

# Materials for Automobiles 9

Lec.9

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# Plan

1	Shot Peening	
2	Phosphating	
3	Quiz 1	

# Benefits of Shot Peening

## Fatigue

- Enhances fatigue strength ,ultimate strength
- Can increase gear life more than 500%
- Can increase drive pinion life up to 400%
- Can increase spring life 400% to 1200%
- Can increase crankshaft life 100% to 1000% (Figure 6)
- Can permit the use of very hard steels by reducing brittleness
- Possible to increase the fatigue strength of damaged parts extending the wear
- Substitution of lighter materials can be possible without sacrificing strength and durability
- Optimal fatigue properties for machined steel components are obtained at approximately 700 MPa, any higher and the materials lose fatigue strength due to increased notch sensitivity and brittleness. When compressive stresses from shot peening are added fatigue strength increases proportionately to increased strength.

# Benefits of Shot Peening

	<p>Corrosion: Leaves a uniformly textured, finished surface ready for immediate use or paint and coatings Prevents corrosion,</p>
	<p>Wear and Lubrication :</p> <ul style="list-style-type: none"><li>•Increases lubricity by creating small pores in which lubricants can accumulate</li><li>•Prevents cracking due to wear</li><li>•Prevents galling</li><li>•Prevents fretting</li></ul>
	<p>Others:</p> <ul style="list-style-type: none"><li>• Prevents hydrogen embrittlement</li><li>• Can be used to curve metal or straighten shafts without creating tensile stress in a Peen forming process</li><li>• Shot Peening can be used in a number of specialized processes such as flow treatment of pipes used to transport polymer pellets used in oil and gas industries. Polymer pellets will slide against the inside of a smooth pipeline, melt and form streamers or angel hair. These long polymer fibers will contaminate the pellet flow and clog up the transfer system. When the inside of the pipeline is roughened by shot peening, the polymer pellets bounce or roll instead of sliding along the inside of the pipe. The pellets contact with the side of the pipe is shortened, and formation of angel hair is prevented.</li></ul>

## Applications

Although the major application of shot peening is related to improvement of fatigue characteristics, other useful applications have been developed, such as metal forming, straightening, improving resistance to stress corrosion, and testing the adhesion of plated deposits of silver on steel.

**Forming.** Shot peening is well suited for certain operations in the forming of thin sections. It has been used to form, as well as to strengthen, structural components of aircraft. An example is integrally stiffened aircraft wing panels. These were machined from slabs of aluminum alloy 2024-T6, 7075-T6, or others, which had to be curved for aerodynamic reasons. The large size of these panels, 10 m (32 ft) by 1.2 m (46 in.), precluded the use of hot forming. Cold forming produced surface tensile stresses of 140 MPa (20 ksi) or more, which were alleviated by shot peening the panels on the tension side. Proper curvature of the panels could be obtained by shot peening alone, with careful control of intensity. The need for conventional cold forming methods was avoided, and the high compressive stresses induced by peening reduced the probability of early fatigue failure.

# Limitations of Shot Peening

**Size and Shape of Workpiece.** The size of the peening cabinet is usually the only limitation on the size of workpiece that can be peened. To some extent, even this limitation can be overcome by the use of portable mechanized peening equipment. Provided the surface to be peened is accessible to the blast, the shape of a workpiece is seldom a limitation.

The peening of small radii in fillets and thread roots is limited by the smallest available media size, currently 0.0200 mm (0.001 in.) diameter glass beads. Sharp edges that must retain their sharpness should not be peened.

**Surface condition,** provided the workpiece surface is free of gross contaminants, is seldom a limitation in shot peening. Water, oil, and grease seriously contaminate the shot and interfere with peening quality and effectiveness. An as forged surface usually shows greater improvement in fatigue strength than a polished surface as a result of peening.

**Temperature Limitations.** Low tempering temperatures, such as those conventionally used for carburized parts, have no adverse effect on peening stresses. Low-alloy steels can be heated to about 175 to 230 °C (350 to 450 °F) for about a half hour before significant decrease in the compressive stresses occurs. Steels intended for elevated-temperature application usually withstand temperatures of 260 to 290 °C (500 to 550 °F) without undergoing a significant stress-relieving effect;

# Methods of Shot Peening

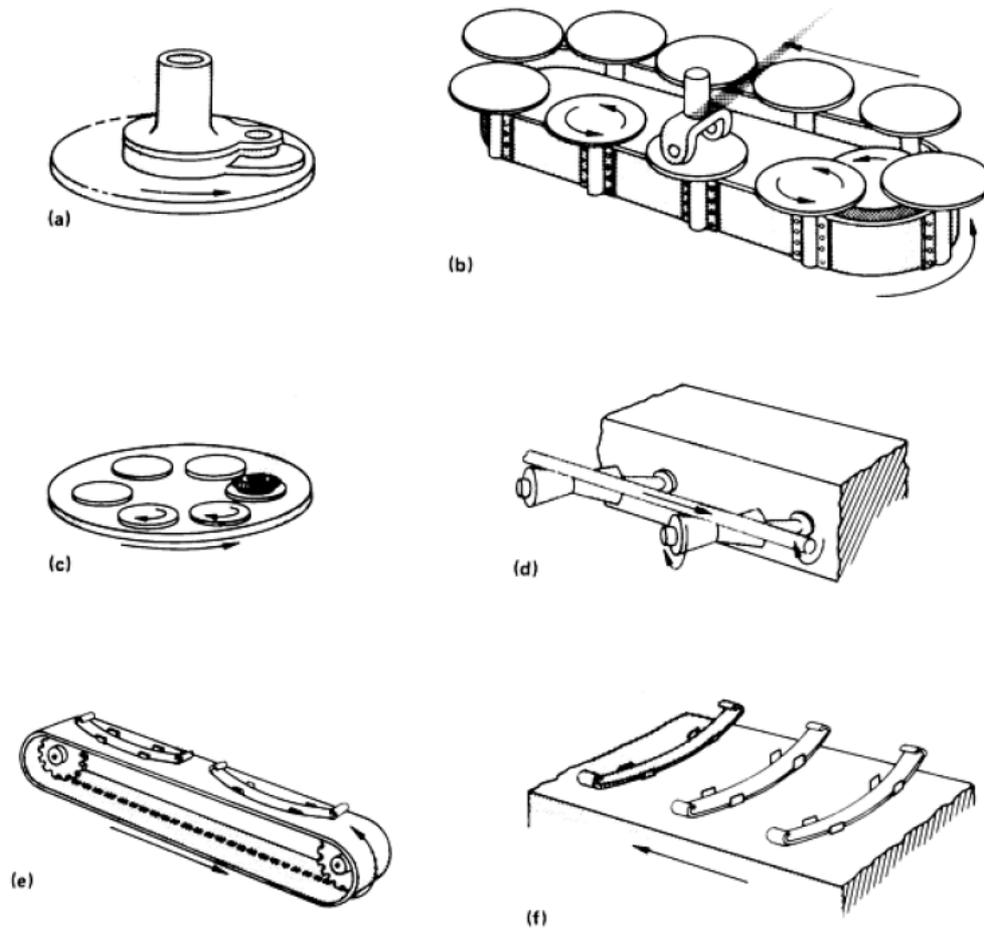
**Conventional (Mechanical) Shot Peening** – Conventional shot peening is done by two methods.

- Method one involves accelerating shot material with compressed air. Shot is introduced into a high velocity air stream that accelerates the shot to speeds of up to 250 ft/s.
- The second method involves accelerating the shot with a wheel. The shot gets dropped onto the middle of the wheel and accelerates to the outer edge where it leaves on a tangential path.

**Dual Peening** – Dual peening further enhances the fatigue performance from a single shot peen operation by re-peening the same surface a second time with smaller shot and lower intensity. Large shot leaves small peaks and valleys in the material surface even after 100% coverage has been achieved. Peening the surface a second time drives the peaks into the valleys, further increasing the compressive stress at the surface.

**Laser-shot Peening** – Laser-shot peening utilizes shock waves to induce residual compressive stress. The primary benefit of the process is a very deep compressive layer with minimal cold working. Layer depths up to 0.40” on carburized steel and 0.100” on aluminum alloys have been achieved. Mechanical peening methods can only produce 35% of these depths.

**Strain Peening** –strain peening develops a greater amount of compressive stress throughout the entire compressive layer. This additional stress is generated by preloading the part within its elastic limit prior to shot peening.. When the peening media impacts the surface, the surface layer is yielded further in tension because of the preloading.



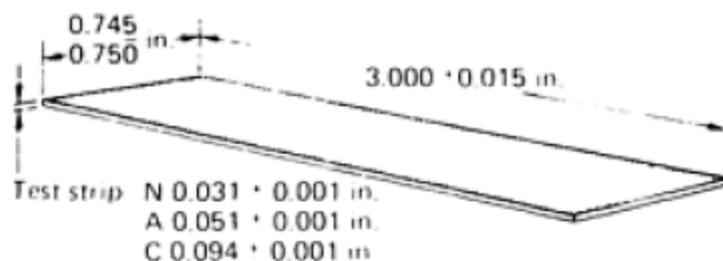
**Fig. 7** Motion and fixturing used in work-handling equipment. (a) Rotation of work around a vertical axis in indexed position. (b) Rotation of work around a vertical axis, with straight-line travel. (c) Rotation of work around a vertical axis, with circular travel. (d) Rotation of work around a horizontal axis, with straight-line travel parallel to the axis of rotation. (e) Straight-line travel of work with no rotation. (f) Straight-line travel of work in a transverse direction

## Peening Test Strips, Holder, and Gage

SAE standard J442 describes the test strips, strip holder, and gage used in measuring shot peening intensity.

If a thin flat piece of steel is clamped to a solid block and exposed to a blast of shot, it will be curved after removal from the block. The curvature is convex on the peened side. The extent of this curvature on a standard sample serves as a means of measurement of the intensity of the peening.

Standard test strips of three thicknesses used are shown in Fig. 14. Made of 1070 cold-rolled spring steel, these strips have a specified hardness of 44 to 50 HRC. Strip A is recommended for testing intensities that produce curvatures having arc heights ranging from 0.15 to 0.60 mm (0.006 to 0.024 in.). For lesser intensities, the N strip is recommended. For greater intensities, the C strip is used. The relationship between strips A, C, and N is shown in Fig. 15. The data represent readings for conditions of identical blast and exposure.



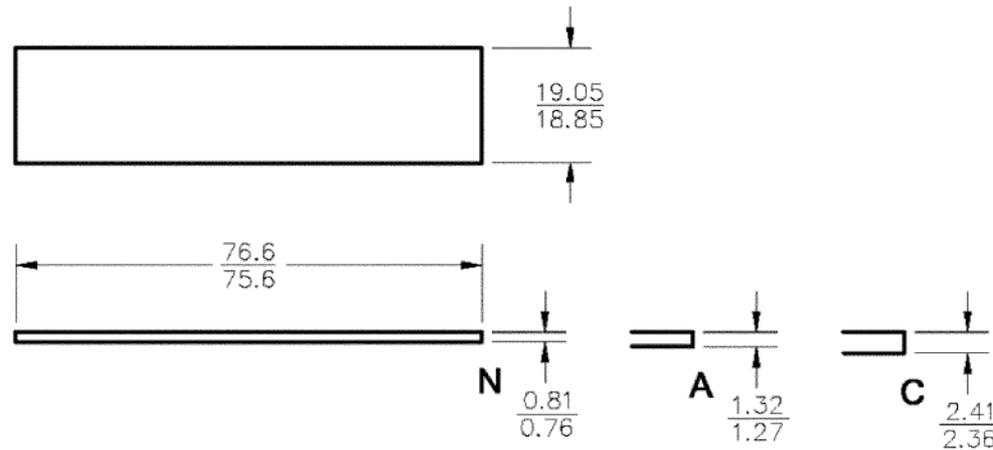
**Fig. 14** Designations and dimensions of standard Almen test strips used in measuring shot peening intensity

### 4.1 Test Strips and Holding Fixture

Standard test strips, N, A, and C are shown in Figure 1 and test strip holder is shown in Figure 2. The approximate relationships between readings of test strips N, A, and C (for conditions of identical blast and exposure) are as follows:

C strip reading  $\times 3.5 =$  A strip reading

A strip reading  $\times 3.0 =$  N strip reading



**Pre-bow:** The arc height as measured by the Almen gage prior to peening. The maximum allowed pre-bow for each strip is as follows:

N - .025

A - .025

C - .038

**Material:** SAE 1070 cold rolled spring steel.

**Edge Type:** Number 1 (does not apply to ends of strip)

**Finish:** Plain tempered, all burrs removed.

**Heat Treatment:** All strips must be uniformly hardened and tempered to produce tempered martensite having a hardness, as measured on the surface, of HRC 44-50 (HRA 72.5-76.0 for the "N" strip).

**Surface Carbon:** Strips shall be free from alteration of surface carbon to the degree that any difference in average hardness between the surface and subsurface shall not exceed two points as measured on the Rockwell 30-N scale. The average of at least four readings in each region should be used to make the comparison. Any such determinations must be made on strips which have not been shot peened, and will preclude other use of strip to be tested. Surface hardness readings that are less than subsurface readings indicate evidence of decarburization. Surface readings which are higher than corresponding subsurface values indicate carburization.

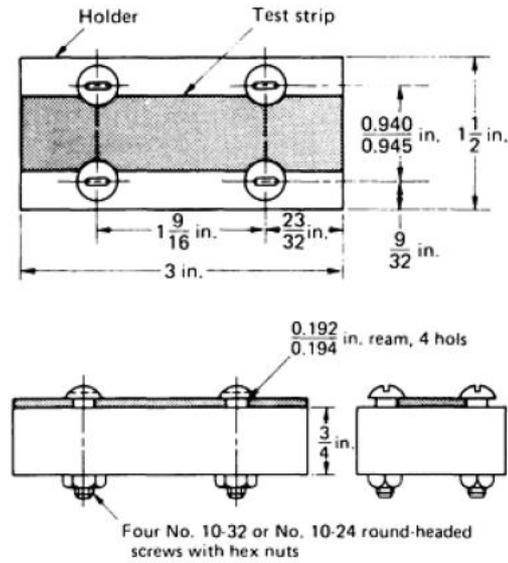


Fig. 16 Assembled Almen test strip and holder

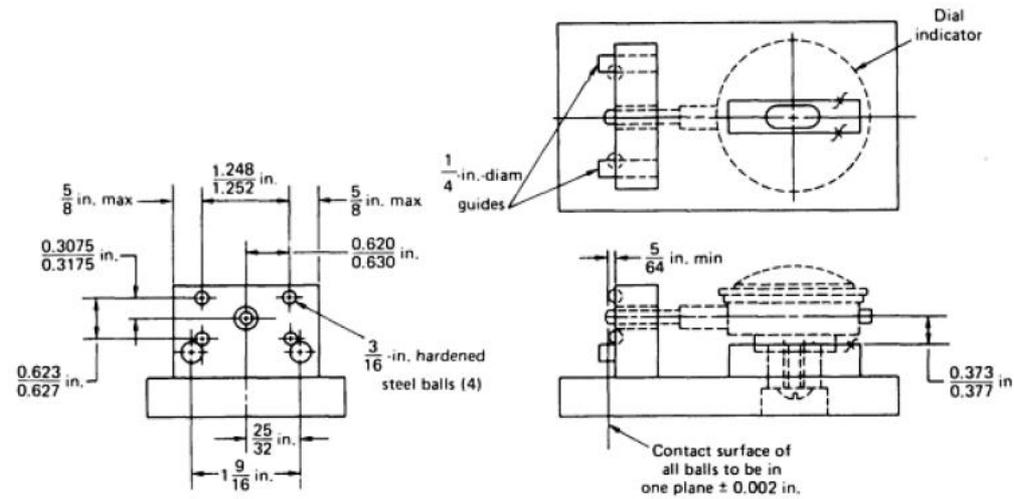


Fig. 17 Almen gage for measuring arc height for test strip

<b>Media</b>	<p>Media control involves using high quality shot that is mostly round and of uniform size and shape. The diameter of the shot should be the same through out the media. If the shot diameter is not uniform, each individual shot will have a significantly different mass. This exposes the material surface to varying impact energies that create non uniformities. These non uniform layers will create inconsistent fatigue results.</p>
<b>Intensity</b>	<p>Intensity control involves changing the media size and shot velocity to control the energy of the shot stream.</p> <p>Using larger media or increasing the velocity of the shot stream will increase the intensity of the shot peening process.</p> <p>To determine what intensity has been achieved, Almen strips are mounted to Almen blocks and the shot peening process is performed on a scrap part. An Almen strip is a strip of SAE 1070 spring steel that, when peened on one side, it will deform into an arc towards the peened side due to the induced compressive stresses from the shot peening process. By measuring the height of the arc, the intensity can be reliably calculated. This process is done before the actual peening process on production parts to verify the peening process is correct.</p> <p>The Almen strips also control how long the material is exposed to the shot peening process. The time to expose a material is determined from the saturation point on a saturation curve. The saturation curve is a plot of Almen strip arc height vs Time. The saturation point is defined as the point on the curve where doubling the exposure time produces no more than a 10% increase in arc height.</p>
<b>Coverage</b>	<p>Coverage is the measure of original surface area that has been obliterated by shot dimples. Coverage is crucial to high quality shot peening and should never be less than 100%. A surface that does not have 100% coverage is likely to develop fatigue cracks in the un-peened surface areas.</p>

### 1.3.1 Smooth Specimen

Figure 3 illustrates the distribution of stress in a smooth beam with no external load applied which has been shot peened on both the upper and the lower surfaces. Since the beam is in equilibrium with no external forces, the area under the stress distribution curve in the regions of compressive stress must be equal to the corresponding area under the curve in the region of tensile stress. Further, the sum of the moments of these areas must be equal to zero.

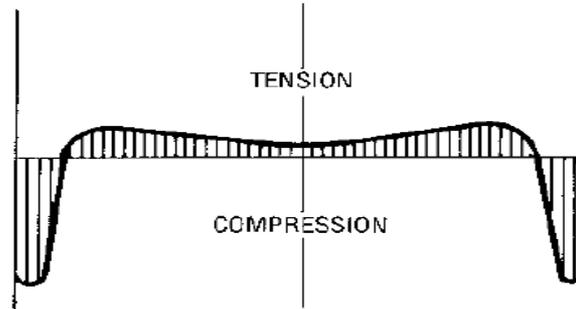


Fig. 3 Typical Residual Stress Distribution After Peening

Figure 4 shows the same beam after shot peening as in the above figure, but with an external bending moment being applied. The resultant stress at any depth will be equal to the algebraic sum of the residual stress and the stress due to the applied load at that depth. The resultant curve of the stress distribution is the solid line and the bending load is shown as a dashed line.

Note that even after loading, the stress at the peened surface is greatly reduced by the compressive stress of shot peening. This condition will help prevent initiation and, more importantly, the propagation of surface cracks.

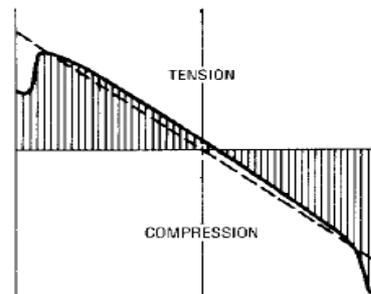


Fig. 4 Superposition of Applied and Residual Stress

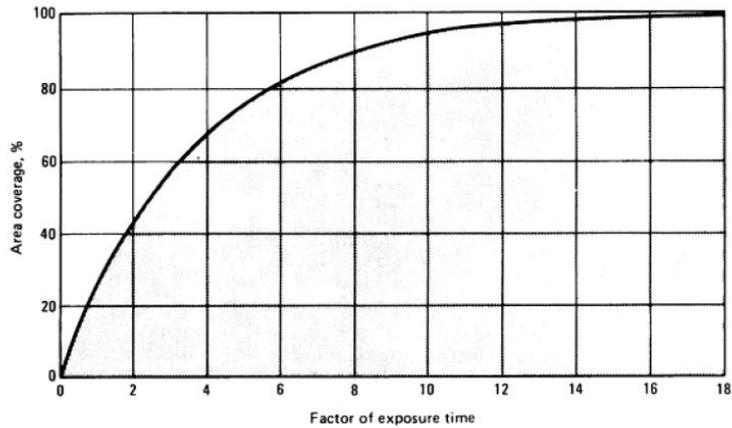


Fig. 1 Area coverage as a function of exposure time in shot peening

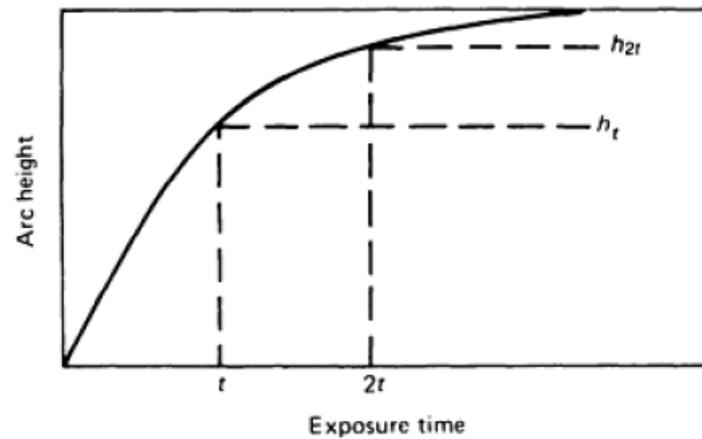
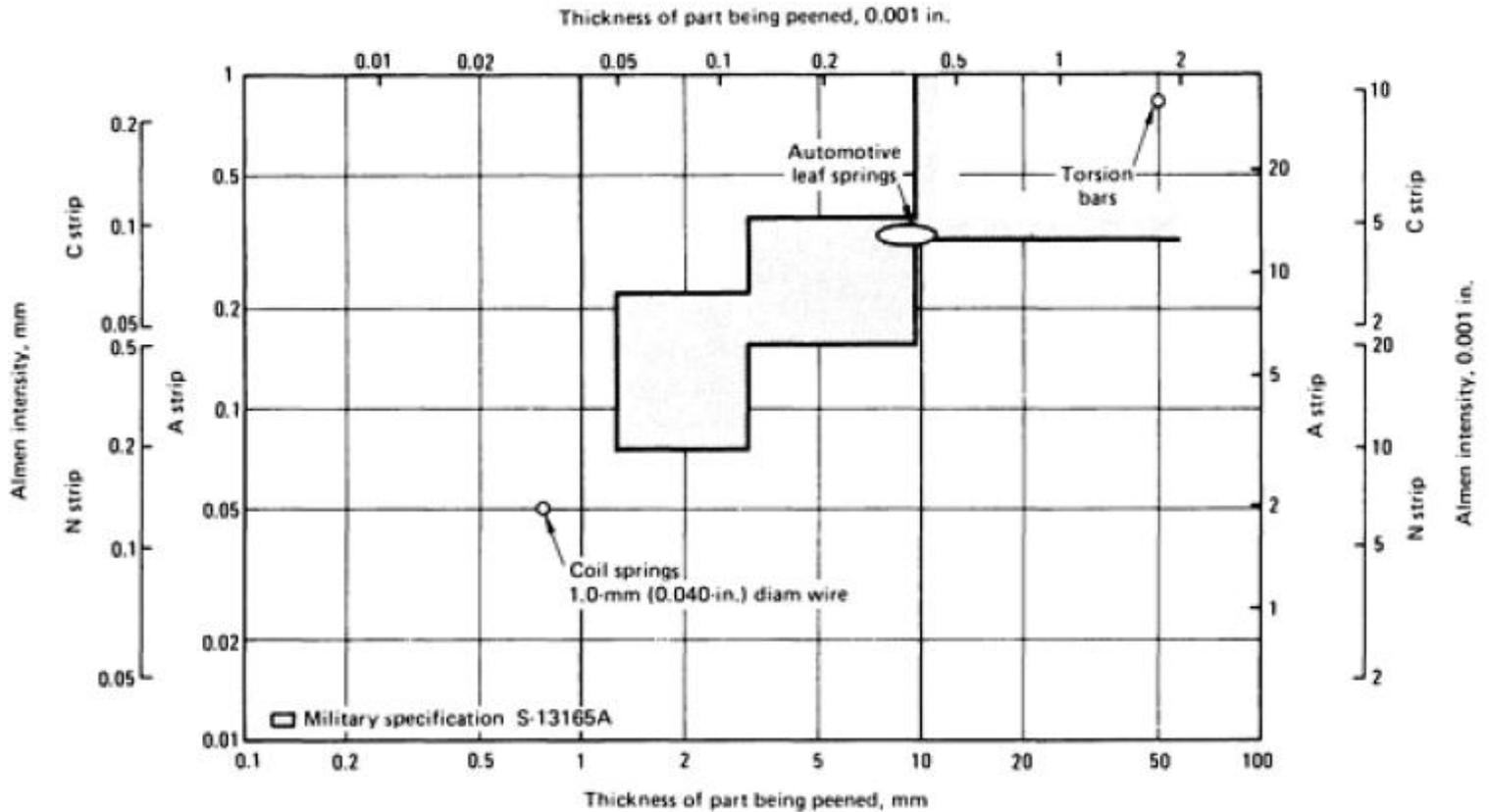
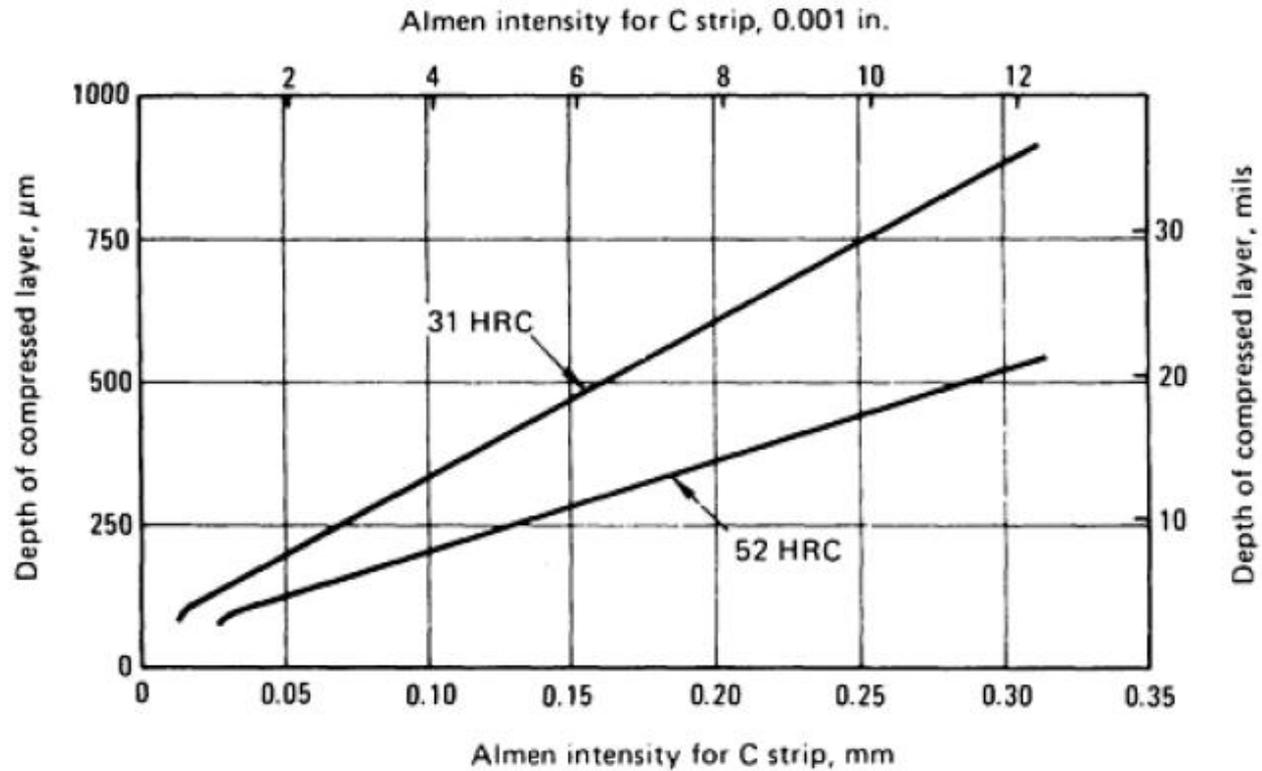


Fig. 2 Relation of measuring coverage to peening time. Coverage is considered full at time  $t$ , if doubling exposure to time  $2t$  results in change in arc height less than 10%.



**Fig. 3** Relation of peening intensity to cross-sectional thickness of parts peened



**Fig. 4** Relation of depth of compressed layer to peening intensity for steel of two different hardnesses

# Phosphating - Introduction

Applications	<p>They are used on</p> <ul style="list-style-type: none"><li>• iron, steel, zinc, and aluminium surfaces</li><li>• to increase corrosion protection, provide a base for paint,</li><li>• reduce wear on bearing parts, and aid in the cold forming and extrusion of metals</li></ul>
Nature of phosphate coating	<p>Phosphate coatings are formed by chemically reacting a clean metal surface with an aqueous solution of a soluble metal phosphate of zinc, iron, or manganese, accelerating agents, and free phosphoric acid.</p> <p>For example, when steel is treated, the surface is converted into a crystalline coating consisting of secondary and tertiary phosphates, adherent to and integral with the base metal.</p>

# Phosphating - Introduction

The performance of a phosphate coating depends largely on the unique properties of the coating, which is integrally bound to the base metal and acts as a nonmetallic, adsorptive layer to hold a subsequent finish of oil or wax, paint, or lubricant.

Heavy phosphate coatings are normally used in conjunction with an oil or wax for corrosion resistance. The combination of the coating with the oil film gives a synergistic effect, which affords much greater protection than that obtained by the sum of the two taken separately.

The stable, nonmetallic, nonreactive phosphate coating provides an excellent base for paint. It is chemically combined with the metal surface, which results in increased adsorption of paint and materially reduces electrochemical corrosion normally occurring between the paint film and the metal

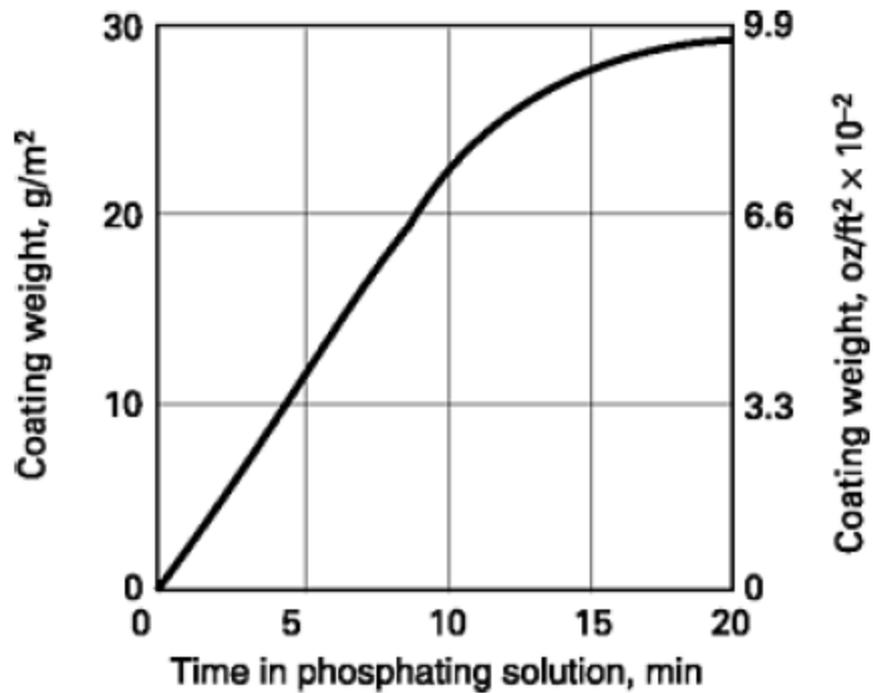
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# Phosphating

Methods of phosphating	<ul style="list-style-type: none"><li>• Small items, such as nuts, bolts, screws, and stampings, are coated in tumbling barrels immersed in phosphating solution.</li><li>• Large fabricated articles, such as refrigerator cabinets, are spray coated with solution while on conveyors.</li><li>• Automobile bodies are sprayed with or immersed in phosphating solution.</li><li>• Steel sheet and strip can be passed continuously through the phosphating solution or can be sprayed.</li></ul>
Coating specifications	<p>Phosphate coatings range in thickness from less than 3 to 50 <math>\mu\text{m}</math> (0.1 to 2 mil).</p> <p>Coating weight (grams per square meter of coated area), rather than coating thickness, has been adopted as the basis for expressing the amount of coating deposited.</p>

# Phosphating -Temperature

	<p><b>Operating Temperature.</b></p> <p>Operating temperatures of different phosphating solutions may range from 30 to 100 °C, or 90 to 210 °F (Table 6), individual solutions are compounded to operate at maximum efficiency within specific temperature limits.</p> <p>The trend in recent years has been to lower operating temperatures. A phosphating solution should be held within the specified operating temperature range.</p>
	<p>If the solution is permitted to operate below the minimum recommended temperature, the phosphate coating is thin or non-existent.</p> <p>If the temperature of the solution exceeds the recommended maximum, the coating builds up excessively and has a non-adherent, powdery surface, and the bath solution may become unbalanced, resulting in excessive sludge and scale.</p>
	<p>Special low-temperature solutions are available for applying iron or zinc phosphate (see the section "Low-Temperature Coatings" in this article).</p>



**Fig. 2** Plot of manganese phosphate coating weight vs. time of exposure of steel surface to phosphating solution

# Phosphating - Process

Cleaning: Derusting Degreasing	<p>All steel must be thoroughly cleaned prior to phosphate coating to remove grease, oil, rust, and undesirable soils on the steel surface, which prevent or alter the formation of a satisfactory phosphate coating and interfere with paint adhesion.</p> <p>The cleaner used to remove oily soil prior to the formation of the zinc phosphate coating is a light-duty, mildly alkaline material especially formulated to function effectively at low temperature. The cleaner that is best suited for use in connection with the low-temperature iron phosphate coating process may be either a light-duty, low-foaming, mildly acidic mixture, or the above mild alkaline cleaner, depending upon the conditions of operation.</p>
Phosphating	<p>Proper formulation of the phosphating solutions allows the coatings to form rapidly at low temperature on the cleaned steel surface. Simple,</p>
Bath control	<p>on-the-job, chemical controls enable the operator to adjust the addition of coating chemicals to the requirements of the steel being treated.</p>

# Phosphating - Process

Water Rinse	Following the coating operation, a cold water rinse is used to remove excess coating chemicals. The flow of water through the rinse is regulated with the rate of production so that contamination of the main body of the rinse is minimized.
Chromate dip	An acidified rinse containing hexavalent chromium compounds follows the water rinse. This operation has the specific effect of enhancing the corrosion resistance of the coating. An oven dry-off to remove surface moisture completes the process.
Application	Typical products being treated by the cold phosphate system are <ul style="list-style-type: none"><li>• automotive body and sheet metal parts,</li></ul>

A typical formulation for an iron phosphate bath is (Ref 1):

Component	Composition, %
Phosphate salts	12-15
Phosphoric acid	3-4
Molybdate accelerator	0.25-0.50
Detergents (anionic/nonionic)	8-10

Basically, then, iron phosphate formulations consist of primary phosphate salts and accelerators dissolved in a phosphoric acid solution. It is the acid that initiates the formation of a coating on a metal surface. When acid attacks the metal and begins to be consumed, solution pH at the metal surface rises slightly. This is what causes the primary phosphate salts to drop out of solution and react with the metal surface, forming a crystalline coating.

# Phosphating Typical Values

**Table 3 Low-carbon sheet steel components spray phosphate coated for paint finishing**

Part	Area		Production, pieces/h
	m <sup>2</sup>	ft <sup>2</sup>	
<b>Zinc phosphate<sup>(a)</sup></b>			
Automobile body	74	800	50
Dryer shell	4.0	42.5	400
Cabinet back panel	1.18	12.7	700
Cabinet top	0.73	7.9	1400

<b>Iron phosphate<sup>(b)</sup></b>			
Washing machine shell	4.91	52.9	330
Dryer top	1.18	12.7	660
Range side panel	0.90	9.7	660
Dishwasher door	0.78	8.4	660
Wiring channel	4.5	4.9	4950

(a) 1.6 to 2.1 g/m<sup>2</sup> ( $5.2 \times 10^{-3}$  to  $6.9 \times 10^{-2}$  oz/ft<sup>2</sup>).

(b) 0.4 to 0.9 g/m<sup>2</sup> ( $1 \times 10^{-3}$  to  $3 \times 10^{-3}$  oz/ft<sup>2</sup>)

**Table 4 Applications of zinc phosphate dip spray coating to facilitate cold forming**

Part <sup>(a)</sup>	Steel	Area		Coating weight		Production, pieces/h	Sequence of operations
		m <sup>2</sup>	ft <sup>2</sup>	g/m <sup>2</sup>	oz/ft <sup>2</sup> × 10 <sup>-2</sup>		
Truck wheel nut	1008	0.007	0.08	4.3-6.5	1.4-2.1	1000	(b)
Piston pin	5015	0.009-0.014	0.1-0.15	5.4-7.0	1.8-2.3	2600	(b)
Standard-transmission output shaft	4028	0.009-0.014	0.1-0.15	4.3-6.5	1.4-2.1	300	(b)

(a) Bath used for all applications listed is zinc phosphate bath accelerated with nitrous oxide.

(b) Alkaline wash, rinse, activating rinse, phosphate, rinse, neutralizing rinse, oil dip.

# Manganese Phosphating

**Table 5 Parts immersion coated with manganese phosphate for wear resistance**

Part <sup>(a)</sup>	Material	Coating time, min	Supplementary coatings
Valve tappets, camshafts	Low-alloy steel forgings or bar stock	7-15	Oils, colloidal graphite
Piston rings	Forged steel, cast iron	15-30	Oils
Gears <sup>(c)</sup>	Forged steel, cast iron	15-30	Oils

(a) Coating weights range from 10.8 to 43.0 g/m<sup>2</sup> ( $3.5 \times 10^{-2}$  to 0.14 oz/ft<sup>2</sup>).

(b) Coating may be applied by barrel tumbling.

(c) Coating weights range from 5.4 to 43.0 g/m<sup>2</sup> ( $1.8 \times 10^{-2}$  to 0.14 oz/ft<sup>2</sup>).

# Manganese Phosphating

When two parts, manganese phosphated to reduce friction by providing lubricity, are put into service in contact with each other, the manganese coating is smeared between the parts. The coating acts as a buffer to prevent galling or, on heavily loaded gears, welding. The phosphate coating need not stand up for an extended length of time, because it is in initial movements that parts can be damaged and require lubricity. For example, scoring of the mating surfaces of gears usually takes place in the first few revolutions. During this time, the phosphate coating prevents close contact of the faces. As the coating is broken down in operation, some of it is packed into pits or small cavities formed in gear surfaces by the etching action of the acid during phosphating.

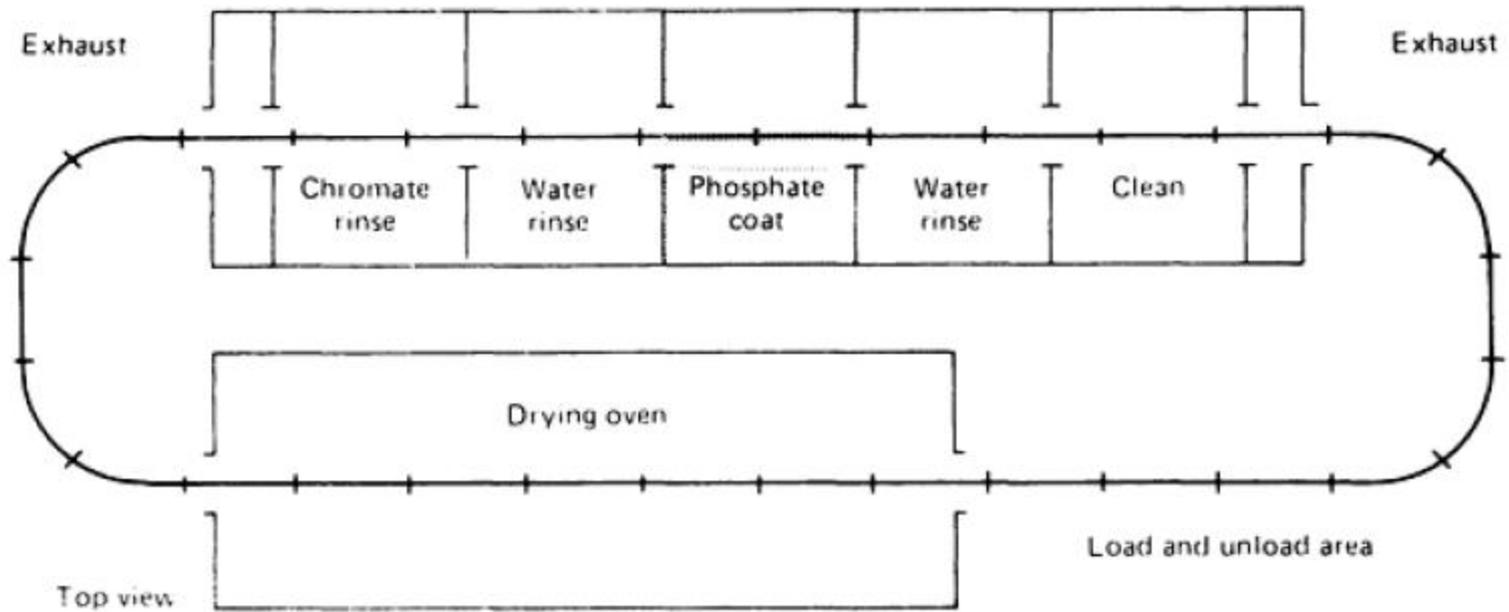
Long after break-in, the material packed into the pits or coating that was originally formed in the pits prevents direct contact of mating surfaces of gear teeth. In addition, it acts as a minute reservoir for oil, providing continuing lubrication.

As work hardening of the gear surfaces takes place, the coating and the etched area may disappear completely, but by this time scoring is unlikely to occur.

# Methods of Phosphating

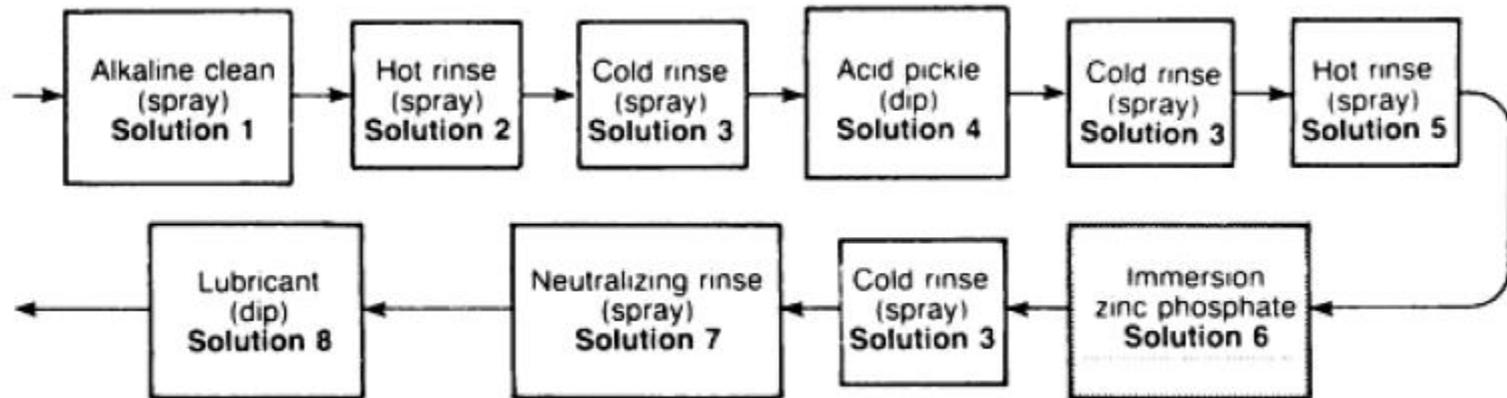
Hot Dip	Most phosphate coatings are formed from heated solutions following a hot cleaning cycle.
Lower temperature	Effective coatings, both the zinc phosphate and the iron phosphate types, are now produced by the relatively cold system with up to 70% savings in heating costs.
Cold phosphating	

# Spray Phosphating Line



**Fig. 6** Typical plant layout for a continuous conveyORIZED spray line for phosphating

# Dip Phosphating Line



# Zinc Phosphating

**Zinc phosphate coatings** encompass a wide range of weights and crystal characteristics, ranging from heavy films with coarse crystals to ultrathin microcrystalline deposits.

Zinc phosphate coatings vary from light to dark gray in color. Coatings are darker as the carbon content of the underlying steel increases, as the ferrous content of the coating increases, as heavy metal ions are incorporated into the phosphating solution, or as the substrate metal is acid pickled prior to phosphating.

Zinc phosphating solutions containing active oxidizers usually produce lighter-colored coatings than do solutions using milder accelerators.

**Zinc phosphate coatings** can be applied by spray, immersion, or a combination of the two. Coatings can be used for any of the following applications of phosphating:

- base for paint or oil;
- aid to cold forming, tube drawing, and wire drawing; increasing wear resistance;
- rustproofing. Spray coatings on steel surfaces range in weight from 1.08 to 10.8 g/m<sup>2</sup> ( $3.5 \times 10^{-3}$  to  $3.5 \times 10^{-2}$  oz/ft<sup>2</sup>); immersion coatings, from 1.61 to 43.0 g/m<sup>2</sup> ( $5.28 \times 10^{-3}$  to 0.141 oz/ft<sup>2</sup>)

# Iron Phosphating

**Iron phosphate coatings** were the first to be used commercially. Early iron phosphating solutions consisted of ferrous phosphate/phosphoric acid used at temperatures near boiling and produced dark gray coatings with coarse crystals. The term *iron phosphate coatings* refers to coatings resulting from alkali-metal phosphate solutions operated at pH in the range of 4.0 to 5.0, which produce exceedingly fine crystals. The solutions produce an amorphous coating consisting primarily of iron phosphates and having an interference color range of iridescent blue to reddish-blue color.

Iron phosphate coatings are applied to steel to provide :

- a receptive surface for the bonding
- as a base for subsequent films of paint.

Processes that produce iron phosphate coatings are also available for treatment of galvanized and aluminum surfaces.

Iron phosphate coatings have excellent adherence and provide good resistance to flaking from impact or flexing when painted.

Corrosion resistance, either through film or scribe undercut, is usually less than that attained with zinc phosphate.

# Iron Phosphate

Spray application of iron phosphate coatings is most frequently used, although immersion application also is practical.

The accepted range of coating weights is 0.21 to 0.86 g/m<sup>2</sup> . Little benefit is derived from exceeding this range, and coatings of less than 0.21 g/m<sup>2</sup> are likely to be nonuniform or discontinuous.

Quality iron phosphate coatings are routinely deposited at temperatures from 25 to 65 °C (80 to 150 °F) by either spray or immersion methods.

# Manganese Phosphating

**Manganese phosphate coatings** are applied to ferrous parts (bearings, gears, and internal combustion engine parts, for example) for break-in and to prevent galling.

These coatings are usually dark gray. However, because almost all manganese phosphate coatings are used as an oil base and the oil intensifies the coloring, manganese phosphate coatings are usually black in appearance. In some instances, a calcium-modified zinc phosphate coating can be substituted for manganese phosphate to impart break-in and antigalling properties.

Manganese phosphate coatings are applied only by immersion, requiring times ranging from 5 to 30 min. Coating weights normally vary from 5.4 to 32.3 g/m<sup>2</sup>, but can be greater if required. The manganese phosphate coating usually preferred is tight and fine-grain, rather than loose and coarse-grain. However, desired crystal size varies with service requirements. In many instances, the crystal is refined as the result of some pretreatment (certain types of cleaners and/or conditioning agents based on manganese phosphate) of the metal surface.

Manganese-iron phosphate coatings are usually formed from high-temperature baths from 90 to 95 °C (190 to 200 °F).

# Phosphate Coatings as a Base for Paint

The useful life of any painted metal article depends mainly on the durability of the organic coating itself and the adherence of the film to the surface on which it is applied.

The method of preparing the metal should reduce the activity of the metal surface, so that underfilm corrosion is prevented at the interface between paint and metal.

- Phosphate coatings promote good paint adhesion,
- increase the resistance of the films to humidity and water soaking, and
- substantially retard the spread of any corrosion that may occur. A phosphate coating retards the amount of corrosion creep, because the coating is a dielectric film that insulates the active anode and cathode centers existing over the entire surface of the base metal.
- Zinc phosphate coatings of light to medium weight (1.6 to 2.1 g/m<sup>2</sup>) and lightweight iron phosphate coatings (0.3 to 0.9 g/m<sup>2</sup>,) are generally used for paint bases.

Phosphated surfaces to be painted should not be touched by bare hands or other parts of the body, to ensure good adherence of the paint film

# Phosphating - Lubrication

Breaking in	<p>The oil-absorptive phosphate coatings are useful in holding and maintaining a continuous oil film between metal-to-metal moving parts.</p> <p>They also permit rapid break-in of new bearing surfaces.</p> <p>Even after the coatings have been worn away, the controlled etched condition of the metal surface continues to hold the oil film between the moving parts.</p>
Deep drawing and cold forging	<p>The ability of a well anchored coating to hold a soap or oil-type lubricant is used in the cold forming and drawing of metals</p>

# Limitations of Phosphating

**Limitations Imposed by Shape.** It is seldom impossible to phosphate a part because of its shape. However, shapes can restrict production or limit the choice of process. Parts with complex passages must be immersion coated, because spray phosphating cannot reach all areas of the passages. Cup-shape parts, phosphate coated by either method, present problems of handling to achieve complete drainage. Blind holes or cavities may entrap air, preventing phosphating solution in the immersion process from contacting all areas to be coated.

Tanks that require a phosphate coating on the inside after fabrication, and that have few drain holes or openings of any size, must be phosphated by immersion. However, if these tanks require phosphate coating on the outside only, spray coating is more appropriate.

**Limitations Imposed by Size.** The size of parts that can be phosphated is limited only by the size and type of equipment available.

However, part size does generally determine the method of application.

Very small parts, such as springs, clips, nuts, bolts, and washers, are almost always coated by immersion. Spray phosphating of these parts on a volume basis would be impractical.

Conversely, for extremely large parts, such as transformer housings, that may be as much as 6 m (20 ft) high, spray phosphating is the only practical method for volume production.

On extremely large parts produced in low volume, however, coatings are usually applied by brushing or wiping.

# Cold Phosphating - Advantages

There are advantages of the cold phosphate system over conventional methods that require higher temperature operation:

1. Direct heat savings — up to 70%
2. Less heat-up time
3. Less maintenance due to decreased load on heating coils, steam traps, etc.
4. Reduced downtime
5. Increased worker comfort near the installation
6. Reduced use of water through decreased evaporation
7. Elimination of exhaust fans