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49004

New CUT-WIRE

Big Boon

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EXPERIENCE with cut-wire shot for peening automotive chassis springs reveals these advantages for the material:

1. Cut-wire shot is an ideal peening material from the standpoint of uniformity of physical properties, size maintenance, and life.

2. It is available in many sizes and can be purchased in production quantities from different sources.

3. It improves the peening operation both in quality and cost.

4. Better methods for manufacture of the cut-wire shot should result in better quality and lower cost.

5. The introduction of cut-wire shot is certainly one of the greatest improvements that has been made in shot peening. It decreases considerably many of the objections to shot peening. It allows greater control of the process. It should result in a new attitude toward peening and probably will make possible many new applications.

6. It is possible that with improved equipment additional changes in the chemical analysis and physical properties of cut-wire shot will allow a further improvement in shot peening costs.

Cut-Wire Shot Described

Cut-wire shot is made from MB hard-drawn mechanical spring wire. This wire is drawn to controlled physical properties and is the stage in wire-making just prior to oil tempering or annealing. The chemical analysis of this material will vary with the wire size. This chemical analysis is as follows:

Carbon	0.45/0.70
Manganese	0.60/1.20
Phosphorus	0.045 max.
Sulfur	0.050 max.
Silicon	0.10/0.30

The shot is made by cutting the wire into lengths which are equal to the diameter. Up until the present time most of the experience has been shot made from 20 gage (0.0348 in. ± 0.001) wire, although larger and smaller sizes are available. The experience has also been confined to the hard drawn type of wire, although the wire is available in the annealed or oil tempered condition.

The wire is purchased on tensile strength and we specify 261,000 to 301,000 psi. Although the wire cannot be purchased to a hardness specification, our experience has been that the hardness is uniformly between 45 and 50 Rockwell C.

As supplied, the shot has sharp edges which make the new material quite abrasive. With new applications it is necessary to use a break-in period to remove the sharp edges. The cut-wire in our first application was blasted against scrap in the peening machine for 4 hr before starting production. In additional applications we have diluted the new shot with used cut-wire shot from the first applications. The necessary day-to-day additions of new shot are very small and cause no particular difficulty. For jobs where there might be more severe surface requirements, such as peening aircraft parts, it might be desirable to buy conditioned shot.

In use, the cut-wire shot deforms into a spherical shape of uniform size. Its value for peening lies in the fact that it can be purchased in a uniform size with controlled physical properties, it maintains size during use, and has remarkable life.

For comparison, Fig. 1 shows new S330 chilled cast-iron shot and new cut-wire shot.

Test Description

The coil suspension spring peening application was selected for the initial tests on cut-wire shot because this was Buick's major shot peening application and very complete shot usage and maintenance costs were available over several years' experience with chilled cast-iron shot. Table 1 gives the operating conditions for both chilled cast iron and the cut-wire test.

As shown in Table 1, changes were made in the operating conditions to accommodate the cut-wire shot. The wheel speed was reduced from 2000 rpm to 1775 rpm because of the increase in the average size of the peening particles. With the lower wheel

SHOT to Peening

Peening automotive chassis springs with cut-wire shot has improved quality and lowered costs, says Miller in this article, based on a paper he presented at a recent meeting of the SAE Shot Peening Division, of the SAE Iron & Steel Technical Committee.

He notes that peening has been a costly and comparatively uncontrollable operation because of excessive peening shot usage, short shot life, formation of grit which prevents control and makes for high maintenance costs, and lack of size uniformity and quality of shot as furnished.

Results of tests with shot made from hard drawn wire, detailed here by Miller, indicate that the new material overcomes these drawbacks.

speed and larger size of the peening particles, it was found necessary to force-feed the shot into the wheel by means of an air jet. The air jet idea was worked out by Chevrolet Gear and Axle; by its use the pounds of shot per minute delivered to the wheel were increased from 145 to 300.

Before the test was begun, the machine was reconditioned and the chilled cast-iron shot was removed from the system. It has never been practical to remove every last trace of peening shot from a peening machine for this type of test and there was a slight carry-over of chilled cast-iron shot in the cut-wire shot test.

To maintain records, a form was furnished to the shop to record information on operating conditions and control. These forms were completed daily, and were in addition to records kept by the production department.

At the start of the test, 1500 lb of cut-wire shot were added to the equipment described in Table 1. Scrap was placed in under the wheels and the machine was operated for 4 hr without conveyor travel to round the sharp edges of the shot. After this break-in period, production was begun. Because it was necessary to add additional shot to fill the cavities of the machine, it was decided to mark the beginning of the test when the quantity of shot added to the machine represented only usage. This condition was reached in seven days. During this seven-day period, the shot was rounding although the springs showed a good surface from the beginning.

Arc heights, Faxfilm impressions of the peened surfaces, and shot samples were taken periodically in addition to the normal control of the operation. This test was continued for 65 two-shift days, when the machine was shut down for overhauling.

Shot Behavior in Breakdown

As a part of the investigation of cut-wire shot, it was considered desirable to determine what pattern was followed in the breakdown during use. Extensive sampling during the first part of the test furnished samples that show the method of rounding. Samples taken periodically during the test show the tendency to maintain a uniform size. The photographs in Fig. 2 illustrate the progressive cold working of cut-wire shot.

The new material, as shown in Fig. 2A, is added to the peening machine. In this stage the particles are quite uniform in size. The wire gage is within a ± 0.001 in. tolerance. Judging from experience to date, it appears that the length of the particles can be maintained well within ± 0.0035 in., the figure used in the Buick specification for cut-wire shot.

As received, the material has sharp edges which will abrade the work and machine in an undesirable manner if the new shot is added in large quantities.

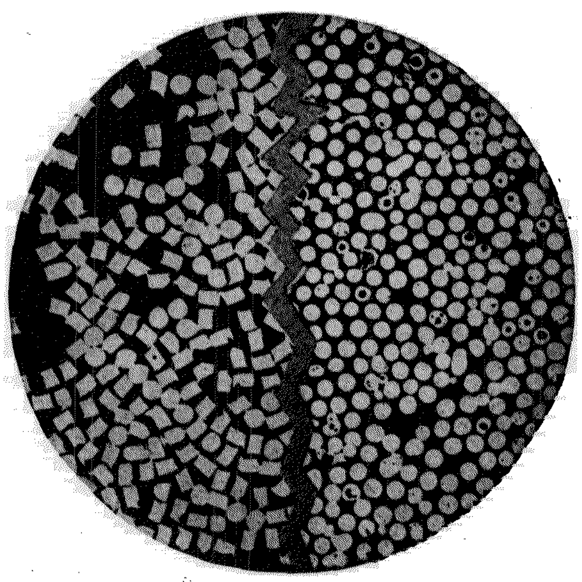


Fig. 1—A sample of new cut-wire shot, 0.035 in. (left) compared with new chilled cast-iron shot, size S330. Both are magnified three times

Table 1—Operating Conditions for Shot Peening Tests

Material	
Coil Spring Material	SAE 9260
Material Size	Varying with application (0.568–0.725-in. diameter)
Sequence of Processing	Heat in walking hearth furnace—Coil—Fixture Quench—Temper—Shot Peen—Load Test (Breakdown solid, compress to specified length and measure load.)
Average Hardness of Coil Spring	51 Rockwell C
Weights of Coil Springs	9 to 13.5 lb (approximate)
Equipment	
Type of Peening Equipment	American Wheelabrator Equipment Corporation
Production	450 springs/hr/machine
Number of Wheels	2
Diameter of Wheels	19½ in.
Width of Wheels	1⅝ in.
Distance of Wheels from Nearest Surface of work	15 in.
Work Rotation	54 rpm
Conveyor Speed	17.14 fpm

Peening Shot	Chilled Cast Iron	Cut Wire
Size of Shot Added	230 and 330 (approximately 50% of each)	0.035-in. diameter × 0.035-in. long
Shot Flow	145 lb per min	300 lb per min
Wheel Speed	2000 rpm	1775 rpm
Shot Consumption/Spring	0.134 lb	0.013 lb
Arc Height	0.0155A2 average	0.0166A2 average

To take care of this difficulty, the shot must be conditioned on new applications before production is started. Fig. 2B shows what happens to the shot during a 4-hr conditioning period. The remaining photographs in Fig. 2 show the progressive rounding of the shot by hours up to 14½ hr and show the condition at 7, 28, and 68 days.

These photographs were taken of unscreened samples which were secured from material being delivered to the wheel of the peening machine. An effort was made to clean the machine of all chilled cast iron before the test was begun, but note the presence of chilled cast iron in Figs. 2B, 2C, and 2D. Chilled cast-iron grit in small quantities was found in shot samples very late in the test.

To determine what happened to the cut-wire shot in breakdown, a sample was screened and the material retained on each screen was mounted, polished to expose the cross-section, and photographed. These photographs are shown in Fig. 3. At first it appeared that the cut-wire shot developed hollow centers as it wore to smaller sizes and the shot resembles hollow chilled cast-iron shot. A closer examination, however, explains this phenomenon.

A micro-examination of the shot in Fig. 3 shows that the shot retained on the 0.033-in. screen, Fig. 3A, has been cold worked to a depth of 0.002 to 0.003 in. below the surface. This material does not show the presence of "hollow" shot. The shot taken off the 0.0197-in. screen has received considerably more cold work. Sections cut through the center of this shot show cold work extending from the surface to the center.

Other shot from this group is ragged and torn at the edges, with voids in the center which give the appearance that the centers pulled out. It is apparent upon closer examination that these hollows are caused by the edges of the broken particles peening over in a secondary rounding. On looking at a plane through this peened-over section in which the sample was polished, it appears that shot is actually hollow at the center, but the hollow is very shallow.

Fig. 4, which is a photograph of the shot used for the cross-section in Fig. 3C, clarifies this explanation further. The peened-over edges can be seen very clearly in many of the particles.

The shot taken from the pan, Fig. 3G, is very heavily cold worked and is either very irregular in shape or appears like splinters that have chipped off as the shot was wearing down. This sample contained a considerable amount of chilled cast-iron grit.

Figs. 5A and 5B show etched cross-sections of cut-wire shot in two stages of cold work. The rounding

A — New cut wire as added to machine

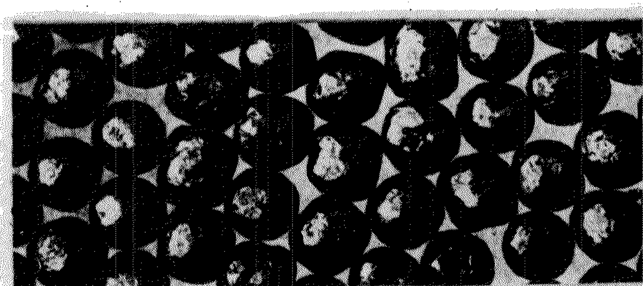
B — After the 4-hr conditioning period, during which the shot was thrown against scrap to remove sharp edges

C — After 5½ hr, which includes 1½ hr on peening springs

D — After 6½ hr, including 2½ hr on springs

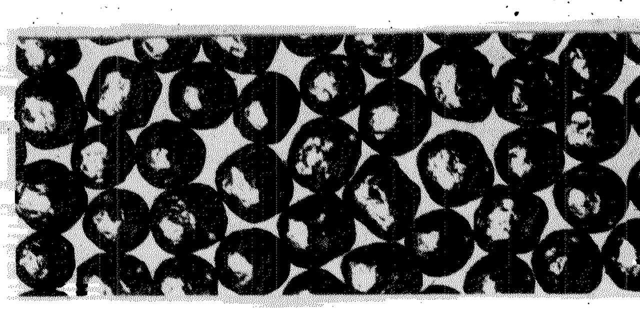
E — After 11½ hr, including 7½ hr on springs

F — After 14½ hr, including 10½ hr on springs



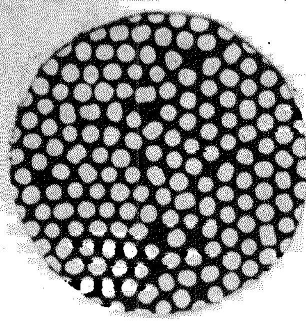
G — After seven days

H — After 28 days

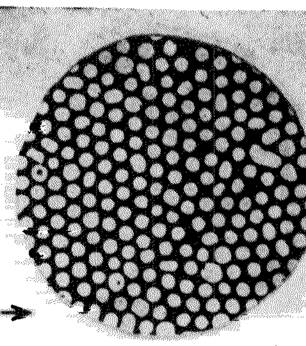


I — After 68 days

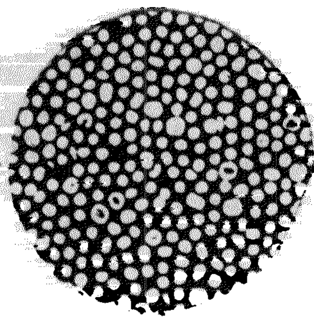
Fig. 2—These photographs—ten-time magnifications—show progressive cold working of cut-wire shot. Before putting fresh, unused cut-wire shot to work, it must be conditioned for about 4 hr to remove its sharp edges, if added in large quantities. Continued use after that, as these photographs show, progressively rounds the shot



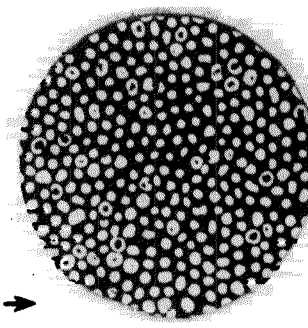
A — 87% retained on 0.0331-in. screen



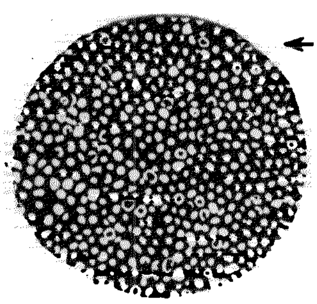
B — Through 0.0331-in. on 0.0280-in. screen — 8.3%



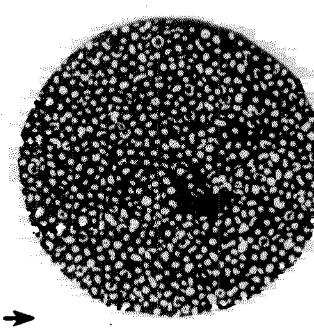
C — Through 0.0280-in. on 0.0232-in. screen — 3.0%



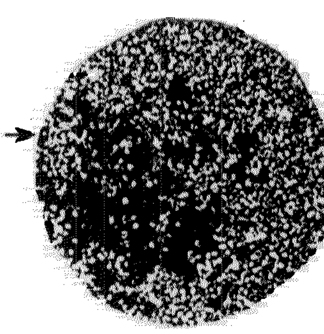
D — Through 0.0232-in. on 0.0197-in. screen — 1.4%



E — Through 0.0197-in. on 0.0165-in. screen — 0.2%



F — Through 0.165-in. on 0.0098-in. screen — 0.1%



G — Through 0.0098-in. screen — less than 0.1%

Fig. 3—Screen analysis of used cut-wire shot, magnified three times, showing unetched cross-sections. While some of the shot seems to have developed hollow centers, this appearance is explained by Fig. 4

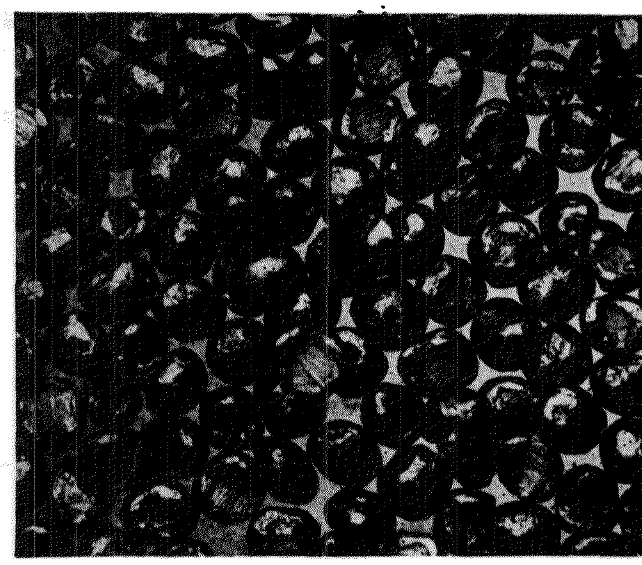


Fig. 4—This is a photograph of shot from Fig. 3C, magnified 10 times. The edges of broken particles, peened over in a secondary rounding, shown here, account for the "hollow" shot in Fig. 3

of the shot is apparently a combination of cold deformation and breaking off of the cold-worked edges. Fractures in the shot start at the surface and the shot breaks in the direction of the grain flow lines. We have not been able to find internal ruptures in the cold-worked shot.

Although the surface hardness of the shot may be increased in hardness considerably by use, we have found no method of determining what the increase might be. However, hardnesses taken on the cross-section of the used shot have shown no more than a one point Rockwell C increase. The method and control of cutting wire shot will undoubtedly have an influence upon the performance. An effort will have to be made by the manufacturer to cut the shot with a minimum amount of deformation and without the formation of shear cracks.

It is our practice to life-test a sample from each shipment and we believe that such a test should become a part of a specification for cut-wire shot.

Test Results

Before shot peening was used, the Buick coil chassis springs were made from four-pass ground bars. This amount of grinding was believed necessary to eliminate surface defects. The fatigue life averaged less than 100,000 cycles. With the introduction of shot peening it was found possible to use one-pass ground bars. In addition to the reduction in the amount of grinding necessary, it was also possible to reduce the amount of material in the spring. The fatigue life increased to an average life of slightly less than 500,000 cycles using chilled cast-iron shot.

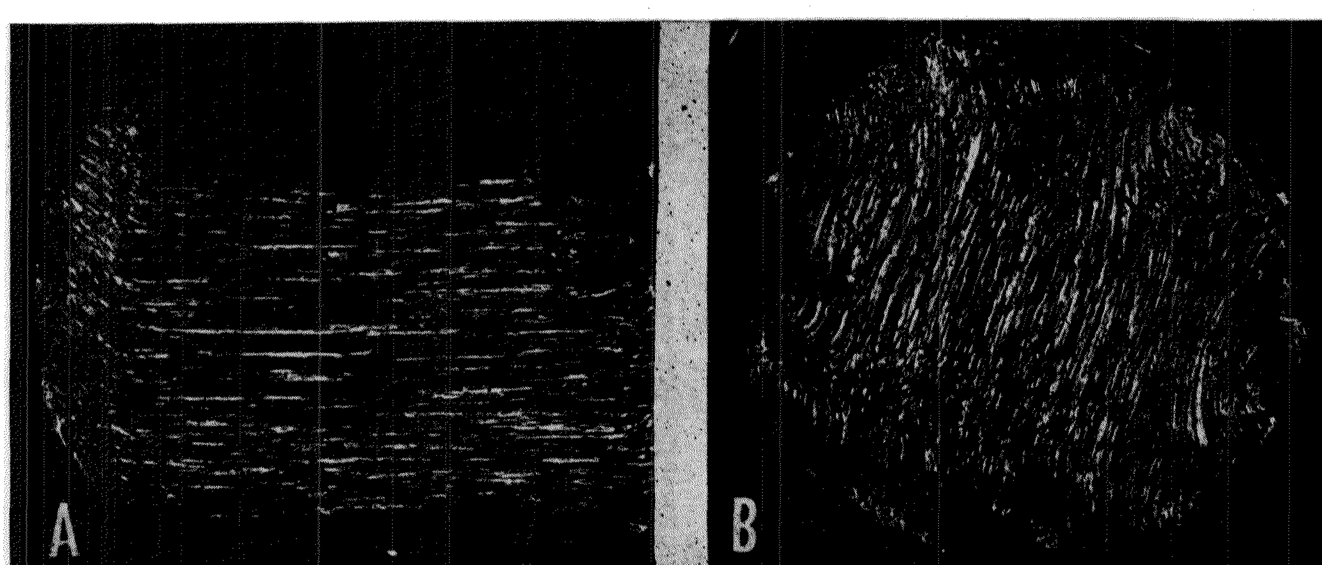
With cut-wire shot and the conditions as outlined, the fatigue life has been increased to a life in excess of 1,000,000 cycles. Our tests are discontinued at 1,000,000 cycles when no breakage occurs. With this improvement in life it may be possible to make further savings in processing costs.

The extent to which a surface is covered with shot impressions or coverage has a bearing on the quality of the peening job. But the extent to which a peened surface is covered with impressions does not necessarily indicate the amount of compressive stress introduced.

In the past, even with the use of separators, a considerable variation in the size of the peening material was encountered. This variation ranged from control of the size as purchased, by means of separators, to no control other than by dust collector. In the latter case visible coverage is better, but the peening job is probably not as good.

The ideal situation is probably to have 100% coverage with a shot of uniform size. However, if satisfactory minimum fatigue life can be obtained with a lesser coverage, it is a waste of money to specify the ideal condition. We do not peen for appearance, but to secure a satisfactory service life for

Fig. 5—These cross-sections of cut-wire shot, etched in 5% Nital, show cold working of the surface. They are magnified 100 times. "A" shows slightly used cut-wire shot, and that in "B" is used cut-wire shot



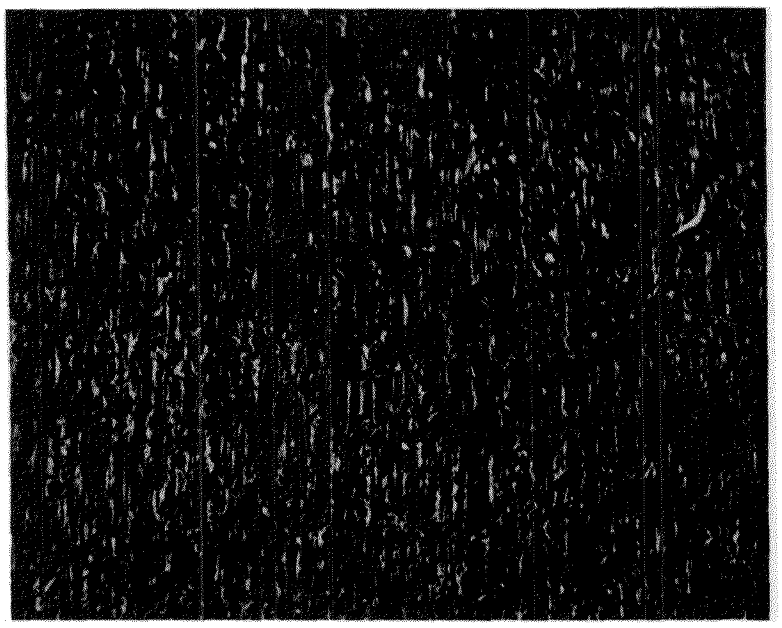


Fig. 6—Surface of a Buick coil spring peened with cut-wire shot, magnified 10 times

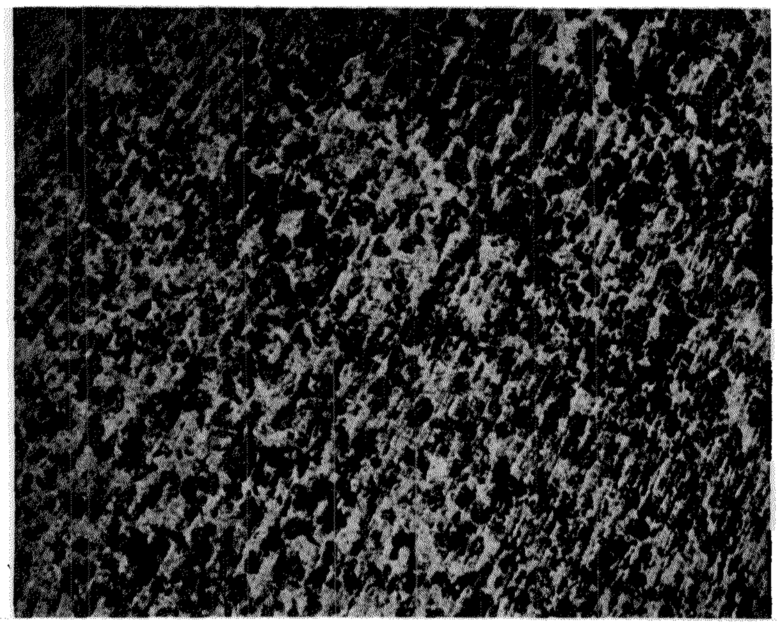


Fig. 7—Faxfilm impression of the same surface shown in Fig. 6 (a coil spring peened with cut-wire shot)

the part. Each application must be proved on its own set of operating conditions.

Because of the greater average size of the cut-wire shot it was necessary to increase the shot flow to secure coverage. Visible coverage is probably reduced from that obtained with chilled cast-iron shot because of the large percentage of small particles present. No attempt other than test has been made by Buick to use the shot separators either with chilled cast-iron shot or cut-wire shot. The percentage of fines using cut-wire shot is very small and we believe the dust collector is an adequate means for maintaining clean shot.

Fig. 6 shows a photograph of the surface of a Buick coil spring peened with cut-wire shot. Fig. 7 shows a Faxfilm impression of the same area.

Shot Usage

In this test, cut wire shot usage was approximately one-tenth of the usage experience with chilled cast-iron shot. A large percentage of shot is lost through waste during the peening operation. It is difficult to determine the percentage lost by wastage; but it can be seen from a comparison of the results found with shot testing machines with production results that shot losses must be a great percentage of the usage. Cut-wire shot will show an advantage of 250 to 300 to 1 over chilled cast iron shot in the test machine, but production experience shows an advantage of only about 10 to 1.

It is true that in a production machine the shot has many impacts per cycle but this cannot account for more than a small part of the difference in results. In peening coil chassis springs the carry-out losses are at a minimum; but despite efforts to stop leakage to the outside, there was considerable shot on top of the machine and on the floor in the immediate vicinity of the machine. This shot was returned to the machine as well as could be done practically. It is certain that much work must be

Table 2—Cost Comparison of Chilled Cast-Iron and Cut-Wire Shot for Peening Chassis Coil Springs

	Chilled Cast-Iron Shot	Cut-Wire Shot
Number of Springs Shot Peened*	1,000,000	1,000,000
Bags of Shot Used—100 lb per Bag	1342	131.97
Shot Cost per Ton†	$110.00	$400.00
Number of Springs per Pound of Shot	7.45	75.77
Shot Cost per Spring	$0.0073	$0.00255
Average Arc Height—Almen A2	0.0155 in.	0.0166 in.
Maintenance Labor	$687.74	$498.93
Maintenance Material	$2994.33	$1451.37
Maintenance Cost per Spring	$0.00366	$0.00195
Total Cost of Shot plus Maintenance per Spring	$0.01096	$0.00450

* The actual number of springs compared was 1,000,528 for the chilled cast-iron shot and 447,076 for the cut-wire shot. The comparison was made on the basis of 1,000,000 springs for ease in reading the table.

† This is not the current market price for either material, but represents costs at the time that the test was carried out.

done with peening equipment so that shot can be used to obtain the benefit of the longer life that is being developed.

A sample of the shot was taken daily from the machine for screen analysis. This sample was taken from shot being delivered to the wheel and was taken at the same time every day. The period when the sample was taken was 8 hr of operation from the time that the last shot was added to the machine. No samples were taken for screen analysis during the first seven days of the test.

The size was found to remain uniform throughout the 80-day period charted and the size is stabilized from the seventh day on. The amount of shot added to the machine each day after the tenth was 100 lb. Screen analysis showed that an average of 80% of the material being delivered to the wheel is maintained on the 0.033-in. screen. About 15% is retained on the 0.028-in. screen, and more than 98% is retained on the 0.033, 0.028, and 0.023-in. screens.

There is a marked decrease in machine maintenance costs when cut-wire shot is used. This is explained by decreased hardness and absence of sharp grit in stabilized cut-wire peening material. The machine used for this test ran approximately twice as many springs before major overhaul was necessary than was experienced with chilled cast-iron shot. Blade life was at least 10 times as good. Other machine parts showed a decrease in replacements.

Cost Advantage

Table 2 shows a cost comparison of chilled cast iron and cut-wire shot for peening chassis coil springs. The comparison was made on the basis of 1,000,000 parts. The savings possible using cut-wire shot, depend upon the application. The cost advantages over other peening materials are explained by its long life which reduces usage, and handling costs. Because of the physical characteristics of cut wire shot, maintenance costs are reduced considerably. In addition to these savings in operation, an improved peening job is secured, and it may be possible to increase stress and thus make productive material savings.

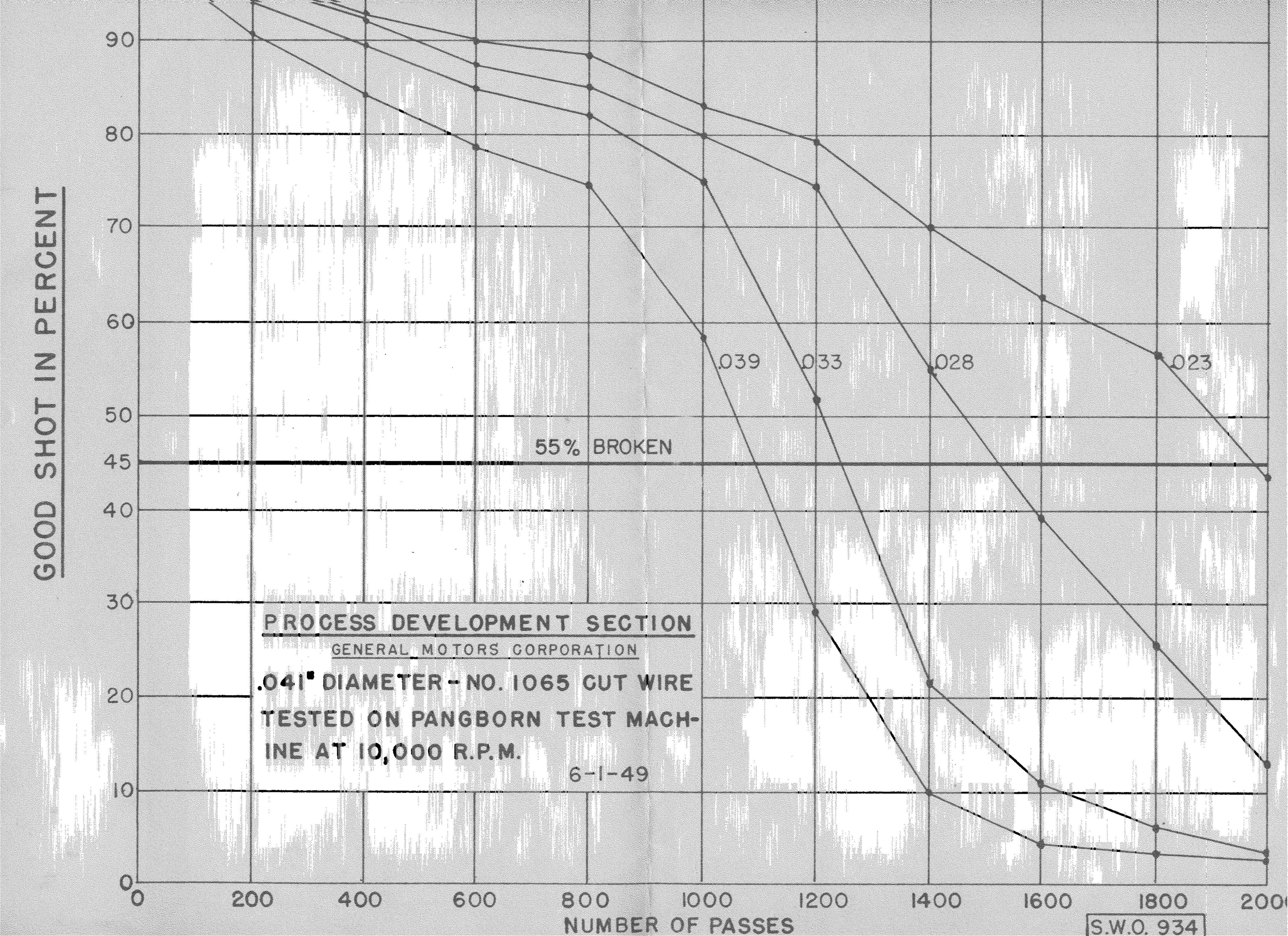
Because of the greater initial cost of cut-wire, it is necessary to investigate each new application thoroughly and to reduce wastage as much as possible, both from carry-out and loss through the machine. Because of the greater tendency to maintain a uniform size, it will generally be possible to reduce wheel speeds and thus secure an additional advantage in the reduction of shot usage and maintenance costs.

New Cut-Wire Shot Uses

At present, Buick has three chassis coil spring peening machines operating with cut-wire shot. Another interesting application that is now in production is the cleaning and stressing of the inside surface of the Dynaflow brake bands with cut-wire shot. This operation was previously carried out with chilled cast-iron grit. The usage was decreased from 6000 lb of grit per week to 60 lb of cut-wire shot per week. Maintenance costs were reduced by an estimated 80%.

The Buick axle shaft is being cleaned with cut-wire shot. Although this is primarily a cleaning operation, some benefits are present from peening. This is in the testing stage.

Arrangements are being made to blast the Buick clutch spring with cut-wire shot. Because it is necessary to use two sizes of shot in this operation with the present operating condition, plans are being made to install a variable speed wheel so that only one size shot will be necessary. Other applications for peening and cleaning are being investigated to determine the advantages possible with the use of cut-wire shot.



GOOD SHOT IN PERCENT
90
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55% BROKEN
.039
.033
.028
.023
PROCESS DEVELOPMENT SECTION
GENERAL MOTORS CORPORATION
.041" DIAMETER - NO. 1065 CUT WIRE TESTED ON PANGBORN TEST MACHINE AT 10,000 R.P.M.
6-1-49
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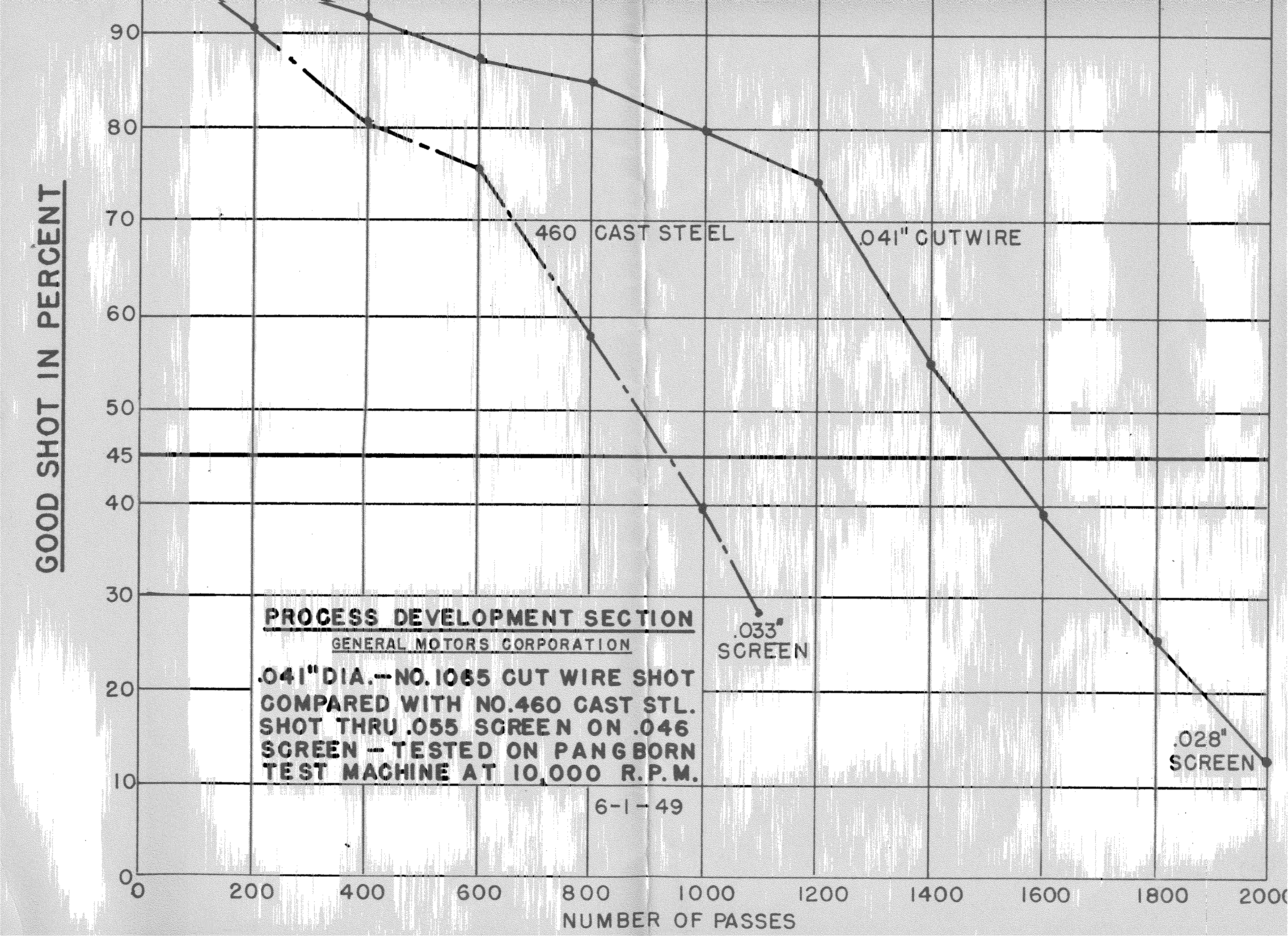
GOOD SHOT IN PERCENT
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460 CAST STEEL
.041" CUTWIRE
.033" SCREEN
.028" SCREEN
PROCESS DEVELOPMENT SECTION
GENERAL MOTORS CORPORATION
.041" DIA.—NO. 1065 CUT WIRE SHOT
COMPARED WITH NO. 460 CAST STL.
SHOT THRU .055 SCREEN ON .046
SCREEN — TESTED ON PANGBORN
TEST MACHINE AT 10,000 R.P.M.
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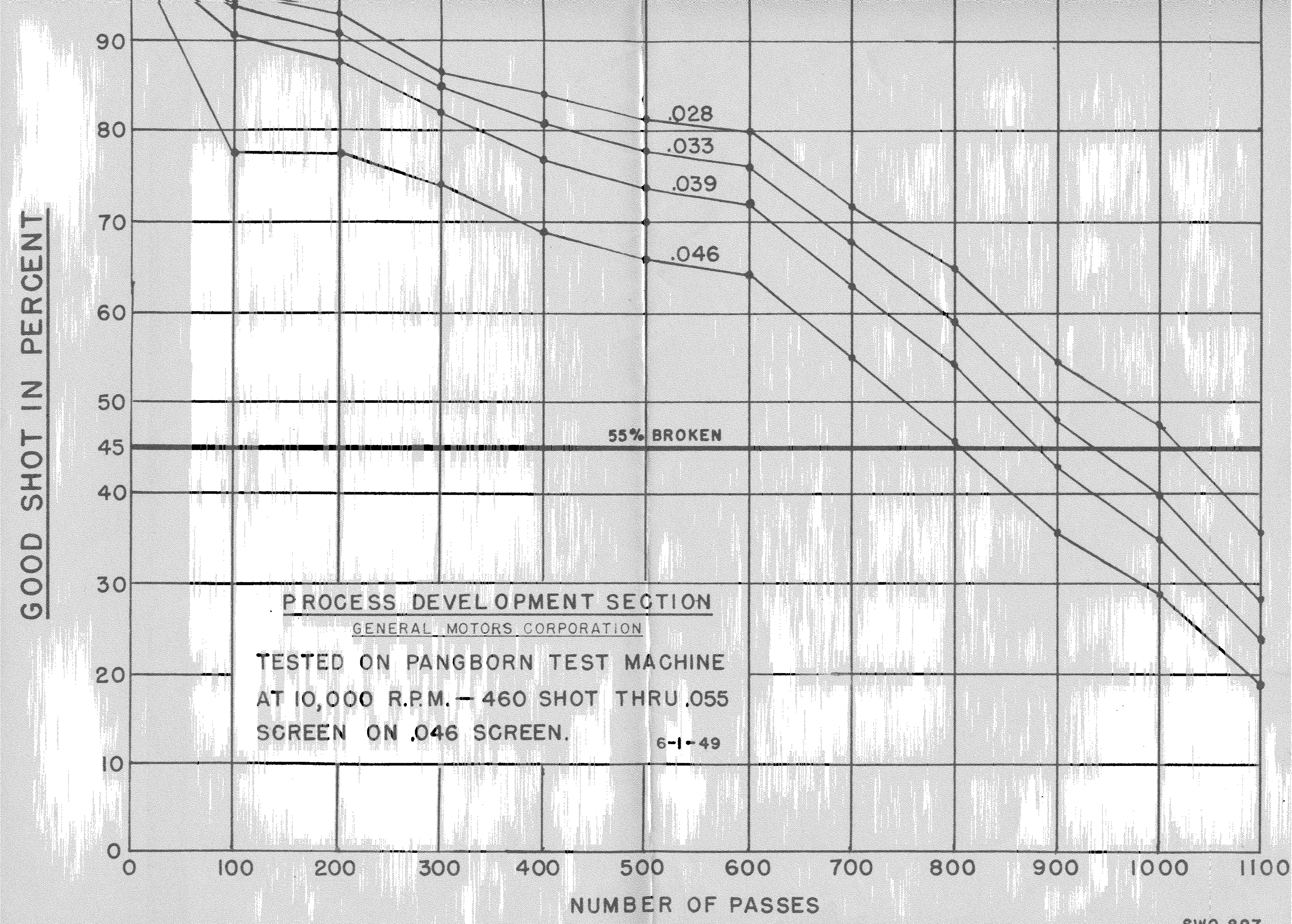
GOOD SHOT IN PERCENT
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55% BROKEN
PROCESS DEVELOPMENT SECTION
GENERAL MOTORS CORPORATION
TESTED ON PANGBORN TEST MACHINE
AT 10,000 R.P.M. – 460 SHOT THRU .055
SCREEN ON .046 SCREEN.
6-1-49

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