Painting Railway Equipment:

By ERIC WILDE

This article covers the steps that should be taken to prepare railway equipment for painting (both interior and exterior), the application of paint, the types of paints that are available and can be used to paint railway equipment and the tools that are used to apply the various coatings.

The painting of railway equipment is a practice that is as old as the business of manufacturing railway equipment itself. Consequently, the profession of car painter is an old and honorable one. However, over the decades, as the profession has gained its venerable status, many things have changed. The coatings industry, under pressure for environmental concerns, has developed paints and finishes that were undreamed of when most of our cars were built.

Along with the advances made in coatings came many commensurate advances in application equipment, some of them as a direct result of the need to apply the new coatings. The advances have been so great in many ways that a good paintbrush, far from being all that is necessary to get into the painting business, is now just the tip of the iceberg as far as painting equipment is concerned.

Although we are restoring old railway equipment, there is no reason why the coatings and finishes that we use shouldn't be state of the art. In fact, some of the old paints that were originally used aren't even available now so we must switch to the latest types.

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This article will detail all of the steps necessary to prepare and paint railway equipment both inside and out. It will cover the all-important area of surface preparation with special emphasis on the materials encountered in a railway car. The types of coatings and finishes commonly used to paint railway equipment will be examined along with their properties and methods of application. As the story unfolds, the modern tools and equipment employed by the pros to achieve the beautiful and durable finishes that one sees today will be covered.

It should be noted in passing that there are a plethora of products designed for the automotive industry along with volumes of reference material on how to use it. Anyone who is setting out to paint their railway car is advised to examine the literature where they will find ample useful and applicable information. They are also advised to consult with their local automotive coatings supplier where they will find numerous products of direct utility. In addition, suppliers of industrial coatings (such as Rustoleum) and equipment fleet finishes (such as Dupont) should be able to provide one with much useful information, free for the asking.

Surface Preparation

The most important step, in my mind, that can be taken towards ensuring a good looking and long lasting paint job is surface preparation. This is where you should spend the most time – applying the paint, from the standpoint of the amount of work required, is almost anti-climactic.

Practically anybody can learn to spray paint but getting the surface ready is another story. This is where skill, dedication and perseverance is required. You must decide how much work you want to put into surface preparation because it will have a direct effect on the outcome of the paint job. A poorly prepared substrate will only result in paint that looks bad and fails early.

There are two goals to be achieved in making a surface ready for painting: cleanliness and flatness.

The first is important because the paint must stick to be effective. Consider a typical mode of failure of a ferrous-metal painted surface. Perhaps some minor imperfection or bit of dirt or rust remains behind under the paint film. Expansion and contraction of the metal or vibration leads to a tiny crack due to the paint not adhering properly. The next thing you know, water and air are able to penetrate the paint film and start to work on the metal. Once these two culprits start work, the rest is history.

There are other reasons why the paint will fail (flying rocks, for example) but, suffice to say that, besides being next to Godliness, cleanliness is extremely important when paint is to be applied.

Flatness is important because most surface irregularities will show or telegraph right through the paint. Think about the dry film thickness of most paints: prime coats are typically 1.5-3 mils and top-coats are typically 1-1.5 mils. Perhaps the whole paint job adds up to a layer 6-9 thousandths of an inch thick. That's not going to hide much, is it?

Another reason to strive for flatness is to avoid paint failure. At any sharp edges or abrupt changes (the edge of a pit or chip, for example) the paint film is thinner, due to the effects of surface tension (did you ever notice how difficult it is to get paint to cover the sharp edge of a piece of metal or something similar – rounded edges and smooth transitions are much easier to cover). Add to this the increase in mechanical disturbance of the paint, caused by the sharp edges that it is applied to protruding into the fray, so to speak (e.g. exterior paint is constantly being impinged upon by the passing air-stream loaded with abrasive dirt) and you have a recipe for early failure.

Flatness of the surface is not to be confused with smoothness, however. On the grand scale or macroscopic level, smoothness is desirable but down at the microscopic level a certain amount of surface roughness or tooth is important. The tooth gives the paint something to stick to. This is the reason for lightly sanding pre-existing paint (to break the glossy sheen which is very smooth) or for etching new metal (to roughen the perfect mill finish) before applying paint. It is also the reason for sanding between coats of paint, if a long period of time has elapsed between recoating (within the recoat time, succeeding layers of paint adhere to prior coats chemically because the prior coat is not completely cured).

Achieving Surface Readiness

The coatings industry has categorized surface preparation treatments for metal objects (primarily steel) based on the quality of the surface achieved (see Table 1). Not all paints require the highest level of surface preparation (although it never hurts). Paint manufacturers long ago realized that surface preparation is **the** biggest cost in a paint job and so they have formulated paints for different applications. Some, like red-lead, are amenable to being applied directly over bird-shit, while others, like certain epoxies, prefer a surface that the FDA will let your customers eat off of.

Deciding what type of paint will be applied, ahead of time, will indicate what type of surface preparation is necessary. The application instructions usually specify what is required (if they don't, ask the manufacturer). Various paints are formulated to be applied over existing paint, rust, new metal, etc. (See "Paint Selection" for more help).

At the very minimum, anything loose or flaking such as dirt, heavy bird-shit, rust, grease and oil, old paint, etc. should be removed. This can be accomplished by hand wire brushing, scraping, needle-scaling, power washing or running the car down that branch-line with the low joints. Whatever will knock things loose.

The next level of surface preparation involves wire brushing with a power tool (usually the infamous angle grinder). My personal favorite brush is the cup wheel but a straight wheel is useful too. An aggressive wheel such as a knot wheel will remove dirt, loose paint and rust much better than a straight crimp type. You should wear a dust mask and safety glasses because lots of small particles will fly off during this operation as well as pieces of broken wire from the brush.

Using the wire brush, you can remove everything that's loose or you can go right down to bare metal. I find that wire brushing doesn't really remove everything, no matter how hard I work. At a certain point it starts to spread things around and blend them together. If completely bare metal is what you want, sand-blasting is the answer.

Without a doubt, sand-blasting is the Cadillac of the surface preparations. Using a sand-blaster, it is possible to render an item surgically clean. Not only that but the minute pits left in the surface of the metal by the impact of each grain of sand provide an excellent tooth for the paint that follows. Sand-blasting is messy and time-consuming but it produces wonderful results. Appendix A describes different types of sand-blasting equipment and how it is used.

There are several different grades of sand-blasted surface preparations, as can be seen from

Rating	Name	Description
SP1	Chemical Cleaning	Use one or more of the following techniques: *Cleaner/Degreasers*: for removal of grease, oil and dirt. Apply directly to surface and rub with cloth, sponge or stiff bristled brush. *Steam Cleaning*: for removal of grease, oil, salt, acid, alkali and similar chemical residue. For maximum effectiveness, use in conjunction with Alkaline Cleaning. *Alkaline Cleaning*: for removal of dust, dirt, wax, grease, oil, fat, salt, acid residue, etc. Scrub surface with a strong detergent such as Trisodium Phosphate (TSP). *Volatile Solvent Cleaning*: Apply solvent to surface with cloths and scrub to remove grease and oil. Several successive wipings with clean cloths and fresh solvent are usually necessary. For best results follow with Alkaline Cleaning. The surface must be rinsed thoroughly with water and be completely dry before the application of the coating.
SP2	Hand Tool Cleaning	Scrape with a hand wire brush for removal of loose rust, loose mill scale and deteriorated coatings. Prior to scraping, remove grease, oil, salt, chemicals, dirt and other contaminants by Chemical Cleaning. May require Commercial Grade Blast Cleaning for problem areas.
SP3	Power Tool Cleaning	Wire brush with a hand-held angle grinder, etc. for removal of loose rust, loose mill scale and deteriorated coatings. Prior to wire brushing, remove grease, oil, salt, chemicals, dirt and other contaminants by Chemical Cleaning. Care should be taken not to polish metal surfaces or abrade them too deeply. Sound coatings which are very hard or glossy should be sanded to remove gloss. Examine carefully for signs of rust beneath coating and remove, if present. May require Commercial Grade Blast Cleaning for problem areas.
SP5	White Metal Blast Cleaning	Complete removal of all mill scale, rust, rust scale and previous coating by abrasive blasting. Surface will have a dull, gray/white appearance.
SP6	Commercial Grade Blast Cleaning	Removal of at least 66% of all mill scale, rust scale and previous coating from each square inch of surface area by abrasive blasting. Shadows and/or streaks caused by rust stain and mill scale oxides may be left behind.
SP7	Brush-Off Blast Cleaning	Removal of loose rust scale, loose mill scale and loose coatings by abrasive blasting. Tightly bonded material may be left in place.
SP10	Near-White Blast Cleaning	Removal of at least 95% of all mill scale, rust scale and previous coating from each square inch of surface area by abrasive blasting so that only slight discoloration remains but surface is otherwise free of all visible residues. Only light stains and small specks of previous coating may be left behind.
SP11	Power Tool Cleaning to Bare Metal	Power tool cleaning to produce a bare metal surface. This specification exceeds SP3 in that it requires complete removal of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products and other foreign matter. Slight residues of rust and paint may be left in the lower portions of pits.

Table 1: Recommended Surface Preparation From The Steel Structures Painting Council

Table 1. Essentially, each grade depends on how much time you want to spend. Simply removing the loose material and dirt with the sand-blaster is very quick but yields the minimum surface preparation. Removing the majority of the material on the surface yields a much better surface while removing everything and blasting the metal until it is uniformly gray/white yields the best surface preparation.

In difficult situations, where rust is present but it is not possible to wire brush or sandblast, rust reformers may be useful. Although it is doubtful that we will ever be able to truly reform rust's nasty ways, these products can help to put it in its place for a while. Most of them contain phosphoric acid and come as a heavy liquid. You paint them onto the rusted surface and they convert the iron oxide to a stable form that protects the underlying metal and is suitable for painting. Not an ideal solution (the **ideal solution** is to **remove** the rust) nor one that should be used everywhere but one that is certainly handy in a pinch.

Dealing with existing paint on a surface is also necessary because most of the equipment one sees has been painted before, sometimes many times. The old paint should be examined carefully to determine what condition it is in. Look for cracking, peeling, blisters, pin holes, chips, etc. If it is found to be intact and adhering to the surface, there is no need to remove it. If the paint lasted this long, it is protecting what is underneath just fine.

Normally, old paint that is to be left in-situ is sanded to prepare it for painting. Start work on the old paint by sanding off anything that's rough or loose. Sandpaper around 80 to 100 grit can be used for this step, followed by 120 grit. Next, move up to 150 grit and smooth everything out. My favorite tool for this step is a palm sander with Aluminum Oxide sandpaper but you may prefer a random orbit sander with Silicon Carbide paper or something else. A discussion of sandpapers can be found in Appendix B and this should prove useful for selecting the right paper for the job.

As mentioned in the previous paragraph, two types of sanders that can be used are the palm sander (accepts a 1/4 sheet of sandpaper) and the random orbit sander (accepts circular disks of paper, usually stuck in place with pressure sensitive adhesive). Both of these sanders are useful to give a surface its final preparation because they move the sandpaper in a fairly random pattern producing small swirls that aren't visible under the paint.

For heavier sanding, a jitterbug sander may be more useful. This type of sander accepts a 1/3 sheet of sandpaper and can be used to remove large amounts of material. The pattern of scratches left behind, however, is not conducive to immediate painting. Similarly, an orbital sander (using circular sanding disks) can be employed to aggressively remove material but the pattern of scratches left behind will also telegraph through the paint.

For large areas (such as a side-sheet) that need to be rendered flat and level without small undulations, a stroke sander is just the ticket. This sander accepts a long strip of paper that can come on a roll or in pre-cut lengths. Its long base removes small bumps and so on and renders everything flat. This sander should be used first followed by one or more of the other sanders to finish off the surface.

Most sanders can be purchased in electric or air-powered versions. If you have the compressor available, air-powered tools tend to be smaller and cheaper than electric tools. There is often much more choice in the air-tool line too.

One word of caution is in order here. If you are going to be doing a lot of sanding, get a pair of anti-vibration gloves and wear them. Otherwise, you may find yourself the victim of an affliction known as white-hand – the fingers start to tingle and go numb followed by turning white of the hand and fingers and then loss of all sensation. If left unchecked long enough, I'm told that the loss of sensation becomes permanent.

The idea of sanding is to make everything flat (as mentioned before). Typically with old paint, there are chips, scratches, dings, and so on that need to be addressed. With chips and scratches, the paint should be feathered out so that there are no abrupt changes in altitude. What does feathering mean? Simply that the thickness of the existing paint varies gradually from its full thickness down to zero thickness at the surface of the bare metal like the edge of a bird's feather. How do you tell when the paint is feathered properly? Easy! Look at the old

paint's edges and make sure that they are broad bands. If there are several colors, each color should change from one to the next in a broad band. Any narrow bands indicate a sharp transition. What constitutes a broad band? Perhaps 1/4 - 3/8", depending on the thickness of the paint film.

lead] or spectacularly failed paint film). The best advice that I can give about stripping is, "leave it for the next guy".

Often, you can repaint a surface without stripping, if the paint on it is sound. If the surface can be tuned up a little by feathering out

1. If old paint is peeling extensively, heavily chalked (chalking is when the paint turns to powder, like chalk dust, and is washed away by rain), blistered or cracked, it fails the test.
2. If there are obviously corroded or blistered spots, soft spots or other indicators of corrosion, the paint is no good.
3. Perform a cross hatch adhesion test as follows:
   a) Select a test area on the surface to be painted and thoroughly clean, de-wax and degrease this area.
   b) With a razor blade, scribe a 2" x 2" area in a 1/4" cross hatch pattern (this should look like a checker board). The cuts must be deep enough to reach the surface.
   c) Apply a top-quality plastic filament packing tape (masking tape isn't acceptable) over the scribed area, making sure that the tape adheres tightly to the paint.
   d) With an abrupt yank, pull the tape back parallel to the surface. Pulling straight up will not test the paint properly.
   e) Examine the test surface. If any square of old paint in the scribed area was removed, the paint fails the test.
4. Perform a solvent resistance test as follows:
   a) Saturate a cotton ball with the reducer used to thin the paint to be applied.
   b) Tape the reducer saturated ball over the scribed area for 30 minutes.
   c) Remove the ball and examine the old paint. If it has been dissolved or severely softened, it is incompatible and the paint fails.
   d) Allow a 15 minute recovery period and then perform the cross hatch adhesion test detailed in step 3 again.
5. Perform a coating compatibility test as follows:
   a) Select a new test area and lightly sand it with 220 grit sandpaper. Clean the sanded area, as appropriate for the paint to be applied.
   b) Paint this area with the paint to be applied.
   c) Allow the paint to cure for the proper amount of time necessitated by the ambient temperature (e.g. 24 hours at 70 degrees).
   d) Perform the cross hatch adhesion test detailed in step 3, on the new test area to check for inter-coat adhesion.

Chart 1: Existing Paint Fitness Tests

Removing Old Paint

There may come a time in the life of some or all of your previously painted surfaces when stripping may be necessary. There are a number of reasons to strip (unsightly paint buildup, obscured details, environmental reasons [i.e.

chips, spot-priming, etc., this is **the** way to go. On the other hand, if new paint is applied over old, poorly-adhering paint, the potential for disaster is very real. So, how do you know for sure whether the old paint is solid? U.S. Paint recommends the steps detailed in Chart 1 to test the existing paint. If your paint passes all of the

tests, it is a good bet that it is sound, whereas, if it fails, it undoubtedly isn't.

If you do decide to strip, there are several techniques, available: mechanical, heat, chemical, and freezing.

"Mechanical" means scraping, sanding, abrasive blasting or wire-brushing. Wire-brushing should only be done on surfaces that can stand the gaffe (i.e. don't even think of using it on aluminum) because the brush will try to chew up more than just the paint. Sanding should be reserved for the last pass over the surface because old paint tends to load up the paper and clog it (although stearate paper can help) and there are admittedly faster ways to remove paint. Similarly, abrasive blasting is better suited to removing rust, loose paint, etc. rather than stripping layers of old paint.

Which leaves scraping, that ancient, tried and true method. Not much has changed in the technique used for scraping since the good old days, although the introduction of the carbide scraper (mine are by Sandvik and they feature a replaceable slug which stays sharp longer and can be tuned up on the side of a green grinding wheel) means that you can scrape longer and remove paint easier than with a traditional spring steel blade. The one modification that I make to the carbide blade is to grind (once again, with a green wheel) a slight bevel on the ends of the blade so that it won't make gouges in anything soft (e.g. aluminum). Gouges are to be avoided at all costs because they may prove downright difficult or even impossible to remove by sanding (requiring filling to remove).

Scraping by itself, isn't going to get you anywhere but frustrated. The paint needs to be convinced that it should come off with the scraper. To do this, one uses either heat or chemicals.

Heat can be supplied by one of the many types of electric heat guns. I use a 1" diameter nozzle and run the sucker on high. It isn't necessary to wait until the paint blisters – it will be soft enough to scrape long before that happens. Pay particular attention to ply-metal. Too much heat can cause de-lamination of the thin aluminum skin. I have also seen problems arise with items such as doors (due to cut-outs for mirrors), etc. Heating the tiny bit of remaining material on the obverse side of the cut-out causes warping and the door no longer closes.

With sheet aluminum, the heat is sucked away from the spot being heated and the metal buckles well before the paint begins to soften. While the buckled metal usually returns to its normal shape, the bulge or indentation that is caused can render scraping very difficult. Metals such as carbon steel and stainless don't exhibit these problems and are usually easy to scrape with the assistance of heat.

If you are faced with a tough problem, chemicals may be the answer. There are two groups of chemicals used for stripping paint: organic solvents; and caustic compounds. The organic solvent of choice is methylene chloride. The caustic compound of choice is sodium hydroxide. Here is a little more information about each.

Organic strippers usually contain methylene chloride (a toxic, carcinogen – isn't **everything** that works a toxic, carcinogen?) in varying proportions and work by dissolving the old paint. Other ingredients in solvent-based paint strippers are acetone, toluene and methanol, N-methyl pyrrolidone (NMP) and dibasic esters (DBEs) such as dimethyl succinate ester and glutarate ester (see Table 2).

If a stripper doesn't contain methylene chloride, it probably won't work very well. One could argue that some of the other organic solvents are pretty good paint strippers but why mess with success? Methlyene chloride works. The only other thing that needs to be mixed with methylene chloride to yield a good paint stripper is a small percentage of wax (say 10%) to prevent the volatile liquid from evaporating before it has a chance to attack the paint. Everything else in a paint stripper is usually just cheap filler. So, the rule is generally, the more methylene chloride, the better the paint stripper and the more expensive it is.

A cautionary note is in order. Methylene chloride attacks aluminum and, in the process, yields an explosive gas. Its not as if your ply-metal will be instantly turned into plywood but, aside from the toxic and carcinogenic properties of this stuff we add explosive gas (methlyene chloride by itself is not flammable but when cut with acetone, toluene or methanol, the resulting witches brew is). Methlyene chloride evaporates

quickly and the vapors are easily inhaled and absorbed into the bloodstream where they can cause a host of problems, not the least of which are dizziness, headache, heart and lung problems and liver and kidney damage. Maybe working outside or in a well-ventilated area **is** a good idea.

Caustic compounds are those such as Peel-Away that contain alkalis. They work by breaking down the old paint into a soft goo. The goo is then stabilized by applying a sheet of plastic after which it can be peeled away in one sheet (no scraping here). They are usually formulated "for use on aluminum" and "for use on everything else". Once the paint is stripped away the surface must be neutralized by a mild acid (such as household white vinegar). After the surface is neutralized, it should be flushed with water to remove the residue and cleaned up by sanding, if necessary.

Again, caution is in order when using caustic strippers. Although there's no danger of explosion or toxicity, these products contain very strong caustic compounds that can produce severe burns, should they come in contact with skin, blindness, should they get in one's eyes, etc. Wearing rubber gloves, long-sleeved shirts, goggles and other protective gear is **more** than just prudent (see Appendix C).

Cleanup is also an area to give consideration to. Caustic paint strippers work by literally

Product	Contains	Remarks
Parks Eco Strip		30-45 mins, 10-15 coats. Oil-based and latex paints. Non-flammable, low vapor toxicity, semi-paste.
Parks Pro Stripper (1513)	Methylene Chloride Five other organic solvents Ammonia	10-20 mins, 10-15 coats. Oil-based, epoxy and polyurethane paints. Strong, non-flammable, toxic, fast-acting, semi-paste.
Parks Liquid Strip (1553)	Acetone Isopropanol Toluene Hexane N-Bytyl-acetate	10-15 mins, 4-5 coats. Oil-based paints. Liquid formula penetrates cracks, details and difficult to reach areas (great for soaking parts). Extremely flammable.
Klean-Strip Premium Stripper (KS-3, KS-221)	Methylene Chloride Isopropanol and Methanol Ethylene Glycol Monobutylether	10-30 mins, 10-13 coats. Epoxy, polyurethane, oil-based and marine paints. Strong, non-flammable semi-paste (KS-3) or sprayable (KS-221).
Klean-Strip Easy Off Stripper (WC-203)	Citrus oils	3-30 hrs, 10 coats. Oil-based and latex paints. Non-flammable, non-toxic, semi-paste.
Klean-Strip Heavy-Bodied (HB-2)		10-30 mins, 5-6 coats. Oil-based paints on metals. Non-flammable, medium viscosity.
Citristrip	N-Methyl-2-Pyrrolidone d-Limonene	Stays wet up to 24 hours. Combustible, skin irritant.
Dumond Chemicals Peel-Away (ST-1)	Sodium Hydroxide	24 hrs, coats up to 40 mils. Alkyd and latex paints on steel. Non-flammable, caustic.
Dumond Chemicals Peel-Away (ST-2)		24-hrs, coats up to 40 mils. Alkyd and latex paints on aluminum. Non-flammable, caustic.
Nu-Tec Industrial Chemical Mfg. Nu-Tec Paint Stripper	Four organic solvents	3-4 hrs, coats up to 40 mils. Alkyd, epoxy and polyurethane paints. Skins over on application and reverses the solvents back into the paint, flammable, sprayable.

Table 2: Examples of Commonly Available Chemical Paint Strippers

liquefying old paint. When you pull away the backing sheet, most of the old paint will come with it but some liquid will remain behind on the surface. You will need lots of paper towels to wipe it off, a container to safely dispose of the still-caustic waste, neutralizer and plenty of water to flush the surface with to rinse it off. And, keep in mind that this whole process is pretty messy so don't attempt it in areas where the mess could pose a problem.

The last method for removing old paint is applicable to painted metal surfaces, especially ply-metal and aluminum. It involves freezing the paint with liquid nitrogen which causes the paint to shrink more than the metal and become extremely brittle. The stresses from shrinkage cause the paint to crack, making it easy to remove from the underlying surface. The residue is a dry powder that can be swept or vacuumed up. If you are interested in this method, contact one of the industrial gas suppliers for more information.

Repairing Surface Imperfections

Ding's and other divots need to be filled with Bondo (a commonly used name for plastic autobody fillers) or some other type of filler. Large holes may require kitty hair Bondo (filler with chopped up fiberglass added to it for strength) or a fiberglass patch, although I prefer to cut out any rot and replace it with new sheet metal or build up decayed structural members by welding and reinforcement.

Most plastic fillers contain a filler material (such as plastic micro-spheres) in a styrene monomer base. When a catalyst (usually benzoyl peroxide) is added to it, the monomer reacts and cures to create a hard, plastic polymer. Fillers with fiberglass chop often employ a different base than the plastic fillers, one that uses methyl ethyl ketone (MEK) as a catalyst.

The higher quality plastic fillers are usually worth their premium price (see Table 3) because they offer superior workability, sandability and adhesion. They may even incorporate the ability to etch the metal that they are applied to (promotes adhesion) and resist bleeding through the paint sprayed over them. In short, using cheaper fillers will probably not gain one anything but grief.

Filler	Price	Rating	Viscosity	Cures	Sandability
3M	High	Excellent	Thick	Quickly	Excellent
Platinum	High	Good	Medium	Quickly	Good
Bodyman's Request	Low	Fair	Thick	Quickly	Good
Body Pro	Low	Fair	Thick	Quickly	Fair
Feather Rite	Moderate	Fair	Thick	Quickly	Fair
Golden Extra	High	Poor	Medium	Slowly	Poor
Marson	Low	Poor	Thick	Average	Poor
White Lightning	High	Poor	Thin	Average	Poor

Table 3: Plastic Fillers

Bondo should be applied in thin layers rather than trowelling it on heavily because the setting mechanism is an exothermic reaction and the build up of heat caused by using large amounts of Bondo can cause cracking or weakness. Applying it in thinner layers takes longer but ensures a better patch. The color of the activator can be varied to show the different layers, as they are applied.

Before applying Bondo, the surface must be clean and dry. It doesn't hurt to roughen the surface a bit and it is even a good idea to drill some holes in large areas so that the Bondo will have something to grip.

Immediately after applying Bondo, cover it up or prime it, if it will be outside. Exposed Bondo will absorb water which can cause problems for the paint film later on (think about steam forming under a layer of paint on a hot, sunny day).

Repairing Sheet Metal

Replacement sheet steel can be welded into place with a MIG welder. The edges of the cut sheet should be beveled to form a vee where they meet or they may be bent inwards on thinner sheets. A straight butt weld applied to the surface of the sheet will have most of the weld bead ground away when it is flattened later on, hence the reason for the vee. Magnets can be used to hold the sheet in place and to line the edges up while it is tacked. Skip welding will tie everything down before the final weld pass and prevent buckling. Car sides and other parts of lightweight steel cars were usually made of #16 gauge hot rolled steel. I keep a sheet of this stuff handy (it is very cheap) for patching and it sees plenty of use.

Fresh welds should be ground flat with the surrounding surface. I use an angle grinder with a stone for very rough work and then finish it off with an 80 grit sanding disk (if you want the latest, killer product for grinding sheet metal, try one of the layered flap wheels such as the Tiger Disk made by Weiler. They are expensive but last a long, long time. Use the next grit down [i.e. 60] from what you're used to in a sanding disk).

Lay the sanding disk flat against the sheet and move it back and forth constantly to ensure that the surface will be smooth and even and that there won't be any gouges. The Tiger Disk works especially well for smoothing and sculpting and you will find that, with practice, you can produce nearly invisible patches and repairs.

The last step, after applying a sheet metal patch, is to fill any irregularities with Bondo. Of course, if you were paying attention to the last paragraph about sculpture and you were thinking like Renoir, you won't be needing much Bondo. But, even if you didn't create a work of art, you can work carefully with the Bondo to line everything up and achieve a patch that is virtually undetectable. Exercising extra care at this step is well worth it for the quality of finish achieved in the long run.

Exotic metals (e.g. aluminum) present more of a problem, if repairs are necessary. While the exotic metals can be welded, it takes special know-how and special equipment (admittedly aluminum can be MIG welded with the proper shield gas but I've never been real impressed with the results).

I usually punt on aluminum and fix it with pop rivets. A counter-sunk rivet can be used to patch holes in an aluminum sheet by attaching the patch to a backing piece. Strips of backing are first riveted around the edges of the hole so that they stick out 3/4". Next, the patch is cut out to fit the hole and then riveted in place. After the rivets are ground flush and filled (I use an aluminum-powder-bearing epoxy filler called Metal-to-Metal) the patch is invisible. One tip is to bevel the outside edges of the patch and the hole so that the joint between them can be filled with a goodly amount of filler. This should prevent hair-line cracks later on.

Repairing Ply Metal

The interior walls of many cars are constructed of a material called ply-metal. This is essentially a sheet of plywood (of varying thickness') laminated to a thin overlay of aluminum sheet on both sides.

Prior to painting the interior you may need to make repairs to ply-metal. It has, in my experience, two modes of failure. The first is when the aluminum sheet de-laminates from the plywood (usually due to the presence of moisture). This type of failure can be repaired by cutting out the de-lamination and filling it with another piece of sheet. The new sheet is glued in place with Resourcinol glue (a two-part glue available from DAP [among others] at better woodworking supply stores). If it is a large patch, I add some counter-sunk flat-head screws to hold it in place permanently.

The second mode of failure is more serious and usually results when a great deal of moisture is present (say from a periodically exploding toilet). In this case, the ply-metal is rotted out and there's nothing substantial left (a third mode of failure results when the idiots from the movie company cut a hole in a wall with a Sawsall, but that's another story).

If the rot is only beginning, one of the liquid epoxy rot repair products may be able to stabilize it. If so, the de-laminated sheet may then be patched (as described in the preceding paragraph) or a heavier piece of aluminum plate may be spliced into the good plywood to provide reinforcement.

Replacing a missing or totally destroyed ply-metal wall presents two problems. One is to remove and re-install the wall (railway

Paint	Examples	Composition	Remarks
Epoxy	Dupont 25P, Corlar 26P Rustoleum 9100, 9300 Griggs DC733 Anchor 3900, 3950 Ben Moore M33/M34	Catalyzed epoxy resins Acetone, MEK or other ketone solvents	Tough, impermeable, long-lasting. Excellent long-term solvent, chemical and abrasion resistance. Used for priming and surfacing under high performance coatings. High-build can fill small surface irregularities and pits.
Polyurethane	Dupont Imron 326, 333 Rustoleum 9400 PPG DCC US Paint Alumigrip Griggs MIL-C-83285B, MIL-C-83286B Anchor Ancothane 9400	Two-component aliphatic polyester resins (cross-linked by isocyantes)	Hard, super-gloss finish. Superior corrosion and chemical resistance. Extremely impact and abrasion resistant. Longest lasting. Product of choice in transportation industry. PPG DCC and Anchor Ancothane are acrylic urethanes which are even tougher than polyurethane.
Acrylic enamel	Dupont Centari	Similar to alkyd enamel but modified with acrylic resin	Dries by solvent evaporation, is not sticky when dry and cures by oxygen absorption. Centari is one of the most forgiving paints.
Industrial Alkyd enamel	Dupont Dulux 30P, 31P, 34P Rustoleum Labor Saver Ben Moore Iron Clad 163, M24 DTM	Alkyd resin VM&P Naptha, Stoddard solvent	Tough, flexible films having excellent color and gloss retention. Dries by solvent evaporation, is sticky when dry and cures by oxygen absorption. Use in mild to moderate environments. Periodic recoating necessary.
Architectural Alkyd enamel	Kelly Moore 1625, 1630 Ben Moore Impervo 235, Dulamel 207	Alkyd resin Stoddard solvent	Interior alkyd enamel can be used in the interior of equipment with excellent results.
Primer	Dupont 25P, Corlar 26P Rustoleum (many kinds) US Paint G9072 (ZnCr) Kelly Moore 1710, 1711 Ben Moore M06/M07	Formulated to adhere like a bandit to the substrate	Can be epoxy, alkyd or acrylic. Special paints like zinc-selenium for cathodic protection, zinc-chromate for aluminum and others are available for solving special problems.
Rustoleum Damp Proof Red Primer	Rustoleum 769	Alkyd resin Fish oil VM&P Naptha solvent	Used on rusted steel only. Fish oil penetrates rust to the metal and drives out air/moisture. Bonds tightly to rust. May be applied to slightly damp surfaces.
Surfacer	Dupont 25P Rustoleum high build 9500 US Paint D8003, D8002	Formulated for sanding	Can be epoxy, alkyd or polyurethane. Surfacers are normally used with automotive finishes. A high build epoxy can be used on railway equipment exteriors.
Acrylic Enamel	Rustoleum 3000, 3100 DTM, 5200 Kelly Moore 1725 Ben Moore M04-01, M29 DTM	Acrylic resin Water solvent	Fast-drying. Better gloss and color retention than alkyd enamels. Low toxicity and odor even in enclosed areas. Easy clean up with soap and water. Can be applied direct to metal: steel; galvanized steel; aluminum.
Acrylic Epoxy	Dupont Corlar 76P Rustoleum 5300 Ben Moore M08/M09 Griggs Hydropox #2	Catalyzed Acrylic Epoxy resin Water solvent	Fast-drying. Low toxicity and odor even in enclosed areas. Easy clean up with soap and water. Excellent base for high-performance topcoats.

Table 4: Paints For Painting Railway Equipment

equipment is put together like automobile dashboards – in layers – and the layer you're trying to work on is at the bottom) and the other is finding new ply-metal.

Removing and replacing the wall is done however is necessary. Screws can be cut with a thin saw blade, the wood can be cut in half, etc. One method to consider for re-installing the wall is to cut it in half, rout two recesses (before cutting) to accept an aluminum splice plate, install the wall and then splice and patch it with Bondo after installation.

The tools used to work with ply-metal are standard woodworking tools, although I prefer to use carbide cutters and blades. You may want to reduce the feed rate and/or cutting speed and use blades with a greater number of teeth. Otherwise, I have found ply-metal to be very amenable to working with portable saws, jig-saws and routers. Also, like plywood, it can be chiseled, planed, etc. Don't let that aluminum bother you, its like paper anyway.

And speaking of finding ply-metal, where **do** you find it? The best source is a company that supplies sign blanks to the advertising industry. They will have this sheet in 1/4" and 1/2" thickness and sometimes 3/4". It comes coated with paint (shiny and meant for screen-printing with ink) that can be scuff-sanded with 320 grit and painted directly (after you peel off the plastic protective sheet).

If you need other thicknesses, good luck. Some wood shops will laminate it up for you but this approach is very expensive. Try fabricating it yourself out of a top-grade plywood and aluminum sheet. The glue to use is Resourcinol or epoxy or maybe polyurethane (something with a long set-up time may be necessary to allow you to get the sheets together) and the clamping method of choice is a vacuum press.

In a pinch, you can use MDO plywood which is an exterior type plywood made of hardwood veneer overlaid with a resin-treated fiber overlay. Medium density overlays are designed with just the right tooth for smooth paint application, making MDO the preferred panel for sign manufacturers. Consequently, it should also be available from any company that supplies sign blanks to the advertising industry. I have seen at least one car remodeling job done with this material and, when painted, it makes a very acceptable substitute for ply-metal, if the real thing isn't available.

Paint Selection

All paint consists of pigments, resins and solvents. The resin is the coating material while the pigments determine the paint color and the solvents reduce the paint to a workable viscosity. Given this basic formula for paint, there are many different ways to produce useful paints and this yields many kinds of paint that are appropriate for use on a railway car. The type of paint being used will depend on the particular application. Table 4 lists most of the paints that are available and shows some of their characteristics. I will discuss the uses of each, where appropriate.

If we start outside the car, the properties that we are looking for in a paint are: protection against severe corrosion and abrasion; chip resistance; longevity; resistance to fading; ease of application (i.e. minimal surface preparation); and lowest cost. Pretty impressive list, huh? Good luck finding this miracle coating. Actually, it isn't possible to meet all of these criteria but it **is** possible to come close.

When one considers the longevity of a coating and the amount of work involved in preparing the surface, the cost formula looks much different than just the initial cost of the paint (see Table 5). If this is done, the epoxy paints look pretty good. Epoxy provides excellent protection against corrosion and exhibits toughness against chipping and scratching. High build epoxies can be used as a surfacer as well as a primer. Although its color can fade significantly in a short time, the longevity of the coating is high (the fading does not affect its performance). Epoxy paint is easy to apply (can be brushed or sprayed), but there is a problem with pot life (once mixed, the paint will harden in a few hours to a few days). The net result is that epoxy should be considered for the exterior of a railway car in all places (roof, sides, underframe, etc.) as a primer and intermediate coat in a 2- or 3-coat system.

The primary problem with epoxy is its color fading. Although it continues to offer protection to the painted surface, the aesthetic quality will diminish rapidly. Fortunately, there is polyurethane paint which has an unsurpassed,

long-lasting aesthetic quality. Many paint manufacturers offer a two- or three-coat system whereby polyurethane is applied over epoxy to give a tough, long-lasting **and** beautiful finish.

Polyurethane's biggest drawbacks are its cost (perhaps $75-$150 per gallon) and its dangerous properties. The cost is actually excellent, if you consider longevity but there is no getting around the danger. Basically, polyurethane is poisonous (remember the methyl-isocyanate leak in Bhopal – same stuff). It comes in two parts (the paint and the activator) and before, after mixing and until it has cured, the vapors or atomized paint must **not** be breathed. Application **must** be done while wearing a supplied-air respirator with a full-face mask and there **must** be a good supply of fresh air to disperse the vapor. **No kidding**! I've seen people get very sick just from breathing a small amount of residual vapor.

Inhalation of isocyantes may sensitize a person, causing an asthma-like reaction. The reaction may occur within days of exposure or may take months or years to develop. Once sensitized, a person is likely to experience recurring shortness of breath upon repeated exposure. Direct skin contact causes rashes, blistering and reddening. Repeated contact may cause skin sensitization. Exposure to airborne isocyanates can cause eye irritation and temporary blurred vision. Direct contact with the eye may cause cornea damage, hence the need for a full-face mask, supplied air respirator.

Polyurethane essentially is plastic that you make at the site. Once you mix it, it's going to turn into plastic, one way or another. The pot life is about eight hours (shorter on hot days) so only mix what you need. Furthermore, it cures by absorbing water so it must be kept dry while curing (roughly four hours). If the paint gets wet (this includes condensation as the sun sets as well as the more obvious sources of moisture such as rain), it **will** go nuts – you **won't** like what happens.

Other than these little problems, polyurethane sprays pretty much like regular paint (it is thin so it levels exceptionally well but it will not hide sharp edges and may form runs and sags easily) but it cannot be applied any other way except by spraying. Once it is on, the finish cures to a hard, glossy surface that looks good for a long, long time. Many car owners consider this paint to be **the** finish of choice for car roofs and sides.

If polyurethane makes you nervous (or poor) you might consider acrylic enamel instead. I have seen several beautiful paint jobs done with Dupont Centari and there are some proponents of it who claim that it effectively lasts just as long as polyurethane – it certainly is more amenable to the repair of rock chips, scratches, etc.

Enamel (either alkyd or acrylic) can be used anywhere and it is very easy to apply, with brush and spray being the preferred application methods. The main disadvantage of enamel is

Paint/Surface Prep	Service Life	Initial Cost per Foot				Cost per Foot per Year
		Surface Prep	Application	Paint	Total	
2-Coat Alkyd Hand Tool Clean	2 yrs	$0.49	$0.41	$0.10	$1.00	$0.50
3-Coat Alkyd Hand Tool Clean	4 yrs	$0.49	$0.61	$0.15	$1.25	$0.31
3-Coat Alkyd Commercial Blast	7 yrs	$0.82	$0.61	$0.15	$1.58	$0.23
1-Coat Epoxy Hand Tool Clean	5 yrs	$0.49	$0.26	$0.22	$0.97	$0.19
2-Coat Epoxy, 1-Coat Polyurethane Near-White Blast	12 yrs	$0.98	$0.84	$0.31	$2.13	$0.18

Table 5: Coating Cost per Year of Service Life

that it doesn't last as long as epoxy and it may fade in color. Otherwise, it is safe and easy to use and relatively cheap to purchase (although more expensive, if application costs are considered – see Table 5).

The acrylic enamels, such as Centari, may be used with a hardener which alters their durability to be more like that of polyurethane (many automotive shops swear by this system). Unfortunately, this hardener is a cyanide compound so the danger associated with using this paint increases significantly to the point where it is similar to that associated with polyurethane. I have had many auto-body guys tell me that they spray paint with hardener and even polyurethane with only an organic vapor respirator but I wouldn't try it.

Regardless of the kind of paint that will be used for the finish coat, once the surface is prepared, the first one or two coats of paint should be primer. The primer stops corrosion and glues itself to the surface (some primers contain special additives such as fish oil to penetrate rust and stop it. In any case, all primers contain additional binders to adhere them to the surface being painted). A second coat of primer, perhaps a contrasting color, may be applied for added protection.

If you want the finish to look extra good, follow the prime coat or coats by one or more coats of surfacer. The surfacer is designed to be sanded to produce a very smooth finish to which the top coat is applied. This step is common in the automotive refinish business but probably is unnecessary for the exterior of railway equipment, especially if epoxy or high build epoxy primers are used.

In general, the primer is chosen to work with the top coat. The recommendations of the manufacturer should be followed but here are a few rules of thumb. A primer can be like its top coat (e.g. alkyd/alkyd). Epoxy is generally good under anything, especially polyurethane. So is alkyd, given a good chance to cure (say for a month). For acrylic enamels such as DuPont Centari, an epoxy primer may be used instead of an enamel primer.

The top coat or coats are applied to seal the primer and yield the final finish and color (most finishes will cover in one coat but a second coat may be necessary to achieve proper hiding – the primer can also be selected to be close in color to the top coat to aid with hiding).

Car interiors can be painted using the same kinds of paint as noted for car exteriors (although polyurethane is not really appropriate). Epoxies make good, long-lasting finishes in critical areas such as kitchens where frequent scrubbing is likely but be sure to choose a paint that is acceptable to the FDA for incidental food contact areas.

The remainder of the car's interior surfaces can be painted with a good quality alkyd house paint (using house paint allows you to get any color that you want, tinted by your paint dealer). You will probably want to spray this finish so choose one that levels well without orange peel. Not all house paints will do this, but I have found Benjamin Moore Impervo Satin to be excellent. If you aren't sure, get a quart mixed up and try it to see.

For interior surfaces, they consisting mostly of aluminum in lightweight cars, you may want to use a primer meant especially for aluminum on any new (or stripped) surfaces. I prefer zinc-chromate primer and apparently so did the car builders because they seemed to apply it to **every** piece of aluminum on the cars I've seen. Even the backs of aluminum sheet in walls and other places were given a coat for added protection. Other primers may be acceptable for use on aluminum (if in doubt, contact the manufacturer of the intended paint) but this isn't true in all cases. Zinc-chromate will take a bite out of aluminum, forming a permanently-adhering finish which is what we want, isn't it?

A direct-to-metal acrylic paint also works well as a primer for aluminum. I have had success with Rustoleum's 3081 water-based acrylic primer applied under alkyd house paints in car interiors. This kind of paint is great for painting during winter time when fast dry time (i.e. while the heat is on) and no possibility of good ventilation is a requirement.

Estimating Paint Needs

Once you have selected the paint that you wish to use, you should check the manufacturer's recommendations for dry film thickness and coverage. Using these figures and the desired thickness of the film that you wish to apply, you can determine how much area a given quantity of

paint will cover. Thicker films will provide more protection but will also require more paint and result in a corresponding reduction in the area that can be covered.

You should estimate the entire surface area to be painted by breaking it down into smaller constituent parts whose surface area can be estimated (see Chart 2). Calculate the surface area for each constituent part and then add them all up to arrive at a total. Don't forget to leave out cut-outs such as windows.

Shape	Area Formula
Rectangle/Square	length * width
Triangle	height * base / 2
Circle	radius * radius * 3.14
Sphere	radius * radius * 12.56
Cylinder	diameter * height * 3.14
Pipe	diameter * length * 3.14

Chart 2: Areas of Various Simple Shapes

The amount of paint necessary is the total surface area divided by the practical coverage of the paint. This will give an estimate of how many gallons of paint to buy, have tinted, etc. Remember that the type of paint gun used to spray the paint can have a large effect here. Depending on whether it is a traditional or HVLP gun, it may put up to 50-60% of the paint into the air, not on the surface being painted (see Appendix E).

Final Preparation

Now that we've prepared the surface for paint and selected the paint to use, we're ready to apply the paint – almost. Before you start, check the weather forecast (if painting outdoors), prepare the area for painting and get everything ready to go. Once you start painting, stopping to screw around isn't good. Unless there is a natural place to break off painting, stopping will produce lines or obvious joints.

I am assuming that you will be applying the paint with a spray gun so we'll proceed accordingly (scope out Appendix E for more information on spray guns). First check over the surface to be painted for any minor imperfections, etc. and repair them. If the recoat time has passed on a previously painted surface, lightly scuff sand it to break the gloss and give the next coat of paint some tooth to stick to.

Wipe down all of the surfaces with clean rags and solvent. You should use the two-rag method to perform this step. First, wet one rag with solvent (each paint manufacturer has a special solvent that they recommend for this job but mineral spirits work well) and wipe off an area about 4 square feet. Next, before the solvent evaporates, wipe it off with a second, clean rag. Repeat this process over the whole surface using a clean section of both rags on each new area. When a rag becomes dirty, throw it away and always ensure that the first rag is wet, not just damp, with solvent.

If the surface is really dirty, wash it with an industrial type detergent and rinse it off with lots of clean water. For new or shiny metal, you may want to etch it with a mild acid (such as Metal Treat) to give it tooth (rinse well and wipe off any powder that forms) or you may want to use a self-etching primer such as DuPont Variprime. Automobile manufacturers next apply a zinc phosphate acid treatment to new steel followed by another rinse to remove the acid. If you do this step it will provide extra corrosion protection and improve paint adhesion. Finally, the surface is allowed to dry thoroughly.

Clean up any dirt and dust that surrounds the area being painted (the spray gun will blow it onto the fresh paint where it will surely stick – not the desired effect). Vacuum and/or wash any floors next to walls and wet down any loose dirt (outdoors). Mask off any areas where over-spray is likely (and even some where it isn't) using painter's masking tape and masking paper.

Tape any striping or other details that are to be left a prior color. Always try to paint stripes and such, where practical, from a lighter to darker color (e.g. paint a yellow stripe first and then paint the blue surrounding it next).

Give all of the surfaces to be painted a final once over to make sure that there is no dirt or dust to mar the paint job remaining anywhere. A painter's tack rag should be used as a final wipe rag, at the very last moment before spraying, to remove any dust.

Get out all of the supplies that you'll need: paint; activator; solvents; rags and paper towels; paint gun; etc. Set up your ladder or scaffold, if necessary, at the first spot to receive paint. Drag

out the air hoses and position them to reach the job.

Before you begin spraying, it is a good idea to take care of your bodily functions, eat lunch, etc. Once you get started, stopping to do something else can cause problems with the finished look.

If you'll be spraying polyurethane paint, hook up the supplied-air respirator (see Appendix D for more about respirators). I position the compressor for mine about 150 ft. upwind of where I'm painting and I'm still alive but be sure about this because, if you smell almonds, you're in trouble. With most paints, it is a sound idea to wear a respirator at all times (even alkyd enamels can cause a sore throat, dizziness and nausea) so get in the habit of putting it on before you open the paint cans.

In addition to a respirator, consider wearing gloves and some kind of body protection such as a Tyvek suit or, at a minimum, a long-sleeved shirt and long pants (bear in mind that many organic chemicals can be absorbed through the skin, including many of those chemicals used in your favorite paint). The gloves that I prefer are nitrile and they look like dishwashing gloves. They have the best tactile feedback that I've found (one word of caution – lacquer thinner and ketones such as acetone and MEK will soften them in a few minutes rendering them easy to tear). Before you don the gloves, blow them up like a balloon and squeeze them shut at the cuffs. If they won't stay inflated, toss them out and get a new pair (see Appendix C).

Paint Mixing/Reducing

Open up the paint can and stir the paint thoroughly to ensure that the pigment and resins are distributed evenly. Do this even if the paint was mixed mechanically beforehand. Some epoxies may require that the activator be stirred also. **Always** use separate tools to mix and measure paint and activators. A tiny bit of either one can contaminate an entire can of the other (unless, of course, your **goal** is to make some plastic curling stones).

Pour the paint and optionally the activator into the paint pot through a strainer. Straining with a paper filter cone is an easy way to ensure no surprises (e.g. a gun clogged by some foreign material and filled with rapidly setting paint). A filter costs 15-20 cents per use and they are easy to find (most big paint stores sell them in boxes of 100). Compared to fifty or a hundred bucks a gallon for paint, a few cents for a strainer is a cheap insurance policy.

Try to mix only as much paint as you'll need or feel comfortable spraying. As you go, you'll get an idea of what kind of coverage to expect or, if possible, try a small area to get a better idea. Alkyd or acrylic enamels can be poured back into the can in a pinch but activated paint and acrylics mixed with hardener are history in a relatively short time after they are mixed.

Also, some of the newer alkyd enamels, which use the latest low-VOC formulations, especially if they have been thinned for spraying, can cause problems such as seeding when they are poured back into the can. Given the choice of saving a few dollars worth of leftover paint along with the possibility of contaminating a whole gallon of paint or throwing away the few bucks worth of paint remaining in the gun, I choose the latter.

Another thing to bear in mind is that, should you run out of paint on a large, flat surface, by the time you mix up some new paint, the paint will have dried on the surface and the new paint won't blend. Consequently, you should try to mix an amount of paint that will take you to the edge of a panel, molding or some other logical stopping place (either that or stop, before the paint runs out, at a good spot).

There are two measuring devices that you will find very handy for mixing activated paints: soup ladles; and coffee cans. Soup ladles come in a handy 8 oz. size and can be used to scoop paint out of the can without making a mess. They are cheap and the chrome plating cleans up easily with solvent. Coffee cans are plentiful (especially if you co-habitate with a coffee addict, as I do) and they have the added benefit of coming with a resealable lid. Calibrate a few ahead of time with a kitchen measuring cup and tap water. A small dent (visible on the inside of the can) should be made at the 8, 16, 24, and 32 oz. marks with a screwdriver blade, nail, etc. (being careful to dent only, not punch through) or the natural rings stamped in the can may be employed.

Mix up the paint in the correct proportions (I could tell all sorts of funny stories about this so

make sure you get it right – apparently, its easy not to). If it needs an induction period (i.e. time to contemplate the meaning of being paint before it is applied), mix it ahead of time and let it stand as required. For big jobs, having one person to spray and one to mix, etc. is a definite plus.

Reducers (painter's jargon for thinner) are: mineral spirits (Stoddard solvent); VM&P Naptha; toluene; xylene; ethyl acetate; butyl acetate; acetone; and methyl ethyl ketone (MEK). Various blends of any or all of these solvents in combination with retarders, accelerators and leveling agents are used to reduce the viscosity of the paint to a sprayable consistency, accommodate climatic conditions (e.g. temperature and humidity), facilitate leveling, speed drying, etc. In general, the smaller the molecular size of the resin (resin size is usually inversely proportional to the solids content), the less reducer required. Following the advice of the paint manufacturer with respect to reduction is wise unless you are familiar with the finish being sprayed.

If a reducer is necessary, add it in small amounts until the desired consistency for spraying is reached. Most paints come with a time marked on the can (e.g. 15 seconds in a #2 Zahn cup), that indicates the ideal spraying viscosity. So what the heck does that mean, anyway? Simple! A Zahn cup is a little cup with a fixed volume and a carefully sized orifice drilled in the bottom. You fill it with paint and time how long it takes the paint to run out of the hole. When it matches the time given (in our example, 15 seconds), the viscosity is correct for spraying. In the software business, we call this a kludge – in the paint business, its called a Zahn. Another name for this kludge, in the paint business, is a #4 Ford viscosity cup – same idea.

Anyway, the pros just eyeball it or time how long it takes for the paint to stop dripping off of the end of a stir stick (say four seconds). If it runs pretty good, it will probably spray pretty good (actually, most anything will spray, its just a question of how will it level out or run and sag and how good it will look when you're done).

You can spend plenty of dough buying the approved reducer with the paint manufacturer's name on the can or you can try my favorites: MEK (methyl ethyl ketone) for epoxy and VM&P (Varnish Maker's and Painter's) Naptha or mineral spirits for alkyd enamel. Polyurethane, having roughly the same viscosity as water, needs no improvement nor do some of the newer alkyd formulations which are sprayable right out of the can or with the addition of a small quantity of mineral spirits.

One other thing: unless your name is Speedy Gonzales, you can probably skip adding any accelerator to your paint. The pot life is usually short enough as it is and the accelerator will only make it shorter. If being assured of an adequate drying time is not possible (or if you are painting the day before a charter) you may wish to use it but, otherwise, I wouldn't.

Paint Application

Begin spraying by testing the flow rate, spray pattern, etc. on a piece of scrap or someplace hidden. I make a note of my paint gun settings for each kind of paint, as I become familiar with the gun. That way, I can load the gun with paint, dial up the numbers and begin blasting with a minimum amount of fine tuning.

You should hold the gun about eight to ten inches from the surface to be painted and at right angles to it. Start off of the surface, if possible and trigger the gun to start the paint flowing (any spattering will not mar the surface). Move the gun in a straight line, holding it perpendicular to the surface and moving it at about one foot per second. Avoid sweeping the gun in an arc as this will result in an uneven application of the paint at the ends and center of the arc. Continue your pass right off of the end of the panel before releasing the trigger. Start the next pass so that it overlaps the first pass by half and continue in this manner.

The paint should go on with the edge of each stripe having a dry appearance and the center of each stripe appearing slightly wet or shiny looking (this is called a medium wet coat). If it goes on wet, the paint will level and look good. If the paint goes on too dry, the surface will acquire a dry textured look like fine sandpaper. If the paint is too thick or has lousy leveling properties it will orange-peel (the surface of the paint will look bumpy like the surface of an orange).

There is a fine line between too thick and too thin, too heavy and to light when spraying paint. If the paint is too thick, it will not level properly. If it is too thin, it will run and sag. Similarly, if

the paint is applied too heavily, it will sag, curtain (long lines of sagging paint caused by the paint running down in a united front, like a wave) or run. And, if the paint is applied too lightly, it won't hide and may telegraph unwanted detail such as surface imperfections. If you do have problems, **resist** the temptation to fix them when they happen – they'll only get worse. Rather, fix them up later when the paint has cured (its not as hard as it sounds).

Other problems that can occur from laying down the paint improperly include failure to protect the underlying surface (dry film thickness too thin) and pores in epoxy (epoxy outgasses slightly when curing. If the paint is applied too heavily, the outgassing will cause a tiny bubble to form. When the bubble bursts, a pore is left behind that can allow water and air to penetrate the film). Effects such as fish-eye (a circular, eye-like appearance to the painted surface) are usually caused by surface contamination (especially by contaminants containing silicone). Orange-peel can be caused by surface contamination as well as poor leveling.

The proper approach to use when spray painting is to lay down several thin coats of paint, one on top of the other, with a short drying time in between (if it isn't practical to allow only a short drying time in between, scuff sand between coats that have cured for longer than 72 hours). Each coat should go on slightly wet or shiny looking. The last coat may go on a little wetter than its predecessors because it has something to stick to. This approach works much better than trying to apply the paint as a single, thick coat in one pass.

Most paint guns spray in a fan-shaped pattern (although my HVLP gun will also produce a circle). The motion to use when spraying, with this kind of spray pattern, is back and forth or up and down in a series of partially overlapping stripes. The air cap can usually be rotated so that the fan is at right angles to the direction of motion (having the fan set at 90 degrees to the direction of travel will lay down a wide stripe) while the gun handle is aligned with you hand so that it can be held at a comfortable angle.

Start painting the spot that is farthest away or hardest to reach (you want to work toward yourself so that you never have to lean on or over the freshly painted area). To reiterate, if you are painting flat or gently curved surfaces, move the gun along in a straight line at an even pace while holding it equidistant from the surface being painted at all times (think about what will happen if the motion is jerky or if you pull the gun away from the surface as you go – the paint is spraying out at a constant rate and it will either build up or get too thin). **Do not** swing the gun in an arc with it far away from the surface at the beginning and end of the arc and up close in the middle. If at all possible, begin and end each spray pass off of the surface being painted. As you make each stripe, overlap the previous stripe by 50 percent.

You can work on any area that is commensurate with your reach. Try to move your whole body as you go back and forth in a smooth, flowing motion. If you want to ensure even coverage, lay down two sets of lighter stripes at right angles to each other. Connect each area to the next before it dries too much or you will have a problem with leveling and misting that can be visible in the paint after it dries. If you must stop (e.g. to refill the paint pot), try to do so at a natural break such as an edge, window frame, seam, molding, etc. where it won't be obvious to the eye. Small imperfections due to misting can be rubbed out with rubbing compound later on, if absolutely necessary.

If you are painting oddly-or irregularly-shaped parts (e.g. undercar components), try to aim the gun at each part from several different angles. Remember, the air (and the paint it is carrying) doesn't go around corners – it only goes one direction (i.e. straight-in) – unless you are using an electrostatic rig. Also remember that, if you can't see it, it probably doesn't have any paint on it.

You will usually start out by applying one or two coats of primer and possibly a coat of surfacer, followed by one or two finish coats. For primer, if two coats are being used, I like to apply a contrasting color with each coat. In this way, I will notice any holidays (a spot not receiving any paint) and, hopefully, correct them.

The finish prime coat should end up being a light color (gray is frequently the choice of discerning painters). Once the primer has cured, study the surface carefully under glancing light. Either wait until the sun is shining at an oblique

angle so that it glances off the roof or car sides or shine a strong light parallel to the surface of walls, etc.

The combination of the strong light, low illumination angle and the light color of the primer will cause any surface imperfections to be highlighted by shadows so that they stand out. Each imperfection can be circled by a pencil so that it will be visible later on when it comes time for final repairs.

The inevitable small nick can be filled with automotive spot and glaze putty. This product is formulated for application over primer and it needs no priming afterwards so it can be used for fixing small areas without requiring repainting. Major divots must be filled with Bondo, sanded out and re-primed.

Once all of the imperfections are repaired, the surfacer, if any, is applied. If you chose a primer that can be sanded or if you aren't looking for a mirror-like finish (or you are just tired of sanding), skip this step. Otherwise, apply the proper surfacer for your chosen paint system, hopefully in a contrasting color and allow it to cure for a few days.

Now, the final sanding should be done. For a surface as smooth as the proverbial baby's bum, you can't beat wet sanding, preferably with 320 grit silicon carbide wet or dry paper. When sanding with this paper keep it well flooded with water. The water will float away the material removed and prevent the paper from clogging (clogged paper can cause scratches as well as wearing out very quickly). Remember that you are not trying to remove too much material. Just smooth things out. The surface is smooth when it appears uniformly dull.

Applying the final coat or coats of paint is just like applying the primer coat or coats. Work on areas that are easy to reach, don't overreach fresh paint, hold the gun level and lay down overlapping stripes so that the paint looks wet. If you are using polyurethane, don't let it spook you. To me, it sprays pretty much like any other enamel or epoxy.

Striping

Striping can be applied in two ways: painted on; or taped on. Wide bands are usually painted on while narrower bands or reflective stripes are taped on. If you have the time and the patience to mask and spray narrow stripes, there is no reason not to paint them on, however.

Products such as Scotchcal and Scotchlite can be used for striping that appears clean and crisp and is easy to apply. This kind of striping is preferred for separating wider color bands, along the edges of side sheets and belt rails or anywhere that a reflective, safety stripe is desired. Essentially, these products are a polyester tape, available in a wide variety of widths and colors, that is applied much like any other adhesive tape. Once it is applied, the adhesive laminates the tape onto the paint to form a strong, unbreakable bond.

If you are spraying on color bands or stripes, plan the painting sequence so that you paint the lighter colors first. Spray the underlying color so that it extends six inches past the boundary between the two colors (e.g. for a six inch stripe, spray approximately 18 inches) and so that the coat of paint tapers off in thickness to the surface. The idea is to avoid any sudden changes in thickness that will telegraph through the overlapping color. You may even wish to sand the first color nearly up to the boundary to feather it out.

Apply the masking using a good quality striping tape like 3M FineLine plastic tape and masking paper, if necessary. Make sure that all of the edges are pressed firmly into the surface so that the paint will not bleed under the tape by capillary action and leave a ragged edge.

Once you have sprayed the paint, allow it to cure for the amount of time specified by the manufacturer and then remove the masking promptly. Pull the tape off carefully by doubling it back, flat on itself and pulling away from the paint at 45 degree angle. This will ensure that the tape peels cleanly away and doesn't remove any fresh paint.

Lettering

Lettering, like striping, can be applied by either painting it on or by using adhesive films such as Scotchcal or Scotchlite (described in the article, "Lettering Railway Equipment"). If you have the time and patience to cut and apply stencils, painted on lettering is the way that it was done in the past. Most lettering, however, is done with adhesive film nowadays because the

time to apply lettering film is much shorter than the time required to paint on lettering and the results are just as good or better.

Should you wish to paint on lettering, the first step is to have a stencil cut or to cut one yourself. Many places that paint signs, billboards, etc. can either cut stencils or direct you to someplace that does. If you elect to cut your own stencils, you will need a large, clear, flat area where you can lay out the stencil film and cut it.

Lettering patterns are pretty easy to generate, especially if you have a computer and a laser printer. There are literally hundreds of fonts available and you can pick one that you like or that matches what you need. Having enlargements made of these letters will give you any special patterns that you require. Otherwise, many common patterns are available from the places that cut stencils. Much of the period car lettering was done with the famous Railroad Roman font which is a classic serif font that is close to Times Roman (and **everybody** has Times Roman).

Sheet products are now all cut by a machine that features a computer-driven cutter that follows an outline of the chosen font. As a result, the selection of fonts available is huge (font libraries often have upwards of 600 fonts). On top of this, practically anything that can be digitized can be used to generate an outline that will drive the sheet film cutter.

After you receive your cut stencil, carefully apply it to the car side using layout lines measured from the edge of the side sheet, belt rail, etc. Use something that won't permanently mark the paint, such as a soft pencil, water soluble marker or registration marks made with small pieces of tape.

Stencils are applied in the same manner as lettering film, by removing the backing paper and carefully pressing the stencil film in place according to the layout marks. Be sure to rub down all of the edges to ensure proper adhesion and eliminate bleeding of the paint under the stencil. Mask around the stencil with masking paper, if you anticipate overspray problems.

Spray the paint at the stencil just as you would normally spray the surface that it is applied to. Start off of the cut-out area and stroke the gun in stripes, as usual, ending up off of the cut-out area. Paint the entire stencil in this manner, overlapping each stripe, the same as always.

When the paint has dried the requisite length of time, the stencil should be carefully removed, exercising caution so as not to peel off any fresh paint with the stencil. A sharp knife may be useful in cutting just through the paint so that the stencil pulls away cleanly from any problem spots.

Finishing Touches

Once the final coat of paint is applied, there are a few things that can be done to enhance your paint job and keep it looking great.

Satin-finish surfaces, such as those found in car interiors, can be kept clean by washing with warm water and a mild detergent. The occasional scratch or chip can be touched up with a small artist's paint brush without appearing too bad. Besides keeping the paint clean and touched up, nothing much else needs or should be done to it.

Glossy-finish surfaces need slightly more work to keep them looking great. Small imperfections, including misty areas caused by overspray from adjacent panels, can be rubbed out using an automotive rubbing compound, available from your paint supplier (see Table 6 for information about the ubiquitous Meguiar's rubbing compounds). Rubbing compound is essentially a very fine abrasive suspended in a lubricant so it removes paint as you rub. Go easy and don't rub through the paint or you'll be very sorry.

Outside paint should be given an initial coat of wax (after it cures for a few months) and then maintained by a periodic application of wax (say once a year). A good quality automotive wax should be used and then buffed out (a powered buffer may help) with a soft cloth.

Any small rock chips (I know it is sad to think about this subject but it is inevitable) can be cleaned out and touched up with an artist's brush or may be feathered out and re-sprayed, followed by rubbing. Polyurethane is, unfortunately, difficult to fix but enamel responds well to this treatment. In either case, bare metal should be covered up before it has a chance to start rusting

and before the rust can work its way under the paint film, causing it to lift.

If the car gets dirty, it can be washed to remove the dirt. Be sure to wash first with

Item #	Description
M-0216 #2	Fine-Cut Cleaner Removes stubborn paint defects such as light oxidation, swirls, scratches and hard water spots.
M-0116 #1	Medium-Cut Cleaner Quickly removes swirls, water spots and water sanding marks.
M-0416 #4	Heavy-Cut Cleaner Removes serious paint defects. Removes deep swirl marks, scratches and severe oxidation as well as etching from acid rain.
M-8432	Compound Power Cleaner Fastest, most aggressive cutting power available for rapid removal of deep paint defects and sanding marks.
C-2000	Compound Power Cleaner Gently wipe away overspray, bug debris, water spots, oil and grease and other surface contamination.
M-0316 #3	Machine Glaze The ultimate machine-applied shine. Revitalizes paint. Residue wipes off easily.
M-0916 #9	Swirl Remover Cleaner and polish in one. Eliminates swirl marks, tiny scratches and mild defects.

Table 6: Meguiar's Compounds and Polishes

detergent and **lots** of water to loosen the dirt and float it away. To loosen the dirt, use a soft rag or brush and **lots** of water. Dirt bears a remarkable similarity to the grit in sandpaper so you can imagine what pushing it around and around, over your paint, will do. Follow up with **lots** of rinse water to flush away the dirt and detergent [Hey, how many times did he say **lots** of water, anyway].

Other than following these few simple maintenance steps, your paint, if properly applied, should look good and keep looking good for 10 to 15 years. And, you'll look great in those publicity photos, standing next to your catchy paint job, for years to come.

Appendix A – Sand-Blasting Equipment

When tackling a restoration project the size of a railway car, owning your own sand-blasting equipment is almost mandatory. There are hundreds of opportunities for using a sand-blaster to clean up parts, remove rust and old paint and so on. Making an investment in some good quality sand-blasting equipment is well worth it.

Sand-blasting equipment can be divided into two categories: pressure feed; and siphon feed. The former type usually is sold as good industrial and professional equipment while the latter type is sold as the cheap, backyard, do-it-yourself sand-blasters. The exception to this rule is in most sand-blast cabinets which are frequently siphon feed, primarily for the purposes of continuously recycling the blasting media. Although, siphon blasters work, they are much slower and less aggressive than pressure blasters. For my money, there is no reason to mess around with siphon blasters when doing big jobs such as large castings, your center-sill, etc. For small jobs and in a blast cabinet, a siphon blaster is OK but even some blast cabinets make a provision for you to use a pressure blaster.

Sand-blasting works by propelling sand (or some other abrasive) against the surface to be cleaned by a high-pressure jet of compressed air. The impact of each particle knocks loose anything that isn't firmly affixed to the surface (e.g. rust, loose paint, bird-shit, etc.) Because the particles are tiny, they can get into every nook and cranny and remove all of the extraneous material. The cleaning action of each individual particle is small but the cumulative result of a constant stream of them is large. Observing a sand-blaster in action is almost a miraculous sight.

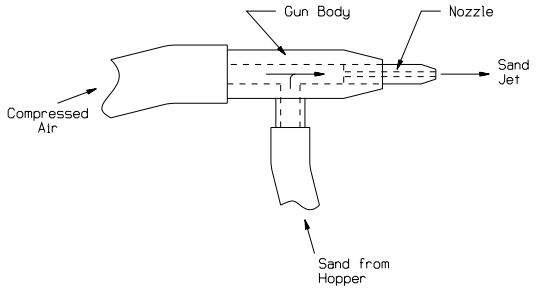

Figure A1: Siphon Blaster

The concept is pretty simple so how do you put it into action? In a siphon blaster, the air from the compressor is fed through a nozzle which is drilled with a small orifice. Ahead of the orifice is a siphon tube set at right angles to the air passage (see Figure A1). As the air passes the siphon tube a vacuum is created. A hose attached to the siphon tube is attached to a gravity-feed hopper filled with sand. The vacuum at the other end of the hose causes sand to be sucked up the hose to the nozzle where it is entrained by the passing air and propelled out the orifice towards the part being sand-blasted.

A pressure-feed sand-blaster uses positive pressure on the sand to feed it to the nozzle. The sand reservoir is a pressure vessel that is filled with sand and then closed. When it is pressurized with air the sand is pushed out of the sand reservoir and mixed with more air. The whole mess, sand and air, accelerates down the sand hose to the nozzle where an orifice forms it into a jet and aims it at the piece being blasted. Because the sand has longer to accelerate, it tends to be form a more energetic stream and, hence, be more efficient at cleaning than the stream of sand from a siphon-blaster.

Both kinds of sand-blasters use a nozzle to form the sand stream into a high pressure jet. The nozzle, as you might imagine, exposed as it is to a constant stream of abrasive, is subject to a high rate of wear. Typical nozzle materials are carbon steel, ceramic and tungsten carbide. Typical nozzle lifetimes are one hour for steel, 3-5 hours for ceramic and 60-100 hours for carbide. The prices vary correspondingly but, when all things are considered, carbide, although pricey, is the best deal and steel, although cheapest, is pretty much pointless.

Although it is frequently called sand-blasting, other kinds of abrasive are often used. Table A1 shows some of the more common along with their suggested uses. Whatever blasting media you use, it should be clean and very dry and you should strain it through a screen, to prevent clogging ,before every use.

Media	Description/Uses
Glass Beads	Several sizes available (60-80 is good). Produces a satin finish on brass, aluminum and other soft metals. Removes rust and scale. Creates little dust.
Crushed Glass	40-80 mesh is typical. Sharp edges cut fast. Coarser finish, moderate dust.
Silicon Carbide	80 mesh is typical. Highest quality abrasive. Stays sharp and lasts longer. Cuts fast. Significant dust. Excellent for etching glass.
Aluminum Oxide	Several sizes available (50 is good). Leaves a smooth, textured finish. Cuts fast. Significant dust. Long lasting.
Walnut Shells	35-60 mesh is typical. Slow rust/paint removal. Very smooth finish. Will not pit or damage chrome. Can be used on wood with care.
Plastic	30-40 mesh is typical. The latest technology. Used to strip airplanes. Perfect for stripping paint and oxidation from aluminum. Will not etch or scratch aluminum or chrome. No dust.

Table A1: Blasting Media

Sand-blasters are known to be air hogs and it is not hard to see why. A sand-blaster is basically an open pipe connected to your air compressor. The amount of air used is determined mainly by the amount of friction in the nozzle. Consequently, one of the things to consider carefully when setting up a sand-blaster is compressor selection.

The smallest pressure-feed sand-blaster will likely require a three horsepower (this is real horsepower, not fake or developed horsepower like many home/hobby compressor manufacturers like to quote) compressor, although five is better. The smallest siphon-feed sand-blaster will likely require a five horsepower compressor. Don't skimp on the compressor. You won't be running the sand-blaster intermittently (trust me) and an underpowered compressor won't keep up.

The air supplied should be clean and dry. I use a moisture filter right at the sand-blaster. A fairly long air line (50-100 ft. of hose or 25 ft. of copper pipe) will ensure that the air has a chance to cool down and that the moisture can condense out and be caught by the moisture filter. If the air is not dry, you will experience problems with clogging that will drive you crazy. Similarly, to prevent clogging, the blasting media must also be clean and dry.

Finally, a few words on safety. Don't aim the sand stream at yourself or anyone else (wear rubber blasting gloves, if you'll be handling parts while blasting). Wear a blasting hood to keep flying sand out of your face and eyes and make sure there's plenty of fresh air available (or wear a respirator, preferably supplied-air). Avoid breathing silica dust, as it irritates the mucous membranes and lungs severely.

Appendix B – Sandpapers

Sandpaper belongs to a family of abrasives more properly known as coated abrasives. This family of products consists of a thin layer of abrasive grains bonded to a substrate such as paper or cloth. Within the family, coated abrasives come in a variety of forms such as sheets, disks, rolls or belts. The commonest abrasive grains used in the manufacture of this family of abrasives are aluminum oxide, silicon carbide, garnet and sometimes alumina zirconium (see Table B1).

There are four major types of backing materials employed in manufacturing coated abrasives: cloth; paper; fiber; and combination. Also, a variety of other substrates such as nylon fiber and screens can be coated with abrasive for special applications.

The most common cloth backing is cotton. Polyester cloth backing is waterproof and provides high strength and resistance to tearing or edge wear. The adhesive film that is used on the backing has a significant effect on its flexibility. Cloth is identified by weight and flexibility. "J" weight is a light, highly flexible material while "X" weight is a heavy cotton backing that can be coated in a full range of abrasive grades.

Paper is identified by weight and flexibility too. The lightest weight paper, "A" weight, is used for fine and medium grades of abrasive. "C" and "D" are intermediate weight papers that can be coated with the medium and coarse grades of abrasives.

Abrasive Grain	Description
Aluminum Oxide	A tough, blocky-shaped abrasive generally used for sanding metals and other high tensile strength materials.
Silicon Carbide	A very hard, very sharp abrasive particularly suited to non-metallic materials such as concrete and for wet-sanding paint.
Garnet	A natural, brittle, red, silicate material, of medium hardness, which tends to fracture in use creating new cutting edges. Used for sanding wood
Alumina Zirconium	A fused abrasive that is very dense with a very fine crystal size. It is crushed to produce a sharp-edged, blocky shape. Use for sanding ferrous metals, stainless, high tensile steel and welds where heavy duty sanding and a high level of material removal is required. Exhibits extremely long life.

Table B1: Coated Abrasive Grains

Fiber backing is a very tough, vulcanized material made from rag stock and used primarily as a backing for abrasive disks.

Combination backing is composed of paper and cloth laminated together and is, consequently, very sturdy and shock resistant. Combination backing is typically used to back up the coarse grits found in floor sanding products and, so, will not concern us.

There are three major types of bond techniques used in coated abrasives: glue over glue; resin over glue; and resin over resin. All of these bond types are two-layer processes used to anchor and lock the abrasive to the backing. Different applications determine which type of bond should be used. Resin over glue makes a bond very resistant to heat. Resin over resin is a very strong bond not susceptible to heat and moisture.

All coated abrasives are stiff and rigid after the curing of the bond. To achieve the flexibility required for the application, a mechanical flexing process is used during manufacturing. This process is actually a controlled cracking of the bond in one or more directions to achieve the desired flexibility.

The stiffness and smoothness of the backing and the hardness of the grit all influence the speed and quality of the cut of coated abrasives. A soft grit on a smooth, pliable backing will cut slowly but produce a smooth surface. The other extreme, a hard grit on a rough (e.g. cloth), hard backing will cut like lightning but leave a lower quality finish. Generally, the manufacturer of the abrasive will select a backing material that augments the grit and helps it to do its intended job. You can control this to a certain extent by exchanging the backing pad on the sander being used: hard equals a more aggressive cut; soft equals a smoother finish.

The terms open and closed coat refer to the spacing between the abrasive grains on the substrate. Closed coat means that the grains are adjacent to one another with no space in between. Open coat means that the grains are set apart from one another with typical surface coverages approaching 60%.

The majority of applications will benefit from closed coat sandpaper because of the quantity of abrasive that is brought to bear on the work. In situations where loading is likely (e.g. soft, non-ferrous materials, painted surfaces, etc.), open coat sandpaper will resist clogging and extend the abrasive's useful life.

As additional insurance against clogging, some sandpapers are available with a stearate coating. Stearate is essentially soap and it prevents the material that is removed from the surface being sanded from sticking to the sandpaper. Stearate paper is not for every application (e.g. it cannot be used to wet sand) but it does work well on body filler, paint, fiberglass and aluminum. Be aware, however, that you may need to clean the surface scrupulously before painting to remove any soap that is left behind.

If you consider sanding on a microscopic scale, those grains of abrasive are actually creating a series of gouges or grooves that run parallel to the direction of sanding. The action desired, when sanding, is for each sanding pass to remove the gouges left by the previous grit. This is accomplished by starting with a coarse grit (80-100) and moving up, a size at a time, until you reach the grit that will give you the desired finish smoothness (150).

You should move up from the lower-numbered grits to the higher-numbered grits in progression (i.e. 80, 100, 120, 150) to keep your sanding time to a minimum and extend the life of the sandpaper. Although this may seem counterintuitive, it isn't. If you keep in mind that each succeeding grit is removing the scratches left by its predecessor, it should be more apparent that when you skip a grit size, the finer abrasive has to work harder to remove the significantly larger scratches and is more prone to wear out, as well as taking much longer to do the job. Skipping a grit size may actually double the sanding time, although, on soft surfaces such as aluminum, it may prove to be an effective technique for speeding things up.

Appendix C – Gloves

A good pair of gloves should be used when handling paints and chemical strippers because the compounds found in them may be toxic and/or caustic – many of the organic chemicals used in paint can be absorbed through or irritate the skin and caustic strippers can severely burn the skin. Gloves are excellent protection against mishap.

It is important to use the proper kind of gloves for the chemicals being handled (see Table C1). Unfortunately, one type of glove material is not protection against everything. Rather, a couple or three different kinds of gloves should be procured so that you'll always have the right ones available. Also, consider buying a few pairs of each kind of glove because it is easy to tear them (when I tear a glove, I set aside the matching one that is still good, on the

off chance that the next time I tear a glove it will be the other one). My two favorite gloves are nitrile for painting and butyl for stripping with methylene chloride type strippers. I use neoprene when working with oils, solvents, tars and caustic strippers and also for painting.

Before you don a pair of gloves, inspect them for wear and tear. Hold each glove in your hand and blow it up like a balloon. Squeeze the cuff shut and press on it with your other hand. If there is a tear, the glove will deflate through it. If the glove is intact, it will prove hard to deflate.

Chemical Tested	Butyl	Neoprene	Nitrile	PVC	Latex
Acetone	>480	9	∅	∅	10
Methanol	∅	103	11	45	20
Methyl Ethyl Ketone	>480	22	∅	∅	5
Methylene Chloride	24	6	∅	∅	∅
Mineral Spirits	∅	127	∞	150	∅
Phosphoric Acid	∅	>480	>480	∞	∅
Sodium Hydroxide	∅	>480	∞	∞	∞
Toluene	21	4	10	∅	∅
Xylene, Xylol	∅	23	75	∅	∅

Table C1: Glove Material Chemical Resistance
(Time in minutes to break through glove. Use not recommended if marked ∅.)

Discard any torn gloves.

Keep your gloves clean by wiping them off with solvent as you clean up your equipment. This will prolong their life and keep them from transferring paint or chemicals to anything that you inadvertently touch. When you remove your gloves, turn them inside out and hang them up to allow accumulated perspiration to dry out. Once they are dry, reverse them and store them out of bright light, flat and in pairs, ready for their next use.

Appendix D – Respirators

There are two types of respirator that can be used when applying paint: the organic vapor respirator; and the supplied-air respirator. Furthermore, when scraping lead paint and/or sandblasting, you should wear a HEPA or supplied-air respirator.

Organic vapor respirators consist of a pliable rubber face mask with straps to hold it in place and a set of replaceable filters that screw into it. There are usually four rubber flapper valves (thin rubber discs that seat on a ring set into the face mask), two for inlet and two for outlet. As you breath, air is drawn through the cartridges via the inlet valves. Exhaled air exits through the outlet valves.

The cartridges contain activated carbon which has a strong affinity for organic molecules. As the air passes over the carbon, solvent (which is an organic molecule) is extracted from the air and it is purified. When the activated carbon is spent (you will start to smell paint), the cartridges are thrown away and replaced. Note that the activated carbon cartridge only works on organic vapors. Paint mist (i.e. small droplets of paint) is frequently removed by a felt-like pre-filter which can be changed often to prolong the life of the organic filter.

Tiny particulates such as asbestos fibers, lead paint dust and silica (sand) are best removed by a HEPA (High Efficiency Particle Arresting) filter, since the organic vapor filter is pretty ineffective at this job. The HEPA cartridges usually screw into the same face mask as the organic vapor cartridges so one face mask may

be made to do dual duty. In some cases, two filters may be ganged up to protect against particles **and** organic vapors as in the case where you are removing lead paint with a methylene chloride stripper.

A supplied-air respirator consists of a rubber facemask, much the same as the facemask used with organic vapor/HEPA respirators, possibly a pressure reducing regulator, a supply line and an air source (compressor or turbine).

The premise behind a supplied-air regulator is that the air source is located in a remote location where the air is guaranteed to be clean. The air is compressed and sent to the face mask, via the supply line, where you get to breath it.

Some supplied-air respirators use a turbine which generates a high volume of air under low pressure. These have a large diameter hose (which, incidentally, must be of a certain length to cool the air that was heated by the turbine and render it breathable) and the air is breathed directly. Others use a pressure reducing regulator to accept typical high-pressure air (e.g. 90 p.s.i.) and reduce it to low pressure at high volume for breathing. These must be supplied with clean, oil-free air through a regular air hose. A small oil-less compressor of 1 to 1-1/2 HP works well and can be remotely situated.

The benefits of supplied-air respirators are that the respirator is always pressurized. If the face mask leaks, the leak is **out**, not in. You won't be breathing solvents or anything other than fresh air and for paints such as polyurethane this is imperative. The benefits of a full-face respirator is that your eyes won't be collecting paint while you are spraying (by the way, the chemicals in polyurethane paint can be absorbed through and/or irritate the skin of the face and eyes) but this is more your own personal choice. Especially if you wear eyeglasses, a full-face respirator can be difficult to fit. Perhaps a partial face mask and goggles may be more to your liking.

Organic vapor/HEPA respirators are acceptable, where appropriate, in most cases, provided that they fit well. Achieving a good seal between your face and the mask is most important and, if you are among those of us who sport a beard, this may be difficult. The respirator should be adjusted so that it fits snugly, and then the seal should be tested by covering the exhaust vent with your hand and blowing out. A good seal will result in the respirator inflating and you should experience difficulty in blowing. If you can't get a good seal, Vaseline can be used to help (especially with beards) but you may need to switch to supplied-air.

Supplied-air is not the answer for everyone, it being much more expensive as well as cumbersome and not acceptable in situations where quick egress in the event of air supply failure is impossible. However, if you do decide to use a supplied-air respirator, a good intermediate cost solution (e.g. I paid about $500 for a facemask, air hoses, and compressor – not too much to pay for a life insurance policy on my measly life) can be had that will do the job in many cases where an organic vapor/HEPA respirator won't.

The set up that I use is a small, oil-less pancake compressor located a couple hundred feet from the spraying area. The air hoses from the compressor should be 3/8" I.D. and should have Schrader-type connectors (so that they won't pop apart when they become snagged on something). The mask, which I purchased from a surplus store for $150, is a full face mask. Full face masks protect your eyes as well as your lungs. To be used with this setup, the mask must come with a pressure demand regulator to drop the high pressure air from the compressor to a few pounds and convert the air flow to high volume.

Appendix E – Paint Spraying Equipment

Probably more so than in any other application, except for large industrial plants and commercial airplanes, the spray equipment that we use to paint railway equipment is of prime importance. The reason is cost! When you consider the price of the paint (e.g. $100-200 per gallon) and the large areas to be painted (e.g. 800 square feet for a car side), you want to be real sure that the paint goes onto the car and not onto your neighbor's laundry, drying on the clothesline.

To me, cost, rather than any other reason, is why I use HVLP spray equipment. However, there is also the release of VOCs into the atmosphere to think about. The EPA is passing rules about paint formulations that are meant to reduce VOCs and they are also becoming

involved in the area of paint application. So, if cost isn't enough to convince you, maybe environmental regulations are. Personally, I wouldn't bother with anything other than HVLP equipment.

Well, what is HVLP equipment, anyway? A little history, first. Conventional spray guns used compressed air to force paint out of the nozzle of the gun where it met with a blast of high-pressure air directed at it by an air cap (see Figure E1). The turbulence of the air stream caused the paint to be broken up into a cloud of tiny droplets in a process known as atomization. Then, the air from the air cap shaped the cloud of paint into a fan and propelled it towards the surface being painted.

The atomized paint droplets impinged on the surface with a significant amount of energy which caused them to stick and level out in a uniform coat. Mostly. The higher the gun air pressure, the finer the atomization and the smoother the resulting finish but with one caveat. The high energy imparted to the paint droplets caused them to misbehave badly. Some of them had so much energy that they would bounce right off the surface. Others were literally blown right by the surface. The net result: 30% of the paint on the surface and **70%** airborne.

Time to rethink the equipment! Why not use air at a lower pressure to move the paint so that, when it strikes the surface, it sticks instead of bouncing around? To make up for the lower pressure, use **lots** of air. This way, the paint goes where it was intended to go, not on Mrs. O'Grady's laundry. Voila! HVLP (High Volume, Low Pressure), with typical transfer efficiencies in the 70% range, was born (for more information about how to keep the paint from missing the mark altogether, check out electrostatic systems at your painting equipment dealer).

But, how to produce the high volume, low pressure air? There are two ways. The first is to take low volume, high pressure air (e.g. from a compressor) and allow it to expand to a much larger volume at a lower pressure. This is the idea behind a conversion gun. The second is to generate lots of low pressure air in the first place. This is the idea behind a turbine gun.

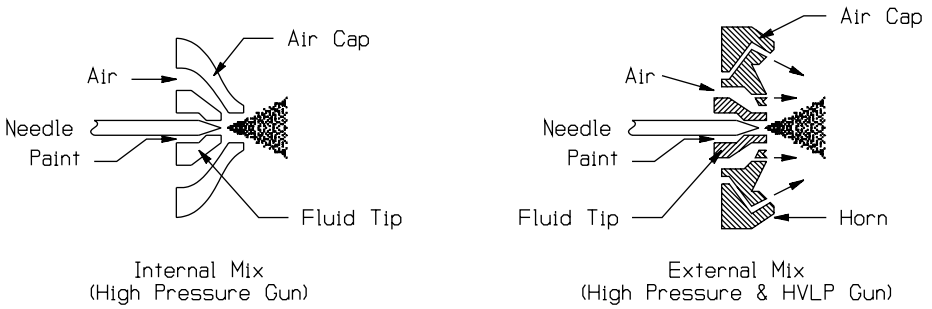

Figure E1: Air Caps

If you have existing spray painting equipment (i.e. a compressor), you will probably want to buy a conversion gun. Another thing to consider is that, while HVLP by definition is any gun that produces 10 p.s.i. or less of air pressure, conversion guns are closer to 10 p.s.i. while turbine guns are in the 3-5 p.s.i. range. As was mentioned before, the higher the air pressure, the better the paint atomization and the smoother the finish. Consequently, conversion guns tend to produce a better finish. On the downside, conversion guns are notorious air hogs (although, the Fuji venturi gun will, when available, be an improvement) so at least a 3-5 HP compressor is mandatory.

A turbine gun uses the same kind of turbine that is used in a vacuum cleaner (as a matter of fact, I have a homemade turbine unit that I built from a vacuum cleaner motor – works great), running as a blower instead of as a vacuum generator. Most of the good turbine units are two- or three-stage (i.e. the blower has two or three impellers that step up the pressure) and they produce 3-5 p.s.i. at 80-100 c.f.m. A unit of this type is a small, light box that can go anywhere and plug into a 120V outlet.

So, how to choose which kind of HVLP gun to buy. If you already have a compressor and are thinking of painting your car's exterior, a conversion gun is probably the way to go. A good one such as the Devilbis or Lex-Aire (my personal favorite) is $300-400. If you want a small, light, portable unit that produces a very acceptable finish, say to do car interiors, a turbine unit is just the ticket. A good one such as the Apollo, Graco/Croix or Fuji is $500-600 (including the turbine) or, if you just want to purchase the gun for your homemade unit, its $250. Given the workout that this gun can expect to be put through, don't scrimp on the amount of money that you spend. Buy a top-quality gun and you won't regret it.

Appendix F – Useful Sources of Information

The following information was found to be useful to me and may also prove to be of help to you in preparing for painting:

U.S. Paint Corporation Application Guide, Edition 12, AWLGrip, AWLCraft 2000, AWLBrite Plus, AWLStar. U.S. Paint, 831 S. 21st Street, St. Louis, MO, 63103. (314)621-0525. www.uspaint.com.

Rustoleum Industrial Coating Systems, Form No. 787, Rustoleum Corp., 11 Hawthorne Parkway, Vernon Hills, IL, 60061. (800)553-8444. www.rustoleum.com.

Also: Rustoleum Labor Saver Industrial Enamels, Form No. 8964; Rustoleum Labor Saver High Performance Epoxy 9100 System, Form No. 8706; Rustoleum 9200, 9300 and 9500 Industrial Epoxies, Form No. 1003; Rustoleum Industrial Urethane, Form No. 1005.

Ketone Industrial has a good description of the DuPont coatings line (industrial, not automotive) at www.ketoneindustrial.com.

Griggs Paint at www.griggspaint.com has a program that you can download that will ask you about your paint application and select paints from their line which includes paints formulated to solve the tough problems experienced by the aerospace industry.

Anchor Paint at www.ajy.net/anchor is a small paint manufacturer that has everything you'd want. The Ancothane 9400 is an acrylic urethane which is supposed to be even tougher than polyurethane.

Benjamin Moore can be found at www.benjaminmoore.com. They have a huge supply of interior and exterior paint and can tint it to any color you want.

Kelly-Moore (Ben's sister?) is at www.kellymoore.com. They have a complete set of spec-sheets available along with charts that suggest interior paint systems.

If you want to read about how the car guys paint automobiles, the two Paint FAQs at www.freenet.edmonton.ab.ca/~bobstory and www.webspan.net/~panhead/pan10.htm are pretty good.

A nice little survey publication of alternative paint stripping methods can be found in a Guide to Cleaner Technologies, Organic Coating Removal, EPA/625/R-93/015, US EPA, Office of Research and Development, Washington, DC, 20460.