Engineered stone

Blocks and slabs process

Application data and cure data

Nouryon is the world's leading producer of organic peroxides for the curing of thermoset resins, coatings and specialty monomers. We're home to the best known brands in the thermoset market. Examples include Butanox®, Perkadox® and Trigonox®. We also have a whole range of auxiliary products, such as accelerators and promoters, to meet your specific production requirements.

This application guide introduces you to our thermoset product portfolio and helps you find a suitable curing system for your specific application.

Engineered stone

In the production of engineered stone we distinguish two different production methods, the blocks process and the slabs process. The so-called block process is executed at ambient temperature. After the cure the blocks are sawn in sheets, calibrated and polished. The other process, a direct production of slabs, is done at elevated temperature (ovens between 80°C and 120°C) and for this process temperature activated peroxides are used.

The block process

This is a casting process, highly filled formulations with about 90% filler as for instance calcium carbonate and marble waste. The mold has a size of 3 x 1.2 x 1.5 m. Mostly an automatic filler/resin mixing unit is used to fill the mold. The formulation contains besides the necessary wetting and rheology additives an accelerator to activate the peroxide which mostly is added as the last component. The ideal peak exotherm in the block is around 65°C.

Reason for our products

- A guarantee of quality and reliability
- Outstanding technical and customer service
- Intensive safety research
- A global distribution network and security of supply
- Customized application research: special formulated products for an optimal performance in your application

Nouryon curing agents

This casting process can be done with standard MEKP like Butanox M-50, however to obtain the right exothermic and a sufficient hardening mostly MEKP/AAP mixtures like Trigonox 61 (hot season) and Trigonox 63 (cold season) are used.

Main products and process equipment

A high solid mixing unit is needed with a possibility for de-aeration under vacuum. The cured block is sawn in sheets which can be further minimized in tiles, wall claddings or kitchen tops.

Reactivity figures

Butanox M-50 in comparison to Trigonox 61 and 63 (SPI laboratory tests in high reactive ortho resin) *

Cure at 20°C

	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
2 phr Trigonox 61 + 0.5 phr Accelerator NL-49PN	14	29	57
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	13	36	44

The slabs process

This is also a casting process but the cure is done at a higher temperatures and the polymerization is started by temperature activated peroxides, so-called peroxyesters. The highly filled resin formulation is casted in the mold, pressed under vacuum and transported into the oven. The oven time is around 30-60 minutes and the most used oven temperatures are between 80 and 100°C. After the cure and the cooling down the slab is calibrated, polished and cut on the right sizes. In this process it is possible to use quartz filler which results in a product with a very high hardness with excellent scratch and chemical resistance, especially for kitchen tops.

Nouryon curing agents

Due to the presence of an oven with temperatures between 80°C and 120°C it is possible to use temperature activated peroxides which, results in a fully cured slab, even a residual styrene content of zero is possible. Promoted peroxyesters are mainly used in combination with a metal accelerator. The most used peroxide is Trigonox 93, this however is an aromatic product and one of the decomposition products is benzene (in small amounts). In case it is necessary to avoid any benzene coming from the peroxide Trigonox 42PR is a good alternative, having almost the same reactivity and cure efficiency.

Main products and process equipment

A slabs production line is needed, a high tech mixing unit, a vibrating table including press and vacuum possibility and an oven for the curing process. Furthermore, the line contains a calibrating, polishing and a sizing unit.

Reactivity figures

(SPI laboratory tests in medium reactive ortho resin) *

Oven temperature 80°C

	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
2 phr Trigonox 93 + 0.2 phr Accelerator NL-51PN	5	20	123
2 phr Trigonox 42PR + 0.2 phr Accelerator NL-51PN	5	22	129

	SHELF LIFE 20°C (HRS)	RESIDUAL STYRENE (%)
2 phr Trigonox 93 + 0.2 phr Accelerator NL-51PN	7.4	<0.01
2 phr Trigonox 42PR + 0.2 phr Accelerator NL-51PN	6.5	<0.01

Common problems and solutions

Resin quality

The used resins mainly include the standard orthophthalic resins but attention should be paid to the scratch resistance of the resin.

Production problems in the blocks:

Cracks

Discoloration in the center of the block or cracks being formed directly after polymerization is often an indication of a too high peak exotherm. Slowing down the reactivity is the most recommended solution. This can be done by reducing the amount of peroxide or accelerator, or by switching to a lower reactive peroxide type.

Cracks being formed during storage is often an indication of under cure. The difference in polymerization speed between the center of the block and the outside is too big. Increasing the reactivity is the most recommended solution. This can be done by increasing the amount of peroxide or accelerator, or by switching to a higher reactive peroxide type.

High residual styrene levels

When the residual styrene levels are too high a longer post cure time, or a reactivity increase of the cure system is recommended.

Production problems in the slabs

Bending

When bending of the slabs occurs, then the cure could be too slow or the peak exotherm could be too high. This can cause stress in the end product when the product has left the oven. The cure system and the oven temperature should be checked.

Discoloration

Discoloration in the middle of the slab. In such case the peak exotherm was too high. This can be solved by decreasing the amount of peroxide.

A summary containing the standard reactivity data of the most used products in this application can be found on the next pages.

Cure data

Butanox M-50

Butanox M-50 is a general purpose methyl ethyl ketone peroxide (MEKP) for the curing of unsaturated polyester resins in the presence of a cobalt accelerator at room and elevated temperatures.

The curing system Butanox M-50/cobalt accelerator is particularly suitable for the curing of gelcoat resins, laminating resins, lacquers and castings; moreover, the manufacture of light resistant parts may be possible contrary to the curing system benzoyl peroxide/amine accelerator.

Practical experience throughout many years has proven that by the guaranteed low water content and the absence of polar compounds in Butanox M-50, this peroxide is very suitable in GRP products for e.g. marine applications.

For room temperature application it is necessary to use Butanox M-50 together with a cobalt accelerator (e.g. Accelerator NL-49PN)

Dosing

Depending on working conditions, the following peroxide and accelerator dosage levels are recommended:

Butanox M-50	Accelerator NL-49PN
1 - 4 phr *	0.5 - 3 phr

* (parts per hundred resin)

Cure characteristics

In a high reactive standard orthophthalic resin in combination with Accelerator NL-49PN (= 1% cobalt) the following application characteristics were determined:

Gel times at 20°C

2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	12 minutes
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN	7 minutes

Cure of 1 mm pure resin layer at 20°C

The speed of cure is expressed as the time to reach a Persoz hardness of respectively 30, 60 and 120 s.

Persoz	30	60	120	s
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	2.4	4.1	13	h
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN	1.7	3.0	9.5	h

Cure of 4 mm laminates at 20°C

4 mm laminates have been made with a 450 g/m² glass chopped strand mat. The glass content in the laminates is 30% (w/w).

The following parameters were determined:

- Time-temperature curve.
- Speed of cure expressed as the time to achieve a Barcol hardness (934-1) of 0-5 and 25-30 respectively.
- Residual styrene content after 24 h at 20°C and a subsequent postcure of 8 h at 80°C.

	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	13	36	44
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN	8	26	64

	BARCOL		RESIDUAL STYRENE	
	0-5 (h)	25-30 (h)	24 h 20°C (%)	+8 h 80% (%)
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	3	15	6	0.3
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN		1	5	0.1

Pot life at 20°C

Pot lives were determined of a mixture of Butanox M-50 and a non-preaccelerated UP resin at 20°C.

2 phr Butanox M-50	12 h
4 phr Butanox M-50	7 h

Solubility

Butanox M-50 is miscible with phthalates and slightly miscible with water.

Colors

Butanox M-50 is available in the colors blue, yellow-A, red-YM and red-YM 1/6.

Accelerator NL-49PN

The curing of unsaturated polyester resins at ambient temperatures can in general not be performed by an organic peroxide alone. The radical formation, which is necessary to start the polymerization reaction, is at ambient temperatures with most generally applied organic peroxides too slow. To speed up the radical formation in a controllable way organic peroxides must therefore be used in combination with a so called accelerator.

For ketone peroxides like methyl ethyl ketone peroxides, cyclohexanone peroxides and acetylacetone peroxide a cobalt accelerator must be used.

For this purpose the following formulations of cobalt 2 ethylhexanoate also called cobalt octoate are available:

Accelerator NL-49PN	1% cobalt in aliphatic ester
Accelerator NL-51PN	6% cobalt in aliphatic ester
Accelerator NL-53N	10% cobalt in white spirit

The reactivity of the various cobalt accelerators is directly correlated with the cobalt content. The use of a lower concentrated version increases the dosage accuracy. However, when the dosage level of e.g. Accelerator NL-49PN must be higher than approx. 3% to achieve the required cure performance, it is advised to use a higher concentrated cobalt accelerator e.g. 0.5% Accelerator NL-51PN.

The cure characteristics of an unsaturated polyester resin/ketone peroxide mixture can, apart from the choice of the ketone peroxide, very effectively be influenced by the dosage level of the cobalt accelerator. The dosage level of the cobalt accelerator expressed as Accelerator NL-53N (10% cobalt) can for this purpose be varied between e.g. 0.025% up to approximately 0.6% calculated on the UP resin.

When the right peroxide has been chosen and still the required gel time and Cure characteristics cannot be obtained with the cobalt accelerator alone, it is possible to increase the reactivity of the cobalt accelerator by the extra addition of a promoter like N,N-Dimethylaniline or Promotor D (N,N Diethylacetoacetamide).

This adaptation of the accelerator system may be necessary when:
- a very short gel time and/or a very fast cure is required e.g. for resin transfer molding or the production of polymer concrete
- highly inhibited and/or low reactive resins must be cured e.g.
- bisphenol A/fumarate and vinylester resins.

The cure system ketone peroxide/cobalt accelerator can further be characterized by:
- the relatively low color, related to the cobalt dosage, of the cured molding
- a very good UV light resistance of the molded parts
- the long pot life of the cobalt accelerator in the polyester resin
- A possible disadvantage may be that the cure system is more sensitive for moisture, pigments and fillers than the cure system dibenzoyl peroxide/ amine accelerator.

Cobalt accelerators can also be used to increase the reactivity of organic peresters, which are applied for the cure of unsaturated polyester resins at elevated temperatures. Moreover, the use of a cobalt accelerator gives in general a lower residual styrene content in the cured molding. For this application peresters like Trigonox C, Trigonox 21S, Trigonox 42S and the special mixture Trigonox 93 can be used.

Dosage

Depending on working conditions the following accelerator dosage level is recommended:

Accelerator NL-49PN

0.25 - 3.0 phr *

* (parts per hundred resin)

Cure characteristics

In the following cure experiments the performance of cobalt 2 ethylhexanoate as accelerator will be demonstrated.

Gel times at 20°C

in a standard orthophthalic resin with various ketone peroxides

ACCELERATOR NL-49PN (PHR)	0.25	0.5	1
2 phr Butanox M-60	22	12	7
2 phr Butanox LPT-IN	65	31	20
2 phr Cyclonox LE-50	20	11	6
2 phr Trigonox 44B	24	14	8

in various resins with Dimethylaniline, 100% as promoter

standard orthophthalic resin

2 phr Butanox M 60 + 1 phr Acc. NL-49PN	7 min.
2 phr Butanox M 60 + 1 phr Acc. NL-49PN + 0.05 phr Dimethylaniline	4 min.
2 phr Butanox M 60 + 1 phr Acc. NL-49PN + 0.10 phr Dimethylaniline	2 min.
2 phr Trigonox 44B + 1 phr Acc. NL-49PN	8 min.
2 phr Trigonox 44B + 1 phr Acc. NL-49PN + 0.05 phr Dimethylaniline	5 min.
2 phr Trigonox 44B + 1 phr Acc. NL-49PN + 0.10 phr Dimethylaniline	3 min.

bisphenol A/fumarate resin

2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN	145 min.
2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN + 0.05 phr Dimethylaniline	65 min.
2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN + 0.10 phr Dimethylaniline	34 min.

bisphenol A/vinylester resin

2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN	32 min.
2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN + 0.05 phr Dimethylaniline	22 min.
2 phr Butanox LPT-IN + 3 phr Acc. NL-49PN + 0.10 phr Dimethylaniline	16 min.

Time-temperature curves at elevated temperatures (70°C and 90°C)

	CURE TEMP (°C)	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
1 phr Trigonox 21S	70	916	233	
1 phr Trigonox 21S + 1 phr Accelerator NL-49PN	70	35	214	
1 phr Trigonox 21S	90	16	258	
1 phr Trigonox 21S + 1 phr Accelerator NL-49PN	90	0.3	1.5	240
1 phr Trigonox C	90	925	236	
1 phr Trigonox C + 1 phr Accelerator NL-49PN	9	26	258	

Pot life at 20°C

The pot life has been determined of Accelerator NL-49PN in a standard orthophthalic polyester resin at 20°C.

1 phr Accelerator NL-49PN	6 months

Accelerator NL-51PN

The curing of unsaturated polyester resins at ambient temperatures can in general not be performed by an organic peroxide alone. The radical formation, which is necessary to start the polymerization reaction, is at ambient temperatures with most generally applied organic peroxides too slow. To speed up the radical formation in a controllable way organic peroxides must therefore be used in combination with a so called accelerator.

For ketone peroxides like methyl ethyl ketone peroxides, cyclohexanone peroxides and acetylacetone peroxide a cobalt accelerator must be used.

For this purpose the following formulations of cobalt 2 ethylhexanoate also called cobalt octoate are available:

Accelerator NL-49PN	1% cobalt in aliphatic ester
Accelerator NL-51PN	6% cobalt in aliphatic ester
Accelerator NL-53N	10% cobalt in white spirit

The reactivity of the various cobalt accelerators is directly correlated with the cobalt content. The use of a lower concentrated version increases the dosage accuracy. However, when the dosage level of e.g. Accelerator NL-49PN must be higher than approx. 3% to achieve the required cure performance, it is advised to use a higher concentrated cobalt accelerator e.g. 0.5% Accelerator NL-51PN.

The Cure characteristics of an unsaturated polyester resin/ketone peroxide mixture can, apart from the choice of the ketone peroxide, very effectively be influenced by the dosage level of the cobalt accelerator. The dosage level of the cobalt accelerator expressed as Accelerator NL-53N (10% cobalt) can for this purpose be varied between e.g. 0.025% up to approximately 0.6% calculated on the UP resin.

When the right peroxide has been chosen and still the required gel time and Cure characteristics cannot be obtained with the cobalt accelerator alone, it is possible to increase the reactivity of the cobalt accelerator by the extra addition of a promoter like N,N-Dimethylaniline or Promotor D (N,N Diethylacetoacetamide).

This adaptation of the accelerator system may be necessary when:
- a very short gel time and/or a very fast cure is required e.g. for resin transfer molding or the production of polymer concrete
- highly inhibited and/or low reactive resins must be cured e.g. bisphenol A/fumarate and vinylester resins.

The cure system ketone peroxide/cobalt accelerator can further be characterized by:
- the relatively low color, related to the cobalt dosage, of the cured molding
- a very good UV light resistance of the molded parts
- the long pot life of the cobalt accelerator in the polyester resin

A possible disadvantage may be that the cure system is more sensitive for moisture, pigments and fillers than the cure system dibenzoyl peroxide/ amine accelerator.

Cobalt accelerators can also be used to increase the reactivity of organic peresters, which are applied for the cure of unsaturated polyester resins at elevated temperatures. Moreover, the use of a cobalt accelerator gives in general a lower residual styrene content in the cured molding. For this application peresters like Trigonox C, Trigonox 21S, Trigonox 42S and the special mixture Trigonox 93 can be used.

Dosage

Depending on application area and working conditions the following accelerator dosage level is recommended:

Accelerator NL-51PN

0.040 -1.0 phr *

* (parts per hundred resin)

Cure characteristics

In the following cure experiments the performance of cobalt 2 ethylhexanoate as accelerator will be demonstrated.

Gel times at 20°C

in a standard orthophthalic resin with various ketone peroxides

	Accelerator NL-51PN (phr)	
	0.08	0.17
2 phr Butanox M-60	12	7
2 phr Butanox LPT-IN	31	20
2 phr Cyclonox LE-50	11	6
2 phr Trigonox 44B	14	8

in various resins with Dimethylaniline, 100% as promoter

standard orthophthalic resin

2 phr Butanox M-60 + 0.17 phr Acc. NL-51PN	7 min.
2 phr Butanox M-60 + 0.17 phr Acc. NL-51PN + 0.05 phr Dimethylaniline	4 min.
2 phr Butanox M-60 + 0.17 phr Acc. NL-51PN + 0.10 phr Dimethylaniline	2 min.
2 phr Trigonox 44B + 0.17 phr Acc. NL-51PN	8 min.
2 phr Trigonox 44B + 0.17 phr Acc. NL-51PN + 0.05 phr Dimethylaniline	5 min.
2 phr Trigonox 44B + 0.17 phr Acc. NL-51PN + 0.10 phr Dimethylaniline	3 min.

bisphenol A/fumarate resin

2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN	145 min.
2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN + 0.05 phr Dimethylaniline	65 min.
2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN + 0.10 phr Dimethylaniline	34 min.

bisphenol A/vinylester resin

2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN	32 min.
2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN + 0.05 phr Dimethylaniline	22 min.
2 phr Butanox LPT-IN + 0.5 phr Acc. NL-51PN + 0.10 phr Dimethylaniline	16 min.

Time-temperature curves at elevated temperatures (70°C and 90°C)

	CURE TEMP MIN	GEL TIME MIN.	TIME TO PEAK MIN.	PEAK EXOTHERM (°C)
1 phr Trigonox 21S	70	9	16	233
1 phr Trigonox 21S + 0.17 phr Accelerator NL-51PN	70	3	5	214
1 phr Trigonox 21S	90	1	6	258
1 phr Trigonox 21S + 0.17 phr Accelerator NL-51PN	90	0.3	1.5	240
1 phr Trigonox C	90	9	25	236
1 phr Trigonox C + 0.17 phr Accelerator NL-51PN	90	2	6	258

Pot life at 20°C

The pot life has been determined of Accelerator NL-51PN in a standard orthophthalic polyester resin at 20°C.

0.2 phr Accelerator NL-51PN	>6 months

Trigonox 42PR

Trigonox 42PR is a peroxide formulation based on tert-butylperoxy-3,5,5-trimethylhexanoate and acetylacetone.

Trigonox 42PR has been developed for the cure of unsaturated polyester resins in combination with a cobalt accelerator in the temperature range of 60°C and higher.

Trigonox 42PR plus a cobalt accelerator can effectively be used as a match for Trigonox 21S in those areas where the use of Trigonox 21S is restricted by its official transport and storage temperature of max. +20°C. Application area for the cure system Trigonox 42PR plus a cobalt accelerator (e.g. Accelerator NL-53N, 10% cobalt) can be e.g. engineered stone, polymer concrete, filament winding, air drying lacquers.

The combination Trigonox 42PR plus a cobalt accelerator and possibly an amine accelerator like (N,N-Dimethylaniline) is also very suitable for the ambient temperature cure of vinylester resins. Trigonox 42PR gives in these resins a much faster cure than the commonly applied peroxides Butanox LPT-IN and Trigonox 239.

Dosing

Depending on working conditions, the following dosage level is recommended:

Trigonox 42PR	Accelerator NL-53N
1 - 2 phr *	0 - 0.5 phr

* (parts per hundred resin)

Cure characteristics

In a high reactive standard orthophthalic UP resin the following application characteristics were determined:

Activation temperature

1 phr Trigonox 42PR + 0.1 phr Accelerator NL-53N	60°C
1 phr Trigonox 42PR	90°C
1 phr Trigonox 21S	60°C

Pot life at 20°C

1 phr Trigonox 42PR + 0.1 phr Accelerator NL-53N	2 days
1 phr Trigonox 21S	22 days

Cure of 1 mm laminates at 80°C

The 1 mm laminates have been made with a 450 g/m2 glass chopped strand mat. The glass content in the laminate is 30% (w/w).

The following parameters were determined
- Time-temperature curve.
- Barcol hardness (934-1) and the residual styrene content after a cure time of time to peak plus 10 minutes

	GEL TIME MIN	TIME TO PEAK MIN.	PEAK EXOTHERM (°C)
1 phr Trigonox 21S	10.5	16.2	148
1 phr Trigonox 42PR + 0.1 phr Accelerator NL-53N	3.0	7.6	146

	BARCOL 934-1	RESIDUAL STYRENE %
1 phr Trigonox 21S	35	1.4
1 phr Trigonox 42PR + 0.1 phr Accelerator NL-53N	42	0.1

In a Bisphenol A/epoxy based vinylester resin, the following Cure characteristics at 20°C were determined:

Gel time at 20°C

2 phr Trigonox 42PR + 0.3 phr Accelerator NL-53N + 0.6 phr N,N-Dimethyl aniline	29 minutes
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N	32 minutes
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N	29 minutes

Cure of 4 mm laminates at 20°C

4 mm laminates have been made with a 450 g/m2 glass chopped strand mat. The glass content in the laminates is 30% (w/w).

The following parameters were determined:
- Time-temperature curve.
- Speed of cure expressed as the development of the Barcol hardness (934-1).
- Residual styrene content after 24 h at 20°C and a subsequent postcure of 8 h at 80°C.

	GEL TIME MIN	TIME TO PEAK MIN.	PEAK EXOTHERM (°C)
2 phr Trigonox 42PR + 0.3 phr Acc. NL-53N + 0.6 phr N,N-Dimethyl aniline	29	60	126
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N	42	134	36
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N	37	128	49

	BARCOL 934-1 after			RESIDUAL STYRENE 1 WEEK + 8 H	
	2 h	4 h	24 h	24h 20°C %	+8h 80°C %
2 phr Trigonox 42PR + 0.3 phr Acc. NL-53N + 0.6 phr N,N-Dimethyl aniline	46	48	48	0.15	0.02
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N	0	4	19	5.9	0.1
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N	3	16	22	5.0	0.1

Trigonox 61

Trigonox 61 is an organic peroxide mixture with methyl ethyl ketone peroxide and acetylacetone peroxide for the curing of unsaturated polyester resins in the presence of a cobalt accelerator at room and elevated temperatures.

With the curing system Trigonox 61/cobalt accelerator a faster speed of cure can be obtained than with Butanox M-50; however, the high cure rates achieved with Trigonox 44B are not attainable. The gel times with Trigonox 61 are in general similar to those with Butanox M-50.

The curing system Trigonox 61/cobalt accelerator is particularly suitable for the curing of gelcoat resins, laminating resins and for applications where a shorter demoulding time than obtained with Butanox M-50 is required. Moreover, the manufacture of light resistant parts may be possible contrary to the curing system benzoyl peroxide/amine accelerator.

For room temperature application it is necessary to use Trigonox 61 together with a cobalt accelerator (e.g. Accelerator NL-49PN).

Dosing

Depending on working conditions, the following peroxide and accelerator dosage levels are recommended:

Trigonox 61	Accelerator NL-49PN
1 - 4 phr *	0.5 - 3 phr

* (parts per hundred resin)

Cure characteristics

In a high reactive standard orthophthalic resin in combination with Accelerator NL-49PN (= 1% cobalt) the following application characteristics were determined:

Gel times at 20°C

2 phr Trigonox 61 + 0.5 phr Acc. NL-49PN	13 minutes
2 phr Butanox M-50 + 0.5 phr Acc. NL-49PN	12 minutes
2 phr Trigonox 61 + 1.0 phr Acc. NL-49PN	7 minutes
2 phr Butanox M-50 + 1.0 phr Acc. NL-49PN	7 minutes

Cure of 1 mm pure resin layer at 20°C

The speed of cure is expressed as the time to reach a Persoz hardness of respectively 30, 60 and 120 s.

Persoz	30	60	120	s
2 phr Trigonox 61 + 0.5 phr Accelerator NL-49PN	2.2	3.5	9	h
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	2.4	4.1	13	h
2 phr Trigonox 61 + 1.0 phr Accelerator NL-49PN	1.0	2.0	6.5	h
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN	1.7	3.0	9.5	h

Cure of 4 mm laminates at 20°C

4 mm Laminates have been made with a 450 g/m^2 glass chopped strand mat. The glass content in the laminates is 30% (w/w).

The following parameters were determined:

- Time - temperature curve.
- Speed of cure expressed as the time to achieve a Barcol hardness (934-1) of 0-5 and 25-30 respectively.
- Residual styrene content after 24 h at 20°C and a subsequent postcure of 8 h at 80°C.

	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
2 phr Trigonox 61 + 0.5 phr Accelerator NL-49PN	14	29	57
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	13	36	44
2 phr Trigonox 61 + 1.0 phr Accelerator NL-49PN	6	20	77
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN	8	26	64

	BARCOL		RESIDUAL STYRENE	
	0.5-25 (h)	25-30 (h)	24 h 20°C (%)	+8 h 80% (%)
2 phr Trigonox 61 + 0.5 phr Accelerator NL-49PN	1.5	9	5.7	0.3
2 phr Butanox M-50 + 0.5 phr Accelerator NL-49PN	3	15	6	0.3
2 phr Trigonox 61 + 1.0 phr Accelerator NL-49PN		<1	4	0.1
2 phr Butanox M-50 + 1.0 phr Accelerator NL-49PN		1	5	0.1

Pot life at 20°C

Pot lives were determined of a mixture of Trigonox 61 and a non-preaccelerated UP resin at 20°C.

2 phr Trigonox 61	11 h
4 phr Trigonox 61	6 h

Trigonox 93

Trigonox 93 is a peroxide formulation based on tert-butylperoxybenzoate and acetylacetone.

Trigonox 93 has been developed for the cure of unsaturated polyester resins in combination with a cobalt accelerator (e.g. Accelerator NL-53N = 10% cobalt) in the temperature range of 60°C and higher.

Trigonox 93 plus a cobalt accelerator can effectively be used as a match for Trigonox 21S in those areas where the use of Trigonox 21S is restricted by its official transport and storage temperature of max. 20°C.

Application area for the cure system Trigonox 93 plus a cobalt accelerator can be e.g. engineered stone, polymer concrete, filament winding and air drying lacquers.

The combination Trigonox 93 plus a cobalt accelerator and possibly an amine accelerator like N,N-Dimethylaniline is also very suitable for the ambient temperature cure of vinylester resins. Trigonox 93 gives in these resins a much faster cure than the commonly applied peroxides Butanox LPT-IN and Trigonox 239.

Dosing

Depending on working conditions, the following peroxide and accelerator dosage levels are recommended:

Trigonox 93	Accelerator NL-53N
1 - 2 phr *	0.1 - 0.5 phr

* (parts per hundred resin)

Cure characteristics

In a high reactive standard orthophthalic UP resin, the following application characteristics were determined:

Activation temperature

1 phr Trigonox 93 + 0.1 phr Acc. NL-53N	60°C
1 phr Trigonox C	80°C
1 phr Trigonox 21S	60°C

Pot life at 20°C

1 phr Trigonox 93 + 0.1 phr Acc. NL-53N	4 days
1 phr Trigonox 21S	22 days

Cure of 1 mm laminates at 80°C

1 mm laminates have been made with a 450 g/m2 glass chopped strand mat. The glass content in the laminates is 30% (w/w).

The following parameters were determined:

- Time-temperature curve.
- Barcol 934-1 hardness and the residual styrene content after a cure time of time to peak plus 10 minutes.

	GEL TIME MIN	MIN. CURE TIME MIN.	TIME TO PEAK MIN.	PEAK EXOTHERM (°C)
1 phr Trigonox 93 + 0.1 phr Accelerator NL-53N	3.8	6.2	8.7	142
1 phr Trigonox 21S	10.5	13.2	16.2	148

	BARCOL 934-1	RESIDUAL STYRENE %
1 phr Trigonox 93 + 0.1 phr Accelerator NL-53N	40	0.2
1 phr Trigonox 21S	35	1.4

Time/temperature curves at 90°C

	GEL TIME MIN	MIN. CURE TIME MIN.	TIME TO PEAK MIN.	PEAK EXOTHERM (°C)
1 phr Trigonox 93 + 0.1 phr Accelerator NL-53N	2.6	3.9	6.9	240
1 phr Trigonox C	22.2	27	30.4	227
1 phr Trigonox 21S	1.7	2.7	5.7	245

In a Bisphenol A/epoxy based vinylester resin, the following Cure characteristics at 20°C were determined:

Gel time at 20°C

2 phr Trigonox 93 + 0.3 phr Acc. NL-53N + 0.6 phr N,N-Dimethyl aniline	29 minutes
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N	32 minutes
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N	29 minutes

Cure of 4 mm laminates at 20°C

4 mm laminates have been made with a 450 g/m2 glass chopped strand mat. The glass content in the laminates is 30% (w/w).

The following parameters were determined:

- Time-temperature curve.
- Speed of cure expressed as the development of the Barcol hardness 934-1.
- Residual styrene content after 24 h at 20°C and a subsequent postcure of 8 h at 80°C.

	GEL TIME (min.)	TIME TO PEAK (min.)	PEAK EXOTHERM (°C)
2 phr Trigonox 93 + 0.3 phr Accelerator NL-53N + 0.6 phr N,N-Dimethyl aniline	42	61	126
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N	42	134	36
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N	37	128	49

	BARCOL 934-1 after			RESIDUAL STYRENE	
	2 h	4 h	24 h	24h 20°C %	+8h 80°C %
2 phr Trigonox 93 + 0.3 phr Acc. NL-53N + 0.6 phr N,N-Dimethyl aniline	42	47	48	0.13	0.02
2 phr Butanox LPT-IN + 0.3 phr Accelerator NL-53N		4	19	5.9	0.01
2 phr Trigonox 239 + 0.4 phr Accelerator NL-53N		16	22	5.0	0.01

Contact us

For product inquiry and ordering information, please contact your Nouryon account manager or regional Nouryon sales office.

Americas

US and other countries
Citadel Center
131 S Dearborn St, Suite 1000
Chicago IL 60603-5566
USA
T +1 800 828 7929 (US only)
E polymer.amer@nouryon.com

Mexico
Av. Morelos No. 49
Col. Tecamachalco
Los Reyes La Paz Estado de Mexico
C.P. 56500 Mexico
T +52 55 5858 0700
E polymer.mx@nouryon.com

Brazil
Rodavia Nouryon no. 707
Portão A – Planta C
Bairro São Roque da Chave
13295-000 Itupeva - São Paulo
Brazil
T +55 11 4591 8800
E polymer.sa@nouryon.com

Europe, India, Middle East and Africa

France, Italy, Spain and Portugal
Autovia de Castelldefels, km 4.65
08820 El Prat de Llobregat
Barcelona
Spain
T +34 933 741991
E polymer.es@nouryon.com

India
North Block 801, Empire Tower,
Reliable Cloud City Campus,
Off Thane – Belapur Road
Airoli, Navi Mumbai - 400708
India
T +91(0) 22 68426700
E polymer.emeia@nouryon.com

Middle East
Silicon park, Building A6
Office no 402, 4th floor
Dubai Silicon Oasis
Dubai
United Arab Emirates
T +971 4 2471500
E communications.me@nouryon.com

Russia and CIS
Smolnaya Str., 24D,
Commercial Tower Meridian
125445 Moscow
Russia
T +7 495 766 16 06
E info.moscow@nouryon.com

Other countries
Zutphenseweg 10
7418 AJ Deventer
The Netherlands
E polymer.emeia@nouryon.com

Asia Pacific

Room 2501 & 26F, Building A
Caohejing Center
No. 1520 Gumei Road, Xuhui District
Shanghai 200233
P.R. China
T +86 21 2289 1000
E polymer.apac@nouryon.com

Additional information

Product Data Sheets (PDS) and Safety Data Sheets (SDS) for our polymerization initiators are available at www.nouryon.com

Nouryon

We are a global specialty chemicals leader. Industries worldwide rely on our essential chemistry in the manufacture of everyday products such as paper, plastics, building materials, food, pharmaceuticals, and personal care items. Building on our nearly 400-year history, the dedication of our 10,000 employees, and our shared commitment to business growth, strong financial performance, safety, sustainability, and innovation, we have established a world-class business and built strong partnerships with our customers. We operate in over 80 countries around the world and our portfolio ofindustry-leading brands includes Eka, Dissolvine, Trigonox, and Berol.

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