AGING CRITERIA FOR PVC ROOFING MEMBRANES

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The quality of roofing membranes relates specifically to their aging and weathering resistance. It is a fact that there are still PVC and other roofing membranes on the market which do not function satisfactorily over a reasonable time period. Premature failures surely will soon become public and the reputation of plasticized PVC as roofing material will just as surely be jeopardized.

Manufacturers of high quality PVC membranes cannot be indifferent to membranes which offer poor aging and weather resistance characteristics.

Official specification boards have failed to include real quality criteria in their specifications, and are responsible for the situation, whereby the buyer of a PVC membrane only has information regarding pure material specifications, which have nothing to do with aging and weathering resistance and may give misleading impressions.

The only true picture of membrane quality is obtained by observing performance on real roofing installations under various climatic conditions. Since this is an undefinable and rather long-term process, we would prefer to be able to assess the quality of a roofing membrane in less than half a year under specific, controlled lab conditions. This should be imperative, not only for specification boards with their national standards, but for all research and development staffs who really have to be sure what they are doing.

This paper deals with a new method for quality assessment developed and successfully used in our labs since 1980. The results of this new weathering test will be compared with conventional weathering tests and aging methods. Conclusions will be made with proposals for new quality standards.

ARTIFICIAL WEATHERING UNDER XENON LIGHT

Based on 30 years roofing experience, beginning with bituminous felts, polymer-modified bituminous membranes, Hypalon, EPDM, and finally PVC roofing membranes, we realized that surface crazing of the membrane under artificial weathering condition is the soundest criterion for judging the quality of a membrane in the laboratory.

From the very moment a roofing membrane starts to show surface cracks, the whole deterioration process accelerates dramatically. All movements of the membrane concentrate at the cracks, rapidly decreasing its performance as a waterproofing membrane. Based on this experience, nine years ago the Swiss Standard for roofing membranes SIA 280 established 5,000 hour artificial weathering without surface crazing as a minimum requirement for roofing membranes. The beginning of surface crazing is determined under the microscope at six times magnification on a double folded sample (*Figure 1*). Some long-lasting PVC membranes easily reach 10,000 hours, 4.3 MWs per cm2 in the Xenon tester, which operates continuously at 986 W/m2. We know that many PVC membranes do not meet the standard of 5,000 hours, and that some PVC membranes complying with this 5,000 hour standard still can fail under special conditions on real roofing installations after six to eight years.

The special condition referred to is ponding water, which is basically a slurry of water, minerals and algae containing dissolved salts and acids. According to the specific environment, hydrochloric, sulfuric and nitric acids and the corresponding sodium and potassium salts can be present. Alternating rain and dry periods change the slurry to a shrinking, rigid-mud layer clinging to the membrane. This layer imparts mechanical stress to the surface of the membrane. Growing salt crystals, which can be recognized in the ponding water, also act as chisels in the microcracks, accelerating the surface deterioration process.

Based on these observations we developed a new weathering procedure. Using a regular Sun Tester with Xenon light (823 W/m2) we flooded the samples with a 5mm deep aqueous solution of 5 percent sodium chloride. Under test conditions this solution heats slowly from 20C to about 60C, and dries out in about five hours to form a rigid film of solid sodium chloride on the surface of the membrane. Every 24 hours during the test fresh water is added to dissolve the salt layer. This test with ponding saltwater (psw) proved to be three times more efficient than normal weathering tests in a Xenon Tester at 982 W/m2, continuous exposure in predicting which membranes will age well and offer extended weather resistance. A slow-aging PVC membrane, which had required 10500 hours, or 15 months, for visible crazing, without ponding saltwater, now requires 3000 hours, or roughly four months' exposure with ponding saltwater to begin visible crazing.

Figure 2 shows the set up of the Xenon Tester with ponding saltwater. Figure 3 illustrates the result on a slow-aging PVC tested with Xenon psw compared to regular a Xenon test.

In order to determine a relation to an actual weathering situation we tested a sample taken from a 6-year-old-roof in Riyadh, and tested it again in the Xenon Tester, continuous exposure. It began to craze after 9600 hours compared to 10500 hours for fresh material. We must assume that six years' exposure in Riyadh decreases UV stability of this membrane by less than 10 percent.

Figure 4 shows the artificial weathering behavior of two fast-aging PVC membranes. Both comply with European and Canadian standards for roofing membranes except SIA 280. All three weathering procedures, Xenon continuous exposure, Xenon alternating exposure and Xenon psw, indicate that the UV stability of fast-aging PVC membranes is roughly three times lower than for slow-aging PVC membranes.

THERMAL AGING AND BEHAVIOR IN WATER

It is very interesting to compare these weathering tests with existing aging tests, such as exposure to elevated temperature and immersion in 50C water and subsequently checking weight loss, change in mechanical properties and water pick-up.

The two slow-aging PVC membranes (V_2 and V_3 in *Table I*) 1.2 mm and 1.5 mm thick were tested and compared with the two fast-aging PVC membranes (V_4 and V_5) 1.2 mm thick. Thermal aging at 80C was tested according to UEAtc 4.19.1 for non-reinforced PVC membranes, whereas immersion tests in water at 50C were performed according to the specifications of CGSB (37-GP-54M).

The results of the tests are shown in Table 1, along with crazing and corresponding property change data after Xenon testing.

Special attention has to be given to the fact that weight loss and mechanical change after the specified aging procedures do not differ significantly between the four products. Only Xenon testing reveals the true aging characteristics of a membrane.

CONCLUSIONS

Surface examination after Xenon testing appears to be the most predictable way to qualify PVC roofing membranes. It dramatically shows the weakness of fast-aging PVC materials, which is not demonstrated by commonly used aging procedures. Weight loss, which really means plasticizer loss and a decrease in physical properties after heat treatment or warm water immersion, does not differ significantly between slow-aging to fast-aging PVC materials. On the other hand, these physical property changes clearly can be seen after Xenon testing. Weight loss and decrease in elongation are significantly higher after Xenon procedures with low-quality PVC. A slow-aging PVC seems also to pick up very little water. This is understandable since we know that water always takes part in hydrolytic disintegration reactions.

Currently it requires more than one year to determine which PVC membranes are slow to age using existing Xenon testing procedures. That time can be reduced to about four months by a new testing procedure with ponding salt water. This method also indicates that critical aging phenomena start with surface deterioration.

Considering these facts it is hard to believe that almost all specifications still qualify roofing membranes according to the change in physical properties and weight loss after common aging procedures. In cases where weathering is tested under Xenon light, existing requirements are too mild, because fast-aging membranes still manage to pass the test. Another real problem is the fact that in some countries, specifications for non-reinforced or glass felt-laminated PVC membranes are applied to polyester-reinforced membranes. Here, because of the fabric, stress elongation properties are completely different than non-reinforced or glass felt-laminated materials. Textile fabrics, such as high strength polyester webs, may change slightly in physical properties after heat treatment under wet or humid conditions. This is a unique and irreversible change in the textile structure and has nothing to do with quality decreases in PVC material. In these cases existing testing procedures do not really identify the aging characteristics of the PVC membranes. High-strength polyester-reinforcing web incorporated into slow-aging PVC membranes is responsible for increased mechanical resistance and dimensional stability, even after a long service life, and considerably increases the durability of a roofing installation. Polyester-reinforcing is another step forward in membrane technology.

In order to clarify the quality situation of PVC roofing membranes we see an urgent need for new quality definitions based on the resistance of the material under Xenon-light. We therefore propose four standards or grades as described in Table 2. Such an approach, with PVC products clearly labelled according to their aging quality, surprises in PVC membranes can be avoided and PVC may be able to securely maintain its position as a roofing material.

	1.2 mm PVC-V_2	1.5 mm PVC-V_3	1.2 mm PVC-V_4	1.2 mm PVC-V_5
Xenon Testing/Crazing after				
continuous exposure	10,500 hrs.	10,500 hrs.	3,200 hrs.	3,700 hrs
alternating exposure	—	—	5,100 hrs.	5,800 hrs.
with ponding saltwater	3,000 hrs.	3,000 hrs.	800 hrs.	900 hrs.
Weight loss after:				
4 months/80 °C	0.72%	0.56%	0.68%	1.54%
4 months/50 °C/H_2O	0.91%	0.79%	0.89%	1.05%
4,000 hrs. Xenon c. exp.	4.25%	5.12%	9.21%	11.47%
6,000 hrs. Xenon a. exp.	6.01%	6.59%	8.92%	9.47%
1,000 hrs. Xenon psw	1.92%	2.13%	2.43%	2.75%
Rel. Decrease in Elongation after:				
4 months/80 °C	9.2%	6.2%	13.0%	8.3%
4 months/50 °C/H_2O	8.0%	4.4%	5.6%	8.5%
4,000 hrs. Xenon c. exp.	9.5%	5.6%	18.0%	12.5%
6,000 hrs. Xenon a. exp.	6.0%	11.0%	19.5%	26.0%
1,000 hrs. Xenon psw	8.0%	4.5%	13.0%	7.0%
Original Elongation	335%	251%	285%	311%
Rel. Decrease in Tensile Strength after:				
4 months/80 °C	5.1%	4.5%	4.8%	6.3%
4 months/50 °C/H_2O	16.3%	14.2%	15.3%	20.0%
4,000 hrs. Xenon c. exp.	3.5%	3.5%	2.0%	3.5%
6,000 hrs. Xenon a. exp.	5.1%	8.0%	6.8%	7.7%
1,000 hrs. Xenon psw	5.0%	6.7%	5.3%	15.1%
Original Tensile Strength	19.8 N/mm2	20.9 N/mm2	18.9 N/mm2	22.1 N/mm2
Water Pick-up after:				
4 months/50 °C	4.88%	3.94%	8.84%	11.55%

Table 1

	Xenon light (986 W/m2) continuous exposure	Xenon light (823 W/m2) with ponding saltwater
very fast-aging PVC	below 4,000 hrs.	below 1,200 hrs.
moderately fast-aging PVC	4,000–6,000 hrs.	1,200–1,900 hrs.
moderately slow-aging PVC	6,000–8,000 hrs.	1,900–2,500 hrs.
very slow-aging PVC	above 8,000 hrs.	above 2,500 hrs.

Table 2 *Visible crazing under the microscope (20x)*

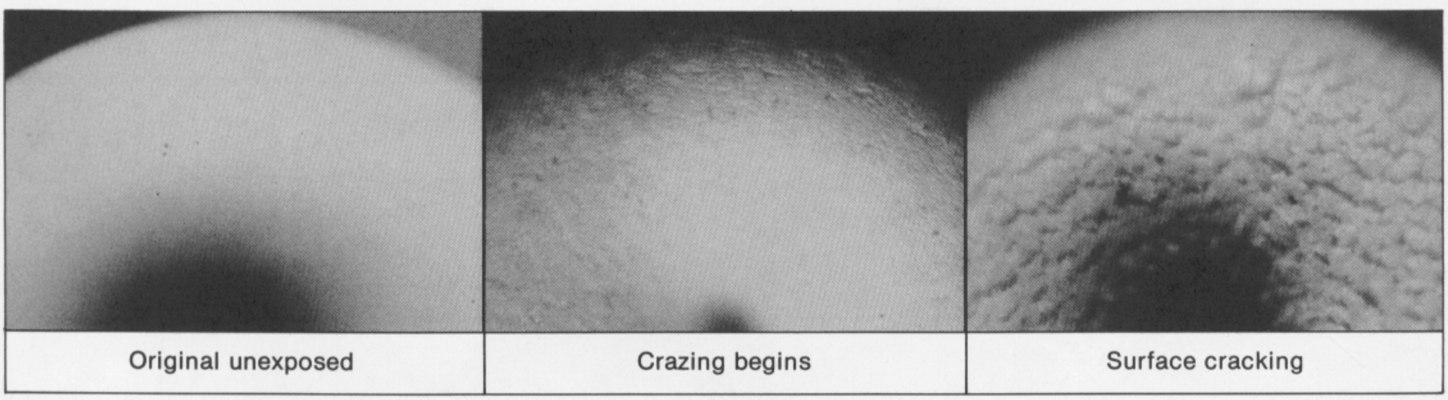

Figure 1 *Surface examination after Xenon testing (magnification 20x)*

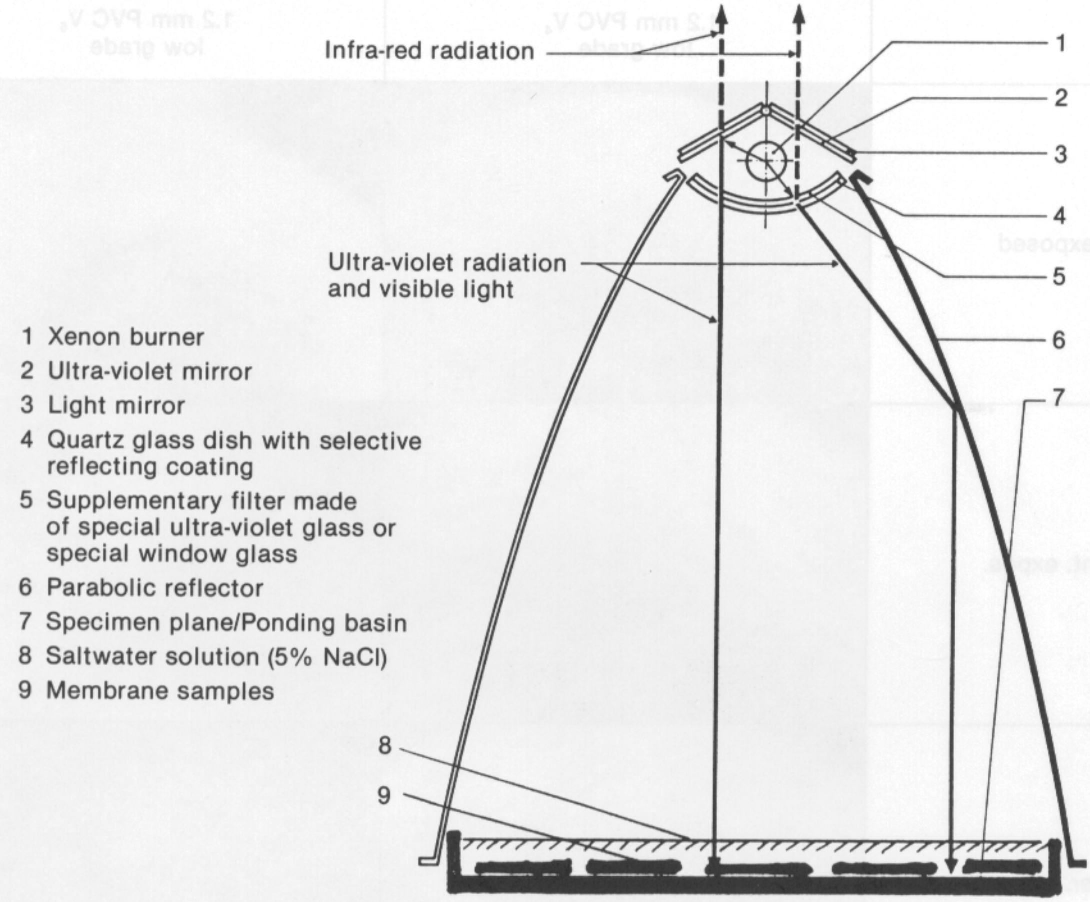

Figure 2 *Xenon Tester (823 W/m²) with ponding saltwater*

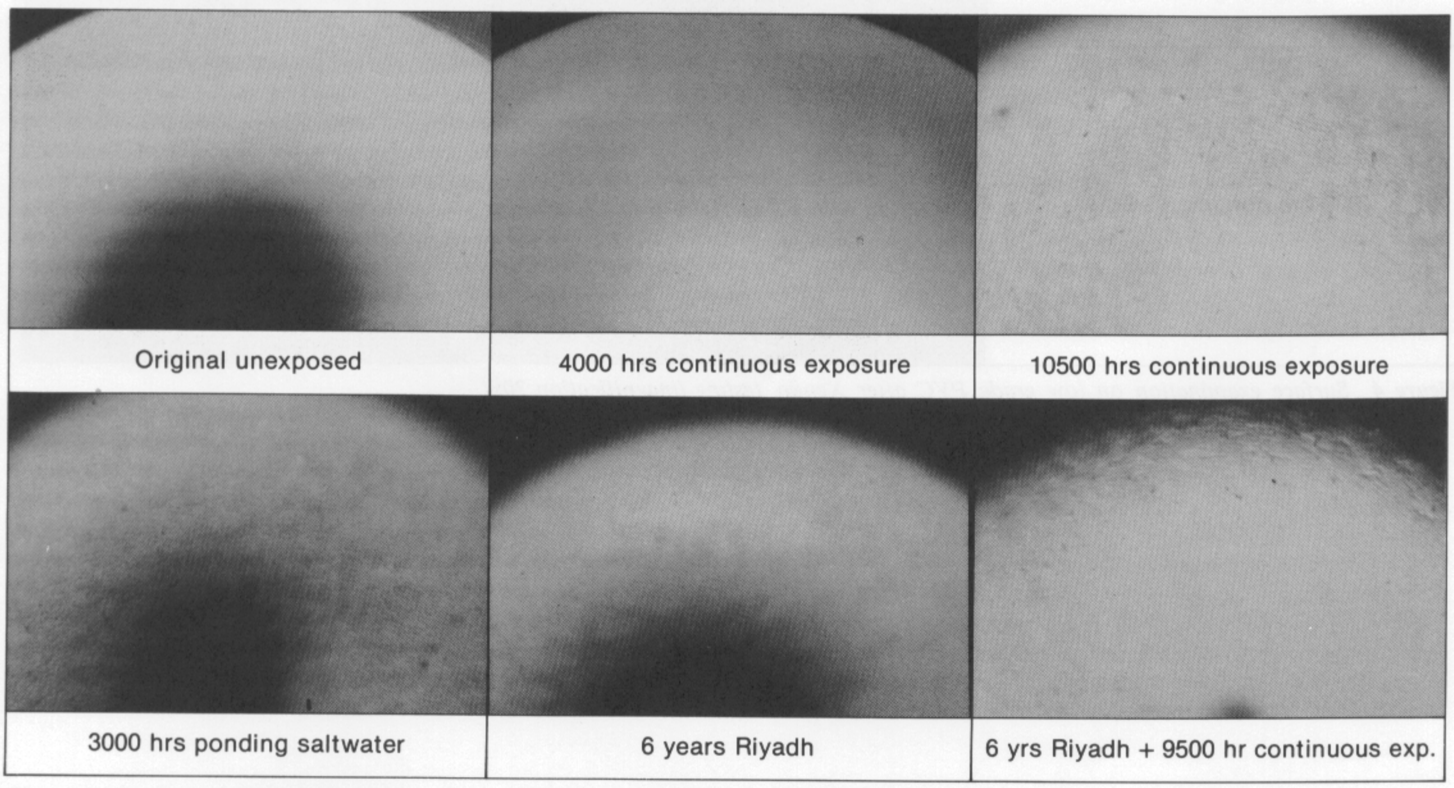

Figure 3 *Surface examination on top grade PVC after Xenon testing (m 20x)*

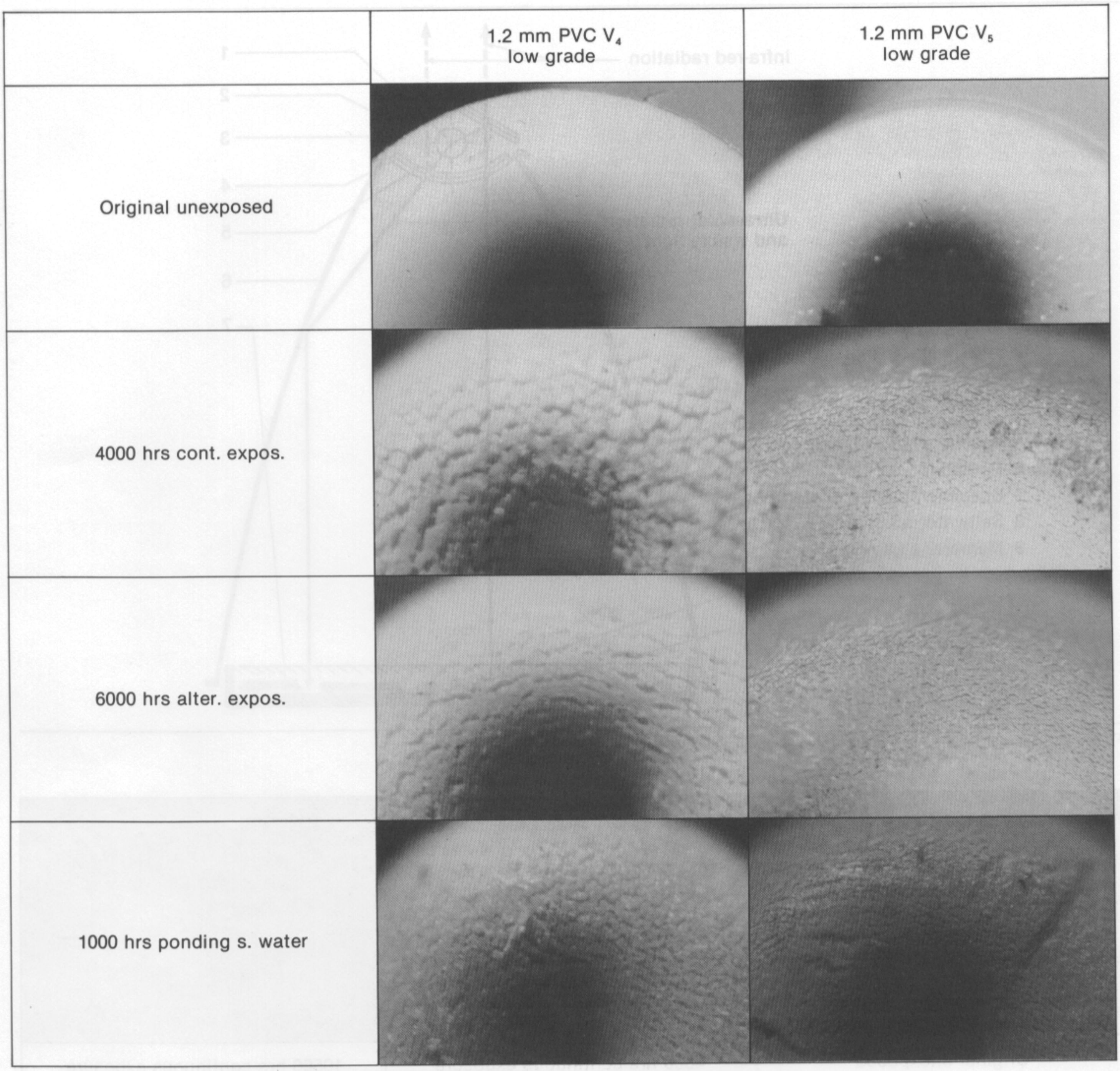

Figure 4 Surface examination on low grade PVC after Xenon testing (magnification 20x)