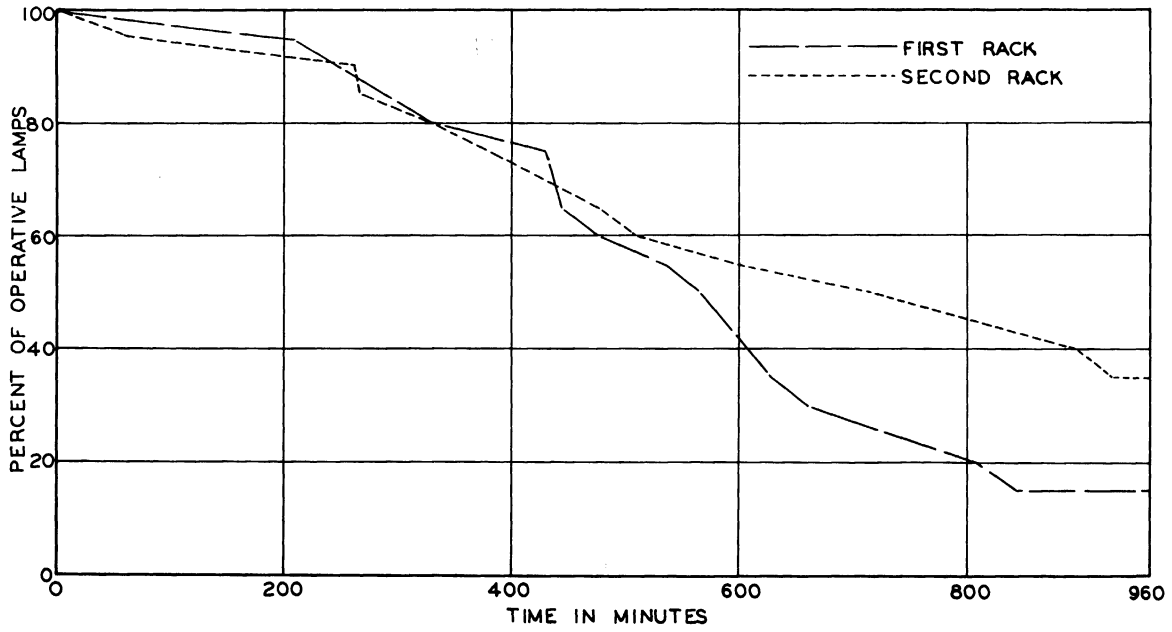


Fig. 3. Mortality curves of two racks of lamps operated on the Auto-Lite arm mounted on the Arsenal base.

Careful study of all these runs indicated no marked change in performance associated with the operation of the Auto-Lite arm on the Arsenal base. They all seemed to indicate somewhat more consistent operation than was obtained when the Auto-Lite machine was first modified, and this trend toward greater uniformity led to the decision to reassemble the Auto-Lite arm on its original base in the Cincinnati laboratory. Figure 4 shows the results

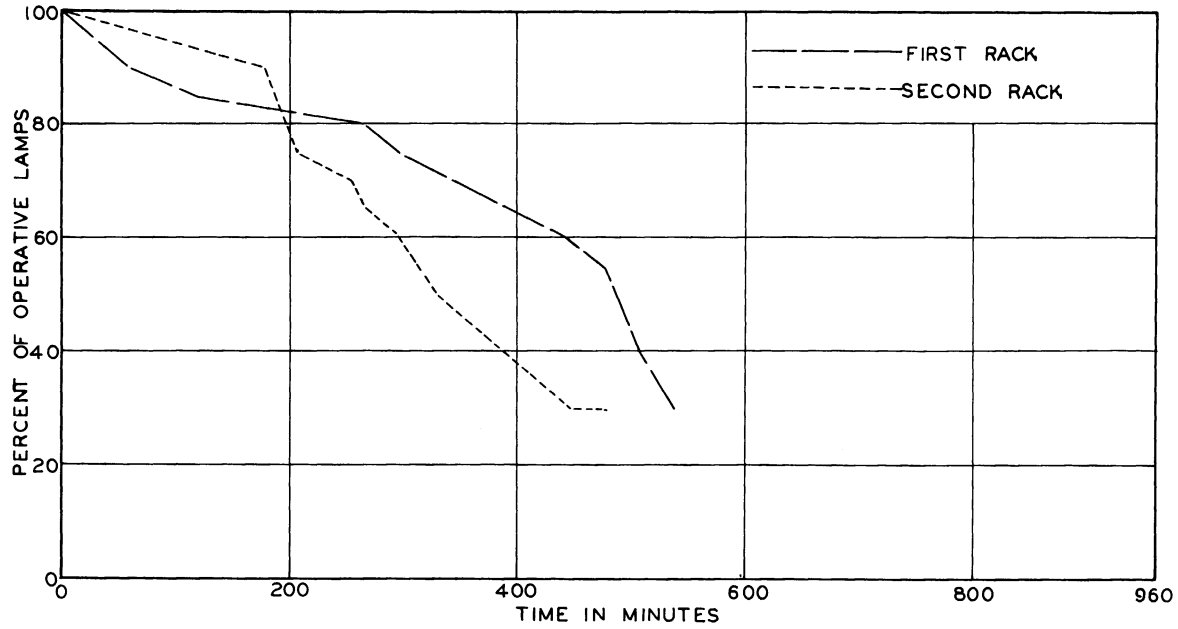


Fig. 4. Mortality curves of two racks of lamps operated on the Auto-Lite impact tester.

of tests, using this machine, on two racks of lamps obtained from the same manufacturer's lot as those shown in Fig. 2. The agreement between these two sets is good enough to offer some assurance that the machine is now performing within the tolerances that seem reasonable for this type of tester.

C. PRINTS AND SPECIFICATIONS FOR THE MODIFIED ARSENAL TESTER

At the request of the SAE Impact-Tester Panel, prints and specifications covering the recommended changes in the Arsenal tester were prepared and distributed to a majority of the panel members. A complete set is included herewith, with a copy of the letter of transmittal.

"In accordance with the suggestion made at the meeting in Ann Arbor on January 27, 1955, we are transmitting herewith the drawings showing the recommended modifications of the incandescent lamp impact tester. It has been determined that the modified tester becomes a fairly consistent shock-testing device if the suggested changes are completed with care and if subsequent operation is accompanied by proper maintenance. It is still our feeling that this is at best an interim device which should ultimately be replaced by a smaller and lighter tester of new design.

"The accompanying notes may be helpful in connection with the changeover. Any difficulties encountered in the modification and/or subsequent operation should be brought to our attention.

"Further operations needed to complete the modification of the impact tester:

1. Mill 0.030 inch off the bottom of each shaft bearing block.
2. Drill two 13/32-inch holes in the upright back plate [part no. 18, drawing no. 7069578 (originally Chrysler drawing)] to match the holes in the new hinge mounting rear plate (part no. 3).
3. Cut assorted shim stock for use under bearing blocks.

"Specifications for physical settings in the assembly of modified impact tester:

1. Cam speed of 700 rpm $\pm$ 2 rpm. Note: this setting should be checked with a hand tachometer and not a Strobotac.
2. The arm should be set so it takes 16 pounds of force to raise the upper anvil 0.0015 inch from rest on the lower anvil. This force should be measured directly above the center of the lamp-holding plate when it is secured in

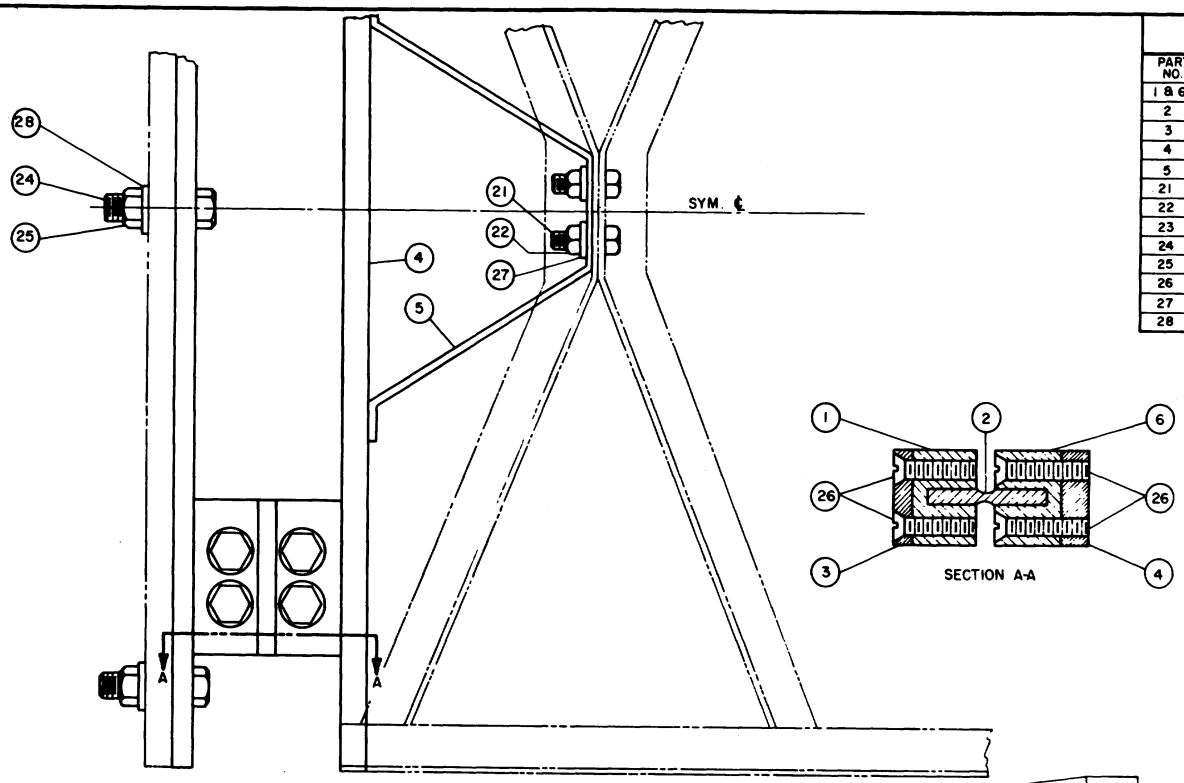
place. A suggested scale for measuring this force is a Chatillon type-027, 20-lb capacity.

3. The cam should allow the upper anvil to fall 0.041 inch.
4. The impact tester should conform to drawings and specifications detailed in the original drawings with the exception of the described modifications.

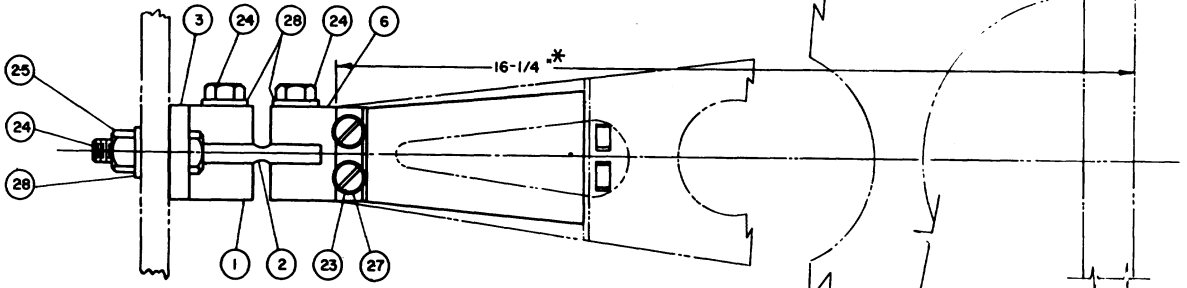
"From previous experience, a number of details have been observed during the assembly of the modified impact tester. Although every detail may not be applicable in every case, each one should be checked either before or during assembly.

1. There must be a moderate clearance between the side edges of the lamp-holding plate and the yoke to prevent distortion of the upper anvils.
2. The lamp-holding plate must rest on the bottom of the groove cut in the yoke. The holes in the plate may be enlarged to permit this fit.
3. The center of the cam must be in vertical alignment with the edge of the cam follower.
4. The bearing blocks should be aligned in such a manner that the shaft will turn freely without binding.
5. The upper plate (part no. 14, drawing no. 7069578) must be rigidly and firmly seated on the concrete base. This plate should be regrouted if not correctly attached.
6. The clearance between the ends of the anvils should be ample to eliminate any change of binding or friction.
7. The end play on the camshaft should be kept to a minimum.
8. A push fit must be maintained between the lamp-holding plates and the slot in the yoke.
9. The surface of the anvils must be smooth and true. If these surfaces become rough after use they should be reground.
10. The anvils must be properly aligned to give a maximum area of contact. A quick check of alignment may be made by sighting at the closed anvils with a light held behind them. Further checks should be made to assure proper alignment in all planes.
11. Shims may be inserted between the rear plate of the hinge mounting and back plate to adjust the amount of upward pull needed to separate the anvils. To increase the pull, insert shims above the attachment bolts.
12. The welded joints in the frame should be inspected for cracks and rewelded where needed.

"The following suggestions concerning maintenance of the modified tester should be carefully noted.



SECTION A-A



* APPROXIMATE

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

SHEET 1 OF 2

ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64" DECIMAL ± .005" ANGULAR ± 30'

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR MICHIGAN

PROJECT 2145

CLASSIFICATION

DESIGNED BY

DRAWN BY

CHECKED BY

APPROVED BY

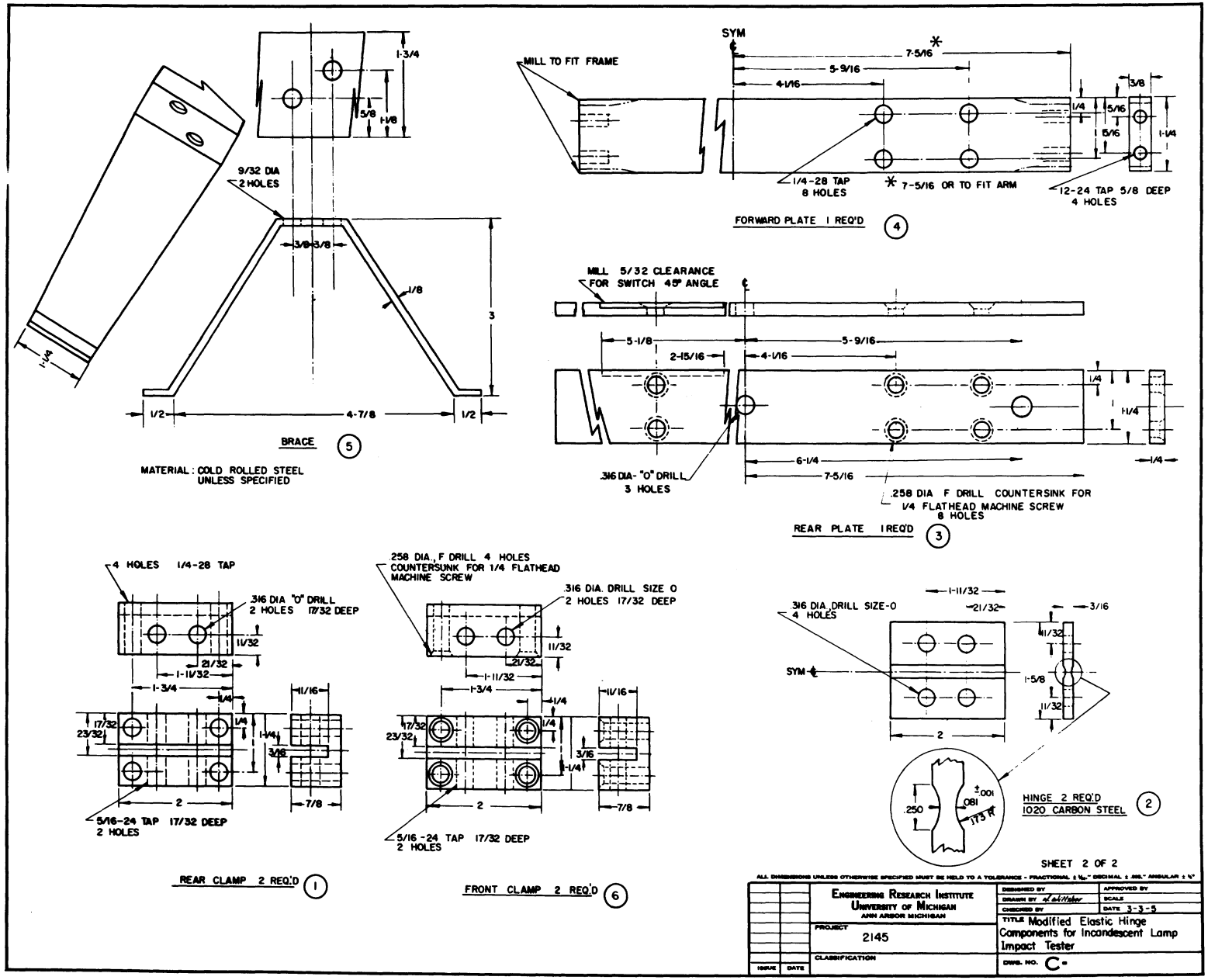
SCALE

DATE 3-1-55

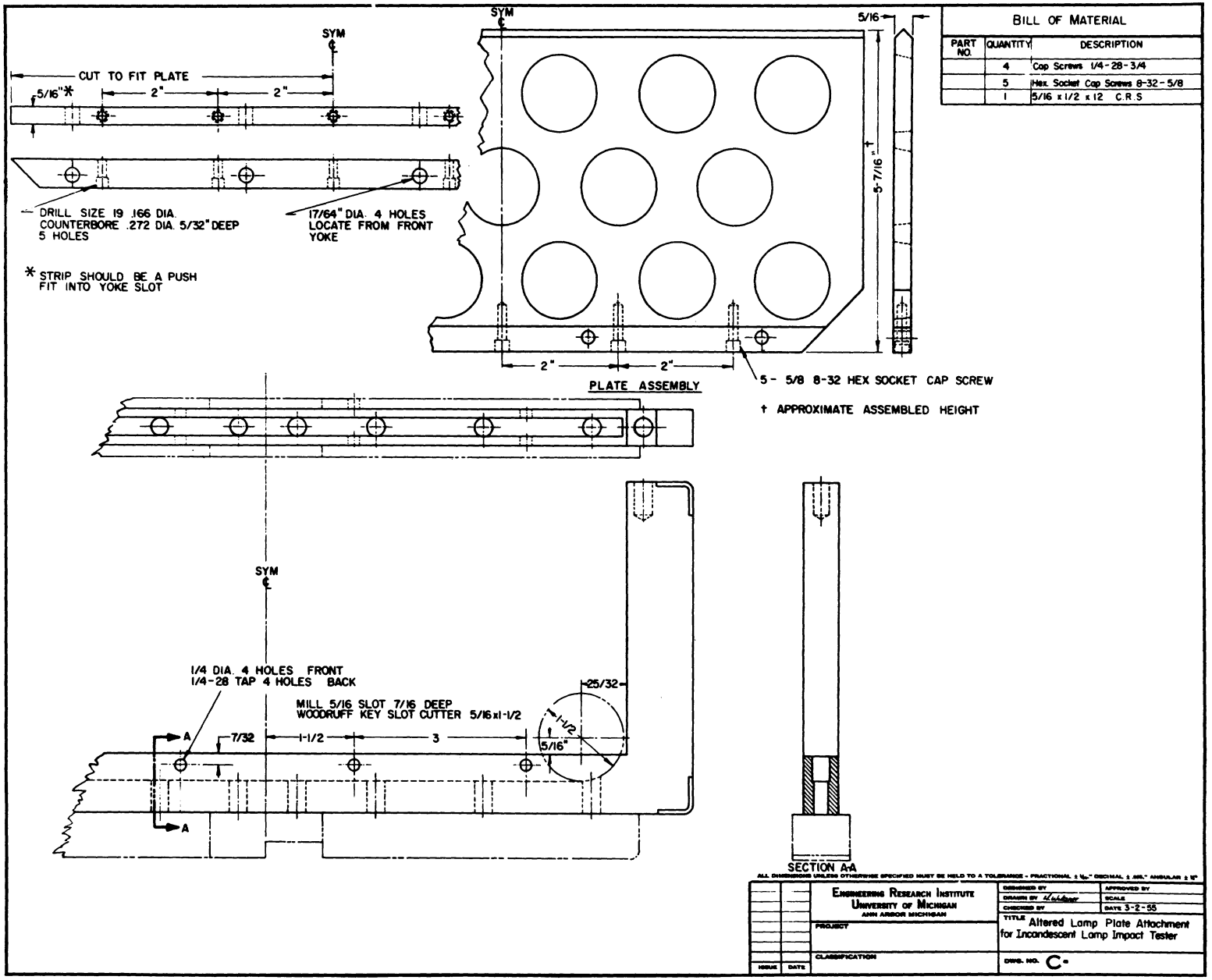
TITLE Modified Elastic Hinge Assembly for Incandescent Lamp Impact Tester

DWG. NO. C-

ISSUE | DATE



1-3/4
5/8
1-1/8
9/32 DIA
2 HOLES
3/8
3/8
1/8
3
1-1/4
1/2
4-7/8
1/2
BRACE 5
MATERIAL: COLD ROLLED STEEL
UNLESS SPECIFIED
SYM
MILL TO FIT FRAME
7-5/16 *
5-9/16
4-1/16
3/8
1/4
5/16
5/16
1-1/4
1/4-28 TAP
8 HOLES
* 7-5/16 OR TO FIT ARM
12-24 TAP 5/8 DEEP
4 HOLES
FORWARD PLATE 1 REQ'D 4
MILL 5/32 CLEARANCE
FOR SWITCH 45° ANGLE
5-1/8
5-9/16
2-15/16
4-1/16
1/4
1-1/4
6-1/4
7-5/16
1/4
.316 DIA- "O" DRILL
3 HOLES
.258 DIA F DRILL COUNTERSINK FOR
1/4 FLATHEAD MACHINE SCREW
8 HOLES
REAR PLATE 1 REQ'D 3
4 HOLES 1/4-28 TAP
.316 DIA "O" DRILL
2 HOLES 17/32 DEEP
11/32
21/32
1-11/32
1-3/4
1/4
11/16
17/32
23/32
1/4
1-1/4
3/16
2
7/8
5/16-24 TAP 17/32 DEEP
2 HOLES
REAR CLAMP 2 REQ'D 1
.258 DIA., F DRILL 4 HOLES
COUNTERSUNK FOR 1/4 FLATHEAD
MACHINE SCREW
.316 DIA. DRILL SIZE O
2 HOLES 17/32 DEEP
11/32
21/32
1-11/32
1-3/4
1/4
11/16
17/32
23/32
1/4
3/16
1-1/4
2
7/8
5/16-24 TAP 17/32 DEEP
2 HOLES
FRONT CLAMP 2 REQ'D 6
1-11/32
.316 DIA. DRILL SIZE-O
4 HOLES
21/32
3/16
11/32
SYM
1-5/8
11/32
2
.250
.081
±.001
.173 R
HINGE 2 REQ'D
1020 CARBON STEEL 2
SHEET 2 OF 2
ALL DIMENSIONS UNLESS OTHERWISE SPECIFIED MUST BE HELD TO A TOLERANCE - FRACTIONAL ± 1/64" DECIMAL ± .005" ANGULAR ± 1/2°
ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR MICHIGAN
PROJECT
2145
CLASSIFICATION
ISSUE
DATE
DESIGNED BY
DRAWN BY
CHECKED BY
APPROVED BY
SCALE
DATE 3-3-5
TITLE Modified Elastic Hinge Components for Incandescent Lamp Impact Tester
DWG. NO. C-



BILL OF MATERIAL

PART NO.	QUANTITY	DESCRIPTION
	4	Cap Screws 1/4-28-3/4
	5	Hex. Socket Cap Screws 8-32-5/8
	1	5/16 x 1/2 x 12 C.R.S.

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

ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR MICHIGAN

PROJECT

CLASSIFICATION

ISSUE | DATE

DESIGNED BY | APPROVED BY
DRAWN BY | SCALE
CHECKED BY | DATE 3-2-55

TITLE Altered Lamp Plate Attachment for Incandescent Lamp Impact Tester

DWG. NO. C-

1. All dirt and excess oil must be removed frequently from the shaft bearings and adjacent areas. The front bearing is especially important.
2. The cam must be lubricated before each 8 hours of operation, using a high-temperature hard grease. The cam and adjacent surfaces should be thoroughly cleaned before each lubrication.
3. The anvils should be cleaned before every test.
4. If it becomes necessary to remove the arm from the tester, detach it at the hinge clamps.
5. Do not disturb the position of the back-mounting plate.
6. Use lamp-holder plates having a collet-type chuck, or a similar clamping device."

D. MODIFICATION OF GENERAL ELECTRIC MACHINE

The lamp-testing section of the General Electric Company in Nela Park decided to modify their impact tester to make it conform to the present Arsenal and Auto-Lite machines. The details of this change-over were reported on April 12, 1955, in a letter from L. J. Corsaro, and are summarized below.

1. The tester was modified to conform to the drawings supplied by the University of Michigan project.

2. The operating speed was changed from 900 to 700 rpm.

3. The drop of the upper anvil was changed from 0.0025 to 0.041 inch.

4. The force required to raise the upper anvil 0.0015 inch was adjusted to 16 pounds.

5. The base plate of the tester was regrouted to the foundation with nonshrinking material.

6. The test cycle for a single-filament lamp was changed to conform to Federal Specifications W-L-1116, April 18, 1952.

Accompanying the Corsaro letter were some curves which are reproduced here as Fig. 5, in which some comparative test results are plotted

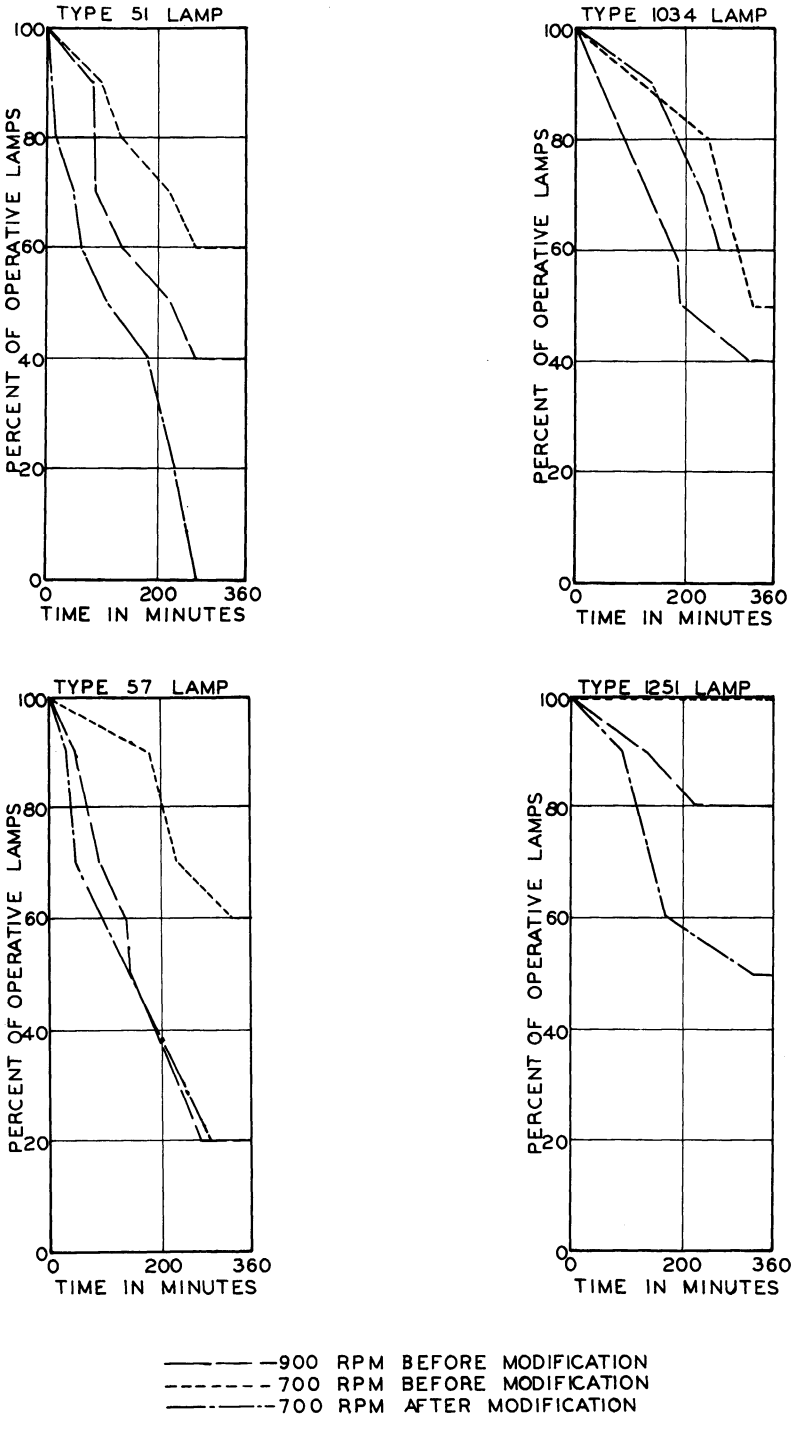


Fig. 5. Mortality curves of four types of lamps operated on the General Electric impact tester before and after modification.

showing the performance of the machine before and after the modifications were completed. There were also comments which indicated that the machine after modification appeared to have a smoother impact sound and more consistent peak acceleration values.

E. COMPARATIVE PERFORMANCE OF MODIFIED MACHINES

In the initial effort to obtain evidence as to the comparative performance of the three modified testers, a small quantity of type 1251 lamps, selected from the same manufacturer and the same production lot, was allocated to each tester for a mortality curve determination. Minor deviations in lamp voltage regulation and testing procedure undoubtedly existed. Nevertheless the results are surprisingly close in their agreement, as will be noted in the curves of Fig. 6. It is anticipated that further comparative data will be obtained under as nearly identical test conditions as possible.

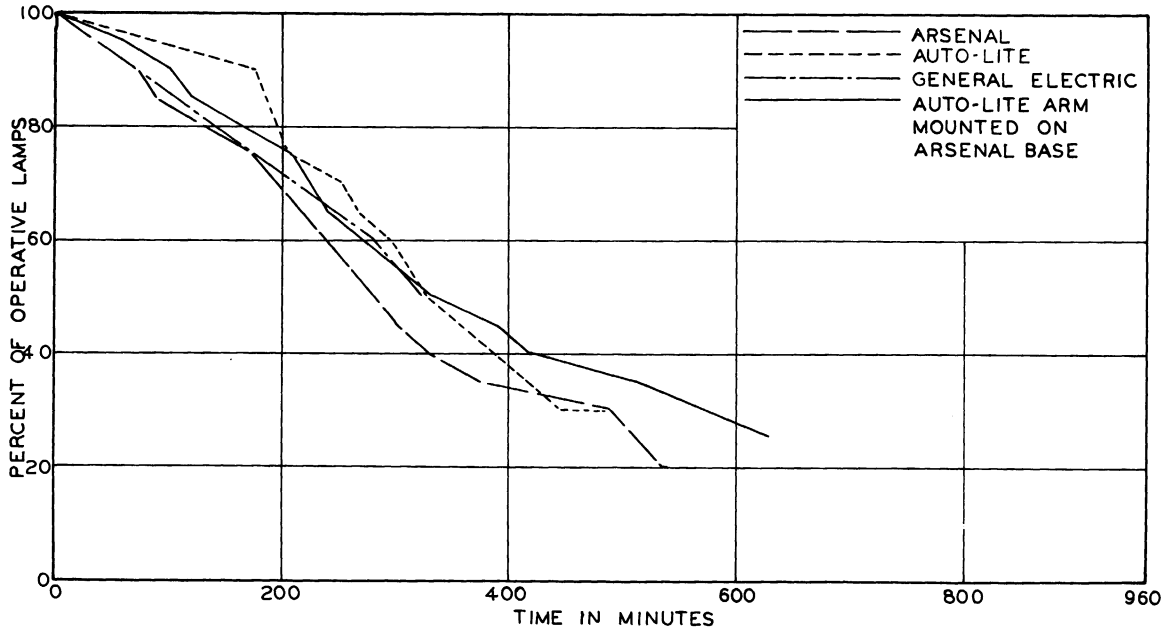


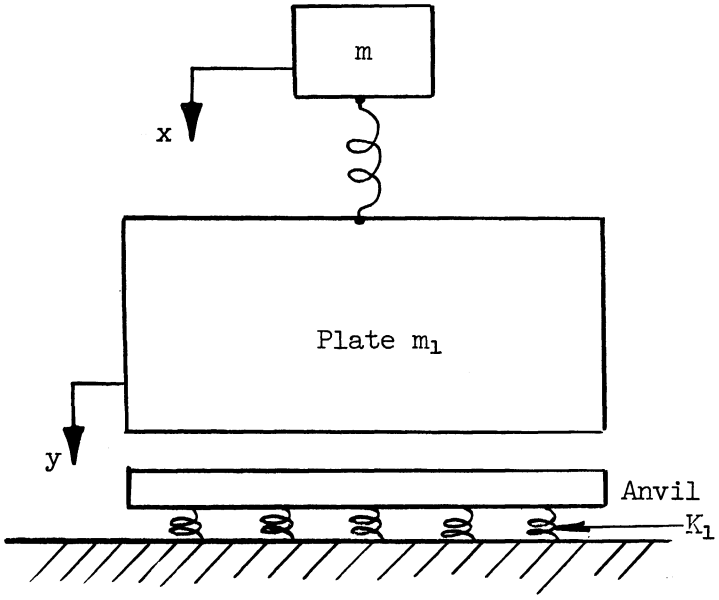
Fig. 6. Comparative mortality curves of the Arsenal, Auto-Lite, and General Electric modified testers.

F. ANALYSIS OF LAMP IMPACT TESTING

There has been some question as to what the Statham accelerometer, as used in conjunction with the Arsenal impact tester, really indicates. Some interesting and pertinent aspects of this problem have been investigated from

a theoretical viewpoint by Professor Jesse Ormondroyd and are presented herewith under the heading - LAMP IMPACT TESTING.

LAMP IMPACT TESTING



Let m be the mass of the filament or the suspended mass in an accelerometer, K be the spring constant of the filament or the accelerometer, and x be the relative motion between either of the masses and the plate. When the plate falls and hits the anvil both the plate and the anvil compress elastically and the plate rebounds from the anvil.

Let the motion of the plate while in contact with the anvil be y. It will be, approximately,

$$y = \frac{V}{P_1} \sin P_1 t$$

where

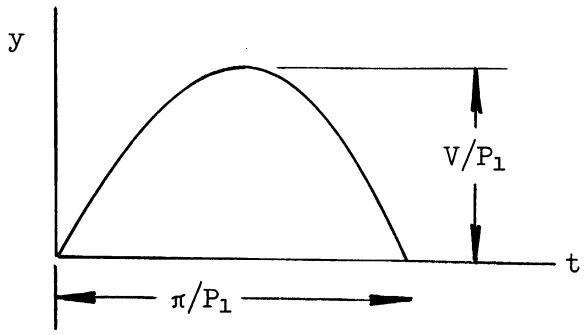
V = velocity with which the plate strikes the anvil,

$P_1 = \sqrt{K_1/m_1}$ = the natural circular frequency of the plate on the anvil,

K_1 = the equivalent spring constant of the plate on the anvil, and

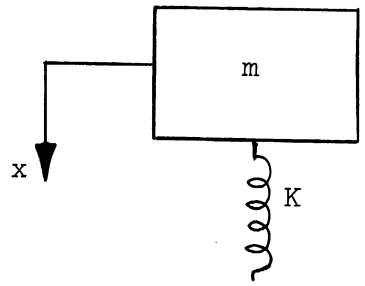
m_1 = the mass of the plate.

With y taken + downward, the motion of the plate is as shown below.



When $t = \pi/P_1$ the plate ceases to be in contact with the anvil.

At the instant of first contact between plate and anvil the relative motion between m and the plate is zero and the relative velocity $\dot{x}$ is also zero.



$$y = \frac{V}{P_1} \sin P_1 t$$

$$m\ddot{x} + Kx = -m\ddot{y}$$

$$\ddot{x} + p^2 x = -\ddot{y} = VP_1 \sin P_1 t \ ;$$

$$p^2 \equiv \frac{K}{m}$$

The solution for this equation is during the time of contact between plate and anvil

$$x = \frac{P_1}{P} V \left(\sin Pt \int_0^t \sin P_1 T \cos PT \, dT - \cos Pt \int_0^t \sin P_1 T \sin Pt \, dT\right) ,$$

$$x = \frac{VP_1}{P^2 - P_1^2} \left(\sin P_1 t - \frac{P_1}{P} \sin Pt\right) ,$$

P_1 = natural circular frequency of the plate on the anvil, and

P = natural circular frequency of the accelerometer or filament.

Suppose $P \gg P_1$; then

$$x \approx \frac{V P_1 \sin P_1 t}{P^2} - \frac{P_1}{P} \frac{V_1 P_1 \sin Pt}{P^2} \text{ ; for } 0 < t < \pi/P_1 .$$

The first terms on the right side then predominate, the second term is small. The motion of m relative to the plate is then proportional to the acceleration of the plate with a slight amount of "noise" at the natural frequency of the filament or the accelerometer.

Suppose $P_1 \gg P$; then

$$x \approx \left(\frac{P_1}{P} \frac{V}{P_1} \sin Pt - \frac{V}{P_1} \sin P_1 t\right) ; \text{ for } 0 < t < \pi/P_1 .$$

Here the motion of m with the natural circular frequency P predominates and the $V/P_1 \sin P_1 t$ is a small "noise" term.

Suppose $P = P_1$; then

$$x \approx \frac{1}{2} \frac{V}{P_1} (\sin P_1 t - P_1 t \cos P_1 t) \approx \frac{1}{2} \frac{V}{P_1} \sqrt{1 + P_1^2 t^2} \sin (P_1 t - \tan^{-1} P_1 t).$$

For $\pi/P_1 < t < \infty$, that is, for times after the contact between plate and anvil is broken.

$$x = \frac{P_1}{P} V \left(\sin Pt \int_0^{\frac{\pi}{P_1}} \sin P_1 T \cos PT \, dT - \cos \int_0^{\frac{\pi}{P_1}} \sin P_1 T \sin PT \, dT\right) ;$$

$$x = -\frac{2V}{P} \frac{P_1^2}{P^2 - P_1^2} \cos \frac{P}{2} \frac{\pi}{P_1} \sin \left(Pt - \frac{P}{2} \frac{\pi}{P_1}\right) .$$

In this motion the frequency is only that of the mass m on the spring, K.

When $P \gg P_1$,

$$x \approx -\frac{2V}{P}\frac{P_1^2}{P^2}\cos\frac{P}{2}\frac{\pi}{P_1}\sin\left(Pt - \frac{P}{2}\frac{\pi}{P_1}\right).$$

If $P/P_1 = 1, 3, 5, \ldots$ odd the amplitude of motion would be zero. In any case it will be very small.

When $P_1 \gg P$,

$$x \approx \frac{2V}{P}\cos\frac{P}{2}\frac{\pi}{P_1}\sin\left(Pt - \frac{P}{2}\frac{\pi}{P_1}\right) \approx \frac{2V}{P}\sin Pt.$$

Rough calculations show that $P_1 = 25000$ radians per second. The 800-cycle-per-second accelerometer used at the University of Michigan has $P = 5000$ radians per second.
The filaments have $P = 1700$ to 1900 radians per second.
For the 800-cycle-per-second accelerometer $P_1/P = 25000/5000 = 5$.

Therefore during the impact $(0 < t < \pi/P_1)$,

$$x = \frac{V}{P}\frac{25}{24}\left(\sin Pt - \frac{1}{5}\sin 5Pt\right).$$

After the impact is over $(\pi/P_1 < t < \infty)$,

$$x = \frac{2V}{P}\frac{25}{24}\cos\frac{\pi}{10}\sin\left(Pt - \frac{\pi}{10}\right).$$

The maximum value of x is reached when

$$t = 3\frac{\pi}{P_1}$$

It is obvious from this that the first high-peaked record obtained from the Statham accelerometer at the University of Michigan does not measure

acceleration at all in this application. But it does give a peak value proportional to the velocity with which the plate strikes the anvil.

For the 300-cycle-per-second filaments,

$$\frac{P_1}{P} = \frac{25000}{1800} \approx 14 .$$

During the impact $(0 < t < \pi/P_1)$,

$$x = \frac{V}{P} \frac{196}{195} (\sin Pt - \frac{1}{14} \sin 14\, Pt).$$

After the impact $(\pi/P_1 < t < \infty)$,

$$x = \frac{2V}{10} \frac{196}{195} \cos \frac{\pi}{28} \sin (Pt - \frac{\pi}{14}) .$$

Since

$$\frac{196}{195} \cos \frac{\pi}{28} \approx 1 ,$$

the maximum amplitude of motion is $x_{max} \approx 2V/P$ and this occurs after the impact is over; the double amplitude is $2x_{max} = 4V/P$.

Our drops are such that $V \approx 5^m/sec$; therefore, for lamp no. 256,

$$2x_{max} \approx \frac{20}{1780} \approx 0.011 \text{ inch.}$$

Actual measured values of $2x_{max} = 0.013$ (University of Michigan).

For lamp no. 276,

$$2x_{max} \approx \frac{20}{1540} \approx 0.013 \text{ inch.}$$

Actual measured values of $2x_{max}$ = 0.0195 inch (University of Michigan); damping ratio C/Cc = n.

In the case of loud-speaker coil tests at resonance with several filaments (hot),

$$\frac{x_o}{y_o} = 10 = \frac{1}{2n\sqrt{1 - n^2}}$$

where

x_o = amplitude of filament, and

y_o = amplitude of loud-speaker coil.

Therefore n = 0.05.

II. THE DESIGN AND EVALUATION OF A SMALL IMPACT TESTER

A. BASIS FOR DESIGN

Of the many impact machines designed and built for lamp-testing purposes, it is certain that the one developed by Chrysler, now known as the Arsenal lamp impact tester, ranks with the best. Most of the erratic and inconsistent behavior initially observed in this tester has been eliminated by several modifications in the structure and operating specifications. With these modifications, it has become a fairly reliable testing device.

There are still several basic disadvantages. The replacement cost is high (estimated as high as $7000); it has a high noise level when operating, a large size and weight, and a need for frequent and careful lubrication, cleaning, and routine maintenance. The noise, in particular, is so disturbing that the majority of installations are in sound-insulated cubicles.

In a theoretical analysis of the Arsenal impact tester (see page 25 of the July, 1954, Semiannual Progress Report on Contract No. DA-20-089-ORD-36543) it was pointed out that freely dropping a lamp a small distance would produce as much vibrational stress in the filament as is produced by mounting the lamp on the present Arsenal tester.

The Arsenal tester has a considerable amount of mass in the moving parts which serves to some extent as an elastic cushion between the anvil and the lamp filament. A logical step in a new approach to an impact device involved a reduction of this cushioning effect to a minimum. It seemed likely that this could be accomplished by arranging to provide impact by tapping the lamp envelope directly, or by dropping the lamp a very short distance onto a relatively inelastic surface. This belief was confirmed by a crude experiment (described on page 37 of the July, 1954, report) where relative vibratory amplitudes were compared for a filament excited first on the Chrysler tester (of the Arsenal type) and then by releasing the lamp from a distance above the masonite surface equal to the cam drop. The free drop gave consistently greater amplitudes.

A pilot model embodying these ideas was then constructed. It consisted of a cylindrical wooden drum provided with a pulley drive and a means of resting the lamp envelope on its upper surface. The drum had four uniformly spaced steps cut parallel to the axis of rotation. As the drum was rotated, the lamp was lifted and dropped 3/32 inch as it encountered each step. The excitation of the lamp filament produced by the operation of this model proved to be more than ample for practical testing purposes.

B. DESCRIPTION OF PRESENT FORM OF SMALL TESTER

A second and enlarged model embodying the essential features of this new design has been completed and its operating characteristics are being studied. Figure 7 will serve to illustrate its principal structural features. The cylindrical drum is composed of four quarter sections of maple turned into cylindrical form as a unit. Each quarter may be offset slightly by adjusting the end clamps, so that a 4-step cam is formed. The amount of cam drop may be adjusted to a maximum of 0.125 inch.

The principal dimensions are:

overall length, 24 in.
nominal diameter, 5-1/2 in.
length of test surface, 19-1/4 in.
approximate weight of assembly, 10-1/2 lb.

Several types of lamp holders have been designed, with modifications to facilitate testing either small or large bulbs. For two-filament lamps having three contact lugs on the base, a form of pivot is provided by passing a smooth nonconducting rod through the 1/8-inch holes in the ground and high-beam lugs. This rod is then mounted in alignment with the drum axis in such a way as to allow the bulb to rest on the drum surface with its highest point directly over the axis. Ten bulbs of this type may be mounted side by side on

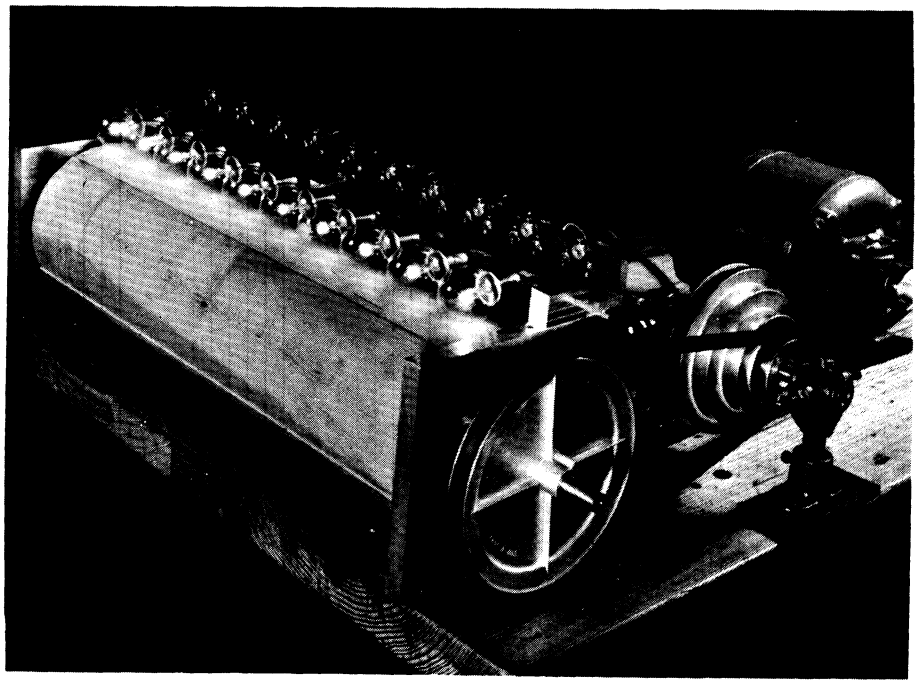


Fig. 7. Principal structural features of the rotary-drum impact tester.

the same rod and tested simultaneously, as shown in Fig. 8. Electrical connections are provided by soldering bare stranded copper wire to each of the lamp lugs; proper lamp spacing is maintained by plastic spacers inserted between adjacent lamps.

For bulbs having a candelabra bayonet base, pivot points have been provided by means of conical dents on diametrically opposite points on the shell. Spring brass clips have been designed which have conical projections to match the dents on the bulb shell. This type of clip support seems to offer little restraint to the vertical movement of the bulb and allows it to respond freely to the action of the cams.

Figure 9 shows a typical assembly of these holders supporting ten type 1265 lamps with RP-11 bulbs. As many as twenty lamps with a G-6 bulb can be accommodated at one time with this arrangement.

Electrical connections are established by using the spring brass clip as the ground connection and soldering a bare copper wire having very flexible strands to the base terminal button.

The present form of drum impact tester requires a supporting bench about 2 feet square. If speed reduction were obtained by another means, the required space would obviously be cut approximately in half.

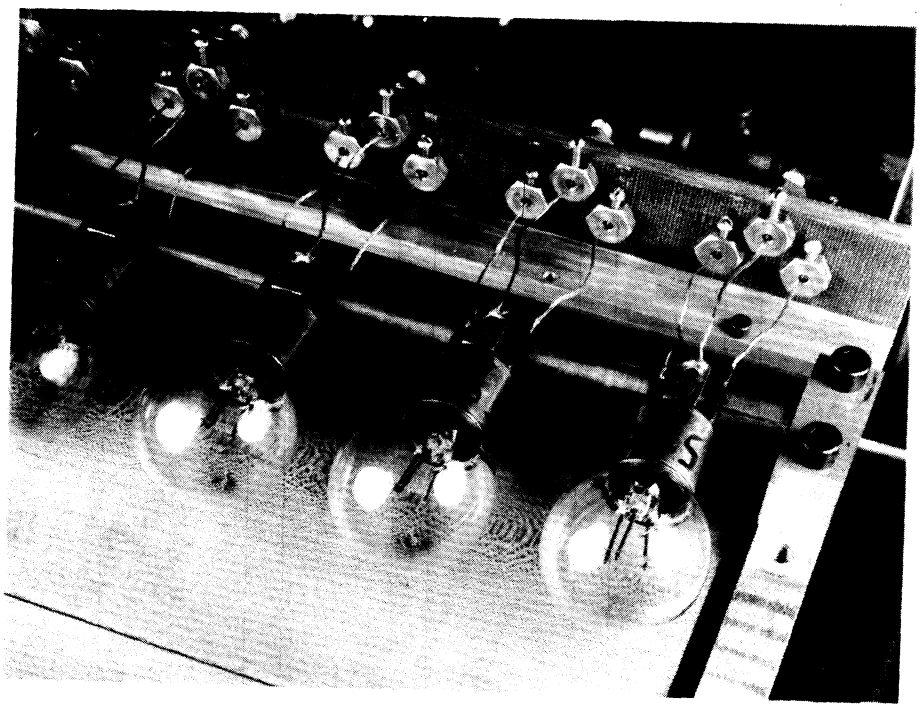


Fig. 8. Three-contact lug-base lamps mounted on the rotary-drum impact tester.

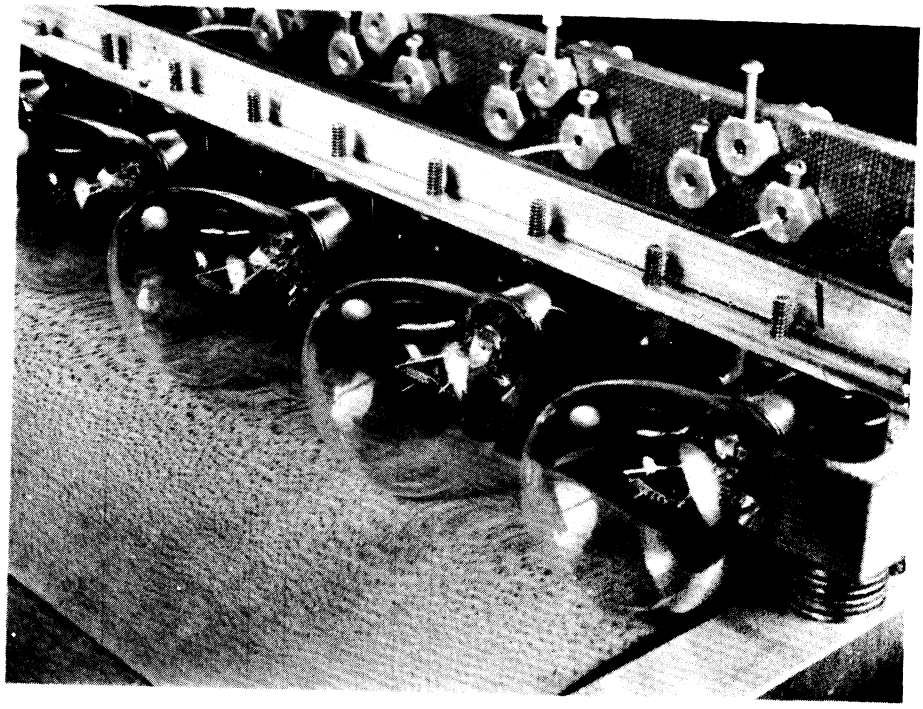


Fig. 9. Type 1265 lamps mounted on the rotary-drum impact tester by means of spring brass clips.

C. OPERATING PROCEDURE

Preparations for impact testing on the drum tester are not difficult or time-consuming. Each lamp must have the necessary connecting wire or wires soldered to its base and then mounted in the pivot device appropriate to the type of lamp to be tested. The time required to do this is about equal to the mounting time required for the Arsenal tester.

Since the drum tester requires little or no cleaning and lubrication, the time formerly required for these operations is saved. Actual testing procedure is unchanged, with the same on-and-off cycle and a drum speed adjusted to give 700 impacts per minute.

D. PRELIMINARY PERFORMANCE TESTS

One item of interest was the matter of determining the relation between the amplitude of filament excitation and the amount of cam drop in the new rotary drum tester. It was possible to determine this quite easily by arranging the end clamps so that the drop was 0.030 inch near one end of the cylinder and 0.060 inch near the other end. One of the standard indicator lamps (described on page 8 of the July, 1954, report) was mounted with the glass bulb resting on the drum surface near the end having the .030-inch cam setting, and its filament deflection was observed with the drum in motion. These observations were repeated with the lamp advanced in suitable steps toward the larger cam settings. The results are plotted in Fig. 10.

Earlier tests with this indicator lamp mounted on the Arsenal impact tester showed an approximate filament deflection of 0.013 inch, and this agreed closely with a similar test on the Auto-Lite machine. Since it appeared that the relation between filament deflection and cam drop was almost linear, and since the selection of any desired drop up to 0.125 inch was a matter requiring only a small adjustment of the end clamps, it was decided to choose a drop which would produce about 50 percent greater filament excitation than was usually produced by the Arsenal tester, so that adequate mortality data might be secured in routine lamp testing within a shorter time. Accordingly, the cam drop was set at 0.062 inch.

As a trial mortality run, ten lamps with 50-watt filaments similar to the type 2416 were mounted and examined carefully after filament failures were secured. Not one showed evidence of excessive impact stresses such as sagging or filament distortion. All failures were typical of normal fatigue effects.

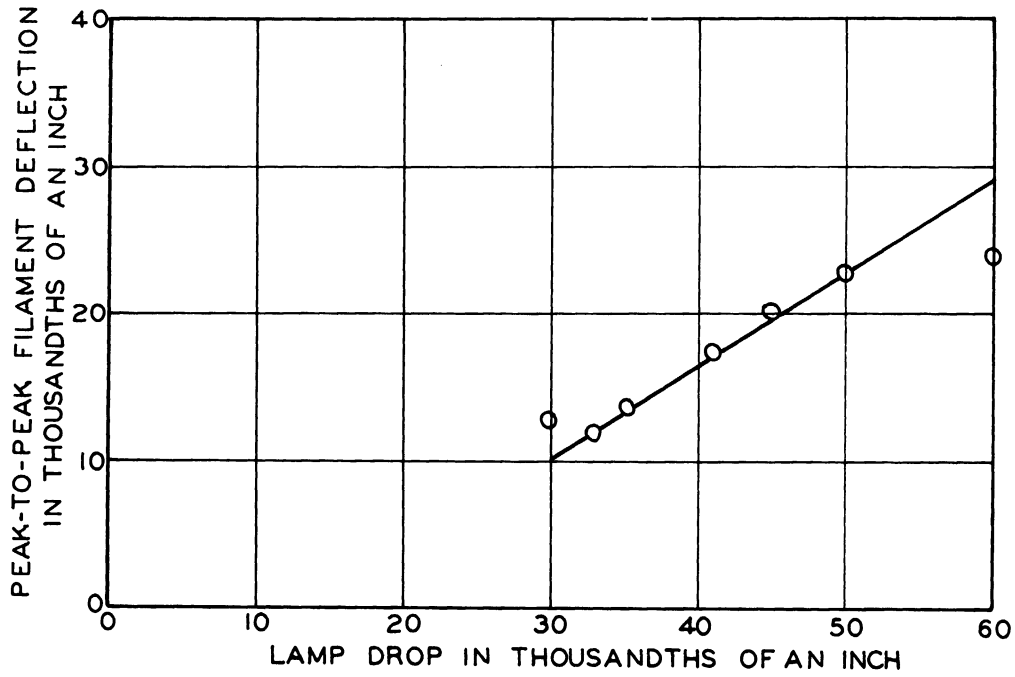


Fig. 10. Relationship of filament deflection and lamp drop for lamp No. 256 on the rotary-drum impact tester.

E. INITIAL EVALUATION TESTS

Only a small quantity of lamps suitable for evaluation tests was on hand when the assembly of the tester was completed. These were of three types:

Type	Base	Bulb
2416	3-lug	B-12
1265	Candelabra	RP-11
1253	Candelabra	G-6

The test procedure duplicated the mortality tests already performed on the Arsenal tester. For this evaluation both testers, the Arsenal and the rotary-drum, were operated simultaneously. The lamps were supplied from the same power source and controlled by the same timing device for on-and-off cycling. In general, equal numbers of lamps were mounted on each machine.

There were enough type 2416 lamps from the same factory batch to permit two test runs using the major filaments. Figure 11 shows the results of these runs. It is evident that the small drum tester produces a larger number of failures in a given time. There is a large and unexplained difference in the slope of the two pairs of runs.

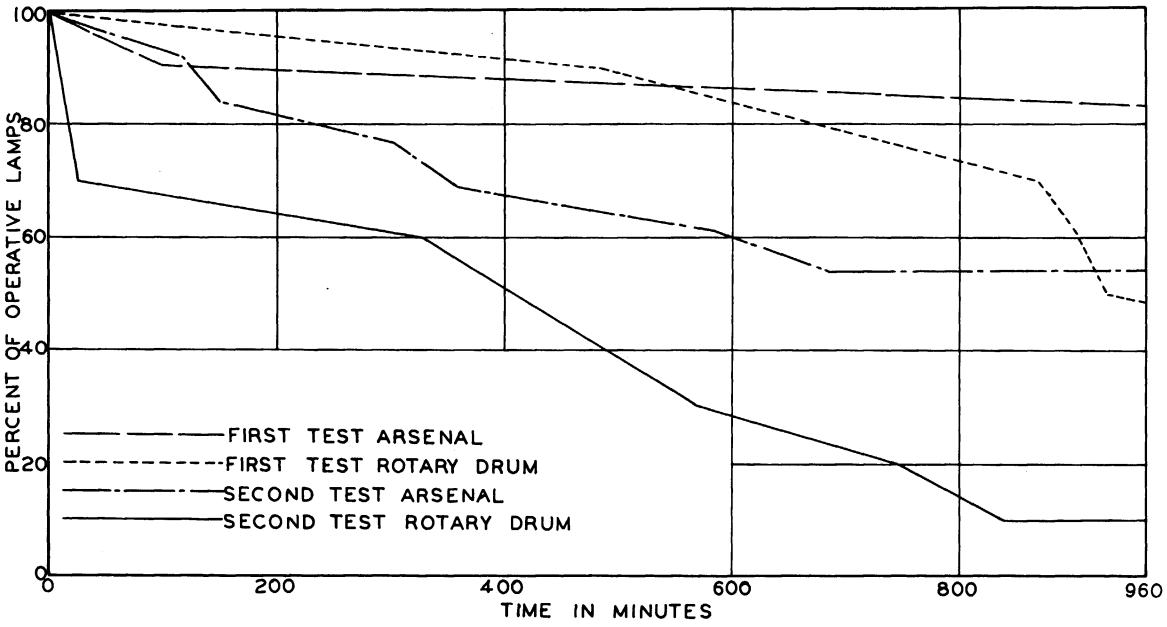


Fig. 11. Comparative tests of 2416 lamps (major filament).

Immediately after the termination of each test of the major filaments, the minor filaments were subjected to a similar test. The results are shown in Fig. 12. It will be noted that the curves obtained from two successive racks practically coincide in spite of the fact that the first rack was operated cold (during the test of the major filament) about 50 percent longer than the second rack.

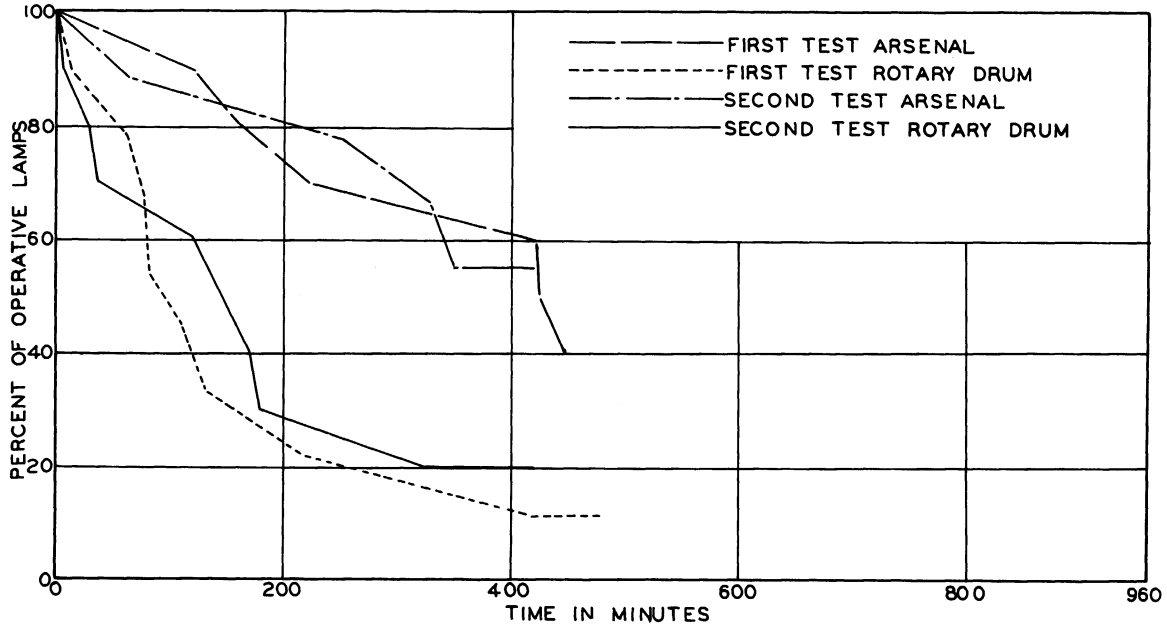


Fig. 12. Comparative tests of 2416 lamps (minor filament).

Figure 13 shows the results of tests on two more racks of type 2416 lamps (from a different manufacturer). Again it is evident that the small tester produces more rapid failures. There is close agreement between successive runs on each type of tester.

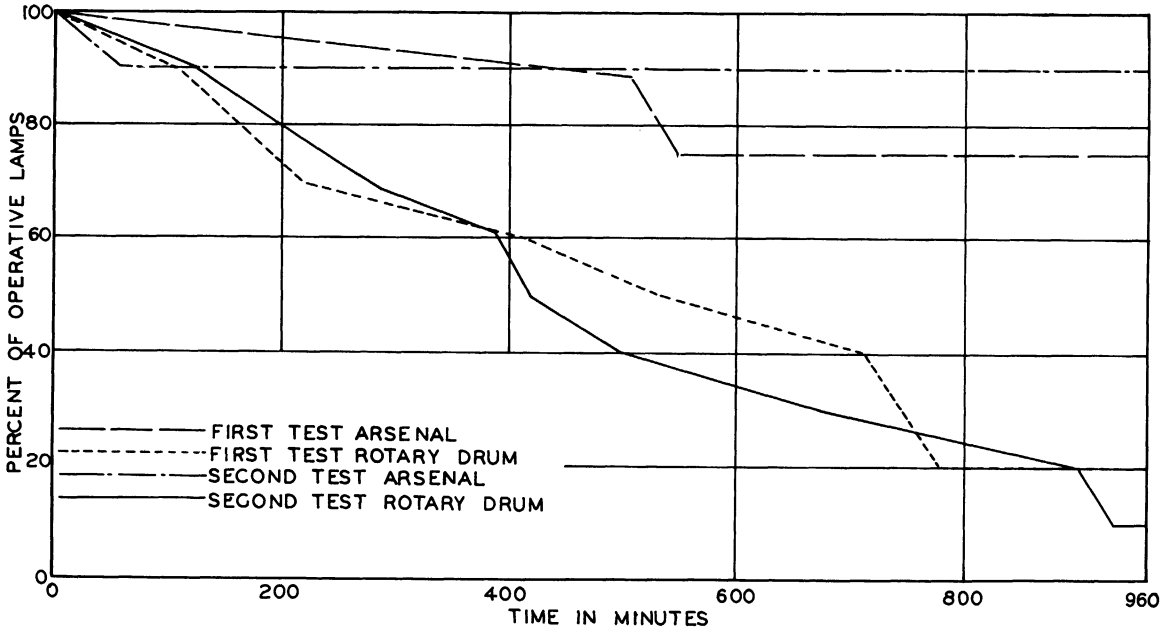


Fig. 13. Comparative tests of 2416 lamps (major filament).

Again the minor filaments were tested immediately following the completion of the major filament tests, with the results shown in Fig. 14.

Figure 15 shows the results obtained with a rack of type 1253 lamps. Here the small tester produced slightly less rapid failures than the Arsenal tester, but the two are in fairly close agreement throughout. There is some evidence that excessive friction at a few of the mounting pivots existed and may have affected the trend of the curve obtained on the small tester to some extent.

Figure 16 shows the results obtained from two tests of type 1265 lamps. Here, as with the type 1253 lamp, the rotary-drum tester produced fewer failures. It also can be noted that there is little agreement of test results for each machine. Again the mounting of the lamps on the rotary-drum tester may have had a definite influence on the results.

The number of lamps involved in all these tests is too small to permit any trustworthy conclusions to be drawn concerning the correlation that may exist between the performance of the two machines.

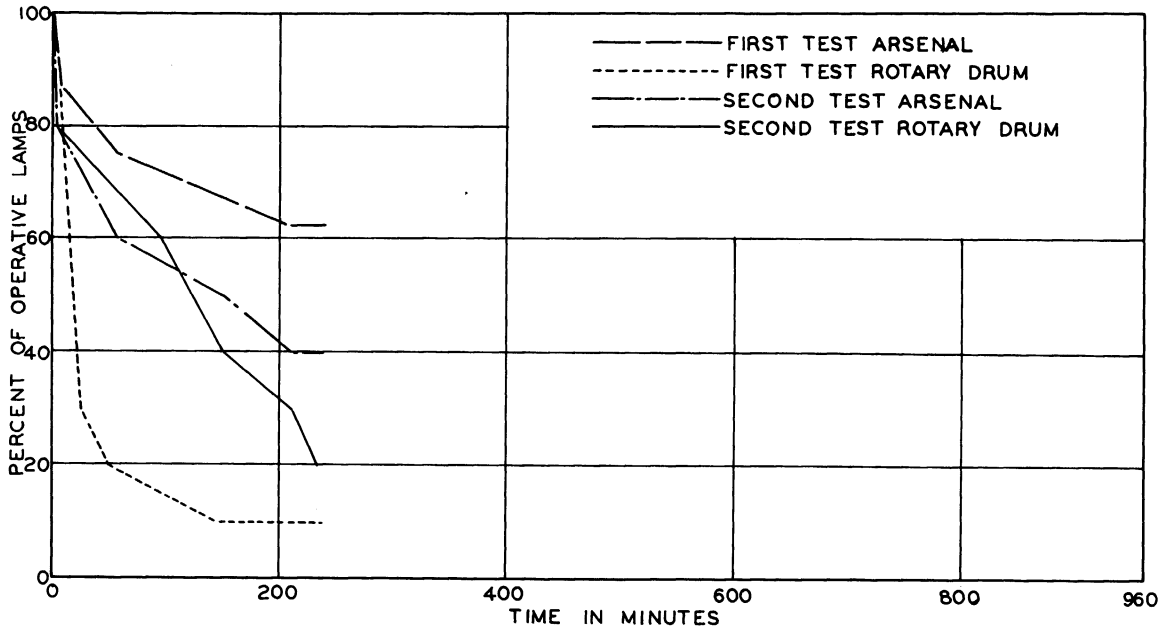


Fig. 14. Comparative tests of 2416 lamps (minor filament).

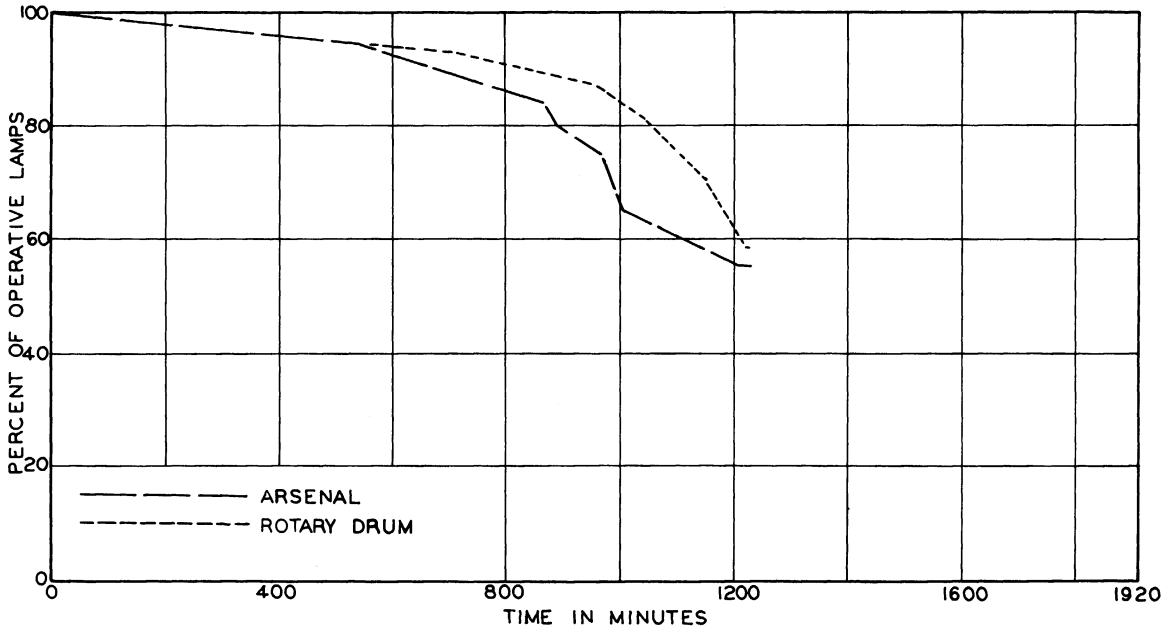


Fig. 15. Comparative tests of 1253 lamp.

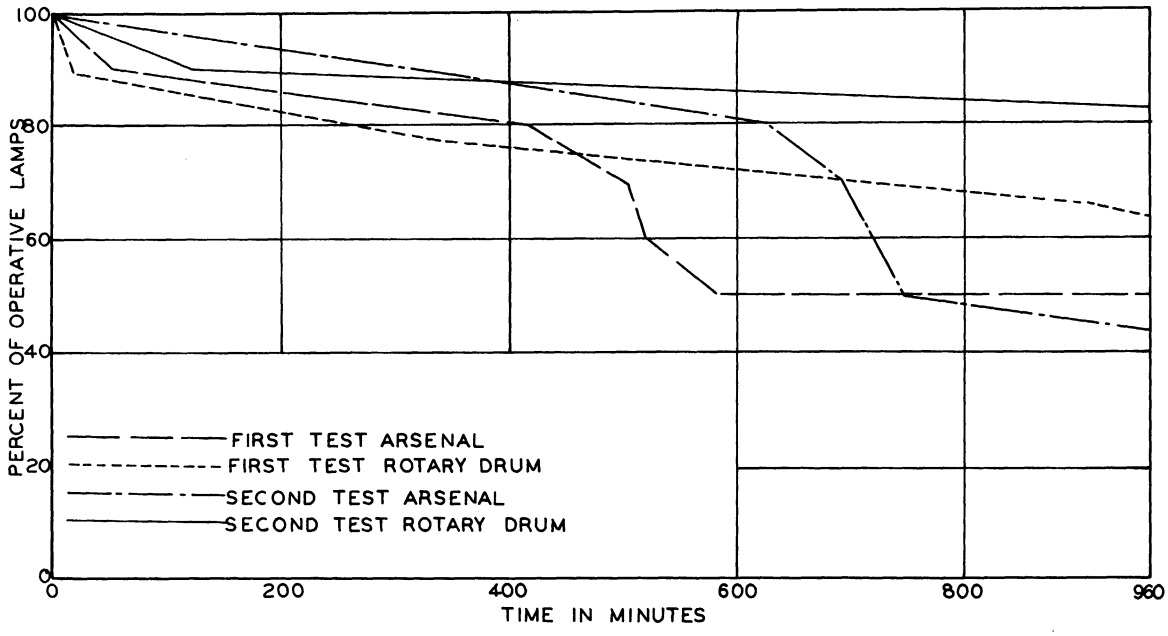


Fig. 16. Comparative tests of 1265 lamp.

F. POSSIBLE MODIFICATIONS

Several small operating difficulties have become evident as testing has proceeded. One problem has arisen in making electrical connections to the lamp. With the larger bulbs there is no particular difficulty, since the added mass of the flexible conductor would be insignificant. With the smaller bulbs, there is danger that the conductor will impose some restraint of a variable and unpredictable amount on the bulb's response to impact. Effort is being made to secure a lighter and more flexible conductor of sufficient current capacity.

The suspension of the three-terminal type of bulb has encountered the problem of finding a suitable nonconductive rod of small diameter that is strong and not affected by heat. Several of those already tried have proved unsatisfactory. More are on order and it is hoped that a practical solution for this difficulty will soon be reached.

Some difficulty has also been encountered in denting the base of the candelabra type of lamps to provide pivot points for insertion in the mounting clips. Dimensional differences between individual lamps in a test group, such as shell diameter and thickness of the metal in the shell, tend to introduce a variable pivot friction which in some cases has interfered with the free motion of the bulb. Experiments with punches of a variety of shapes and with other methods of mounting are continuing in an effort to eliminate this difficulty.

G. WORK IN PROSPECT

It is planned to start soon on correlation tests involving mortality data obtained on the drum tester and the Arsenal machine. Groups of identical lamps will be life-tested on both machines in sufficiently large number to permit tentative conclusions to be drawn concerning the reliability of data obtained on the new machine. If these tests show encouraging results, studies of further refinements in lamp mounting devices and in other components will be undertaken.


UNIVERSITY OF MICHIGAN
3 9015 02086 6318