Climate Independent Painting: Is Infrared Heating a Solution for Professional Painters?

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Summary: Today's costs of maintenance of buildings are very high due to labour. Enlarging the period for painting outdoors and faster drying can reduce these costs. Therefore, the professional painters ask for paint products that should dry within15 minutes. Infrared heating could be used to achieve these goals. Medium wave infrared heaters show accelerated drying of water borne coatings. Infrared heating results in fast drying, excellent film formation and anti-blocking properties. For solvent borne alkyds and high solids, faster tack-free times and through-dry times are achieved. Raw material suppliers, paint manufacturers and IR-equipment suppliers are challenged to develop new products and equipment to meet the needs of professional painters.

Keywords: infrared; drying; paint; water borne; solvent borne

Painters' problems

Today's costs of building maintenance, by painting windows, doors and cladding, are very high due to indirect labour activities. Interior and exterior maintenance should therefore be carried out with more efficiency. Normally the period from November until March cannot be used for outdoor painting. Outdoor painting is difficult due to humid and cold climate conditions. This has a negative effect on continuation and profitability of the companies. One of the possibilities of improvement is to enlarge the period for painting outdoors.

Earlier research

As a first step, in1998 a research project, initiated by the Dutch Association of Professional Painters (Association), was carried out by the Dutch Research Institute TNO [1]. In this project, the impact of climate conditions on painting during winter times was investigated.
In the period November until March, there are 80 to 90 working days available. Due to climate conditions, only 50 – 65% of these days can be used, which leads to approximately 45 days. This is, until now, the main reason to stop outdoor painting in November.

 CCC 1022-1360/00/$ 17.50+.50/0

Two assumptions were made to calculate the extra days that could be gained by painting during difficult climate conditions such as high humidity and/or low temperatures. First, some temperatures and relative humidity were found at which painting is not possible. The second assumption was that special paints are available to use during these conditions. Results are presented in table 1.

Table 1. Calculated number of available working days related to climate conditions.

Climate conditions *	**1**		**2**		**3**	
Temperature	10° C		5° C		1° C	
Relative humidity	80%		90%		95%	
Normal available days	45					
Extra days	Approx. 20%	9	Approx. 70%	31	Approx. 80%	36
Total days	54		76		81	

* Data from the Dutch Meteorological Institute (KNMI)

Forty paints (conventional alkyds, high solids and water borne paints) were tested under conditions as mentioned in table 1. Application features (viscosity), drying time, gloss reduction, chalking and cracking were checked. Some results on drying time and gloss are depicted in table 2.

Table 2. Tack-free time and gloss related to climate conditions.

	20° C/50% RH*		**10° C/80% RH**		**5° C/90% RH**		**1° C/95% RH**	
	drying time	gloss	drying time	Gloss	drying time	gloss	drying time	gloss
Conven. Alkyd	4.2 h	45	4.9 h	55	6.0 h	70	7.4 h	45
High Solid	4.9 h	60	6.0 h	45	7.8 h	30	9.5 h	5
Water borne	1.4 h	35	2.1 h	30	2.4 h	45	3.2 h	40

*The condition 20° C/50% RH is used as a reference.

The long tack-free time of conventional paints and high solids causes problems in closing windows. During application, the fast drying time of the water borne paints was a disadvantage.

The gloss of the high solids was reduced very strongly. Water borne paints showed a rather stable gloss.

The main conclusions were that outdoor painting could be possible in winter periods. However, the painters must be aware of negative effects of the performance of the paints due to application in wintertime. Especially drying time and film formation must be improved. This should result in new products with a longer durability.

Aim

The aim of the Association in this field is to stimulate development of paints (primers and topcoats) and drying techniques to reduce the drying time of paints to 15 minutes. The properties of the paint film should be at least identical to the conventionally dried paints. Experts concluded that a reduction of the drying time to 15 minutes is needed to have significant improvement in efficiency.

A desktop feasibility study [2] pointed out that infrared drying of paints could be very successful. In the automotive sector, it is already a well-known technique to enhance drying of automotive repair lacquers [3]. Some first experiments with infrared heating were carried out by SHR [4].

In this paper, the effect of medium wave length infrared emitters on drying of water borne acrylics and solvent borne conventional alkyd and high solid paints for the professional painter is presented [5]. This is the first step to increase the effective working time of the painter. To show the advantage of IR drying, experts of the Association calculated, based on the results, the effects of IR drying on the effective working time of the painter.

Experimental set-up

The experimental set-up is split into infrared drying of several paint types and economic calculations on time spending.

IR drying

Several types of infrared emitters can be used for paint drying. Available are short wave infrared light (wavelength around 1 μm), medium (wavelength 1.5-3.0 μm) and long wave (3 μm and higher). For painters' use, the best infrared emitter seems to be the medium wave length ones, due to the fact that they are robust and able to heat up the surface slowly to relatively low temperatures (not more than 100 °C). Furthermore, these emitters are available in 'ready to use' handhold equipment.

Subject of research in this paper were some commercial paint formulations, such as a water borne acrylic, solvent borne conventional alkyd, and a high solid paint. These paint types are available for the professional painter only. Specifications of the paint as stated by the manufacturer are given in table 3.

The water borne acrylic was tested in three formulations: with normal content of coalescent (100%), 50 % of coalescent and without coalescent to investigate the effect of higher drying temperatures on film formation.

Table 3. Drying times of tested paint, data provided by supplier.

	1	2	3
Paint type	Water borne	Solvent borne	Solvent borne
	Acrylic	Conventional alkyd	High solid alkyd
Tack free time (h)	1.5-2	6	5
Overcoat time (h)	4-5	18	24

First aim was to find out the optimal flash off time, surface heating temperature and drying time by infrared irradiation. Primed spruce and meranti panels were coated by brush application. The wet film thickness was about 80 – 100 μm. Meranti panels were chosen to evaluate blister formation on the pores during heating. Drying properties were evaluated by checking the tack-free time and nail hardness. The influence of colour on surface temperature was evaluated by application of paints in white (RAL1013) and darkgreen (RAL4823) colour and was measured with a pyrometer.

Secondly, the drying properties were evaluated by application of paint on glass strips with a BA applicator to wet film thickness of 80 – 100 μm. The paint was dried by using medium wave length IR light and putting the strips on a drying recorder (Brave Instruments type 5315). The drying process of the paints was evaluated with the drying recorder during 8 hours. A typical pattern of a drying process is shown in figure 1.

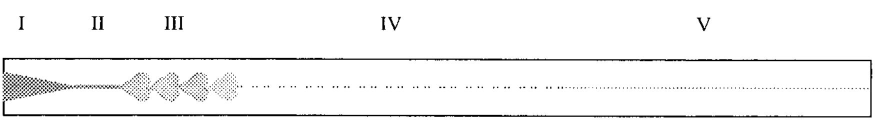

Figure 1. Drying stages of paint: levelling (I), setting (II), surface-drying (III), through-drying (IV), dry (V).

Thirdly, film properties after infrared drying were evaluated by water uptake of coated spruce panels of 150x70x20 mm (method similar to EN 927-5). The panels were treated with the water borne acrylic dispersion according to the following scheme:

Reference 1	30 minutes drying of each layer at 21 °C and 55 % RH after application of primer and after application of topcoat
Reference 2	2 hours drying of each layer at 21 °C and 55 % RH after application of primer and after application of topcoat
Infrared	Drying with infrared after application of primer and after application of the topcoat. After each application 5 minutes flash off, 5 minutes drying at room temperature with ventilation, 2 minutes infrared heating at 60 °C. Total drying time of each layer was 30 minutes.

For water uptake, the panels have been floating on water for 72 hours. The coated surface was faced to the water; the other sides were sealed with two layers of a two component polyurethane coating. After water uptake, the adhesion was tested according to ASTM D 3359 A by making a double cross cut in the coating. The adhesion was tested by putting adhesion tape (3M Scotch Brand No. 800 Adhesion tape) on the cuts and pulling it of under an angle of 180° after one minute. Results were rated in classes. Adhesion class 5 indicates no adhesion, class 0 indicates total loss of adhesion.

Economic calculations

Experts of the Association carried out many time studies in the past, to be able to calculate the cost of labour. It turned out that approximately 80 – 85% of painting costs are labour costs. Costs for painting can be split into direct and indirect costs. Direct costs are defined as costs, which are directly related to the painting job. These costs contain activities like sanding, cleaning and actual painting. Indirect costs are defined as costs, which are made to realise the actual painting job. These activities are: (scaffolding), climbing, preparing the working place and materials, planning, appointments with owners to open doors and windows, instructions by management and cleaning the workplace. This results in a direct/indirect ratio of 57/43.

Results and discussion on IR drying

Water borne acrylic

First the results on drying parameters are presented. It appeared that a flash off time without heating and ventilation is important in obtaining good appearance of the coating. There is a difference between with and without infrared drying for water borne formulations with and without or with half of the amount of coalescent. It appeared that coalescent is necessary to obtain a coating film without orange peel. It turned out that the normal amount of coalescent is needed to obtain a smooth film.

A clear difference was observed for drying with and without ventilation. The water borne formulation could be dried till temperatures of 80 °C for 1 minute with 2-3 m/s air ventilation speed. Higher temperatures or longer drying times resulted in blisters. With ventilation it is possible to dry at higher temperatures. The results are presented in table 4 and are compared with the drying time of the reference (without ventilation and infrared heating).

Table 4. Results on IR drying for a water borne acrylic. + Indicates flash off or IR heating with ventilation

Water borne acrylic				
Substrate	Flash off time (min.)	IR heating time (min.)	Surface temperature (° C)	Results
S	-	-	-	**Reference, tack-free after 1.5 h**
S	2 / 10+	1+	100	Before IR already surface dry Blisters after 40 seconds IR irradiation After IR tack-free
S	5+	1+	60	After IR dust-free
S	5+	2+	60	After IR tack-free
S	5+	1+	80	After IR tack-free
S	5+	1/2+	80	After IR dust-free, almost tack-free
M	5	2	60	During application, appearance of blisters. During irradiation with IR, blisters increase without formation of more blisters

S stands for spruce, M indicates meranti

Solvent borne conventional alkyd

For the solvent borne alkyd, the surface could be heated up till a temperature of 100° C for 5 minutes. Higher temperatures or longer drying times resulted in blisters. Compared with the reference (without IR irradiation), initial drying was enhanced by IR heating. Through-drying time was the same.

During the tests, it appeared that air ventilation was needed to prevent blister formation at higher temperatures or longer drying times at high temperatures.

The results are given in table 5 and are compared with the drying time of the reference (without ventilation and infrared heating).

Table 5. Results on IR drying for a solvent borne conventional alkyd.

Solvent borne conventional alkyd			
Flash off time (min.)	IR heating time (min.)	Surface temperature (° C)	Results
-	-	-	**Reference, tack-free after 6 h**
10	5	60	After 2 h, no difference with reference
10	5	80	After 2 h, no difference with reference
10	5	100	After 2 h, no difference with reference

Solvent borne high solid alkyd

For the solvent borne high solid alkyd, a drying temperature of 100 °C with ventilation of 2-3 m/s can be reached. Without ventilation, blisters occur at a temperature of 80 °C. Compared with the reference, earlier dust-free times are obtained by IR irradiation. Through-drying is moderately influenced by IR heating; after 2 h the paint film is not tack-free. Results are shown in table 6 and are compared with the drying time of the reference (without ventilation and infrared heating).

Table 6. Results on IR drying for a solvent borne high solid alkyd.

Solvent borne high solid alkyd			
Flash off time (min.)	IR heating time (min.)	Surface temperature ()	Results
-	-	-	***Reference, tack-free after 5 h***
10	5	60	Earlier dust-free as reference
10	5	80	Earlier dust-free as reference and 5 min. at 60 ° C
10	5	100	During heating, blisters occur. After 30 min. the film is dust-free
10 / 10+	5+	100	No irregularities. After cooling down, film is dust-free. Seems to be through-dry earlier as reference
10+	5+	100	No irregularities. After cooling down, film is dust-free. Seems to be through-dry earlier as reference

+ Indicates flash off or IR heating with ventilation.
For flash off: 10/10+ indicate 10 minutes flash off without ventilation and 10 minutes with ventilation.

The results of drying on glass strips are depicted in table 8. Drying conditions before putting the glass strips on the drying recorder are depicted in table 7.

Table 7. Drying conditions before putting the glass strips on the drying recorder

	Flash off (min.)	Ventilation (m/s)	Temperatur e (°C)	Time (min.)
Water borne acrylic	5	2-3	60	2
Solvent borne alkyd	10	2-3	100	5
Solvent borne high solid alkyd	10	2-3	100	5

Table 8. Results of drying on glass strips

	Water borne acrylic		Solvent borne alkyd		Solvent borne high solid alkyd	
	Ref.	IR	Ref.	IR	Ref.	IR
Tack free [min.]	145	10	70	15	70	10
Through dry [min.]	145	10	470	80	400	110

A remarkable increase in drying time was obtained by IR irradiation. Due to the fact that these results are obtained on the more heat-conductive substrate glass in stead of wood, differences in drying time occur. As a result of IR drying, the films do not show a levelling and setting period.

The results of water uptake are depicted in figure 2. It was noticed that the samples without IR heating were not dried enough. Therefore, no difference in water uptake is observed between reference 1 and the uncoated samples. A clear difference in water uptake (i.e. film formation) is observed between reference 1 (30 minutes drying without IR) and IR (2 minutes drying with IR). A 40 g/m^2 lower water uptake (i.e. a better film formation) is obtained for IR compared to reference 2 (2 hours drying). After water uptake, the coating on samples without IR irradiation is softer compared to the IR treated surfaces. Directly after water uptake, adhesion was measured. For all systems, the adhesion failed (class <3 according to ASTM D 3359). Two weeks after the water uptake, the adhesion was class 4 or 5 according to ASTM D 3359.

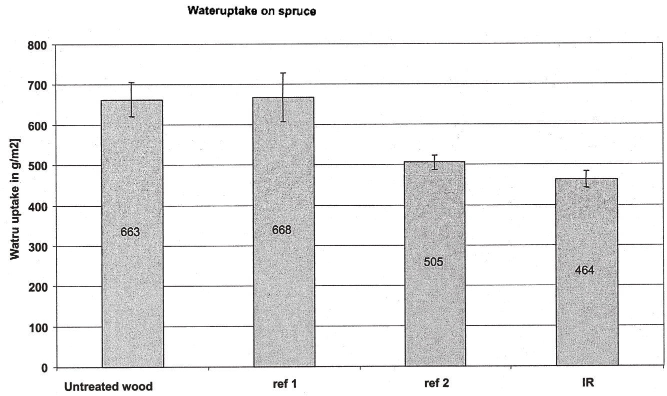

Figure 2. Water uptake in g/m2 for IR and non-IR dried painted spruce panels

Summarising the results, it was shown that infrared radiation is a powerful technique to shorten drying times of water borne acrylics to minutes. Water uptake as an indication for film formation showed a slight lower value for IR dried paint. Early good adhesion is not obtained; indicating that film formation is not completed after the short drying period.

The solvent borne types showed an earlier touch dry time. Although the through dry time was improved significantly, it was still in the order of hours. Differences in results on wood panels and glass strips could be explained by heat uptake of the glass thereby enhancing drying speed.

For all paint systems, air ventilation is necessary to obtain drying without blister formation. Air ventilation without IR heating is known to enhance drying properties too.

Results and discussion on economic calculations

The economical calculations are based on real time studies for maintenance of buildings. The results presented in this paragraph are an average of four time studies carried out during painting four different buildings. The impact of the use of infrared equipment is based on estimations, guided by the results of increased drying properties as described earlier. Experts in the field made the estimations and calculations. In general, it is recognised that IR heating is not a solution for all situations. For each project, a decision should be made whether it is a proper solution or not.

Using infrared equipment has only an effect on the indirect activities; the paint job itself does not change. The calculations were made for the following painting job, which is a typical maintenance scheme:

- cleaning and sanding,
- primering 50% of the surface,
- application of 1 primer layer,
- application of 1 topcoat layer.

The data available from the time studies and the estimations are depicted in table 9 and figure 3.

Table 9. Time spending during a painting job: direct and indirect activities with and without infrared drying.

		Normal	IR drying
Total direct activities		**56,6**	**65,5**
	cleaning, sanding, painting	56,6	65,3
	using IR-equipment	0,0	0,2
Total indirect activities		**43,4**	**34,5**
	climbing/scaffolding	3,7	1,9
	preparation	4,7	4,2
	waiting, due to occupants	1,2	0,8
	changing working place	3,8	1,5
	precautions due to rain	0,7	0,7
	repair and rework	7,8	7,2
	guidance/control	5,7	2,4
	cleaning working place	2,0	1,8
	personal hygiene/breaks	13,8	13,8
	handling IR-equipment	0,0	0,3
Total time spending		**100,0**	**100,0**
Index direct/indirect		**1,3**	**1,9**

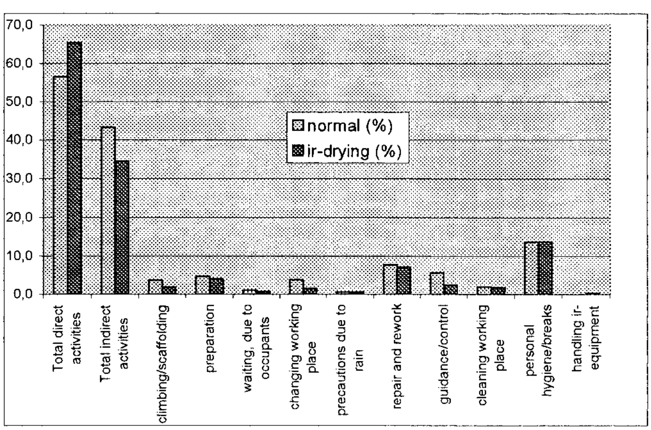

Figure 3. Time spending during a painting job: direct and indirect activities with and without infrared drying.

It is shown that the ratio direct/indirect changes from 1.3 to 1.9. This indicates an improvement of 46% in the ratio. With infrared heating, painters could stay longer on their working spot and finish the maintenance scheme in one time. Therefore, the indirect activities (such as climbing) will be done in a much more efficient way. Also time, spend to make appointments with occupants of the houses will be reduced.

However, using infrared drying probably even more important factors cannot be calculated such as:

- Faster closing of windows and doors,
- A smaller change of damaging of the paint work
- Less delay in finishing the paint job,
- Enlarged time of painting, because infrared drying could be less dependent on climate conditions.

By using infrared radiation, it is possible to create the proper climate conditions for a paint to dry. After application and drying of the primer layer, the topcoat can be applied immediately. Due to the fact that infrared radiation cures the paint layer, lower temperatures and higher relative humidity are believed to have less effect on the drying time. This indicates that the paint job could be done at temperatures of 1 – 5° C and at an RH of 80 – 95%. Herewith, the painting could be done during difficult climate conditions in wintertime. In the near future this kind of experiments will be made with newly developed and specially designed infrared equipment.

Conclusions

- Infrared radiation significantly reduces drying time of water borne acrylics
- Drying of solvent borne alkyds (conventional and high solids) is improved by infrared heating
- Air ventilation is needed to prevent blister formation.
- A significant reduction of indirect activities of painting is possible
- Improvements in drying results in less damaging and less delay of the paint film,
- Enlarging the period for painting in humid and cold climate conditions is realistic.

Future developments

After experimental work on laboratory scale, developments in the industry are needed. Developments on the paint formulation might result in even faster drying times. Portable infrared heating devices must be developed to enable the professional painter to cure the paint on the building site. Attention should be paid to the fact that these devices should be easy to work with and easy to handle.

In the Netherlands, the painters are convinced that these developments will be successful and offer new opportunities. They are optimistic about the preliminary results and are confident to start using IR heating within two years.

Therefore, the Dutch Association of Professional Painters challenges the raw material, the paint and the IR-equipment industry, to develop new products and equipment that meet the specification of completely dried paints within15 minutes.

Organisations

The Dutch Association of Professional Painters (Mr. G. Jonkers B.Sc.) represents more than 6,000 companies with approximately 30,000 individual painters. The association stimulates innovations by sponsoring research programs. One of the goals is to introduce industrial techniques and high-tech applications in painters' daily business. The image of painters will change in this way to a more professional one.

SHR Timber Research (Mr. J. Nienhuis M.Sc., B. Van de Velde B.Sc.) is a research institute carrying out independent contract research for the wood working industry (joinery and furniture), its suppliers (such as coating industry) or its associated professions (such as professional painters). Specific knowledge of infrared heating of wood and curing of paints is used in this project.

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