NO.28
(1990)

BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

BRANZ STUDY REPORT

CI/SfB Vv5

Date May 1990

PERFORMANCE OF NEW ZEALAND WOOD PRIMERS

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PREFACE

This report has been prepared as the second stage of a project looking at methods of testing the performance of wood primers; and using the test methods investigated to evaluate the performance of modern New Zealand wood primers.

ACKNOWLEDGEMENTS

D.P. Krouse and S. Harper are thanked for valuable assistance in the statistical analysis of the data in this report. Rohm and Haas, Resene Paints, and ICI Paints NZ are thanked for their assistance in preparing reference paints.

This report is intended for paint manufacturers, researchers and paint specifiers.

PERFORMANCE OF NEW ZEALAND WOOD PRIMERS

Study Report SR28

REFERENCE

Bennett, A.F. and Jansen, M.L. 1990. Performance of New Zealand wood primers. Building Research Association of New Zealand, BRANZ Study Report SR28, Judgeford.

KEYWORDS

From Construction Industry Thesaurus - BRANZ edition: Bibliography; Durability; Exposure; Finger-jointed; Paints; Pinus radiata; Primers; Testing; Testing procedures; Timber; Treated timber; Water paints

ABSTRACT

Recent developments in wood priming practice in New Zealand have been moves away from lead pigments in primers and oil-based paint systems. New practices include the use of acrylic and oil-alkyd resins for wood primers and overcoat systems. Finger-jointed weatherboards and priming by machine at the mill are also relatively recent developments. This report describes a testing programme using a range of New Zealand primers, both acrylic water-borne and oil-alkyd solvent-borne, which was designed to investigate the effect of these new practices on the performance of paint systems on timber. The main areas looked at were; length of primer exposure before overcoating, effect of finger-joints in timber, type of topcoat, machine application of primer and preservative type.

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INTRODUCTION

This report describes the second stage of a project set up to investigate the performance of wood primers in New Zealand.

The project was set up after surveys were carried out by BRANZ in the early 1980s to assess whether wood priming methods and materials constituted a significant problem in the New Zealand building industry. The survey identified a number of areas where changes to traditional wood priming practices had occurred over the past twenty years or so. These were:

(a) A move away from lead pigments.

(b) The use of different binders in primers i.e., oil-alkyd and acrylic resins instead of oils.

(c) The use of acrylic latex finishing systems.

(d) The use of finger-jointed treated Pinus radiata for weatherboards and sidings.

(e) The use of machines to apply primers to timber at the mill.

It was recognised that given these developments, there was a need for further information on the durability of wood primers. Stage one of the project was set up with the objective of exploring and validating test methods to be used in evaluating wood primers. The results of this stage would then be used in stage two, where durability assessments of primers would be carried out.

Stage one has been completed and the results reported by Jansen and Whitney (1983) and Jansen (1986). This Study Report describes stage two of the project where a variety of wood primers, including proprietary brands, were evaluated using the methods verified in stage one.

Project Objectives

The project objectives were:

(a) To determine whether the performance of modern wood primers is significantly affected by a long period of exposure to the weather (i.e., six months) before overcoating.

(b) To determine the effect of different overcoating systems (acrylic and oil-alkyd) on wood primer performance.

(c) To investigate the performance of wood primers formulated for application by machine at timber mills and yards.

In addition a small scale investigation into the use of different timber types and treatments was also planned.

Project Outline

The project used the experimental outline given in Appendix 2 of Jansen and Whitney (1983). This consisted of subjecting primers to a series of laboratory tests and to natural weathering trials.

Laboratory tests on the primers were carried out for adhesion, blistering, and, in some cases, flash-rusting and blocking. Natural weathering involved exposing sets of timber panels primed with test primers on the BRANZ natural weathering site. One set was exposed for six weeks, and another for twenty-six weeks. After these exposure periods the primed panels were evaluated for surface defects, overcoated and re-exposed. Further evaluations for surface defects were carried out after one year and three years.

Figure 1 gives an outline of the project.

Primers Used In The Tests

The terms acrylic primer and oil-alkyd primer are used throughout this report and refer to water-borne acrylic primers and solvent-borne oil-alkyd primers respectively.

Two of the wood primers which were used in stage one of the project were also included in this work as reference primers. These were an acrylic primer based on Rohm and Haas Rhoplex MV-23 resin and an oil-alkyd primer. A commercially available Totara primer (oil-alkyd based) and a commercially available oil-alkyd primer with aluminium leaf pigment were also included.

Invitations were extended to New Zealand paint companies asking if they would like to participate in the project by submitting wood primer samples. Eight companies responded and provided seventeen primers in addition to the reference primers. The primers are identified by generic type in Table 1. Primer P (an experimental primer under development) was removed from the test programme shortly after testing started.

Two types of undercoat/topcoat system were used; an acrylic system, and an oil-alkyd system. For primers A to D the acrylic overcoating system was based on Rohm and Haas Rhoplex AC 507 (Jansen and Whitney, 1983). For convenience this system will be referred to as the BRANZ acrylic overcoat system. The oil-alkyd system consisted of the oil-alkyd undercoat described by Jansen and Whitney (1983, Appendix 1), and a proprietary high-gloss enamel. This system is referred to as the BRANZ oil-alkyd overcoat system. In each case the topcoat was tinted blue to BS 2660 7-077 (British Standards Institution 1955). Where an overcoat system was specified and supplied with the proprietary primers, these were used. In the cases where they were not specified and supplied, the BRANZ overcoat systems were used. Details of the primer/overcoat combinations are given in Appendix 2.

EXPERIMENTAL PROCEDURE

Laboratory Tests

Blistering Tests

Blistering tests were carried out as described by Jansen and Whitney (1983). This test was based on that of Gans (1972). Panels of finger-jointed radiata, treated to C7/H3 with copper chrome arsenate (CCA) preservative, were primed and exposed for six weeks on the BRANZ natural weathering site facing north at an angle of 45 degrees from the horizontal. Samples for blister resistance testing were cut from the exposed panels, divided into halves and overcoated with the BRANZ overcoat systems, one half being overcoated with the acrylic system and the other half with the oil-alkyd system. The panels were then immersed in water at 20°C for seven days. After immersion the panels were evaluated for blistering according to ASTM D714 (1956) as modified by Gans (1972). After evaluation the panels were placed in an oven at 150°C for thirty minutes. After heating the panels were again evaluated for blistering. The rating scheme is shown in Tables 2 and 3. A microscopic examination was carried out to determine at which interface blistering occurred (i.e., primer to timber, undercoat to primer or topcoat to undercoat).

Tensile Adhesion Tests

Circular aluminium studs, 20.25 mm in diameter were glued, using Ciba Geigy Araldite epoxy adhesive, to panels which were prepared as described for blistering tests. Two replicates, with four studs on each, were prepared for each primer/overcoat combination. After the adhesive had cured for least 24 hours, the paint around the circumference of the stud was cut and the panels soaked for 24 hours in water at 20°C. The studs were pulled off using a Dartec Universal testing machine with a cross-head speed of 5 mm/min.

Blocking Tests

Blocking tests were carried out on one commercial primer and the BRANZ reference primers. The test was based on BS 5082: 1974 as modified by Jansen and Whitney (1983). Quarter sawn 0.6 mm Pinus radiata veneer was used as a substrate for the primers. Two veneers were placed between glass plates with the primed faces in contact. A mass of 500 g/625 mm^2 was applied to the top glass plate for 24 hours. The veneers were then separated and evaluated for surface damage. The rating scheme is shown in Table 4. All tests were carried out in duplicate at 20±2 °C and 65±5 % RH.

Flash Rusting Tests

Flash rusting tests were carried out on three commercial primers and the two BRANZ reference primers. The test used was that described by Jansen and Whitney (1983). Flat-head bright-steel nails were inserted into a panel of Pinus radiata (CCA treated to C7/H3 specifications). The nail heads were not punched below the surface. The primers were brush-applied

and allowed to dry for 24 hours at 20±2°C and 65±5 % RH. The panels were examined then placed primed surface down, on a condensing cabinet at 30°C for 24 hours, then examined again.

Outdoor Exposure

Exposure tests were carried out at the BRANZ site at Judgeford near Wellington (latitude 41 degrees south). The exposure racks faced due north and were at an angle of 45 degrees from the horizontal. The primed timber panels were fastened by plastic tabs at each corner to battens allowing free circulation of air around the panels. The panels were exposed for one of two periods, six or twenty-six weeks. At the completion of the exposure, the panels were evaluated for deterioration as discussed below. After evaluation the panels were overcoated, then exposed for three years with further evaluations for deterioration being carried out at the completion of one and three years' exposure. The panels had dimensions of 500 x 150 x 19 mm. Two replicates of each panel/primer/overcoat combination were used.

Table 5 summarises the timber types, treatment and conditioning used for the exposure panels.

Primers A-T were applied by brush to the panels in accordance with the manufacturers' instructions. The panels were then conditioned for three weeks at 65±5 % RH and 20±2°C. The primed panels to have six weeks' outdoor exposure before overcoating were exposed for two three week periods. The first began on 15 February 1984 (summer) the second began on 26 July 1984 (winter). Between exposures the panels were stored indoors. The panels to receive twenty-six weeks' exposure were placed on the exposure racks on 24 February 1984 and removed on 15 August 1984.

In addition to the panels primed in the laboratory with primers A-T, finger-jointed timber panels were sent to four sawmills which produce weatherboards to prime them at the factory using mechanical priming equipment and then to return them to BRANZ. The four factories used primers G, J, S and U respectively. These panels were to be exposed for twenty-six weeks over the same period as the panels primed in the laboratory. The panels primed with primers J and S were returned as planned, but the panels primed with primers G and U were returned late and were exposed two weeks later. Also, the timber panels primed with primers G and U were not those originally sent for priming.

After exposure for six or twenty-six weeks the panels were rated for cracking, checking, flaking, chalking and front surface disfigurement. The following ASTM standards were used in the evaluation:

- flaking to ASTM D772-81
- surface disfigurement to ASTM D3274-82
- cracking to ASTM D661-44
- chalking to ASTM D659-80
- checking to ASTM D660-44

Following evaluation the panels were overcoated and allowed to condition at 65±5 % RH and 20±2°C for one to two weeks. The overcoated panels were exposed for one year from October 1984 then evaluated as described by

Jansen and Whitney (1983, Appendix 2). In this evaluation the panels were rated for: cracking of the front surface, rear surface and ends, and cracking and flaking of the edges. The scale used for rating of the edges differed from that in ASTM D661 and was that described by Jansen and Whitney (1983) and is shown in Table 6.

The panels were then exposed for a further two years from May 1986. In May 1988 the panels were removed from the exposure rack and evaluated as described for the one year exposure. In addition, the front and rear surfaces were rated according to ASTM 3274-82 for surface disfigurement.

RESULTS

Laboratory Tests on Primers Exposed for Six Weeks

Blistering Tests

A summary of results of the blistering tests are shown in Table 7. The panels were only rated for blistering where the blisters involved the primer i.e., where the primer lifted from the timber or the undercoat lifted from the primer.

The blistering tests showed no significant effect by primer type, but the overcoat system did have a significant effect on blistering. More blistering was observed with oil-alkyd topcoats.

To enable statistical analysis, the rating scale for frequency of blistering shown in Table 3, was converted to a numerical scale as follows S=8, F=6, M=4 and MD=2.

Adhesion Tests

The results of the adhesion testing are summarised in Figures 2 and 3. Considerable variability was observed in the results for the adhesion tests with a coefficient of variation of 77% for all the samples combined. Because the magnitude of the standard deviation of the individual adhesion results increased with the magnitude of the means, a logarithmic conversion of the adhesion data was used to test for differences in performance.

No significant difference could be detected between the means of the results for the acrylic primers versus the oil-alkyd primers. The type of top coat did have a significant effect at the 95% confidence level. Overcoating with the acrylic system resulted in greater tensile strengths being recorded. The variability between timber samples with the same primer was significant and obscured variations within the primers themselves.

Flash Rusting Tests

Flash rusting tests were carried out on primers A and B and three commercial primers I, O and R. Primers A, B and I showed no rusting in

this test. Primer R showed very slight rusting, and primer O extensive and heavy rusting on all nail heads.

Blocking Tests

The results of the blocking tests are shown in Table 8. Primer B had moderate blocking resistance whereas primer R had good resistance. The oil-alkyd reference primer A had good blocking resistance.

Outdoor Weathering

Exposure of Primed Panels

The primer/timber combinations, with one exception, were in good condition after the six and twenty-six week exposures. The exception was a series of panels primed with primer P. These panels showed severe deterioration after twenty-six weeks' exposure with flaking and cracking of the primer film. Signs of this deterioration were visible on the panels exposed after six weeks. This primer was withdrawn from the test programme at this point. Minor cracking on the front and ends of some of the panels primed with other primers was observed. This was in most cases due to cracking of the timber beneath the primer. Disfigurement of the front surface and chalking were noted for a number of primers.

A summary of the evaluation results is given in Table 9.

After One Year's Exposure of Fully Overcoated Panels

The overcoated panels were in good condition after one year of weathering on the exposure rack. All variables except cracking of the panel edges received a mean rating greater than 9 (Tables 10 and 12).

An analysis of the results was carried out using the procedures described in Appendix 1. The effect of length of primer exposure was considered using primer/timber combinations for which there were balanced data on exposure and topcoats (i.e., primer/timber combinations exposed for both six and twenty-six weeks and with both an acrylic and oil-alkyd topcoat). In most cases the mean values over all the timber/primer samples were higher for the panels which had been exposed for 6 weeks only (see Table 10). However, for only two variables (cracking of the ends of the panels), were the differences shown to be statistically significant at the 5% level (see Table 11). Interaction between the overcoat type and the primer exposure period was noted for many of the variables.

It is not possible to separate out the influence of substrate on the performance of the different primers, but a comparison can be made of acrylic and oil-alkyd primers on the C7/H3 treated panels with both acrylic and oil-alkyd overcoat systems. Table 12 gives the mean ratings for variables by primer type and overcoat type. The effect of primer type is not strongly evident but a significant effect can be seen on end-cracking and edge-cracking (Table 13). For end-cracking, oil-alkyd primers gave higher ratings while acrylic primers gave higher ratings for edge cracking. Some interaction with the topcoat type is also evident with

higher ratings being recorded for top-edge-cracking where the topcoat was acrylic.

Three Years' Exposure of Overcoated Panels

Summaries of the panel evaluations after three years' exposure are given in Tables 14-20.

The panels in general are in good condition and at first observation appeared to have deteriorated very little during the two years' exposure since the last evaluation. The statistical analysis described above for the one year results was repeated using the three year results, with the addition of analysis of ratings for disfigurement of the front and rear surfaces of the panels.

Primer Exposure Period

Table 21 gives mean ratings for the variable evaluated by primer exposure period and topcoat type. As with the one year exposure results, the general trend is for higher ratings for the panels where the primer was exposed for six weeks compared with those where it was exposed for twenty-six weeks. However only for one variable, cracking on one end, was the difference statistically significant at the 5% level (Table 22).

Primer Type

Table 23 gives the mean ratings by primer type (oil-alkyd or acrylic) and topcoat type (oil-alkyd or acrylic). The effect of primer type varies with the variable being rated. For cracking of the front surface, the oil-alkyd primers gave a higher mean rating, but the difference was not significant at the 5% level. Acrylic primers gave higher mean ratings (significant at the 5% level) for cracking of the rear, one end, the top and bottom edges and for disfigurement of the rear of the panels (see Table 24).

Overcoat Systems

The effect of the overcoat system shows up strongly in the analysis of the results for both exposure period and primer type (Tables 22 and 24). The use of acrylic overcoat systems gave higher ratings for most of the variables evaluated apart from cracking of the rear of the panels and disfigurement of the rear of the panels (which were left in the primed only condition).

Timber Type

The effect of timber on primer performance (Table 19) is difficult to separate from the effects of the primers themselves. Looking at primers A to D exposed for six weeks, information can be gained on rimu, totara and C7/H3 and C8/H1 radiata pine. Totara appears to perform better than the other timbers but as the total number of observations is small (32) it is difficult to determine any significance in the results.

An informal comparison of the different primer/timber combinations for which there is balanced data, reveals that no combination is consistently worse than the others across all the variables rated. The finger-joints in the CCA and boric treated panels did not detract from the performance of the paint systems. The presence of the joints could be detected by close visual inspection, but they were not associated with any increased degree of paint failure.

Factory Primers

A comparison was made between the panels primed (by both brush and machine) with primers marketed for machine application, and the standard primers on C7/H3 treated radiata pine. This showed that the factory primers performed as well as the standard primers. For one variable, cracking on the left end of the panel, the factory primers gave higher ratings significant at the 95% level.

A comparison of the performance of machine applied primers with brush application of the same primer was only possible for primers J, S, L and U, as primer G, brush applied, was not exposed for twenty-six weeks. The comparison showed that, apart from one variable (cracking on the rear left half of the factory primed panels), there were no significant differences visible after three years' exposure.

DISCUSSION

Primer Exposure

The primers were generally in good condition after the six and twenty-six week exposures and, in most instances, met the various performance levels suggested by Jansen and Whitney (1983). In summary the minimum rating levels proposed by these workers were: chalking 7, surface disfigurement 7, checking 10, cracking of front surface for 6 weeks' exposure 10, cracking of front surface for twenty-six weeks exposure 9, cracking of ends for 6 weeks exposure 9, cracking of ends for twenty-six weeks' exposure 8, flaking 10.

Primer P after twenty-six weeks' exposure, failed to meet these criteria for flaking, cracking of the ends and cracking of the front surface. No other primer showed more than one rating below the suggested minimum. Chalking ratings of 7 or less were obtained only for primers used in factory priming of timber. In two cases (primers G and J), this occurred when the primer had been exposed for only six weeks. All the primers apart from T and S (both factory applied), met the suggested level for surface disfigurement. After twenty-six weeks' exposure these two primers had surface disfigurement ratings less than 7. This result suggests that these primers would be best limited to shorter term exposures. None of the primers showed any flaking and the mean ratings for front surface cracking were above the minimum levels suggested. One primer had ratings for cracking of the ends below those suggested above. Primer B (the reference acrylic primer) on C8/H1 treated finger-jointed radiata timber after twenty-six weeks' exposure had a rating of 7.

Overcoated Primed Panels

The overcoated panels were in very good condition after one year's exposure with little deterioration visible. Three years' exposure resulted in further deterioration of most of the painted panels but overall the level of deterioration was still low. This has made it difficult to detect differences between the effect of primers and the effect of timber treatments. The experimental method has been shown to detect poor performance of primers in stage one of this project, (Jansen and Whitney, 1983) and in the deterioration of primer P described above. The low level of deterioration of the primers described in this report reflects the good quality of the primers used and the optimal application to most panels in laboratory conditions. Several years further exposure would be required to produce a wider spread in the primer performances.

Perhaps the most obvious indicator of poor paint performance is flaking. Flaking is extremely undesirable and ideally maintenance schedules should be designed so that re-painting occurs before flaking begins. Three boards showed very minor flaking on the front surface after one year's exposure. After three years weathering the number had increased to 35. Most of the panels had only minor flaking and it is difficult to determine whether these result from local surface problems on the timber or are indicators of poor long term performance. Combinations of timber/primer/exposure/ topcoat which had unacceptable flaking were primers D, T and S (factory primed only), on C7/H3 treated timber, exposed for twenty-six weeks and overcoated with oil-alkyd systems.

Practical considerations have limited the number of replicates of each primer/timber/exposure combination used in the test. The small number of replicates for primers other than the reference primers has meant the ability to determine significant differences statistically has been limited. The rating system utilised in the project uses discrete values from zero to ten. This places restrictions on the methods which can be employed to analyse the data. A categorical method of analysis is necessitated in place of the usual methods of analysis of variance.

Effect of Primer Exposure Period on the Performance of Overcoated Panels

The evaluations of the primed panels after the initial period of primer exposure are difficult to relate to the performance after one and three years' exposure of the overcoated panels. Most of the oil-alkyd primers showed chalking particularly after twenty-six weeks' exposure, but this does not appear to be related to poor performance after three years. There is little evidence at this stage of identifiable correlation between the condition of the individual primed panels after the initial primer exposure, and the performance of the individual panels after overcoating and one and three years' exposure.

Current painting practice recommends that primed timber should not be left exposed to the weather for more than about four weeks (Building Research Association of New Zealand 1987). This work shows that the period of primer exposure before painting has an effect on the performance of the the overcoated panels. The primers exposed for six weeks performed slightly better than those exposed for twenty-six weeks. Further

weathering of the panels is required to establish whether the primers exposed for twenty-six weeks will continue to perform satisfactorily over the the expected time to first maintenance of about six to eight years.

Acrylic Versus Oil-Alkyd Primers

A comparison of the acrylic primers as a class, versus the oil-alkyd primers as a class, showed some differences in performance between the two classes. These differences are minor at this stage and further exposure is required to clearly establish whether either of the systems is superior to the other. It is difficult to compare the individual primers apart from A and B because of the small sample size and the effects of the different topcoats.

While the project was set up to evaluate primer performance, most manufacturers market wood primers as part of a paint system for timber. To account for this the topcoats used with many of the primers have been those marketed for use with the particular primer. While this is a more realistic simulation of trade practice than using generic undercoats and topcoats, it has meant the performance of the primers and their interaction with the topcoats has been obscured by the effects of using a variety of different overcoats.

Overcoat Systems

After one year's exposure of the overcoated panels there is little detectable difference between oil-alkyd and acrylic overcoat systems. After three years' exposure the acrylic systems are showing better performance for most of the variables rated. Although the combination of acrylic primer and acrylic overcoat systems generally gave higher mean ratings, there were no indications that the general use of mixed systems such as oil-alkyd over acrylic or vice versa, would result in unsatisfactory performance.

Effect of Timber Type and Preservative Treatment

The primers have performed well on all the timbers used in this study and no deleterious effects from the different preservative treatments have been detected. Totara is known as a timber which can be difficult to paint due to an oily exudate which can retard paint film curing. There was no evidence of this problem with the primers and totara used in this study. But because the totara was from one source only, it cannot be considered representative and problems may still be encountered with this timber. The presence of finger-joints in the timber panels has not caused any reduction in paint performance after three years.

Factory Primers

The results for machine primed panels are complicated by the fact that two of the factories returned primed timber panels which were not those supplied to them for priming. In addition, delays in receiving the panels meant that the dates of exposure for the factory primed panels were two to

three weeks later than the other panels. The small number of factory primed panels also means that it is difficult to determine the significance of variations in performance.

Factory machine priming should provide an environment where conditions for priming are superior to site conditions and approaching those of a laboratory. The results after three years' exposure indicate that factory primers applied in accordance with the manufacturers' specifications will perform satisfactorily. The chalking tendency of the primers used in machine priming applications noted earlier, does not appear to have affected the performance of the painted panels at this stage. Problems with factory primed weatherboards have been reported to BRANZ in the past. The results of this Report suggest that poor performances reported with these products may be influenced by factors such as less than ideal application of the primer, transport and storage abuse, or extensive exposure before overcoating, more than by composition of the product.

Comparison between Laboratory Tests and Natural Weathering

The adhesion results show considerable variability among replicates making it difficult to determine differences between primers. The possibility of using a reference primer as a control on half of each adhesion test timber panel should be considered. All the primers apart from O and P had a mean adhesion strength greater than 200 kPa. This figure has been suggested by Emery (1980) as a minimum level for good primer performance. Primer P which showed severe deterioration and was removed from the study, had a mean adhesion strength of less than 200 kPa for both overcoat types. The value with the acrylic overcoat system was 14 kPa. The mean value for O overcoated with an acrylic overcoat system was 189 kPa, close to the proposed minimum. This primer had not shown significant failure after three years' exposure, supporting the theory that an adhesion strength of around 200 kPa is satisfactory. The adhesion tests were all carried out on unweathered timber. Several reports (Williams et. al. 1987, Underhaug et. al. 1983, Kleive 1986) have shown that adhesion of primers to weathered timber is reduced compared to adhesion to unweathered timber. This emphasises the need for proper preparation of timber surfaces before, priming if satisfactory adhesion is to be attained.

The laboratory tests for blistering do not show any clear relationship with performance after three years' natural weathering. In many cases during the laboratory tests blistering of the topcoat was observed, particularly where an oil-alkyd topcoat was used. These have not been considered in the ratings as these effects are believed to have only a small dependence on the primer, as evidenced by the appearance of these blister types on almost all of the primers used. Primer P showed blistering when heated after water soaking, particularly with the acrylic overcoat system. Primer O also showed blistering after water soaking and heating, but only when overcoated with the acrylic topcoat. The tendency of these two primer/topcoat combinations to blister appears to be linked to their low wet tensile adhesion strength (i.e., less than 200 kPa).

Flash rusting tests were only carried out on four acrylic primers and one oil-alkyd primer. This test is particularly relevant for acrylic primers as the water vehicle may contribute to rusting of steel during the film formation process (Grourke 1977). The extensive flash rusting seen with

primer O highlights this. However, in general flash rusting is not expected to be a significant problem for acrylic primers as anti-corrosion additives are likely to be present in these products to prevent rusting of paint tins.

CONCLUSIONS

After three years' exposure of primed and overcoated wood panels, little deterioration is visible. While there is an overall trend towards better performance by painted panels where the primer has been exposed to the weather for six weeks compared to twenty-six, a statistical analysis shows the trend is only statistically significant for one of the variables rated. The effect of period of primer exposure on the long term durability of paint systems (i.e., five to eight years) has not yet been established and will require further weathering of the panels. Until further data on the effect of primer exposure is available, the general recommendation of overcoating primers as soon as is practicable should be maintained.

After three years' natural weathering, acrylic primers have performed at least as well as oil-alkyd primers overall. The influence of primer type on performance of the painted panels is more evident than the effects of the period of primer exposure. As a class, the acrylic topcoats have also shown excellent performance, and after three years' exposure have higher ratings than oil-alkyd topcoat systems.

Factory primed panels have performed well after three years' exposure of the overcoated primer and cannot be distinguished in performance from the rest of the primers which were brush applied. The number of factory primed samples used for the statistical analysis was very small and limits the sensitivity of the comparison.

No difference was detectable after three years' weathering between the different timbers and preservative treatments used in this study. The presence of finger-joints in the CCA and boron treated panels has not adversely affected primer performance.

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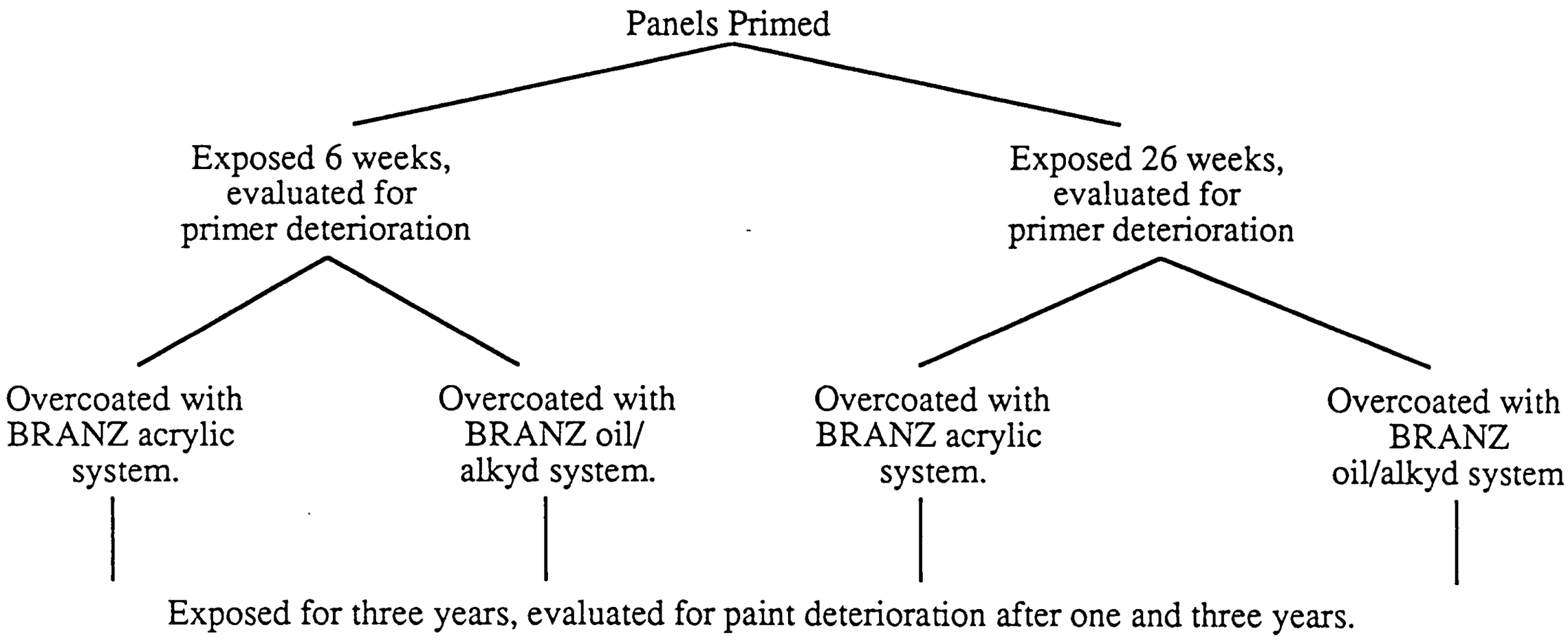
APPENDIX 1 Statistical Analysis

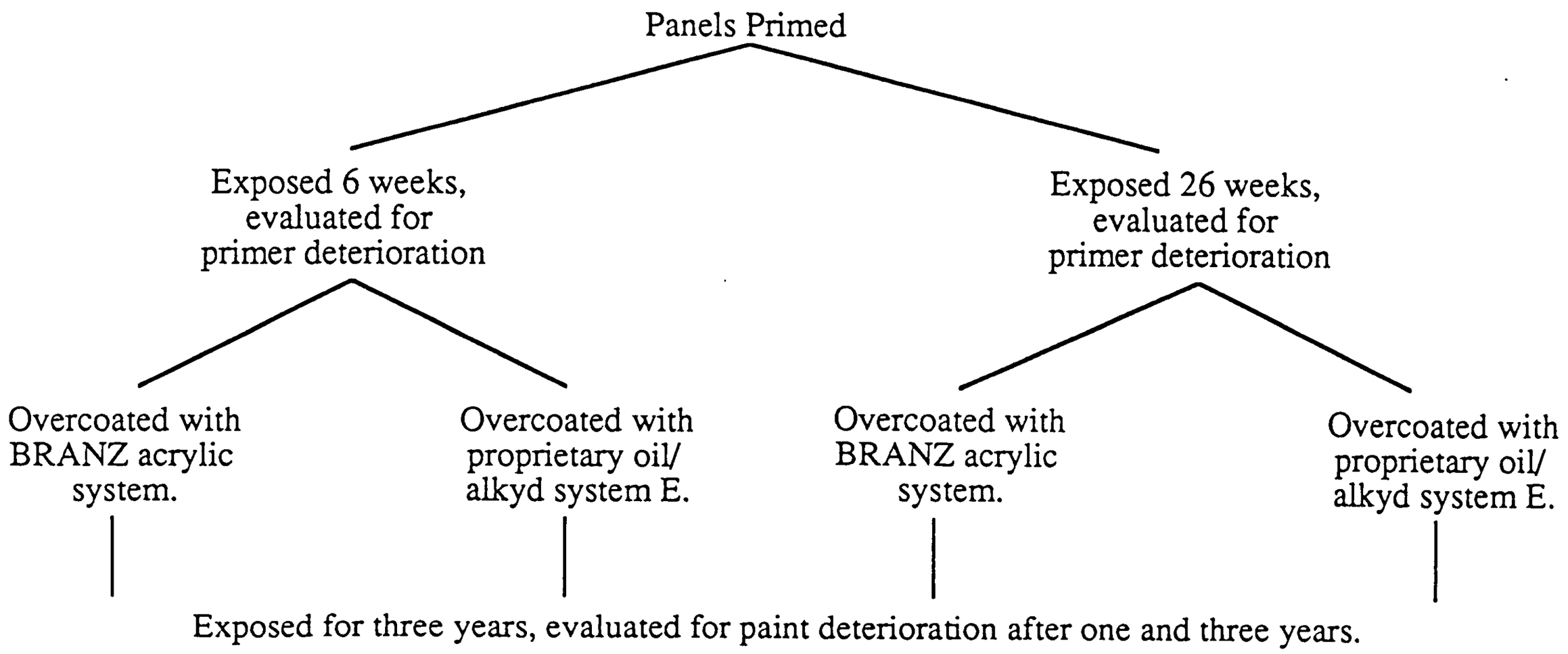
Statistical analysis was carried out using categorical data methods. This was necessitated by the fact that the rating systems use discrete rather than continuous values. Two methods were used; in the first, an approximation was made by subsetting the outdoor evaluation data into two variables. Ratings of 9 and 10 were set to two and those less than 9 to 1. Fisher's exact test (Kendall and Stuart, 1979) for an association between response and primer was used. The second used the categorical data analysis method described by Grizzle, Starmar and Koch (1969), as implemented in the SAS statistical analysis package (SAS Institute Inc. 1985), The latter used data from primer substrate combinations for which balanced information was available (i.e, in this study the C7/H3 treated panels, and the C8/H1 treated panels with primers A and B).

APPENDIX 2. Primer/Overcoat Combinations Used in Natural Weathering Tests.

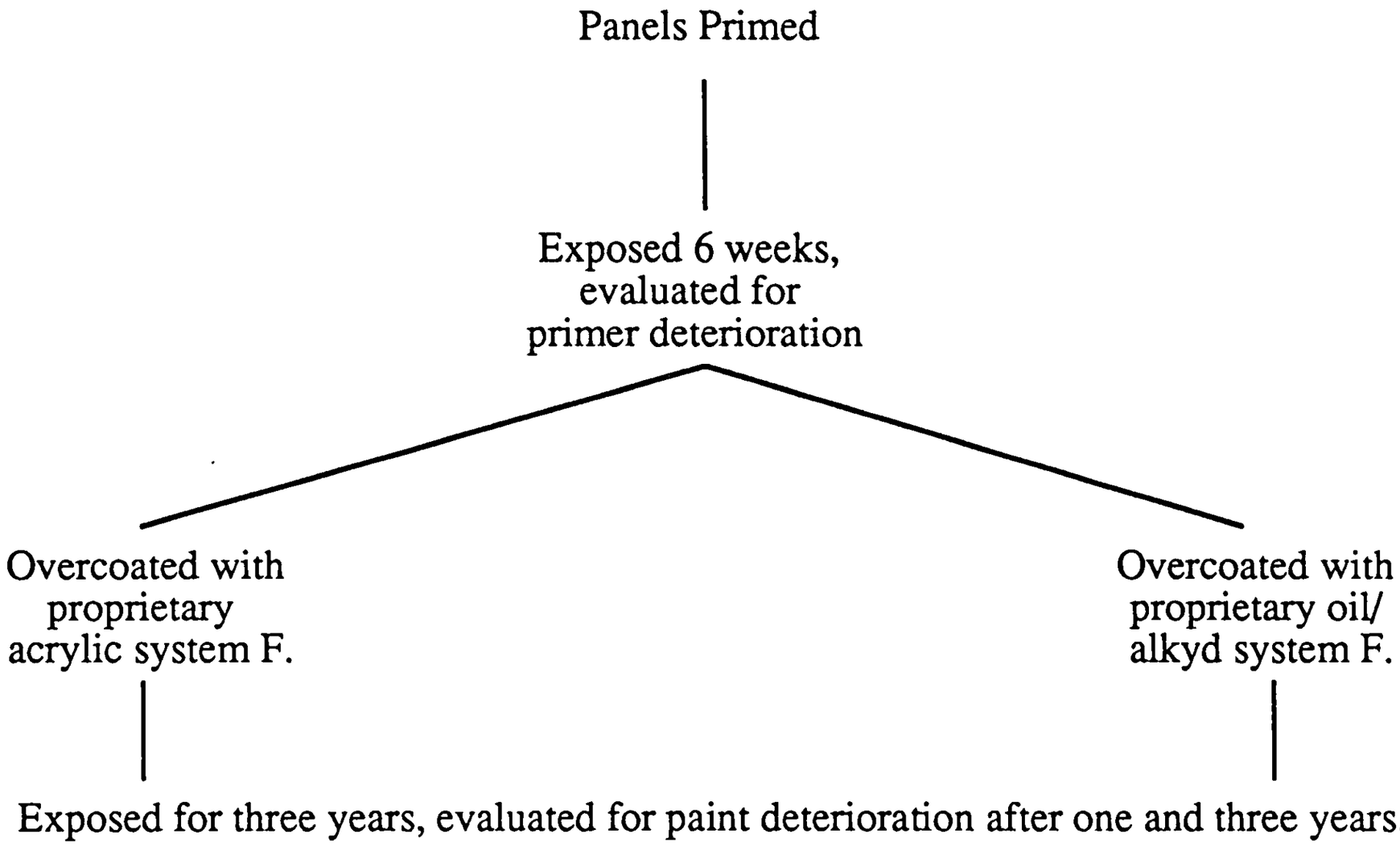
For Primers A-D, S and T:



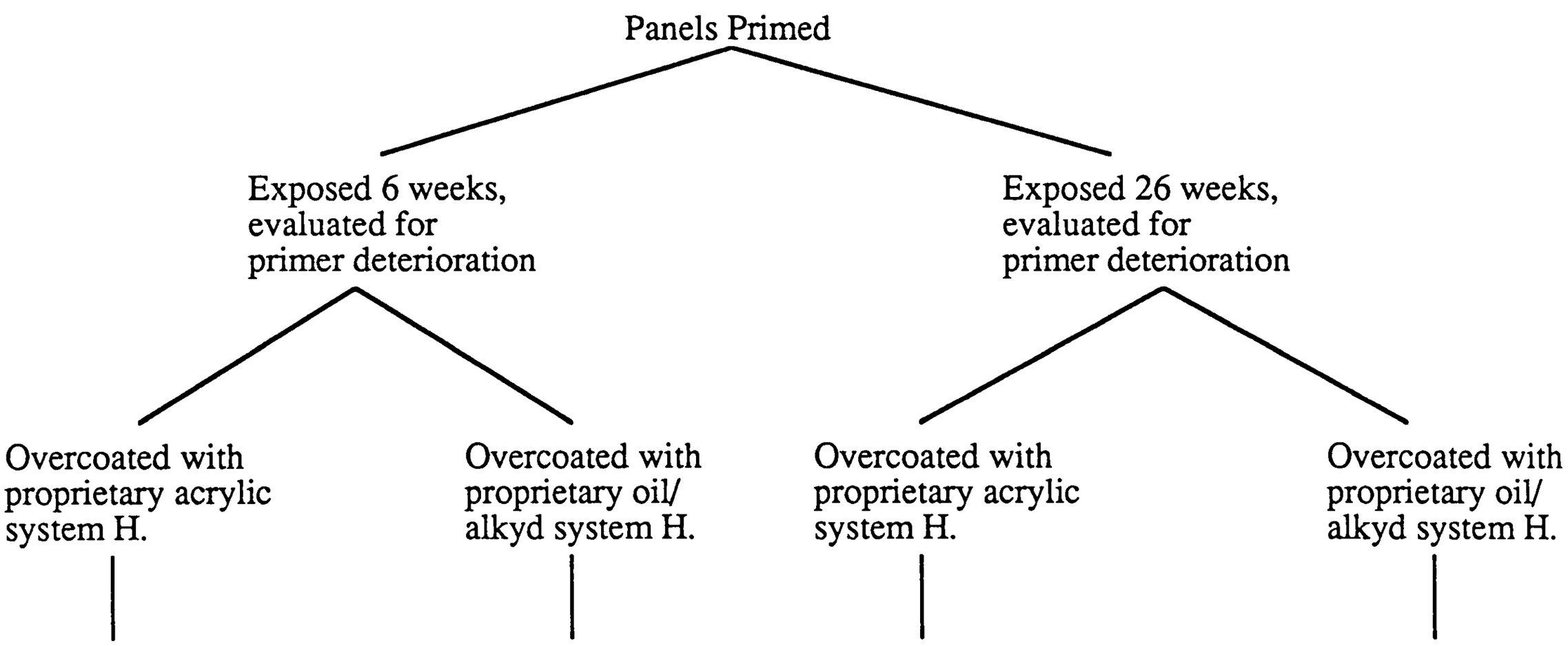
Primer E.



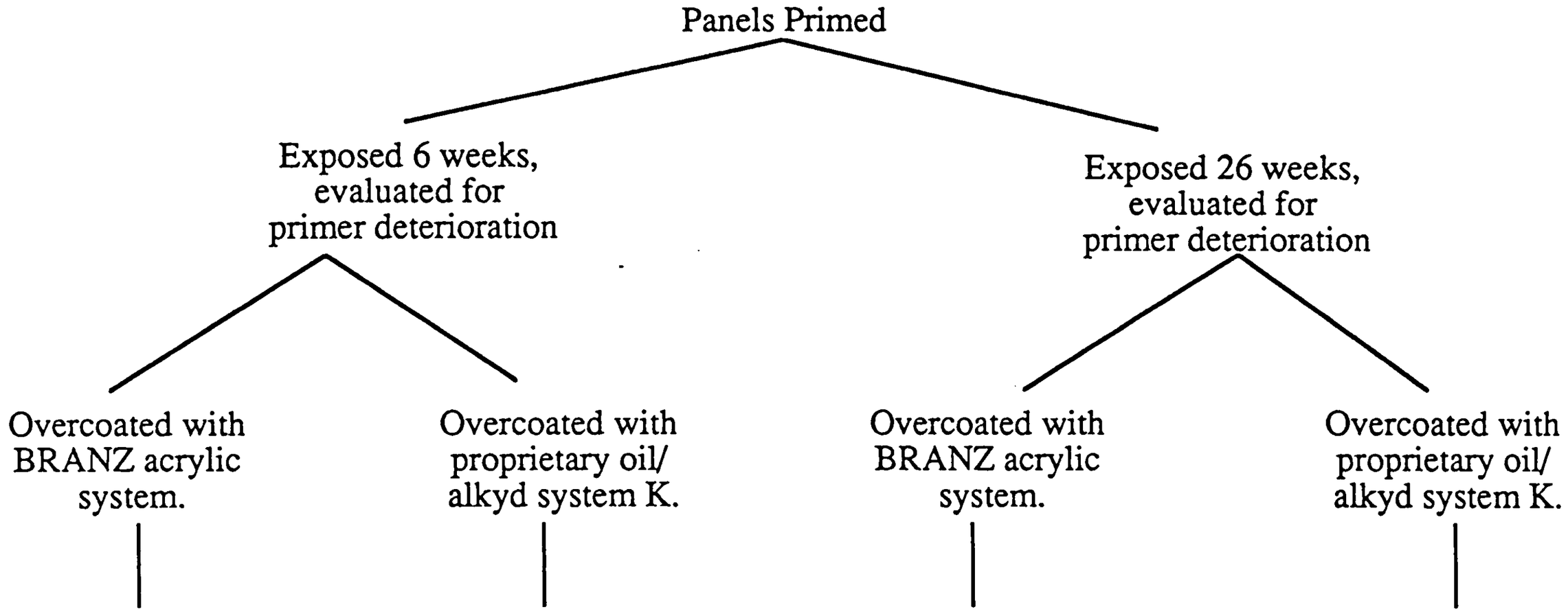
Primers F and G.



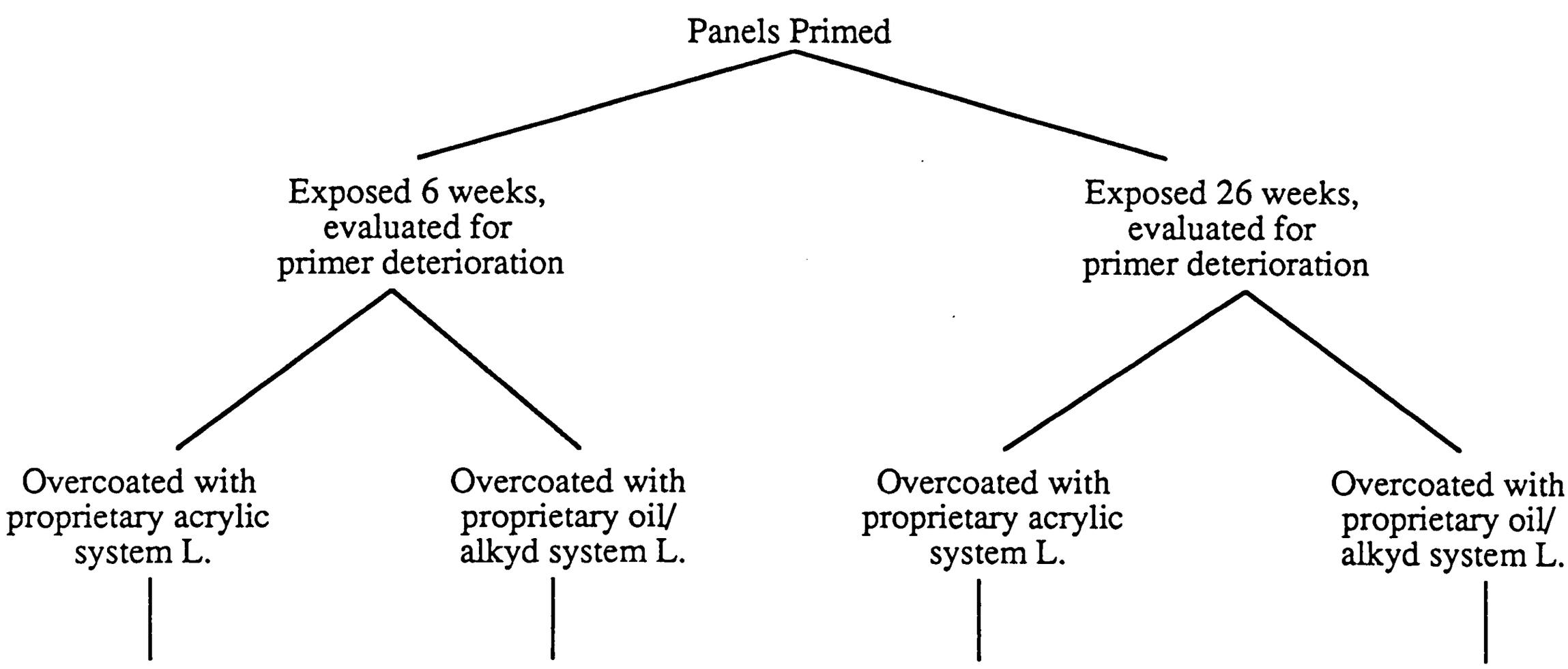
Primers H, I and J.



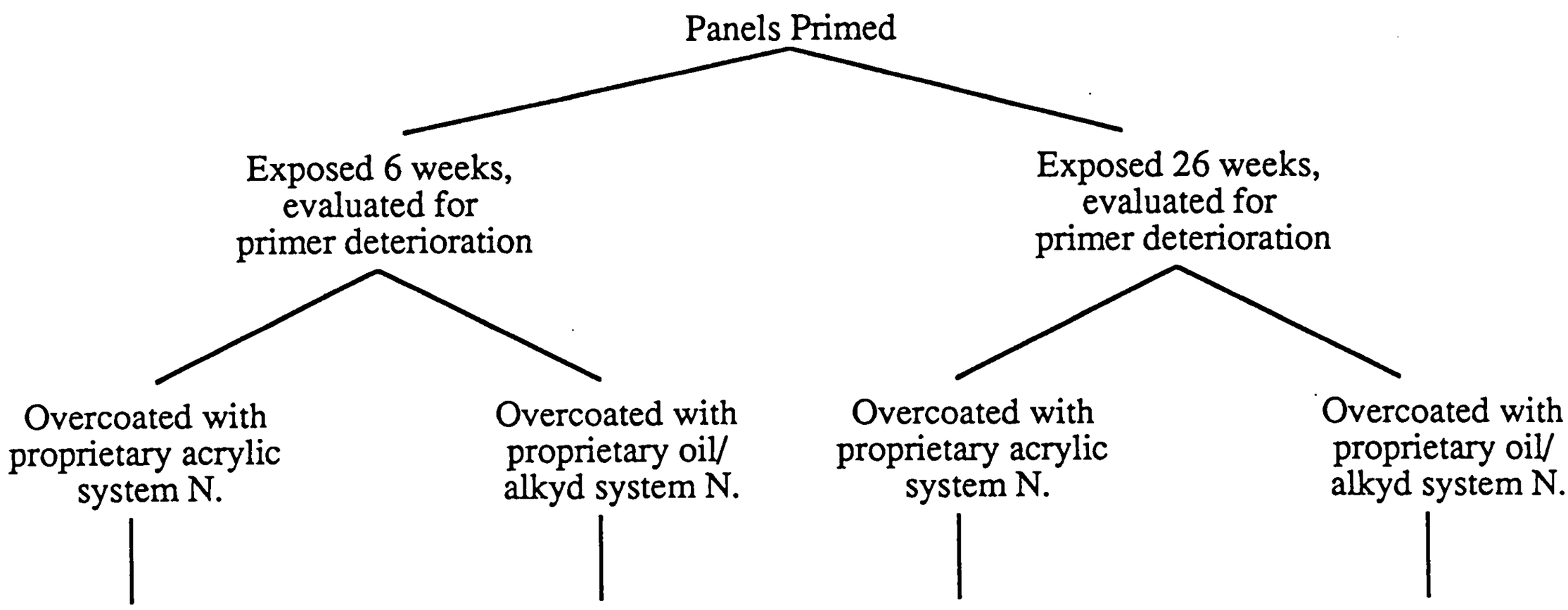
Primer K.



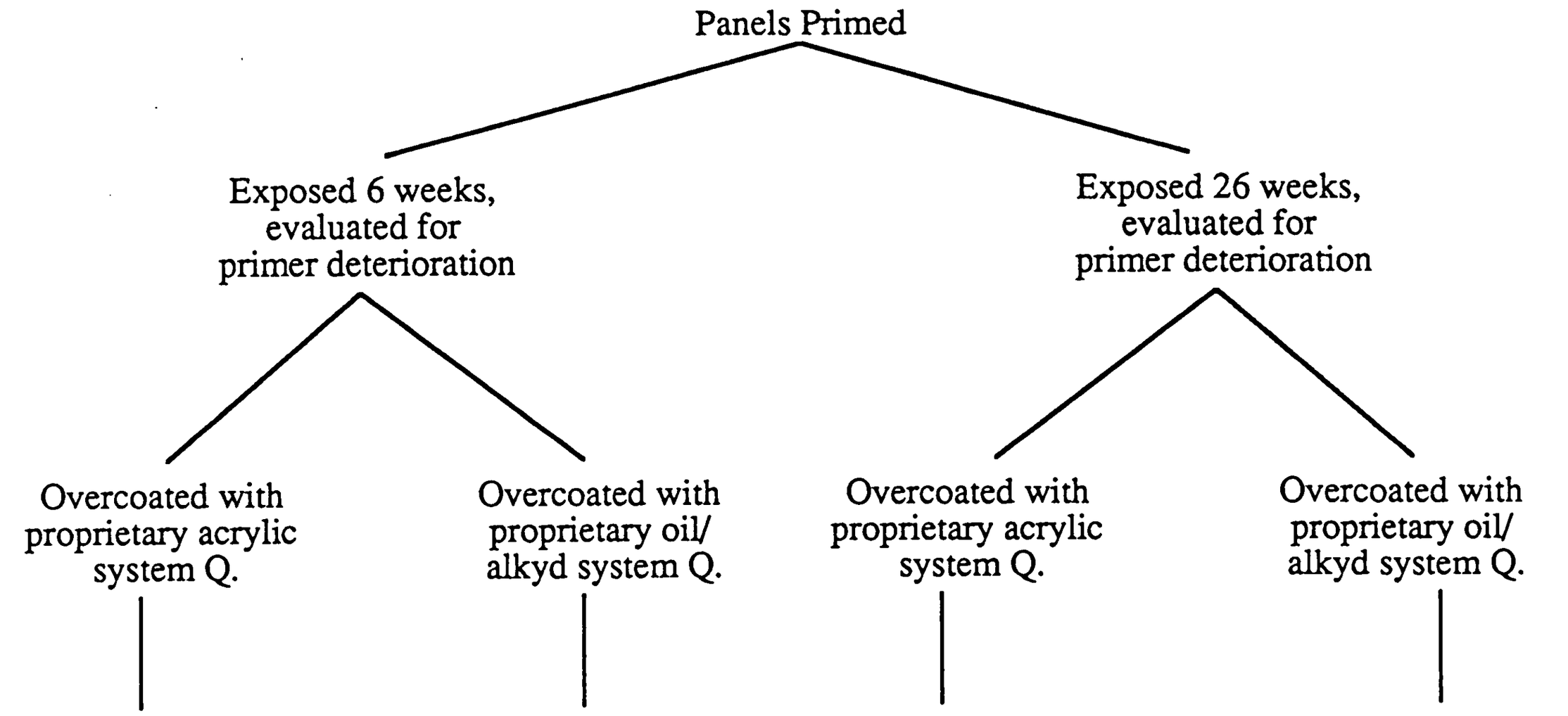
Primers L and M.



Primers N and O.



Primers Q and R.



Panels Primed by Machine at the Factory with Primers G, J, S, and U.

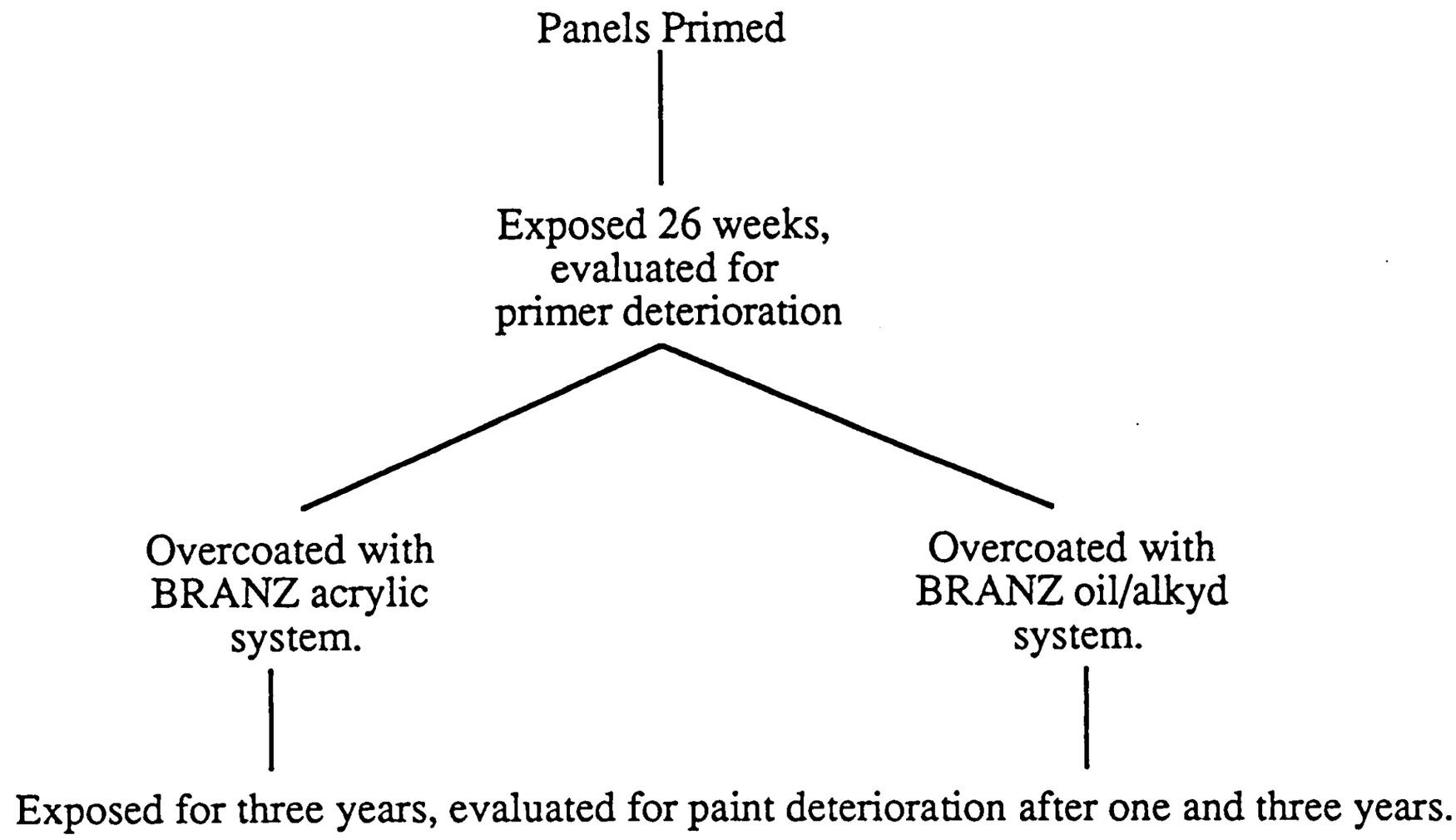


Figure 1: Outline of Project

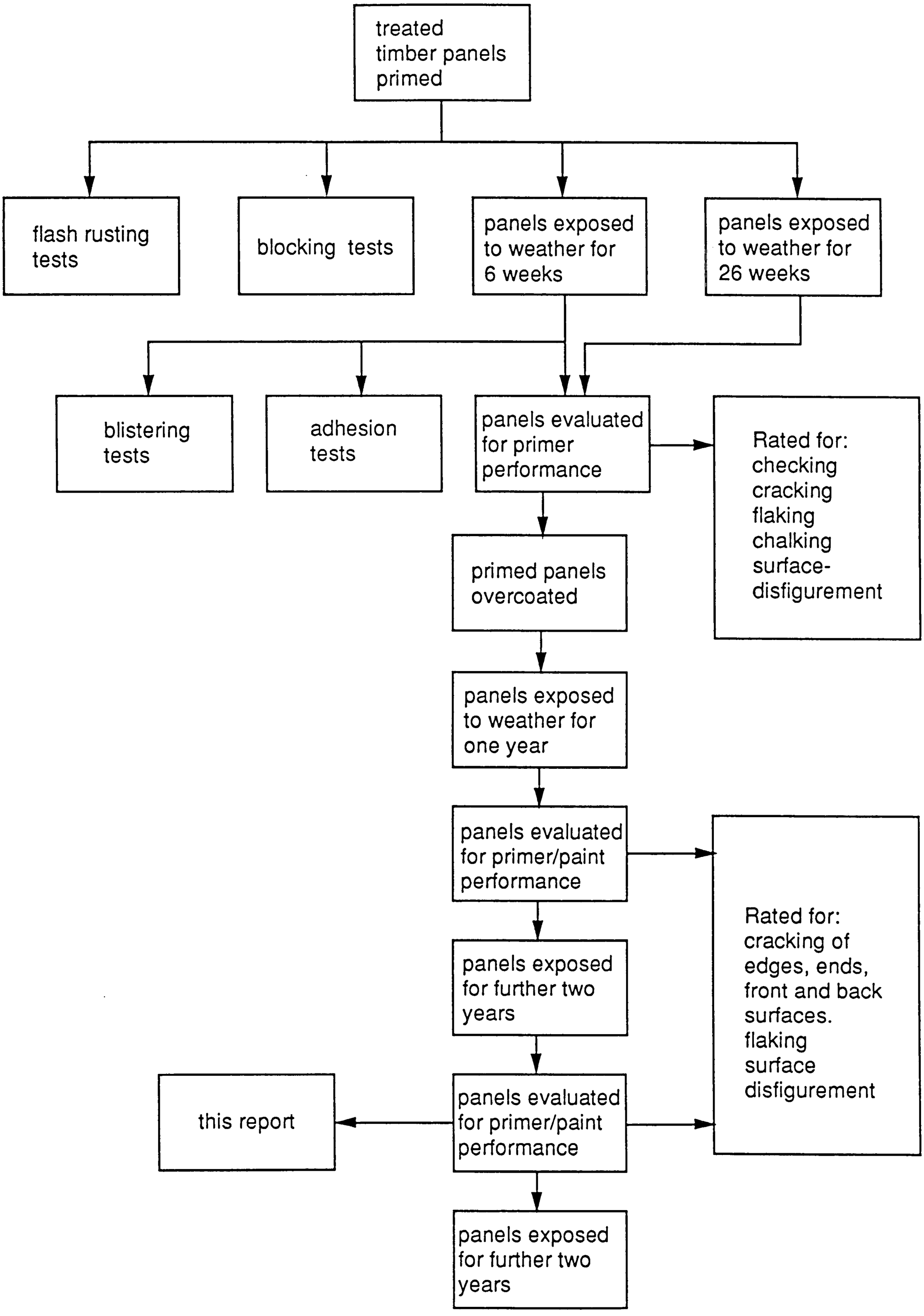


Figure 2: Results of tensile adhesion tests on primers exposed for six weeks then overcoated with the BRANZ oil/alkyd overcoat system (------ minimum recommended value, Emery 1980)

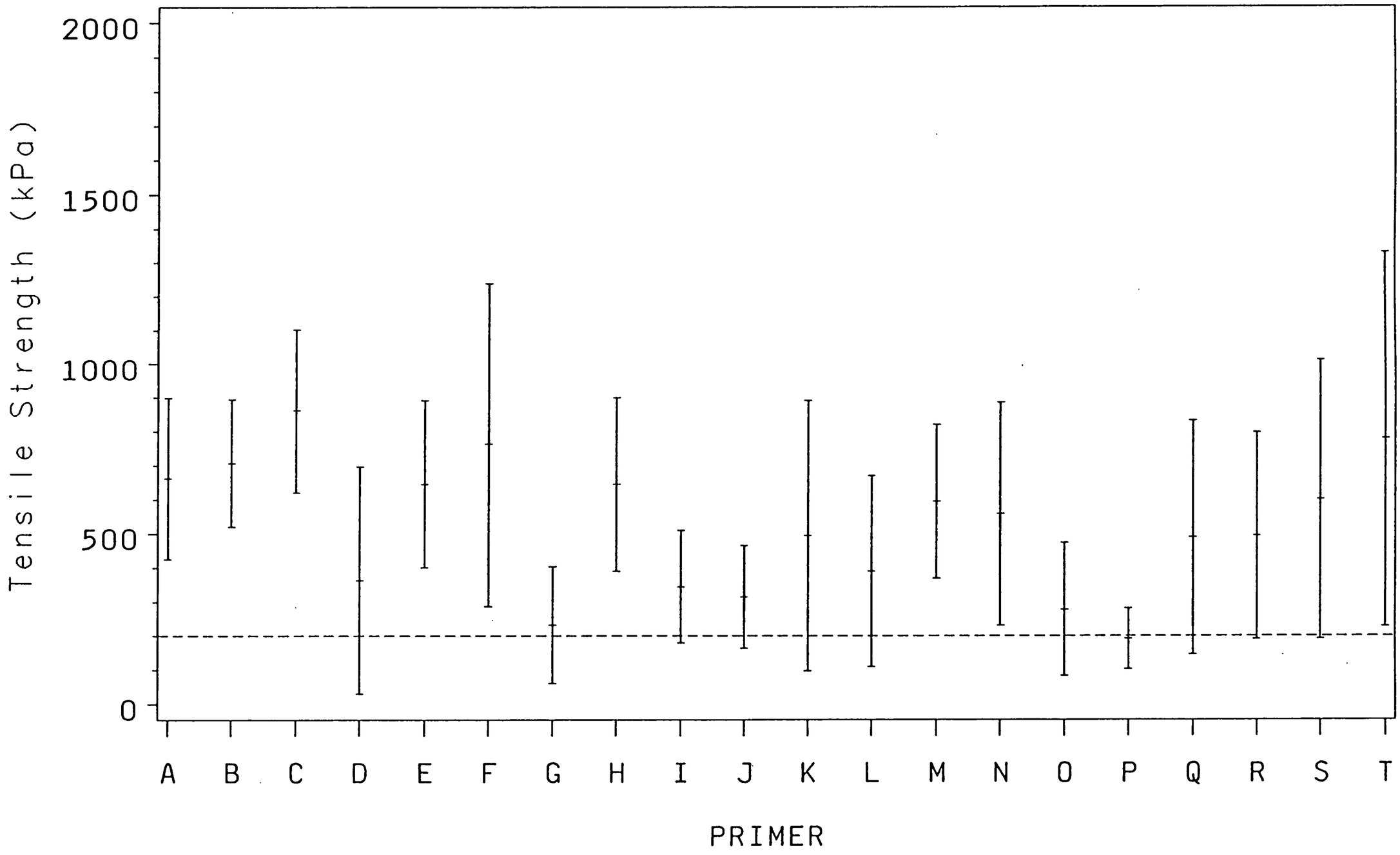


Figure 3:Results of tensile adhesion tests on primers exposed for six weeks then overcoated with the BRANZ acrylic overcoat system (------ minimum recommended value, Emery 1980)

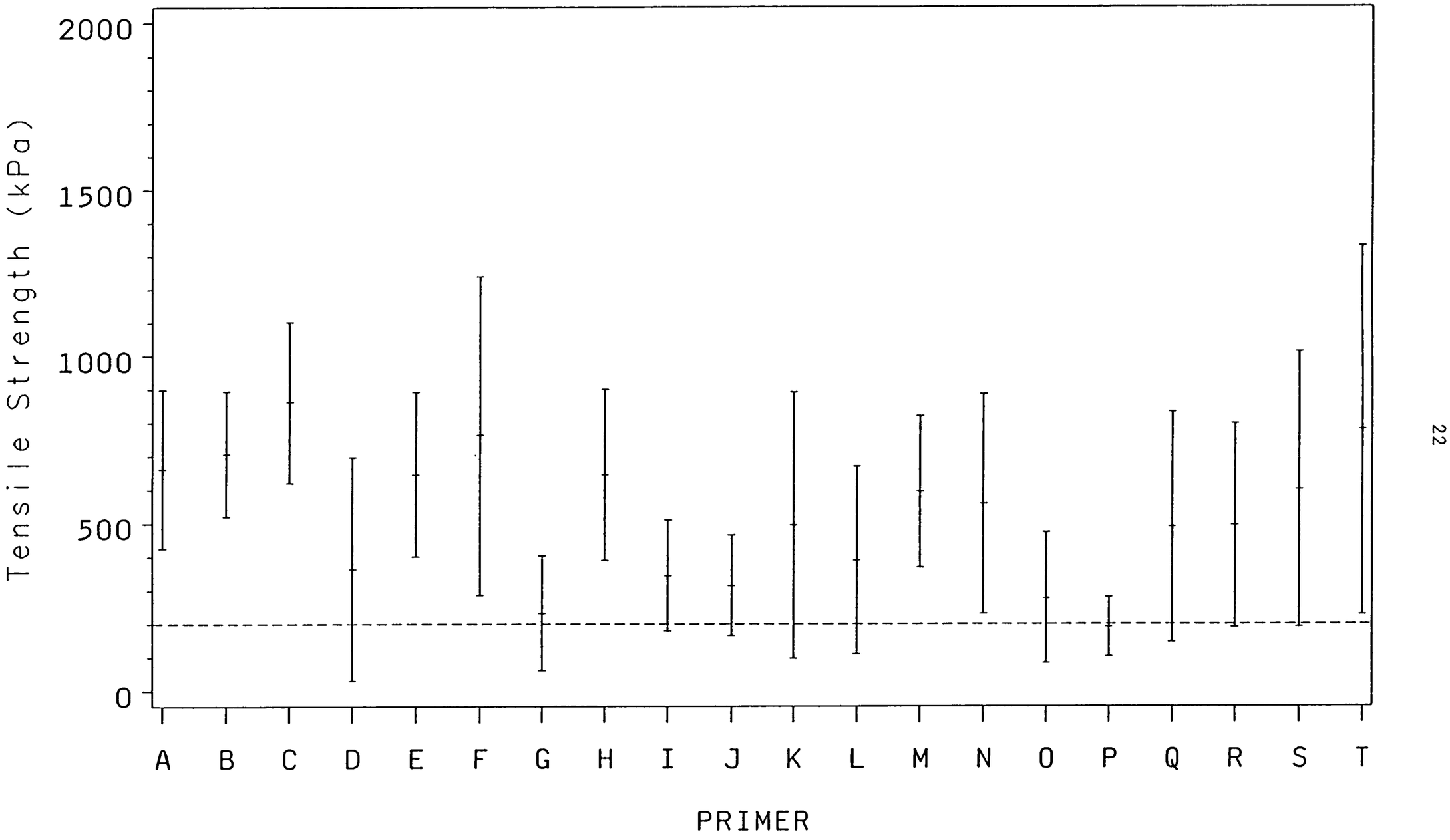


TABLE 1. Primers Used in the Study

primer	binder	comments
A	oil-alkyd resin	reference oil-alkyd primer
B	acrylic resin	reference acrylic primer
C	oil-alkyd resin	totara primer
D	oil-alkyd resin	aluminium primer
E	oil-alkyd resin	
F	oil-alkyd resin	
G	oil-alkyd resin	formulated for machine application
H	oil-alkyd resin	
I	acrylic resin	
J	oil-alkyd resin	formulated for machine application
K	oil-alkyd resin	
L	oil-alkyd resin	
M	acrylic resin	
N	oil-alkyd	
O	acrylic resin	
P	acrylic thermoset	testing of this primer stopped
Q	oil-alkyd	
R	acrylic resin	
S	oil-alkyd	also used for machine application
T	oil-alkyd	
U	oil-alkyd	modified version of L for machine application

TABLE 2. Blister Size Rating

Size	Average diameter
8	0.4 mm
6	0.8
4	2.5
2	5

TABLE 3. Blister Frequency Rating

Frequency rating	Frequency per 650mm^2	
	size 2	size 6
S (scattered)	-	-
F (few)	1	5
M (medium)	2	75
MD (medium-dense)	50	300
D (dense)	100	500

TABLE 4. Blocking Resistance Ratings

Rating	Description
10	No damage; surfaces separate under the weight of the slide
8	No damage; surfaces do not separate under the weight of the slide
6	<= 10% surface damage
4	10-50% surface damaged
2	>= 50% surface damaged

TABLE 5. Substrate-Primer Combinations Used in Outdoor Exposure Tests.

Timber	Pinus # radiata	Pinus # radiata	Pinus radiata	Pinus # radiata	Totara	Rimu
Preservative treatment	CCA C7/H3	Boric C8/H1	LOSP	CCA C7/H3 *	none	none
Moisture content before priming	12%	17%	13%	12%	16-18%	16-18%
Conditioning prior to priming	2 days at SC	21 days at SC	14-21 days SC	factory primed	21 days at SC	21 days at SC
Primers which were used	all	A & B	A & B	A & B	A - D	A - D
Primed panels exposed for (weeks)	6 & 26	6 & 26	26	26	6	6
no. of panels in test	152	16	8	16	16	16

\# Panels were finger-jointed with resorcinol formaldehyde adhesive.
* 8 panels CCA (C7/H3), 8 of unknown origin returned by factory priming companies.
SC standard conditions, 65±5 % RH and 20±2°C.

TABLE 6. Rating Scale for Cracking and Flaking of the Edges

Rating	Description
10	No defects
8	Microscopic defects along < 20% of the edge
6	Microscopic defects along > 80% of the edge
4	Defects detectable with the unaided eye; paint flaking to within 1mm of edge
2	Paint flaking to within 5 mm of edge
0	Paint flaking beyond 5 mm of edge

TABLE 7. Results of Blistering Tests

Primer	Topcoat	before heating size	before heating frequency	after heating size	after heating frequency
A	S	9.0	9.6	8.2	9.2
A	W	10.0	10.0	10.0	10.0
B	S	9.8	9.6	10.0	10.0
B	W	10.0	10.0	10.0	10.0
C	S	9.0	8.0	10.0	9.0
C	W	10.0	10.0	10.0	10.0
D	S	7.5	6.0	5.5	4.0
D	W	10.0	10.0	10.0	10.0
E	S	7.5	7.0	7.5	8.0
E	W	7.0	9.5	10.0	10.0
F	S	10.0	10.0	10.0	10.0
F	W	10.0	10.0	10.0	10.0
G	S	10.0	10.0	10.0	10.0
G	W	10.0	10.0	10.0	10.0
H	S	10.0	10.0	10.0	10.0
H	W	10.0	10.0	10.0	10.0
I	S	8.5	9.0	10.0	10.0
I	W	10.0	10.0	10.0	10.0
J	S	8.5	9.0	8.5	9.0
J	W	10.0	10.0	10.0	10.0
K	S	10.0	10.0	10.0	10.0
K	W	10.0	10.0	10.0	10.0
L	S	10.0	10.0	10.0	8.0
L	W	10.0	10.0	10.0	10.0
M	S	7.5	9.0	7.5	9.0
M	W	10.0	10.0	8.0	9.0
N	S	10.0	10.0	10.0	10.0
N	W	10.0	10.0	10.0	10.0
O	S	10.0	10.0	10.0	10.0
O	W	10.0	10.0	3.5	7.5
P	S	10.0	10.0	7.5	8.0
P	W	10.0	10.0	2.0	4.0
Q	S	7.0	6.0	7.5	8.0
Q	W	8.0	9.0	10.0	10.0
R	S	9.0	8.0	10.0	10.0
R	W	10.0	10.0	10.0	10.0
S	S	8.0	9.0	8.0	9.0
S	W	10.0	10.0	10.0	10.0
T	S	10.0	10.0	10.0	10.0
T	W	10.0	10.0	10.0	10.0

S = oil-alkyd topcoat
W = acrylic topcoat

TABLE 8. Blocking Resistance of Primers

primer	rating	
	replicate 1	replicate 2
A (oil-alkyd)	8	10
B (acrylic)	6	6
R (acrylic)	8	8

TABLE 9. Results of primer evaluations after 6 and 26 weeks of primer exposure

timber	primer	exposure	cracking front	cracking ends**	checking*	flaking*	front* disf	chalking*
b	A	6	10	10	10	10	10	9
b	A	26	10	9	10	10	9	9
b	B	6	10	9	10	10	10	10
b	B	26	10	7	10	10	10	10
c	A	6	10	10^	10	10	10	9
c	A	26	10	10	10	10	8	9
c	B	6	10	10^	10	10	10	10
c	B	26	10	9	10	10	10	10
c	C	6	10	10	10	10	10	9
c	C	26	9	9	10^	10	8	9
c	D	6	10	10	10	10	10	10
c	D	26	10^	10^	10	10	10	10
c	E	6	10	10	10	10	10	10
c	E	26	10	10^	10	10	9	9
c	F	6	10	10	10	10	10	9
c	G	6	10	10	10	10	10^	7
c+	Gf	6	10^	10	10	10	9	7
c	H	6	10	10	10	10	10	9
c	H	26	10^	10^	10	10	8	8
c	I	6	10^	9	10	10	10	10
c	I	26	10^	9	10	10	8	10
c	J	6	10	10	10	10	10	7
c	J	26	10	10	10	10	10	6
c	Jf	26	10	10	10	10	9	6
c	K	6	10	10	10	10	10	8
c	K	26	10	10	10	10	7	8
c	L	6	10	10	10	10	10	10
c	L	26	10	10^	10	10	10^	10^
c	M	6	10	10^	10	10	10	10
c	M	26	10	10^	10	10	10^	10
c	N	6	10	10	10	10	10	8
c	N	26	10	10	10	10	9	8
c	O	6	10^	10^	10	10	10	10
c	O	26	9	9	10^	10	8	9
c	P	6	10^	9	10	10^	10	9
c	P	26	8	7	10	6	10^	9
c	Q	6	10	10^	10	10	10	9
c	Q	26	9	10	10	10	8	8
c	R	6	10	10^	10	10	10	10
c	R	26	10	9	10	10	10	10
c	S	6	10	10	10	10	10	10
c	S	26	10	10	10	10	10	9
c	Sf	26	9	10^	10	10	5	9
c	T	6	10	10	10	10	10	9
c	T	26	10^	9	10	10	5	9
c+	Uf	26	10	10	10	10	10	7
l	A	26	10	10	10	10	10	9
l	B	26	10	10^	10	10	10	10

TABLE 9. Continued

timber	primer	exposure	cracking front	ends**	checking*	flaking*	front* disf	chalking*
r	A	6	10	10	10	10	10	9
r	B	6	10	10	10	10	10	10
r	C	6	10	10	10	10	10	9
r	D	6	10	10	10	10	10	10
t	A	6	10	10	10	10	10	9
t	B	6	10	10	10	10	10	10
t	C	6	10	10	10	10	10	9
t	D	6	10	10	10	10	10	10

b = boric treated timber, c = CCA treated timber, l = LOSP treated timber
r = rimu (untreated)
t = totara (untreated)
f = factory primed.
+ timber of unknown origin returned from factory.
* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
** Average of eight ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
^ At least one rating was less than 10.

TABLE 10. Mean ratings for various primer exposure period overcoat system combinations after one years exposure of panels.

Variable	Primer exposure period/ Overcoat Combination			
	6 S	6 W	26 S	26 W
cracking front right	9.97	9.97	9.82	9.92
cracking front left	9.89	9.97	9.79	9.92
cracking rear right	9.84	9.74	9.75	9.63
cracking right end	9.82	9.92	9.24	9.71
cracking left end	9.82	9.92	9.34	9.68
flaking	10.0	10.0	10.0	9.97
cracking, top edge	5.63	6.21	5.47	5.76
cracking, bottom edge	5.55	5.03	5.03	4.87

Primer exposure period in weeks
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 11. Results of a categorical analysis looking at the effects of primer exposure period and topcoat type on panel performance after one years exposure of panels.

Variable	Primer exposure period	Overcoat system
cracking front right	-	-
cracking front left	-	-
cracking rear	-	-
cracking right end	6 +	-
cracking left end	6 +	-
flaking #	-	-
cracking top edge	-	W +
cracking bottom edge	-	-

\+ Mean rating better (statistically significant at 1% level)
\- Differences are not statistically significant
\# An addcell adjustment was used because of the limited number of response levels.

TABLE 12. Mean ratings for various primer overcoat combinations after one years exposure of panels.

Variable	Primer Overcoat Combination			
	S S	S W	W S	W W
cracking front right	9.91	9.96	9.85	9.90
cracking front left	9.80	9.95	9.85	9.90
cracking rear	9.70	9.68	10.0	9.75
cracking right end	9.73	9.88	9.30	9.65
cracking left end	9.84	9.88	9.20	9.80
flaking	10.0	9.98	10.0	10.0
cracking top edge	5.13	5.63	6.45	6.50
cracking bottom edge	4.80	4.64	6.25	5.50

S Oil-alkyd
W Acrylic

TABLE 13. Results of a categorical analysis looking at the effects of primer overcoat combinations on panel performance after one years exposure of panels.

Variable	Primer type	Overcoat system
cracking front right	-	-
cracking front left	-	-
cracking rear #	-	-
cracking right end	S *	-
cracking left end	-	-
flaking #	-	-
cracking top edge	W +	W *
cracking bottom edge	W +	-

\+ Mean rating better (statisticallly significant at 1% level)
* Mean rating better (statisticallly significant at 5% level)
\- Differences are not statistically significant
\# An addcell adjustment was used because of the limited number of resonse levels.

TABLE 14. Results for cracking of the front surface of C7/H3 treated Pinus radiata after three years exposure of the overcoated primed panels

Primer	6 weeks exposure *		26 weeks exposure *	
	S	W	S	W
A	10^	10^	9	10
B	10	10	9	10
C	9	10^	8	8
D	10^	10	9	9
E	10^	10^	10^	10^
F	9	10	-	-
G	10	10	-	-
H	10	10	10	10
I	9	10	9	9
J	9	10	9	10
K	8	10	10	10
L	9	10	10^	10
M	9	10^	9	10
N	10	10	10	10
O	10^	9	9	9
Q	9	10^	9	10^
R	8	1^	9	9
S	10	9	10^	10^
T	9	10	7	10

* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
\- primed panels exposed for six weeks only.
^ At least one rating was less than 10.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 15. Results for cracking of the rear surface of C7/H3 treated Pinus radiata after three years exposure of the overcoated primed panels

Primer	6 weeks exposure		26 weeks exposure	
	S	W	S	W
A	9	8	10^	9
B	10	10^	10	10
C	8	7	7	7
D	10^	9	9	10^
E	8	8	8	8
F	9	9	-	-
G	9	10^	-	-
H	9	10^	9	10^
I	9	10^	10^	9
J	9	10^	10	10^
K	10^	10^	8	9
L	8	9	7	9
M	8	10	9	10^
N	10^	9	10^	10
O	9	9	8	9
Q	8	9	9	9
R	9	10^	7	9
S	10^	9	9	10^
T	8	9	7	8

* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
\- primed panels exposed for six weeks only.
^ At least one rating was less than 10.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 16. Summary of ratings for end cracking on C7/H3 treated Pinus radiata after three years exposure of the overcoated primed panels

Primer	6 weeks exposure *		26 weeks exposure *	
	S	W	S	W
A	8	9	7	8
B	10^	10^	8	10
C	8	9	7	8
D	10^	9	9	9
E	9	8	10	7
F	8	9	-	-
G	9	10^	-	-
H	10^	9	10^	9
I	10^	9	10^	9
J	9	9	10	10^
K	9	9	9	9
L	10^	9	10^	9
M	10	10	10	10^
N	10	10	9	10
O	10^	8	9	9
Q	7	7	8	7
R	10^	9	10	10
S	10	10^	10^	10
T	8	8	7	9

* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
\- primed panels exposed for six weeks only.
^ At least one rating was less than 10.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 17. Summary of ratings for edge cracking on C7/H3 treated Pinus radiata after three years exposure of the overcoated primed panels

Primer	6 weeks exposure *		26 weeks exposure *	
	S	W	S	W
A	4	4	3	4
B	5	5	5	5
C	4	4	4	3
D	4	5	4	4
E	5	5	4	4
F	4	5	-	-
G	4	4	-	-
H	4	4	4	4
I	5	5	5	5
J	5	5	5	4
K	4	5	4	4
L	4	5	4	5
M	4	4	4	4
N	5	4	4	4
O	4	4	4	4
Q	4	4	4	4
R	5	5	5	5
S	4	4	4	4
T	4	4	3	3

* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
\- primed panel exposed for six weeks only.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 18. Summary of ratings for flaking on C7/H3 treated Pinus radiata after three years exposure of the overcoated primed panels

Primer	6 weeks exposure		26 weeks exposure	
	S	W	S	W
A	10^	10	10^	10
B	10	10	10	10
C	9	10	9	9
D	10	10	8	10
E	10	10	10	10
F	9	10	-	-
G	10	10	-	-
H	10	10	10	10^
I	10	10	10	10
J	10^	10	10	10
K	10	10	10	10
L	10^	10	9	10
M	10	10	10	10
N	10	10	10	10
O	10	10	10	9
Q	9	10	10	10
R	10	10	10	10
S	10^	10	10	10
T	9	10	7	10

* average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
^ at least one rating was less than 10.
- primed panel exposed for six weeks only.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 19. Results after three years weathering for primed timbers other than C7/H3 radiata

Timber	Primer	Topcoat	Primer exposure	Cracking front	rear*	ends	Flaking front*	edges	Disfigurement front*	rear*
H1	A	S	6	10^	10^	9	10^	3	8	7
Pinus	A	W	6	10^	10^	10	10	4	10	8
rad-	A	S	26	10^	9	8	10^	3	8	7
iata	A	W	26	10	9	8	10	4	10	7
	B	S	6	8	10	8	10	5	8	9
	B	W	6	10^	10	10^	10	5	9	9
	B	S	26	9	10^	6	10	5	7	9
	B	W	26	10	10	9	10	5	9	9
LOSP	A	S	26	9	10^	9	10	4	7	8
Pinus	A	W	26	10	9	9	10	4	9	9
rad-	B	S	26	9	10	10	10	4	5	9
iata	B	W	26	10	10	10^	10	4	9	9
rimu	A	S	6	9	9	9	10	4	8	9
	A	W	6	10	10	9	10	4	10^	8
	B	S	6	8	10	9	10	5	7	9
	B	W	6	9	10	10^	10	5	10	10^
	C	S	6	9	9	7	9	3	7	8
	C	W	6	9	9	8	10	4	9	9
	D	S	6	10^	10^	10^	10	4	8	9
	D	W	6	10^	10^	10^	10	4	9	10^
totara	A	S	6	10	10	9	10	5	7	9
	A	W	6	10	10	9	10	5	10	9
	B	S	6	10	10	10^	10	5	7	9
	B	W	6	10^	10	10^	10	5	10^	10^
	C	S	6	10	10^	9	10	5	8	9
	C	W	6	9	10	9	10	5	9	9
	D	S	6	10^	10^	10^	10^	5	8	10^
	D	W	6	10	10	10^	10	5	9	9

average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.

* average of two ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
^ At least one rating was less than 10.
S Oil-alkyd topcoat
W Acrylic topcoat

TABLE 20. Summary of results for factory primed panels after three years weathering of the overcoated panels.

Primer	Topcoat	Primer exposure	Cracking front	rear*	ends	Flaking front*	edges	Disfigurement front*	rear*
G+	S	26	10^	10^	10^	10^	4	8	9
G+	W	26	10	10^	9	10	5	9	8
J	S	26	10^	9	10	10^	3	7	8
J	W	26	10	9	10	10	4	9	9
S	S	26	8	8	8	8	4	8	9
S	W	26	9	7	9	10^	4	9	9
U+	S	26	10^	7	8	10	4	7	8
U+	W	26	10	8	9	10	4	9	8

average of four ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.

* average of two ratings, values rounded to nearest whole numbers, where the fraction was 0.5 it was rounded up.
^ At least one rating was less than 10.
+ origin of timber unknown

TABLE 21. Mean ratings for various primer exposure period overcoat combinations for panels exposed for three years.

Variable	Exposure period/ Overcoat Combination 6 S	6 W	26 S	26 W
cracking front right	9.24	9.82	9.08	9.71
cracking front left	9.32	9.76	9.11	9.55
cracking rear right	9.16	8.76	9.11	9.00
cracking rear left	9.08	8.87	9.11	9.13
cracking right end	8.53	9.13	8.18	8.84
cracking left end	9.08	9.39	8.24	8.95
flaking	9.71	10.0	9.53	9.87
cracking, top edge	4.13	4.45	3.95	4.21
cracking, bottom edge	4.24	4.21	4.11	4.05
disfigurement, front	7.61	8.82	7.55	8.84
disfigurement, rear	7.55	7.95	7.53	8.03

Primer exposure period in weeks
S = Oil-alkyd topcoat
W = Acrylic topcoat

TABLE 22. Comparison of primer exposure time and topcoat for three year evaluation results of a categorical analysis looking at the effects of primer exposure period and topcoat type on panel performance after three years exposure of panels.

Variable	Primer exposure period	Overcoat system
cracking front right	-	W +
cracking front left #	-	W +
cracking rear right	-	-
cracking rear left	-	-
cracking right end	-	W +
cracking left end	6 +	W +
flaking #	-	W *
cracking top edge	-	W *
cracking bottom edge	-	W +
disfigurement front	-	W +
disfigurement rear	-	-

\+ Mean rating better (statisticallly significant at 1% level)
* Mean rating better (statisticallly significant at 5% level)
\- Differences are not statistically significant
\# An addcell adjustment was used because of the limited number of response levels.
W Acrylic topcoat

TABLE 23. Mean ratings for various primer type/overcoat combinations for panels exposed for three years.

Variable	Primer Overcoat Combination			
	SP S	SP W	WP S	WP W
cracking front R	9.23	9.77	9.00	9.60
cracking front L	9.29	9.70	9.05	9.55
cracking rear R	8.80	8.57	9.75	9.45
cracking rear L	8.77	8.73	9.70	9.35
cracking right end	8.43	8.84	8.50	9.35
cracking left end	8.89	9.11	8.55	9.50
flaking	9.39	9.93	10.00	9.90
cracking top edge	3.82	4.25	4.60	4.55
cracking bottom edge	3.96	4.02	4.55	4.30
disfigurement, front	7.48	8.84	7.70	8.60
disfigurement, rear	7.18	7.70	8.50	8.75

SP = Oil-alkyd primer
WP = Acrylic
S = Oil-alkyd topcoat
W = Acrylic topcoat

TABLE 24. Comparison of primer exposure time and topcoat for three year evaluation results of a categorical analysis looking at the effects of primer type and topcoat type on panel performance after three years exposure of panels.

Variable	Primer type	Overcoat system
cracking front right	-	W +
cracking front left	-	W +
cracking rear right	W +	-
cracking rear left	W +	-
cracking right end	W *	W +
cracking left end	-	W +
flaking #	-	E +
cracking top edge	W +	E +
cracking bottom edge	W +	-
disfigurement front	-	W +
disfigurement rear	W +	-

\+ Mean rating better (statistically significant at 1% level)
* Mean rating better (statistically significant at 5% level)
\- Differences are not statistically significant
E Overcoat effect is significant, but no clear result because of exposure time interaction.
\# An addcell adjustment was used because of the limited number of response levels.

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ISSN 0113 - 3675