<u>**For how long would you like it to last?**</u>

By Peter Svane[1]

Coatings should last for a long time, and the literature is full of papers describing how various factors affect the durability. Most of it is probably right, and it may give the impression that the question is extraordinary complicated. However – how difficult is it actually? Here is a pragmatic proposal of *"how to design the service life of a coating"*

Anyone dealing with surface coatings knows that no coating job is better than the initial steps: cleaning, washing, sanding, sandblasting, pretreatment etc. That applies to architectural coatings, to protection of steel and wood, to ships as well as to buildings. Finally you can mention some important factors that influence the service life of the applied coating system:

- the substrate
- the coating material
- the coating system
- the climatic conditions during application
- the climatic conditions during drying and curing
- the skills of the painter or operator
- the conditions the coatings are subjected to during its use
- and many, many other issues

All of this is surely right, and the many demands and preconditions could easily make you confused or distressed. The same applies if you as houseowner have to repaint your windows every five years, or as a shipowner must take your supertanker into dock every second year to renew the antifouling. Anyway: the beheld is in the eye of the beholder, and others may have a different opinion.

The Protocols of the Elders

Some of the papers published in journals for oil- and colourchemists leave the impression that the author is complicating things beyond the necessary. One paper on surface coatings on wood in a Scandinavian journal a couple of years ago for instance showed a route diagram so complex that it ressembled the British railway net – after privitisation. The diagram was an attempt to describe how to paint wood, including all the factors that makes the process so terribly difficult, and that eventually might explain why it doesn't last anyway, even though there was nothing wrong with the coating materials. The author was empolyed at a paint factory – I shall omit the reference.

I have the privilege of a visit from and older oil- and colourchemist that occationally drops in and lets a little of his wisdom shine through. He is now retired and concentrates on important issues like golf and bridge. His view is that the question of durability is not as complicated as that. He has formulated two axioms (a statement that does not require scientific proof):

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[1] Article "Hvor længe skal det holde?" (in Danish) by Peter Svane, Industriel Overfladebehandling 2, June 2002, p. 12-16. Copenhagen, Denmark. Translated 2014 by the author

- The protective value of a coating mainly depends upon its barrier properties
- The ability of a coating material to spread on the substrate is decisive

I myself have taken the liberty to propose a third axiom:

- The durability depends upon the paint film thickness

If you ask whether this applies to coatings on wood, concrete, steel or something completely different, the answer is: Yes, exactly.

Of course there are examples where a thin and porous layer is better suited for a particular purpose than a thick and tight one – but not in the present article. ..

Positive experiences – and some not so good

It is obvious that paint film thickness and barrier properties are related; the thicker the layer, the less permeable it is. The barrier can protect the substrate against some factors *from the outside*: sun, rain, chemical influences, wear and impacts. A barrier however can not protect against harmful factors *from the inside:* underrusting, microorganisms in the substrate or moisture ingress from behind the film; but the barrier (and the ability to spread on the substrate) may help avoiding that degradation from the inside is initiated.

Of course it is not enough to establish a thick barrier; the coating must stick to the substrate and stay stuck. This means that the coating as such must be able to resist various factors, and it should be able to live in peace and harmony with its substrate. If the substrate moves, the coating must be able to follow the movement, and if the substrate heats up, the coating must tolerate the higher temperature. Etc. etc.

Project experiences

The influence from paint film thickness on durability was investigated from 1975 to 1979 in a project "Coating and Maintenance of Exterior Wooden Materials" at Technological Institute Copenhagen. Different coating materials were included in the investigations: high- and low build alkyd and acrylic stains and paints. Even polyurethane paint participated. Exposed panels were evaluated annually for changes in colour, gloss, cracking and flaking; finally all the numbers per panel were combined in a "degradation index" giving an impression of how fast each coating system degraded on a particular substrate; the lower the index, the better the durability. The results are combined in fig. 14 from the final project report.

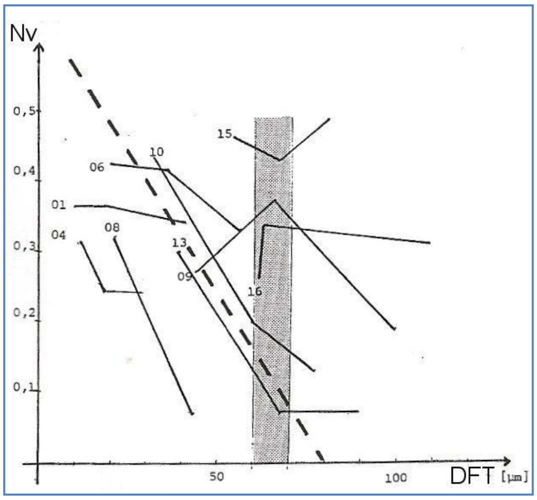
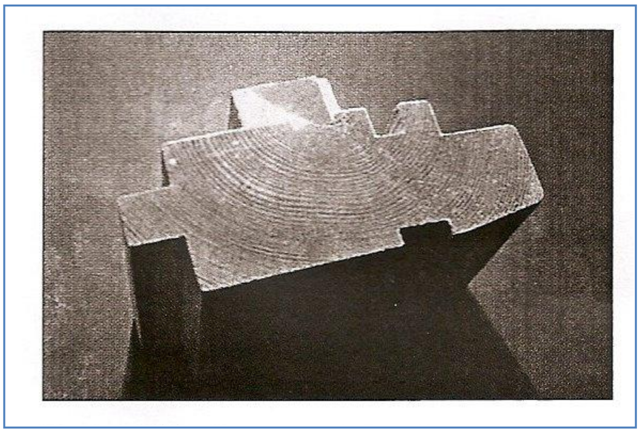


Fig. 14 (Techn. Inst.) How durability of different systems is affected by film thickness expressed by the "degradation index Nv". The dotted line is a mean of all systems.

It is evident from fig. 14 that most systems last longer, the higher the film thickness is. For some systems the dependency is directly proportional (systems 01, 08 and 10), whereas other curves have annoying shapes. I have tried to combine all the graphs in one – the dotted line in fig. 14. This is unscientific, but convenient. If you take the dotted line approach for face value, the degradation index is zero at 80 µm DFT. This means that we - within the project period that was 3-4 years – would not have registered any notable changes on the surface, provided that the DFT was 80 µm or more. Basically this sounds reasonable.

Dr. Miller's 28 year old window

In No 3 (2001) of this journal Dr. E. R. Miller related about his experiences with with a particular coating system introduced around 1970. It was a two-coat acrylic based system for timber windows, and it was applied to a relatively high DFT (250-300 µm). It is documented that *this coating system has lasted 28 years (on windows in British schools) without any other damage than normal soiling (dirt pickup).*



Cross section through one of Miller's renowned windows after 28 years service

"Storstrømmen" Bridge

Back to another article in this magazine; to No. 2 (2001) where we related of a Danish riveted steel bridge "Storstrømsbroen" that was coated with an anticorrosive waterborne acrylic paint applied to a DFT around 400 µm. The Danish Railway Agency informs that they plan to perform maintenance coating every 25 years. This is solidly founded on consecutive research projects carried out by the Agency through a number of years.

Rehacek's investigations

Karel Rehacek from Prague published an investigation in 1996 "Massenabnahme bei Bewitterung organischer Beschichtungen" – "Mass loss by exposure of organic coatings" - (Farbe & Lack No. 8, 1996). He quantifies the degradation in µm / year. From "Abb. 7" of the paper it transpires that a water borne acrylic paint loses 0,5 µm per year whereas a styrene-acrylic paint loses 1,6 µm - i.e. three times as much.

In his "Table 3" Rehacek presents degradation figures for several coating types. It is clear that pigments improve durability; the results show a considerable spread between different coating types. "Pure acrylics" definitely are among the best. The question however is how "pure" normal commercial acrylics are. Estimating conservatively this type of coating hardly loses more than 2 µm / year; nevertheless in the following I have used the estimate 4 µm / year .

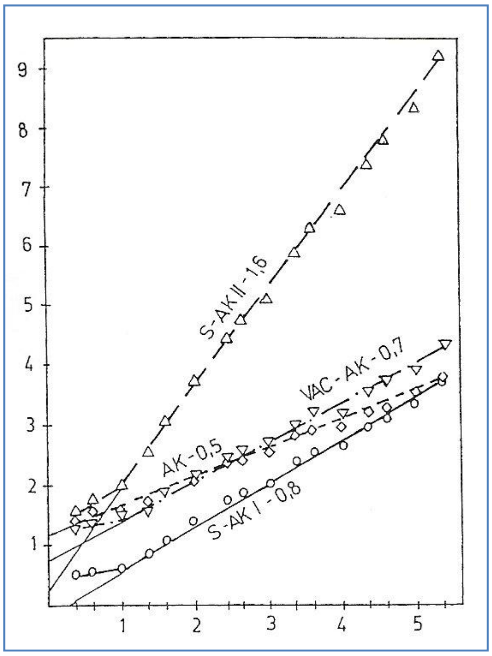


Abb 7. (Rehacek – translated) Paint film reduction by exposure of pigmented (PVC 15 % TiO_2-R) coatings made with waterborne polymer dispersions. AK ~ pure acrylic. S-AK ~ styrene-acrylic. VAC-AK ~ vinyl acetate acrylic. X-axis unit: Years. Y-axis unit: µm

Binder	Pigmentation	
	0	15 % TiO_2
	DFT-reduction µm / year	
Alkyd resins	1,7 – 6,0	0,7 – 1,7
Alkyd-melamine (oven baked)	2,1 – 2,5	1,1 – 1,5
Alkyd-melamine NAD (oven baked)	1,8	1,1
Polyurethane (arom.)	8,8	3,6
Epoxy	7,2	4,2
Disp. Pure acrylic[2]	0,6	0,5
Disp. Styrene-acrylate	2 - 20	0,8 – 1,6

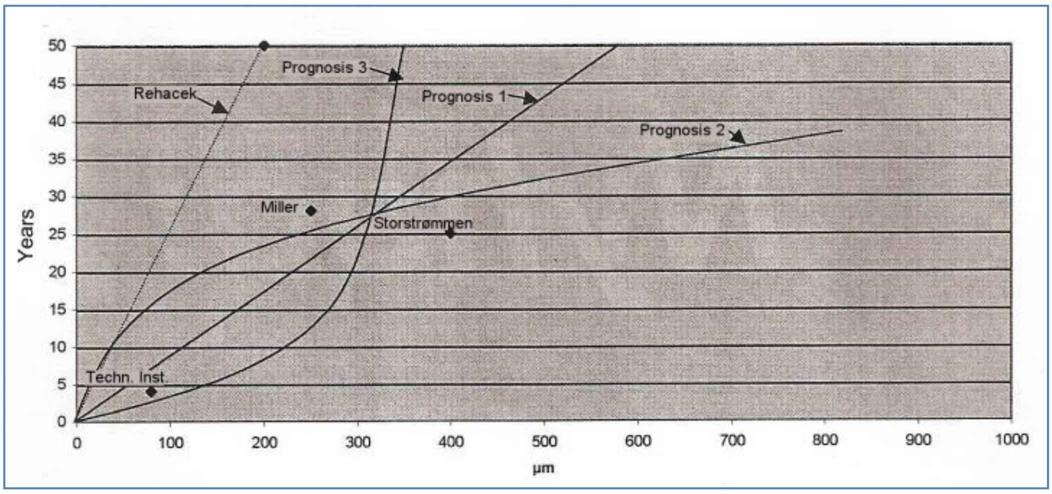
Table 3 (Rehacek - translated): Annual reduction of dry film thickness for coatings with different binders

Theory and real life

In the above we have quoted four different sources that provide information on durability of coatings – most of them on wood, and mainly dealing with waterborne acrylics. The findings are summarised in the table below:

Source	DFT µm	Durability better than years
Techn. Inst.	80	4
Miller	250	28
Storstrømmen	400	25
Rehacek	X	X/4

Documented service life data



Durability versus paint film thickness

[2] This corresponds well with an erosion rate of 1 µm p.a. stated by Miller, E.R: Maintenance-Free Paint for Softwood Windows. Conference paper "Woodcoatings – Challenges and Solutions in the 21th century" Paint Research Association, London (2000)

With these admittedly few data we will now try to estimate how durability depends on dry film thickness. The four data sets are inserted in the diagram "Durability versus DFT". Each of the data represent a documented durability of a certain number of years. It may be that the durability is longer, but it is hardly shorter.

The line "Rehacek" simply represents a surface degradation of 4 µm / year. But the durability of a coating depends on many other factors than superficial erosion, therefore this line is a much too optimistic estimate – or expressed in a different way: a realistic graph must lie "to the right of Rehacek".

In the diagram we have made three assumptions of how durability depends on film thickness:

1) a linear estimate drawn to the best of our ability between the few data points
2) a graph that levels out at high DFT
3) a graph that increases steeply at high DFT

Of these 3 prognoses No 3 seems the most improbable. If it was true you could reach an unbelievably long durability once you exceded a certain DFT-value

Prognosis 2 may be more probable. The idea is that the durability increases with DFT until a certain limit – then you don't achieve much by further increasing the thickness

Graph No 1 is the simplest, and it may be as good as No. 2 which anyway is slightly speculative. The experience from the project at Tecnological Institute somehow also supports the idea of a linear relation. Finally it is convenient that the graph has the inclination

10 µm / year.

If this is right you can design the dry paint film thickness to accomodate any demand for durability quite easily. Do you wish 10 years durability then you should go for 100 µm DFT. But if it ends up with just 50 µm then you must realise that the paint will only last 5 years. If you wish to wait 30 years before you shall repaint your windows, that corresponds to 300 µm DFT – and so on.

It must be stressed that these assumptions are based on limited information, experience and investigations mainly with waterborne acrylic coatings on exterior wood. When the binder changes – e.g. from acrylic to alkyd, or when the substrate is a different one, then the arguments get even more questionable.

But anyway : 10 µm dry film thickness for each year you want the coating to last.

- Is that too simple? - Probably
- Can it be made more complicated? – Definitely
- Is it practically applicable? – Try