Preservation of eucalypt paling fences, a test of sub-standard treatments

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The traditional hardwood paling fence in Australia is installed untreated. Treatment attempts fall short of Australian Standard requirements due to limited penetration in heartwood. Nevertheless, evidence is presented that sub-standard treatment of *Eucalyptus regnans* and *E. obliqua* fencing components with either copper-chromium-arsenic or pigment emulsified creosote is beneficial to above-ground (H3) components. Palings and rails H3 exposed at Clayton near Melbourne were mostly without decay after 13-5 years. However, the top ends of chromated copper arsenate-treated posts sometimes had decay, and tops sloped for increased water-shedding did not reduce this damage. Treatment benefit was less clear for in-ground (H4) sawn fence posts. Treated posts were usually in worse condition against decay than untreated naturally durable *E. camaldulensis* posts after 7-5 years in an accelerated field simulator and 13-5 years at Clayton. The reverse was true after 13-5 years at Walpeup, where the main hazard was from termites.

**Keywords:** Sawn eucalypt, Paling fence, CCA, Creosote, Decay, Termites

**Introduction**

The heartwood of sawn eucalypts is known to be difficult to treat (Tamblyn 1984; Cookson 2000), and usually cannot be treated to meet the standard requirements of 5 or 8 mm penetration for outdoor above-ground use (H3) and 10 mm for in-ground use (H4) (AS 1604-1-2010). Nevertheless, the sub-standard treatments that can be economically applied may still provide useful benefits. For example, light organic solvent and boron preservatives were found to be fit for purpose in window joinery if the timbers were then painted (Cookson 2010). This paper examines the performance of sub-standard treatments with chromated copper arsenate (CCA) and creosote for sawn *Eucalyptus regnans* F. Muell. (Mountain Ash) and *E. obliqua* L’Herit. (Messmate) in paling fences. It was shown previously that *E. obliqua* was more difficult to treat than *E. regnans*, and treatments in both timbers generally failed to meet standard requirements especially in regards to penetration (Cookson et al. 1996).

The traditional hardwood paling fence in southern Australia is untreated and has posts and plinths cut from naturally durable timbers such as *E. camaldulensis* Dehn. (River Red Gum), and palings and rails cut from timbers of low natural durability such as *E. regnans* and *E. obliqua*. Because the fence is untreated, palings and rails often need replacing after 15–20 years of service, while posts are usually still serviceable after this time. Although of durable timber, plinths also often need replacing due to decay in the lower edge resting on soil, where because of thinner cross-section, decay is more noticeable than in posts.

For this trial, the timbers were treated unseasoned or only partially seasoned with pigment emulsified creosote (PEC) (Greaves et al. 1986) or a water-repellent CCA also known as PROCCA (Cookson et al. 1998). Timbers were treated unseasoned because a drying step would make the product too expensive compared with treated pine. Treatment, penetration, laboratory bioassay and 5-year field results were described in a series of conference papers (Cookson et al. 1996, 2002; Scown and Cookson 2001). This paper presents the final inspections of a 13-5 year model fence trial at Clayton near Melbourne (decay trial), and post stub trials after 7-5 years in an accelerated field simulator (AFS; decay trial) and 13-5 years at Walpeup (termite plus decay trial).

**Materials and methods**

**Timbers and preservatives**

The timber species examined were *E. regnans*, *E. obliqua* and untreated *E. camaldulensis*. Preservative treatments were with PEC which contained 65% high temperature creosote and 5% brown oxide pigment (PEC usually contains a white pigment). The water-repellent CCA treatment solution contained 10% CCA salts and 5% oil. A 4-h Bethell schedule was used to treat test specimens for exposure, and involved an initial vacuum of −95 kPa for 30 min, a hydraulic pressure of 1400 kPa (CCA) or 1200 kPa (PEC) for 240 min and a final vacuum of −95 kPa for 30 min.

**Post stub trials**

All timber posts for the stub trials were treated as 800 mm lengths and then cut in half before installation.
The freshly cut ends were covered with aluminium flashing and became the post top ends. Untreated *E. camaldulensis* posts were included for comparison. All posts for installation were 400 mm long, and 125 × 75 mm profile for *E. regnans* and *E. camaldulensis* and 120 × 70 mm for *E. obliqua*. Before treatment, *E. regnans* and *E. obliqua* posts were either left rough sawn (‘plain’), incised (‘incised’) or incised and slotted (‘slotted’) (Fig. 1). The density of incisions was meagre from the machine available, with incisions ~12 mm long, 10 mm deep and 23 mm apart within rows. Rows were 60 mm apart. Slotting aimed to improve preservative uptake for the in-ground portion of the post and involved making three longitudinal cuts 200 mm long from the bottom end with a band saw and parallel with the widest face.

Five replicate posts were exposed at each site, the AFS and the field at Walpeup. Posts were buried 300 mm into the soil. In the AFS, posts were distributed between two soil troughs containing ‘Toolangi forest loam’ (Da Costa 1979; Cookson et al. 2000). Each post was separated by approximately 50–80 mm of soil and incubation conditions were 28°C and 85% relative humidity. Posts and soil were sprayed with water weekly to promote soft rot activity (Cookson et al. 2002).

A similar set of 400 mm long post stubs were installed at a semi-arid test site at Walpeup (Creffield et al. 1994; Cookson et al. 2002), which has a moderate termite and low decay hazard. A further variation at Walpeup was that a set of slotted posts had 100 mm docked from their bottom ends (‘docked’ posts) to determine the effect in soil of a breached treatment envelope (Fig. 1). Specimens were arranged randomly within five rows (one replicate per row), and posts were 600 mm apart.

**Model fences**

A field trial of model fences and single posts with attached palings was installed at Clayton near Melbourne, where there is a moderate fungal decay hazard. The posts were 1.6 m long, and included the ‘plain’, ‘incised’ and ‘slotted’ variations described above. These posts were also notched for the reception of rails (Fig. 2), before (slotted posts) or after (plain and incised posts) treatment. The slotted posts also had their top ends cut to a 15° slope to improve water shedding. Also, ‘thin’ posts were exposed and had profiles 100 × 75 mm for *E. regnans* and 90 × 70 mm for *E. obliqua*. Thin posts were incised and slotted as described above (Fig. 2), but a drilled hole replaced each notch because rails were tied into position using 2.5 mm diameter galvanised fencing wire. Four replicates of each post type were exposed, some as part of the model fences and some as single standing posts (Fig. 3).

Other timbers in the model fences for *E. regnans* were palings 1200 (or 1300) × 100 × 20 mm, rails 1600 × 76 × 37 mm and plinth 1600 × 150 × 25 mm. For *E. obliqua* palings were 1200 (or 1300) × 90–100 × 14 mm, rails 1600 × 75 × 35 mm and plinth 1600 × 142 × 25 mm.

One model fence 1.6 m wide of each timber species and treatment was constructed for exposure (Fig. 4). Each fence included two thin posts and two slotted posts arranged in alternate order. Three rails were attached to the posts. Additionally, the top and bottom rails were cut into two pieces after treatment so that there was one rail join over each central post. The bottom edge of the plinth was 400 mm from the bottom end of the posts, and posts were buried 380 mm into the soil. Palings were attached to rails using 45 mm long nails, hot dip galvanised on one half of the fence and plain steel on the other. Also, one half of the fence had palings treated as 1.2 m lengths. The other half had palings treated as 1.3 m lengths, but with 100 mm docked from one end. Those 1.3 m cut palings were further arranged so that
half had the cut end facing upwards and half faced downwards towards the plinth. The bottom edges of plinths were covered with 20–30 mm of soil.

There was also an untreated fence for comparison, consisting of four *E. camaldulensis* posts, and rails and palings of untreated *E. obliqua* and *E. regnans*. Palings on one half of the fence were *E. regnans* and those on the other were *E. obliqua*.

The single standing posts each had three short (200 mm long) rails and two palings attached to mimic the model fence exposure. These posts were installed in two rows that were 2 m apart. Posts within rows were 0–5 m apart. Palings on all structures faced north.

During this final inspection, the fences were pulled from the soil and disassembled so that all sides of each timber could be viewed. Depths of damage were determined, and results were expressed as mm of decay or according to a rating scale of 0–8 (Table 1). A specimen rating 3 is considered unserviceable.

**Chemical analyses**

Within 1 year of treatment, unexposed treated rails and palings 1.2 m long and containing only heartwood had 30 mm long pieces cut from their centres for chemical analysis. The CCA-treated timber was digested as described in AS 1605:2000 and the resultant solution was analysed using an inductively coupled plasma spectrophotometer. The regions analysed included the outer 5 mm envelope of treated wood. In another piece, this region was further dissected to analyse the outer 1 mm of wood and the remaining 4 mm (1–5 mm) of wood. Additionally for rails, the inner core left after removal of the outer 5 mm was analysed. Penetration was checked using the chromazurol S spot test (AS 1605:2000). For PEC-treated rails and palings, the creosote component in the outer 5 mm of treated wood was determined by Dean-Stark extraction (AS 1605:2000), and compared with results obtained by solution uptake.

**Results**

**Penetration and retention**

According to AS 1604-1 (2010), when the lesser cross-section of a timber is 35 mm or less, the outer 5 mm should be penetrated. The total active element retentions obtained by chemical analysis of CCA-treated timbers are shown in Table 2. The outer 5 mm of the rails and palings of both timber species had mean retentions that met the minimum H3 requirement of 0.38% m/m (although some replicates of *E. obliqua* did not meet the minimum). However, the spot test showed that all timbers failed the penetration test, indicating that there was a steep treatment gradient in this outer 5 mm region. To investigate this gradient further, the outer 1 mm was analysed and found to have retentions ranging from 1.36 to 2.00% m/m, while the remaining 1–5 mm region had much lower retentions ranging from 0.12 to 0.43% m/m. Treatment requirements for H4 post exposures are more stringent.

The mean creosote retentions in PEC-treated palings and rails are shown in Table 3. The mean retentions obtained by Dean-Stark analysis of the outer 5 mm all failed to meet the minimum H3 requirement of 8.0% m/m. Dean-Stark analysis may not extract all creosote, and the solution uptake results obtained by weighing

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**Table 1** Performance rating used to assess fencing timbers

| Rating | Cross-section loss | Approximate depth of decay from timber surface in posts | Degree of attack |
|--------|--------------------|--------------------------------------------------------|------------------|
| 8      | No loss, sound     | 0 mm                                                   | No attack/decay  |
| 7      | Up to 15%          | Up to 3.5 mm                                           | Light            |
| 6      | 15–30%             | 3.5–7.0 mm                                             | Light–moderate   |
| 5      | 30–45%             | 7.0–11.5 mm                                            | Moderate         |
| 4      | 45–60%             | 11.5–16.5 mm                                           | Moderate–heavy   |
| 3      | 60–75%             | 16.5–22.5 mm                                           | Heavy            |
| 2      | 75–90%             | 22.5–30.0 mm                                           | Severe           |
| 1      | 90–99%             | 30.0–36.5 mm                                           | Severe-destroyed |
| 0      | 100%               | 36.5–37.5 mm                                           | Destroyed        |

**Table 2** Mean retentions from chemical analysis of CCA-treated rails and palings (eight replicates)

| Timber species | Outer 1 mm | Outer 5 mm | 1–5 mm | 5 mm to core |
|----------------|------------|------------|--------|--------------|
| Rails          |            |            |        |              |
| *E. regnans*   | 1.92 (0.27)| 0.81 (0.24)| 0.43 (0.23)| 0.08 (0.11)  |
| *E. obliqua*   | 1.47 (0.15)| 0.44 (0.12)| 0.15 (0.11)| 0.02 (0.03)  |
| Palings        |            |            |        |              |
| *E. regnans*   | 2.00 (0.22)| 0.61 (0.14)| 0.26 (0.14)| Not tested   |
| *E. obliqua*   | 1.36 (0.28)| 0.38 (0.14)| 0.12 (0.12)| Not tested   |
timbers before and after treatment suggested that higher creosote retentions may have occurred.

**Posts, in-ground portions**

Mean ratings for the in-ground portions of posts exposed in the AFS, Walpeup and Clayton are shown in Table 4. Untreated *E. regnans* heartwood was destroyed in the AFS by decay fungi (mean rating 0–8) and at Walpeup mainly by termites (mean rating 0–0). This timber was unserviceable after 4 years in the AFS and 5 years at Walpeup due to termites. *E. obliqua* has moderate natural durability as shown by its mean rating of 5–0 after 7–5 years in the AFS. However, this timber was unserviceable some time between years 7 and 13·5 at Walpeup due to termites. The naturally durable timber *E. camaldulensis* had only light–moderate decay or termite attack at all sites, with mean ratings of 6–2–6–6.

Incising and slotting did little to improve performance of posts compared with unmodified posts at any of the sites (Table 4). One consistent difference was that PEC gave slightly better performance than CCA for each site, with mean ratings for the in-ground portions of posts exposed in the AFS, Walpeup and Clayton (five replicates) shown in Table 4. Untreated *E. camaldulensis* heartwood was unserviceable some time between years 7 and 13·5 at Walpeup due to termites. The naturally durable timber *E. camaldulensis* had only light–moderate decay or termite attack at all sites, with mean ratings of 6–2–6–6.

**Model fences, above-ground portions**

The above-ground regions of the paling fence were tested at Clayton, with results for posts given in Table 5 and for rails, palings and plinths in Table 6. Table 5 expresses results as mm depth of decay. Any decay found above ground on posts was in the top end or in notches (water-trapping regions) rather than the exposed sides where water sheds readily. The PEC-treated posts had no decay on their top ends (except for one *E. obliqua* post where it was 3 mm deep), compared with CCA-treated posts where decay was found in three of the four incised *E. regnans* posts and nine of all 12 *E. obliqua* posts (plain, incised and thin posts). The sloped top end of slotted posts did not improve performance compared with horizontal top surfaces (Table 5).

There was much shallower decay in notches when it occurred (Table 5). Again, PEC-treated posts had less decay than CCA-treated posts when notches were cut after treatment. For example, PEC-treated *E. regnans* incised posts had a mean decay depth of 0·3 mm compared with 1·9 mm for similar CCA-treated posts. All slotted posts with notches cut before treatment lacked decay in this region. Similarly, thin posts were designed to avoid notches but with rails attached using

**Table 3** Mean retentions from chemical analysis and solution uptake of PEC-treated rails and palings (eight replicates)

| Timber species | Chemical analysis, outer 5 mm | Solution uptake of piece |
|----------------|-----------------------------|--------------------------|
| Rails          |                             |                          |
| *E. regnans*   | 6·2 (2·5) & 6·2 (3·2)       | 7·0 (2·6) & 7·1 (3·5)    |
| *E. obliqua*   | 5·7 (2·3)                   |                          |
| Palings        |                             |                          |
| *E. regnans*   | 5·3 (1·2) & 5·3 (2·4)       | 12·8 (3·9) & 12·6 (4·8)  |
| *E. obliqua*   | 5·3 (2·4)                   |                          |

**Table 4** Mean ratings in-ground for posts exposed in AFS (five replicates), Walpeup (five replicates) and Clayton (four replicates)

| Timber species | Treatment | AFS 7–5 years | Walpeup 13–5 years | Clayton 13–5 years |
|----------------|-----------|---------------|--------------------|--------------------|
| *E. regnans*   | Untreated | 0·8 (1·1)     | 0·0 (0·0)          | NT                 |
| *E. obliqua*   | Untreated | 5·0 (1·0)     | 1·8 (2·7)          | NT                 |
| *E. camaldulensis* | Untreated | 6·2 (1·3)     | 6·6 (0·5)          | 6·5 (0·6)          |
| *E. regnans*   | PEC, plain | 5·0 (2·0)     | 7·8 (0·4)          | NT                 |
| *E. obliqua*   | PEC, incised | 6·2 (0·8)     | 7·8 (0·4)          | 7·0 (0·0)          |
| *E. regnans*   | PEC, incised, thin | NT*          | NT                 | 6·5 (0·6)          |
| *E. obliqua*   | PEC, slotted | 5·4 (1·5)     | 8·0 (0·0)          | 6·5 (0·6)          |
| *E. regnans*   | Mean of PEC means | 5·5          | 7·9                | 6·7                |
| *E. obliqua*   | PROCCA, plain | 4·4 (0·9)     | 6·6 (2·1)          | 6·3 (0·5)          |
| *E. regnans*   | PROCCA, incised | 5·4 (0·5)     | 7·2 (0·8)          | 5·0 (0·9)          |
| *E. obliqua*   | PROCCA, incised, thin | NT          | NT                 | 6·0 (0·8)          |
| *E. regnans*   | PROCCA, slotted | 5·4 (0·5)     | 8·0 (0·0)          | 5·5 (0·6)          |
| *E. obliqua*   | Mean of CCA means | 5·1          | 7·3                | 5·7                |
| *E. regnans*   | PEC, plain | 6·4 (0·9)     | 7·4 (0·9)          | NT                 |
| *E. obliqua*   | PEC, incised | 6·0 (1·4)     | 7·8 (0·4)          | 7·0 (0·0)          |
| *E. regnans*   | PEC, incised, thin | NT          | NT                 | 6·8 (0·5)          |
| *E. obliqua*   | PEC, slotted | 7·0 (0·0)     | 8·0 (0·0)          | 6·8 (0·5)          |
| *E. regnans*   | Mean of PEC means | 6·5          | 7·7                | 6·9                |
| *E. obliqua*   | PROCCA, plain | 6·2 (0·4)     | 6·8 (0·8)          | 6·0 (0·0)          |
| *E. regnans*   | PROCCA, incised | 4·8 (1·9)     | 6·4 (1·3)          | 5·5 (1·3)          |
| *E. obliqua*   | PROCCA, incised, thin | NT          | NT                 | 5·8 (0·5)          |
| *E. regnans*   | PROCCA, slotted | 4·4 (1·5)     | 6·6 (1·7)          | 6·0 (1·4)          |
| *E. obliqua*   | Mean of CCA means | 5·1          | 6·6                | 5·8                |

*NT = not tested.*
wire so that the vertical join could drain more readily lacked decay on the interface between rail and post.

The mean ratings obtained for the rails, palings and plinths are given in Table 6. Untreated rails had light–moderate decay (mean rating 5·8), and the greatest depths of decay were 3–4 mm on the top faces and beside palings and posts, and 6 mm into the end-grain of one join. In comparison, all PEC-treated rails from both timber species lacked decay, as did the CCA-treated rails of E. obliqua. However, the mean rating for CCA-treated E. regnans rails was 6·6 due to light–moderate decay within notches.

The plinth (one per fence) had the bottom edge buried in soil. The untreated E. obliqua plinth with 30% sapwood was unserviceable and rated 3·0. Treated plinths also had decay usually 1–3 mm deep along their bottom edges so that ratings were 6·0 or 7·0.

Untreated E. regnans palings 1·2 m long had light–moderate decay with a mean rating of 5·9 (Table 6). Mean depths of decay in the 12 palings were 2·5 mm on sides, 6·3 mm top ends and 1·7 mm bottom ends. Untreated E. obliqua had light decay with a mean rating of 6·9, and mean depths of decay were 1·5 mm on sides, 2·1 mm top ends and 0·2 mm bottom ends. Once more for PEC, treated palings lacked decay in both timber species. There was minor decay in CCA-treated palings in 1 out of 12 replicates from each timber species. Some palings were treated as 1 m lengths and then docked after treatment to 1·2 m, with docked end placed up or down. All palings with docked end down lacked decay. Some palings with docked end up had decay, which was 1 mm deep in E. regnans for one out of five palings and 1 mm deep in E. obliqua for four out of five palings.

After 13–5 years, CCA-treated fences had retained their bright green colour, while PEC-treated fences were more weathered with palings appearing brown to grey-brown. Hot dipped galvanised nails did not show any rust stains on the wood, compared with dark stains below steel nails on palings.

### Discussion

Conventional treatment of sawn eucalypts with CCA and creosote rarely meets Australian Standard above-ground (H3) and in-ground (H4) requirements for penetration and retention. Nevertheless, these ‘sub-standard’ treatments may still provide sufficient extension of service lives in certain products to be ‘fit for purpose’. This study shows the contrasting benefits of sub-standard treatments for sawn eucalypt fencing timbers placed in-ground or above-ground. In-ground results against decay were often disappointing and could not be relied upon fully to give service lives comparable with naturally durable timber, while above-ground most of the treated timbers were without decay except in certain water-trapping regions where improved design could mitigate these problems.

For in-ground posts, there was little consistent difference in performance between plain (non-incised), incised and slotted posts. It should be noted that this study used a low density of incisions. Higher densities are likely to improve results (Morris et al. 1991; Jenang et al. 1997; Hamid et al. 2009).

| Timber species | Treatment | Notch | Mean depth of decay/mm |
|----------------|-----------|-------|------------------------|
| E. camaldulensis | Untreated | Notched | 0·0 (0·0) |
| E. regnans | PEC, incised | Pre-treatment | 0·0 (0·0) |
| E. regnans | PEC, incised, thin | None | 0·0 (0·0) |
| E. regnans | PEC, slotted | After treatment | 0·0 (0·0) |
| E. regnans | CCA, plain | Pre-treatment | 0·0 (0·0) |
| E. regnans | CCA, incised | Pre-treatment | 15·0 (19·9) |
| E. regnans | CCA, incised, thin | None | 0·0 (0·0) |
| E. regnans | CCA, slotted | After treatment | 15·0 (19·9) |
| E. obliqua | PEC, incised | Pre-treatment | 0·8 (1·5) |
| E. obliqua | PEC, incised, thin | None | 0·0 (0·0) |
| E. obliqua | PEC, slotted | After treatment | 0·0 (0·0) |
| E. obliqua | CCA, plain | Pre-treatment | 14·5 (2·3) |
| E. obliqua | CCA, incised | Pre-treatment | 9·3 (2·9) |
| E. obliqua | CCA, incised, thin | None | 3·5 (7·0) |
| E. obliqua | CCA, slotted | After treatment | 4·3 (7·2) |

*Two pieces were E. obliqua and three pieces were E. regnans.
†Two palings also contained large areas of sapwood failed to Lyctus, not included in this heartwood rating.
The AFS was the fastest in-ground decay test, and when results after 5 years were compared for all posts, the AFS was seven times faster than Walpeup (not including termite damage) and twice as fast as Clayton (Cookson et al. 2002). After 7–5 years in the AFS, mean ratings for treated E. regnans and CCA-treated E. obliqua were less than for untreated E. camaldulensis. After 13–5 years at Clayton, both CCA-treated eucalypts also had mean ratings lower than for E. camaldulensis, while PEC-treated timbers were mostly performing as well as E. camaldulensis. In the longer term, it seems likely that the treated posts would fail more quickly than E. camaldulensis as fungi had breached their treatment envelopes and could attack lower durability heartwood, while the full cross-section of E. camaldulensis is naturally durable.

An interesting contrast to the in-ground decay hazard in the AFS and at Clayton was the moderate termite and low decay hazard at the semi-arid site at Walpeup. Here, common termite species include Heterotermes ferox (Froggatt), Coptotermes acinaciformis (Froggatt), Microcerotermes curvus (Hilli) and Amitermes (Crefield et al. 1994). At Walpeup, the treated posts were performing as well or better than untreated E. camaldulensis, except when the bottom ends were docked after treatment to expose poorly treated heartwood. Thin envelope treatments are known to be effective against species such as Coptotermes in the above-ground exposure of softwoods (Peters and Creffield 2004), and bifenthrin H2F treatments in hardwoods (AS 1604-2010). However, in tropical northern Australia, Mastotermes darwiniensis Froggatt can destroy such treatments.

Above-ground regions of the paling fence tested at Clayton performed well, with clear benefits obtained for palings and rails as many had no decay after 13–5 years. Water-trapping regions such as the top end of posts and areas within notches had most decay when it occurred, while exposed vertical and horizontal faces lacked decay. Decay occurred on the top end of some CCA-treated posts, and a slope cut to improve water-shedding did not reduce this decay. The top end grain may have been too absorbent suggesting that a cap or durable coating would be a better option.

Above-ground regions of palings and rails cut after treatment generally performed better when PEC-treated than CCA treated. Also, notches in posts cut after treatment performed better when PEC treated probably because of the tendency of PEC to bleed and partially reseal cut timber. This improved performance of PEC over CCA was predicted by a laboratory bioassay conducted 14 years earlier, along with the possibility that notches in PEC-treated timber would perform better due to bleeding (Cookson et al. 1996, 2002).

This trial demonstrates that eucalypts with low natural durability can be treated unseasoned with CCA or creosote to have greatly extended service lives for palings and rails especially. Similar timbers treated as posts and plinths also gain improved performance, although they may not last as long as untreated naturally durable eucalypt posts and plinths when those timbers are available.

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