POLE SLEEVES PREVENT FAILURE OF ENVIRONMENTALLY ACCEPTABLE H3 BORON-TREATED POSTS IN H4 GROUND CONTACT CONDITIONS

Albin A W Baecker
Baecker Research, Thornville, South Africa

Summary

Four batches of green *Eucalyptus grandis* posts were dip-treated with boron in a formulation of disodium octaborate tetrahydrate and wax. Boric acid equivalents (BAE) absorbed by the posts were calculated and shown to be present at retentions in the order specified for service in Hazard Class 3 conditions. Field Liner pole sleeve prototypes of the barrier protection system (BPS) now known as the Biotrans Pole Sleeve were fitted to the ground contact regions of posts at the four BAE retentions. Two field trials were established by setting the posts in soil in an inland forest ecosystem and also in a coastal pastoral ecosystem in KwaZulu Natal. All posts without BPS failed within 24 months at both sites because the boron had been leached from the wood. In contrast all posts with BPS were sound and remained sound after 36 months' exposure at both sites. When sacrificed their ground contact regions showed that boron remained present. It was concluded that BPS permit the use of boron in clean technology at H3 retentions as a safe environmentally preferable wood preservative in H4 soil-contact conditions.

Introduction

The water solubility of borates precludes their use for protection of wood exposed to moisture in service, but many environmental benefits would be created if a suitable boron treatment could be developed for wood in service in Hazard Class 4 situations.

Totim-B is a proprietary boron formulation developed for use in Hazard Class 3 conditions. As such it comprises a water-borne concentrate of wax, surfactant and a boron compound, and can be used as a concentrate or diluted in make-up water for the treatment of "green" poles or "wet-off-saw" lumber. When the wood is withdrawn from the dip tank it becomes coated by the formulation and if the wood has sufficiently high internal moisture content the borate will diffuse into it while the wax remains an external coating on the surface of the wood. Wood treated in this manner has been approved for use in Hazard Class 2 use in interior situations not exposed to weather conditions. Furthermore, since wax is a water-repellent, approval of this formulation was being sought for preservation of wood in Hazard Class 3 exterior situations not in contact with soil when the present work commenced in 1996,

Although the wax coating demonstrates weather-resistance, it is well known that waxes comprise one of the three major groups of naturally occurring polymers which are all rapidly degraded by soil microflora Alexander, 1977). Preliminary trials confirmed that the wax in the formulation being used was not soil-resistant. Posts and poles treated with this formulation would be likely to leach the boron component to moist soil after the wax had been degraded by the soil microflora.

The pole sleeve is a barrier protection system (BPS) derived from hurdle theory (Baecker, 1993a) to prevent microbiological attack of the soil-contact regions of poles and posts in soil. It was later postulated (Baecker, 1993b) that another function of the BPS was preservative-related, i.e., (i) loss of traditional preservatives from poles to soil could be prevented if such poles were protected by BPS, and (ii) leachable, but environmentally preferable, preservatives could be used in wood in Hazard Class 4 situations if such poles were protected by BPS. The former postulate was subsequently confirmed with creosote-treated posts (Behr and Baecker, 1994) and distribution poles (Behr, Shelver and Baecker, 1996; 1997) using heat-shrink Field Liner prototypes of the barrier protection system now commercially known as the Biotrans Pole Sleeve. The present work was conducted to investigate the second postulate by establishing whether or not BPS could be used to prevent leaching from agricultural posts treated with the above environmentally-acceptable boron formulation.

Materials and Methods

The experiments were designed as three-year field trials in ground contact in South Africa. The active ingredient of Totim B is disodium octaborate tetrahydrate present in the concentrate at 30% (m/v) boric acid equivalents (BAE). A toxic threshold of 5kg.BAE.m^{-3} timber for Hazard Class 3 service outdoors was known to be effective. Since there was 300g.BAE present per litre of Totim B concentrate, 16.66 litres of concentrate were required to be taken up per cubic metre of timber to meet this threshold.

Treatment. The volumes of twenty eight *Eucalyptus grandis* freshly cut agricultural posts were measured by water displacement. While still 'green' (>60% MC dry mass) four batches of the posts were separately immersed in Totim B for different periods in a dip tank built to measure uptake volumes. After withdrawal from the dip tank the uptake of concentrate by each post was measured and the retention of each post was calculated from the uptake values. All posts were stored under cover for a week to permit boron diffusion to occur while the wax coatings solidified. BPS were then fitted to the posts as listed in **Table 1** and illustrated in **Figure 1**.

Table 1. Numbers of boron-treated posts with barrier protection systems applied to their ground contact zones before exposure in field trials set up in two ecosystems in KwaZulu Natal.

Dip period (mins)	Retention (kg.BAE.m-3)	Number of posts in field trial ecosystem			
		inland forest		coastal pasture	
		BPS	no BPS	BPS	no BPS
1	4.718	3	2	3	2
1	3.965	3	2	3	2
5	4.155	1	1	2	nil
10	7.266	1	1	2	nil

Fig. 1 *Eucalyptus grandis* agricultural posts treated with disodium octaborate tetrahydrate and fitted with pole sleeves before field trials in soil test beds in KwaZulu Natal.

Field trials. The two test sites chosen were representative of inland and coastal conditions in subtropical KwaZulu Natal. The inland site was a forest ecosystem on the banks of the Palmiet River where termites and fungi thrived. The coastal site was a pastoral ecosystem in Ballito where termites could not be detected. The posts were installed in their respective test beds in November 1996 to coincide with the start of the summer rainfall season.

Fourteen posts were set in a soil test bed at the inland forest site (c.f., **Table 1**) shown in **Figure 2a**. An overhead irrigation system was constructed above the test bed (**Fig. 2b**) and when water was discharged from it the posts were thoroughly wetted (**Fig. 2c).** The remaining 14 posts were set in the coastal pastoral test bed shown in **Figure 3**.

Fig. 2a Boron-treated posts with and without BPS set in soil test bed at inland forest site in KwaZulu Natal.

Fig. 2b Overhead irrigation system installed over the soil test bed at the inland forest site.

Fig. 2c Irrigation water drenched the posts at the inland forest site for four hours twice per week.

Fig. 3 Boron-treated posts with and without BPS set in soil test bed for 12 months at coastal pastoral site in KwaZulu Natal.

Results

In each test site the sections of the posts exposed to the H3 environment above the ground line were inspected weekly. The wood surfaces of posts fitted with BPS retained the property of water-repellence and the wax remained functional in this respect throughout the 36 month field trial. However the 60% moisture contents of the posts fell to 22% - 28% during the course of the first year, showing that water egress from the posts had occurred. Therefore, although the property of water-repellence remained intact, the wood became drier. The posts however showed none of the surface checking characteristic of *Eucalyptus* after normal drying occurs. It was therefore concluded that the wax affected the rate of moisture evaporation from the posts and reduced the fibre stresses normally associated with the extreme moisture gradients set up between inner and surface regions of *Eucalyptus* during drying at normal rates, which in turn prevented checking. Since checks in treated wood poles often expose untreated inner wood to the environment, decay can be initiated at such portals of entry. It thus seemed clear that the wax component of the preservative tested here could play a positive role in wood protection in H3 environments.

Status of posts after 12 months' exposure.

Within a few weeks' exposure at the inland forest site termite activity was evident on posts without BPS (**Fig. 4a**). At the 11-month stage (**Fig. 4b**) one post without BPS had failed and when it was

Fig 4a Posts at the inland forest site after six weeks' exposure. Note termite activity on post without BPS on right.

Fig 4b Posts at the inland forest site after 11 months' exposure. Post without BPS in centre foreground has failed and lies where it collapsed on the soil surface.

examined *in situ* it was seen that termite activity in the groundline zone had caused the failure to occur (**Fig. 4c**). In contrast, all posts with BPS at the inland forest test site appeared sound.

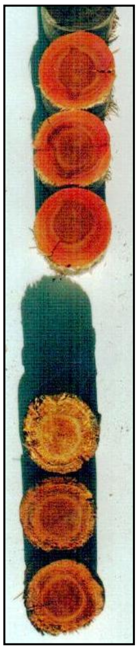
Fig 4c Failed post without BPS lying where it collapsed at the inland forest site after 11 months' exposure (c.f., **Fig. 4b**). Post showed typical termite attack at the groundline.

Posts exposed at the coastal test site were not attacked by termites but those without BPS were visibly colonised by fungi at the groundline (**Fig. 5**) at the 11-month stage of the field trials. When

Fig. 5 Post without BPS *in situ* at the coastal pastoral ecosystem in KwaZulu Natal after 11 months' exposure.

one of these posts was withdrawn from the soil after 12 months' exposure (**Figs. 6a**) it was evident that the whole subsoil surface of the post was colonised by soil fungi (**Fig. 6b**). The post was sectioned (**Fig. 6c**) and the sections were arranged on the laboratory bench in the order in which they had been present on the post during the test period (**Fig. 6d**). A boron-disclosing agent was sprayed on all transverse sections of the post (**Fig. 6e**) and when the boron that remained in the post was disclosed (**Fig. 6f**) it was obvious that while some boron was present in wood that had been in service above the groundline, sections that had been in the soil manifested no presence of boron.

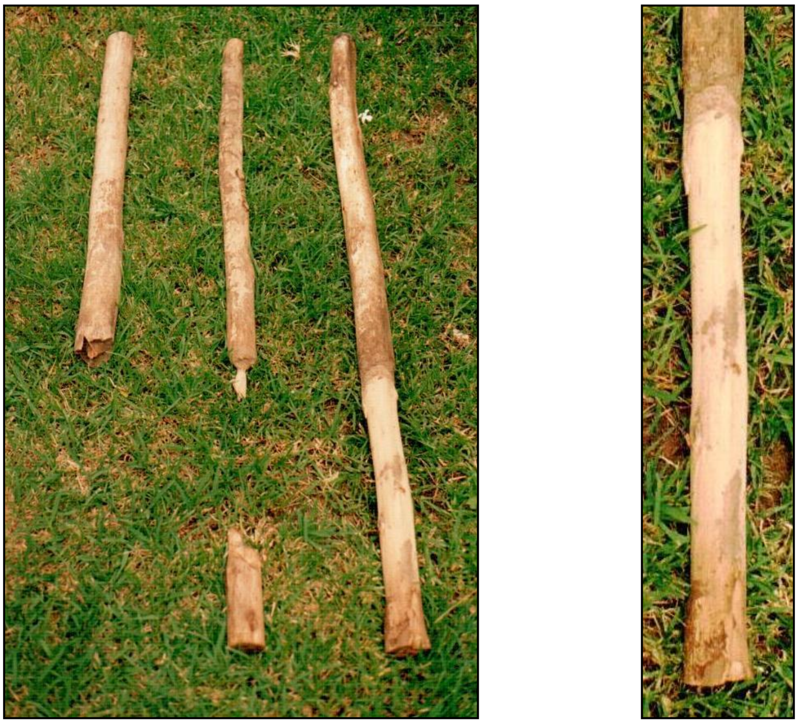
(a) **(b)** **(c)**



(d) **(e)** **(f)**

Fig 6a – f Post without BPS (c.f., **Fig. 5**) after withdrawal **(a)** from the test bed at the coastal pastoral ecosystem in KwaZulu Natal after 12 months' exposure. The ground line zone was clearly decayed on its surface **(b)** and when transversely sectioned (**c**) it was evident that the decay extended throughout the soil-contact region of the post. The transverse sections were aligned in the order they occupied before the pole was cut **(d, left and centre)** and sprayed with a boron-disclosing agent **(d, right)** which showed (**e**) that boron had been lost from the subsoil sections of the post during the test period in comparison with the relative intensity of boron disclosure observed in sections that had been in service above the ground line (**f**).

At the 12-month stage in the forest ecosystem two posts without BPS had failed and a third one without BPS was withdrawn for inspection (**Fig. 7a**) because it failed to ring when sounded by the conventional hammer test. Inspection revealed (**Fig. 7b**) that the post had failed the hammer test because termites had removed much of the sapwood from it. In contrast all posts with BPS passed



(a) **(b)**

Fig. 7 Posts without BPS at the inland forest ecosystem after 12 months' exposure had either failed and collapsed (**a, left and centre**) or were in the process of failing (**a, right**). The cause of failure was seen to be a typical pattern (**b**) of termite attack.

the hammer test therefore no posts with BPS were withdrawn from the soil beds for further inspection at either test site.

Status of posts after 24 months' exposure.

All posts without BPS had failed at the 24-month stage of both field trials and all posts with BPS continued to pass the hammer test. It was decided to sacrifice one post with BPS from the test bed at the inland forest ecosystem for destructive tests. Since there was little or no wood left below the respective ground lines of any of the failed posts that had been without BPS (**Fig. 7**) the post with BPS sacrificed at the 24-month stage could be directly compared only with the post without BPS that had been withdrawn at the 12-month stage of the inland forest trial (**Fig. 8)**.

Both these posts were transversely sectioned above their groundlines and the sections that had been below the groundlines were then sectioned longitudinally (**Fig. 9a**). When internal surfaces of these posts were sprayed with the boron-disclosing agent and compared with each other (**Fig. 9b**) it became apparent, as evidenced by the relative colour-intensities of the respective samples, that the post without BPS had lost boron during the 12-month exposure period within which termites attacked the post, whereas the sound post with BPS had retained boron throughout the 24-month period.

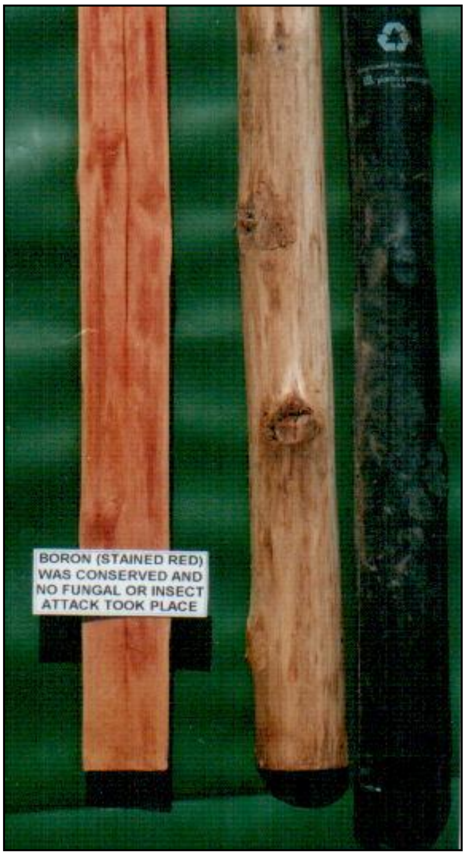
Fig. 8 Post with BPS sampled at the 24-month stage (left) of the inland forest trial compared with failed posts without BPS sampled at the 12-month stage of the trial.

(a) **(b)**

Fig. 9 Posts sectioned longitudinally below their groundlines to show (**a**) the external and internal surfaces of each post. The post on the left had been without BPS when sampled at the 12-month interval (c.f., **Fig. 7b**) and it showed external termite attack while the post on the right had been with BPS when sampled at the 24-month interval (c.f., **Fig. 8, left)** and was sound. The sections were rearranged (**b**) to show both internal surfaces of each post and application of boron-disclosing agent to one internal surface of each post showed that boron had been lost from the subsoil sections of the post without BPS during the test period (**b, second from left**) in comparison with (**b, third from left**) the relative intensity of boron disclosure observed in the post that had been with BPS for 24 months.

Status of posts after 36 months' exposure.

All posts with BPS in both soil test beds continued to pass the hammer test at the 36-month stage. Posts uplifted and sectioned as above continued to manifest the presence of boron when sprayed with the boron-disclosing agent (Fig. 10).



(a) **(b)**

Fig. 10 Internal and external surfaces of post with BPS removed (**a**) after 36 months' exposure in the soil bed at the inland forest ecosystem. A colour-enhanced close-up (**b**) highlights the red colour caused by boron on the internal surface when sprayed with boron-disclosing agent.

Discussion and Conclusions

The present findings showed unequivocally that when water-soluble boron was applied at Hazard Class 3 levels to *E. grandis* posts protected by pole sleeves the BPS prevented leaching-induced failure of the posts for three years in Hazard Class 4 soil-contact service conditions. Moreover, the wood in each post protected with BPS remained in perfect condition after the three years' exposure.

When these field trials were ongoing Mr. Ean von Buddenbrock, a farmer at Ceres in South Africa, set up a fruit orchard with 600 Totim B dip-treated freshly cut poles (**Fig. 11a**) of *Pinus radiata* and *P. canariensis*. At 5.37kgBAE.m^{-3} the boron retention in the wood was slightly over the H3 target level and the poles were all fitted with BPS before being put into service. The orchard was in existence for several years (**Fig. 11b**) and when the fruit was cropped the farmer reused the poles for other service on his farm. Mr. von Buddenbrock's own account of the success of that project is presented in **Appendix 1**.

(a) **(b)**

Fig. 11 Transverse sections (**a**) of poles converted from freshly-felled *Pinus radiata* and *P. canariensis* after dip-treatment with boron preservative and challenge with boron-disclosing reagents to reveal the extensive (red colouration) penetration of boron. The 600 poles with BPS fitted were then used to construct fruit orchards (**b**) that served for several years before the poles were put into other service on the farm (c.f., **App. 1**)

The present work was completed in 1999 but many workers have since replicated it in similar field trials. For example, researchers in Australia (Howgrave-Graham, Cookson and Hale, 2008) tested pole sleeves as BPS with water-soluble alkaline copper quaternary (ACQ) preservative under controlled conditions in accelerated field simulation trials over exposure periods the same as those reported here. The ACQ was applied to *E. globulus* and *E. cladocalyx* merely at Hazard Class 1 retentions and it was established (Howgrave-Graham, Cookson and Percy, 2009) that BPS extended the lives of untreated posts 3.6 fold. In contrast, all the treated posts with BPS remained sound throughout the tests therefore it was “not possible to estimate how much a BPS would extend the life of even a lightly treated post or pole.” The workers concluded however that if the extension was the same as for untreated posts, “an H5 pole expected to last 35 years without BPS may last 126 years with BPS at a cost of A$17 less than the cheapest alternative to timber.”

On the basis of the work presented here it was therefore concluded that the BPS constitutes a means to use boron with water repellent in clean technology at the H3 retention as a safe and environmentally preferable wood preservative in H4 service conditions.

Acknowledgements All posts tested in this work were treated with the boron formulation in 1996 by the late Colin T Bundy and his then-colleague Louis Kleynhans in their laboratory at Rentokil (Pty) Ltd., Pinetown, South Africa. The test site at Ballito was also managed by them and their contribution to this work is gratefully acknowledged. The ongoing technical assistance of Michael R Behr throughout the duration of this project is also gratefully acknowledged.

References

Alexander, M. (1977)
Introduction to Soil Microbiology, Second Edition. John Wiley, New York. 467pp.

Baecker, A.A.W. (1993a)
A non-pressure method of protection based on hurdle theory to control the spectrum of internal environmental factors which affect the decay of poles in soil contact.
Paper presented at **IRG 24**, 24th Meeting of the International Research Group on Wood Preservation, Orlando, USA, 1993.
Int. Res. Grp. Wood Pres., Doc. No. IRG/WP/93-20005. 20pp.

Baecker, A.A.W. (1993b)
A non-toxic method to combat incipient decay of CCA- and creosote-treated poles in soil-contact.
International Biodeterioration and Biodegradation, 32, 289-303.

Behr, M. and Baecker, A.A.W. (1994)
Quantification of creosote migration down wooden poles and the prevention of its depletion during flood irrigation.
Paper presented at **IRG 25**, 25th Meeting of the International Research Group on Wood Preservation, Bali, Indonesia, 1994.
Int. Res. Grp. Wood. Pres., Doc. No. IRG/WP/94-50032. 17pp.

Behr, M.R., Shelver, G.D. and Baecker, A.A.W. (1996)
Field Liners prevent creosote migration from transmission poles to soil during service.
Paper presented at **IRG 27**, 27th Meeting of the International Research Group on Wood Preservation, Guadeloupe, West Indies, Caribbean Islands, 1996.
Int. Res. Grp. Wood Pres., Doc. No. IRG/WP/96-40067. 12pp.

Behr, M.R., Shelver, G.D. and Baecker, A.A.W. (1997)
Transmission poles with sub-standard creosote retentions protected by Field Liners outperform standard poles in service.
Paper presented at **IRG 28**, 28th Meeting of the International Research Group on Wood Preservation, Whistler, Canada, 1997.
Int. Res. Grp. Wood Pres., Doc. No. IRG/WP/97-40095. 7pp.

Howgrave-Graham, A.R., Cookson, L.J. and Hale, T. (2008)
Field liners as physical barriers to prevent wooden utility pole decay in soil: an accelerated field simulation trial.
Paper presented at **IRG 39**, 39th Meeting of the International Research Group on Wood Preservation, Istanbul, Turkey, 2008.
Int. Res. Grp. Wood Pres., Doc. No. IRG/WP/08-20384. 12pp.

Howgrave-Graham, A.R., Cookson, L.J. and Percy, A. (2009)
Using physical barriers to prevent in-ground wooden pole decay: protecting forest and economic resources as well as soil and groundwater.
The International Journal of Environmental, Cultural, Economic & Social Sustainability, 5(2), 305 – 316.

APPENDIX 1

ACCOUNT of COMMERCIAL USE of timber treated with BORON (Totim-B) and Biotrans FIELD LINERS for use as POLES in an ORCHARD TRELLISING SYSTEM

PE von Buddenbrock Pr.Sci.Nat., 16th June 2011

Background

I returned to the family fruit farm in the Ceres area of the Western Cape in 1990 after some 10 years in forestry management in the then Kangwane Homeland (an area surrounding Swaziland in the Lowveld as well as on the Highveld) where amongst other tasks we treated timber poles with Creosote in heated open tanks as well as CCA poles in a pressure vessel, mostly for fencing in the area. At that time the deciduous fruit industry was moving towards more densely planted orchards on trellising systems so that larger fruit trees could be planted and branches could be more easily manipulated to induce earlier bearing and hence improved profitability.

Commercial use

In preparing new orchards I needed to remove a stand of mature pine trees (*Pinus radiata* and *Pinus canariensis)* and I calculated that it would be cheaper to cut these trees into 100mm x 100mm square "poles" and treat them with Totim-B and shrink wrap the ends with a Field liner, than to purchase CCA or Creosote poles in order to trellis the new orchards.

The timber was duly cut and sawn into 100mm x 100mm beams and immersed in Totem-B achieving a BAE of 5,37 kg/m^3. Heat shrink prototype Biotrans Field Liners (BOL-210-15-500) were applied and the poles were planted at a depth of 0,8m in the soil. Some 600 poles were treated. The field liners had a total length of 1,5m which meant that 0,7m of Field Liner was above ground. This was specifically done to protect the poles from irrigation water. The Western Cape has a Mediterranean climate with winter rainfall and summer drought necessitating irrigation in the summer. The orchards were equipped with a microjet (sprinkler) system with 1 emitter/tree providing about 5mm of irrigation per hour. At the height of the irrigation season the orchards received about 10 hours of irrigation broken up into 3 cycles per week. A total of 7000 to 8000m^3 of irrigation water is applied per hectare per season. Annual rainfall averages about 750mm per annum.

The poles were planted in Orchards A6 and B1 in 1996 and 1997 respectively. These poles were carefully removed in 2003 and re-used in orchards B5 and C2 in the same year. A few poles with damaged sleeves were not re-used due to incipient decay at soil level. After 13/14 years in service the poles were removed from the latter two orchards in Nov/Dec 2010 and although numerous poles were still sound some more with damaged sleeves showed incipient decay.

Conclusion

The problem experienced with the square poles was that the Field Liners were heat shrink prototypes that failed on the edges after a few years because they were thinner there due to the heat shrinking over the sharp edges.

In my opinion this type of treatment without the heat shrinking application method on square poles could be a viable alternative to the use of creosote and CCA treated poles.