METHODS OF SURFACE PREPARATION

This section will describe the various methods of surface preparation that are used for removing surface contaminants and old paint systems, and also for profiling the underlying substrate. It will, however, concentrate on dry abrasive blasting, which is the most widely used method of surface preparation in the marine industry.

1. HIGH PRESSURE FRESH WATER WASHING

There are several reasons for using high pressure fresh water washing as a surface preparation method. Module No. 3 described three reasons why ships are high pressure washed when they come into drydock, as follows:-

1 To remove salts from the surface of the hull.
2 To remove slime, weed and some animal fouling from underwater areas.
3 To remove the leached layer of antifouling paints from the underwater area of vessels.

High pressure fresh water washing is usually specified in **any** situation where salts have to be removed. For example **prior** to other surface preparation and coating operations on deck or ballast tank remedial work.

In addition, it has also been stated that high pressure fresh water washing is an effective method of removing salt contamination from the bottom of corrosion pits in steel **after** blasting.

1.1 HIGH PRESSURE AND LOW PRESSURE FRESH WATER WASHING METHODS

SSPC-VIS 4 (1) NACE No. 7 standard defines low pressure water cleaning at pressures less than 34 MPa (5,000 psi) and high pressure water cleaning at pressures between 34 MPa and 70 MPa (5,000 and 10,000 psi). There are several types of equipment that can be used for this purpose, including the lower pressure water jetting machines. However, the two types of equipment normally used for washing rather than blasting are the fan jet lance and the rocky washer.

1.1.1 Fan Jet Lances

Fan jet lances achieve their effect by pumping fairly low volumes of water at high pressure through flexible lines to a hand held lance. Pressures are typically in the 21 MPa (3,000 psi) range. The water emerges from a tip about 2mm wide in the form of a fan, which will be about 20cm wide at a distance of 40cm from the tip. The water energy and its cleaning power are dissipated within a short distance from the tip and optimum cleaning is carried out at a distance of 20cm. The operator therefore requires good access to the work surface and best results are achieved by working in a systematic manner, from top to bottom on vertical surfaces, overlapping each pass of the lance.

1.1.2 Rocky Washers

Rocky washers which are mainly found in the Asia Pacific shipyards achieve their effect by pumping high volumes of water at lower pressure through flexible lines to the water head. Pressures are typically in the 8-10 MPa (1200-1500 psi) range. The water emerges from a washer head of about 2cm diameter which is attached to a metal nozzle of approximately 1m in length. This is pivoted to its support to enable the operator to 'rock' the jet of water vertically or horizontally over the surface. Cleaning is carried out by the operator directing the jet of water on a substrate several metres away. Each stroke of the jet cleans a width of only 5-6cm.

You should note that these machines are ineffective in removing the leached or depleted layer of antifouling paints, and they have problems in reaching and cleaning the flat bottoms of ships.

The fan jet lance is more effective than the rocky washer and it has faster cleaning rates. It is therefore the cleaning device in most common use.

Fresh water should be used for washing whenever possible, but if fresh water is unavailable then salt or brackish water is sometimes used. This is only acceptable as long as sufficient fresh water is used afterwards to remove salt residues.

2. SOLVENT CLEANING OR DEGREASING

It is essential to remove oil and grease contamination that can prevent proper adhesion of the coating to the substrate.

The American 'Steel Structures Painting Council' standard SSPC-SP1 is the recognized standard for solvent cleaning which describes these methods. It is the standard which is specified in the Marine Interspec under Code 1 as a pre-requisite for virtually all surface preparation specifications.

2.1 SOLVENT CLEANING METHODS

SSPC-SP1 defines the methods of solvent cleaning as follows:

Remove heavy oil or grease first by scraper, then remove the remaining oil or grease by any of the following methods.

1. Wipe or scrub the surface with rags or brushes wetted with solvent. Use clean solvent and clean rags or brushes for the final wiping.
2. Spray the surface with solvent. Use clean solvent for the final spraying.
3. Vapor degrease using stabilized chlorinated hydrocarbon solvents.
4. Immerse completely in a tank or tanks of solvent. For the last immersion, use solvent which does not contain detrimental amounts of contaminant.
5. Emulsion or alkaline cleaners may be used in place of the methods described. After treatment, wash the surface with fresh water or steam to remove detrimental residues.
6. Steam clean, using detergents or cleaners and follow by steam or fresh water wash to remove detrimental residues.

In general, solvent wiping and washing are commonly used in the marine industry and these methods are useful provided that they are properly carried out. Vapor degreasing is not commonly used and solvent immersion is only applicable for small items. Alkaline cleaning is not widely used, the cleaners are effective but they can cause burns to operators and they also strip paint by saponification. This means that they have to be thoroughly removed by washing prior to painting. The preferred methods of degreasing in the marine industry are therefore emulsification and steam cleaning.

Emulsification cleaners are usually a mixture of oil soluble soaps or emulsifiers along with kerosene or white spirit. They are usually sprayed onto the surface, where emulsification occurs by the action of the high pressure water. A residue of the emulsion will almost always be left on the surface, which can prevent coating adhesion. This residue must be washed off with clean fresh water after degreasing has been carried out.

Steam cleaning is also effective at degreasing, although you should be aware that it can also damage coatings. The steam and the hot water themselves tend to remove the oils and grease by thinning them with heat, emulsifying them and diluting them with water. Ultra high pressure hydro blasting also has the same effect. However, steam cleaning is particularly effective when detergent or alkaline cleaners are used in conjunction with the water, but it must be followed by a final washing with clean fresh water.

The SSPC-SP1 specification describes methods of solvent cleaning, but gives no information on which solvents to use. If you are selecting or advising the yard or ship-owner on a solvent for cleaning, you must consider both the health and safety and substrate acceptability aspects of the problem.

You should note that vapor degreasing should only be carried out with non-flammable chlorinated hydrocarbons, because of the fire and explosion risk. Unfortunately these solvents are also toxic and are not recommended for general use.

Substrate acceptability is not a problem if bare steel is being degreased. Solvents such as xylene are perfectly adequate for this purpose. However, if a painted surface is to be degreased without being damaged, a solvent must be chosen which will not dissolve the paint film.

3. MANUAL METHODS OF SURFACE PREPARATION

Manual methods of surface preparation are only suitable for preparing small or localized areas of corrosion or paint breakdown. It is not generally cost effective to manually prepare large areas and in any case, the standards achieved are generally low. All manual methods of surface preparation will leave an adherent layer of rust or scale on the surface of bare steel. This means that the likelihood of eventual coating failure in these areas is high, especially in maintenance and repair situations. There are three methods in common use.

3.1 HARD SCRAPING OR SLICING

Hard scraping or slicing is carried out with various types of scraper. Two scrapers commonly encountered are the hand scrapers used for small local areas and the long handled scrapers with wide blades used on the outside hull of ships for removing animal fouling and detached coatings.

Scrapers are useful for removing loose material, but they are virtually ineffective at removing tightly adhered corrosion and scale.

3.2 CHIPPING HAMMERS OR CHISELS

Chipping can be carried out using a wide variety of hammers or chisels, but it is a very slow and laborious method of surface preparation. Heavy deposits of scale are often removed by impact chipping prior to grit blasting, but the technique is used mainly for removing loose corrosion products and old paint coatings.

Best results are obtained if chipping is followed by secondary preparation such as wire brushing. This helps to remove the remaining contamination left by chipping.

3.3 WIRE BRUSHING

Wire brushing can remove loose contamination, but it is ineffective at removing scale and deep seated corrosion. It can, however, polish residual scale, giving the appearance of a clean surface. If this polished surface is scraped with a knife, the rust that has not been properly removed will be exposed.

Preparation of steel substrates by hand-tool cleaning is described in ISO 8504-3.

4. POWER TOOL METHODS OF SURFACE PREPARATION

Using portable pneumatic or electric power tools is less laborious than using hand tools and it is economical to prepare larger areas. Technically, power tools can produce cleaner surfaces than hand tools and give standards of preparation that are acceptable for most of International Paint's products. However, it should be stressed that these surfaces are not 100% clean. Power tooling does not normally remove all contamination from the substrate, and products applied over these surfaces will not have the same long term performance as products applied over grit blasted surfaces.

Power tools used for cleaning fall into two basic categories. Rotary cleaning tools and impact cleaning tools.

4.1 ROTARY CLEANING

Two types of rotary cleaning commonly used for marine applications are rotary wire brushing and rotary discing.

4.1.1 Rotary Wire Brushing

Different types of wire brush are used for different applications. Radial brushes attached to straight or in-line tools are used for preparing awkward areas such as corners or weld seams. Cup brushes attached to vertical or angle grinders are more often used for preparing large areas.

Power wire brushing can clean loose contamination from a substrate, but it is generally ineffective at removing tightly adherent scale, which may in fact be polished giving the appearance of a clean surface. Polishing of actual steel surfaces may also be a problem if brushing is carried out over zealously, because smooth polished surfaces can be detrimental to coating adhesion.

You should also be aware that rotary wire brushing is notorious for spreading oil and grease contamination over previously uncontaminated areas. It is therefore essential to use clean brushes, and to degrease areas prior to rotary wire brushing.

4.1.2 Rotary Discing

Rotary disc cleaning of a surface is achieved by coated abrasive discs attached to angle grinders. Similar cleaning effects can also be produced by using abrasive flap wheels attached to straight or in-line tools. Various types and grades of abrasive disc are used for different applications. Some typical applications are described below:

Disc- sand can be used for removing both loose and tightly adherent rust or scale. However, it is not a practical or economical method of removing tightly adherent mill scale. Disc- sand can be used for feathering back edges of old paint, Particularly in spot blasted, or block join up areas. Unfortunately the discs can become clogged and ineffective if used on soft paint systems.
Disc-sand will also remove base metal and it should be used only in areas where is acceptable. In fact, removal of bare metal to produce a profile is one of the

reason disc-sand is used.
Because of this ability to remove contaminants and produce a surface profile, Disc-sand can be seen as a viable alternative to spot blasting and it is recommended as the best method of power tool preparation when blasting has been ruled out.

Preparation of steel substrates by power-tool cleaning is described in ISO 8504

4.2 IMPACT CLEANING

The action of impact cleaning tools is dependant upon the cutting blade or point of the tool pounding the surface and breaking away the contaminants. They are therefore good at removing brittle substances such as heavy deposits of scale, rust, mill scale, thick old paint coatings and welding slag. Unfortunately they are only effective at the point of impact and will leave residual contamination in the bottom of pits and other areas untouched by the tool. It is therefore a good idea to follow impact cleaning with rotary wire brushing, in an attempt to remove this contamination.

Impact tools include chipping or scaling hammers, chisels and needle guns. These tools work when the impact piece is struck by an internal piston which forces it into violent contact with the work surface. Needle guns are slightly different because a bundle of needles are simultaneously struck by the piston and the needles themselves are able to adapt to and clean irregular surfaces.

Other types of impact tools include scabblers, which are used mainly for decks, and rotary impact tools which flail the surface with a series of small hardened hammers.

A major problem with all impact tools is that they can cut the steel surface, throw up sharp burs and produce a very rough surface profile. This is obviously dependant upon the sharpness of the tool and the pressure at which it is used. However, if this type of surface is painted without further preparation, the burs and rough peaks can stick through the coating and cause rash rusting and coating failure.

5 DRY ABRASIVE BLASTING

There are two main types of dry abrasive blasting processes in common use. In the first, the abrasive is carried by compressed air, in the second ‘airless’ process it is thrown from an impeller wheel. Compressed air blasting is more suitable for site work because the equipment is reasonably portable, whereas the airless process lends itself to fixed workshop installations and is more common in blasting and shop priming plants.

Preparation of steel substances by abrasive blast cleaning is described in ISO 8504-2. The visual cleanliness of the substrate produced after blasting is described in ISO 8501-1.

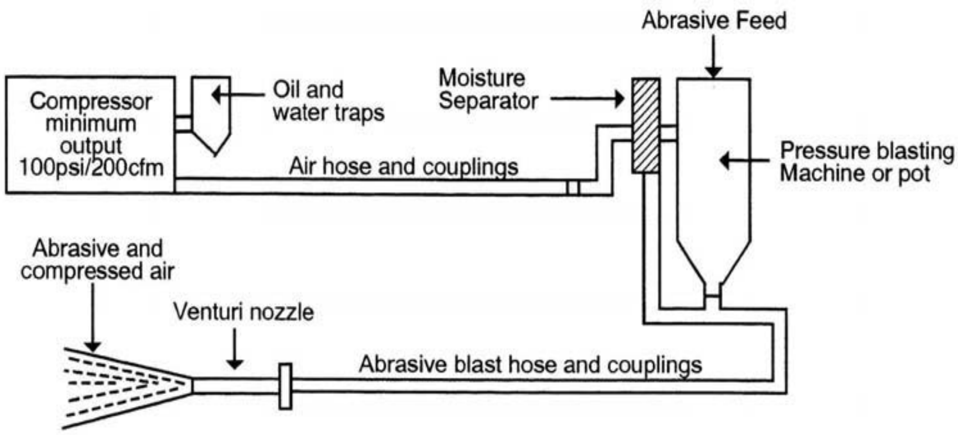
5.1 COMPRESSED AIR BLASTING

Since its inception in the 1930's air blasting has become the most common type of surface preparation in use. This is because of the reliable nature of the equipment, its versatility and its efficiency in cleaning substrates. Basically the system works by propelling abrasive at high speed with compressed air at the substrate surface. The higher velocity and impact force, the greater the rate of cleaning.

The components of a compressed air blasting set up are as follows:

An air supply
An air hose and coupling
A moisture separator
A pressure blasting machine or pot
Abrasive blast hose and couplings
A blast or venturi nozzle
Properly trained and equipped operators
Blasting abrasives

See figure 12. Each component will be discussed in turn.



5.1.1 Air Supply

The air supply provides the energy for the entire operation. In shipyards it is normal practice to take this supply from a portable compressor, because the yard air supplies are often inadequate for this purpose. The compressor has to meet two basic requirements. Firstly it must produce air at the required pressure. For grit blasting purposes this must be at least 7 kg/cm^2 (100 psi) which should be maintained throughout the equipment up to the nozzle. Secondly it must produce the required volume of air. The volume requirement is largely determined by the nozzle orifice size, but would be in the region of 340m3/hour (200 cubic feet per minute) for 9.5mm (3/8") nozzle. Typical blasting requirements of 7kg/cm^2 pressure at a throughput of 340m^3/h could be supplied by a 37 kw (50hp) compressor.

Tables 1 and 2 show the relationship between nozzle size, pressure, air flow and compressor power requirements in both metric and imperial units.

Nozzle	Nozzle Pressure KG/CM^2								
Orifice (MM)	2.11	2.81	3.52	4.22	4.92	5.62	6.33	7.03	
3.175	13.60 0.75	17.00 0.93	19.21 1.20	22.44 1.54	25.67 1.90	28.90 2.30	30.60 2.61	34.43 3.13	air m^3 per hour power kw
4.760	30.60 1.38	37.40 2.00	44.20 2.66	51.00 3.42	56.10 4.11	64.50 5.16	69.70 5.95	75.50 6.95	air m^3 per hour power kw
6.350	57.80 2.61	69.70 3.73	79.90 4.80	91.80 6.16	103.70 7.60	115.60 9.23	125.60 10.60	137.70 12.51	air m^3 per hour power kw
7.940	90.10 4.07	110.50 5.92	130.90 7.87	151.30 10.16	171.90 12.59	192.10 15.34	214.20 18.05	232.90 21.16	air m^3 per hour power kw
9.530	129.20 5.84	154.70 8.28	183.60 11.04	214.20 14.40	243.10 17.83	273.70 21.86	294.10 24.77	333.20 30.29	air m^3 per hour power kw
11.110	170.00 7.68	210.80 11.27	249.90 15.00	289.00 19.40	329.80 24.17	368.90 29.50	408.00 34.39	431.80 39.24	air m^3 per hour power kw
12.700	232.90 10.52	280.50 15.00	331.50 25.60	380.8 31.41	428.40 38.05	476.00 44.24	525.30 52.22	574.60	air m^3 per hour power kw

Table 1 – Metric nozzle size against pressure, air flow and compressor power requirements

Nozzle	Nozzle Pressure PSI								
Orifice (Inches)	30 psi	40 psi	50 psi	60 psi	70 psi	80 psi	90 psi	100 psi	
1/8”	8 1	10 1.25	11.3 1.61	13.2 2.07	15.1 2.55	17 3.09	18 3.5	20.25 4.19	air cfm power hp
3/16”	18 1.85	22 2.68	26 3.56	30 4.59	33 5.51	38 6.92	41 7.87	45 9.32	air cfm power hp
¼”	34 3.5	41 5.0	47 6.44	54 8.26	61 10.19	68 12.37	74 14.2	81 16.77	air cfm power hp
5/16”	53 5.46	65 7.93	77 10.55	89 13.62	101 16.87	113 20.56	126 24.19	137 28.36	air cfm power hp
3/8”	76 7.83	91 11.1	108 14.8	126 19.3	143 23.9	161 29.3	173 33.2	196 40.6	air cfm power hp
7/16”	100 10.3	124 15.2	147 20.1	170 26.0	194 32.4	217 39.5	240 46.1	254 52.6	air cfm power hp
½”	137 14.1	165 20.1	195 34.3	224 42.1	252 51.0	280 59.3	309 70.0	338	air cfm power hp

Table 2 –Imperial nozzle size against pressure, air flow and compressor power requirements

More than one pressure blasting machine can be run from a single compressor, providing it has a large enough output of air. Knowing the output will enable the operators to correctly size the number of machines and the diameter of the nozzles that can be used. It should be borne in mind that it is unwise to continuously run a compressor at more than 75% of its output capacity.

Example

A 215m^3/hour compressor is available to a blasting operator to carry out a blasting contract. This effectively gives him 161m^3/hour (94 cfm) for continuous use and the machine must be run at 7 kg/cm^2 (100 psi) for effective blasting purposes. By reference to Table 1 it can be seen that he can operate either:

1 off 6.35mm nozzle requiring 138m^3/hour or 2 off 4.76mm nozzles requiring 2 x 75.5m^3/hour

His choice will depend upon the number of locations to be cleaned, the cleaning rates required and the additional cost of plant, abrasive and labour if two machines are used.

You will have seen that the contractor could have used a variety of smaller nozzles which would have required less air. He would probably not have chosen them, because contractors are generally interested in a high work rate, and the work rate is directly proportional to the air flow. For example, if he had chosen 2 off 4.76mm nozzles using a total of 151m^3/hour instead of 2 off 7.94mm nozzles using a total of 466m^3/hour he would only have required one third of the air supply but would only achieve one third of the work rate. (He would only use one third of the abrasive, because abrasive consumption is also proportional to air flow).

It has already been stated that a working pressure of 7kg/cm^2 (100 psi) at the nozzle is ideal for blasting and has been accepted as the industry standard for many years. Lower pressures reduce the work rate and they are normally caused by equipment faults. Higher pressures are intentionally used to increase the work rate.

Low blasting pressure can be caused by a malfunctioning compressor, wrongly sized air or blasting hoses, or more usually a wrongly sized or badly worn nozzle. Every drop in pressure of 0.07kg/cm2 (1 psi) results in a 1.5% drop in work rate and a point is reached at around 4.22kg/cm2 (60 psi) where blasting is no longer effective. Pressure above 7kg/cm2 (100 psi), increase work rates by the same ratio and are commonly used for this reason when larger compressors are available. There are two potential problems with higher pressures which you should be aware of. Blasting 'pots' are pressure vessels and should not be used above their specified working pressure. High compressor inputs may pressurise the blasting pot above this specified working pressure. The pots may well be fitted with pressure relief valves but, as mentioned in Module No. 2, it is not uncommon for the machines to rupture and injure people.

Secondly, higher pressures mean that the abrasive strikes the substrate with considerably more impact energy. In certain cases this may cause the abrasive to impinge into the steel surface. When this happens the abrasive cannot be thoroughly removed by blowing down or vacuum cleaning and reblasting with a finer abrasive may be needed to remove it. If it is left in place and painted over, the impinged abrasive may well lead to early coating failure through loss of adhesion or blistering.

Air pressure at the compressor can be checked by looking at the output pressure gauge. The pressure at the nozzle can be checked by inserting a hypodermic needle gauge into the blast hose just behind the nozzle.

Finally, you should note that the air from the compressor must be clean and dry to avoid contamination of the substrate. For this reason the compressor should be fitted with a functioning oil trap, many are also fitted with a moisture trap, and this is particularly important when the blasting equipment itself is not fitted with a moisture separator. If the abrasive itself becomes wet it will cause blockages in the blasting pot and will delay the blasting process.

5.1.2 Air Hose

From the compressor, the air is taken through a compressor manifold valve, couplings and air hose to a moisture separator beside the blasting pot. The air hose has to be of ample size to throughput the air without creating undue pressure drops due to friction. As a general rule, the air supply hose should be 3 to 4 times the diameter of the nozzle orifice. In long lines over 30m the line should be a minimum size of 4 times the nozzle orifice size. Tables 3 and 4 give more accurate information for calculating the pressure drops in both metric and Imperial units.

You should also note that pressure drops can be caused by internal air hose couplings and by small compressor outlet valves. If compressors are fitted with small valves they should be replaced with outlets to match the size of the air hose.

Size of Hose (Internal Diameter cm)	Gauge Pressure on Compressor (kg/cm^2)	Loss of pressure in kg/cm^2 per 15.2m length Cubic metres per hour passing through 15.2m hose			
		$170m^3/hr$	$272m^3/hr$	$394m^3/hr$	$544m^3/hr$
1.905	4.22	0.61	1.97		
	4.92	0.50	1.547		
	5.62	0.40	1.27		
	6.33	0.35	1.09		
	7.03	0.31	0.95	2.38	4.28
2.54	4.22	0.14	0.58	1.44	
	4.92	0.11	0.38	0.95	
	5.62	0.10	0.28	0.70	3.17
	6.33	0.08	0.23	0.56	2.53
	7.03	0.07	0.19	0.48	2.15
3.175	4.22	0.04	0.14	0.35	1.58
	4.92	0.03	1.11	0.27	1.20
	5.62	0.03	0.11	0.23	1.10
	6.33	0.02	0.07	0.18	0.80
	7.03	0.02	0.07	0.16	0.73

Table 3 – Air and Blast Hose Pressure Drops – Metric Units

Size of Hose (Internal Diameter)	Gauge Pressure on Compressor (psi)	Loss of pressure in psi per 50 foot length Cubic feet per minute passing through 50 ft hose			
		100 cfm	160 cfm	232 cfm	320 cfm
¾”	60	8.6	28.0		
	70	7.0	22.0		
	80	5.8	18.0		
	90	5.0	15.5		
	100	4.4	13.5	33.8	60.8
1”	60	2.0	8.2	20.5	
	70	1.6	5.4	13.5	
	80	1.4	4.0	10.0	45.0
	90	1.2	3.2	8.0	36.0
	100	1.0	2.7	6.8	30.6
1¼”	60	0.6	2.0	5.0	22.5
	70	0.4	1.5	3.8	17.1
	80	0.4	1.5	3.3	14.9
	90	0.3	1.0	2.5	11.3
	100	0.3	1.0	2.3	10.4

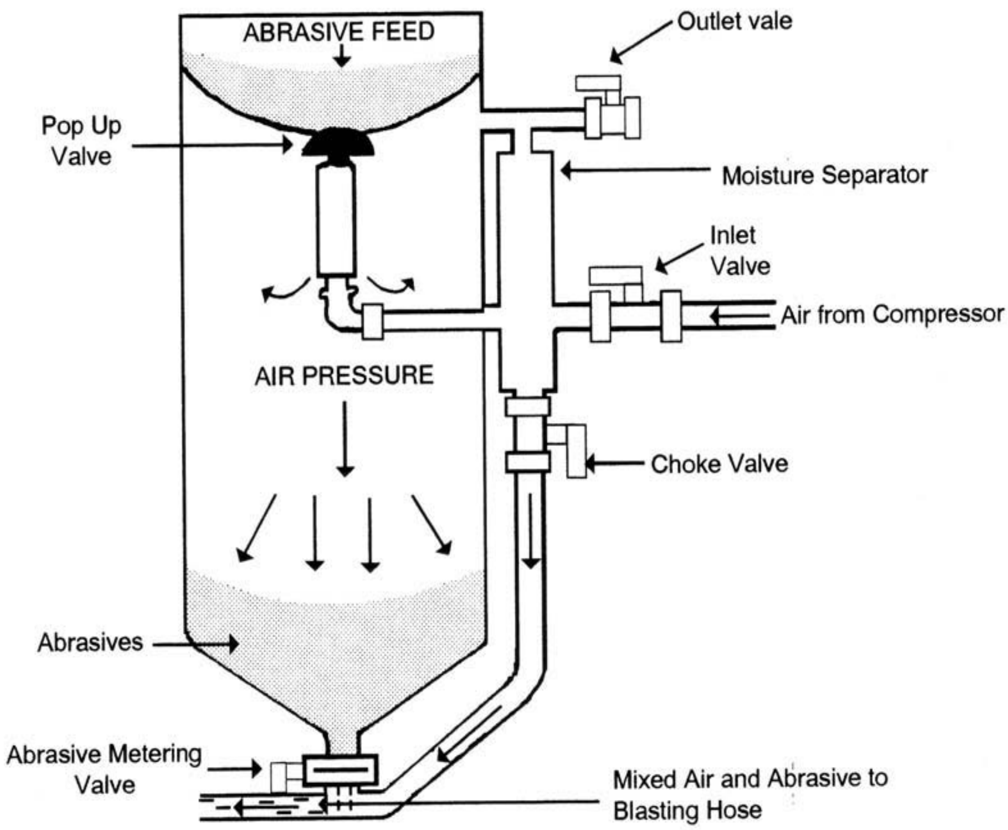
Table 4 –Air and Blast Hose Pressure Drops –Imperial Units

5.1.3 Moisture Separator

Before the compressed air goes through the blasting pot it should be fed through a moisture separator to ensure that the air reaching the substrate is dry. Unfortunately some older blasting pots are not fitted with separators at all, and must rely on the compressor moisture traps. Where this is the case, you must ensure the moisture traps are functioning properly. Small portable blasting pots often have the separator attached to the side of the machine, but larger blasting machines have separate moisture separator vessels. All separators will have water dump valves, some of which may operate automatically. When there are no moisture traps on the compressor or blasting pot, compressed air should be blown through the whole system before blasting starts, until there is no more visible moisture coming out of the venturi nozzle.

5.1.4 Pressure Blasting Machine or Pot

The blasting machine or pot is a pressurized vessel designed to give a controlled feed of abrasives into the compressed air supply as it goes through the blast hose. See figure 13.



Abrasives are fed into the top of the pot, past the internal pop-up valve, when the machine is depressurized. The abrasives can be stored in a hopper feeding directly into the pot, or they can be emptied into the pot manually by a 'pot man'. When the pop-up valve is closed, compressed air which has been fed through a moisture separator via an inlet valve, pressurizes the section of the machine containing the abrasives.

The cone bottom of the machine allows gravity feed of the abrasives through an abrasive metering or 'miser' valve into the main air flow from the compressor, passing through the blast hose.

All machines are fitted with an exhaust or outlet valve which opens the pop-up valve and depressurizes the pot. This cuts the abrasive feed into the blasting hose. On some machines the inlet and outlet valves are operated by the pot man, but on better machines both the inlet and outlet valves can be automatically controlled by the blaster when the machine is fitted with a remote control or 'dead man's handle'. This means that the blaster, rather than the 'pot man' can switch the abrasive supply on and off. This is an important safety feature. On small machines the dead man's handle works hydraulically and can take several seconds to operate, but some larger machines are fitted with an electrical cut-off, which depressurizes the machine very quickly.

Most machines will also be fitted with a choke valve, which is meant for cleaning obstacles in the abrasives. It works by creating pressure differentials between the blast pot and the outlet feed.

Blasting operations usually require a two man crew, the blaster himself, and a 'pot man'. The pot man ensures that the machine has supplies of abrasives, he controls the throughput of abrasives and depressurizes the machine by use of the inlet and outlet valves. Good communication between the blaster and the pot man is therefore essential.

Since noise levels make verbal communication impossible, visual signaling or electronic communications are the methods normally adopted. Signaling between the blaster and the pot man is only possible where visual contact can be made, for example, when the blaster is working on the outside hull of a ship. When the blaster is working in an enclosed space such as a tank and is out of sight of the pot man, electronic communication is becoming increasingly common and it has huge safety advantages in these circumstances. Both the pot man and the blaster have earphones and microphones, which in the case of the blaster, are fitted into his air fed blast helmet.

5.1.5 Blast Hose

From the blasting pot, the abrasive and compressed air are fed to the nozzle via a blast hose. The hose itself must be the correct type for carrying compressed air and abrasive. Air hoses are not made for this purpose and they should never be used.

The blast hose must be of an antistatic type to dissipate the static charge that is built up when blasting is in progress. Older hoses had a copper wire running through the length of the hose itself, and this had to be grounded at the blasting pot. Unfortunately this wire had a tendency to break after a short life. For this reason, modern blast hoses have a 'carbon black' incorporated into the rubber to dissipate static electricity, and there is no danger of this breaking and interrupting electrical continuity.

Pressure drops due to friction can also occur in blast hoses, and contractors must take this into account when setting up the equipment. Pressure drop calculations can be made by reference to Tables 3 and 4.

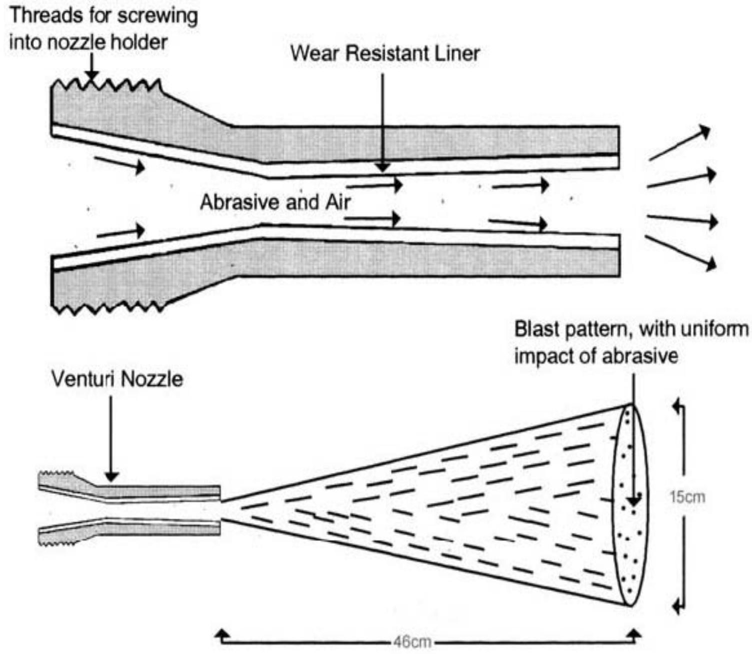
5.1.6 Blast Hose Couplings

Blast hoses should always be fitted with external couplings. Internal couplings should not be used to connect lengths of blast hose, because they restrict the flow of air and abrasive by reducing the internal diameter. This causes pressure drops and reduces blasting efficiency. For example, internal couplings that reduce the internal diameter from 3.2cm (1¼”) to 2.5cm (1”) will reduce the carrying capacity of the hose by 50% and cause turbulence in the air and abrasive flow. There are also safety problems with internal couplings. The abrasive flow tends to wear them out and this can lead to blow-outs, which are extremely dangerous.

External couplings will allow the free flow of air and abrasive from the blasting pot to the nozzle and will help to maintain efficiency. The couplings can be connected and disconnected without tools and this makes them quicker and easier to connect than internal couplings. The ‘working end’ of the blast hose is connected to the blast nozzle. There are two ways of doing this. The nozzle may be pushed into the end of the hose and held in place with a ‘jubilee’ clip, or it may be connected to the hose by a properly fitted external nozzle holder. External nozzle holders help prevent pressure drops and they stop excessive wear of the nozzle itself. They are also safer to use. Nozzles which have been pushed into the hose can cause pressure build-ups that may eventually expel the nozzle from the hose, injuring the blaster.

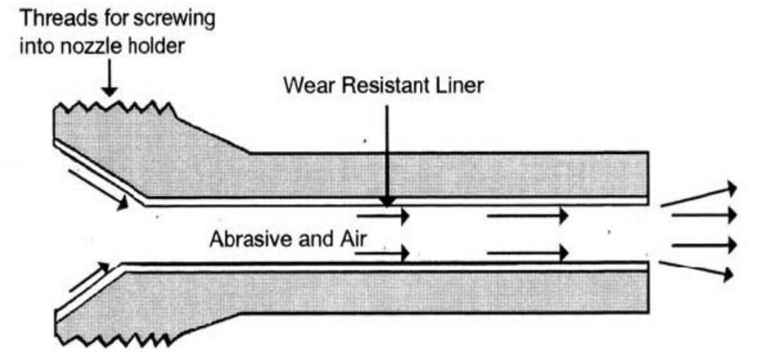
5.1.7 Blast Nozzles

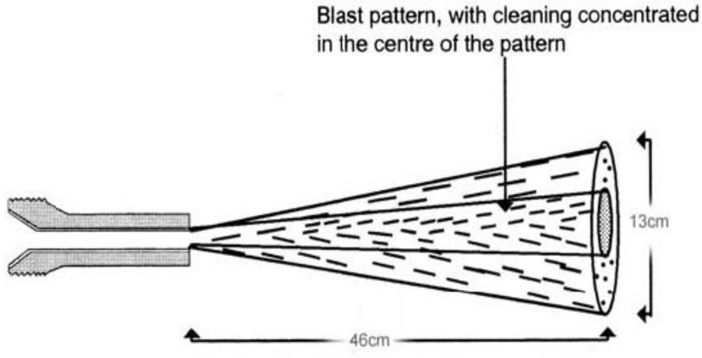
There are two types of nozzle available for blasting, the venturi nozzle and the conventional or straight bore nozzle. See figures 14 and 15. Venturi nozzles have largely superseded straight bore nozzles because of their much greater efficiency and cleaning rates, but you occasionally see straight bore nozzles or even pieces of old pipe used as blast nozzles.



The venturi nozzle has a large entrance throat or converging angle, tapering gradually into a straight section, which flares out slightly towards the outlet end. Abrasive passing through the straight section of the venturi accelerates and develops an outlet speed of about 724 km/h (450mph) with 7 kg/cm^2 (100 psi) blast pressure. This is twice the speed of a straight bore nozzle. This gives venturi nozzles a much faster cleaning rate, because the rate is dependant upon the energy of the abrasive E, the mass of the abrasive M and the velocity V, via the formula $E = \frac{1}{2}MV^2$. The cleaning rate therefore increases with the square of the velocity.

Abrasive from a venturi nozzle is very hard hitting, but more importantly it has uniform impact over the entire blast pattern, which means that the blaster can move quickly over the surface being cleaned without overlapping the blast passes. A distance of about 46cm (18") from the nozzle to the surface generally produces good results, but this obviously requires the blaster to have good access to all areas being cleaned. Where it is impossible to directly blast awkward areas, such as the backs of bars, with the abrasive stream, the blaster will reduce this distance and ricochet the abrasive into these areas to obtain the same cleaning effect. You should be aware of these problems when carrying out blasting inspections in awkward areas.





Straight bore nozzles are not widely used now. They have a sharp converging angle into the nozzle orifice, which leads to the straight section of the nozzle. This does **not** flare out towards the outlet end and it gives the abrasive a velocity of about 354 km/h (220 mph) with 7 kg/cm^2 (100 psi) blast pressure.

A nozzle distance of 46cm (18”) from the surface will give a blast pattern of about 13cm (5”). However, only the centre 5cm (2”) of the pattern will receive the full impact of the abrasive and be properly cleaned. This means that the blaster will have to give a considerable overlap when blast cleaning and make more passes with this type of nozzle.

Nozzles can be constructed from various types of material, which all have different wear rates and different costs. To save on expense, some nozzles are made from cheaper material but are lined with a more expensive, wear resistant, material. The choice of nozzle will therefore depend upon economics and, of course availability. The following types are in common use:

Ceramic Nozzles They can have a short life and are prone to accidental damage.
Cast Iron Nozzles They can have a short life, but are better than ceramic nozzles.
Boron Alloy Nozzles They are relatively inexpensive and have a life of up to 60 hours hen used with mineral abrasives.
Tungsten Carbide Nozzles They are expensive, but have a long life, making them Relatively economical.
Boron Carbide Lined Nozzles They are very expensive, but have a very long life, Making hem very economical.
Silicon Nitride Lined Nozzles They have a moderate cost and a very long life, making hem very cost effective.

5.1.8 Blasting Operators

The most important components of a blasting set up are, of course, well trained and properly equipped operators, who can work safely and efficiently.

The safety hazards of compressed air, abrasive velocity, dust, noise and electrostatic discharge associated with blasting, have been described in Module No. 2. However, the normal safety precautions taken by blasting operators should include the following:

1 Making sure the equipment is in good condition and is not over-pressurised.
2 Making sure the equipment is properly earthed.
3 Having an agreed signalling system between the blaster and pot man and between other site personnel.
4 Putting up warning notices to ensure other people stay behind the blaster's nozzle.
5 Making sure that blast hoses are not worn or damaged by traffic running over them.
6 Lashing blast hoses to staging, where necessary, to reduce drag and deadweight.
7 Taping the remote control lines (where fitted) to the blast hose to avoid kinking.
8 Making sure that staging is safe and suitable for the job.

The pot man should wear the type of safety equipment described in Module No. 2, but the blaster will need more specialist equipment to protect himself from the abrasive, dust and noise produced by blasting operations. The most important item is an air-fed helmet. In some parts of the world these helmets are compulsory and must comply with health and safety legislation. In general, the helmets are fitted with protective capes to cover shoulders and arms, they are normally sound insulated and they have replaceable visors. Most importantly, they must be fitted with an external air supply to allow the blaster to breathe. This air supply should maintain a small positive pressure to keep dust out of the helmet, and, if it is fed via a take off from the compressor or blasting machine, it must be filtered and purified. The blaster will also need to wear leather gloves or gauntlets to protect his hands and wrists against rebounded abrasives and, of course, a protective overall and safety boots.

Blasting efficiency depends upon many factors. We have described the importance of correctly sized nozzles, correctly set up equipment and good access. However, the rate of cleaning will largely depend upon the standard of cleanliness required, and the type of contaminants or coatings that are being removed. It will obviously be quicker to remove alkyd paint to give an Sa2 standard that it will to remove tightly adherent epoxies to give and Sa2½ standard. Blasting contractors will take these factors into account when pricing jobs on a square meter or square foot basis.

As a 'rule of thumb' guide, you should be aware that a good operator, holding the nozzle between 30-46cm (12-18") from the surface, should be able to blast between 12-18m^2 per hour. At that rate he would use approximately 500kg of expendable abrasive per hour. You may find that you can use the comparative consumption of abrasive as a useful check on the performance (and standards) of cleanliness achieved by different blast operators.

Different techniques of dry abrasive blasting are used to obtain different types of preparation. We will look at spot blasting, light and heavy sweep blasting, full blasting and vacuum blasting.

5.2 SPOT BLASTING

Spot blasting is usually specified by shipowners where patch corrosion has occurred on the outside hull of a vessel. The idea is to blast the corroded spots to a specified standard, usually Sa2 or Sa2½ (or equivalent), then to move the abrasive stream onto the next area of corrosion, leaving the uncorroded areas of intact paint untouched.

The owners and yards usually agree upon the area to be blasted as a percentage of the total. For example, 10% of the topsides, which have a total area of 5000m^2 = 500m^2 of spot blasting. This can seem a relatively inexpensive method of dealing with scattered corrosion, but there are certain problems associated with spot blasting which you must be aware of. These are as follows:

1 Spot blasting can lead to undercutting by abrasives of paint immediately adjacent to the blasted area. This is especially true of epoxies. Undercut areas, or loose edges should be removed to a firm edge by thorough scraping, or by feathering using a rotary disk. If this is not done, the undercut paint film may curl up when it is softened by solvents during overcoating. These areas then corrode, if left untreated. In fact, most blasters tend to blast back to a firm paint edge rather than feather. This can greatly increase the area of blasting.

2 The surrounding paint will be peppered by stray abrasive particles, which can destroy the protective value of the paint scheme, in the vicinity. These areas must be included in 'touch-up' painting which is normally specified for spot blasted areas.

3 Damage can also occur in the areas between patches if the abrasive stream is played across the surface. Ideally blasting should be discontinued whilst moving from one patch to the next, but this is rarely done because it increases the blasting time considerably. These damaged areas must also be treated during touch-up painting.

4 Paint used for touch-up coats after spot blasting will cover areas which are much greater than the total area specified for blasting. There are two reasons for this. The touch-up coats must treat the damaged areas as described above, and the painter himself will tend to overlap each touch-up coat by a considerable margin because of the inadequacies of the spraying equipment, and to make sure he has covered everything. This is not good painting practice, but it does happen, and it means that the final touch-up coat may cover 50 or 60% of an area which has only been specified for 10% spot blasting. You must take this into consideration when ordering and allocating paint for these areas and explaining to the superintendent why the actual paint consumption is higher than originally quoted by the salesman.

5 It is difficult to estimate accurate percentages for spot blasting, and it may not be easy to stick to agreed areas, because more and more patches of corrosion become apparent as the job proceeds. This can lead to arguments over areas between the yard and the

superintendent into which you may be drawn. It is therefore recommended that the patches to be blasted should be defined by 'chalking in' the boundaries wherever possible. It is better still to take out entire blocks where there are many small spots of corrosion in one area.

5.3 SWEEP BLASTING

Sweep blasting is a method of preparation that relies upon sweeping a jet of abrasive across a surface. It's effectiveness depends upon the nature and condition of the surface, the type and particle size of the abrasive and, above all, the skill of the operator. The latter can be extremely variable. Two types of sweep blasting are commonly specified, light sweeping and hard of heavy sweeping.

International Paint have produced standards for sweep blasting and for abrasive sweep blasting of shop primed surfaces.

5.3.1 Light Sweep Blasting

Light sweeping involves the rapid sweeping of the abrasive stream over a surface. It can be carried out for two distinct purposes, as follows:-

1 A light sweep is often used to key or etch the surface of an existing hard or smooth coating to improve the adhesion of the following coat. Coal tar epoxies, used as anticorrosive paints on the submerged areas of vessels, are often treated by light sweeping at drydockings prior to the application of tie coats or antifouling paints.

2 Light sweeping can be used for the removal of contaminants, loose coats of paint and the partial removal of corrosion products from a surface. It can also be used to remove particular coats of paint without damaging underlying coats, by using a fine grit. However, it will not remove more deep-seated corrosion. Weathered shop primer steel is often treated in this manner on newbuilding projects to International Paint AS1 standard.

The particle size of abrasive used for light sweeping is important. A fine abrasive in the 0.2mm-0.5mm range is most suitable when destruction of the paint surface under treatment has to be avoided.

5.3.2 Hard or Heavy Sweep Blasting

Hard sweeping will remove most old paint coatings down to shop primer or bare steel, and it will remove most deposits of rust or scale. It is not a cheap method of producing a totally clean surface, but it will produce an acceptable surface for some coatings. It is often specified for the following:

1 Removal of old coatings prior to upgrading.

2 Removal of shop primers on newbuilding projects to International Paint AS3 standard.

Getting all of the concerned parties to agree upon an acceptable sweep blast standard can be a real problem. There is obviously a conflict of interests. Owners may specify a hard sweep, because it is considerably cheaper than specifying an Sa2 blast, but they may expect to get an Sa2 standard. Blasting contractors may want to save time and money by producing the lowest standard they can get away with, and you are in the position of having to accept or reject the blast as suitable for overcoating with International Paint's products. Disagreement may be resolved by the production of a visual standard. In the absence of any internationally recognized standards for sweep blasting, International Paint have produced two sets of pictorial standards:

Where possible, these standards should be used to gain agreement on the required level of surface preparation. This is best achieved as described as follows:

1 Blast a test patch area before the main blasting starts.
2 Have everyone agree upon the standard of the patch using International Paint's pictorial standards. The overcoating suitability and cost criteria may also be resolved at this time.
3 Blast the rest of the job to the same standard.
4 If possible leave the test area as a reference until all of the blasting has been completed.

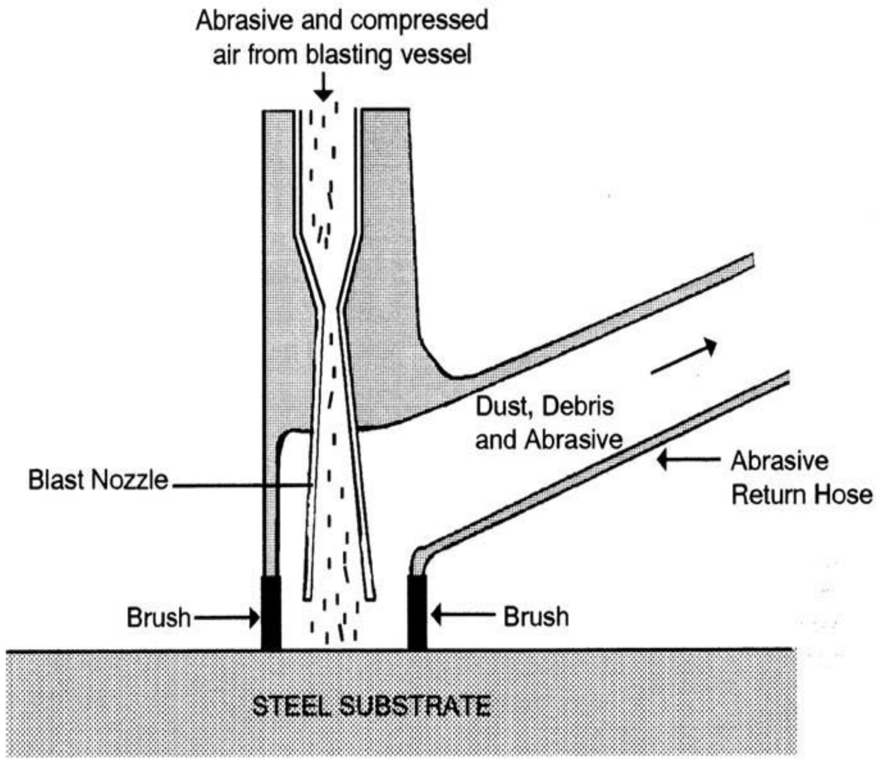
5.4 Full Blasting

Full blasts are specified where the removal of all, or nearly all, paint and contamination is required. It is therefore important for the industry to work to clearly understood standards. The most commonly quoted reference standards are International Standard ISO 8501-1-1988, (incorporating the old Swedish standard SIS 05 59 00), Japanese JSRA standards, and American SSPC standards.
All consist of written definitions, photographic references, or a combination of the two. If necessary everyone concerned with blasting should therefore be able to resolve disagreements by reference to these standards books.

5.5 VACUUM BLASTING

You will be aware that all of the blasting techniques described above produce large quantities of spent abrasive and dust. The pollution and safety problems caused by open blasting are unacceptable in some situations and the process is becoming increasingly prohibited throughout the World. Alternative techniques of surface preparation are therefore being developed, and the ones that show the most promise are hydro blasting, slurry blasting and vacuum blasting. We will look at vacuum blasting here because it is usually a form of compressed air blasting, although large vacuum blasting machines may be ‘airless’ with abrasive propelled by an impeller.

Vacuum blasting machines eliminate or reduce dust by combining the blast nozzle with a suction device in a specially designed head. This head is held in position on the surface being blasted so that the abrasive, dust and other debris are sucked back into the machine instead of flying off in all directions. See Figure 16.



The blast nozzle itself is usually enclosed in a rubber cup or brush, which is surrounded by a vacuum. The dust, debris and abrasive are sucked back into the machine via an abrasive return hose. The dust and debris are separated from the abrasive so that they can be collected and disposed of later. The abrasive is redirected back into the blasting pressure vessel where it is reused. Vacuum blasting therefore tends to utilise metallic abrasive which can be recycled many times, rather than abrasives such as sand and copper slag which tend to break up on impact and are usually classed as expendable.

The use of metallic abrasive and the fixed nozzle to surface distance generally ensure that vacuum blasting machines produce high standards of cleanliness. An Sa2½ standard is normal and an Sa3 standard is not uncommon. However, the rates of cleaning vary considerably with the size of the machine.

Several sizes of machine are available for different applications. Small hand held head units are often used for cleaning welds and burn damage. They are often used in tank coating operations to blast staging contact points, where blast ricochet damage and dust contamination of cleaned and painted surfaces would create problems. Rates of cleaning are relatively slow for these machines. Larger manually operated ‘blast track’ machines are often used to clean decks where contamination of sensitive equipment has to be avoided. Rates of cleaning are usually acceptable. Finally, automatic and semi-automatic machines are being developed to blast the entire outside hull of vessels when they are in drydock. This type of machine will become more and more common as dry abrasive blasting is prohibited.

5.6 WASH/BLAST/WASH

At major refurbishment, if a holding primer is not specified when coating the hull of a ship, the n compressor power requirements in both metric and imperial units. ional blast/prime etc. However, if the drying time of the primer is not sufficiently short, freshly coated areas can be damaged by the blast cleaning process when blasting the adjacent section. In these cases, and with certain products, a "wash/blast/wash" technique can be used as follows:

High pressure fresh water wash at minimum 211kg/cm^2 (3000 psi)
Abrasive blast clean the entire area to be coated to the required standard
Carry out a second high pressure fresh water wash
Measure residual salt levels on the steel surface. If the level is above that specified for the coating (e.g. 10μg/cm^2) re-wash until acceptable.
Provided that the visual standard for flash rusting is acceptable for the primer concerned, apply a full coat of paint.