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Master degree in Mechanical Engineering

Safety and Maintenance for Industrial Systems

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SAFETY AND MAINTENANCE IN AUTOMOTIVE PAINT SHOP

STUDENTS:

ANDREA LUPI **1614324**

SANDEEP OMKARNATH GUPTA **1844011**

AKSHAY DHALPE **1855686**

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1 INTRODUCTION

1.1 Automotive paint shop

The automotive industry involved in the manufacture of motor vehicles, including most components, such as engines and bodies, but excluding tires, batteries, and fuel. The industry's principal products are passenger automobiles and light trucks, including pickups, vans, and sport utility vehicles. This industry involved in design, manufacture, and marketing of the vehicle. There are several processes in automotive industry in manufacturing a vehicle. The processes in manufacturing a vehicle are stamping process, body assembly process, painting process etc. One of the major cost factors in car manufacturing is the painting of body and other parts such as wing or bonnet.

Surprisingly, the painting may be even more expensive than the body itself. Maybe the high costs are in terms of processes that occur in painting process and not the machines that applied in paint shop. From this point of view, it is clear that car manufacturers need to observe the painting process carefully to avoid any deviations from the desired result. Reduced paint use and reduced defects would save $683 million annually for the Big 3 manufacturers and would lower costs and improve quality for consumers.

With these time costs, manufacturers could only afford sampled quality control, measuring approximately 1 to 3 cars per day, or about 1 out of every 500 vehicles. Moreover, the slowness of the quality control contributed to poor feedback response time. By the time quality control detected a problem and made proper adjustments, up to 100 vehicles had passed through the defective painting production line. Manufacturers had to repair all vehicles with defective paint coatings by using one or both of the low bake repair (LBR) and high bake repair (HBR) processes, at a cost of $600 to $1,200 per vehicle in 1995. In some extreme cases, the manufacturer had to completely scrap the vehicle. Car painting is a complex combination of different layers of base coat, color and protective finishing coat. The setup for the painting process requires the optimal adjustment of a variety of different parameters such as humidity, temperature and the consistence of the lacquer itself.

Painting process is an important process in automotive industry. The purposes of the process are to give more attractive appearance to the vehicles and to provide

the layer of protection against corrosion and weathering. The painting process include a few other processes, which are Pre-Treatment and Electrodeposition (ED) Process, ED sanding, process, sealant and PVC process, primer process, and top coat process. In this study we will focus on safety rules and regulation should be followed while the installation of paint shop specifically the booth area i.e paint application area and PMR area and later we will highlight the maintenance schedule for the smooth operation of paint shop.

2 PAINTING PROCESS

2.1 Pre-treatment and ED

This process is usually done to remove oil and dust attached to the car body. It can be done by two process mechanically and chemically. Now, as the technology advance chemical process is conventionally used for Pre-treatment process. Cleaning is very good; however, coating must be done immediately because the cleaned surface is in a highly reactive state and corrosion occurs very soon. Chemical cleaning includes removal of dirt, oil and grease, and the rust particles present on the surface by means of chemical actions. The chemicals may be applied by wiping, spraying or dipping. The nature of chemicals used depends upon the base metal. Mild Steel is known for its tendency of going under rapid oxidization when exposed to atmosphere. Degreasing and Derusting are the two process involve in Pre-treatment.

2.1.1 Degreasing

It removes oil and grease particles deposited on the MS surfaces. The best method of degreasing; as of today, is by use of alkaline based degreasing powders. This is a blending of an alkalis and surfactants and the best results are obtained under hot conditions, generally, 60-70 degrees centigrade.

2.1.2 Derusting

It removes rust and light scales from the MS surfaces. These are necessarily acidic chemicals and is a blend of mineral acids like phosphoric acid, sulphuric acid and hydrochloric acid with added inhibitors. Higher concentration of acids helps in removing of rust fin a faster way, but this affects the life of the conversion coating applied in later stages. Phosphoric acid based derusting chemicals are most suggested for MS components before applying paint.

2.1.3 Electro-Deposition

After Pre-treatment Electro-Deposition process (ED) is carried out to protect the car from future rusting. In this process the car part is dipped in the tank containing the charged particles from the paint emulsion move to Anode (AED) or Cathode (CED) under electrical forces. The direct current established through the bath makes the pigment and resin base of the paint wander towards the body surfaces. Coating reaches all the recessed area. Deposited film does not re-dissolve. However, the un-deposited material is rinsed. Ultra-filtrate (UF) equipment's are used for ED paint ingredients separation of those not forming film and recovery of Paints. Deposited film after stoving becomes hard, durable polymeric film.

2.2 Sealant application line

After the part has been treated for the protection of surface, it is necessary to provide sealant to avoid that fluids and gases enter into the car. Form is used to fill the cavity between two mating parts and sealant play a vital role in car manufacturing.

2.3 Primer

It's a protective layer which is applied on the car body using manual and robot. Primer provide adhesion to the base coat paint and smoothen the ED applied coat. Primer application process take approx. 20 minute and have a thinness of 25μm.

2.4 Base coat

This coat provides the visual color to the car body and desire appearance to the car. This process is carried out with the help of painting robot and manual spray gun. Base coat application takes approx. 20 minutes and have a thickness between 10μm.

2.5 Top coat

It provides the glossy and protective layer from UV light the basecoat and the most important layer for the car body. Top coat takes approx. 20 minutes and has a thickness of 45μm.

2.6 Oven

After coating of paint, the car body is delivery to the oven for curing. Curing of paint can be done using oven or air-drying by increasing the time span between the coat application (Flash off zone). It also depends on the mixture of paint (thinner and hardener mixture in the paint).

2.7 Inspection

After completion of painting and curing process, car body follow visual inspection for the defect in painting and checking the DFT of the paint. Defect can be spot on the body due to foreign item and uncovered part on the body. If there is any defected part is sent to the repair zone.

2.8 Repair

Defect has been fixed by using touchup zone. The whole body is not treated for the complete process only the spot where the defect is been treated.

2.9 Waxing

This process is done for the cavity in the car body panel such as car door panel.

This process is carried out to fill the holes and gap which is left due to uneven mating parts of the car body. Waxing act as a damping in the car body. Waxing fluid is fash curing time and its get cured within seconds as it comes with the

atmosphere. Waxing pipeline is provided with heating system within a permissible limit as define by the supplier.

3 STRUCTURE OF THE PAINT SHOP

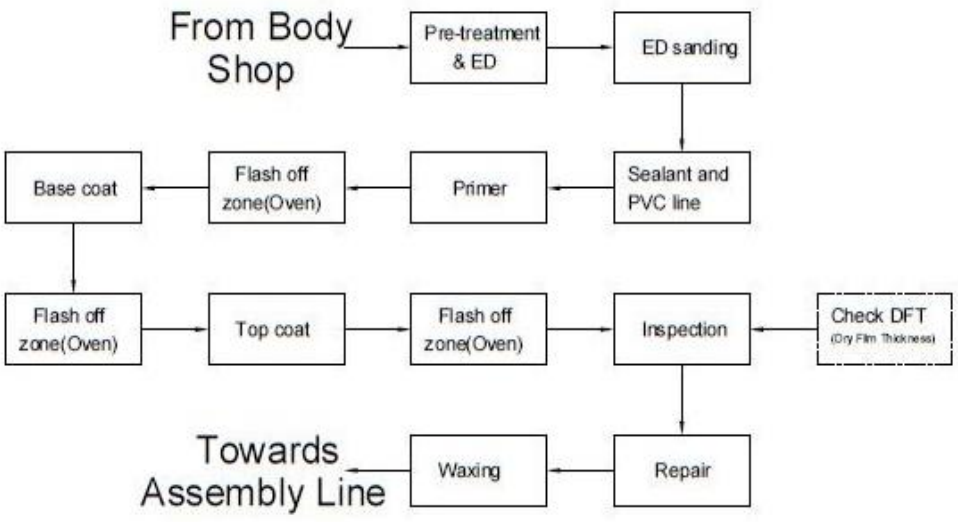


Fig. 3.1 - Paint shop process

3.1 Paint Mixing Room

The Paint mixing Room (PMR) is the area where the system Paint circulation system known as PCS arrangement is done. Paint circular system is design as per the flow requirement of the paint for the car body application. System is assembled using pump, filter, Surge tank, Back Pressure regulator (BPR). Paint flows through a pipeline from the PMR to booth.

Fig. 3.2 - Installation of PCS system inside the PMR is in process

Fig. 3.3 - PCS system installed inside the PMR Area.

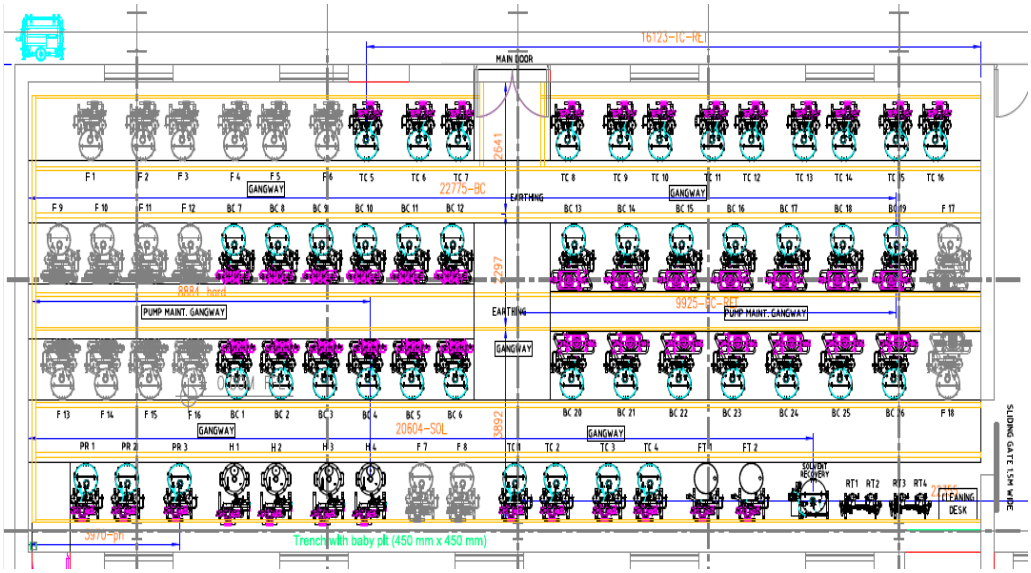


Fig. 3.4 - PCS System Arrangement inside the PMR Area

3.2 Paint application area (BOOTH)

Paint Application Area mainly consist of Manual and Auto Zone (Auto Zone include robot). Application area is divided as per the coating such as primer zone, Base coat zone and Top Coat Zone. There is other zone as well touchup zone, under body sealer application zone, wax application zone. We will focus on three paint application zone such as primer, Basecoat, Top Coat Zone.

4 WORKING OF THE PAINT CIRCULATION SYSTEM

In this chapter we will discuss about the flow of the paint from system which is installed in the PMR to the booth. Flow of fluid takes with the help of Stainless-steel pipe and fittings (SS 304/SS304L- Material used for the pipe and fittings). System used for the transfer of paint from the PMR to booth is called PCS system (Paint Circulation System). It consist of transfer tank, supply tank, pump, Agitator, filter, surge regulator, BPR (Back Pressure Regulator), level sensor, pressure sensor, interconnecting fittings and pneumatic connection for air supply to pneumatic operated equipment. There are also pressure release valve and many other equipment as per the requirement of the system.

Fluid is filled from 20L/200L barrel with the help of pump or can be filled manual up to a sufficient level (Generally transfer tank is of 80/100/150/200 liter as per the consumption of paint per hour). Now the fluid (paint) is transfer from the transfer

tank to supply tank with the help of pump. When level in the supply pump is below sufficient level, which is detected by level sensor installed in the supply tank, pump start and supplies the fluid to the supply pump. Supply pump transfer the fluid to supply line from the supply tank. Surge regulator is used to reduce the fluctuation in the fluid. Supply line is installed around the booth and it gets terminated to last dropper. Return line start where the supply line gets terminated and it moves around the booth and enter inside the PMR and flow to the supply tank passing through the BPR (Backpressure regulator). Backpressure regulator reduces the pressure of the return line downstream so that fluid flow inside the tank at a constant flow. Agitator help us to avoid the settlement of the pigment present in the paint and we provide baffle in tank for proper agitation.

Piping around the booth is called header and we extract dropper from the header as per our requirement. Dropper is connected to robot and manual gun (Electrostatic Gun) with the help of flexible hoses specially manufactured for paint (Nylon or Polyurethane material). Robot paint hose is connected to color changing valve (CCV). CCV has at most 48 port for connection (24 supply + 24 return) we can connect 24 paint line to the robot. Structure in which CCV is mounted is called robo-bell. Robo-bell have a spindle that sprays paint on the surface of the car body to be painted. Atomizer is installed inside the robot for mixing of air with paint for providing precise flow of paint on the car body with less loss of paint.

Dropper at the manual zone is connected to the gun with the help of flexible hose made up of nylon and polyurethane. Z-swivel is provided for the easy movement of the gun during the painting operation.

Interconnected fitting include union, wieldable connector, hex nipple, ball valve which is made up of SS material.

PCS system is placed in the PMR area. Distance between the two systems are 500-600 mm from each other for the man movement.

Electrical instrument used inside the PMR should be x-proof (well packed so that no spark should come in contact with the fumes of the paint.

The PSR (Paint Storage room) is where all the paints are stored. Paint should be stored at particular temperature to maintain the quality of paint. Before feeding the paint to the PCS system from the barrel, paint has to be mixed properly with the

help of drum rotator so that paint pigment which is been settled due to long storage of paint get mixed properly. To maintain viscosity of the paint we use thinner which is a rapid volatile fluid.

All this system PCS is design considering the speciation such as flow rate, viscosity, usage of the paint. Hardener is mixed with the paint at the time of application of paint on the car body because hardener has the property to cure when it comes in contact with the air. Hardener should not come in contact so tank is filled with nitrogen to avoid contact with air.

Pump for the system has been selected as per the flow rate and viscosity of the paint requirement. For every application, pump selection has to be made.

Ex: We have to paint 60 car body per hour and each car body requires 5 liters (Including Loss) to paint a car. We require 60 multiply 5 Liters equal to 300 liters of paint per hour. 300 liters of paint to be pumped through the system to fulfill the requirement. We will select the pump which provide flow rate of 0.083 liters of paint per sec.

Fig. 4.1 - PCS system manufactured at the workshop

Fig. 4.2 - Paint Circulation System General Arrangement Drawing

5 COMPONENTS HAZARDS AND SAFETY GUIDELINES

EN 1SO 12100 states General principle for design safety of machinery

5.1 PUMP (air motor and pump lower)

We are using pump in a potentially explosive area so pump should satisfy the European norm ATEX 94/9/EC and Machinery Directive 2006/42/EC.

The following hazards warnings are for the setup, use, grounding, maintenance, and repair of this equipment.

- Fire, Explosion and Electric Shock Hazard:

Improper grounding, poor ventilation, open flames or sparks can cause a hazardous condition and result in a fire, explosion, or electric shock. Flammable fumes, such as solvent and paint fumes, in work area can also ignite or explode. To help prevent fire and explosion:

1) Electrical equipment must be installed, operated, and serviced only by trained, qualified personnel who fully understand the requirements stated in this instruction manual.

2) Ground the equipment and all other electrically conductive objects in the spray area. After grounding test with ohmmeter to ensure earth continuity is 1 ohm or less.
3) Keep all covers tight while the motor is energized.
4) If there is any static sparking or you feel an electric shock while using this equipment, stop spraying/dispensing immediately. Do not use the equipment until you identify and correct the problem.
5) Provide fresh air ventilation to avoid the build-up of flammable fumes from solvents or the fluid being pumped.
6) Keep the pumping area free of debris, including solvent, rags, and gasoline.
7) Electrically disconnect all equipment in the pumping area.
8) Extinguish all open flames or pilot lights in the spray/dispense area.
9) Do not smoke in the spray/dispense area.
10) Do not turn on or off any light switch in the spray/dispense area while operating or if fumes are present.
11) Do not operate a gasoline engine in the spray/dispense area.
12) EN 1127-1 states basic concept for explosion prevention.
13) EN 13463 states basic methods, requirements and protection by constructional safety for non-electrical equipment for use in potentially explosive atmospheres.

Fig. 5.1 - Representation of Fire Hazards

- Hot Surface Hazard

The electric motor becomes hot during operation, and the heat may be transferred to other connected equipment. To reduce the risk of burning yourself:

1) Do not touch the motor surfaces while it is operating.
2) Before servicing, allow the motor to cool.

3) Keep flammable materials and debris away from the equipment.

➢ Pressurized Equipment Hazard

Spray from the gun/valve, hose leaks, or ruptured components can splash fluid in the eyes or on the skin and cause serious injury.

1) Do not stop or deflect leaks with your hand, body, glove or rag.
2) Relive the pressure when you stop spraying and before cleaning, checking, or servicing equipment.
3) Tighten all fluid connections before operating the equipment.
4) Check the hoses, tubes, and couplings daily. Replace worn, damaged, or loose parts immediately. Permanently coupled hoses cannot be repaired; replace the entire hose.
5) EN 4414 states general safety rules and safety requirement for pneumatic fluid power.

Fig. 5.2 - Representation of Pressurized Equipment Hazards

➢ Toxic Fluid Hazard

Hazardous fluid or toxic fumes can cause serious injury or death if splashed in the eyes or on the skin, inhaled, or swallowed.

1) Know the specific hazards of the fluid you are using.
2) Store hazardous fluid in an approved container. Dispose of hazardous fluid according to all local, state and national guidelines.
3) Always wear protective eyewear, gloves, clothing and respirator as recommended by the fluid and solvent manufacture

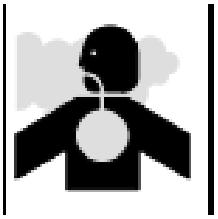


Fig. 5.3 - Toxic Gas Hazards

- Moving Parts Hazard

Moving parts can pinch or amputate fingers and other body parts.

1) Keep clear of all moving parts when starting or operating the pump.
2) Do not operate equipment with protective guards or covers removed.
3) Pressurized equipment can start without warning. Before checking, moving, or servicing equipment disconnect power or air supply.

Fig. 5.4 - Representation of Moving part hazards

5.2 Pressure Regulators

They are needed for a precise pressure and flow control of the fluid to the guns and to maintain proper pressure for circulation.

The hazards and safety guidelines related with this equipment are:

- Equipment misuse hazard:

  Equipment misuse can cause the equipment to rupture or malfunction and result in serious injury. To prevent that:

  1) Read all instruction manuals, tags, and labels before operating the equipment.
  2) Use the equipment only for its intended purpose.
  3) Do not alter or modify this equipment.
  4) Check equipment daily. Repair or replace worn or damaged parts immediately.

5) Do not exceed the maximum working pressure of the lowest rated system component.
6) Use fluids and solvents that are compatible with the equipment wetted parts. Refer to the Technical Data section of all equipment manuals. Read the fluid and solvent manufacturer's warnings.
7) Wear hearing protection when operating this equipment.
8) Comply with all applicable local, state, and national fire, electrical, and safety regulations.

INSTRUCTIONS

Fig. 5.5 – Read the instruction manual

- Skin injection hazard:

  Spray from the gun, leaks or ruptured components can inject fluid into the body and cause extremely serious injury, including the need for amputation. Fluid splashed in the eyes or on the skin can also cause serious injury.

  Prevention measures:

  1) Fluid injected into the skin might look like just a cut, but it is a serious injury. Get immediate surgical treatment.
  2) Relive the pressure if the spray tip clogs and before cleaning, checking or servicing the equipment.
  3) Do not stop or deflect leaks with your hand, body, glove or rag.
  4) Be sure all equipment safety devices are operating properly before each use.

Fig. 5.6 - Representation of Skin Injection Hazard

- Halogenated hydrocarbon hazard

Never use 1,1,1–trichloroethane, methylene chloride, other halogenated hydrocarbon solvents, or fluids containing such solvents in these regulators. In the unlikely event that there is a diaphragm failure and the vent hole in the aluminum spring cap is plugged, a serious chemical reaction could occur, with the possibility of explosion, which could cause death, serious injury, and/or substantial property damage. Make sure that the fluids used are compatible with aluminium parts.

5.3 Others components and hazard

Components	Hazards
High pressure filter	1) equipment misuse
	2) skin injection
	3) toxic fluid or fumes
Pump runaway valve	1) equipment misuse
	2) moving parts
Agitator	1) fire and explosion
	2) moving parts
	3) pressurized equipment
	4) equipment misuse
	5) toxic fluid or fumes
	6) hot surface
Surge suppressor	1) equipment misuse
	2) pressurized equipment
	3) fire and explosion
	4) toxic fluid
	5) moving part
Electrostatic spray gun	1) fire, explosion and electric shock
	2) pressurized equipment
	3) equipment misuse
	4) toxic fluid or fumes
	5) plastic part cleaning solvent

Table 5.1 – components and hazards

Fig. 5.7 – General danger indication

6 SYSTEM AND AREA HAZARDS

6.1 PMR Hazards and Precaution:

PMR area is like a bomb factory even a single spark can damage the whole plant. PMR and PSR both contain fumes of solvent used for paint which is capable to catch fire. So before entering inside the PMR and PSR switch off all your electronic device. Wear PPE (Personal Protective Equipment- Face Mark, Safety Shoes, Gloves, Coverall, Safety Helmet) before entering inside the PMR and PSR (basically all this equipment to be wear during the entering inside the paint-shop).
Outside the PMR and PSR water bay and air shower is present to remove dust from your dress, uncovered body, Shoes.
As pump is operating at high pressure it produces vibration and noise inside the PMR. To avoid this PCS system is anchored properly with the help of fasteners.
Operator working inside the PMR should wear ear plug for noise system.
Fire safety system should be provided inside the PMR.

6.2 PCS System Hazards and Precaution:

Equipment installed on the PCS system are high pressure equipment.
During installation of PCS system as due to assembly of fluid handling equipment system become heavy and should be carried carefully and with proper transport.
Operator appoint for handling of PCS system should be well trained.
PCS system should be operated as per instruction provided from the supplier.
All electrical Instrument and cables used inside the PMR should be x-proof (spark should not come in contact with atmosphere).
No hammering process should be carried out side the PMR.

6.3 Booth Hazards and Precaution:

Booth consist of two section manual zone and auto zone. In manual zone person use electrostatic painting gun to paint the automatic parts and in auto zone robot are used to paint the parts. Electrostatic Gun is connected to hose and hose is connected to paint pipe line using the interconnected fittings and ball valve.

During installation of piping ball valve are installed inside the outside the booth for safety and maintenance of the gun and replacement of the hose.

NRV (Non-Return Valve) is provided near the Gun so that while dismantling of the Gun paint spillage should not occur. Paint should be in continuous circulation during working hour to make this possible Y-connector is provide near the near. For easy dismantling of Gun QRC (Quick releasing Coupling) is provided.

During working of Auto zone no one is allowed to move inside the auto zone. A indication signal in installed just above the door of the auto zone signal turns red when the robot is working.

In PMR fire sprinkler is installed and smoke detector is installed.

Air Balance is a important factor inside the booth. During spray jobs in a paint booth, the exhaust system must draw substantial quantities of air out of the shop in order to operate. These volumes must be replenished with equal volumes of air coming into the booth. The AIR MAKE-UP (AMU) is a mechanical means of replacing air that has been exhausted out of the booth.

It’s all about paint booth air flow. How much air in being put into the booth and how much is being taken out. Airflow while spraying takes the over-spray away from the paint job and out of the booth.

7 OTHERS HAZARDS AND PRECAUTIONS

7.1 Working in confined space:

Confined space includes areas where the accumulation of hazardous gas, vapors, dust, fumes, or the creation of an oxygen deficient atmosphere may occur.

- Workers must be competent and trained in confined space entry (and provide proof of such accreditation) or they will not be permitted to enter any confined spaces in the plant.
- All mechanical equipment is to be disconnected and locked out in accordance with Lock-Out procedures.
- The atmosphere in the confined space is to be tested by the trained/competent contractor prior to entry.
- The contractor entering the space must wear a full bodied harness.
- A trained person must remain at the entrance of the space at all times a person is in the confined space. There must be a suitable means of communication between the two persons at all times.
- A contractor must not enter the confined space if hazardous conditions exist (gas, vapor, etc. content are present; or oxygen levels are less than 18% or more than 23% unless the area is purged and ventilated and tests show conditions not longer exist, or a suitable protective breathing apparatus is worn.

7.2 Fire hazard:

It is a important phenomenon in paint-shop. As paint is highly reactive with fire. We should be always cautious while working in paint-shop regarding fire and should report immedialy to the respective department.

Area	Raw Material	Risk
Paint Storage	Flammable paints, Thinner	1. Fire due to flammable paint and thinner. 2. Fire due to flammable paints and fumes
Primer Line	Primer	Fire due to flammable primer.
Paint Mixing Room	Flammable paints, Thinner	1. Fire due to flammable paint and thinner. 2. Fire due to mobile phones inside the paint mixing room. 3. Sparks
Painting booth	Thinner, Flammable paints	1. Fire due to storage of thinner inside the paint booth 2. Fire due to flammable paints and fumes
Paint baking oven	Flammable paint fumes	Fire and explosion hazard due to explosive and flammable paint fumes
Paint Circulation	Flammable paints, Thinner	1. Fire due to flammable paint and thinner. 2. Fire due to flammable paints and fumes

Table 7.1 – fire risk

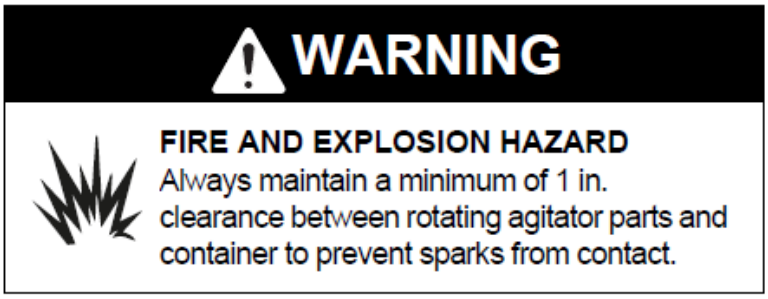


Fig. 7.1 – Safety sign for fire prevention

7.2.1 Fire prevention

Area	Preventive measures
Paint Storage	Open flames and smoking shall not be permitted in flammable or combustible liquid storage areas, fire protection system like carbon dioxide, water spray is provided
Paint Mixing Room	Fire extinguishers, no smoking area, flame proof lightening, CO2 flooding system, prohibition of mobile phones, proper grounding to prevent static electricity
Primer Line	Fire extinguishers, no smoking area, flame proof lightening, CO2 flooding system, prohibition of mobile phones, proper grounding to prevent static electricity
Painting booth	Limited quantity is being stored. Flame proof fittings, no smoking area, mobile prohibition, restricted entry, CO2 flooding system. Fire extinguisher, no smoking area sign board, proper grounding to prevent static electricity
Paint baking oven	Flame proof lightening, CO2 flooding system, trained and experience person, safety caution displayed.
Paint Circulation	Safety valves, Isolation Valves, Fire tender and fire- extinguisher

Table 7.2 – fire preventive measures

7.3 Heat stress

“Heat stress” occurs when a strain is placed on the body because of hot weather or hot process. The most common health effects caused from heat stress include heat rush, fatigue, fainting, cramps, nausea, headaches, weakness and exhaustion. Heat stress can lead to heat stroke if not attended to.

The purpose of this procedure is to minimize the risk of employees developing these symptoms and it applies to all plant employees.

The key elements are:

- Monitor heat

  The Human Resource Department will monitor temperature levels on hot days and notify Shift Supervisors when the humidex is above 40°C. Supervisor will be advised to be observant for signs and symptoms of heat stress.

- Education and communication

  Education regarding heat stress will take place on an annual basis during employee meetings. Open and ongoing communication is encourage at all times.

- Water/electrolyte replacement

  Water and electrolyte fluid replacement will be made accessible to all employees any time during warmer days.

- Appropriate clothing

  Employees are encouraged to wear lighter shirts and short sleeve shirt where appropriate, in warmer weather. It must be noted that this may not be suitable for all jobs.

- Intervention and record keeping

  Authorization will be given to supervisors to give additional health relief on shifts when temperatures are above 40°C, with the humidex. Those exhibiting signs and symptoms of heat stress will be referred to First Aid for medical attention. Methods for treating heat related illness are posted in the First Aid Room. If employees experience moderate or severe heat stress, they must go to the hospital for professional health care.

  Records all heat related incidents in the plan will be maintained by the Human Resource Department.

7.4 Working at height

Working at height should be a last resort. Consideration should always be given to alternative methods of working at height. When the risk assessment is conducted, alternative methods must be considered. If alternative methods are not an option, the risk assessment shall identify the safest method of performing the work.

In a paint shop, working a height is often necessary for maintenance work (i.e. maintenance of lighting system).

To protect the health and safety of employees who are or have the potential to be working at height, as well as to ensure compliance with local legislation, a working at height procedure must be submitted.

Some important aspect to take into account are:

- A permit to work must be completed when working at 2 m or greater.
- Only authorized employees, contractors and visitors are allowed to work at height.
- All employees that are to work at height should be trained and all training should be documented.
- Prior to use, a pre use inspection shall be performed to ensure any item/equipment is in safe condition (i.e. ladders, powered mobile work platforms, scaffoldings, PPE, fall arrest equipment). If a pre use inspection finds an unsafe condition, the item must be taken out of service and maintenance should be contacted for repair. If the item cannot be repaired, it should be permanently taken out of service.
- Any item/equipment shall be part of a preventive maintenance inspection program.
- Records of safety inspections and training shall be retained for 3 years.
- When a contractor is used, prior to starting work, a method statement and risk assessment must be submitted to the responsible supervisor.
- A plant emergency response plan must be submitted. It shall include procedures that must be followed when in the unlikely event a person should fall or become suspended from the fall arrest equipment. The response plan shall include:
  1. Immediately contacting emergency services
  2. Do not move the individual
  3. Notify the most senior person on site and contact the plant manager
  4. Follow corporate crises procedure

8 RISK ASSESTMENT:

Based on the previous analysis of hazards and safety measures, we have done Risk Assessment for the workers and personal present in the PMR and in the Booth area, where the main hazards are the same.

We have chosen to analyze the risk finding a Risk Score derived from its probability of happening (P) and severity of the damages that it can cause (S).

$$\boldsymbol{Risk\ Score = P \times S}$$

The range of values selected for severity and probability is from one to five, so that the risk score goes from a minimum of one to a maximum of twenty-five, as it is described in the following tables.

Severity S	Evaluation	Description
1	very low	- No injury - No damage to the system
2	Low	- minor injury - Neglectable damage
3	Medium	- Limited injury - Limited damage
4	High	- Serious injury - Serious damage
5	very high	- Death - Loss of the system

Table 8.1 - severity table

Probability P	Evaluation	Description
1	improbable	No occurrence
2	remote	Improbable but possible
3	occasional	Limited occurrence
4	probable	Repeated occurrence
5	frequent	Probability of frequent occurrence

Table 8.2 - probability table

Risk score	Evaluation
> 20	Critical
20-15	Unacceptable
14-11	Undesirable
10-6	Acceptable with control
5-3	Acceptable with monitoring
< 3	Neglectable

Table 8.3 - risk score table

Sr. No	Hazards	Counter Measures	Risk		
			S	P	Risk Score
1	Fire Harzard	Firefighting system, PPE, Training	5	2	10
1.1	Poor ventilation	Proper ventilation, Maintenance	2	1	2
1.2	Sparks due friction in mating part.	Proper lubrication	3	2	6
1.3	Fire due to flammable paint and solvent.	Firefighting system, PPE, Proper ventilation	5	2	10
2	Health Hazard	PPE, Training	5	2	10
2.1	Inhalation of fumes from toxic paints and solvent.	Mask	4	2	8
2.2	Skin and eyes irritation.	Safety glasses, Coverall, Gloves, Washing area	3	2	6
2.3	Heat Stress	Proper working shift, Water/electrolyte replacement	2	1	2
2.4	Bad posture	Proper working shift	3	3	9
2.5	Injection of paint into the body.	Coverall, Gloves, Training	5	1	5
2.6	Nosie	Earplugs	2	3	6

3	Electrical Hazard	Insulation, X-proof equipment	5	2	10
3.1	Improper grounding.	Proper grounding and maintenance	4	2	8
3.2	Short circuit	Proper grounding ,maintenance and no loose piece of wire	4	2	8
3.3	Electrostatic Phenomenon	Proper grounding and maintenance	3	2	6
4	Mechanical Hazard	Maintenance, PPE, Training	2	3	6
4.1	Vibration	Maintenance, Proper installation, earplugs	2	4	8
4.2	Material handling	Proper transportation mode, PPE	2	3	6
4.3	Friction and abrasion	Maintenance	2	4	8
4.4	Leakage of pressurised fluid	PPE, maintenance	4	2	8
5	Failure Equipment	Maintenance	4	1	4
6	Falling from height	PPE (fall arrest equipment)	5	2	10
7	Confined space Hazard	Proper ventilation, Controlled atmosphere	4	2	8
7.1	Oxygen deficiency	Proper ventilation, Oxygen level indicator	4	2	8
8	Equipment misuse	Workers training	3	3	9

Table 8.4 - risk analysis

As it is possible to read from the risk analysis table, the main hazards of the paint shop are related to fire, electrical failure and health of workers, due to the unavoidable presence of flammable and toxic paint. The risk score is anyway in the range of acceptability thanks to the safety measures. In fact the main objective of the risk control in a good work place, when the severity of an hazard is high, is to reduce its probability of happening to the minimum.

9 HEALT AND SAFETY PROCEDURES

These procedures have the scope to guarantee a healthy work place and the safety of everyone inside the paint shop.

9.1 Lighting

Work areas and their access should be adequately lit at all times. The lighting of the work environment must satisfy fundamental human needs such as:

-good visibility: to carry out a specific activity correctly, the object of vision must be perceived and unequivocally recognized with ease, speed and accuracy;

-visual comfort: the whole visual environment must satisfy physiological and psychological needs;

-security: the lighting conditions must always allow safety and ease of movement and a prompt and safe discernment of the dangers inherent in the working environment.

We must always privilege lighting with natural light since the presence of a building with openings towards the outside allows to understand the modulations of the light cycle to which important physiological functions are linked and to maintain a bond visual with the surrounding world, which is an elementary psychological need of man. The general requirements are: FLDm≥ 2% in the main activity spaces and in the fixed work points; FLDm≥ 0.7% in the spaces destined to multiple functions, where FLDm is the average factor of daylight.

When artificial lighting is required, the average maintained illuminance (Ēm, that is the illuminance value below which the average illuminance on a specific surface can never go down) should be 200÷2000 lx.

9.1.1 Emergency lighting

In the event of danger, all workers must be able to evacuate quickly and safely. A rapid and safe exodus presupposes that there are appropriate paths without obstacles, and that these paths, together with the potential dangers and the safety and emergency measures, are always recognizable in a certain and immediate way, even in the absence of normal lighting, to avoid dangers to the safety of people. There are three types of emergency light:

1) Safety lighting for exodus: in the absence of ordinary lighting, the visibility must in any case be such that people can unequivocally identify the path to a safe place, and locate and use safety devices (fire extinguisher and first aid). This lighting must be provided in all workplaces, as defined by art. 30 of DLgs 626/94.

2) Anti-panic lighting: the loss of ordinary lighting can generate panic in people and a state of confusion and disorientation causing wrong behavior. Anti-panic lighting is designed to prevent that providing sufficient visibility to move safely until it identifies and reaches an exodus. It is necessary in areas where the identification of an escape route is not immediate, in areas with a large number of people, or in areas greater than 60 m^2 (pr EN 50172).

3) High-risk area lighting: in workplaces where activities or potentially dangerous processes take place, the lack of ordinary lighting determines particular risk conditions for workers, and for other occupants of the workplace. The purpose of the safety lighting is therefore to guarantee the visibility necessary to perform the correct procedures for stopping operations and the safety of machinery or systems.

9.2 Ventilation system

The basic requirements that must be met by ventilation (natural and artificial) are:

- Control of indoor air quality to reduce the presence of chemical-physical and biological contaminants that are hazardous to the health of the building occupants;
- Respiratory-olfactory and thermo-hygrometric well-being of individuals;
- Humidity control to avoid condensation and its negative effects;
- To avoid that annoyingly created currents of air hit people;
- Sufficient opening for rapid air exchange.

For all the rooms in which natural ventilation can be guaranteed, it is necessary to have a continuous aeration n> 0.5 m^3 / hm^3 (n = changes of air/hour; i.e. the specific flow rate per m3 of ambient air).

In the areas where is impossible to have natural ventilation, it should be adequately compensated with forced ventilation systems that guarantee the supply of permanently healthy air during the exercise of the activities, with alarm devices to signal the interruption of the intake of fresh air and with procedures that define the times for evacuating the rooms. The reference is the UNI 8852: 1987, which provides a values of Q_{op} =15 ÷ 40 m^3 / h and n = 0.5 volumes / hour.

In the presence of moderately or very toxic pollutants and well identifiable sources, it is necessary to address localized aspirations.

10 PERSONAL PROTECTIVE EQUIPMENT

Wearing appropriate personal protective equipment when in the work area helps prevent serious injury, including eye injury, hearing loss, inhalation of toxic fumes, and burns.

The following PPE are mandatory inside the plant:

- Safety glasses
- Hearing protection (hear plugs)
- Safety shoes with steel toe
- Safety nose mask
- Safety helmet
- Safety gloves
- Fall protection: a fall arrest system is required whenever a contractor is exposed to a fall hazard of three meters or more

Fig. 10.1 - Representation of PPE

11 SAFETY COSTS

We have made an estimation of safety cost related to the mandatory PPE and the main safety equipment present in the plant. We are considering a number of 20 workers per shift (including supervisors) and one PMR area and one booth area. (Source for costs of equipment: *https://www.rs-online.com*).

PPE			
Equipment	***N***	***Cost (€/u)***	***Tot cost (€)***
Mask	20	35	700
Safety helmet	20	6	120
Hear plug	20	25	500
Safety shoes	20	70	1400
Safety glasses	20	10	200
Gloves	20	3	60
Coverall	20	12	240
Safety harness	5	100	500
Fall arrest system	5	200	1000
		Tot.	**4720**
Safety Items			
Items	***N***	***Cost (€/u)***	***Tot cost (€)***
First aid kit	2	65	130
Oxygen detector	2	400	800
Fire extinguisher	8	250	2000
Smoke detector and Fire Sprinklers	8	120	960
		Tot.	**3890**
Total cost of safety			**8610**

Table 11.1 – safety cost

12 MAINTENANCE

12.1 Total Productive Maintenance

The Total Productive Maintenance approach was initially developed in Japan and widely promoted and distributed by the Japan Institute of Plant Maintenance. Nippondenso was the first Japanese manufacturer of components for the automotive industry who started using TPM in 1961. Later Toyota and other Japanese manufacturers also implemented the approach.

As many other maintenance strategies, TPM strives to achieve a continuous production cycle without any breakdowns by maintaining and improving the integrity of production and quality systems.

The main tools of TPM are the 5S and the 8 supporting pillars. By applying this concept, the Total Productive Maintenance approach has a major impact on the quality of industrial maintenance, on the manufacturing techniques improvement, on plants' cleanliness and order and on the skills and education of maintenance employees. Setting goals for maximized equipment efficiency and engaging all departments in planning, production, quality and maintenance are the main goals of the 5S and the 8 supporting activities. Employees are at the center of this system and are continuously educated in lean manufacturing techniques by identifying and eliminating waste. In maintenance, this would mean: no breakdowns, no production interruptions, no defects and no accidents.

What Are the 5S of the TPM?

In simple terms, the 5S methodology is simply aiming at removing unnecessary items and organizing the ones that remain in the best possible way by developing behaviours that keep the workplace organized. The implementation of the concept is essential for the safety, quality, efficiency and downtime of work. 5S stays for 5 Japanese words, beginning with "S" and describing the steps of a workplace organization process:

1. *Seiri* (Sort)

   The first S aims to eliminate anything that is not truly needed in the work area as for example unnecessary materials and equipment.

2. *Seiton* (Straighten, Set)

   The objective of the second S is to organize the remaining items in order to define and maintain clean locations for tools, machines and materials.

3. *Seiso* (Shine, Sweep)

   The third S refers to the implementation of regular cleaning practices by dividing the manufacturing floor into different cleaning areas and assigning a responsible team to each area.

4. *Seiketsu* (Standardize)

The fourth S is focusing on creating standards for performing the above three activities.

5. *Shitsuke* (Sustain)

   The objective of the fifth S is to make the system sustainable by ensuring that all standards are regularly applied.

The successful implementation of the 5S should result in a clean and well-organized work environment where tools are easier to find and emerging issues as leaks, cracks and spills can be immediately detected.

What Are the 8 Supporting Activities of the TPM?

The 8 supporting pillars of the Total Productive Maintenance Program help professionals to achieve the objectives set for higher rate of machine utilization and productivity.

1. Focused Kaizen

   During this activity, problems related to equipment failures are identified and improvement goals are set in the so-called kaizen event. The most important step here is to ensure that cross-functional teams work together to come up with the root cause of the problems and apply solutions targeting continuous improvement.

2. Autonomous Maintenance

   The second activity is characterized with autonomous maintenance where operators of particular machines are responsible for machine adjustments and minor maintenance of that machine (for example: cleaning, lubricating and inspections). This results in more motivated and skilled employees, understanding the objectives of a lean organization and cost savings due to the reliable equipment, that has been continuously monitored and maintained. Access all documents (photos, videos, etc.) and checklists from the equipment sheet in your Mobility Work application.

3. Planned Maintenance

   Planned maintenance includes preventive and predictive maintenance routines based on the monitoring of machines' behavior, the maintenance history as well as the sensor data. Scheduled maintenance can anticipate major breakdowns,

reduce unplanned stop time and thus increase the capacity for productive activities. Mobility Work's calendar feature allows you to schedule all your preventive and predictive maintenance tasks.

4. Education and Trainings

   This activity is focusing on the continuous improvement of all employees' skills by initiating training and coaching programs. For example machine operators develop skills for autonomous maintenance, senior maintenance professionals learn techniques for preventive, predictive and prescriptive maintenance techniques and managers are trained into improvement strategies as Kaizen and total productive maintenance.

5. Early Equipment Maintenance

   This pillar is about the design stage of a piece of equipment and is aiming at designing a machine in a way that it is easy to operate and maintain. This includes for example easy cleaning, lubrication and inspection, accessibility of machine's parts and paying a special attention to ergonomic aspects. This leads new equipment to reach planned performance levels much faster.

6. Quality Maintenance

   This activity is ensuring that equipment is able to detect and prevent errors during production. Using lean tools such as automation (jidoka) and andon, machines can detect and report any abnormal condition targeting the removal of all root causes of defects.

7. The Office TPM

   This pillar is addressing the use of TPM principles in the administration aiming at improving for example the order processing procedures, procurement and scheduling. The main idea here also remains "waste elimination" through improved administrative operations.

8. Safety, Health and Environment

   The last pillar of Total Productive Maintenance is setting standards for the working conditions of all employees by eliminating potential health and safety risks. An example of such an activity includes the implementation of a set of measures (as guards, work standards) making machines safe to use.

12.1.1 Benefit of TPM

The implementation of the golden 5S and the related supporting activities depends on the size, needs, processes and culture of your business. But no matter what your objectives are, you can definitely enjoy numerous benefits from adopting the TPM best practices. Here are some of the most important once at a glance:

- Cost savings
- Optimized working schedule of all employees
- More efficient workforce
- Safer and cleaner workplace
- Equipment reliability
- Minimized delays, breakdowns and production stops

12.1.2 Mobility work

Total Productive Maintenance requires constant observation to succeed. A next-gen Computerized Maintenance Management System (CMMS) is streamlining your daily maintenance routines ensuring that all technicians are at the right place in the right moment. Preventive maintenance plans, monitoring, and maintenance history, everything is stored and accessible anytime and anywhere from any smart device though your CMMS mobile app. In case anomalies occur, they can be easily identified and addressed via the notifications sent to the assigned team. Like this all problems get solved before turning into real failures.

The main objective of Mobility Work CMMS is to ease the participation of each employee involved in the daily maintenance routines. Therefore the tool is user-friendly and versatile, offering a wide range of features, adaptable to the needs of various businesses. One of the guiding principles of our team when creating Mobility Work was to launch a product that creates an environment conducive to the growth of employee's motivation.

12.2 Maintenance of PMR and booth

Before starting maintenance of the equipment, we should carry out the following procedure:

1) Pressure relief procedure should be carried out

2) Tag out and Tag In: This is important to do because some visual symbol (visual safety) is provided.

These are the two important procedure before start of the maintenance procedure for every equipment installed on the PCS system and booth equipment

12.2.1 PMR:

PMR area should be clean and free from foreign element. To keep this we use exhaust duct that flew away the fumes of paint solvent present in the PMR and making PMR work friendly for employees. PCS system in PMR is placed 500mm away from each other and 300-400mm away from wall for maintenance. Walkway should be 1-1.2 meter and height of the PMR should be three meter that makes PMR dimension three-meter width and three-meter height.

PMR area should be cleaned on daily basis.

Fig.12.1 - Paint Mixing Room

12.3 Maintenance of equipment installed on the PCS System

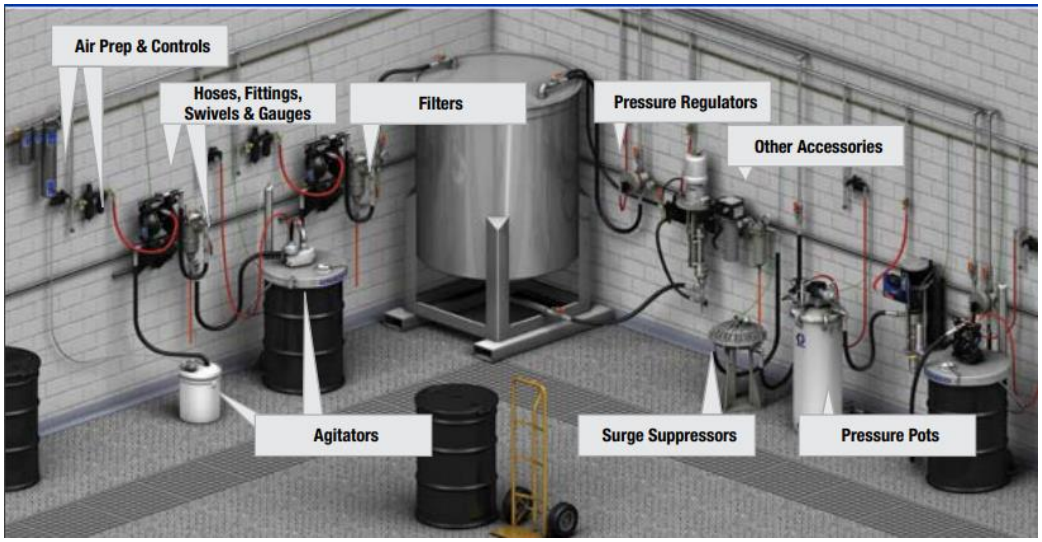


Fig.12.2 – Equipment in PCS

12.3.1 Pump:

Every PCS system consist of pumps. As per the usage pump ratio differ and type differ.

For transfer of fluid from barrel to Transfer tank we generally use husky pump that is a diaphragm pump but to delivery fluid from supply tank to paint line we use displacement pump.

- Pump should not run in dry stock mode for a long time, this can damage the seal of the pump.
- Pump should be lubricated frequently so that smooth operation take place between piston and the seal.
- Pump should be operated as per prescribed pressure and temperature.
- Pump have two main elements known as Motor and pump lower. Motor are two type electric and pneumatic. Before staring of the pump maintenance make sure pressure is been release this is done by opening the bypass valve which is connect to the tank.
- Disconnect the air supply to the pump (Close the Air Ball valve).
- Use proper tool and tackle for dissembling part of the motor.
- For Throat compatible lubrication oil is provided (Throat seal liquid) which is used for lubrication of the piston during working.

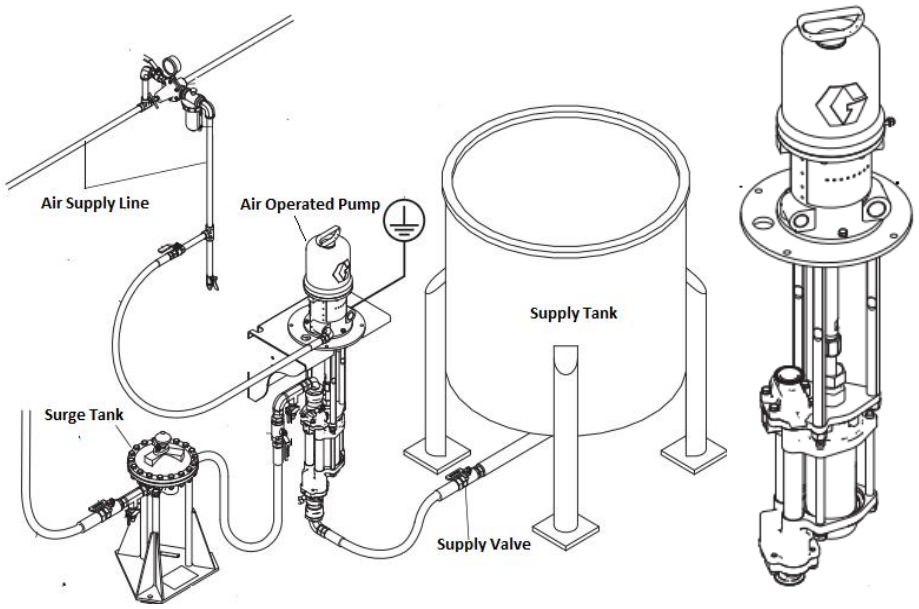


Fig.12.3 – PCS and pump

Problem	Cause	Solution
Pump output low on both strokes.	Restricted air supply lines.	Clear any obstructions; be sure all shutoff valves are open; increase pressure, but do not exceed maximum working pressure.
	Exhausted fluid supply.	Refill and reprime pump.
	Clogged fluid outlet line, valves, etc.	Clear.
	Worn piston packing.	Replace. See lower manual.
Pump output low on only one stroke.	Held open or worn ball check valves.	Check and repair.
	Worn piston packings.	Replace. See lower manual.
No output.	Improperly installed ball check valves.	Check and repair.
Pump operates erratically.	Exhausted fluid supply.	Refill and reprime pump.
	Held open or worn ball check valves.	Check and repair.
	Worn piston packing.	Replace. See lower manual.
Pump will not operate.	Restricted air supply lines.	Clear any obstructions; be sure all shut off valves are open; increase pressure, but do not exceed maximum working pressure.
	Exhausted fluid supply.	Refill and reprime pump.
	Clogged fluid outlet line, valves, etc.	Clear.
	Damaged air motor.	See air motor manual.
	Fluid dried on piston rod.	Disassemble and clean pump. See lower manual. In future, stop pump at bottom of stroke.

Table 12.1 - Pump problems and solutions (from equipment manual)

12.3.2 Filter

Filter has filter element of various micron size which is mounted inside the filter body. Pressure gauge is installed both the end of the filter and drain and vent is provided on the filter body.

Visual inspection can be made by observing the reading on the pressure gauge. If the filter element is chocked both the pressure gauge will show different reading, so it is an indication that filter element is to be replaced or cleaned.

- Before staring of the maintenance of the filter, pressure release procedure is to be carried out. This can be done by closing the inlet and outlet supply of the filter and opening the drain and draining the fluid.
- Before opening the drain ball valve, we have to open vent so that vacuum created inside the filter should be filled with air and draining of fluid can take place.

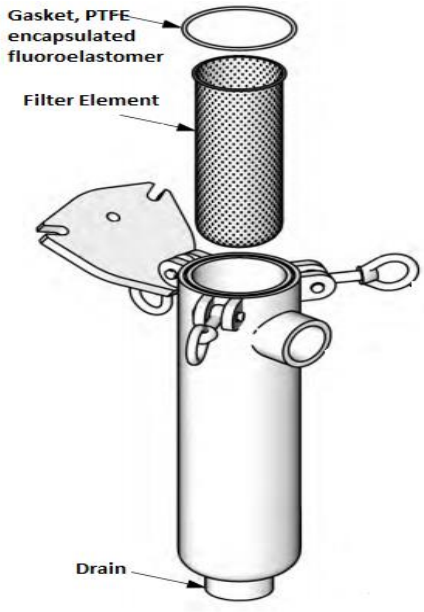


Fig.12.4 – Filter

12.3.3 Surge Tank

Surge regulator is provided to reduce the fluctuation generated by the pump during it stock. Surge regulator consist of two section Air and fluid which is separated by the diaphragm. During working of PCS system surge tank provide the addition fluid so that there should be no any fluctuation of the fluid while painting of Car body.

- During maintenance of the surge tank, pressure release procedure has to be carried out and tag out to be provided.
- When diaphragm get damage paint flow inside the air line.

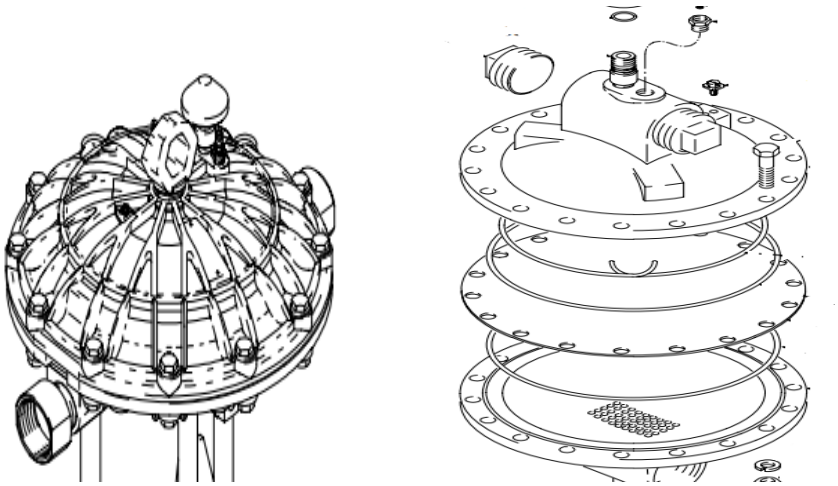


Fig.12.5 – Surge tank and exploded view

Problem	Cause	Solution
Surge tank will not accept a gas charge.	Plugged restrictor in charge valve (not applicable for Model 233736)	The restrictor is a safety device that prevents overpressurization during charging of the tank. Clean or replace the restrictor bushing: Ref. No. 25 on page 17. Ref. No. 25 on page 18. Ref. No. 13 on page 20.
Poor pulsation reduction.	Incorrect gas charge pressure	Charge the surge tank to recommended air pressure (see **Operation** section).
	Surge tank undersized for application	Reduce working fluid pressure and/or flow rate.
		Install a larger surge tank model.
		Install a surge regulator (SR200)
	Extended pump change-over time due to worn or held open check valves	Repair the piston pump.
Surge tank gas charge bleeds off.	Ruptured diaphragm	Replace diaphragm.
	Relaxed diaphragm seal	Check flange bolt torques. Re-torque as necessary. See **Parts Drawings** for torque specifications.
	Damaged diaphragm seal	Replace.
	Leaking charge valve or relief valve	Replace charge valve or relief valve.

Table 12.2 – Surge tank problems and solutions (from equipment manual)

12.3.4 Run Away Valve

This equipment is use for pump safety. Run away valve is used in air line supply of pump. When the pump operated in dry stock it consume more air so we use run away valve to cut off the air supply when pump consume more air as per the described in the pump technical data sheet.

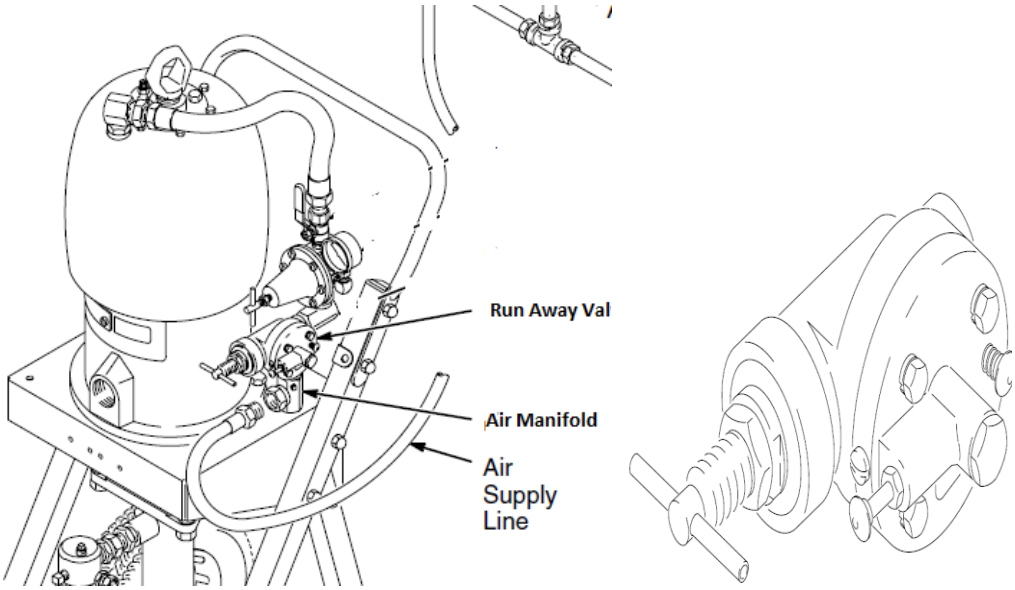


Fig. 12.6 - Run away valve

PROBLEM	CAUSE	SOLUTION
Valve does not slow down pump when it should; pump runs away	Valve is not adjusted properly.	Readjust valve and test.
	Ruptured diaphragm. (If diaphragm is ruptured, the TEST button will have no effect.)	Replace the diaphragm.
	Decreased air pressure has caused pump speed to decrease.	Readjust valve and test.
	Piston is stuck.	Disassemble and clean valve. Replace o-rings.
	Poppet valve (11, 14, 15) is stuck closed.	Disassemble and clean poppet valve.
Constant blast of air from vent when air supply is turned on.	Poppet valve (11, 14, 15) is stuck open.	Disassemble and clean poppet valve.
Valve shuts down for no apparent reason	Increased air pressure has caused pump speed to increase.	Readjust valve and test.
	Interrupted or exhausted fluid supply.	Check fluid supply and ensure that it remains constant.
	Valve is not adjusted properly.	Readjust valve and test.
	Decreased pump outlet pressure.	Check for properly adjusted fluid outlet pressure.
	Defective poppet valve.	Check and repair.
	Air supply was turned on too quickly.	Press RESET valve.
	Air leaking around TEST valve.	Replace TEST valve.
Valve does not reset when RESET valve is pressed	Piston is stuck; no air is escaping from vent.	Disassemble and clean runaway valve.
	Air blowing from poppet vent.	Remove RESET valve. Clean needle and seat area. See page 8.
	Valve is not adjusted properly.	Readjust valve and test.
	Poppet vent hole plugged.	Disassemble and clean poppet valve.

Table 12.3 – Runaway valve problems and solutions (from manual)

12.3.5 Robot and Manual Gun:

Painting Robot installed inside the booth require daily maintenance.

Gun consist of Diffuser and Fan Valve. Diffuser is use to atomize the paint and air and Fan Valve is used to regulate the Fan Pattern.

Electrostatic is a important phenomenon, it is introduced to reduce the loss of paint. Electrostatic air assist gun cover 60% of the surface in one run in compare with the conventional gun. For electrostatic gun we use electrostatic hoses in which earthing is provided.

- Before starting the painting of the car body check earthing is provided.
- Daily maintenance is necessary for the gun.

- Robot end-effector, which is a rotating part, should be clean daily and lubrication is provided to the robo-bell part which is expose while painting.
- At the end of shift, the robot and Manual gun should be flushed.
- While cleaning of gun do not use cloth dip in solvent.
- Do not point gun in upper direction while cleaning.
- Do not dip the gun in solvent.
- Do not clean the cap hole of gun with a metal tool it can develop scratch on the hole and distort paint pattern.

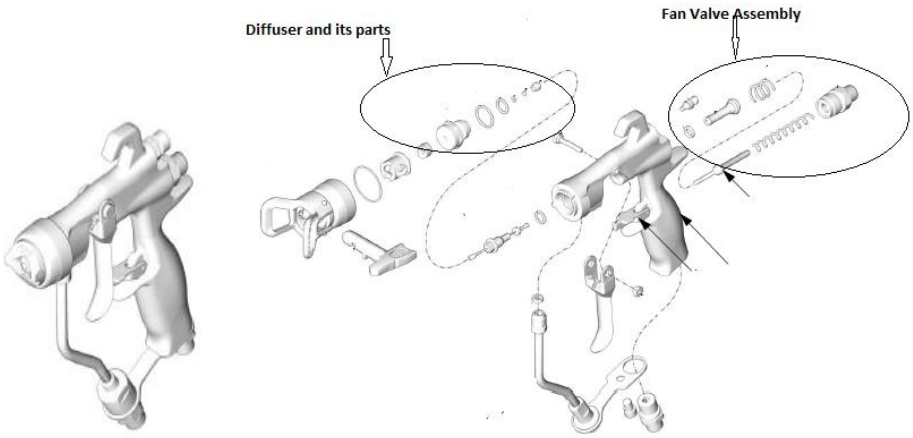


Fig. 12.7 - Manual gun and its exploded view

Problem	Cause	Solution
Fluttering or spitting spray. 	Insufficient fluid supply.	Adjust fluid regulator or fill fluid supply tank.
	Air in paint supply line.	Check, tighten pump siphon hose connections, bleed air from paint line.
	Attempting to "feather" (partially trigger the gun).	Cannot "feather" with an AA gun. Feather will cause drastic reduction of pressure at the tip, resulting in poor atomization and/or spitting.
Striping spray. 	Spray tip partially plugged.	Clean or replace spray tip. See page 14.
Irregular pattern.	Fluid build-up on spray tip, or spray tip partially plugged.	Clean or replace spray tip. See page 14.
	On defective side of pattern, air horn holes are partially or totally plugged.	Clean air horn holes with solvent and soft brush. See page 14.
Pattern pushed to one side, same side of air cap gets dirty.	Air horn holes partially or totally plugged.	Clean air horn holes with solvent and soft brush or toothpick. See page 14.
Material build up on air cap.	Air pressure setting too high.	Reduce inlet air pressure. Seven to 10 psi (4.9 to 7.0 kPa, 0.49 to 0.7 bar) air pressure when triggered is recommended.

Table 12.4 – Spray pattern problems and solutions (from manual)

Problem	Cause	Solution
Fluid leakage from back of fluid packing area.	Worn packings or needle shaft.	Replace needle assembly
Air leakage from gun.	Air valve not seating properly.	Clean or replace air valve
Fluid leakage from front of gun.	Needle ball worn or damaged.	Replace needle assembly
	Worn seat assembly.	Replace the seat and gasket carbide models only). The gasket must be replaced whenever the seat assembly is removed. Do not reverse the direction of the plastic seat (5c, model 24C854 gun only) if it is worn. The seat must be replaced it if is worn.
	Fluid viscosity too low for proper seal with carbide seat.	Install plastic seat
Fluid in air passages.	Spray tip seal leaking.	Tighten retaining ring or replace spray tip
	Leaking around seat housing.	Replace the gasket (carbide models only). The gasket must be replaced whenever the seat assembly is removed.
	Fluid inlet fitting leaking.	Replace the fluid tube gasket . The gasket must be replaced whenever the fluid tube connector is removed.
Slow fluid shut-off.	Fluid buildup on fluid needle components.	Remove and clean or replace the fluid needle assembly
No fluid output when triggered.	Spray tip plugged.	Clean spray tip.
	Fluid filter or fluid hose plugged.	After tip removal (see above), very slowly loosen the hose end coupling at the gun and relieve pressure gradually. Then loosen completely to clear the obstruction. Clean or replace filter

Table 12.5 – Gun problems and solutions (from manual)

12.3.6 Pressure Regulator:

Pressure regulator is installed in the supply and return line and is it named as back pressure regulator (BPR) and Fluid pressure regulator (FPR). It is needed for precise downstream pressure and flow control.

- Do not allow fluid to settle in the system.
- Flush the regulator whenever the rest of the system is flushed. Before you flush the system, relive the pressure, and then completely decrease the regulated fluid pressure.
- Before you remove the regulator for thorough cleaning and inspection, follow the Pressure Relief Procedure. Then remove the regulator, clean it, and inspect all parts.

- Always use the lowest possible air and fluid pressures for your application. High pressures can cause premature spray tip, regulator, and pump wear.
- When changing the system pressure, the new system must be cleaned and tested before admitting fluid to the regulator.

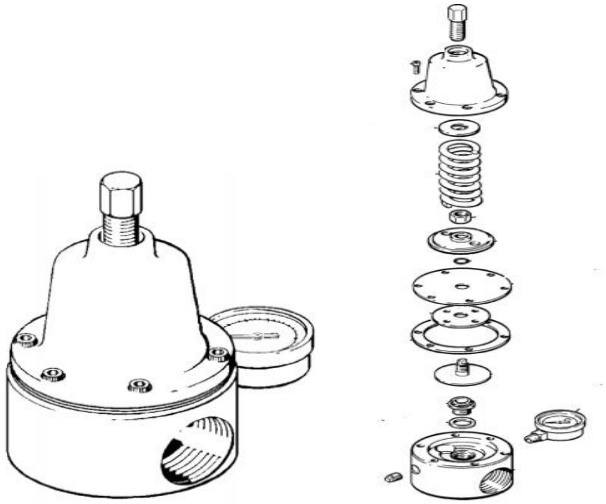


Fig. 12.8 - Pressure Regulator and its exploded view

Problem	Cause	Solution
No pressure regulation	Damaged diaphragm	Replace diaphragm.
	Leaking or dirty seat	Replace cartridge, or clean seat.
No fluid flow	Damaged valve actuator	Replace valve actuator.
Pressure creeps above setting	Metal chip or contamination between ball and seat	Replace cartridge, or clean seat area.
	Damaged diaphragm	Replace diaphragm.
	Damaged o-ring or improper seal	Replace the o-ring under the seat.
	Damaged or clogged air regulator or line (air-operated regulator only)	Clear obstruction in line. Service regulator if necessary.
	Leaking or dirty seat	Replace cartridge, or clean seat.
	Large change in inlet pressure	Stabilize regulator inlet pressure.
Pressure drops below setting	Empty/clogged supply line	Fill/flush supply line.
	Damaged or clogged air regulator or line (air-operated regulator only)	Clear obstruction in line. Service regulator if necessary.
	Using valve beyond its rated flow capacity	Install valve for each spray gun or dispensing valve.
	Large change in inlet pressure	Stabilize regulator inlet pressure.
Fluid leaks from spring housing	Loose fluid housing	Tighten the four cap screws.
	Damaged diaphragm	Replace diaphragm.
Chatter	Excessive pressure differential between pump and gun	Reduce pump pressure to not more than 2000 psi (14 MPa, 138 bar) greater than required gun pressure.
	Excessive flow rate	Reduce fluid flow through regulator. Connect only one spray gun or dispensing valve to each fluid regulator.

Table 12.6 – pressure regulator problems and solutions (from manual)

13 COST OF MAINTENANCE

Cost of maintenance depends upon the frequency and time required by the employee to perform the given task. The following table gives an idea of the annual cost of doing maintenance on the main components of the paint shop. We are assuming a medium cost of labour of 20 €/hour (source: ISTAT).

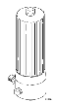
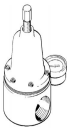
Number	Component Photos and Name		Function	Maintenance Activity	Frequency	N Cycles / Year	Time(Min) Required to perform	Time (Hr) / Year	Labour Rate	Labour Cost	Cost of Preventive Cycle
1		Filter	Supply Paint Filteration	Cleaning	Daily	365	15	91,25	20	1825,0	1998,3
				Lubrication		0	0	0,00	20	0,0	
				Inspection	Weekly	52	10	8,67	20	173,3	
				Tightening		0	15	0,00	20	0,0	
				Replacement		0	30	0,0	20	0,0	
2		Pneumatic Pump Lower with Build In Filter	Paint Supply	Cleaning		0	30	0,00	20	0,0	116,7
				Lubrication		0	27	0,00	20	0,0	
				Inspection	Forthnightly	26	10	4,33	20	86,7	
				Tightening	Half yearly	2	45	1,50	20	30,0	
				Replacement		0	150	0,0	20	0,0	
3		Pneumatic Motor	Paint Supply	Cleaning		0	10	0,00	20	0,0	176,0
				Lubrication		0	25	0,00	20	0,0	
				Inspection	Forthnightly	26	18	7,80	20	156,0	
				Tightening	Half yearly	2	30	1,00	20	20,0	
				Replacement		0	60	0,0	20	0,0	
4		Surge Suppressor	Reduce the fluatuation in paint line	Cleaning		0	10	0,00	20	0,0	228,7
				Lubrication	Forthnightly	26	25	10,83	20	216,7	
				Inspection	Half Yearly	2	18	0,60	20	12,0	
				Tightening		0	30	0,00	20	0,0	
				Replacement		0	60	0,0	20	0,0	
8		Pressure Gauges Calibration & Glycerine Level Check	Supply Paint Pressure Monitoring	Cleaning		0	10	0,00	20	0,0	20,0
				Lubrication		0	0	0,00	20	0,0	
				Inspection	Forthnightly	26	0	0,00	20	0,0	
				Tightening	Half yearly	2	30	1,00	20	20,0	
				Replacement		0	60	0,0	20	0,0	
9		Pneumatic Agitator	Paint Suction and Proper Agitation of Fluid	Cleaning	Weekly	52	10	8,67	20	173,3	173,3
				Lubrication	Daily	365	0	0,00	20	0,0	
				Inspection	Weekly	52	0	0,00	20	0,0	
				Tightening		0	30	0,00	20	0,0	
				Replacement		0	60	0,0	20	0,0	
10		Pressure Regulator	To Regulate the Fluid	Cleaning		0	10	0,00	20	0,0	20,0
				Lubrication		0	0	0,00	20	0,0	
				Inspection		0	0	0,00	20	0,0	
				Tightening	Half yearly	2	30	1,00	20	20,0	
				Replacement		0	60	0,0	20	0,0	
11		Run Away Valve	To Cuoff the Air During Dry Stock of Pump	Cleaning		0	10	0,00	20	0,0	20,0
				Lubrication		0	0	0,00	20	0,0	
				Inspection	Weekly	52	0	0,00	20	0,0	
				Tightening	Half yearly	2	30	1,00	20	20,0	
				Replacement		0	60	0,0	20	0,0	
12		Manual Gun	To spray Fluid to adhere on the automobile parts	Cleaning	Daily	365	10	60,83	20	1216,7	4866,7
				Lubrication	Monthly	12	0	0,00	20	0,0	
				Inspection	Weekly	52	0	0,00	20	0,0	
				Tightening	Daily	365	30	182,50	20	3650,0	
				Replacement		0	60	0,0	20	0,0	

Table 13.1 – Cost of maintenance

14 Bibliography (TO FINISH)

Source of Information:

Patvin Engineering Pvt Ltd, Graco Inc. Ltd, George-Koch Sons.

Industries: JCB India-Jaipur,Tata Motor and TVS India