CRYSTIC®

Corrosion Resistant Resins for Chemical Containment and Piping

Range and Specification

SCOTT BADER

Chemical containment

Scott Bader offers an outstanding range of corrosion resistant, chemical grade high performance unsaturated polyester and vinyl ester resins. They are suitable for the manufacture of GRP tanks, pipes and containers for acids, alkalis, fuels, foodstuffs, wine, water and other demanding materials.

Crystic chemical grade resins have been used to make a wide variety of glass reinforced polyester (GRP) components for the transfer and containment of chemicals for over 50 years and can be used with confidence. Crystic chemical grade resins are used in demanding chemical environments where long-term resistance to heat and chemical attack is essential.

Water decontamination stripping tower

Typical GRP applications

- Storage tanks
- Piping
- Ducts
- Scrubbers
- Containers
- Chemical plants
- Sewage and water treatment plants

Typical chemical products handled

GRP tanks, containers and pipes are ideally suited for the safe, reliable storage and transfer of:

- Corrosive chemicals
- Fuels
- Potable water
- Effluents and contaminated liquids
- Wine
- Sewage
- Agricultural waste
- Animal feeds
- Foodstuffs

Filament wound GRP underground pipes

Benefits of using GRP

Crystic polyester GRP components are:

- Lightweight, strong, tough composite structure
- Require little maintenance
- Easy to clean using a high-pressure hose
- Repair work can be carried out in-situ, fast and cost effectively
- On-site system modifications are often feasible

GRP chemical storage tank

Pipes and pipe linings.

Scott Bader has supplied polyester resins to GRP pipe and pipe liner manufacturers for over 40 years. Much of the early development with GRP pipes was for applications in chemical plants.

Filament winding and centrifugal casting techniques have been developed to produce lightweight, low maintenance GRP pipes efficiently and effectively.

Crystic resins and gelcoats

A complete range of proven Crystic products is offered for piping and lining applications including isophthalic and vinyl ester resins for sewage and water carrying pipes.

Major GRP pipe applications

- Chemical plant pipework
- Underground piping
- Above ground pressure pipes
- Sewage piping
- Potable water distribution

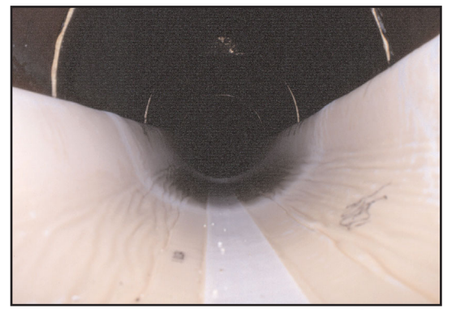
Trenchless pipe repairs with GRP liners

In -situ repair work can be carried out using a cured-in-place GRP liner, which is placed inside a damaged pipe then expanded to fit the existing pipe and simultaneously cured by circulating hot water. Pipe repair work can also be carried out by using a pre-fabricated GRP slip liner, which can be used to line 'live' piping systems.

Both pipe repair techniques are now used worldwide. Costs and disruption are kept to a minimum whilst essential repair work is carried out.

Scott Bader's long association with the GRP pipe and pipe lining markets and its technical expertise and range of proven products for the GRP pipe industry gives customers peace of mind and a real competitive advantage for their business.

Trenchless sewer repairs using the KM INLINER® system used successfully throughout the world since 1980 by KMG International of Germany



The result of pipe refurbishment with KM INLINER® is a long lasting, corrosion and abrasion resistant lining

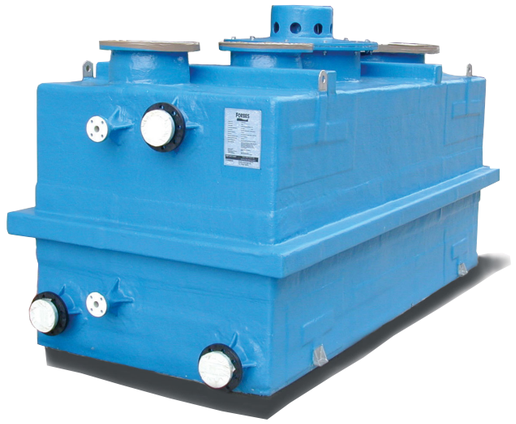
Pipe jointing

This can be carried out using spigot and socket systems with gaskets. Polyester resin collars can easily be cast onto pipe ends and machined to the appropriate dimensions.

Resilient polyester resins containing a high loading of filler - such as ground silica flour - can be cold cured extremely rapidly and prove to be ideal for casting pipe collars. Pipes can also be butted together and joined using an overlay GRP joint, wet laminated on site.

High performance corrosion resistant range

Crystic resins are carefully formulated to offer the specifier excellent chemical resistance combined with good mechanical properties at a competitive price. They give the moulder the greatest advantages in ease-of-use and mould turn-round whilst maintaining their excellent properties.



Bottom tank for acrylate vapour scrubber tower, fabricated in Crystic 397PA by Forbes Technology Limited.

Crystic 196
Orthophthalic polyester resin for laminates with low taint and good resistance to non-alkaline conditions.
BS 3532: Type B.

Crystic 197
A higher temperature resistant modification of Crystic 196 for use in warm climates.

Crystic 198
Orthophthalic polyester resin with high heat resistance.
BS3532: Type C

Crystic 474PA
Pre-accelerated, thixotropic version of Crystic 198.

Crystic 272
Low viscosity, isophthalic polyester resin capable of producing high performance laminates with low taint. Recommended for filament winding processes.
Water Bylaws Advisory Service approval.

Crystic 491PA
Pre-accelerated, thixotropic version of Crystic 272.
Wine Laboratories Ltd approval, Water Bylaws Advisory Service approval (with Crystic Gelcoat 65PA)

Crystic 274
A higher temperature resistant modification of Crystic 272 for use in warm climates.

Crystic 199
Isophthalic polyester resin for laminates requiring very high heat resistance.
BS 3532: Type C,

Crystic 392
Isophthalic-NPG polyester resin for strong, durable laminates with exceptional resistance to a wide range of chemicals. Gives good adhesion to uPVC liners.
Wine Laboratories Ltd approval.

Crystic 397PA
Thixotropic, pre-accelerated isophthalic-NPG polyester resin producing laminates with low taint and excellent resistance to a wide range of chemicals. Gives good adhesion to uPVC liners.
Wine Laboratories Ltd. Water Bylaws Advisory Service approval (with Crystic Gelcoat 69PA)

Crystic 600PA
Pre-accelerated epoxy modified bisphenol polyester resin with excellent resistance to many chemicals, including alkalies.

VE 673
A vinyl ester resin based on epoxy novolac with excellent solvent, general chemical and thermal resistance.

VE 676
A vinyl ester resin based on epoxy Bisphenol A for the manufacture of components with excellent chemical and thermal resistance.

Cost-effective design information based on maximum operating temperatures

The aim of this section is to assist our customers in the cost-effective design of GRP products with resistance to a specific chemical or mixtures of chemicals.

Information is presented on the recommended Crystic resins, ranging from orthophthalic polyester resins (which have good resistance to acidic conditions) to the improved resistance of isophthalic polyester resins. also available are the more sophisticated and expensive bisphenol modified resins and vinyl ester resins, which are designed for exceptional all-round chemical resistance. These resins are listed in Table I. Table II covers a wide range of chemicals and presents the maximum operating temperature in °C for laminates made as recommended on page 5, with these Crystic resins, under the chemical groups listed below.

Inorganic Chemicals

1.1	Acids (mineral)
1.2	Alkalies
1.3	Hypochlorites
1.4	Plating solutions
1.5	Miscellaneous inorganic chemicals
1.6	Salt solutions
1.7	Water

Organic Chemicals

1.8	Acids (organic)
1.9	Alcohols/glycols
1.10	Foodstuffs/edible oils
1.11	Fuels/oils
1.12	Miscellaneous organic chemicals to which GRP is resistant
1.13	Miscellaneous organic chemicals to which GRP is generally not resistant
1.14	Fire extinguisher foams
1.15	Surfactants

[o]Within each chemical group, the chemicals are listed in alphabetical order and where possible the Maximum Operating Temperature for fully post cured material is given.

Background to the Maximum Operating Temperatures

The Maximum Operating Temperatures for chemical-resistant Crystic resin laminates in various environments have been determined from a number of sources including case histories, laboratory tests and practical experience in various parts of the world.

Provided that the GRP structure is manufactured to high standards and in the case of chemical tanks, designed in accordance with the requirements of BS 4994:1987 with full post-cure, the design life period will be ensured. Some GRP tanks made with Crystic polyester resin have already operated for over 12 years within our recommended temperature limits.

Guidelines to assist in the design of GRP components using the 'K' factor of safety approach used in BS 4994 are presented on page 7. BS 4994:1987 provides options other than full post-curing, which are linked to the factor of safety k_5. However, in critical environments our recommended curing procedures at elevated temperatures should be obtained from our Technical Service Department.

The given Maximum Operating Temperatures apply to GRP mouldings and NOT GRP liners used in the protection of metal, concrete and other materials. GRP linings will extend the life of many materials but the Maximum Operating Temperature of the GRP lining should not exceed 60°C. because of factors such as:- differential thermal expansion and the inability to post-cure effectively and completely.

Recommendations for chemical resistant laminates

Assessment of the evidence over several decades shows that the following factors together are particularly important in achieving maximum resistance of glass reinforced polyester laminates operating in chemical environments.

- Matched fully formulated barrier layer and structural resin system
- Complete wetting-out of the reinforcement
- Minimum void content in barrier layer and laminate
- Reinforcement with non-hydrolysable binder
- Fabrication under optimum workshop conditions and post-curing at our recommended elevated temperatures
- Use of recommended thickness of barrier layer *
- Reinforcement not pressed too close to the surface
- Sufficient protection of the back of the laminate to be resistant to splashes etc.

* Barrier layers can consist of either a thermoplastic liner, or a GRP barrier layer of 3-4mm thick made up of C glass surface tissue or a suitable synthetic tissue reinforced with chopped strand mat at a high resin:glass ratio.

To be CONFIDENT in the chemical resistance of glass reinforced laminates in contact with chemical environments follow the complete recommendations above including the specification of a matched Crystic barrier layer resin and a Crystic chemically resistant structural resin.

Acid environments

In acid environments it is important to ensure that the structural laminate is adequately protected from the environment by a substantial barrier layer. This can consist of either a thermoplastic liner or a GRP barrier layer several millimeters thick made up of C glass surface tissue and chopped strand glass mat at a high resin:glass ratio. GRP in acid environments can suffer premature degradation as a result of the stress corrosion cracking of glassfibre reinforcement. It is therefore necessary that the recommended barrier layer be backed with the appropriate Crystic resin, as listed, reinforced with an acid resistant glass eg ECR (Extra Chemical Resistant).

Post-curing

Post-curing recommendations for some resins are contained in individual technical leaflets or, if not, they should be obtained from our Technical Service Department. If the proposed operating temperature is above 80°C then the laminate must receive, in addition to the general recommended post cure mentioned, a further minimum post-cure of at least three hours at 100°C or at the design working temperature, whichever is the greater. The entire laminate must be immersed in hot air, which is controlled at the recommended temperature.

Potable water, wine and foodstuffs

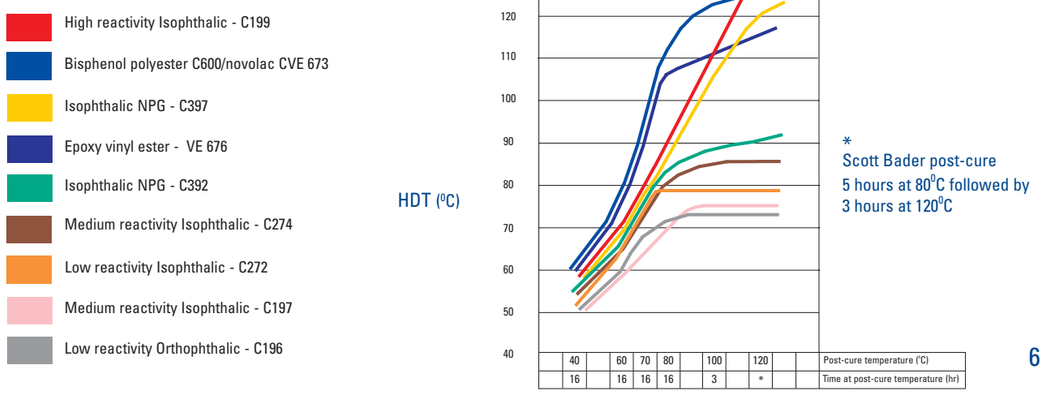
Selected Crystic resins are recommended for use with the above and have been approved to the requirements of various authorities. Post-curing requirements are important. In these and all critical environments, specific recommendations about curing and post-curing procedures must be obtained from our Technical Service Department.

Variation of HDT of cast polyester resin with post-cure temperature

Barcol hardness is generally used as an indication of the degree of cure of the laminate but this is not sensitive enough to assess the level of cure for chemical or food storage applications.

A laminate cured at room temperature or 40°C, for example, will achieve an acceptable Barcol hardness for most applications. However, the Heat Distortion Temperature (HDT) and the degree of cross linking within the polymer will, generally, be below the level required for safe chemical containment.

16hr at 40°C has been shown to give the same level of post cure as 28 days at room temperature (20°C) and reference to the graph below shows that this results in HDT's of only 50-65°C, depending upon the resin type. The use of higher post-cure temperatures leads to a higher percentage of the material's HDT (and chemical resistance) being achieved.



Guidelines for designing with 'k' factors used in BS4994:1987

To assist in the design of components utilising the K factor approach used in BS 4994, it is proposed that the following guidelines be adopted in interpreting Maximum Operating Temperature data in terms of the k_2 factor and the k_5 factor (relating to post-cure conditions). These factors are then multiplied together and used with other factors defined in BS 4994 to obtain the overall factor of safety, K.

Relationship between recommended Maximum Operating Temperature (t_m) and Factor k_2

Temperature of use	k_2
t_m	1.4
10°C below tm	1.4
20°C below tm	1.3
30°C below tm	1.3
40°C below tm	1.2
50°C below tm	1.2
60°C below tm	1.1
70°C below tm	1.1

t_m is the recommended Maximum Operating Temperature for the fully oven† cured resin (as shown in Table II of this booklet). When k_2 = 1.2, BS 4994 assumes that the strength is >80% of the original ultimate tensile strength.

If the loss in strength is >50%, BS 4994 states that the material is unsuitable for total confidence in assessing the level of k_2.
For chemicals aggressive to GRP full oven† post-cure to our recommendations is essential.

It is recommended that Appendix E of BS 4994:1987 is consulted to assist in the determination of k_2.

Relationship between the effect of post-curing (as determined by Heat Deflection Temperature measurement) and Factor k_5

Post Cure temperature (for 6 hours)	k_5
At the quoted Heat Deflection Temperature (HDT)*	1.0
10°C below quoted HDT*	1.0
20°C below quoted HDT*	1.2
30°C below quoted HDT*	1.4
40°C below quoted HDT*	1.8

At concentrations and use at a Maximum Operating Temperature well below those shown in Table II, where post-curing at elevated temperatures may not be necessary, then k_5 = 1.0.

If post-curing is carried out at 100°C or above, then k_5 = 1.0.

In very aggressive environments, even at low operating temperatures, high temperature post-cure is essential to achieve cost-effective reinforced structures for chemical plant applications [see BS4994:1987, Section 2 Part 9.2.2.(e)].

If a thermoplastic lining is used which is chemically resistant to the specific conditions, then, in all cases, k_2 = 1.1 and k_5 = 1.0.

* See Table 1 Page 8
† Total immersion in hot air, controlled at the recommended temperature.

Table I. Crystic resins recommended for safe chemical containment

		Post cured ✞ **HDT** (1.8 MPA stress)
Crystic orthophthalic polyester resins		
196	Good resistance to acidic conditions, low taint	72°C
197	Higher temperature resistant C196 type resin	77°C
198	High heat resistance	110°C
474PA	Thixotropic pre-accelerated version of Crystic 198	110°C
Crystic isophthalic polyester resins		Post-cured ✞ **HDT**
272	Low viscosity, high performance resin with low taint. (Particularly suitable for filament winding)	75°C
491PA	Thixotropic pre-accelerated version of Crystic 272	75°C
274	Higher temperature resistant C272 type resin	84°C
199	Very high heat resistance	130°C
Crystic isophthalic-NPG* polyester resins		
392	Tough with exceptional resistance to a wide range of chemicals. Good adhesion to uPVC liners.	90°C
397PA	Thixotropic heat resistant resin, with exceptional resistance to a wide range of chemicals and elevated temperatures. Low taint. Good adhesion to uPVC liners.	125°C
Crystic bisphenol polyester resin		
C600E/C600PA	Propoxylated bisphenol A modified unsaturated polyester resin.	120°C
Crystic epoxy-modified vinyl ester resins		
VE 676	Based on epoxy bisphenol A, excellent chemical and thermal resistance.	100°C
VE 673	Based on epoxy novolac, very good chemical resistance and good thermal resistance.	130°C

*NPG denotes that neopentyl glycol has been used in the formulation. This is a symmetrical glycol allowing a close-knit molecular structure which resists chemical attack.
†Cast resin specimens cured for 24 hours at 20°C, followed by 5 hours at 80°C and 3 hours at 120°C, tested to BS 2782.

TABLE II - Maximum operating temperatures in °C for chemical resistant FRP laminates fully post-cured at elevated temperature and produced according to the recommendations in our data sheets.

Chemical environment / Barrier layer side in contact with environment		Crystic Resin								
	% conc ❖	196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
Inorganic chemicals 1.1 Acids (mineral)										
Aqua regia		NR	NR	NR	NR	NR	NR	NR	NR	NR
Boric acid[1] - aqueous solution	Sat.	45	55	50	70	70	85	95	85	95
Carbonic acid[1]	Sat.	45	55	50	70	70	85	95	95	95
Chlorine water	Sat.	NR	NR	25	30	45	50	55	75	75
Chromic acid[1] - aqueous solution	5	35	45	45	55	70	75	65	65	65
	10	35	45	45	55	55	60	55	60	60
	20	NR	NR	NR	25	30	35	30	60	50
	30	NR	NR	NR	NR	25	30	30	30	30
Fluosilicic acid[1] - aqueous solution	10	NR	30	30	65	60	65	65	70	70
	15	NR	25	25	40	35	40	40	50	50
	25	NR	NR	NR	30	25	30	30	35	35
	34	NR	NR	NR	25	25	25	25	30	30
Hydrobromic acid[1]	20	40	55	50	70	65	80	95	95	85
	48	35	55	45	60	60	70	70	65	65
Hydrochloric acid[1] (see also 1.5 Misc Inorganic Chemicals - Hydrogen chloride)	5	40	55	50	70	70	80	95	95	90
	15	35	50	40	70	65	75	85	90	75
	20	30	45	35	70	55	65	70	80	65
	25	30	40	30	55	45	55	65	65	55
	35	NR	35	25	40	30	40	30	50	50
Hydrofluoric acid[1]	20	25	25	25	35	30	35	40	40	40
Nitric acid[1]	5	35	50	45	55	65	70	70	70	55
	10	30	45	25	50	55	60	60	60	60
	20	NR	NR	NR	NR	40	45	45	45	45
	40	NR	NR	NR	NR	NR	NR	25	25	NR
Concentrated	71	NR	NR	NR	NR	NR	NR	NR	NR	NR
Fuming	95	NR	NR	NR	NR	NR	NR	NR	NR	NR
Oleum (fuming sulphuric acid)		NR	NR	NR	NR	NR	NR	NR	NR	NR
Perchloric acid[1] - aqueous solution	10	NR	NR	25	NR	50	55	50	55	55
	25	NR	NR	NR	NR	30	35	30	35	35
Phosphoric acid[1]	50	45	55	50	70	70	80	95	95	90
	85	45	55	50	70	70	80	95	95	90
Sulphur Dioxide, aqueous solution (sulphurous acid) (see also1.5 Misc Inorganic Chemicals)	10	NA	50	45	65	65	80	90	95	90
Sulphuric Acid[1]	10	45	55	60	70	70	80	95	95	90
	50	50	80	60	85	75	85	100	95	90
	65	25	50	30	65	65	70	70	75	75
	77	NR	NR	NR	NR	25	25	40	50	40
	90	NR	NR	NR	NR	NR	NR	NR	NR	NR

1. A resistant veil such as saturated polyester should be used in the surface in contact with this chemical, in place of glass.
2. A resistant veil such as polyacrylonitrile should be used in the surfacein contact with this chemical, in place of glass.
❋ Use polypropylene liner.
NR = Not recommended
NA = Data not available
❖ Concentrations (by weight unless otherwise stated) prepared according to ISO/R175 where relevant.

TABLE II - Maximum operating temperatures in °C for chemical resistant FRP laminates fully post-cured at elevated temperature and produced according to the recommendations in our data sheets.

Chemical environment / Barrier layer side in contact with environment		Crystic Resin								
	% conc ❖	196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
1.2 Alkalies										
Ammonia[2] -aqueous solution	5	NR	NR	25	NR	30	35	60	60	60
	20	NR	NR	NR	NR	25	30	50	50	50
	28	NR	NR	NR	NR	NR	NR	35	35	35
Ammonium hydroxide[2] - see Ammonia aqueous solution										
Barium hydroxide[2] - aqueous solution	10	NR	NR	NR	NR	NR	25	30	50	50
Calcium oxide[2] (quick lime)		NR	25	35	30	45	50	60	70	70
Calcium hydroxide[2] - aqueous solution		NR	25	35	30	45	50	60	70	70
Caustic potash[2] - aqueous solution	30	NR	NR	NR	NR	35	40	50	55	55
Caustic soda[2] - aqueous solution (see also sodium hydroxide)	<1	NR	NR	NR	NR	55	60	70	60	75
	10	NR	NR	NR	NR	45	45	60	55	60
	25	NR	NR	NR	NR	35	30	50	55	55
	50	NR	NR	NR	NR	50	45	80	75	75
	Sat.	NR	NR	NR	NR	NR	NR	80	75	75
Potassium hydroxide[2] - aqueous solution	30	NR	NR	NR	NR	35	40	50	55	55
Sodium hydroxide[2] - aqueous solution (see caustic soda)										
1.3 Hypochlorites										
Bleach solution[2] (Sodium hypochlorite[2] 5.25% active chlorine)	The suitability of FRP for the storage of hypochlorites depends very much upon the pH of the solution. At pH < 11 FRP should not be used									
Calcium hypochlorite - aqueous solution up to 17% active chlorine[2]										
Sodium hypochlorite[2] - aqueous solution 14% active chlorine [2]										
1.4 Plating solutions										
Heavy plate solution (see notes at end of table)	40	65	50	65	70	80	80	80	80	
Plating solutions (see notes at end of table)										
Cadmium cyanide	NR	NR	NR	NR	NA	NA	80	80	80	
Chrome	NR	NR	NR	NR	25	30	25	35	30	
Gold	35	50	45	65	65	75	90	70	70	
Lead	35	50	45	65	65	75	90	70	70	
Nickel	35	50	45	65	65	75	90	80	80	
Platinum	NA	NA	NA	NA	NA	NA	80	80	80	
Silver	25	40	30	50	45	60	90	80	80	
1.5 Miscellaneous inorganic chemicals										
Bromide liquid	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Carbon dioxide	Gas	55	100	70	120	75	90	110	120	100
	Sat.	45	55	50	70	70	85	95	95	90
Carbon monoxide	Gas	55	100	70	120	75	90	110	120	100
Chlorine dioxide, wet	Gas	NR	NR	NR	NR	45	50	45	50	50
Chlorine - see also ACIDS (chlorine water)	Gas	50	70	65	80	70	85	100	70	70
Cyanide gas (dry) (hydrogen cyanide)	Gas	NA	NA	NA	NA	NA	NA	25	25	25
Hydrogen chloride (dry gas)-see hydrochloric acid	Gas	55	80	65	90	70	85	100	110	100
Hydrogen peroxide	20_{vol}	NR	NR	NR	30	60	65	65	65	65
	100_{vol}	NR	NR	NR	NR	25	25	25	25	25

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❋ Use polypropylene liner.
NR = Not recommended
NA = Data not available
❖ Concentrations (by weight unless otherwise stated) prepared according to ISO/R175 where relevant.

TABLE II - Maximum operating temperatures in ºC for chemical resistant FRP laminates fully post-cured at elevated temperature and produced according to the recommendations in our data sheets.

Chemical environment / Barrier layer side in contact with environment	% conc ✣	Crystic Resin 196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
Misc inorganic chemicals continued										
Hydrogen sulphide gas	100	50	60	60	60	55	65	65	95	75
Iodine, tincture	2	NR	NR	NR	NR	NR	NR	NR	NR	NR
Mercury	100	50	60	60	100	60	70	100	120	100
Photographic developers		35	50	45	65	70	80	90	80	80
Silage effluent		NA	NA	25	NA	NA	NA	NA	NA	NA
Sulphur - solid	100	55	65	60	90	60	75	90	90	90
Sulphur dioxide gas (dry) - see also Acids	Gas	55	95	65	115	70	85	105	110	100
1.6 Salt solutions										
Aluminium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Aluminium fluoride - aqueous solution	Sat.	NR	NR	NR	NR	NR	NR	NR	25	25
Aluminium nitrate - aqueous solution	10	35	45	40	60	65	80	70	70	70
Aluminium potassium sulphate-aqueous solution	Sat.	45	55	50	70	70	85	95	95	95
Aluminium sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Alums - aqueous solution	Sat.	55	70	60	75	60	70	95	95	90
Ammonium carbonate - aqueous solution	Sat.	NR	NR	NR	NR	NR	NR	30	40	40
Ammonium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Ammonium citrate - aqueous solution	Sat.	35	50	45	60	50	70	70	65	65
Ammonium nitrate - aqueous solution	Sat.	35	50	45	65	65	80	90	90	90
Ammonium persulphate - aqueous solution	Sat.	NA	NA	NA	NA	NA	NA	70	75	75
Ammonium sulphate - aqueous solution	Sat.	45	50	50	70	70	85	95	95	90
Ammonium thiocyanate - aqueous solution	20	45	50	45	65	65	80	90	90	90
Antimony pentachloride - aqueous solution	Sat.	NR	NR	NR	25	NR	25	25	25	25
Antimony trichloride - aqueous solution	Sat.	NR	NR	NR	25	NR	30	30	30	30
Barium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Barium nitrate - aqueous solution	Sat.	35	50	45	65	65	70	80	90	85
Brine (see Sodium chloride)	Sat.	45	55	50	70	70	85	95	95	90
Calcium bisulphite - aqueous solution	Sat.	35	50	45	60	65	70	80	80	80
Calcium carbonate - slurry		45	55	50	70	70	75	95	95	90
Calcium chlorate - aqueous solution	Sat.	45	55	50	70	70	75	95	95	90
Calcium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Calcium nitrate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Calcium sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Chromic sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	80	80
Cobalt (II) chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	80	80
Copper sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Epsom salts (magnesium sulphate)	Sat.	45	55	50	70	70	85	95	95	90
Ferric chloride - aqueous solution	Sat.	40	50	45	65	65	80	90	90	90
Ferric nitrate - aqueous solution	Sat.	40	50	45	65	70	85	95	95	90
Ferric sulphate - aqueous solution	Sat.	40	50	45	65	70	85	95	95	90
Ferrous sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Glauber salts (sodium sulphate)	Sat.	45	55	50	70	70	85	95	95	90
Lead acetate - aqueous solution	Sat.	45	55	50	70	70	75	95	95	90
Lithium salts - aqueous solution	Sat.	NR	NR	NR	NR	NR	NR	NR	70	70
Magnesium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90

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NR = Not recommended
NA = Data not available
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TABLE II - Maximum operating temperatures in ºC for chemical resistant FRP laminates fully post-cured at elevated temperature and produced according to the recommendations in our data sheets.

Chemical environment / Barrier layer side in contact with environment	% conc ✣	Crystic Resin 196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
Salt solutions continued										
Magnesium sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Mercury salts		55	70	60	75	55	70	95	95	90
Nickel chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Nickel nitrate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Nickel sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Potassium carbonate - aqueous solution	10	NR	NR	NR	25	25	30	80	65	65
	40	NR	NR	NR	NR	NR	NR	30	40	40
Potassium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Potassium ferricyanide - aqueous solution	Sat.	40	55	50	70	70	85	95	95	90
Potassium ferrocyanide - aqueous solution	Sat.	40	55	50	70	70	85	95	95	90
Potassium permanganate - aqueous solution	Sat.	NR	NR	NR	25	25	30	35	45	45
Potassium phosphate - aqueous solution	Sat.	40	50	45	65	65	80	90	65	55
Potassium sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Silver nitrate - aqueous solution	Sat.	NR	35	30	40	60	65	60	70	70
Soap - aqueous solution	Sat.	40	60	60	75	60	70	85	75	75
Sodium acetate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium bicarbonate - aqueous solution	Sat.	45	55	50	70	70	80	95	80	80
Sodium bisulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium carbonate[2] - aqueous solution	10	NR	NR	25	30	30	35	80	80	80
	25	NR	NR	NR	25	25	30	75	75	75
Sodium chlorate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium ferricyanide - aqueous solution	Sat.	40	55	50	70	70	75	95	95	90
Sodium (meta) silicate - aqueous solution	Sat.	35	40	45	60	65	80	80	90	85
Sodium phosphate - aqueous solution	Sat.	40	60	45	65	65	80	90	90	85
Sodium sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium sulphide - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium sulphite - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Sodium thiocyanate - aqueous solution	20	35	50	45	65	65	80	90	80	80
Sodium thiosulphate (hypo) - aqueous solution	Sat.	40	55	50	65	70	75	85	80	80
Stannous chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Zinc chloride - aqueous solution	Sat.	45	55	50	70	70	85	95	95	95
Zinc cyanide[1]		NA	NA	NA	NA	NA	NA	25	60	60
Zinc sulphate - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
1.7 Water										
Water										
De-ionized	100	40	50	45	65	65	80	90	80	80
Sea		45	55	50	70	70	85	95	80	80

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	% conc ✣	196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
Organic chemicals 1.8 Acids (organic)										
Acetic acid[1] - aqueous solution	10	25	45	50	30	55	30	90	90	90
	25	NR	30	35	45	60	75	85	85	85
	70	NR	NR	25	35	50	55	65	65	65
	98	NR	NR	NR	NR	NR	NR	NR	25	NR
Acrylic acid[1]	100	NR	NA	NR	NA	NA	NA	35	NR	NR
Benzoic acid[1] - aqueous solution	Sat.	45	55	50	70	70	75	95	95	90
Chloroacetic acid (mono)[1] -aqueous solution	25	NR	30	40	50	55	70	70	50	50
	50	NR	NR	25	30	35	50	60	40	40
Chlorosulphonic acid	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Citric acid - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Cresylic acid	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Formic acid[1] - aqueous solution	20	25	30	35	50	55	65	70	70	70
	50	NR	NR	25	40	45	55	55	40	40
	75	NR	NR	NR	25	30	40	40	40	40
	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Lactic acid[1] - aqueous solution	44	40	55	50	70	70	75	95	95	90
Maleic acid[1] - aqueous solution	Sat.	40	50	45	65	65	80	90	95	90
Oleic acid[1]	100	45	55	50	70	70	75	95	85	90
Oxalic acid[1] - aqueous solution	Sat.	40	40	45	60	60	70	80	50	50
Phthalic acid[1] - aqueous solution	Sat.	40	50	45	65	65	70	90	90	90
Propionic acid[1]	100	NA	NA	25	NA	NA	NA	NA	25	NR
Stearic acid (Commercial)	100	40	50	45	65	65	80	90	95	90
Tannic acid - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Tartaric acid - aqueous solution	Sat.	45	55	50	70	70	85	95	95	90
Trichloroacetic acid[1] - aqueous solution	25	NR	NR	30	40	45	50	60	70	70
	50	NR	NR	NR	NR	25	30	50	60	60
1.9 Alcohols / glycols										
Amyl alcohol	100	25	40	30	40	25	35	35	80	40
Benzyl alcohol	100	NR	30	25	30	NR	NR	25	25	NR
Brake fluid		25	35	30	35	25	30	30	40	40
Butyl alcohol	100	25	35	30	35	25	30	30	40	40
Cyclohexanol	100	35	45	30	45	30	45	35	35	25
Diethylene glycol	100	45	70	55	80	70	80	95	95	80
Dipropylene glycol	100	45	70	55	80	70	80	95	95	80
Ethanol (ethyl alcohol)	95	NR	25	25	30	25	30	25	35	25
Ethyl alcohol	95	NR	25	25	30	25	30	25	35	25
Ethyl alcohol - aqueous solution	20	25	30	30	35	25	35	30	50	35
Ethylene glycol	100	45	70	55	80	70	80	95	95	90
Hydraulic fluid		25	35	30	35	25	30	30	70	70
Isopropyl alcohol	100	NR	35	30	35	25	35	30	40	40
Methanol (methyl alcohol)	100	NR	35	25	35	25	30	30	NR	NR
Polyethylene glycol	100	40	50	45	65	65	80	90	NA	NA
Propyl alcohol	100	NR	35	30	35	25	35	30	NA	NA
Propylene glycol	100	45	70	55	80	70	80	95	95	90

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	% conc ✣	196/197	198/474PA	272/491PA/274	199	392	397PA	600E/600PA	VE673	VE676
1.10 Foodstuffs / edible oils										
Beer		NA	NA	55	NA	NA	NA	NA	NA	50
Castor oil	100	55	95	70	110	55	70	110	70	70
Coconut oil	100	NA	NA	50	NA	NA	NA	NA	90	75
Cotton seed oil	100	NA	NA	50	NA	NA	NA	NA	90	90
Fruit juices		NA	NA	50	NA	NA	NA	NA	NA	NA
Gelatine - aqueous solution	1	45	60	50	70	45	60	85	NA	NA
Glucose		NA	NA	60	NA	NA	NA	NA	95	90
Glycerine (glycerol)	100	55	85	60	100	70	85	100	100	90
Meat extracts		NA	NA	60	NA	NA	NA	NA	NA	NA
Molasses		NA	NA	60	NA	NA	NA	NA	NA	NA
Olive oil	100	45	95	50	100	40	55	90	95	90
Sugar (hot)*	100	NR	NR	NR	NR	NR	NR	NR	90	90
Yeast		NA	NA	50	NA	NA	NA	NA	NA	NA
1.11 Fuels / oils										
Aviation fuel AVTAG/JP4	100	NR	30	25	35	NR	25	25	NA	NA
AVGAS (Aviation gasoline)	100	NR	NR	NR	30	NR	NR	NR	50	50
AVTUR (kerosene)	100	25	45	30	50	25	30	35	50	50
Crude oil, sour or sweet	100	NA	NA	NA	NA	NA	NA	85	95	90
Diesel fuel	100	30	40	35	45	25	30	40	55	45
Ester based lubricating oils (to E.Eng.RD 2487)	100	45	95	50	100	40	55	90	NA	NA
Fuel oil (see Diesel fuel)										
Gasoline (see Petrol)										
Heavy aromatic naphtha (HAN)	100	NR	40	NR	45	NR	NR	25	60	45
Kerosene (domestic)	100	30	50	30	55	25	40	35	50	50
Linseed oil	100	55	95	70	110	70	85	105	110	90
Lubricating oil	100	45	95	50	100	40	55	90	100	90
Mineral oil	100	45	95	50	100	40	55	90	110	90
Naphtha	100	25	35	25	40	25	35	30	60	40
Paraffin	100	30	50	30	55	25	40	35	50	50
Petrol (gasoline 98 octane, 4 star, super or unleaded)	100	NR	NR	NR	40	NR	NR	NR	25	25
Silicone oils	100	55	95	70	110	70	85	105	105	95
Transformer oils	100	45	95	50	100	40	55	95	110	95

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1.12 Miscellaneous Organic chemicals to which GRP is resistant										
Acetone	10	NR	25	NR	25	NR	NR	25	40	40
	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Acriflavine - aqueous solution	2	45	50	50	50	45	50	50	NA	NA
Amyl acetate	100	NR	NR	NR	25	NR	NR	25	40	NR
Aniline sulphate - aqueous solution	Sat.	30	45	45	60	65	70	90	90	90
Blood		NA	NA	25	NA	NA	NA	NA	30	20
Detergents	see surfactants - section 1.15									
Diallyl phthalate	100	45	50	50	60	45	60	70	80	70
Dibutyl phthalate	100	45	50	50	60	45	60	70	80	70
Diethanolamine	100	NR	NR	NR	NR	25	35	50	50	50
Dimethyl phthalate	100	45	50	50	60	45	60	70	70	60
Dioctyl phthalate	100	45	50	50	60	45	60	70	80	60
Ethyl oleate	100	40	50	45	65	65	70	90	NA	NA
Fire extinguisher foams	see section 1.14									
Formaldehyde - aqueous solution (Formalin)		30	up to maximum stable temperature							
Heptane	100	25	35	25	40	25	30	30	80	80
Hexane	100	25	35	25	40	25	30	30	50	50
Industrial Methylated Spirits (IMS)		NR	25	25	30	25	30	25	NA	NA
Iso-octane	100	25	35	25	40	25	35	30	NA	NA
Lanolin	100	45	55	50	70	70	75	95	NA	NA
Latex rubber emulsions		NA	NA	NA	NA	NA	NA	25	40	40
Naphthalene	100	25	55	40	65	35	50	50	70	70
Paraffin wax	100	55	95	70	110	70	85	105	NA	NA
Polyvinyl acetate emulsion		NA	NA	NA	NA	NA	NA	65	50	50
Starch - aqueous solution	Sat.	45	55	50	70	70	80	95	NA	NA
Surfactants - aqueous solutions	See section 1.15									
anionic										
cationic										
non - ionic		40	50	45	65	55	70	90	NA	NA
Tallow	100	55	95	70	110	70	85	105	NA	NA
Turpentine	100	25	30	25	35	25	30	30	80	40
Urea - aqueous solution	2	35	40	40	45	55	70	90	80	80
Urine		30	25	30	35	35	50	65	65	65
White Spirit	100	35	35	25	40	25	35	30	NA	NA

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1.13 Miscellaneous organic chemicals to which GRP is generally not resistant.										
Acrylonitrile	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Amyl chloride	100	NR	NR	NR	NR	NR	NR	NR	30	NR
Aniline	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Anisole	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Benzaldehyde	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Benzene	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Benzyl chloride	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Butyl acetate	100	NR	NR	NR	NR	NR	NR	NR	20	NR
Butyl amine	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Carbon disulphide	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Carbon tetrachloride	100	25	25	25	30	NR	NR	30	60	45
Chlorobenzene	100	NR	NR	NR	NR	NR	NR	NR	20	NR
Chloroform	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Creosote (coal-tar)	100	NR	NR	NR	25	NR	NR	25	30	30
Cresols	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Crop spraying chemicals	-	NR	NR	NR	NR	NR	NR	NR	NR	NR
Dichlorobenzene	100	NR	NR	NR	NR	NR	NR	NR	20	NR
Dichloroethylene	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Diethyl ether	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Diethyl formamide	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Diethyl ketone	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Dimethyl aniline	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Dimethyl formamide	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
1,4 Dioxan	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ethyl acetate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ethyl acrylate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ethyl carbonate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ethyl ether	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Ethylene (di) chloride	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Furfural	15	NR	NR	NR	NR	NA	NA	35	NR	NR
	20	NR	NR	NR	NR	NA	NA	35	NR	NR
	25	NR	NR	NR	NR	NR	NR	NR	NR	NR
Methyl acetate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Methyl bromide (gas)	100	NR	NR	NR	NR	NR	NR	NR	20	20
Methylene chloride	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Methyl ethyl ketone	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Methyl methacrylate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Monochlorobenzene	100	NR	NR	NR	NR	NR	NR	NR	20	NR
Nitrobenzene	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Paraquat®	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Perchloroethylene	100	NR	NR	NR	NR	NR	NR	NR	NR	NR

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1.13 Miscellaneous organic chemicals to which GRP is not generally not resistant continued										
Phenol - aqueous solution	1	NA	NA	NA	NA	NA	NA	25	30	NR
	Sat.	NR	NR	NR	NR	NR	NR	NR	NR	NR
Pyridine	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Styrene	100	NR	NR	NR	25	NR	NR	NR	35	NR
Tetrachloroethylene (Perchloroethylene)	100	NR	NR	NR	NR	NR	NR	NR	40	NR
Tetrahydrofuran	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Tetralin	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Thionyl chloride	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Toluene	100	NR	25	NR	30	NR	NR	NR	30	25
Trichlorethane	100	NR	NR	NR	NR	NR	NR	NR	30	NR
Trichloroethylene	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Vinyl acetate	100	NR	NR	NR	NR	NR	NR	NR	NR	NR
Xylene	100	NR	40	NR	45	NR	NR	25	35	25
1.14 Fire extinguisher foams										
Protein / Nicerol		NA	NA	25	NA	NA	NA	50	NA	NA
Flouroprotein / FP70		NA	NA	25	NA	NA	NA	50	NA	NA
Flouropolydol		NA	NA	NR	NA	NA	NA	25	NA	NA
Floursynthetic / Tridol 3		NA	NA	NR	NA	NA	NA	25	NA	NA
Synthetic / Expandol		NA	NA	NR	NA	NA	NA	25	NA	NA

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1.15 Surfactants												
N-alkylamines	Cationic	Armeens	5	NR	NR	NR	NR	NR	NR	NR	NA	NA
		Crodamines	5	NR	NR	NR	NR	NR	NR	NR	NA	NA
Acetate salts of N-alkylamines		Armacs		NR	NR	NR	NR	NR	NR	NR	NA	NA
		Crodamacs	5	NR	NR	NR	NR	NR	NR	NR	NA	NA
Alkyl propylene Diamines Acetate salts	Cationic	Duomeens	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Dicrodamines	5	NR	NR	NR	NR	25	25	25	NA	NA
		Duomacs	5	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Dicrodamacs	5	NR	NR	NR	NR	25	25	25	NA	NA
Quaternary Ammonium salts	Cationic	Arquads	1	35	45	40	60	65	65	80	65	50
		Quadrilans	1	35	45	40	60	65	65	80	65	50
Alkyl benzyl dimethyl ammonium chloride (benzalkonium chloride)			<500 ppm	40	50	45	65	70	70	90	65	50
Dialkyl dimethyl ammonium chloride	Cationic		7	40	50	45	65	70	70	90	70	50
			If solvent used, max working temperature is of the solvent if below the temperature limit given.									
Aliphatic sulphates and Sulphonates	Anionic	Teepol	100	40	50	45	65	70	70	90	80	70
For Non Ionic see Surfactants in Section 1.12												

Plating solutions - explanatory notes

The following plating solutions have been used in Section 1.4. If the solutions to be used differ in composition then advice should be sought from our Technical Service Department.

HEAVY PLATE SOLUTION	% by weight
Hydrochloric acid (conc)	7
Sulphuric Acid (conc)	24
Water	69

Gold	% by weight
Potassium ferrocyanide	22.8
Potassium gold cyanide	0.2
Sodium cyanide	0.8
Water	76.2

Platinium	% by weight
Manufacturers recipe (Sulphato- dinitritoplatinous acid)	100

PLATING SOLUTIONS

Cadmium	
Cadmium oxide	3.2
Sodium cyanide	9.5
Caustic soda	1.2
Water	86.1

Lead	
Lead	8.0
Flourboric acid	0.8
Boric acid	0.4
Water	90.8

Silver	
Silver cyanide	3.9
Potassium cyanide	6.5
Potassium carbonate	1.6
Sodium cyanide	4.5
Water	83.5

Chrome	
Chromic acid	18.5
Sodium fluosilicate	0.62
Sodium sulphate	0.01
Water	80.87

Nickel	
Nickel sulphate	11.3
Nickel chloride	1.4
Boric acid	1.1
Water	86.2

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