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SHOT-PEENING TREATMENTS

John J. Bush, Royal Oak, Raymond L. Mattson, Bloomfield Hills, and James George Roberts, Warren, Mich., assignors to General Motors Corporation, Detroit, Mich., a corporation of Delaware

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This invention relates to the treatment of metal surfaces and more particularly to a method of increasing the fatigue life of metal parts.

Hammering or peening is well known to cause small, permanent surface deformations which contribute to an increase in strength and hardness of the metal of which the part is composed. In addition to hammering, it has previously been known to peen metal surfaces with small, hardened shot particles which impinge on the surface at a high velocity. Conventionally, shot-peening has been a single step process in which the surface of a metal part is subjected to a high velocity stream of shot in a given manner for a predetermined time. Heretofore, the shot-peening treatment ordinarily was applied as a single, continuous treatment rather than a series or plurality of shorter treatments of similar intensity. The plurality of treatments of similar intensity provided no material benefit in strength or hardness of the part treated over the benefits obtained from a single, continuous treatment.

However, we have now found that a plurality of shot-peening treatments can be used to materially increase the fatigue life of a metal part to a much greater degree than that ever accomplished by means of a conventional, single shot-peening treatment. We have unexpectedly found that by using a plurality of treatments in a specific manner we can increase the fatigue life of a metal part generally to at least twice the normal life obtained from a conventional shot-peening operation.

In accordance with our invention a metal surface is first shot-peened in a conventional manner and thereafter subjected to a secondary shot-peening treatment which differs from the first. We have found that when the secondary shot-peening treatment is of a lower intensity or it is accomplished with a smaller size shot than used in the initial treatment, material benefits can be obtained. Moreover, when both a lower intensity and a smaller shot size are used in the secondary treatment than was used in the first, unexpected substantial increases in fatigue life of the part are obtained.

Other advantages, objects and features of this invention will appear more clearly from the following description of a preferred embodiment thereof and from the drawings, in which:

FIGURE 1 shows a diagrammatic view of the essential steps involved in our invention;

FIGURE 2 shows a bar chart which compares the fatigue life of parts treated by the subject method with the fatigue life of parts which are conventionally peened;

FIGURE 3 is a Weibull plot of fatigue life of unpeened parts, conventionally peened parts, and parts treated in the subject manner;

FIGURE 4 is a Weibull plot comparing fatigue life of single and double peened specimens showing the effect of lowering the intensity of a second peening treatment; and

FIGURE 5 is a Weibull plot of fatigue life of single and double peened specimens showing the effect of reducing shot size in a second peening treatment.

Conventionally, shot-peening is practiced by imparting an impetus to the shot so that the shot will impinge on a given surface at a high velocity. In one method the shot is accelerated to the high velocity by means of a rapidly rotating wheel or impeller. The wheel has a central cavity into which the shot is introduced. Several

passages radially extend from the central cavity of the impeller to corresponding openings in the periphery of the wheel. The shot placed in the central cavity of the wheel passes through the passages of the rotating wheel where it is accelerated to a suitable velocity whereupon it is discharged from the openings on the circumferential perimeter of the wheel. The shot can be emitted from the wheel in the form of a single, unidirectional stream, if desired, by employing a control device in the central cavity of the wheel to regulate the point of entry of the shot into the wheel passages. The particular size of shot used, intensity of the shot blast, duration of peening, etc. are variable, and the preferred treatment to be used will depend upon the composition, hardness, configuration, etc. of the specific item being treated. However, typically a workpiece is conventionally treated in accordance with the methods and apparatus set forth in the SAE Manual on Shot-Peening, SP-84.

Conventional shot-peening is usually accomplished with hardened metal shot, such as cast steel shot, cut steel wire shot or cast iron shot having a mean diameter of from about 0.005 inch to about 0.13 inch, and in some instances a shot size as low as about 0.002 inch can be used. The duration of the shot-peening treatment is variable, depending upon the intensity employed and the coverage desired. For example, a heretofore satisfactory shot-peening treatment for hot-rolled SAE 5160 steel springs which are hardened and tempered to Rockwell "C" 48 hardness involves shot-peening to full visual coverage with SAE 70 chilled iron shot using an intensity of about a 0.0020C SAE intensity.

This invention comprehends subjecting previously shot-peened parts to a second shot-peening treatment which differs from the first. In order to obtain the substantial benefits of the two-step treatment, the second shot-peening treatment should be of an SAE intensity which is lower than that initially used or a smaller shot size should be employed. Although marked improvements in fatigue strength are obtained by singly varying either the shot size or the intensity of the secondary treatment, we have experienced the most significant success in obtaining increases in fatigue life when both the shot size and intensity are lowered in the secondary treatment.

The optimum intensity and shot size for each treatment, of course, is dependent upon the nature of the part being peened. However, we have experienced considerable success with our invention using an optimum, conventional shot-peening treatment for the first step and an SAE intensity and shot size which is approximately ⅕ to ⅓ that which is used in the initial treatment. The word "intensity" is used herein to describe the nature of a shot blast in accordance with the normal and accepted practice as described in the Society of Automotive Engineers 1956 Handbook. The term "intensity" therefore refers to the effect produced on a standard test specimen by a shot-peening treatment. The basis of measurement of "SAE intensity" is the measurement of the degree of curvature of an initially flat steel test strip after the test strip is subjected to a shot-peening treatment. The extent of this curvature on the standard test sample after full visual coverage serves as a measurement of the intensity of the blast. The degree of curvature or intensity depends upon the properties of the blast, e.g., velocity, size, shape, density, kind of material and hardness of the shot. Additionally, the curvature depends upon the properties of exposure to the blast, e.g., length of time, angle of impact and shot flow rate. Thus, varying shot blasts can be used to accomplish the same effect and are, therefore, designated as having similar intensities.

In practicing our invention we have found that, in general, any reduction in the intensity or shot size of the second treatment from the intensity of the initial, conventional peening treatment contributes to an increase in fatigue life of the metal part. The optimum intensity and shot size of the second treatment is primarily dependent upon the intensity of the first peening treatment and the nature of the material. However, it has been established that when the spring steel surface is initially shot-peened in a treatment of approximately 0.016A to approximately 0.034A SAE intensity, highly satisfactory increases in fatigue life can be obtained if the secondary treatment is of an SAE intensity of about 0.003A to about 0.011A (0.001C intensity=0.0035A intensity).

The nature of shot used to practice our invention in an economical, commercial manner is as pertinent as in conventional peening treatments. For example, this invention can be practiced using cut steel wire shot, conditioned cut steel wire shot, cast iron shot and cast steel shot.

Due to the difference in physical properties in various types of materials which may be treated in accordance with our invention, the individual responses of a number of different materials to a shot-peening treatment is quite variable. Moreover, similar materials may even exhibit varied responses to a shot-peening treatment due to differences in hardness and the like. Accordingly, it is difficult to establish an optimum treatment which will provide the most beneficial increases in fatigue life for all materials using our invention. This is particularly true with respect to the size of shot which is preferably employed in the first and second peening treatments. However, satisfactory results are obtainable when a metal part is initially shot-peened in the known and accepted manner for such treatments to provide optimum fatigue resistance and then shot-peened in a second treatment using a smaller shot size. We have found that the shot size for the second treatment generally is preferably approximately ⅓ to ⅕ the size of the shot used for the initial peening treatment. In general, satisfactory results are obtainable when spring steel, for example, is initially shot-peened using a shot having a mean diameter of about 0.023 inch to 0.066 inch and thereafter subjected to a second peening treatment in which the mean diameter of the shot is about 0.007 inch to 0.011 inch in size.

Serving as a specific example of the practice of our invention, leaf-spring specimens were formed of hot-rolled SAE 5160 spring steel. These specimens were finished to a rectangular configuration of 0.192 inch in thickness, 1.5 inch in width and 12 inches in length. The finished specimens were then hardened and tempered to a Rockwell "C" 48 hardness and then shot-peened in accordance with the invention. After the shot-peening treatment, each of the specimens was fatigue tested by subjecting the shot-peened side to a uniform bending tensile stress over the central six inches of length with a range of zero to 200,000 pounds per square inch at the surface in each cycle.

In the table immediately following, a number of such specimens were subjected to each of the treatments described.

FATIGUE TEST RESULTS

Group	Primary Treatment		Secondary Treatment		Mean Life [3]
	SAE Shot Size [1]	SAE Intensity [2]	SAE Shot Size	SAE Intensity	
A	230	0.0046C	70	0.0014C	479,000
B	660	0.0090C	70	0.0014C	384,000
C	110	0.0029C	70	0.0014C	272,000
D	70	0.0020C	----------	----------	207,000
E	110	0.0029C	----------	----------	141,000
F	230	0.0046C	----------	----------	115,000
G	660	0.0090C	----------	----------	82,000
H	110	0.0017C	660	0.0095C	57,000
J	(4)	(4)	(4)	(4)	22,400

[1] Chilled iron shot used.
[2] Commonly designated by deflection in thousandths of an inch of a standard strip.
[3] Number of bending cycles before complete rupture.
[4] No peening.

The above table further shows the relative differences in mean life produced by varying treatments which include a single peening and a double peening treatment in which larger shot and a larger intensity treatment are used in the second step.

We have also found that an increase in fatigue life is also obtained by grit blasting the surface of a previously shot-peened metal part. We have now also found that grit blasting can be used as a secondary treatment for conventionally shot peened parts. Major increases in fatigue life of metal parts can be produced by grit blasting a previously conventionally peened part. Although improvements in fatigue life are obtained in this manner, the overall results obtainable therewith are not as satisfactory as those obtained from the previously described method.

In general, we have found that an air blast carrying metallic particles having an average mean diameter of from about 0.003 inch to 0.017 inch or an SAE grit number of from about G–200 to about G–40 can be used. These particles can be directed onto the previously shot-peened surface with a conventional grit blasting apparatus, such as that commonly used in the art, employing an air pressure of approximately 70 pounds per square inch to approximately 80 pounds per square inch.

More specifically, a metal leaf-spring specimen generally similar to that previously described, was subjected to shot-peening treatments of an SAE intensity of approximately 0.009C to 0.011C using SAE 660 chilled iron shot. Following this shot-peening treatment the specimen was grit blasted with a conventional grit blasting apparatus with an SAE G–80 grit and an air pressure of approximately 70 pounds per square inch under an exposure of about 15 seconds. This treatment of the metal leaf-spring provided more than a 100% increase in the fatigue life of the leaf-spring specimen.

The beneficial results obtainable with our invention are more particularly indicated by the bar chart in FIGURE 2 and the graph shown in FIGURE 3. FIGURE 2, for example, compares fatigue life cycles of untreated metal parts, conventionally peened metal parts, and metal parts treated by the method of our invention. While untreated parts have a median fatigue life of less than 100,000 cycles, parts treated in accordance with our invention display a median fatigue life of over 350,000 cycles.

Although the chart of FIGURE 2 clearly indicates the large improvement in fatigue life resulting from the use of our invention, it is not entirely satisfactory. Of great interest are the probability of failure after testing for x stress cycles and the accuracy with which we can estimate probability.

Information concerning these points is obtained using satistical techniques previously described by Johnson ("The Median Ranks of Sample Values in Their Population with an Application to Certain Fatigue Studies," Leonard G. Johnson, Industrial Mathematics, vol. 2, 1951; "Fatigue Tests Proved by Three Statistical Checks," Leonard G. Johnson, SAE Journal, March 1958, pp. 72–73; "Statistical Estimation of the Minimum Life in Fatigue," Leonard G. Johnson, G.M. Research Laboratories Technical Memorandum 34–948, March 10, 1958; Statistics of Extremes, E. J. Gumbel, Columbia University Press, 1958, p. 302). Briefly information was found on the above points from Weibull plots and 90% confidence bands, respectively. A Weibull distribution function is of the form

$$F(x)=1-e^{-\left(\frac{x-a}{\theta-a}\right)^b}$$

where

$F(x)$=percent failure in population occurring at some fatigue life, $x (x>a)$
a=minimum fatigue life ($a \geqq 0$)
b=Weibull slope ($b>0$)
θ=characteristic life

The minimum fatigue life (*a*) and the median population curves used in the Weibull plots of FIGURES 3 through 5 are those that best fit the observed fatigue lives. Goodness-of-fit numbers given in FIGURES 3 through 5 are an index to the fit, with a goodness-of-fit number=1 describing a condition wherein all $(x-a)$ quantities fall on a straight line. The slope (*b*) of the best fit straight line is known, as is the characteristic life θ, and the Weibull median population line is completely determined.

FIGURE 3 is a Weibull plot comparing the fatigue lives of the test groups noted in Table I. With percent failure in population,

$$\left(\frac{100}{1-F(x)}\right)$$

as ordinate and life cycles (*x*) as abscissa, the Weibull plots in FIGURES 3, 4 and 5 clearly illustrate the increase in life at different survival levels by our invention.

Table I

Test Group	Goodness-of-Fit	(*a*) Cycles	(*b*) Slope	Median Life
Non-Peened	0.99500	0	7.76	22,720
Single Peened: SAE 660 at 0.0090C	0.98191	40,000	2.27	80,730
Double Peened: SAE 660 at 0.0090C; SAE 70 at 0.0014C	0.98841	200,000	1.82	372,000

A Weibull plot of the test groups listed in Table II is shown in FIGURE 4. This graph indicates that merely lowering the intensity of the secondary treatment serves to increase median life.

Table II

Test Group	Goodness-of-Fit	(*a*) Cycles	(*b*) Slope	Median Life
Single Peened: SAE 660 at 0.0090C	0.98191	40,000	2.27	80,730
Double Peened: SAE 660 at 0.0090C; SAE 660 at 0.0016C	0.97183	20,000	5.42	121,000

The Weibull plot in FIGURE 5 is a graph comparing fatigue lives of the test groups listed in Table III. This Weibull plot shows that by solely reducing shot size in the secondary peening treatment, material benefits can be obtained.

Table III

Test Group	Goodness-of-Fit	(*a*) Cycles	(*b*) Slope	Median Life
Single Peened: SAE 660 at 0.0073A	0.82292	0	3.32	135,400
Double Peened: SAE 660 at 0.0072A; SAE 70 at 0.0070A	0.96017	100,000	1.06	149,300

The 90% confidence bands, also shown on the Weibull plots of FIGURES 3 through 5, estimate the boundaries which enclose the middle 90% of all fatigue lives. Confidence interpolation indicates that the median life at 1% or 50% failure in population level is significantly improved over a single (conventional) shot-peening treatment by:

(1) Secondary peening by using smaller shot and lower intensity than used for the primary shot-peening treatment.

(2) Secondary peening by using reduced intensity for secondary peening alone.

(3) Secondary peening by using smaller shot size fcr secondary peening alone.

Specification of shot size and intensity for the secondary shot-peening treatment to produce greatest fatigue life

is difficult because of the paucity of systematic fatigue data. Nonetheless, some boundaries appear rather clearly. For optimum results on spring steels, for example, the primary shot size should be between 0.023 inch to 0.066 inch in diameter and the intensity should be between 0.016A to 0.034A, the secondary shot size should be between 0.007 inch to 0.011 inch in diameter, and the intensity between 0.003A to 0.011A.

It is to be understood that although this invention has been described in connection with certain specific examples thereof, no limitation is intended thereby except as defined in the appended claims.

We claim:

1. A method of increasing the fatigue life of a metal part which comprises applying an initial particle blast treatment to a surface of a metal part and thereafter further subjecting said surface to another particle blast of a lesser intensity and smaller particle size than was employed in said initial particle blast treatment.

2. A method of increasing the fatigue life of a metal part which comprises applying an initial particle blast treatment to a surface of a metal part and thereafter further subjecting said surface to another particle blast of an intensity and particle size which is approximately ⅓ to ⅕ that employed in the initial particle blast treatment.

3. A method of increasing the fatigue life of a metal part which comprises applying an initial shot-peening treatment to a surface of a metal part and thereafter further shot-peening said surface with a treatment involving a lower intensity and smaller shot size than was employed in said initial shot-peening treatment.

4. A method of increasing the fatigue life of a metal part which comprises applying a particle blast treatment to a surface of a metal part and thereafter further subjecting said surface to a particle blast having a lesser intensity than the intensity of said former particle blast treatment.

5. A method of increasing the fatigue life of a metal part which comprises applying a particle blast treatment to a surface of a metal part and thereafter further subjecting said surface to a particle blast treatment having an intensity which is approximately ⅓ to ⅕ the intensity of said former particle blast treatment.

6. A method of increasing the fatigue life of a metal part which comprises applying a particle blast treatment to a surface of a metal part and thereafter subjecting said surface to another particle blast treatment having an intensity of approximately ⅓ to ⅕ that of said former particle blast treatment and in which particles are used which are approximately ⅓ the size of those used in said former particle blast treatment.

7. The method of increasing the fatigue life of a metal part which comprises conditioning the surface of a metal part by inducing a compressive stress thereon with an initial shot-peening treatment and thereafter further conditioning said surface with a shot-peening treatment having an intensity which is lesser than that of said initial shot-peening treatment

8. The method of increasing the fatigue life of a metal part which comprises conditioning the surface of a metal part by inducing a compressive stress thereon by an initial shot-peening treatment and thereafter further conditioning said surface with a shot-peening treatment using a shot size which is smaller than that employed in said initial shot-peening treatment.

9. The method of increasing the fatigue life of a metal part which comprises conditioning a surface of a metal part by inducing a compressive stress thereon with a shot blast treatment and thereafter further conditioning said surface with a shot blast treatment having an intensity of approximately ⅓ to ⅕ that of said former shot blast treatment.

10. The method of increasing the fatigue life of a metal part which comprises conditioning a surface of a

metal part by inducing a compressive stress thereon with a shot blast treatment and thereafter further conditioning said surface with a shot blast treatment having an intensity of approximately ⅓ that of said former shot blast treatment and in which the shot used is approximately ⅓ to ⅕ the size of that used in said former shot blast treatment.

11. The method of increasing the fatigue life of a metal part which comprises shot peening a metal surface with a blast of shot from the class consisting of cut wire shot, conditioned cut wire shot, cast iron shot and cast steel shot and thereafter further shot peening said surface with a blast of shot from the class consisting of cut wire shot, conditioned cut wire shot, cast iron shot and cast steel shot, wherein said latter shot blast treatment is of an intensity of approximately ⅓ to ⅕ that of said former shot blast treatment and the shot used therein is approximately ⅓ to ⅕ the size of that used in said former shot blast treatment.

12. The method of increasing the fatigue life of a metal part which comprises shot-peening a surface of a metal part with a blast of shot from the class consisting of cut wire shot, conditioned cut wire shot, cast iron shot and cast steel shot, wherein the intensity of said shot-peening treatment is about 0.016A to 0.034A and the mean diameter of shot used is about 0.023 inch to about 0.066 inch, and thereafter further shot-peening said surface with a blast of shot from the class consisting of cut wire shot, conditioned cut wire shot, cast iron shot and cast steel shot in which said further shot-peening treatment is of an intensity of about 0.003A to about 0.011A and the mean diameter of shot used is about 0.007 inch to 0.011 inch.

13. The method of increasing the fatigue life of a metal part which comprises shot-peening the surface of a spring steel part with shot having a mean diameter of about 0.023 inch to about 0.066 inch, wherein said shot-peening treatment is of an intensity of about 0.016A to 0.034A, and thereafter further shot peening said surface with shot having a mean diameter of about 0.007 inch to 0.011 inch, wherein said shot-peening treatment is of an intensity of about 0.003A to 0.011A.

14. The method of increasing the fatigue life of metal parts which comprises shot-peening the surface of a metal part and thereafter grit blasting said surface of said metal part.

15. The method of increasing the fatigue life of a metal part which comprises shot-peening a surface of a metal part to approximately 100% coverage and subsequently grit blasting said surface with grit having a mean diameter of approximately 0.003 inch to 0.017 inch.

16. The method of increasing the fatigue life of metal parts which comprises shot-peening a surface of a spring steel part with shot from the class consisting of cut wire shot, conditioned cut wire shot, cast iron shot and cast steel shot having a mean diameter of about 0.023 inch to 0.066 inch, wherein said shot-peening treatment is of an intensity of about 0.016A to 0.034A, and thereafter grit blasting said surface of a metal part with grit having a mean diameter of approximately 0.003 inch to 0.017 inch.

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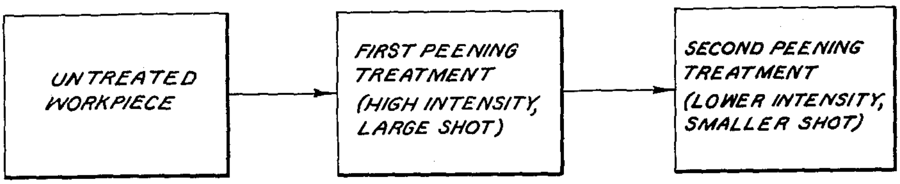

Fig. 1

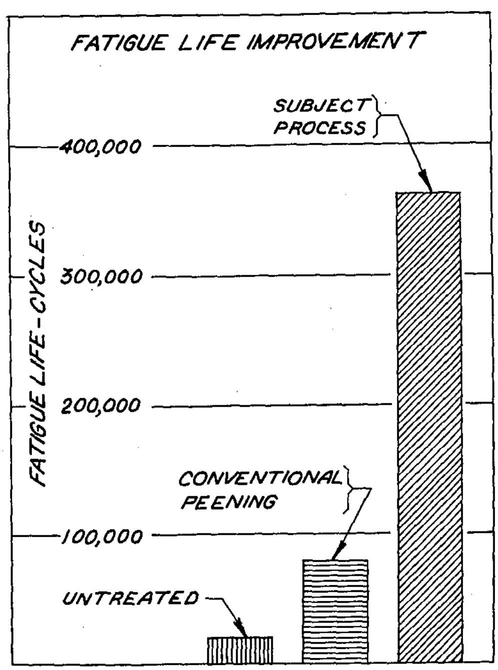

Fig. 2

INVENTORS
John J. Bush,
BY Raymond L. Mattson &
J. George Roberts
J. M. Shamko
ATTORNEY

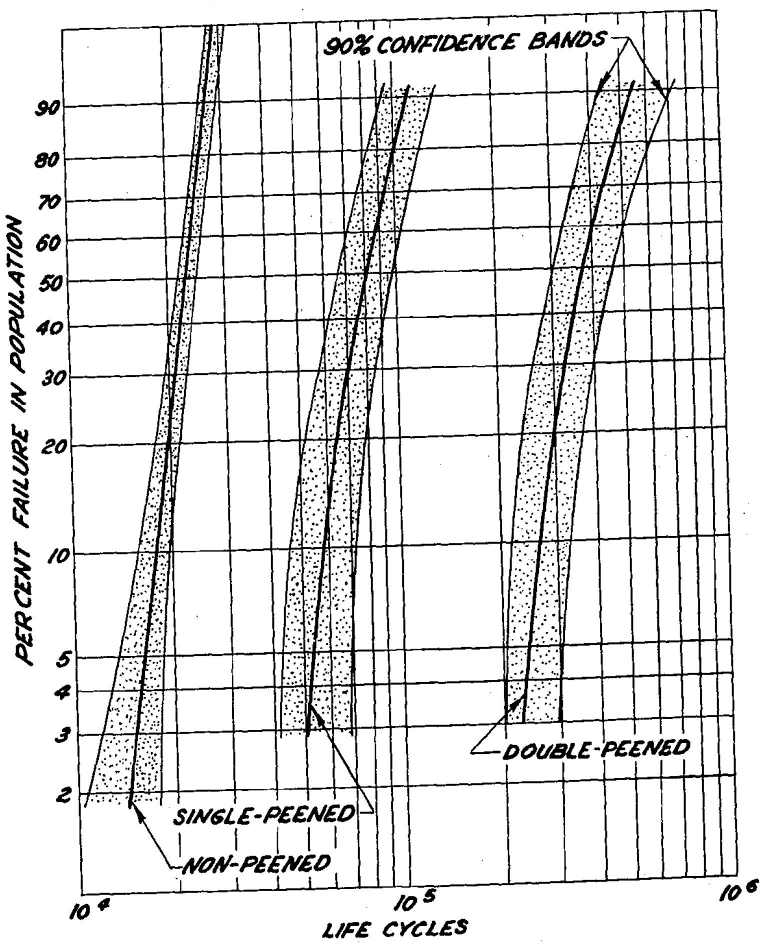

Fig. 3

INVENTORS
John J. Bush,
Raymond L. Mattson &
J. George Roberts
BY
J. M. Shamko
ATTORNEY

SHOT-PEENING TREATMENTS

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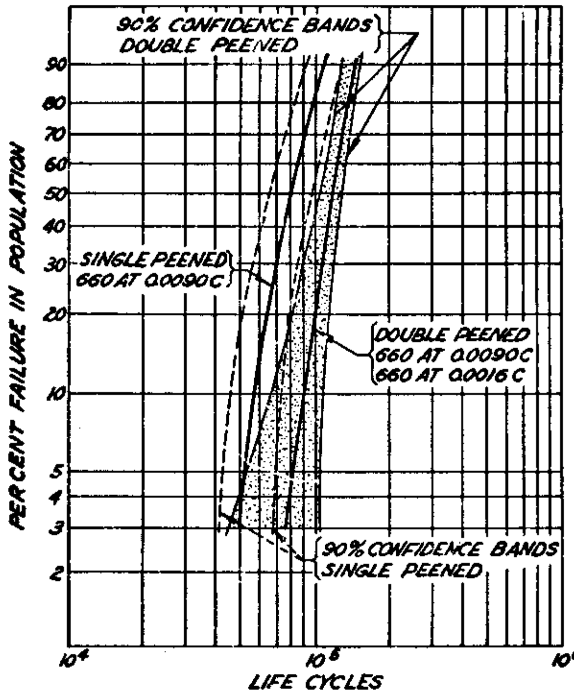

Fig. 4

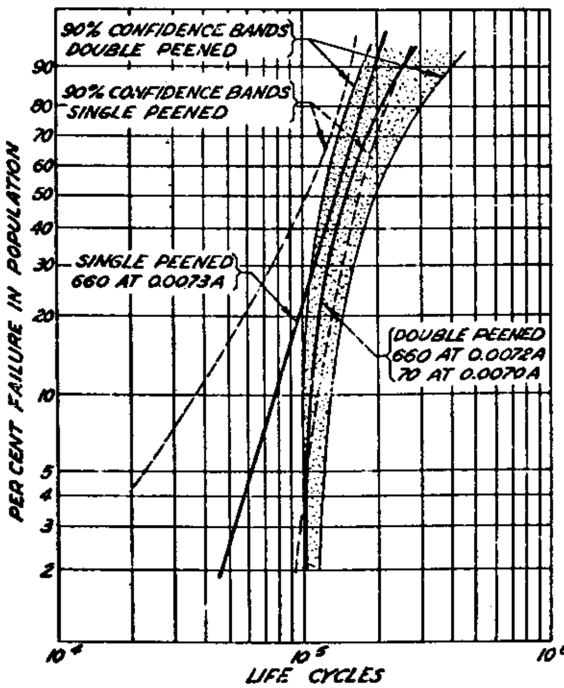

Fig. 5

INVENTORS
John J. Bush,
Raymond L. Mattson &
J. George Roberts
BY G. M. Shanko
ATTORNEY