PAINTING MAKES THE DIFFERENCE

PAINTING MAKES THE DIFFERENCE

A chemically resistant, mechanically durable, pleasant in appearance and finish painting is sought for by all automobile users. Design constraints of product, customer preferences, and local government regulations related to environmental control - all affect the painting process decisions. A close and effective interaction between the concerned experts from auto-plant, paint process plants, paint application equipment, and paint as well as chemical plant/s are essential for achieving the highest possible paint-shop efficiency. Other goals are the best of product quality, minimum unit production cost, and conforming to emission control requirements. A high degree of automation has become a necessity for consistency in quality and to avoid the hazardous working environment demanded by the painting processes.

PRODUCTION SEQUENCES OF PAINT SHOP

For painting of a passenger car body, the typical processes to be followed are as follows:

- *Precleaning*
- *Multistage Phosphate Pretreatment*
- *Electro-deposition of primer coating*
- *Underbody PVC & Sealer Application*
- *Filler primer (surfacer) application*
- *Top coat or dual coat application*
- *Wax application*

Precleaning removes the dust and dirt on body-in-white from the previous processes. Phosphate pretreatment assists good paint adhesion and resistance against corrosion. Electro-deposition ensures uniform primer coating on the surface. Sealer application on underbody protects it against the stone throw. The thick filler primer(surfacer) smoothes any roughness of the surfaces and the top coat determines the visual appearance of the car. Fig. 7.1 shows a schematic flow chart of the processes in a typical automotive paint plant.

PRECLEANING

At precleaning stage, heavy contamination of body shop is removed to extend the life of degreasing baths of pretreatment stages. Methods followed for precleaning, as shown in Fig. 2, may be:

1. manual precleaning with high pressure devices
2. brush (3M Scotch-Brite pads) cleaning using some chemical,e.g. Chem-Kleen 338, a glycol-based material of Chemfil Corp.
3. low and high pressure spray cleaning or,
4. combination of 1~3 methods

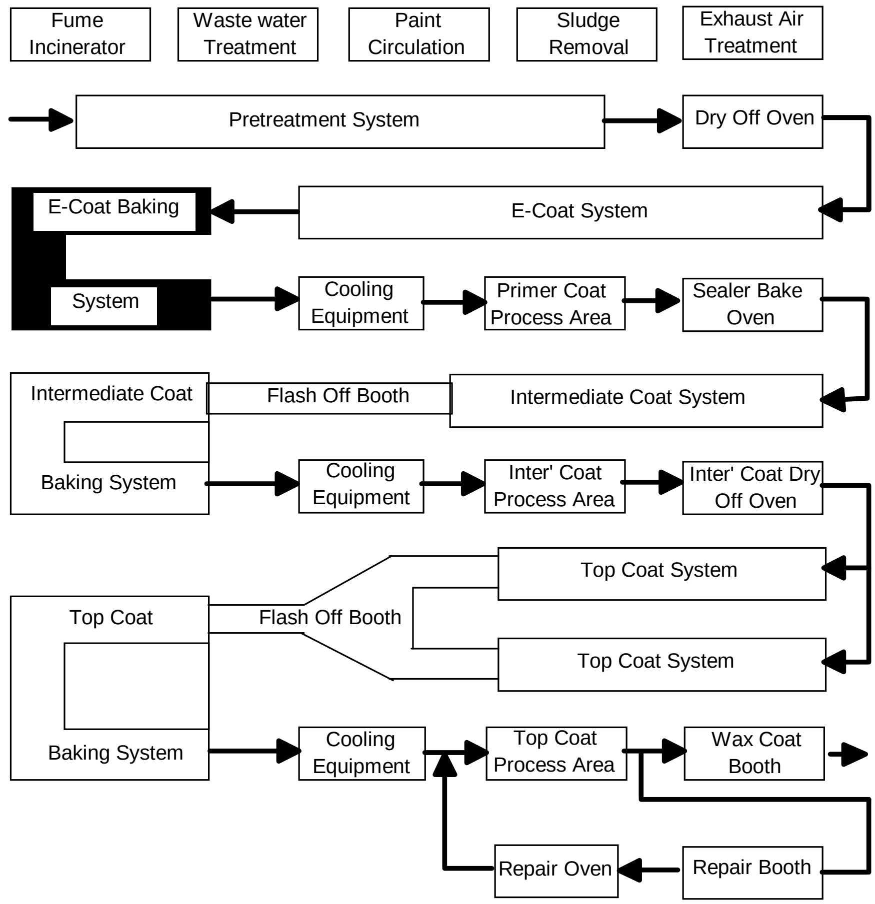


Fig. **7.1. Process Flow Chart in a Typical Paint Shop**

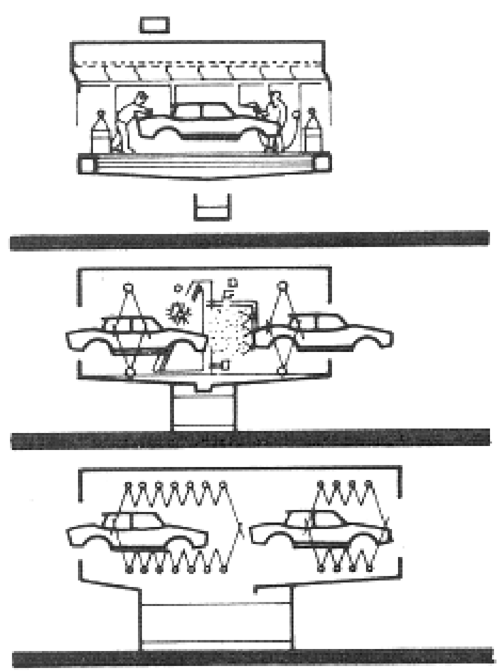


Fig. **7.2 Different Methods of Precleaning**

MULTI STAGE PHOSPHATE PRETREATMENT

Pretreatment is carried out in number of stages. All surfaces of the bodies are thoroughly cleaned and degreased before the application of zinc phosphate (Low zinc, nitrate free process is the present trend), as the improper cleaning inhibits the proper phosphating of surfaces.. Main objective of phosphating is for good paint adhesion and to assist to protect the metal surface against corrosion. Phosphate coating texture, crystal size, morphology, and coating weight are controlled and manipulated by proper surface conditioning for the desired quality out of pretreatment process. Between these stages, the bodies pass through rinse zones. At the end of pretreatment line, passivating and neutralising is carried out, and a final rinsing is done with fresh demineralised (DM) water. Every care is taken to prevent the contamination of solutions and rinsing tanks. Typically, the stages of pretreatment system and the parameters are as follows:

No.	**Process**	**Method**	**Temp, ^{0}C**	**Process (drain) time, sec.**
1	Pre- Hot water rinse	spray	30-40	30 (40)
2	Hot water rinse	dip	30-40	30 (40)
3	Pre-degrease	spray	45-50	30 (40)
4	Degrease	dip	45-50	120 (40)
5	Water rinse 1	spray	ambient	30 (40)
6	Water rinse 2	dip & spray	ambient	30 (40)
7	Activation	dip	ambient	30 (40)
8	Phosphate	dip	45-50	120 (40)
9	Water rinse 3	spray	ambient	30 (40)
10	Water rinse 4	dip & spray	ambient	30 (40)
11	Recirc. DM rinse	spray	ambient	30 (40)
12	Clean DM rinse	spray	ambient	30 (40)
13	Air blow/setting	-	-	-

Pretreatment processes, as shown in Fig. 7.3, may be:

1. Manual with high pressure equipment.
2. Spray in either intermittent or a continuous straight-through operation.
3. Combined spray and dip.
4. Full immersion with horizontal or vertical dip.

Manual pretreatment process is for small volume production, where investment constraints are serious, and is highly operator-dependent for quality and productivity with high unit consumption of chemicals. Inaccessible and box-sections are not treated. Working environment is poor with almost no automation.

Spray pretreatment process requires less space. Cavities and hollow sections are not fully treated. Energy consumption is relatively high. The system is more prone for breakdown.
Combined spray and dip process covers the hollow section to the extent the body is immersed (normally upto the window level). Chemicals for spray as well as dip must be compatible. Space requirement is more. Chemical consumption is higher than for spray process.

Full Immersion process covers all surfaces exterior and hollow sections. Process operation is more difficult because of the larger sizes of tank volume required. Maintenance is simple and unit energy consumption is more favourable, as the sprays are largely eliminated. However, the chemical consumption is higher.

Vertical immersion is easier than horizontal, as the tank volume is smaller. Energy consumption is much lower, while the chemical consumption is almost same.

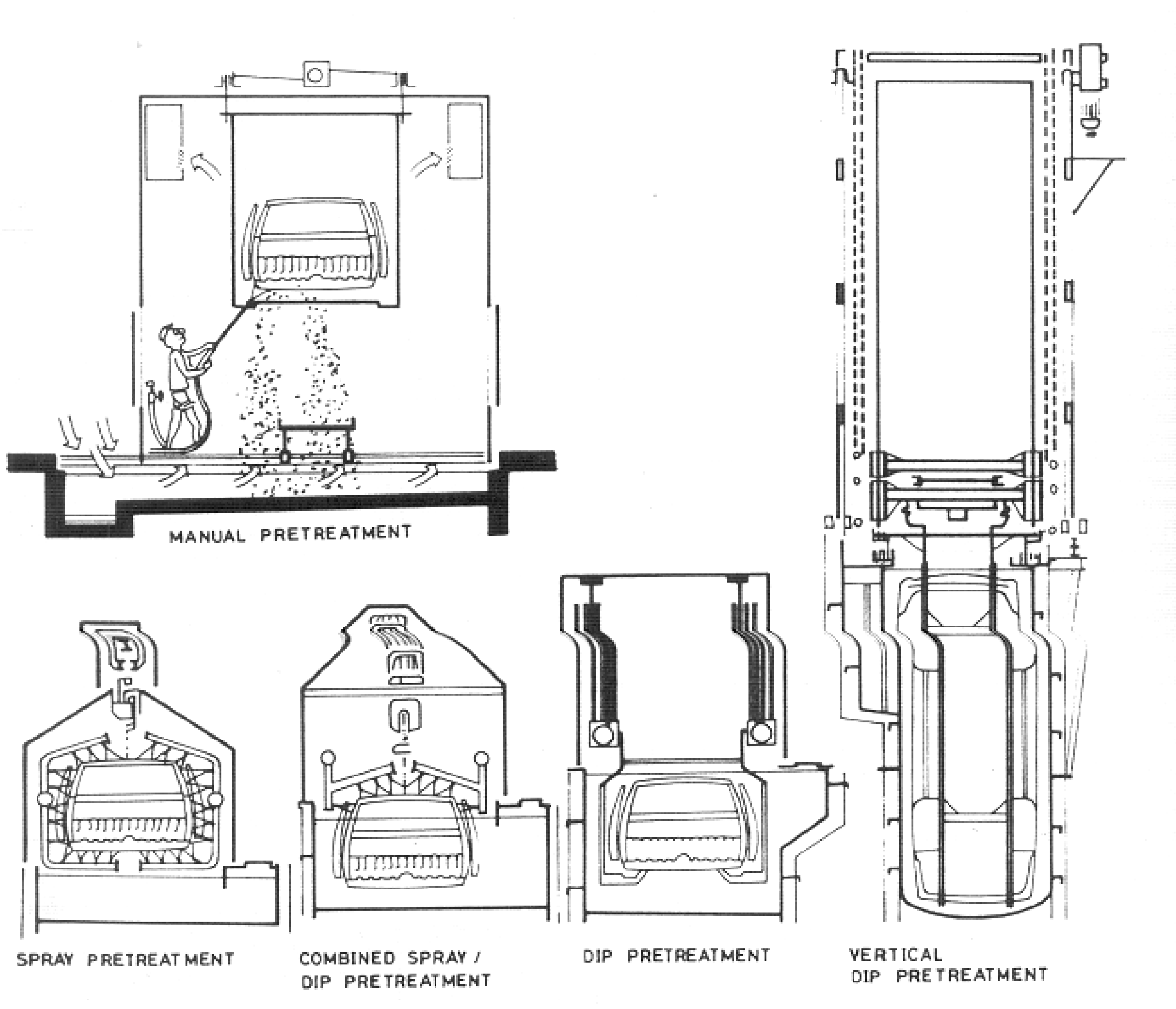


Fig. **7.3 Various Pretreatment Processes**

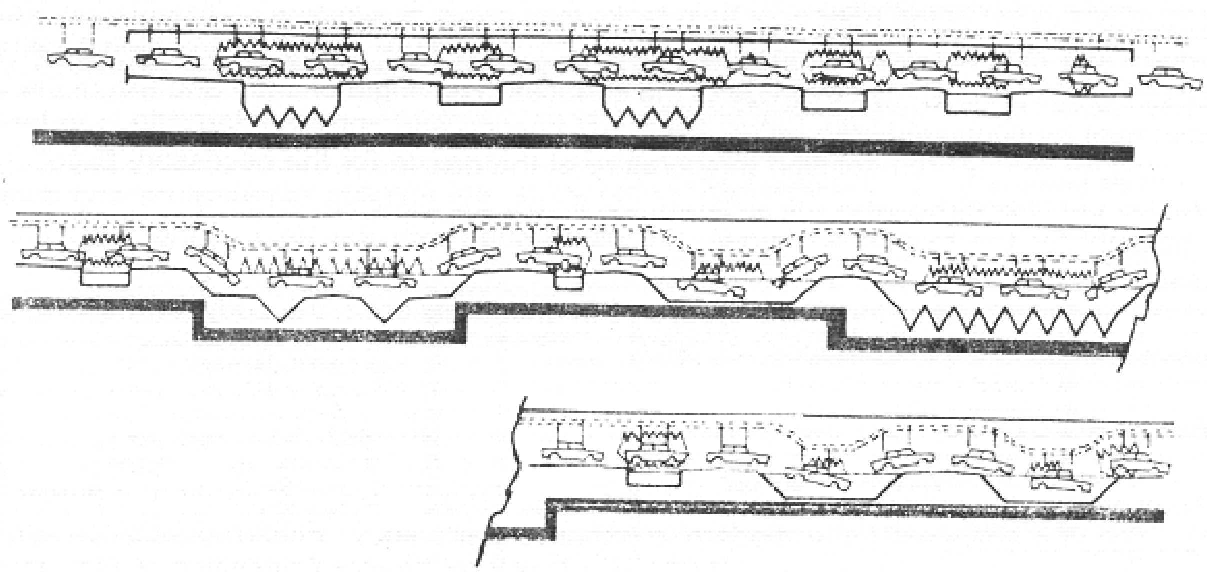
Pretreatment system design is aimed at:

1. Reduction of water requirement
2. Reduction of chemical carry-over from one process to another
3. Improvement of phosphate finish
4. Reduction in sludge volume and efficient disposal

5. Low energy consumption

Reduction of phosphating temperatures has significant influence on operating cost and sludge volume. A combination of dip-spray rinse system has been proved superior to spray-spray rinse system. A four-stage post-phosphate (dip-spray-spray-dip) rinse system requires much less DM water. Intensive post degreasing and post phosphating rinses reduce chemical carry over significantly. A control system covers bath chemistry, filtration system to maintain rinsing tank purity and techniques to prevent the contamination of solutions through bath circulation and an efficient sludge removal system. The automatic control eliminates the causes of imperfections on car body surfaces.

Depending on the production capacity, the body may be transferred in intermittent or continuous modes. Fig. 7.4 shows a number of alternatives of pretreatment systems for different production capacity. For very low volume of production, a 2-zone pretreatment may be justified (Fig. 7.4A). Single station (booth) system, where the stationary car body is sprayed by means of mobile nozzle banks, is used for low volume production. The liquid is pumped from one tank at a time out of a number of tanks with different liquids, and then drains back into its respective tank. The system uses the treatment sequences in planned manner and may be made fully automatic. Fig. 7.4B shows a 4-zone intermittent spray pretreatment for medium volume of production. For higher capacity of production, one of the alternatives shown in Fig. 7.4C-E is used. However, vertical dipping system is uniquely different of these systems. Different automobile manufacturers adopt almost similar systems with certain changes based on their experiences and those of their paint suppliers.



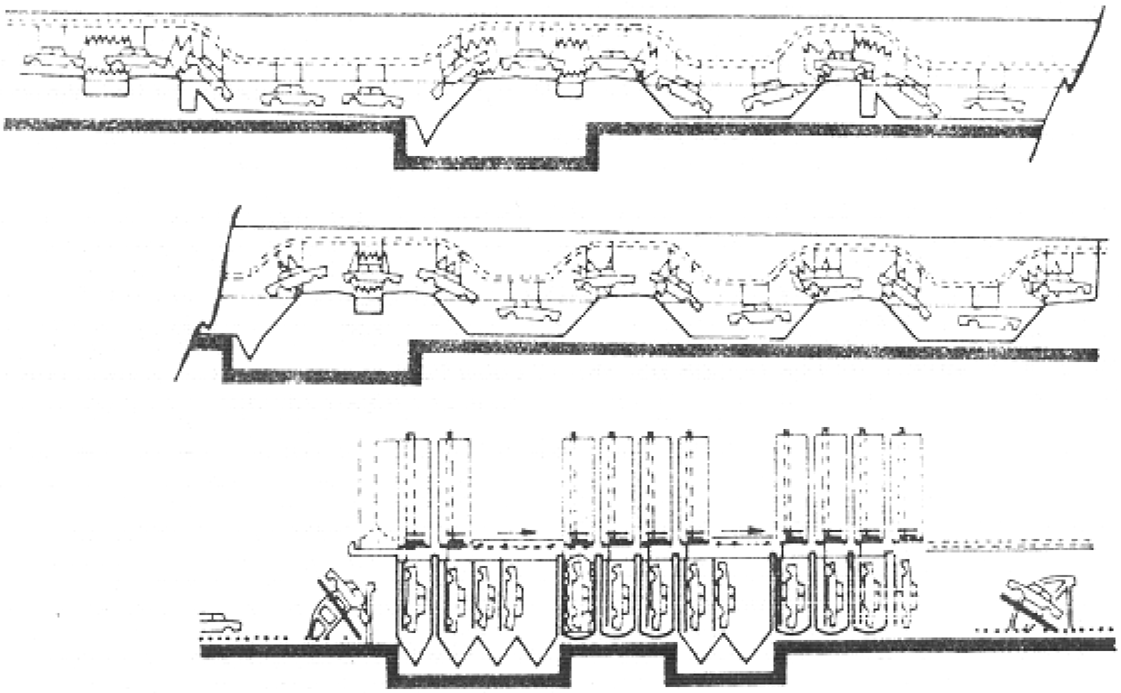


Fig. **7.4 Different Alternatives of Pretreatment System**

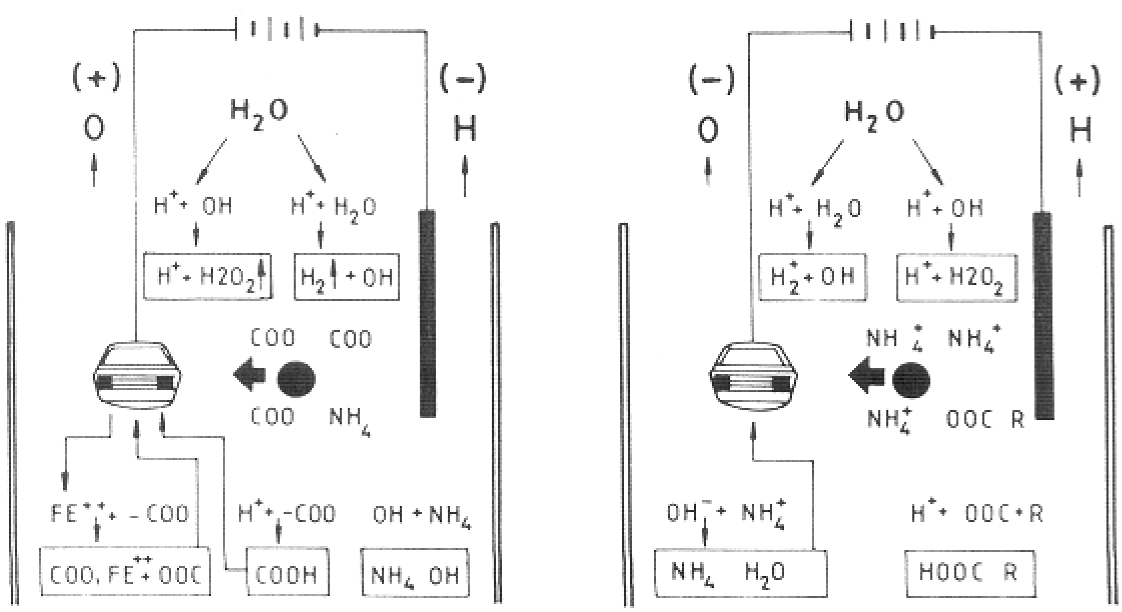
Continuous desludging is a necessity for larger pretreatment system to keep the solutions effective. Design of the bottom of bath tanks may assist in avoiding sedimentation. For spray zones, the maintenance of nozzles is as critical as their initial design and locations for ensuring complete spray coverage of the surfaces. The angle of entry and exit of the body is important for continuous dip baths. Sufficient heating and pumping capacity is to be built-in to produce the desired solution temperature at the nozzle for the necessary exposure time. Values of concentration of the different solutions, the suitable temperature and duration of treatment for the respective zones, are established with the help of the suppliers of the chemicals and paints.
At the end of the pretreatment, a sprayed DM rinse wets down the body for the entry into the paint (of cathodic electro-deposition tank).

ELECTRO-DEPOSITION COATING

To overcome the drawback of full dip primer application, electro-deposition of primer coating has become universal for a modern automotive paint shop. Electro-deposition are of two types: Anodic Electro-Deposition (AED) and Cathodic Electro-Deposition (CED). In electro-deposition, charged particles from the paint emulsion move to Anode (AED) or Cathode (CED) under electrical forces (because of voltage created between the electrodes - one of which is car body itself). It happens during the period the body remains completely submerged in the paint bath. In anodic system, the car body is made positive electrode. In cathodic system, the car body is made negative electrode, as shown in Fig. 7.6. The direct current established through the bath makes the pigment and resin base of the paint wander towards the body surfaces. Ultrafiltrate (UF) equipment is used for condensation of ED paint ingredients to form film and separation of those not forming film. Filtrates of the ingredients that do not form film are used in a multiple cleaning process as a solution to clean out surplus paint adhered to electro-coated body. As the film formed has high resistance, so further deposition ceases. Coating reaches all the recessed area. Deposited film does not redissolve. However, the undeposited material is rinsed. Neutraliser in the system is controlled. The film is compact almost touch dry with high solids. Deposited film after stoving becomes hard, durable polymeric film. Major advantages of electro-deposition over conventional solvent borne dip primer are:

- Fully automatic operation, including the facility of controlling film thickness
- More uniform coating
- Better coverage in box and interior surfaces
- Deposition of film of comparable thickness on the inner and outer surfaces of box section
- Good coverage of sharp corners
- Better penetration between spot welded surfaces
- No runs and sag
- No solvent boil
- micron dry film buildup
- Better chip resistance
- Better corrosion resistance
- Nearly 100% paint utilisation because of closed loop system
- Superior in anti-pollution, safety, health hazard

Disadvantage of Electro-deposition system of coating is its high capital investment and operating cost. While mild steel is good enough as material for alkali resistant anodic plant bath, acid resistant stainless steel or PVC is used for cathodic tank. Cathodic plant is almost 80% or so costlier than anodic. Electro-deposition was



. **7.6. Anodic and Cathodic Electro-Deposition Systems** initially anodic. However, over the years cathodic electro-deposition has become universally preferred system in automotive industry. Some clear advantages of cathodic over anodic systems are the resulting superior quality characteristics. A typical comparison of the results is as follows:

	Quality characteristics	AED	CED
1.	Pencil hardness	min. H-2H	min. 2H-3H
2.	Impact resistance, Duepoint	min. 30 cm.	min. 50 cm.
3.	Corrosion resistance (zinc phosphate dip)	600 hours	> 1100 hours
4.	Acid resistance ($0.2N\ H_2SO_4$)	5 days	8~9 days
5.	Distinctness of image	7-8	8-9

Other advantages of the cathodic elecro-deposition are:

- Increased throwing power(about 50% more) with better capability for the paint to reach recessed and critical corrosion prone areas, which might not be possible with anodic system
- Smoother film deposit as the film flows smoothly during baking, and so lesser necessity of rectification work that ensures a smoother final finish
- With its better corrosion resistance, the film thickness can be reduced(upto half in comparison with the film thickness of anodic paint).
- Less problem in maintenance of the quality of paint as the cathodic paint has a greater resistance to bacteria.

Pretreatment systems influence the relative performance of both anodic and cathodic electro-deposition as shown in Fig. 7.6.

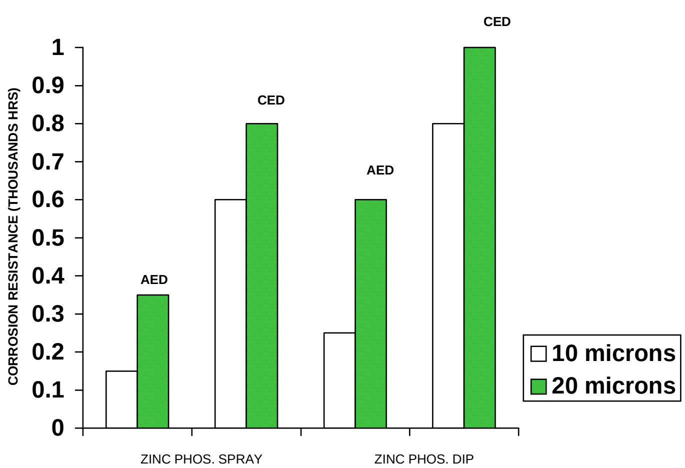


Fig. **7.6. Relative Performance of Electro-Deposition with Different Pretreatments**

Pretreatment coating must meet the basic requirements for CED. Typical quality characteristics for good CED are as follows:

Coating weight	2-3 gm/m^2
p ratio	more than 90%
Crystal size	less than 10 microns
Conductivity of dripping water after final DM rinse	less than 30 micro Mhos/cm.

Primer coating deposited with cathodic dip electro-deposition provides excellent anti-corrosion properties and reliably protects edges and cavities. The body is completely submerged. The paint is evenly deposited on the entire outer surface as well as hollow sections and interior spaces, ensuring complete corrosion protection. The bath is maintained at a temperature of approx. 25-27°C (pH-value of approx. 5.6-6.6 and solid contents 16-20%) with deposition voltages between 350~500 V (depending on the paint characteristics). A coat thickness of 15~20 μm is achieved at a deposition equivalent between 40 and 80 As/g. With improved primer paint material being developed by the industry, coat thickness of 30-35 μm with deposition voltages of 500 V and a deposition equivalent of 100 - 120 As/g will be possible. Neutralising agents set free during the coating process diffuse through integrated anion exchange membranes, and are discharged through the anolyte circuit. The ED system incorporates very effective paint agitation system to maintain homogeneity and to prevent sedimentation that ensures consistent high quality of the primer coating. An efficient and continuous filtration system is used in electro-deposition tank-the pumping system turning the bath over six times or so. The filtration eliminates dirt and oil that could cause defect like cratering in cathodic electro-deposition coating. Deposition process is followed by a rinse stage to remove any paint particles that are still not electrically deposited. The filtrate produced by ultrafiltration is allowed to return in cascades from the end of the rinse zone back to the dip tank to minimise paint loss. With highly efficient filtration system, almost 100% Electro-deposition bath residues are reused. A DM water dip rinse system may be used before the final DM rinse where the DM water is compensated through recirculation. Final rinse is carried out with virgin demineralised (DM) water.

The ED-coated body is cured at 165-180 °C in oven to set the paint prior to sanding operation and come out cooler from the conveyor. Only minor spot sanding and repair defects such as craters or sags, if they occur, are required. After the dry sanding, a compressed air blow off is used to remove the sanding dusts.

A typical process sequence of electro-deposition system is as follows:

No.	**Process**	**Method**	**Temp, ^0C**	**Process(drain) time, sec.**
1	Cathodic ED	dip	27 +/-	180 (40)
2	UF rinse	mist spray	-	-
3	Recirc. UF rinse 1	spray	-	30 (40)
4	Recirc. UF rinse 2	spray	-	30 (40)
5	Recirc. UF rinse 3	dip & spray	-	30 (40)
6	Recirc. DM rinse	spray	-	30 (40)
No.	**Process**	**Method**	**Temp, ^0C**	**Process(drain) time, sec.**

7	Clean DM rinse	spray	-	30 (40)
8	Air blow/setting	-	-	300
9	ED oven	-	165-180	20-30 min.
10	Cooler	-	-	5 min.

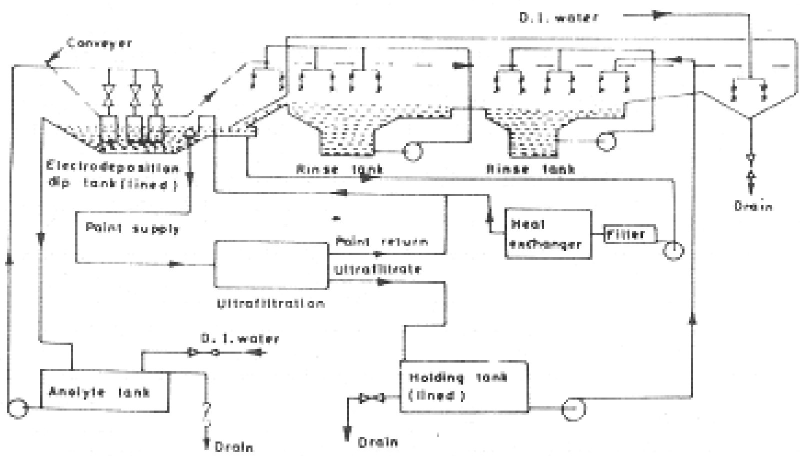


Fig. **7.8 A Schematic Diagram of an ED System**

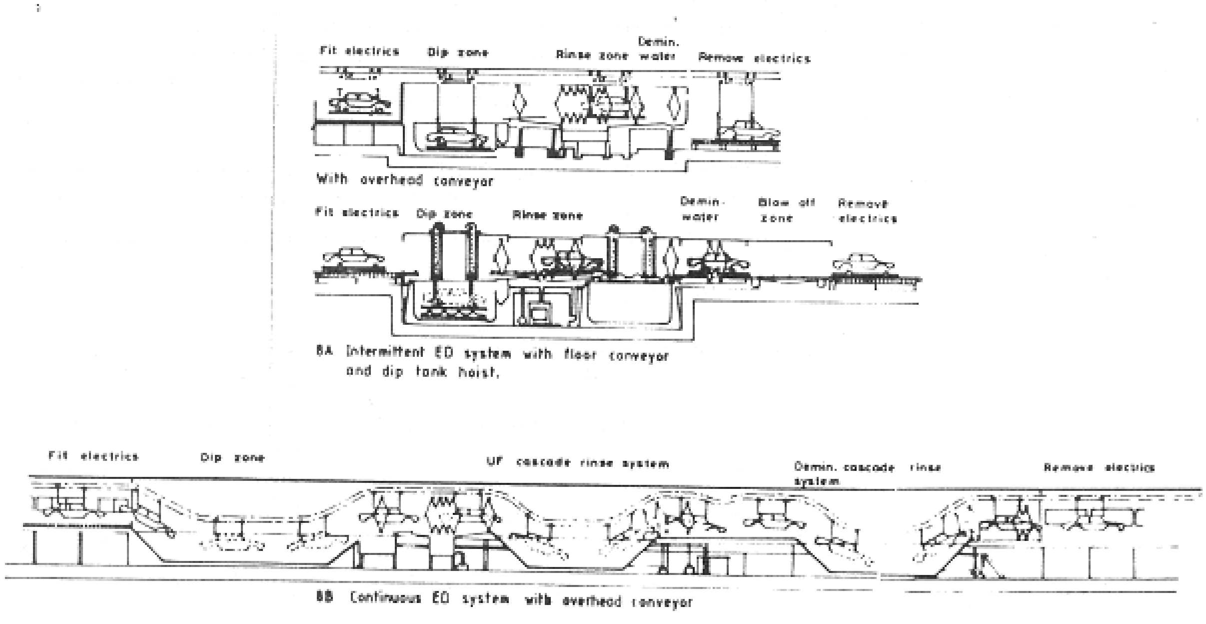


Fig. **7.9. Alternative Processes of Electro-deposition System**

Fig. 7.8 shows a schematic diagram of an ED system.

ED systems may be intermittent or continuous, manual, semi-automatic, or fully automatic. While Fig. 7.9A shows an intermittent system, Fig. 7.9B is a continuous operation system for volume production - the length depending on production per hour.

Japanese paint equipment manufacturers recommend upto four UF rinses, heated DM rinses, as shown in Fig. 7.9, and heated exit vestibules to improve first run percentages and to reduce operating costs. UF consumption is reduced significantly (approximately 25 litres per body) with additional spray systems with reduction in UF cost. Maintenance cost in filter replacement is also less. Recovery efficiency improves. Heated DM rinses (at 45 °C) permit improved solution flow from car body and reduces ED coat defects due to post-rinse dripping in the oven. When the result of a 2-stage dip-spray rinse is compared with 2-stage spray-spray, fewer ED-coat defects are reported when the dip process is included.

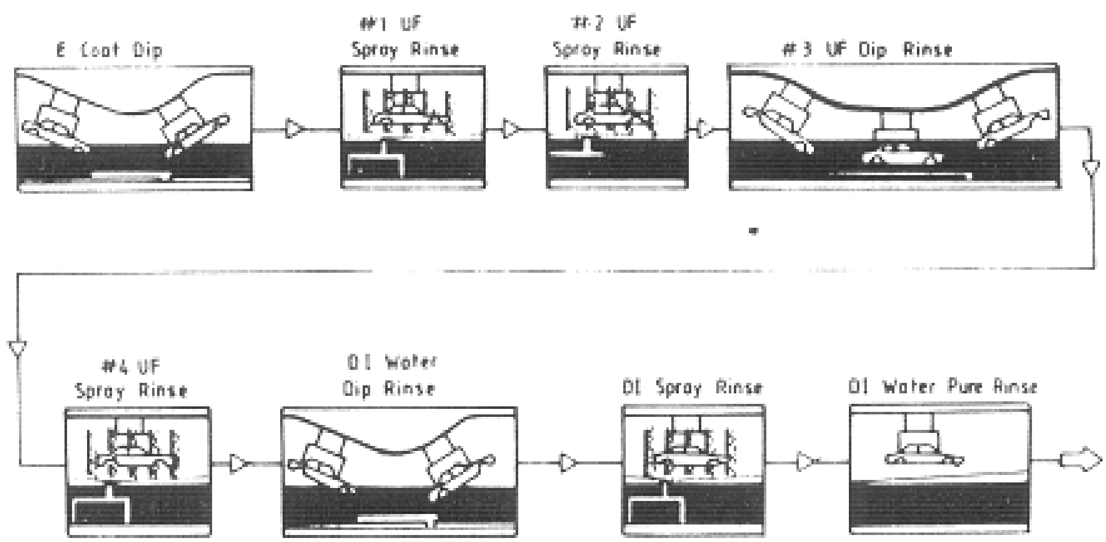


Fig. **7.10. 4 UF Rinses and Heated DM Rinse System**

The heated tunnel from ED-coat exit to oven entrance (120 °C), Fig. 7.10, provides a number of advantages:

- Reduces delayed dripping in oven at metal mating plates due to abrupt heating of E-coat. The system does not increase energy consumption as heat recovery from E-coat oven is the heating source for tunnel heating.
- Improves finish due to reduced sanding requirements.

- Eliminates resin vapour because of gradual heating up.

PVC UNDERBODY COATING & SEALING APPLICATION

After electro-deposited primer application, underbody coating and sealer application to weld joints and other areas that are prone to corrosion, is carried out for two purposes:

1. to provide a protective function with regard to weather effects.
2. to provide resistance to stone throw that damages the protective skin.

Sealants are applied to gaps, cracks and seams. Underbody PVC coating is applied. Some 80% of the sealing work for hollow sections may be executed by suitably programmed robot. Precise positioning of the body will be required for the robotisation of seam seals. The seam seals must be placed with an accuracy of about 1 millimetre. In one plant, video cameras enable the control system to position the body precisely with an accuracy of one tenth of a millimetre. Four robots are employed for the total seam sealing within seconds. At the end, the sealer is baked at about 160^0 C.

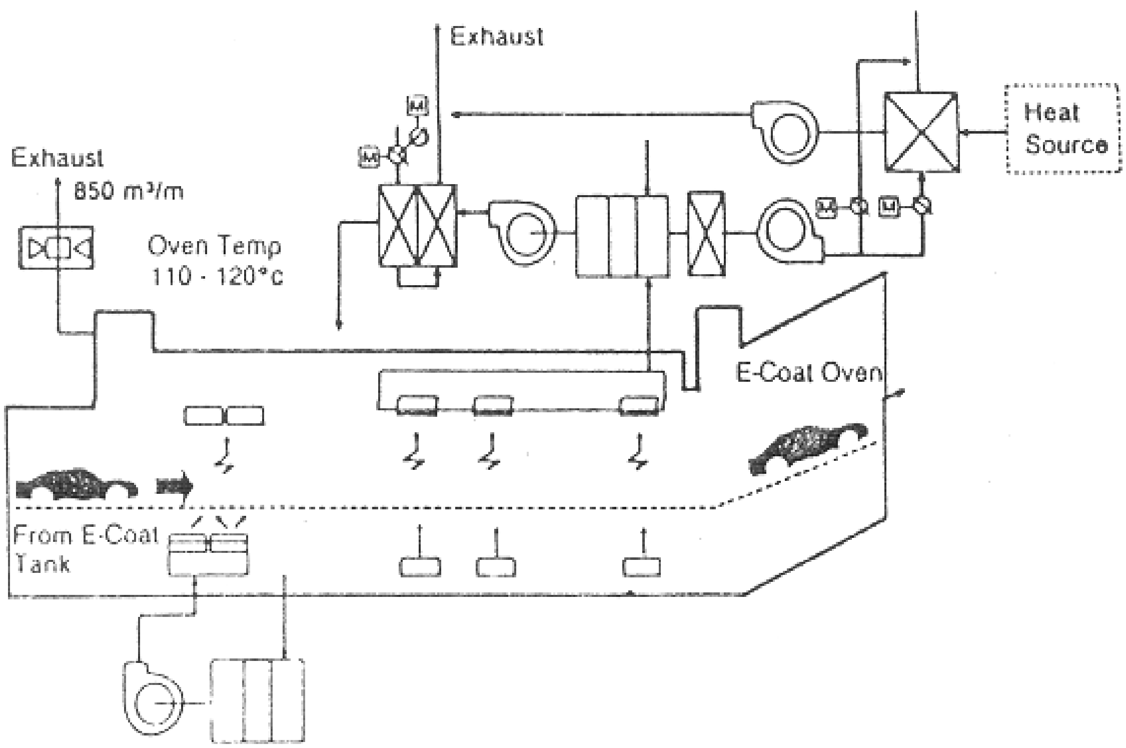


Fig. **7.10 Flow Diagram of Preheat Oven**

3 COAT-3 BAKE OR 2 COAT-2 BAKE PAINTING PROCESS :

The outer surface of the car body is prepared and painted through 3 coat (i.e. primer surfacer, base coat, top coat) - 3 bake or 2 coat (primer surfacer, top coat) - 2 bakes process.

The primer surfacer application is carried out in number of sections of the booth such as

- ✓ wiping off contaminants and an ionised blow-off to eliminate static electricity
- ✓ application of anti-chip coating to lower body area
- ✓ application of primer surfacer to entire body exterior
- ✓ inspection and repair of primer surfacer, if required

After a flash off, the body is moved through an oven for about 30 minutes at about 170^0 C for baking of primer surfacer. The bodies before moving to base coat and/or clear coat wet sanded, rinsed, and dried off. A preparation area is used for manual wipe down, compressed air blow-off and deionised air application. Depending on the manufacturer's process plans either the body moves through a clear coat application booth or a two-coat (basecoat/clear coat) booth. Between each coat, a flash off is necessary. The bodies are baked for about 30 minutes at around 160 ^{0} C. Inspection is carried out after demasking. The inspection is carried out after demasking. The painted body may move to the trim line, and only if required, either to a repair booth and oven or a minor spot repair with wet sand, air blow off and dry-off oven. Some unique differences in processes are observed from manufacturer to manufacturer.

While painting is carried out in booths, the body moves through oven for baking. Painting booths and ovens are specially designed to meet the quality requirements of the car.

PAINT BOOTHS

Different stages for spray booths of various processes are typically as follows:

Sealer/Finish	**Metallic Finish Coat**	**Final Repair**
1. Tac-rag zone 2. Manual preliminary spray 3. Automatic spray 4. Manual repair spray 5. Flash -off	1. Tac-rag zone 2. Manual preliminary spray 3. Automatic spray, base coat 4. Manual repair spray 5. Blow 6. Automatic spray, clear coat 7. Manual repair coat 8. Flash-off	1. Tac-rag 2. Manual spray 3. Flash-off

A uniform coat of paint is applied manually or automatically in booths. A stable painting environment is the basic necessity for a good booth. Controls in air supply system maintain the desired temperature, humidity and cleanliness of the air in the different portions of the booth. Air from the atmosphere drawn by supply fans placed at outer end of the air supply system passes through air intake grilles, air intake dampers, primary air filters, and the air supply fan. Depending on the climatic conditions of the plant location and the specifications of paints; systems for heating, cooling or air conditioning with humidity control are incorporated in the air supply line. The air supplied by the fan passes through the duct to the plenum chamber, from where the air is divided and passes through the secondary filters placed in the ceilings of the different sections of the spray booth, the entrance and exit vestibules. The air entering the vestibules travels towards the outside ends, and precludes the entry of dust from the outside. It also carries away the dust that might have been brought by the car bodies on the entrance vestibules. The quantity of the air supplied must be sufficient to obtain an outward air movement of approximately 0.5 metres per second. The air entering the spray booth becomes charged with paint overspray and is drawn out through the floor that is flooded continuously with water flow. Various orifices that are suitably located and that create the correct suction at the inlet of their throat. It creates a pressure drop that decides the collection efficiency. In one case, a pressure drop of 80 mm WG results in 99.8% collection efficiency. Higher pressure drop may improve it further. The flow pattern of down draft air also assures good paint transfer efficiency, sufficient air flow stability in the line, and the best application zone dimensions. A typical air flow around the car body with a venturi type overspray eliminator in a paint booth is shown in Fig. 7.11.

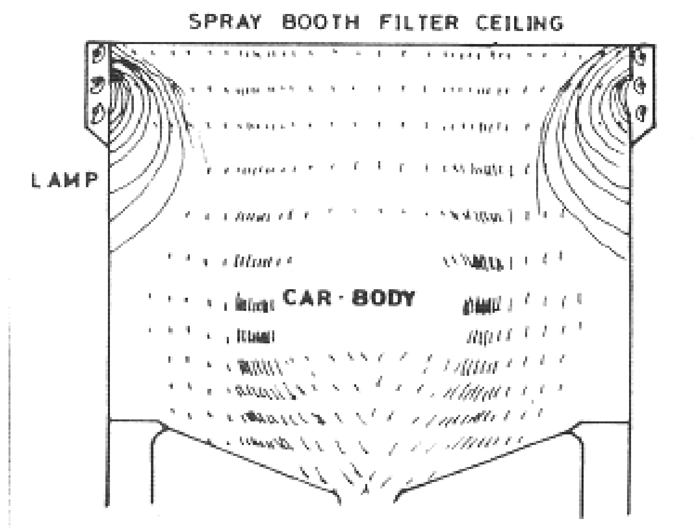


Fig. **7.11. Air Flow Pattern around Car Body in a Spray Booth**

Through the floor, the paint laden air is drawn through the venturi orifices of various designs located under the sloping water flow plate. The paint over spray is turbulently mixed with the cleaning water carrying the paint ‘deadner’. (The deadner is a fast acting chemical agent which denatures the paint and makes float on the surface of the water or sink.) The water is atomised by the air and the water and paint particles get intimately mixed. The atomised mixture travels into the dewatering section where the water and air are separated. Air that is now clean and free of water droplets moves through exhaust and is generally reused. As the paint mist is killed when it passes through the orifice, no paint buildup takes place.

The water enters the spray booth at the top of the water flow plates and is distributed along the whole width of the respective water flow plates. The water is drawn into the longitudinally placed venturi orifice where it mixes with the paint-laden air, extracts the paint out of the air. The water with paint particles is separated from the air in the scrubber. Efficient scrubber systems, shown in Fig. 7.12 assist to achieve paint emissions of less than 2 mg/Nm^2. The scrubber can be adapted to process modifications. Downdraft velocities may be changed.

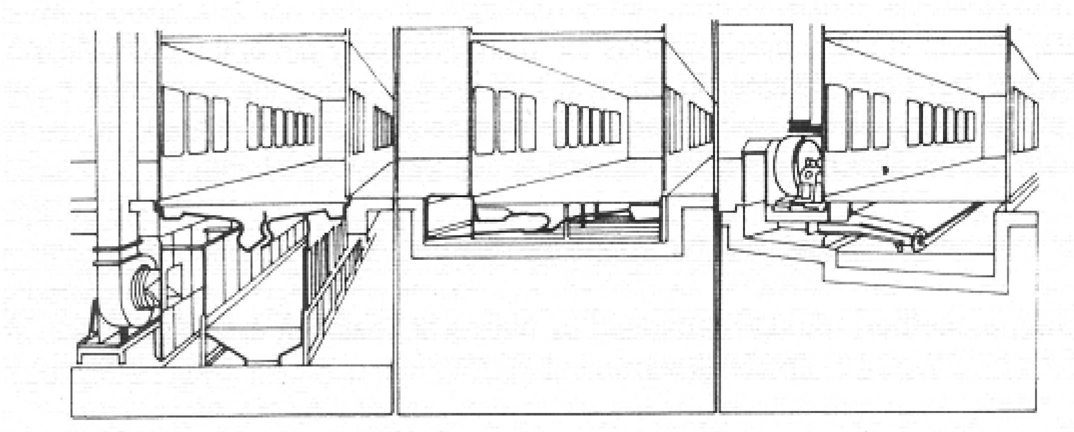


Fig. **7.12 Different scrubber Systems in Paint Booth**

Colour booths may be in various designs: with or without glazing, as sheet metal construction with 2-component interior coating or in aluminium or stainless steel.

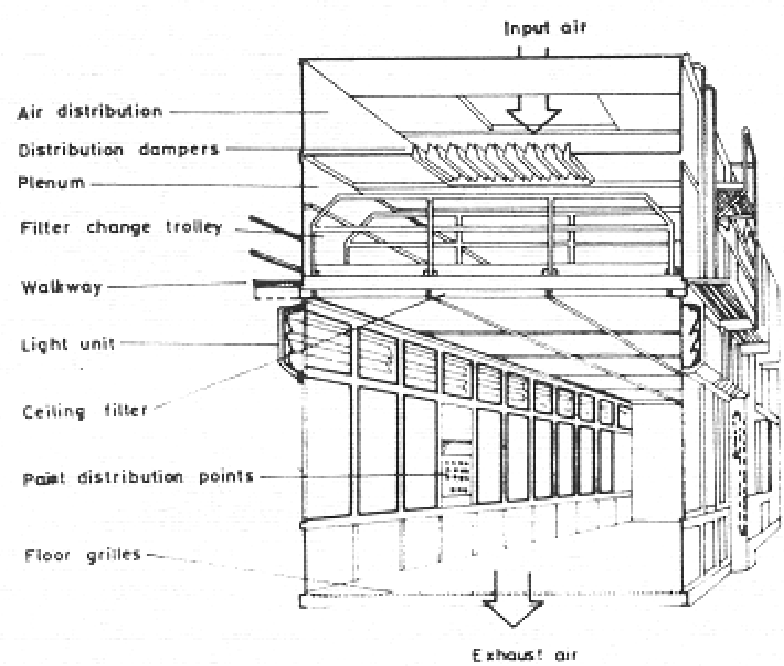


Fig. **7.13 A Cross-sectional View of a Paint Booth**

Stainless steel is used to increase the effective life of booths. Lately, the booth wall configuration has been made flexible through separate supporting structure and the cladding. Large glass windows, a variable door assembly, optimum illumination, a greater freedom for the paint connection points, etc. are features of colour booths in a new automobile paint shop. Spray booths using solvent based paints are provided with automatic fire extinguishing system for safety. Fig. 7.13 provides a cross-sectional view of a typical paint booth.

The water system in spray booth washes the paint overspray out of the paint laden air. The water carries the paint deadner in solution and finally carries the deadened paint in the sludge pit. In sludge pit, the paint rises to the surface and can be collected, while the water is drawn through a filter by recirculation pump and recycled to the booth.

Different methods may be utilised for sludge removal.

Conventional method -Sludge separated by means of floatation or sedimentation in a tank is removed by different methods as shown in Fig. 7.14.

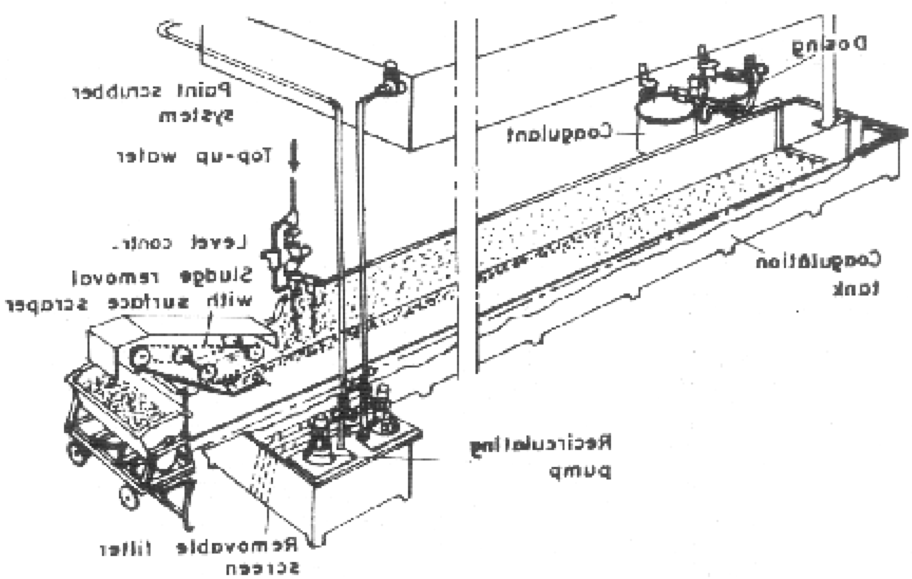


Fig. **7.14. Conventional Sludge Removal Systems**

Floatation overflow method *(based on the principle of coagulation)* - The paint-laden water is mixed with an alkaline or chemo-physical coagulant. The denatured paint is separated from a floatation tank. The paint sludge is periodically collected in filter bags.

External partial circuit waste treatment *(based on the principle of adsorption)* - The paint is denatured by the withdrawal of the solvent surrounding the paint particles through the reaction of the specific adsorbing agents, such as aluminium *oxide.* The reaction is almost spontaneous. Paint sludge separation is from the outside coagulation tank. Precipitating tank can be small.

The **exhaust air** volumes from spray booths are very high and the solvent proportion is low. A process to increase the concentration of the solvent content in the exhaust air is necessary. In one process, electric wet separator is used to eliminate all paint particles from the exhaust air. In another process, the continuous rotation of rotor with carbon fibre causes adsorption and desorption of paint particles. The hot air volume required for desorption is only a small portion of the solvent-containing exhaust air. Exhaust air purification may be carried out by:

- Adsorption plant designed with activated carbon fibre mat system with solvent recovery.
- Thermal purification plant for the combustion of solvent containing exhaust air at high temperatures.
- Catalytic purification plant for the combustion of solvent containing exhaust air at low temperature.

Activated carbon fibre mat adsorption systems provide many advantages:

- extremely high adsorption power and speed
- high desorption power and speed
- better quality of recovered solvent
- less weight and compact size

Paint circulation system covers paint delivery, paint mix, paint transfer, paint filtration and the final delivery to the point of paint application equipment. Paint circulation system maintains stable temperature, viscosity and pressure of the paint for the effective functioning of the painting equipment. A fixed rate of paint fluidity and viscosity is preserved with no sedimentation of solids to achieve uniform paint thickness. Optimum combination of paint temperature, car body temperature, and the temperature and relative humidity inside the spray booth facilitates smoothness and gloss finish for the car body.

Colour spraying may be executed by air atomising, airless spray, electrostatic spraying through manual or automatic equipment or by spraying robot. Conventional air spray guns are still in use, particularly for retouching work. However, the disadvantages are the excessive overspray and resulting waste requiring extremely expensive ventilation system to meet VOC legislation.

In *airless spraying*, a special high pressure hydraulic pump delivers the paint to a spray gun with a tungsten carbide nozzle- the spray tip. The energy required to atomise the paint comes from the sudden change in pressure as the paint emerges from the spray tip. The absence of air helps the spray penetrate corners and cervices better and substantially reduces overspray. However, heavy wear of nozzles caused by the high speed of the paint leaving the gun and often frequent blockage due to the fine hole of the spray tip; are the problems.

Air assisted airless spraying is a synthesis of the conventional air spray gun and airless spraying. A small pump partially atomises the paint by hydraulic pressure. With the Kremlin Airmix system, the paint fan at the gun nozzle is then uniformed and enveloped by the air jets incorporated in the spraying head to give fine atomisation. Overspray is reduced upto 30% in comparison with conventional air spray. It requires a compressed air volume of only one twentieth of that needed by a conventional spray gun, and a paint feed pressure which is lower than an airless gun.

HVLP (High Volume Low Pressure) spraying is a logical development of air assisted airless spraying. HVLP version utilises high volume of air (at pressure below 70 kPa) lowers overspray even more than that by air assisted airless version. With improved coating rates, it results in considerably low VOC emission, as the transfer efficiency is in excess of 65%. HVLP is very successful with low viscosity paints.

Electrostatic spraying has increasingly been accepted as the best method. The method of atomising the paint may be:

1. By centrifugal force off rotating sharp edge as in high speed rotating bell. The high voltage imparts the maximum electrostatic charge at the edge.
2. By high pressure fluid feed and airless atomisation through a small orifice
3. By air-assisted airless feed with certain clear advantages over 2.
4. By compressed air as in conventional spray gun

In the case of centrifugal atomisation, the particles are charged as they leave the rotating bell. Other systems ionise the air at the tip of a sharply pointed external electrode and depend on partial transfer of the charge from air ions to the atomised paint particles. Paints are generally charged with negative polarity. Close tolerance of electrical resistance is the most critical feature of the paint formulations. The bodies to be coated are earthed to attract all the paint and create a 'wrap around' effect of the paint particles. The method has many advantages over conventional spray finishing:

- Faster painting
- Better uniformity once the parameters are established
- Considerable saving in paint through absence of overspray
- Less need for comprehensive exhaust facilities

Different methods of providing the high potential are used by paint equipment manufacturers and the equipment are available for both manual, automatic, or robotised application.

While manual painting can hardly attain 25~35% paint transfer efficiency, automatic painting machines achieve a transfer efficiency of 80~90% with electrostatic bells, and 60~70% with air atomising reciprocating paint machinery. Automated painting also achieves uniform paint deposition over all the surfaces, and the quality is consistent unlike skill-dependent manual spray painting. Water borne paints are replacing solvent borne ones for better emission control. **Application of water borne paints by electrostatic methods** requires special precautions, as the higher conductivity of these paints provides an earth path via the distribution system. Some major systems have been developed by the paint application equipment manufacturers to meet this requirement of water borne paint.

The *Internal Charge System* uses a paint reservoir situated within the machine and sized to provide sufficient paint for one application. This is filled from the distribution system and then physically isolated before the high voltage applied. The reservoir is finished and refilled for every body painted. The transfer efficiency is same as one with solvent-based paint. Application does not depend on the booth conditions. The paint finishing is excellent. However, the system is not suitable for very fast colour changes.

The *Electrode System* uses external electrodes. The atomised paint from the high speed bells passes through a corona field created by a system of electrodes arranged around the rotating bell but electrically isolated from the main body of the machine. The system can make very fast colour changes, but the environment in the booth must be perfectly controlled in terms of humidity, temperature and ventilation to achieve the optimum efficiency.

In a new system called *Accubell*, a single tank is fitted as close as possible to the bell. The tank can be filled with the quantity of paint necessary for one job. To change colour, the atomiser travels to a docking station which is connected to the colour changing block for colour change cycle to begin. The tank is first cleaned with water as are the bell and the paint injector, and then all are flushed with compressed air. Finally, the tank is filled with the new colour. The colour change time is short. It prevents paint waste and water consumption is low. The principle for Accubell has also been applied with electrostatic guns. The tank in this case is bigger as the flow rate for a gun is usually higher for a bell and the system is called Accustat. It has to correspond to the multi-axis robots. The high voltage power unit is integrated into the gun so that only the low voltage cable runs through the arm of the robot.

A judicious integration of automated paint finishing machines, robots and automated spray guns may be required to maintain the spraying needs of each section of a car body in highly automatic paint plant, as shown in Fig. 7.15. In an automatic paint facility, the thick primer surfacer and clear coats are applied by means of electrostatic high speed rotary atomisers. Bonnet, decklid, wheel arches, etc. can be painted with industrial robots that move along side of the body controlled by means of a tracking system. With the optimisation of the spraying system, the air through-flow may be reduced. Some new machines have incorporated the internal routing of the supply lines as against the outside routing on conventional machines. With no open, loosely suspended cables and conduits above the body, the flaws on the paint finish caused by falling dirt is avoided. Paint and solvent losses during automatic colour changes are considerably reduced, as the colour change devices are located close to the spray nozzles. Quantity of cleansing liquid required to flush the system before the colour change is also reduced considerably. Further, modularity in construction is another feature of these machines that provides flexibility for model change. In a typical metallic spray booth using solvent borne paint, the process sequence may be as follows:

- Tac rag manual or using ostrich feather machine
- Inside painting of base coat with robots
- Outside first base coat with electrostatic paint spraying machine
- Outside second base coat with paint machines
- Intermediate blowoff
- Inside painting -clear coat with robots
- Outside clear coat with electrostatic paint spraying machine.

The paint shop operators are provided a control system that graphically displays and simulates the operating parameters. For operator, it is easier to set the enormous number of coating parameters and to optimise the system.

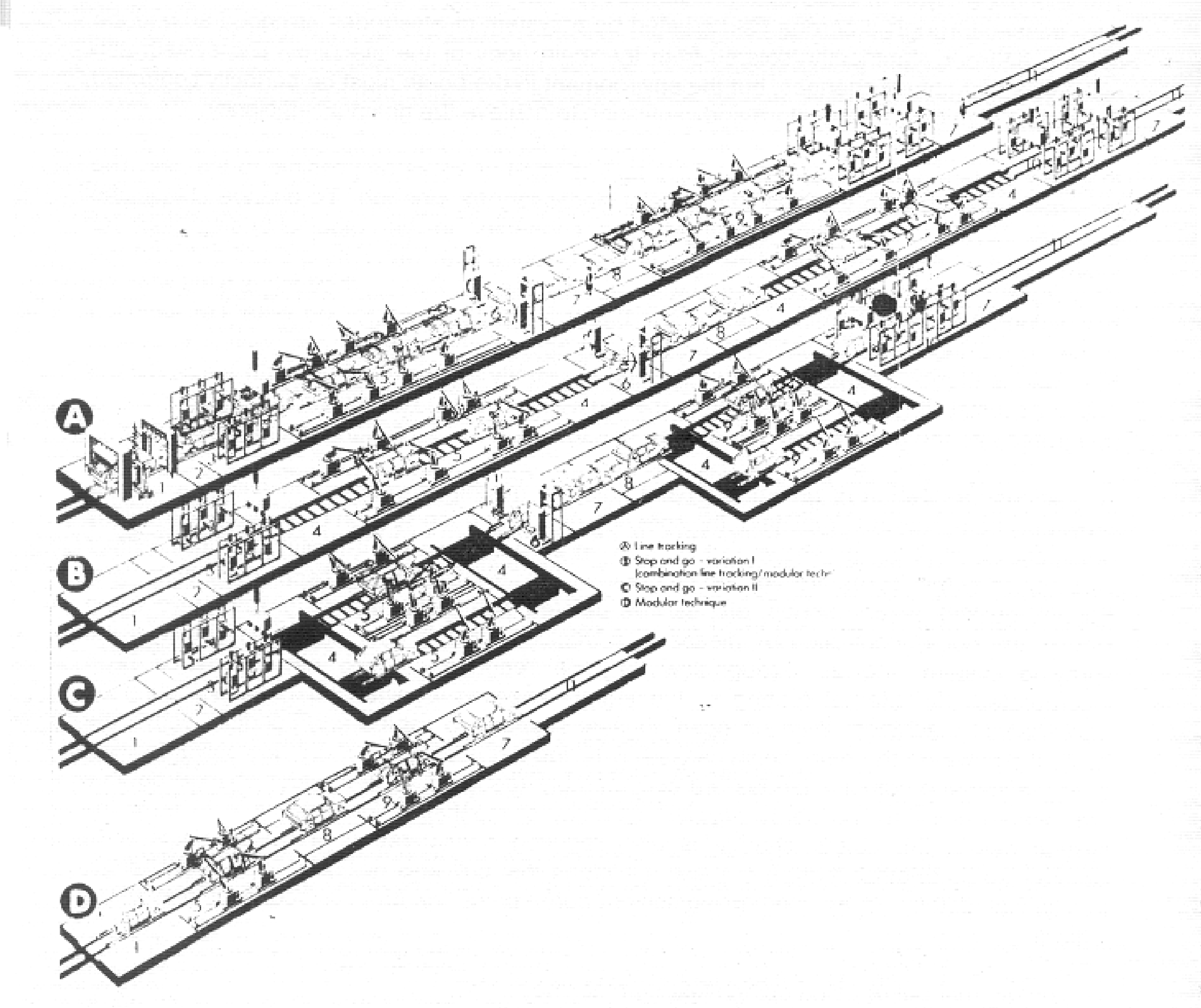


Fig. **7.15. Automatic Painting Machine and Robots in a Paint Shop**

Paint spray booth is thus a totally integrated system with paint supply system, colour changing system, and painting equipment. Air turbine driven minibells with high voltage block and efficient paint atomisation system are capable of flexible positioning through a 3-axis control. Controls for the conveyors, application equipment, robots and the safety installations are integrated through a control panel mounted into the side wall construction of spray booth.

OVEN

After every paint coating, ovens are required to cure the coating in addition to drying off the wet surfaces. The type of oven system generally depends on the type of paint coat used. Typically in a paint shop, the ovens are: pretreatment water dry-off oven, electro-deposition oven, underbody sealer oven, surfacer coat oven, dry-off oven after wet sanding, finish coat oven, metallic finish coat oven, repair oven.

Dry-off ovens are used to ensure that the body surfaces are absolutely dry before paint application. Sufficient time is provided to allow the body to be heated to about 125-150 ^{0}C at which all water is evaporated. Ventilation is necessary to take away the evaporated water. With direct gas heaters, ventilation must be sufficient to provide the amount of oxygen required for the combustion as well to take away the flue gas produced.

Paint bake ovens are divided in two parts: the heat-up zone and the holding zones followed by the cooler. Air seals are incorporated at oven ends. In heating zone, the painted bodies are rapidly brought up to the required baking temperature. The holding zone then maintains the temperature of the bodies for the time required for complete baking of the paint. Layout of an oven with a cooler is shown in Fig. 7.16.

Convection ovens, radiation heat ovens, or a combination of both systems may be used in paint stoving process.

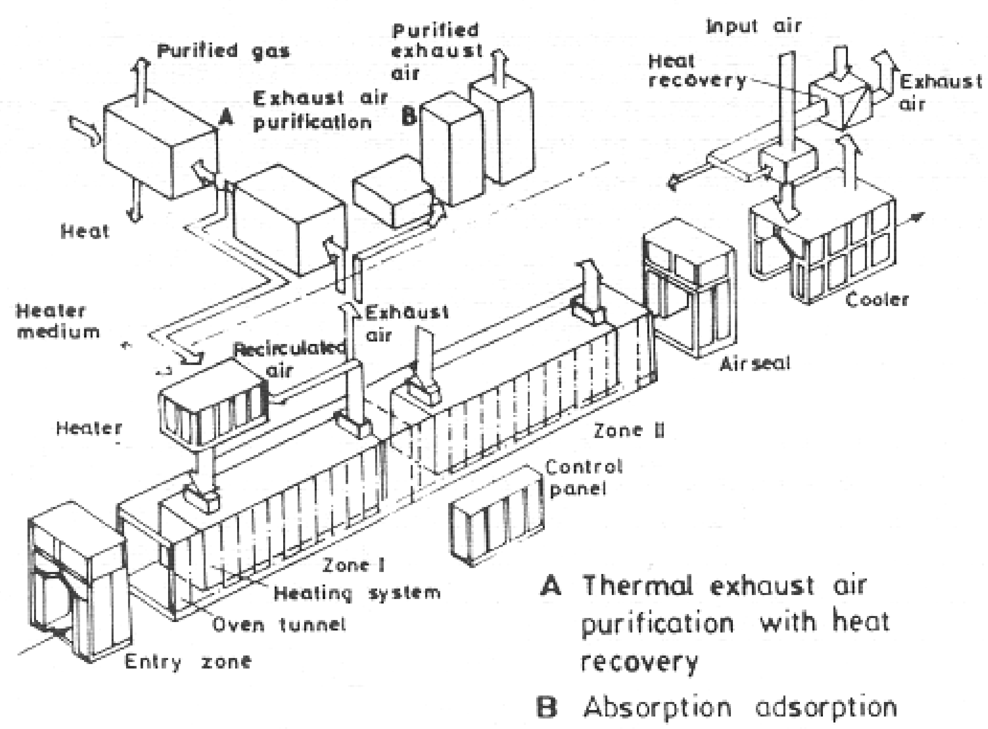


Fig. **7.16 A Layout of a Paint Baking Oven**

Convection ovens: The body is heated by means of circulating air that sweeps over the surface thus transferring its heat to the body by convection. For a uniform metal temperature, the circulatiing air is blown into the oven at floor level. The air then is made to pass through the oven vertically towards the ceiling from which it is extracted and conveyed back to the heating unit.

Radiation ovens: Due to the natural air circulation caused by the heat convection against the radiation panels, there is a tendency of temperature increase just below the oven ceiling in radiation oven. A supplementary air circulation fan is used to
exhaust the hot air under the ceiling and blow it again at floor level to maintain an even temperature inside the oven.

Combined radiation-convection oven: The radiation zone is used as a heating zone, as the radiation heating is expected to be quicker than convection heating- particularly for the surfaces exposed to the effects of radiation. Adequate ventilation is provided to eliminate the evaporating solvent and the make-up air is filtered before entry into the oven. Convection zones work as holding zones in which the temperature of the bodies can be kept constant during the full time required for complete baking of the paint.

The number of heated zone is dependent on application and capacity. Heating may be indirect or direct with electricity, gas or oil. Oven heat transmission may be through convection. Blast nozzles may be arranged at the top or at the sides. It may be indirect heating in infra-red oven. The bodies pass through a cooling zone where fresh air is directed onto them at high velocity. The fresh air thus heated up is carried away via the exhaust air system.

Coolers at the end of ovens allow the bodies to be handled rapidly and to prevent large quantities of heat from the bodies to escape into the shop atmosphere. Air seal at exit may be designed to work as a cooler for low production. The air seal is provided with an air supply fan that delivers filtered outside air via an intake stack. An exhaust fan removes the used air through another stack. Temperature control of the supply air is achieved by interconnecting the two stacks so that the out going air may be mixed with incoming air in suitable proportions. However, for large production painting oven, a separate cooler is essential besides exit air seal. The principle is same as that for air seal, but longer time and larger air quantity are required.

Even and quick heating up of the body, independent of the body shape and material suspension is normally the objective of a sound oven planning. In one case, in drying zones, medium wave infra red radiators allow a controlled heat up within small tolerances, Fig 16. The intensity of the radiation is controlled to a pre-selected temperature of the body. Detection of the measured values is by contact free radiation thermometers, while the radiator output is controlled electrically.

Advantages are:

- An uniform and quick heat up of the car body, independent of sheet metal thickness and car body shape.
- Optimum drying conditions despite shorter oven length
- No overstoving due to over temperature reaction e.g. in case of conveyor breakdown.

Excessive heating up of plastic, rubber electrical components during repair curing is avoided due to spot heating of the repaired surface. An additional benefit is energy saving.

The preferred oven design is the ‘A’ or ‘camel back’ type because of its capability to reduce fume spillage Fig. 7.18. Comparison of Dual pass in line A configuration oven with dual pass 180 degree turn camel back oven is as follows:

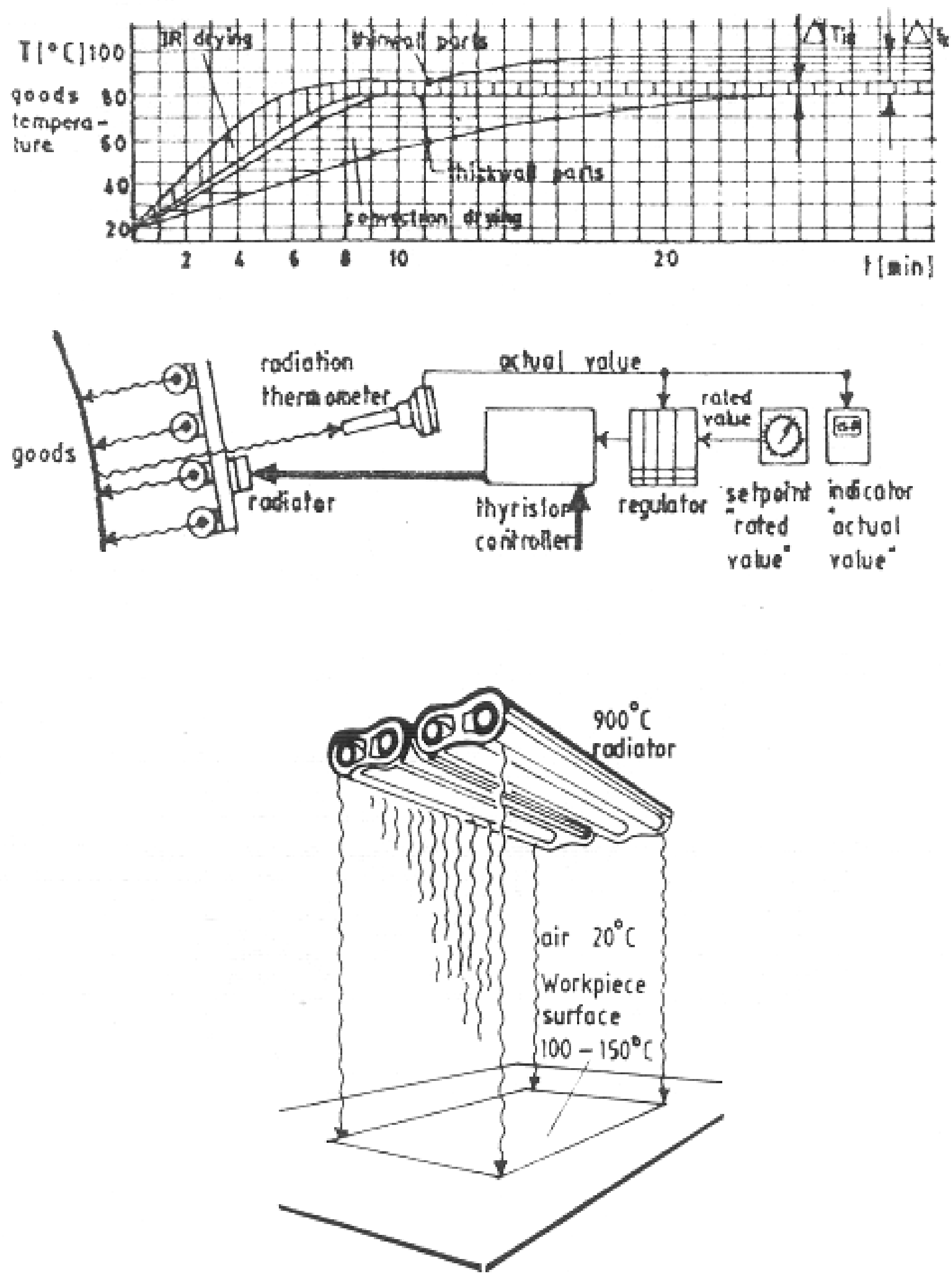


Fig. **7.17. An Infra-red Heating System for an Oven**

‘A’ CONFIGURATION	‘CAMEL BACK’
Two entrances and 2 exits for each oven	One entrance and one exit opening reduces energy loss
Increased energy loss due to larger area of openings	Less exhaust volume
Greater probability of heat loss into plant atmosphere	Smaller incinerators due to reduced exhaust volumes
Larger incinerators required to treat increased exhaust volume	Lower initial investment and operating cost.
Higher initial investment and operating cost	

Feature such as “Dark” radiant heat up zone is also used to reduce the risk of dirt contamination. Fig. 7.19. shows cross sections of still air dark radiant zone and hot air circulation zone of an oven.

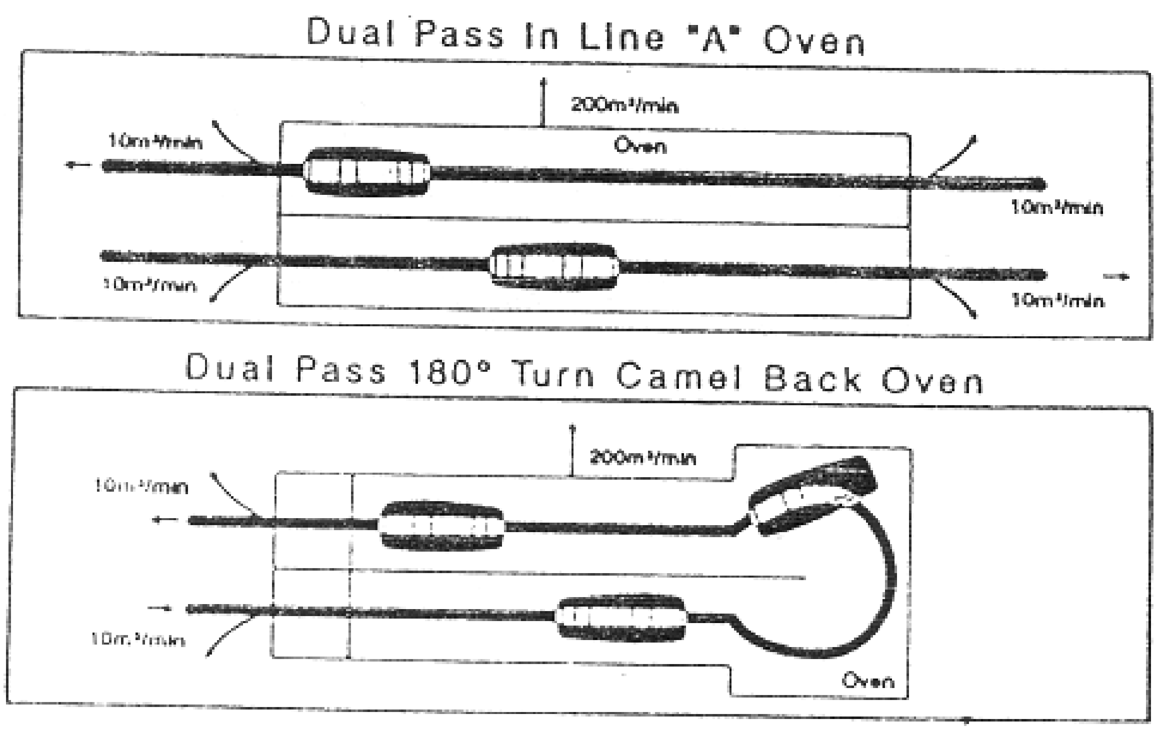


Fig. **7.18 ‘A’- type and ‘camel back’ type oven systems**

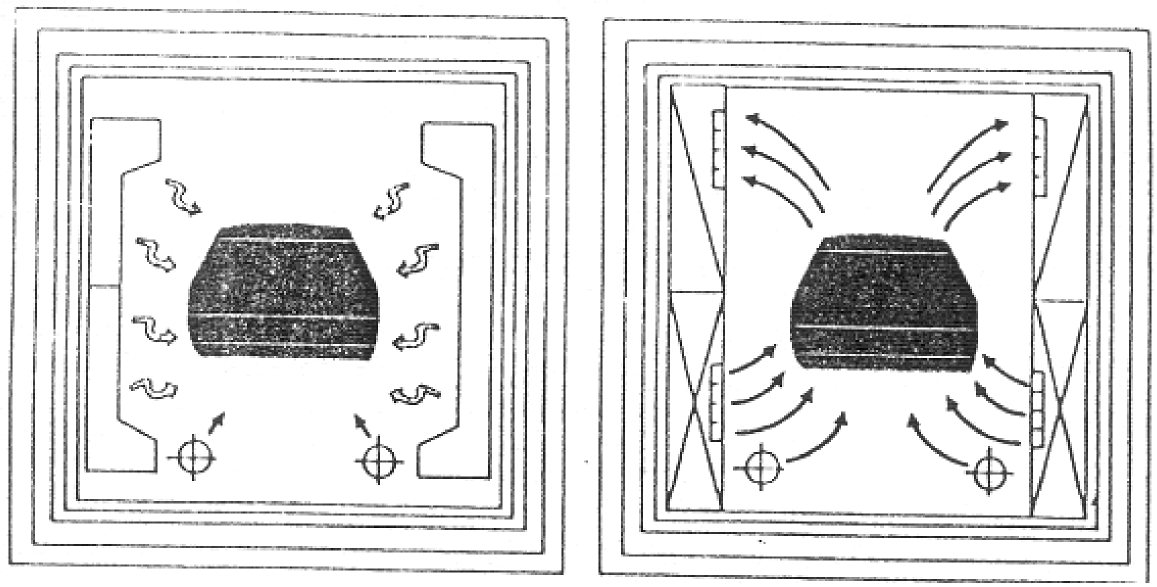


Fig. 7.19 A Dark Radiant Heatup Zone and Circulation Zone - Cross sections

Fig. 7.20 shows a schematic flow diagram in an ED oven.

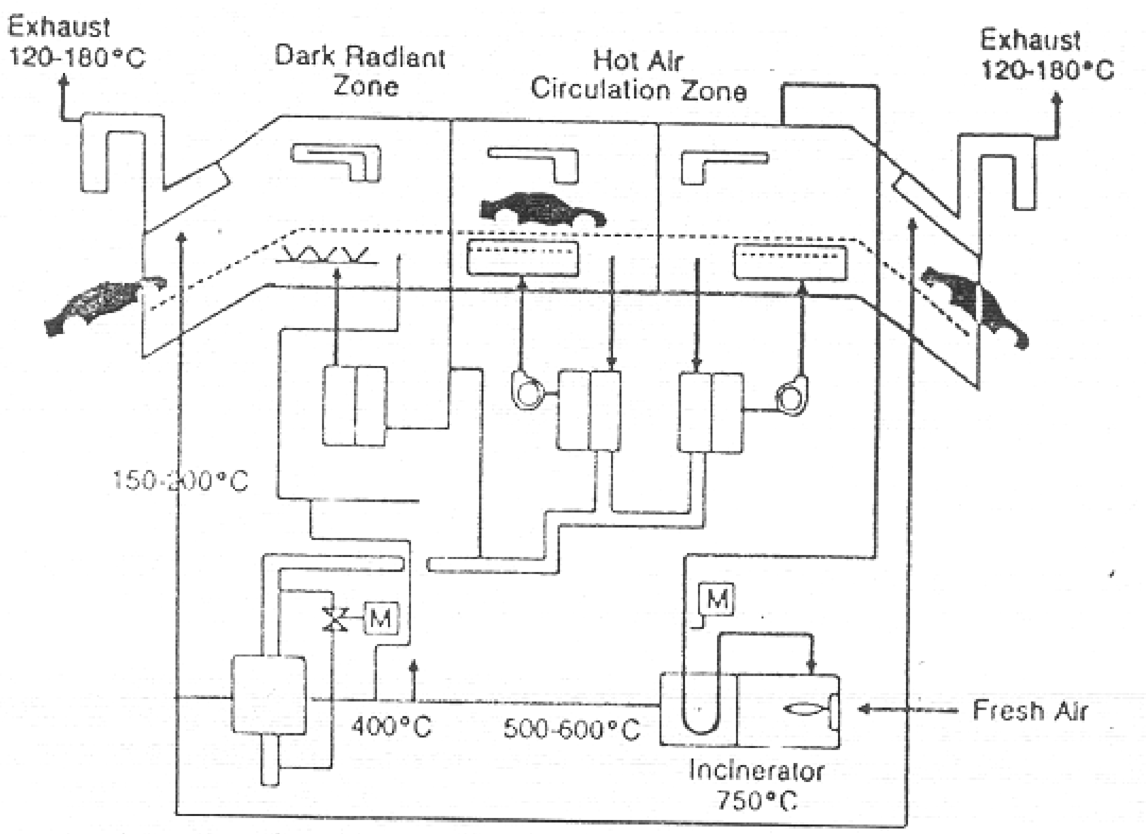


Fig. **7.20 A Schematic View of an ED Oven**

Haden Drysys uses an oven design that eliminates the need for external recirculation fans and duct work. The design combines dark radiant heat up zones to allow the paint film to flow and case harden, and turbulators. It claims to improve quality. However, it is necessary to use natural gas or LPG as a fuel for this oven. For water borne clear coats, the oven design requires a change, and an infra-red forced flash-off zone is added to remove water. The car body passes through the following zones after paint booth:

→	Infra red forced flash off	10 minutes 80 °C
	↓	
	Dark radiant heat up	10 minutes
	↓	
	Turbulent convection heat up	5 minutes
	↓	
	Convection hold zone	15 ~ 20 minutes

Ovens are generally modular welded steel structure with absolutely gas tight interior. Modular design is for the oven tunnel equipped with various components for heat transfer and for ease of transportation. Units for heating of recirculated air, for radiation control, for fresh air, pre-heating as well as exhaust air filtration, are part of the modular design of the ovens. Advantages are:

- The modules can be easily tested in the plant of equipment manufacturer. Assembly and erection time at the customer's plant get significantly reduced.
- Contamination of the insulation and risk of fire hazard due to penetration of condensate through the oven tunnel are avoided.

Solvent and other pollutants emitted during the stoving have to be eliminated and minimised to the value permitted by the local clean air regulation. Either thermal exhaust incineration units or absorption units are used for the purpose. The organic and inorganic combustible noxious substances contained in the exhaust air is burnt at around 750^0C. The temperature depends upon the legal requirements and the noxious substances contained in the exhaust gas or fuel used in incinerators. The heat released during incineration is mostly used for pre-heating of polluted exhaust air or can be directly or indirectly used into the air seals at entrance and exit of the ovens. Solvents contained in exhaust gas are separated and incinerated with patented special equipment to yield harmless carbon dioxide and water. There are some noxious substances that can not be eliminated by combustion. Absorption is used to purify the large exhaust air volume with small content of these noxious substances.

WAX PROTECTION

Box section and cavities in the body are protected against corrosion by applying a protective film of wax either by manual spray method or by automatic flooding method.

In manual method, the solvent containing preservative wax is sprayed into the box sections of the body with spray nozzles. One spray nozzle with adapter plate according to the geometry of the box section opening is required. Equipment provides control for the amount of the sprayed volume.

In flooding method, hot wax (solvent free) at about 120°C from a flooding tank is pumped via automatically introduced automatic nozzles into specific box section openings of the body. The box sections are completely filled and then emptied to drain the excess wax to return into the flooding tank. Before the flooding process is started, the body is preheated to 50~80.

MATERIAL HANDLING SYSTEM FOR PAINT SHOP

Selection of the appropriate conveyance method for each process is vital and depends on the layout. The system combines several types of conveyors and other handling and storage equipment. Body-in-white from body welding shop is transferred to overhead conveyor that moves the body through pretreatment, cathodic dip Electro-deposition and underbody seal stage. C-, or S-type (swan neck) hangers along with dirt trays are used to protect the conveyors from chemicals and water during the pre-treatment stages, and to protect the possibility of any contamination. Counter measures against chemicals and heat are taken through heat resistant grease for chain trolley-rollers and carrier rollers. For Electro-deposition area, an assured current supply with the connection of a conducting mechanism to the hanger and insulation are the built in features. The conveyor systems may be electric overhead monorail or dip tank hoist for intermittent operation, and overhead or pendulum conveyor for continuous operation. Particularly, during intermittent dip operation, a swiveling system is built-in for uniform coating and exit with minimum dripping, Fig 7.21. Fig. 7.22 shows dunk type pretreatment and electro-deposition with manually operated or programmable traversers and hoists for low volume production. Fig. 7.23 shows a typical hanger for ED bath. Some European automanufacturers have used special roller and shuttle conveyors in pretreatment and ED bath to avoid the problems with soiling by particles of dust, grease or oil. Bodies from pretreatment, Electro-deposition, and ovens are to be removed at the end of shift and require a storage system to start the process again. An auxiliary conveyor is planned at the exit of elctro-deposition oven based on the capacity calculation for ascertaining the sufficient length and stations.

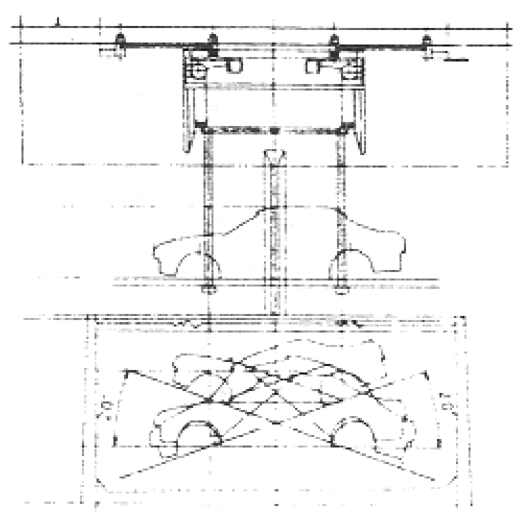


Fig. **7.21 Swiveling System of Hanger in ED Bath**

Thereafter, the body is transferred from the overhead conveyor to floor conveyor that moves through surfacer, wet sanding, colour coating, finishing and final inspection. Countermeasures against adhesion of paint are taken with an umbrella plate used in coating booth on specially designed chains. Water resistant and wear resistant conveyor chain become essential for sanding line. For explosion prevention, drive units of all booth

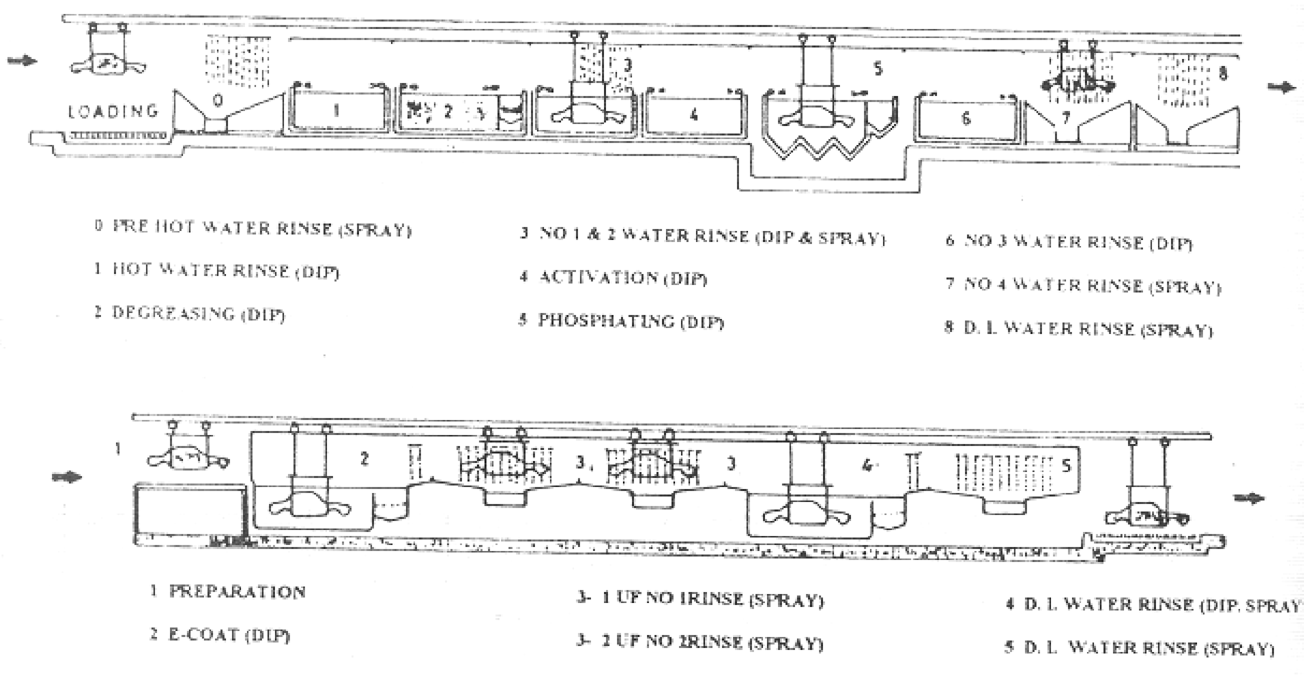


Fig **7.22 A Dunk Type Pretreatment and ED system**

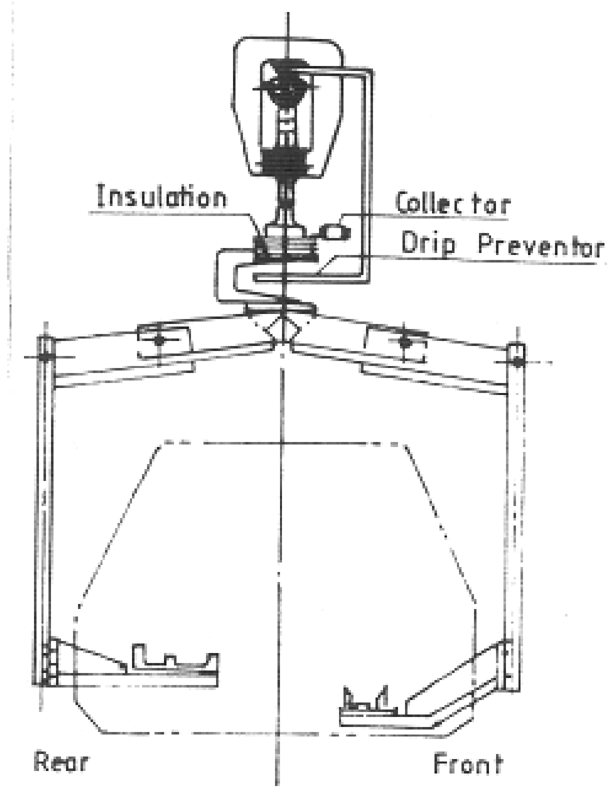


Fig. 7.23 An Overhead Hanger for ED Bath

conveyors are located outside. Oven conveyor rails and dolly rails are made heat resistant. Depending on the layout requirements, cross transfers of bodies are also executed.

Power and free overhead conveyor for pretreatment and electro-deposition areas and 'inverted' power and free conveyor with skid system for paint booths and ovens are preferred for body handling in body shop. Overhead conveyor provides free floor area. Body movement is independent of equipment on floor. Different body handling systems used in a typical paint shop are:

Power pulled conveyor (Fig. 7. 24) consists of a chain, powered by a caterpillar-type or rotary-type drive unit, to which load carrying trolleys are attached at regular intervals. Speed can be varied. Overload protection devices are incorporated in the drive system.

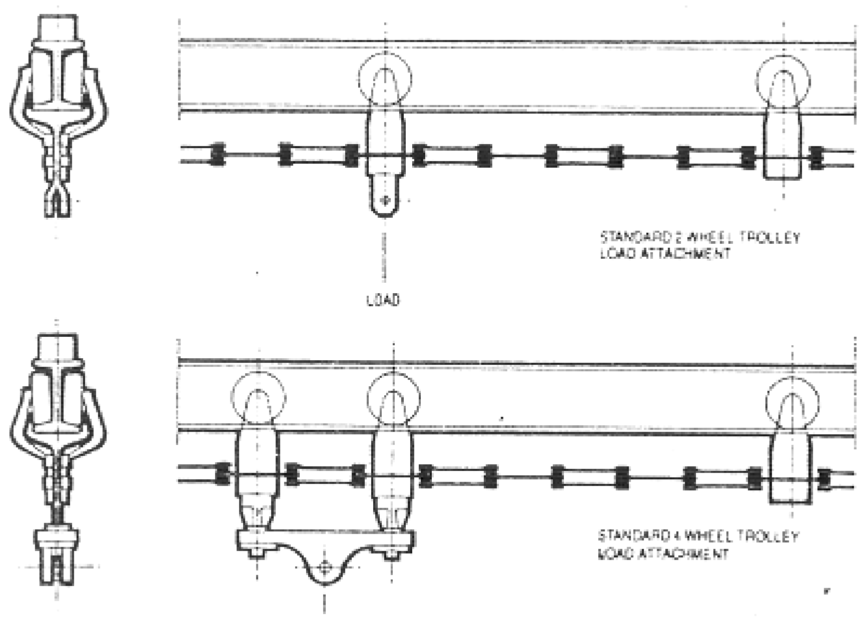


Fig. **7.24 Power Pulled conveyor**

Power and free conveyor, Fig. 7.25: Unlike the power pulled systems, the load is not fixed to the chain. The propulsion unit and the carrying device operate independently. The chain is the propulsion unit for transferring the free pulleys. The chain-driven trolleys are supported by a secondary twin-channel track. The loads can travel at differing speeds and pitches, as well as through changes in elevation. Accumulation system allows the automatic live storage of loads in maximum close proximity. System offers maximum flexibility.

Inverted power and free conveyor, Fig. 7.26 is basically an overhead power and free conveyor that is practically turned upside down to mount it on floor. The inverted power and free conveyor provides automatic transfers between conveyors that have varying speeds and pitches, and gives the opportunity to have in-line or selective storage banks between processes. The feeding and take away conveyors can negotiate upto 30 degree vertical bends for elevational changes such as may be required by high level ovens or empty trolley return lines. Inverted conveyors are ideally suited for all types of spray booths. The free trolley rail and chain rail are concealed safely under a steel cover, and dolly links are sealed with rubber to keep out paint and other coating materials. At booth entrances and exits, only dolly rail is raised and lowered- allowing its interior to be flooded with water to prevent paint from adhering to the wheels. Minimum electrical equipment minimises the chance of sparking an explosion inside spray booths or drying areas.

Skids or trolleys are used on floor conveyor for bodies. Skids provide the most advantageous form of transport for bodies in paint shop. Conveyors may be:

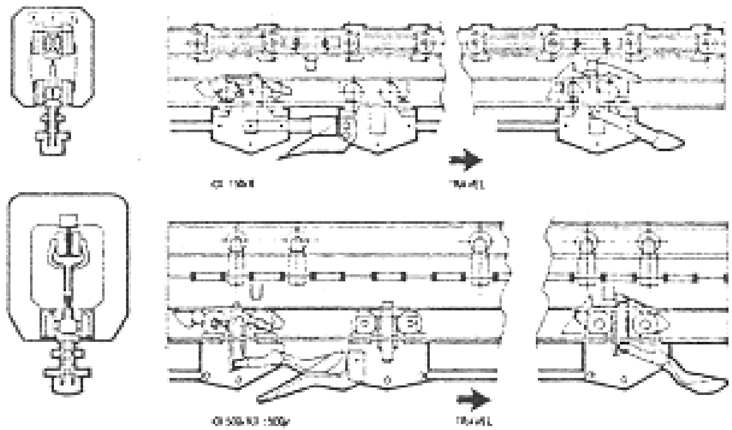


Fig. **7.25. Overhead Power and Free Conveyor**

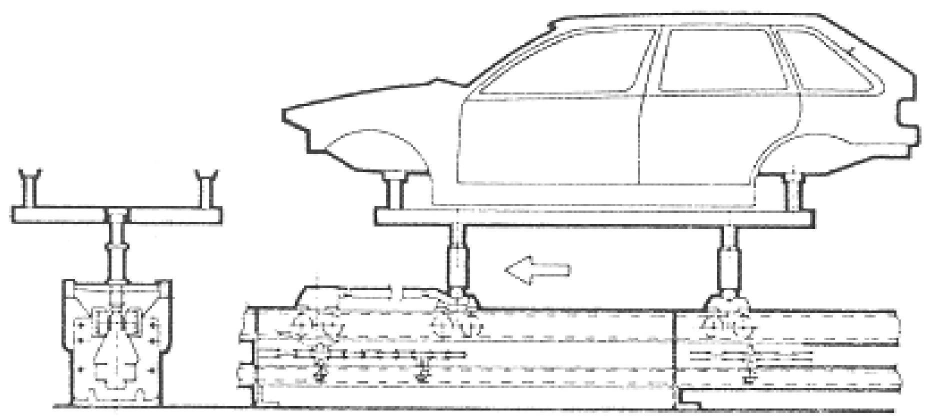


Fig. **7.26 An 'Inverted' Power and Free Conveyor**

Horizontal axis chain conveyor for trolleys, Fig 7.27 provides material flow change over capability via switches and transfer units. Variable speed is possible through separate conveyor circuits. It may be used for both intermittent and continuous operations.

Floor conveyor for skids: The system, Fig. 7.28 consists of:

1. Longitudinal transfer

- Chain conveyor with fixed arrangement between chain, conveyor unit and skids, and no relative movement between chain and skids.

- Buffer chain conveyor employs rolling movement between chain and skids, and is installed as storage unit between individual production sections.

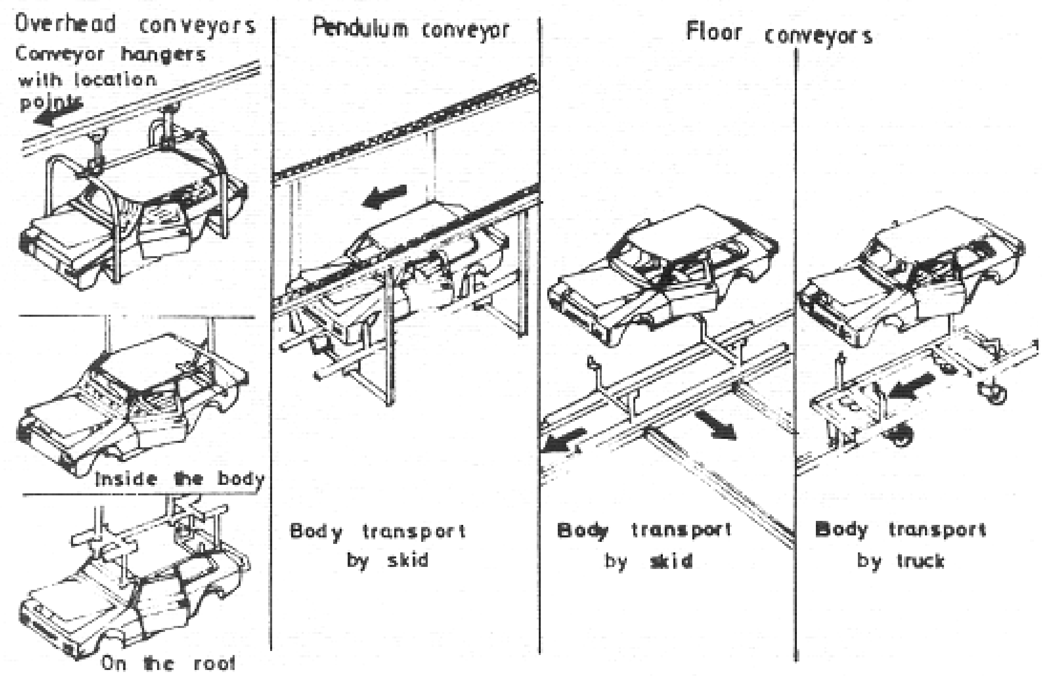


Fig **7.27 Skids and Trolleys used in Paint Shop**

2. Cross transfer

- Transfer chain conveyor is used for high volume and continuous travel. Transferring is by lift table.
- Transfer carriages are used for low volume and intermittent travel.

3. Vertical transfer:

The system to be adopted depends on the production capacity and conveyor height:

- Lift table and carriage lift for intermittent operation
- Paternoster-conveyor for continuous operation

Electrical monorail overhead conveyors, Fig. 7.29 may be used for feeding the bodies in and out of the paint shop, particularly where the explosion proofing is not necessary. The system combines drive and carrying units and permits horizontal

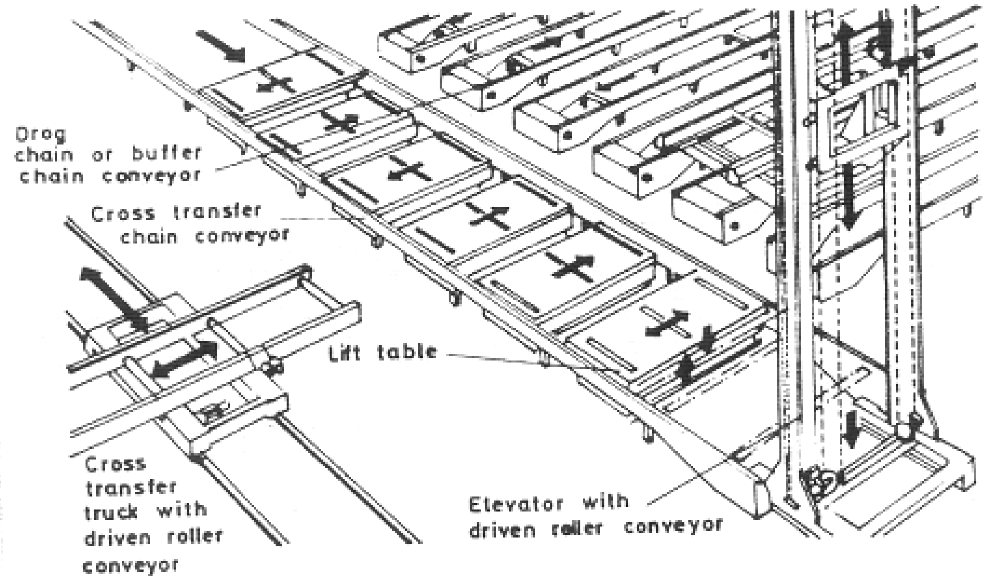


Fig. 7.28 Skid Conveyor System for Paint Shop

body routing, vertical body movement, variable speed control, intermittent and continuous operations.

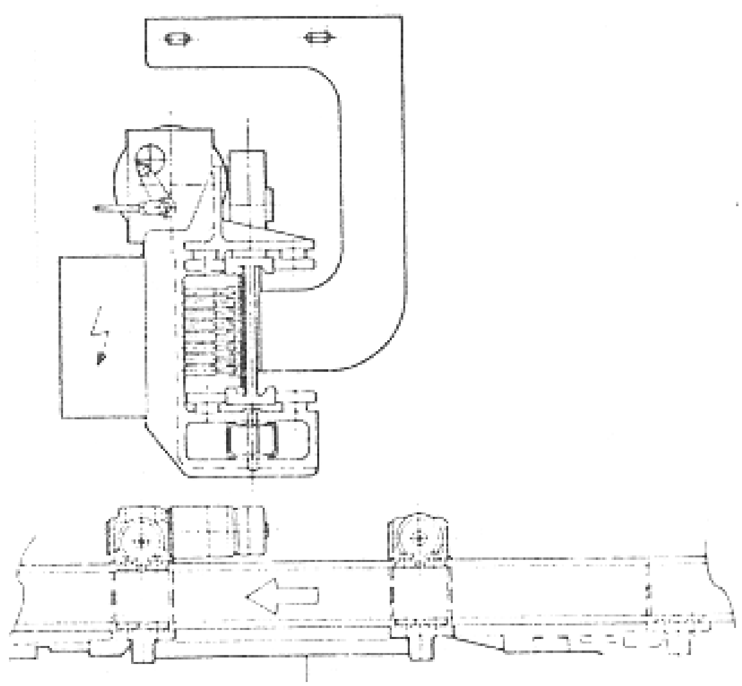


Fig. **7.29 Electrical Monorail Overhead Conveyor**

Different automanufacturers select different systems of material handling. However, cleanliness, reduced energy consumption, and lower noise levels in operations, are other major factors that influence the selection of a specific material handling method for a particular process.

ROBOTS IN PAINT SHOP

One major factor deciding the quality of a painted body - high luster of the outer surface, is the stability of movement of spray gun. Human hand has a limitation. It becomes difficult for him to keep moving the spray gun continuously at a uniform speed and angle with respect to the body surface to assure a uniform coating of paint. Application of properly programmed robot provides the ideal solution. With robot it is possible to obtain a film uniformity of within +/- 5 microns in painting and an improved luster.

The quality of panel joint sealing again depends on the skill of the worker. On a continuously moving line, it becomes difficult to perform the task without deviating from the set sealing speed and path. Robots overcome the drawbacks and operate at a stable sealing speed steadily along sealing path providing uniform sealing.

TABLE: ROBOT'S SUPERIORITY IN PAINT SHOP OPERATIONS

Characteristics		Deviation with human worker	Deviation with robot
Luster Film thickness	Gun speed Gun attitude normal to surface within	+/-50~100% $+/-10\sim20^0$ +/-10μ	+/-10% $+/-1^0$ +/-5μ
Water tightness through sealing Sealing bead diameter	Gun speed Gun attitude normal to surface within	+/-50~100% +/-5 mm 3~4 mm	+/-10% +/-1~2 mm +/-1 mm

With naked eye inspection for imperfections of painted surface, the average imperfection detection rate is about 60%. The trend is towards using a robot with an inspection instrument employing laser beams to form a system for automatically detecting imperfections. The system improves the imperfection detection rate to 100%. Similarly, the robot may be used to inspect the sealing applications.

Water System and effluent treatment

An automobile manufacturing plant consumes approximately $4m^3$/cm car. Paint shop requires water of differing quality and in large quantity. A DM (demineralised) water plant that is based on ion exchange principle is essentially setup. Waste water volume from the paint shop can be significantly reduced. Process water from the pretreatment and sanding area is cleaned and recirculated through ultra-filtration, ion exchange, and other methods such as reverse osmosis and electro-dialysis. Industry's average of 900 litres per body of waste water discharge has been reduced to 200 litres per painted body through different improvements as shown in Fig. 7.30 by an automobile manufacturer.

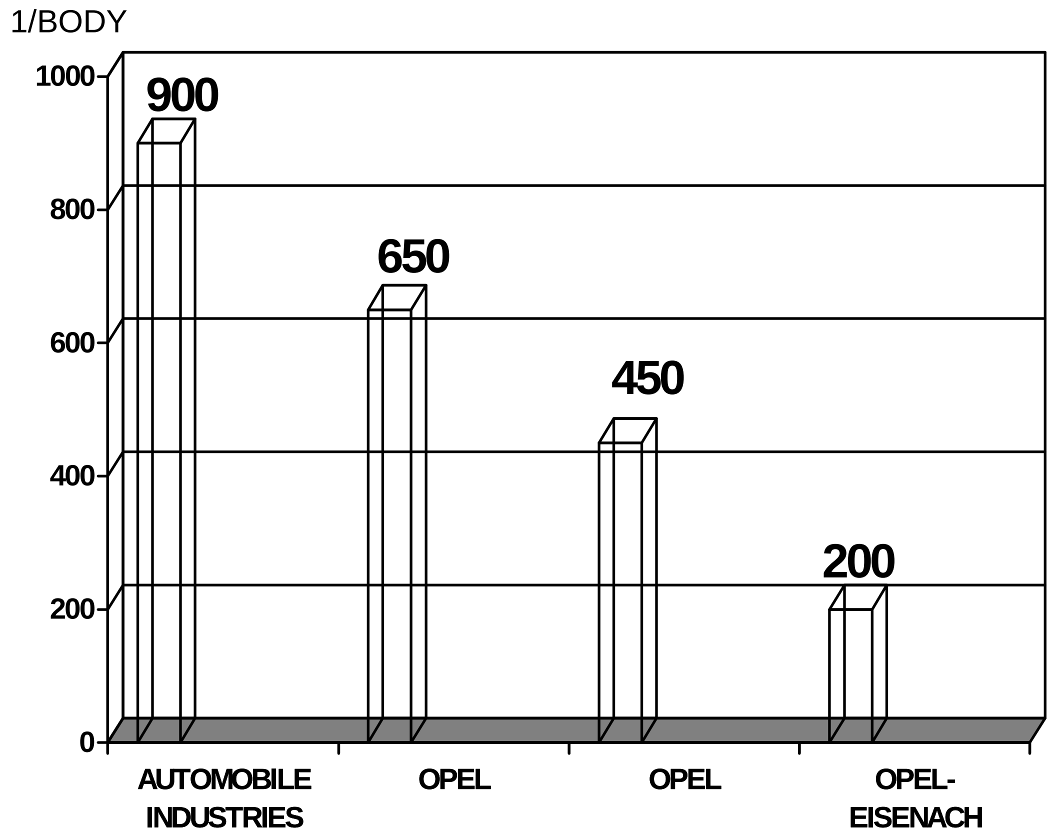


Fig. **7.30 Gradual Reduction Of Water Requirements In a Paint Plant**

Effluent treatment is essential mainly to remove pollutants as per the regulations of local environment control authority. The effluent system involves all the painting stages, as schematically shown in Fig. 7.31. Effluent treatment involves:

- Emulsion separation plant with ultrafiltration
- Detoxification and neutrisation
- Paint coagulation
- Sludge treatment and/or filtration
- Final cleaning

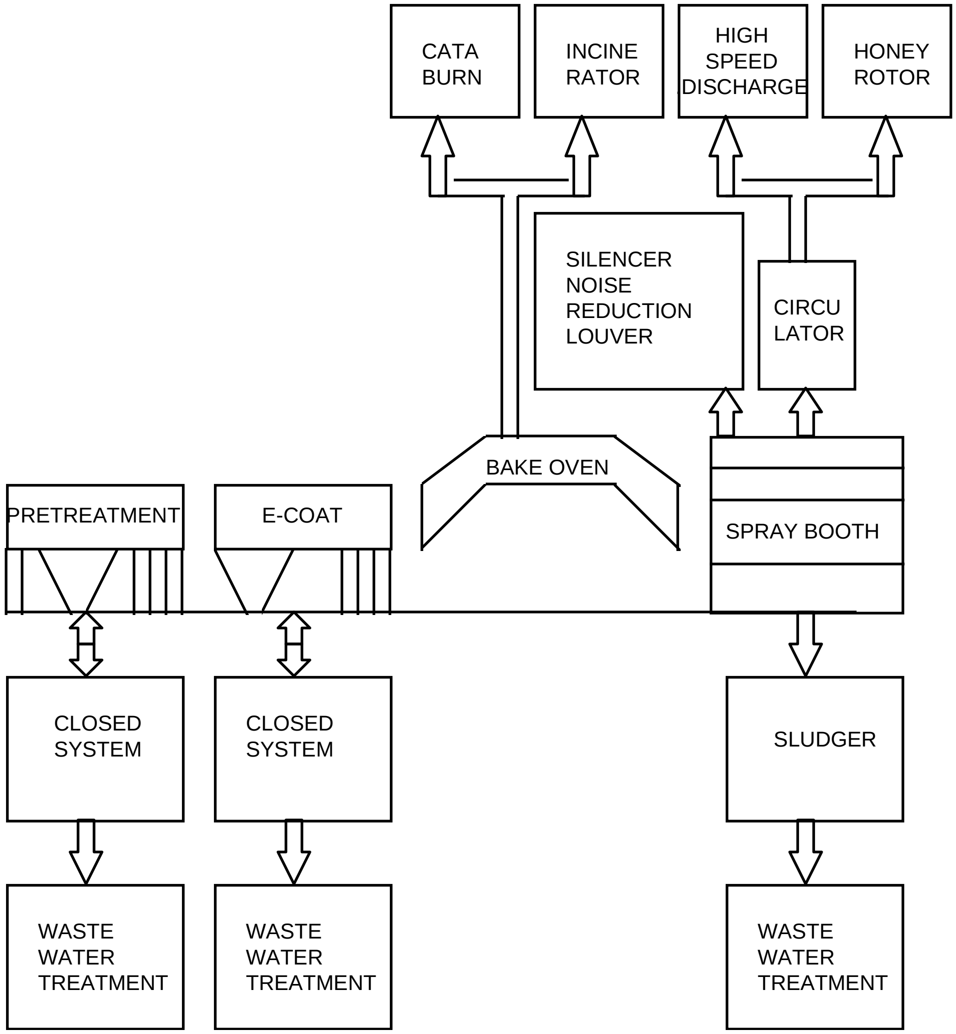


Fig. **7.31 Effluent at Various Stages in Paint Process and Treatment**

Sludge disposal problem is tackled in many ways for paint shop in automobile manufacturing plant. Firstly, through efficient mechanical and thermal dewatering, the sludge volume is being reduced. Subsequently the sludge is disposed through landfill or by on-site incineration for energy production or incineration in a hazardous waste incineration plant. However, direct recycling of paint sludge is being given the first priority. Fig. 7.31 provides an overview on paint sludge disposal that is being proposed to meet the environmental regulations, with necessary variation for the different countries.

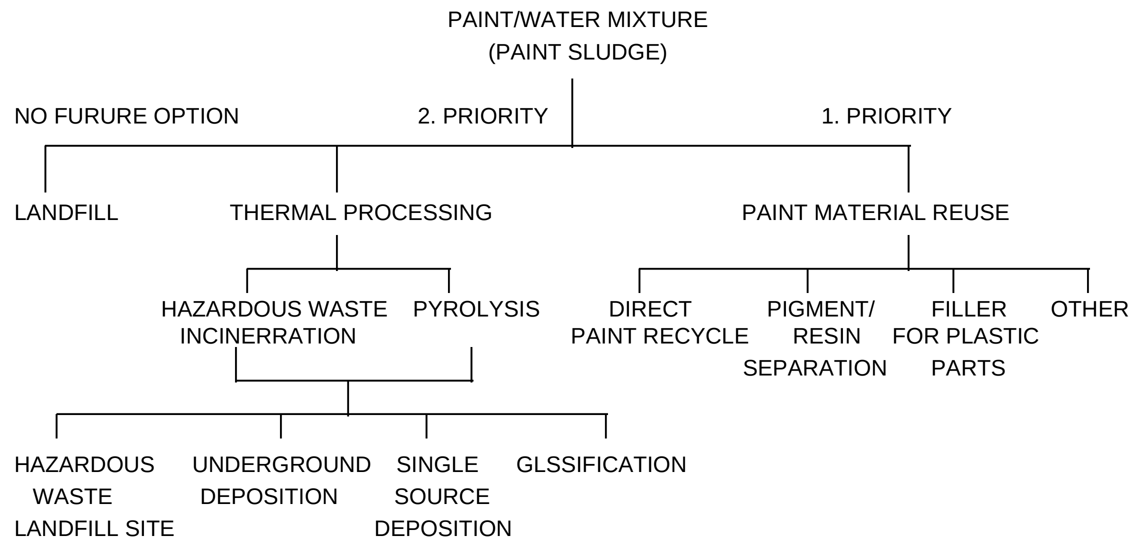


Fig. **7.32 Overview of Sludge disposal Systems for a Paint Shop**

PAINT RECOVERY

As per one study, only 50% of the paint coming out of spray gun reach the car body. Some over spray ends up on the wall and roof and some in the waste water treatment in the floor of the booth. Every effort is being made to work on saving potential of paints and chemicals.

In one of the system, the extracted spray mist is subjected to a two-stage process of ultrafiltration to recover the paint directly. The recovered paint can be mixed with new paint to give an almost waste free paint process, Fig. 33.

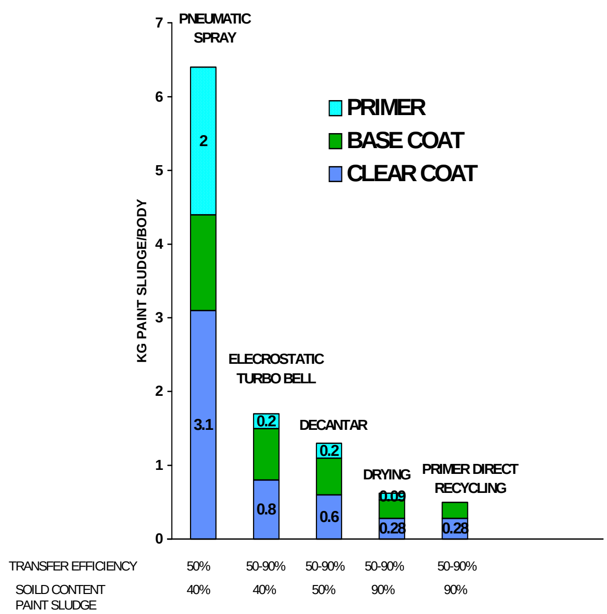


Fig.**7.33 Recycling of Overspray in Paint Shop and Reduction in Wastage**

Paint coagulation process is used to treat overspray from both base and clear coat (top) processes. Upto 95% of the solid content of the paint coagulation generated can be reconditioned for future use.

Toyota has introduced a new process to recycle paint residue from its automated painting operation. The process involves the collection of residue as it is drained from the floor of the paint shop. After the electro-deposition coat, each of the cars gets three coats of paint - a primer and two top coats. The three coats require approximately 7.5 kg of paint. Of that, 40%-or 3 kg-fails to stick and runs off into a holding pool (measuring 25 metres by 25 metres by 2 metres). Toyota claims a paint transfer rate of around 60%; this compares with 98% for the electro-deposition coating.

In the pool an inorganic dispersion agent is added to the liquid residue, facilitating removal of contaminants and stickiness. The residue, which gradually thickens into sludge, is then run through a centrifugal dehydrator where it is dried into coarse powder.

The coarse powder is then pulverised into a fine powder (30 microns) for use as a paint additive. The fine powder when mixed with a corrosion-resistant paint, creates a new, lightweight coating that is more resistant to chipping than blends employing calcium carbonate as an additive. According to Toyota, the powder, which is strictly controlled for impurities, accounts for 10% of the new paint's weight. The new coating is finding use for the underbody and wheel house. Toyota is also studying the possibility of applying it to the fuel tank.

PAINT STRIPPING

During painting of the body, a considerable percentage of paint gets deposited on the supporting equipment, such as skids, trolleys, hangers and grids. Material getting deposited may be partially stoved paint, e.g. on body skids, and partially may be uncured paint, e.g. on grids. A paint stripping at regular intervals becomes necessary. Paint stripping may be carried out in a number of ways:

1. High pressure paint stripping uses the kinetic energy of pressurised water jets to remove the adhering paint particles from the metallic substrate. No chemical is used in water to get clean, pollutant free paint stripping. Cleaning efficiency is improved by moving nozzles (oscillating system). The cris-crossing jets clean areas that are otherwise difficult to reach.

2. Chemical paint stripping uses inorganic baths to remove non-cured paint, and organic baths for stoved paint.

ENERGY CONSERVATION

An overall integrated energy conservation is aimed at the planning stage for all the systems used in a paint shop through recycling heat generated for the painting process. Taikisha - the Japanese paint system supplier, recommends one-burner system in bake ovens integrated with the incinerator so that exhaust heat can be utilised as a heat source for the bake ovens and other processes. Spray booth exhaust recycling system filters the exhaust air generated and recycles the large volume of heat contained in the air. Air flow through the spray booths is automatically reduced during shut down thereby reducing energy consumption by 40 to 50%. Air escapes from ovens during the period ovens are not in operation are prevented through a draft damper system, so the amount of energy required for restart after a shut down is reduced. Location of all ovens adjacent to each other is part of the strategy to use common heating source system and result in considerable saving. Highly effective insulation of panels used in construction also reduces the heat loss and so conserves energy. Though the different zones are heated as per the process requirement by integrated thermal exhaust air purification equipment, supplementary burners may be built in to cover peak consumption and for operational safety. Excess heat from the system may be used for fresh air heat-up or generation of warm water. Heat exchangers may be used to store heat and dry the air that may be conducted through the ventilation system as well as spray booth. Overall energy saving is one of the main objective of system supplier. The system suppliers can be the most effective to propose the best energy utilisation concept for not only the stand alone process equipment, but also for the whole paint shop facility.

AIR CLEANING SYSTEM

A report in a newspaper in UK blamed once the ‘deodorants as the cause of cars’ blemish’. Bubbles on the paint work of the cars passing through the paint shop alerted the quality inspectors. They traced the problem to silicon in deodorant used by some employees, which prevented the paint adhering to the car bodies. Once the supervisors had drawn it to the attention of employees, no further cases were reported. Clean air in the whole of painting areas is a necessity. Prevention steps are started with building design itself.

A statistical analysis of defects in painted bodies shown in Fig. 7.34 indicates particle inclusions such as hair and textiles - both originating from the working group in the paint shop as the most critical one.

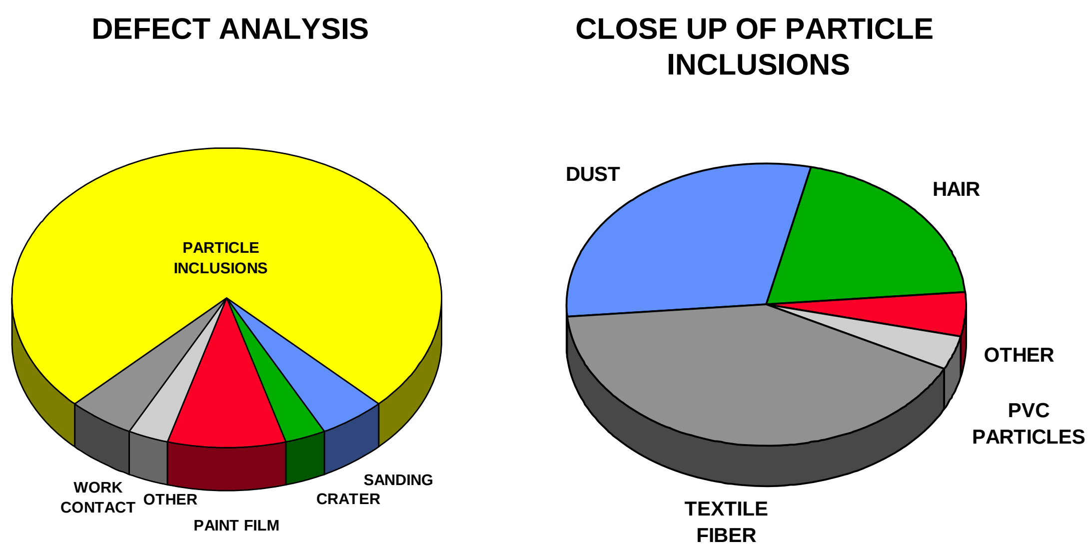


Fig. **7.34 Statistical Breakups of Defects in Painted Bodies**

A **concept of ‘clean room’** is becoming integrated part of the paint booth system. It reduces the painting defects arising out of dirt or dust particles carried in by the persons, and also the residues coming in as adhered to the car body from previous processes. The area adjacent to the spray booths is totally enclosed with separate ventilation and air filters to clean very fine dust particles from the body before it is transferred to the paint booth. Air lock is additionally for the access route of workers. Workers are also required to wear special lint-free clothing made of asbestos-resistant fibres.

To achieve a real ‘clean room’ condition, prevention of the direct entry of the outside air is necessary. However, the more importance is to restrict the movement of air between different sections of the paint shop. In air pressure based zoning system, air pressure rises together with the required level of air purity. Air from the painting area can go to the cleaning area, but the air from the cleaning area can not be allowed to go to the painting area. Clearly separate areas are allocated for painting and car body storage. In each area, the necessary level of cleanliness is maintained through balanced air pressure as shown in Fig. 7.35.

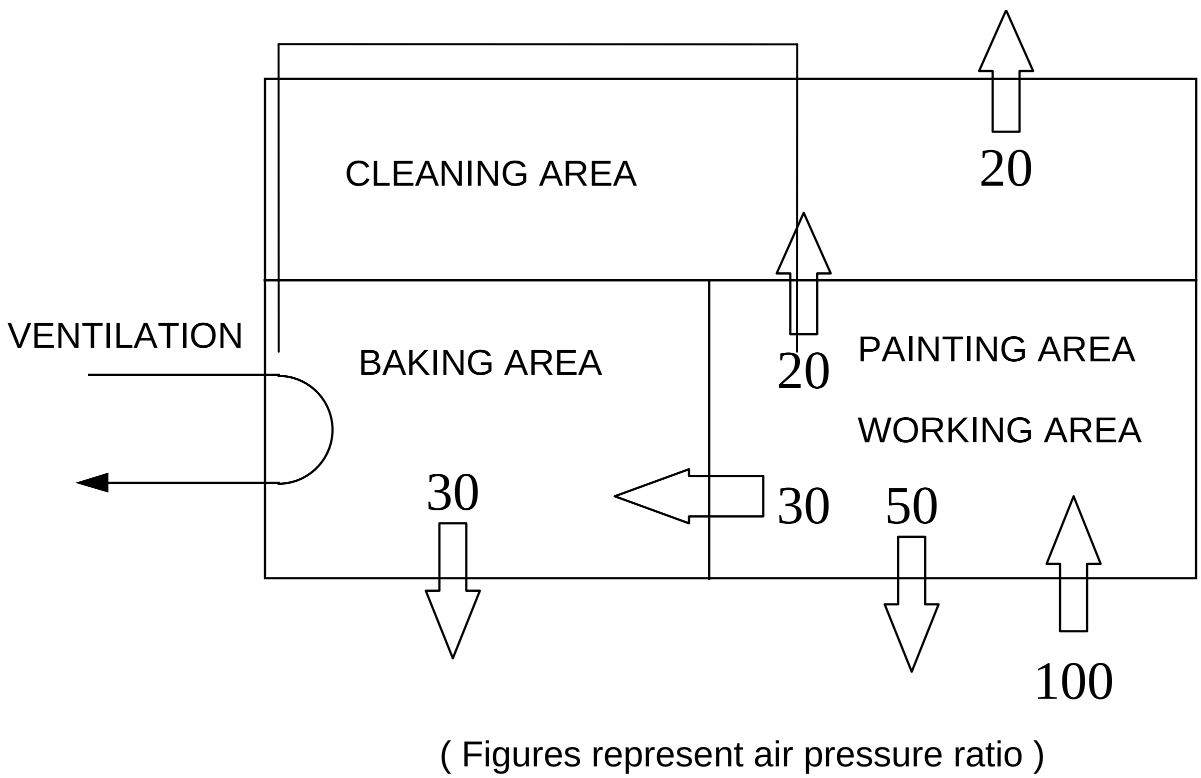


Fig. **7.35 Balanced Air Pressure in Different Areas**

Prevention of dust and dirt during operation, air shower is used at entrance and exit for workers. Double doors are provided at passage to other factories, entrance and exit for out side maintenance staff, staircase room. Air curtains are installed at opening for conveyor. Spray booth exhaust uses high speed discharge.

During down time when the plant is inoperative, draft prevention is attained by air pressure damper and interlocked operation of fire prevention damper with booth. Shutters at entrance and exit of paint booths and take ovens are use for protection of equipment against dust and dirt.

NEW CHEMICALS AND PAINTS

Pretreatment

The type of steel sheets used for the body-in-white decides the formulations, controls and specifications of cleaners and phosphating solution. The switch over to zinc coated steel, and new oils and waxes used for preservation of these steels demand a change from the traditional alkali based detergents used in cleaners. The pretreatment system now uses *cleaners* with bio-degradable surfactants that can be easily separated from the oil and reused, *alkaline inorganics* that are simple to treat and dispose off, and *additives* that enhance the subsequent phosphate coating. Alkaline baths contain sodium salts and other additives including nitrates that work as corrosion protectives during long transfer times to allow sufficient drainage from the car bodies. However, the drying out on side panels with subsequent rust blushing and staining has an adverse effect on electrocoat and corrosion resistance. Activators are used to over come the pre-passivation caused by the drying between the stages and to give a more consistent surface for the new paints. Titanium continues to be the basis of activation but more efficiency has come out of improved formulation and manufacturing method. The surface active agents are almost fully bio-degradable and are matched to the oils used on panels. Standardisation of oils used by different steel vendors is essential. The surface active agents are normally depleted by the oil and additions can be made to maintain the level of activity in the cleaning solution. Zinc phosphate dominates the pretreatment process. In modern treatment plant, the system, controls the total acid, free acid and accelerator; monitors also the zinc, nickel and manganese in solution, and makes liberal use of additives containing varying mixtures. New developments are related to the use of safe accelerators that are biodegradable, removable and reusable through 'sludge recycling'.

Chromium remains the passivating agent after phosphating. Non-chromate passivation rinses may come as a break-through with banning of chromium based products by the government regulations.

Developments in the pretreatment were as follows:

Phosphate system developed chemical formulations (Ni-F type chemical) first for low temperature (from 55-60 ^{0}C to 40-45 ^{0}C) phosphating and then for zinc coated steel (Ni-F-Mn type chemical).

Cleaners are non-silicate type from silicate type. Surface conditioning was used to improve inside phosphatabilty (Prepalene 4023). Next developments were for achieving finer and denser crystal simultaneously with ease of control through low temperature (Prepalene 4040). With zinc coated steel, improvement for wet adhesion was attained (Prepalene 4040 modified).

ED coating

Anodic paint has an acid component that is the resin in which the pigments are dispersed, and an alkali. Both the components provide complete water solubility. The resin and pigments deposit on the anode(+ive) and the alkali moves to the cathode. Cathodic paint consists of two parts, but the resin is alkaline in nature and also insoluble in water. Water solubility is attained by combining the alkali resin and an acid component. The alkali resin and attached pigments deposit on the cathode
(-ive) and the acid goes to the anode.

All the changes (from solvent borne dip primers to water borne dip primers, from anodic to cathodic electro-deposition), have been aimed at improved corrosion prevention of auto body, reduced solvent loss, and minimal emission levels. Water borne electro deposition paints are having a solvent content less than 5%.

Paint

The developments of hydrobase coat and water borne primer surfacer, water borne clear coats and powder paint systems as substitute for conventional primer, and clear coat materials are aimed at reduction of solvent emission. Powder has been used as a primer surfacer with good anti-chip properties and as very glossy clear coat materials.

For final top coat, the tendency is to switch over to 'clear over base' technology. A base coat with non volatile content of 20% is applied to give a film coating of 15-20 microns. The solvent is flashed off in the spray booth and the clear coat with a non volatile content of 40% is applied to give a film thickness of 35-40 microns. After a total cure in oven, the paint system gives a very high quality gloss finish, so bright, clean colours can be used. Limits on VOC (volatile organic emissions) from paint plant are becoming highly demanding. For example, a maximum of 60 grams of VOC per square metre of car body is permissible in UK, whereas the limit in Germany and Sweden is 35 grams per square metre. Solutions may be either to install sophisticated and expensive pollution control system or to change to water borne paints. The application of water borne paint requires some major changes in the plant design. With greater foaming characteristics of water borne paints, the scrubber design will undergo change. In spray booth design, a combined infra-red and recirculated air flash off section is introduced between the base and clear coat
section of the booth. The system typically may be:

Base coat booth		
'Air seal' or still zone	1	minute
infra red zone	1~2	minute
Hot recirculated air zone(60-80 DC)	2~3	minute
Cooler zone(using chiller coils)	1	minute
'Air seal' or still zone	1	minute
Clear coat booth		

Fig. 7.36 shows schematically the difference between the oven for solvent-based and water borne paint system, clearly showing the additional length of oven necessary for water borne paint.

Either water borne base coats and clear coats can be used, or solvent borne acrylic or two-component polyurethane clear coats may be applied over water borne base coats.

As reported, Nissan in co-operation with 4 paint manufacturers developed an innovative painting technology capable of producing a surface highly resistant to scratches and stains.

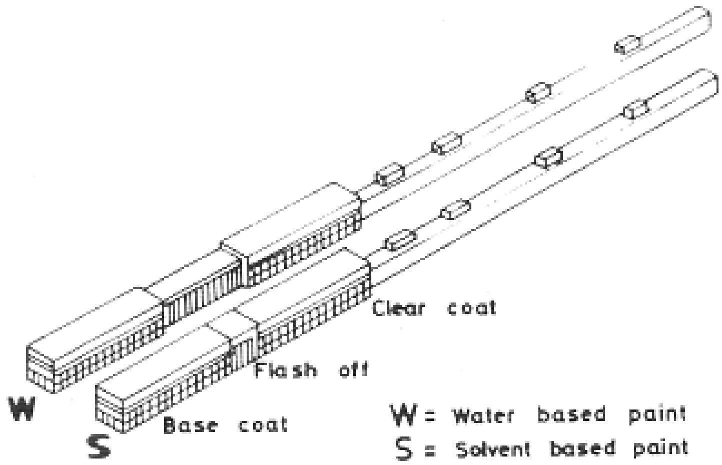


Fig. **7.36 Ovens for Water-borne and Solvent-borne Paint System**

The technology uses a highly durable, clear (the final) transparent coat of paint applied to a vehicle to reinforce the hardening process during baking and drying. The test indicates the reduction in scratches from cleaning brushes and sand particles, stains from bird droppings, soot and dirty water, to one third in comparison with the conventional paint in use. Conventional clear coatings consist of a mixture of acrylic and melamine resins. Melamine resin performs the hardening function. The new clear coat uses carboxyl and epoxy (in place of melamine) resins. That allows a more uniform, higher density structure after hardening, and creates a stronger surface. It is more resistant to external contamination and provides greater chemical stability..

EMISSION REDUCTION

A rough average estimate can account for a total of 10 kg of organic solvent per body emitted into atmosphere. *Emission reduction is beginning to be the biggest concern and the main objective of paint manufacturers as well as process engineers of automobile manufacturing plants.*

Strategies of emission reduction through a change in paints in use:

- Electro-deposition preferred as 100% transfer efficiency possible
- Higher solids solvent borne paints
- Waterborne paints
- Powder anti-chip coatings and clear coat

Relative emission % of each major paint by a paint process for metallic colours:

Cleaning solvents	4.3
Electro deposition	1.4
Stone chip Sealer	1.4
Sun facer	15.7
Base coat	50.8
Clear coat	13.0

Wax protection	13.4

Now generations of cathodic electro-deposition have further reduced emission levels. Paints with higher solids (50-60%) reduce emission. Higher solid primers, solid colour enamels, base coats and clear coats are commercially available and are in use. Water borne coatings provide a better potential for significant reductions in solvent levels and thus emission. Water borne base coat technology is being commercially used for all type of plant capacity. The existing paint shops are required to be modified to adopt water borne base coat in place of solvent borne base coats. It is mainly because of the need to install a drying tunnel capable of removing 90-95% of the water from the base coat in reasonable time (1~3 minutes) prior to application of clear coat. Powder anti chip coatings - including powder clear coat, are having the best potential to cut down on emission. Water borne base coat with powder clear coat would give the lowest emission level for a top coat automotive paint system.

Process changes related to emission reduction

A progressive improvement in transfer efficiency and thus the reduction in emission has been achieved through the equipment used for paint application, that are as follows for the different types:

- Air atomised water borne 30%
- Air atomised solvent borne 40%
- Manual electrostatic 62%
- Automatic electrostatic 75%

Distribution of volatiles between spray booth area and oven is typically as follows.

	% in Booth	**% in Oven**
Electro-deposition	10	90
Primer	65	35
Water borne primer	55	45
Base coat (high solid)	75	25
Waterbase coat	95	5
Clear coat	70	30

As it is clear, most paint volatiles are emitted in the spray booth. It is extremely difficult to treat 1.5 million cubic metres of air per hour is exhausted from a typical spray booth. In comparison, only around 0.15 million cubic metres of air exhaust per hour is emitted from oven (for 50 cars per hour) and that is manageable for incineration or absorption treatment. As the polluting solvent volatiles are less in the water borne paint, consequently they release less solvents to be treated in air exhaust system of spray booth.

Other major steps for emission reduction are through process improvements to achieve better first run capability and minimising final line repairs.

PROJECT MANAGEMENT- A new approach

The conventional manner used to implement a new paint shop facility is in sequential steps such as, specification preparations and the bid optimisation by the in-house plant engineering, detail engineering, manufacturing, erection and commissioning by the paint equipment manufacturers. The process is being discarded. An integrated approach based on close co-operation between automobile manufacturer and the system suppliers being increasingly used to reduce project execution time, resource requirements and costs. Full utilisation of talents, and experiences positively complimented by both the supplier and automobile manufacturer is necessary. Simultaneous engineering saves time and maintains high flexibility for process and facility optimisation. The turnkey idea of responsibility saves the integrity of all the equipment and provides a smoothly operating paint finishing facility inside a proper built building. Besides a potential saving of 15-20% in the project cost, the major accomplishment may come through reliable performance and high availability. A new approach is being experimented by transferring the responsibility of guaranteed performance to the paint and chemicals suppliers through their involvement from the project stage itself.

AND FINALLY

Auto manufacturers are trying for multi-fold improvement in painting system: mirror type outer finish (expanded use of laser dull sheet steel, 4-coating, new baking system rotating a vehicle after overcoating, etc.); anti-corrosiveness (expanded use of surface processed sheet steel, edge cover ED, paint characteristics, etc.); extended durability (wax free florescent resin paint, dark colour centred scratching - resistant clears, acid rain counter measure coats); expansion of plastic paint parts beginning with PP bumpers, new design exterior (oxidised iron coated with titanium dioxide, new brightness pigments such as carbon graphite and micro titanium). Development of maintenance free coatings will be the final aim of auto manufacturers.

While equipment and processes will be more and more flexible, the retrofitment or adaptation of new innovations will be easier to be incorporated. Improvement areas will be productivity, emission control, waste elimination and resource utilisation. Total productive maintenance with assistance from improved control system will be necessary to improve the available hours. Total automation will not only move human beings out of the paint shop, but will also make 3 shifts running possible to justify the high investment.