due to bacteria. Specimens of the rust were then submitted to the eminent bacteriologist, Dr. Shorler of Dresden, who identified *Gallionella ferruginea* in great abundance in the material. The method of attack of this organism is first the elimination of an acid product by which the iron is dissolved, and then each individual forms a pit by eating out the metal. The structural damage was reported to have been enormous for the short period of less than a year that the bridge had been in service.

The foregoing considerations apparently warrant the conclusion that the corrosion of underground iron and steel structures is in part due to bacterial activity:

- (1) Directly, or by the attack of a specific microbe.
- (2) Indirectly, or by creating acid conditions in the soil. Certain bacteria present, owing to peculiar modes of absorption and elimination of sulphur and its compounds convert harmless substances into corrosive acids.

The remedies proposed are:

- (1) Free drainage quickly carrying off the acid solutions formed should arrest or prevent destructive action.
- (2) In localities or situations where drainage is impracticable, slack lime should be packed about the metal, to neutralize acids formed as a result of bacterial activity.

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[CONTRIBUTION FROM ARTHUR D. LITTLE, INC., LABORATORY OF ENGINEERING CHEMISTRY.]

VARIATIONS IN CAR PAINTING PRACTICE.

By CARL F. WOODS.

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The past few years have witnessed a wide-spread movement in this country towards the standardization of paint products. Public attention has been called to the prevalence of adulteration and to the practice, particularly in mixed paints, of selling goods of short weight, while certain investigators ably supported by the reputable paint manufacturers have revealed many such frauds and have taken decisive steps toward the education of the consumer and the establishment of definite standards. Important data are being accumulated on the relative value of the various pigments and vehicles, but comparatively little attention is being given to the proper application of the paints themselves. The responsibility for poor results in painting rests both with the painter and the paint manufacturer, for although inferior materials cannot be made to give long life even in the hands of the most skilful painter, it is equally true that good paint improperly applied affords no better results than poor paint. There is no class of painting in which this is more clearly illustrated than in that of car finishing, for this is not a comparatively simple operation like house painting, but on the con-

trary is a complex and highly skilful procedure, requiring expert labor and involving the application of many coatings.

The object of car painting is both for protection and for decoration, although the latter consideration has exerted the greater influence on the modern practice of car finishing. It is possible to preserve the woodwork of a car body just as efficiently by frequent painting with suitable oil paints as by covering it with the ten to fifteen coats of paint and varnish customarily applied. This is well illustrated by the practice of the Interborough Rapid Transit Company of New York, who paint the bodies of the subway cars with a dark red house paint. Not a vestige of ornamentation is used and the cars are not even varnished. This is an extreme case, but the practice has been adopted by an experienced management, and indicates the simple method of car finishing which can be used where the appearance of the car is of no importance. The steam or electric car operated on the surface, however, occupies a prominent position, and the public justly demands that it present a well-kept exterior. The appearance and condition of the cars is frequently considered an indication of the liberality of the management, and as a result many companies have carried this idea to an extent which brings an unnecessary burden on the earning capacity of the system. The cost of painting the same type of car varies on different roads from \$30.00 to \$60.00, and in certain cases an even larger amount, while some roads are forced to repaint their cars every two years, and others with the aid of one coat of varnish each year are able to operate for ten to fifteen years before complete refinishing becomes necessary. It is particularly significant that those cars which have had the most expensive finishing are not of necessity the longest-lived. It is obvious, therefore, that there are certain underlying principles upon which the durability of the finish depends.

Car paints as a rule are mixtures of liquids and solids having widely different chemical and physical properties. Between the priming coat and the final varnish, there are not less than twenty elements intimately in contact, some of which have an affinity for each other, while others may tend to dissociate. This is particularly true of varnishes, for two different brands of equal durability may so react as to materially injure the wearing qualities of either one. While each succeeding treatment has its own specific demands, the entire paint coating must amalgamate and act as a unit to prevent separation of the various films under the physical stresses of service, produced by the expansion and contraction of the car under changes of temperature, and the wrenching and twisting incidental to operation. The importance of selecting the right composition for the successive coats is self-evident, but it is equally essential to employ a method

of finishing which will take into consideration the specific demands which are imposed upon each coat.

There are four fundamental operations in car painting which must be performed to obtain the proper finish and the desired durability:

First, the pores of the wood must be thoroughly saturated to prevent the absorption of succeeding coats and to form a cementing bond between the wood and the paint films.

Second, the natural inequalities of the surface must be corrected and a smooth, hard foundation prepared for the application of the succeeding color and varnish coats.

Third, the required color must be applied in a smooth, homogeneous film which is sufficiently thick to cover the underlying coats and which at the same time possesses proper elasticity.

Fourth, the color coat must be covered with a film of varnish, both to protect the underlying paints from the effect of the weather and to obtain the glossy, smooth finish desired. It is necessary that this final coat be hard enough to withstand the abrasive action of sand and dirt and the general deteriorating effects of sun, wind and weather, but at the same time possess the maximum amount of elasticity.

Three distinct processes for car finishing are in use, each of which, if properly applied, produces satisfactory results, but obtains the requisite qualities by essentially different methods. These three systems may be called the "Lead and Oil," the "Surfacer" and the "Color and Varnish" Processes. Other methods of finishing are employed but all of them are abbreviations or combinations of the three main types.

The "Lead and Oil" Process is the oldest system in use, and requires the application of the greatest number of coats and the expenditure of the most labor. This process consists in thoroughly saturating the wood with a thin paint of white lead and linseed oil, followed after proper drying by thicker coats of the same paint until the woodwork is properly "primed and filled." On the foundation so prepared, several coats (usually three) of a special paint known as "rough stuff" are applied. This consists essentially of a mineral silicate of moderate fineness mixed with white lead and ground in varnish. Such a paint dries quickly and can be brought by rubbing with blocks of pumice to a smooth, slate-like finish, which affords an admirable surface for the body color. Car colors, often known as coach colors, form a special class of paints and consist of a suitable pigment ground to the last degree of fineness in "Grinding Japan," which is really a special varnish generally made of high-grade shellac, and loaded nearly to the point of saturation with lead and manganese driers. The paint so prepared thinned for application with a suitable amount of turpentine dries readily and affords a smooth homogeneous color.

After a sufficient amount of color has been applied, the entire surface is given several coats of varnish, allowing each to dry thoroughly before adding the next. Two different types of varnish are sometimes employed on the same car: the first a "Rubbing Varnish," which contains from 6 to 12 gallons of linseed oil to every 100 pounds of hard gum and which dries to a very hard, dense film capable of being rubbed to a high polish, the second, or "Finishing Varnish," contains about 25 gallons of oil to every 100 pounds of gum, and, although slow-drying, produces a very elastic, tough and durable film. Experience has demonstrated the unfitness of "Rubbing Varnish" for exterior purposes, so that in the majority of cases "Finishing Varnish" alone is employed.

The "Surfacer" Process was devised about thirty years ago to reduce the time, labor and expense of the old "Lead and Oil" System. The fundamental difference between the two processes is that the "Surfacer" System omits the lead priming and filling and the "rough stuff" coats, but builds up the surface rapidly by the application of specially prepared paints. The first, or priming, coat is usually a quick-drying varnish containing a very small amount of a mineral silicate. The second, or loading, coat is of much thicker consistency and is a mixture of yellow ochre, white lead and dolomite or other equivalent substances ground in quick-drying varnish. The third coat, frequently known as the leveling coat, is similar to the "rough stuff" of the older process, but is devised to amalgamate with the preceding coats. Three applications of this material are usually made and the entire surface rubbed with block pumice to the desired finish. From this point on, the process is identical with the "Lead and Oil" System, the "Surfacer" Process confining its efforts to the rapid preparation of a surface for the color coat.

The "Color and Varnish" Process is of very recent origin and is a radical departure from the two previously described systems. The fundamental idea of this process is that the fewer the number of coats and the more similar in composition, the more durable will be the final results obtained. With this in view, a combination of coats are applied which are so composed as to prime the wood, prepare a surface and obtain the desired color at the same time. This is accomplished by employing heavy silicate paints, containing the proper color ground in the same kind of varnish, each coat possessing suitable drying qualities for its respective demands. The best results are obtained by the use of dark colors such as green or brown, as the principal ingredient may be ochre, umber or some other natural earth pigment which not only produces the desired shade, but is well adapted for preparing a foundation. The surface so obtained is covered with a coat of the body color ground in varnish followed by one thick coat of finishing varnish.

A fourth process is used to some extent which is really an abbreviation of the "Lead and Oil" Process and consists in priming and filling with lead and oil, but instead of applying "rough stuff," which requires expensive labor in rubbing, the lead coats are brought to a reasonable smooth finish with sandpaper. This process is further improved by tinting the surfacing coats in the direction of the body color so that by the use of dark colors, which are also more permanent than the lighter and more brilliant ones, one coat of color will be sufficient.

Each of the processes above described had its specific faults and virtues, so that no one has completely superseded the other two. The "Lead and Oil" Process if properly applied requires from three to four weeks and the application of ten or more coats. The "Surfacer" Process requires about the same number of coats, but, owing to the quicker drying of the surfacers, requires but two to three weeks for application. The "Color and Varnish" Process is the simplest of all and has been applied with apparently successful results in from six to eight days with an application of four to six coats.

The "Lead and Oil" Process produces very satisfactory results both in appearance and in durability, but the lead undercoats require considerable time for drying, the rubbing of the "rough stuff" necessitates the employment of skilled labor and the number of coats applied involves the expenditure of time and money out of proportion to the value of the actual results obtained. In addition, the process is susceptible to serious faults, such as improperly made "rough stuff" paints which are very brittle and produce cracks on drying which destroy the appearance and durability of the finish. The Japan colors serve no function except coloring and yet involve the expenditure of applying one or more complete coats. The most serious drawback to the employment of this method is that few companies are willing to spend the time and money necessarily involved and attempt to cheapen or hasten the work with consequent injury. The process actually produces too fine a surface for cars, and a certain amount of handsome finish can very properly be sacrificed for greater durability.

The "Surfacer" System is capable of producing excellent results with a smaller expenditure of time, but is little cheaper than the "Lead and Oil" Process, as the specially prepared surfacers are expensive. These paints are claimed to give better results than lead and oil, but owing to their nature are dependent upon the skill and honesty of the manufacturer and afford additional opportunity for adulteration. As the process of finishing on the prepared surface is the same as in the "Lead and Oil" Process, the objection to Japan colors applies with equal force. It is true of both processes that the necessary ex-

penditure of time and money to obtain so handsome a finish is not justified by the demands imposed.

The faults of the "Color and Varnish" Process are not as yet thoroughly understood, as the method is of very recent development and has not been subjected to the test of long-continued service. It should be understood that the aim of this shorter process is durability at the lowest cost, and that appearance is in a measure sacrificed, but it is claimed that the finish obtained is fully as durable as by the older methods, that it is free from many of their faults and that it produces a finished appearance sufficiently good for the purpose. On the other hand, the process is dependent upon specially made paints in which adulteration is difficult of detection, and which if carelessly made are not only short-lived but render more difficult the refinishing of the car. It is also claimed that the body colors employed which are in reality a sort of enamel are very apt to produce checking, but this fault can be avoided by proper manufacture. The system is only applicable to dark colors as the lighter and more brilliant pigments do not possess sufficient covering power, but this is not in itself a failing as the use of dark green and brown colors is rapidly increasing, owing to the greater stability and length of life obtained. In this connection it is of interest to note that the Pullman Company has adopted a brown body color as the most satisfactory shade available, while a large proportion of the railroads both steam and electric employ a color of similar nature.

The foregoing brief description of the methods of car finishing in use indicate the wide variation in the processes employed and the results obtained. It has been shown by actual results that a saving of \$20.00 to \$30.00 can be made on the painting of each car and an increase in life obtained of from 5 to 10 years by the adoption of scientific methods of finishing. It is probable that no one of the methods in use embody the maximum efficiency possible of attainment and in view of the very large amount of money involved it is desirable that the entire subject be given careful study by technical chemists. The improvements in methods up to the present time have originated largely with those concerns interested in the sale of paint materials, and the consumer has accepted the changes with no thorough understanding of the underlying principles. The development of surfacers, and body colors is particularly the work of the chemist, for it necessitates a knowledge of the behavior of the various pigments and vehicles under different conditions, and the limitations imposed by manufacturing conditions. It is the duty of the industrial chemist in this as in all other lines of work to select those portions of the older systems which have proven their value and to develop new materials and methods which will lead to a standardization along the lines of maximum efficiency.