CHECKING AND SPLITTING OF HARDWOOD RAIL TIES IN SEASONING AND SERVICE

by

E. Perem

Résumé en français

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ABSTRACT

This study evaluated the merits of the common practice of embedding S-irons in the ends of ties to minimize the development of large checks.

Development of checks in boxed-heart hardwood ties was studied in experimental seasoning piles and in commercial seasoning piles, and the checking and splitting of ties in service was observed in test tracks.

The results showed that frequency and dimensions of major checks are not reduced either in seasoning or in service by embedding S-irons in the ends of ties before seasoning. The study also indicated that the position of the pith in boxed-heart ties strongly influences the extent of check development in seasoning and in service, as well as the susceptibility of the ties to splitting in service.

In seasoning the major checks usually form on the broad face nearest the pith and extend toward the pith by following the planes of rays, and the closer a tie face is to the pith, the greater are the length and width of the principal checks. The fact that a broad face close to the pith represents an approximately radial plane of the stem cross section while the opposite face is nearly tangential, causes the pith side to become convex in seasoning and this in turn causes principal checks to widen excessively. However, the best location for the pith is that which has the best effect on tie service life rather than on checking behavior during seasoning. In service, the most severe checking occurs in ties in which the pith is about halfway between the broad faces. In such ties an initial narrow seasoning check, present at the time of track installation, creates a plane of weakness in the tie along which, under conditions of repeated loading in service, separation and subsequent splitting may develop. For this reason, the risk of splitting in service is least in boxed-heart ties in which the pith is less than 1 inch from a broad face, whether the tie is placed in the track with the pith side up or down.

The study indicates that the expense of providing the ends of ties with S-irons before seasoning is unwarranted and that the average service life of boxed-heart hardwood ties could be improved by the adoption of tie specifications in which allowance is made for the location of the pith.

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RÉSUMÉ

Le propos de cette étude était d'évaluer les mérites du procédé courant d'insertion de ferrures en S aux bouts des traverses de chemin de fer, afin d'en prévenir le crevassement.

L'auteur a étudié le processus de formation de crevasses dans les traverses de bois dur à moelle encastrée, en piles de séchage tant sur le site de l'expérience que dans des chantiers commerciaux. Il a également observé leur crevassement et leur fendillement à l'usage sur la voie ferrée.

Il appert des résultats obtenus que l'insertion préalable de fers en S aux bouts de ces traverses ne réduit guère la fréquence ni les dimensions des principales crevasses qui s'y forment au séchage ou à l'usage. Cette étude a également montré que la position de la moelle influe beaucoup sur le degré de crevassement ainsi que sur la susceptibilité de ces structures de se fendiller à l'usage.

D'ordinaire, les principales crevasses se forment au séchage sur la grande face des traverses la plus rapprochée de la moelle vers laquelle elles s'étendent selon le plan radial, et leurs dimensions (longueur et largeur) sont d'autant plus grandes que les faces sont proches de la moelle. Le fait qu'une grande face voisine de la moelle représente un plan à peu près radial d'une section transversale de la tige alors que la face opposée y est presque tangentielle fait que le côté médullaire devient convexe en séchant, ce qui à son tour occasionne un élargissement excessif des principales crevasses. Toutefois la situation idéale de la moelle c'est celle qui exerce la meilleure influence sur la résistance des traverses, à l'usage, plutôt que sur leur crevassement au séchage. A l'usage le pire crevassement s'observe dans les traverses où la moelle se situe à mi-chemin entre les grandes faces. Dans de telles traverses une étroite crevasse provenant du séchage crée à l'usage un plan de faiblesse selon lequel peuvent se développer leur décollement et leur fendillement subséquent sous l'effet de charges répétées. Pour cette raison, le risque de fendillement à l'usage est moindre dans les traverses de bois dur à moelle encastrée où la moelle se situe à moins d'un pouce d'une grande face, que le côté médullaire se trouve placé en haut ou en bas sur la voie ferrée.

Selon cette étude le coût de l'insertion de fers en S avant le séchage des traverses n'est pas justifié, et la résistance moyenne à l'usure de celles en bois dur à moelle encastrée pourrait être améliorée par l'adoption de spécifications tenant compte de la situation de la moelle.

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CHECKING AND SPLITTING OF HARDWOOD RAIL TIES IN SEASONING AND SERVICE

by

E. Perem[1]

INTRODUCTION

The widespread use of pressure preservative treatment for rail ties has greatly reduced decay. As a result, causes other than fungal deterioration have gained relative prominence as reasons for removal of ties from service. One of the more important is a type of mechanical failure known as splitting. In addition, wide and deep checks, which do not necessarily develop into splits, often form in ties in service. Such checks expose the inner untreated parts of the tie to fungal infection and thus initiate deterioration. Splitting and checking is particularly severe in hardwood cross ties of the boxed-heart type, i.e. ties that contain the pith.

Various preventive measures have been developed for minimizing the losses due to checking and splitting, the most common being the application of S-irons to the tie ends before seasoning.

On the initiative of the major Canadian railway companies a Joint Committee on Checking and Splitting of Cross Ties[2] was formed in 1958 for the purpose of studying checking and splitting of ties in seasoning and service. The Committee initiated a study to establish the effectiveness of S-irons in preventing checking and splitting. This study was carried out in four phases: (a) observations of the changes in moisture content (MC) and moisture distribution in hard maple rail ties in relation to development of checks in seasoning; (b) observations of the checking of hard maple rail ties in commercial seasoning piles; (c) observations of the checking and splitting of test ties after an initial period of service in a test track; (d) observations of the checking and splitting of hardwood rail ties after long service in a test track.

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[1]Department of Fisheries and Forestry, Canadian Forestry Service, Forest Products Laboratory, Ottawa.

[2]Participants in the work of the Committee were the following: H. Britton, V. Bushell, T.J. Delaney, D.W. Gill, and C. Wagner, of the Canadian National Railways; D.H. Fenwick and P.E. Bird, of the Canadian Pacific Railway; and H.P. Sedziak (Chairman), J.D. Hale, J. Krzyzewski, W.W. Calvert, and E. Perem, of the Forest Products Laboratory, Ottawa.

In all phases of the study, special attention was directed to the performance of S-irons in preventing checking and splitting of the ties.

A. OBSERVATIONS OF THE CHANGES IN MOISTURE CONTENT AND MOISTURE DISTRIBUTION IN HARD MAPLE RAIL TIES IN RELATION TO DEVELOPMENT OF CHECKS IN SEASONING

The tests carried out at the Ottawa Forest Products Laboratory in 1959 were aimed at obtaining basic information necessary for planning extensive detailed observations of the behavior of S-ironed and not S-ironed maple rail ties in seasoning and service.

Test Material

The test material for this phase of the study consisted of 104 hard maple rail ties (Table 1). All ties were squared no. 2, with boxed heart. The nominal dimensions of the ties were: width, 8 inches; thickness, 6 inches; length, 8 feet. Three groups of ties, which differed as regards the initial MC (moisture content), were recognized in the study:

Group A - 42 commercial ties showing some initial drying
Group B - 50 commercial ties with high initial MC
Group C - 12 ties prepared at the laboratory from freshly felled trees

After the initial weights and measurements were recorded (May 5-8, 1959), the ties were placed in two experimental piles of "2 x 11 type" (one pair of stringers between every two rows of ties) in the laboratory yard, the piles being protected from direct sunlight but otherwise exposed to the weather.

Of the total of 104 test ties, 35 (20 in Group A, 11 in Group B, and 4 in Group C) were separated for the purpose of observing the effect of end-coatings on seasoning.

TABLE 1. WEIGHT AND VOLUME OF TEST TIES AT BEGINNING OF TESTS

Group of ties	Number of ties	Weight (lb.)		Mean volume (cubic ft)	Mean weight (lb/cubic ft)
		Mean	Standard deviation		
A - Low initial MC	42	158.7	13.8	2.74	57.9
B - High initial MC	50	172.1	8.6	2.79	61.7
C - From freshly felled trees	12	166.4	7.4	2.70	61.6
Average		166.0	-	2.76	60.1

Changes in the Average MC

The outdoor seasoning period for the untreated ties of the two main groups (A and B) lasted 5 months (May 5-6 to October 5-6). For the third group of ties the outdoor seasoning period was approximately 3 months (July 6 to October 6).

After the outdoor seasoning was completed, all ties were moved indoors so that they would develop checking. The purpose was to observe more closely the relations existing between the patterns of checking and the gross anatomical features of the ties.

The moisture-loss history of the untreated test ties during seasoning is shown in Table 2, and the progress of seasoning with time is illustrated in Figure 1.

Since it was impractical to establish the average MC of ties at the different stages of seasoning, the progress of seasoning was recorded in terms of average moisture loss in pounds per tie. However, since the average basic weight of Canadian sugar maple is 37.5 pounds per cubic foot, the oven-dry weight of an average tie 6" x 8" in cross section and 8 feet long would be 100 pounds. On this basis it can be assumed that the initial MC of the average test ties of the different groups was in the neighborhood of the following values:

Group A - 59%
Group B - 72%
Group C - 66%

In general, the rate of drying varied directly as the MC. The initial rate of drying of Group C was greater than the B rate, but the C sample was very small and the initial drying occurred in a different period of the season. The amount of moisture that evaporated from individual ties during the period varied between 11.2 and 45.5 pounds for all groups. A high moisture loss was usually associated with a high proportion of sapwood in the tie.

In the limited study of the effect of end-coatings on seasoning, two types of end-coatings were used: white lead mixed with linseed oil and a commercial waterproofing compound. Both types of end-coatings reduced the loss of moisture in the ties, but the commercial waterproofing compound was slightly more effective. Group C ties end-coated with white lead during 3 months of seasoning lost 20.9 pounds of moisture, compared with 26.5 pounds for untreated ties. Six Group B ties, which were soaked in water for 7 days and then end-coated, had an average moisture loss during 70 days of seasoning of 3.9 pounds, compared with 6.5 pounds for ties soaked but not end-coated. Twenty Group A ties were also soaked in water; 10 of these were end-coated with white lead and 10 with the commercial waterproofing compound. The ties end-coated with white lead lost 11.7 pounds per tie during 12 weeks, whereas the ties end-coated with the waterproofing compound lost 10.9 pounds per tie.

TABLE 2. AVERAGE LOSS OF MOISTURE FROM TEST TIES DURING SEASONING

Group	Wt at May 5/59 (lb.)	Loss* in wt (lb.)	Wt at June 15/59 (lb.)	Loss in wt (lb.)	Wt at July 6/59 (lb.)	Loss in wt (lb.)	Wt at July 21/59 (lb.)	Loss in wt (lb.)	Wt at Oct. 5/59 (lb.)	Total seasoning time (months)	Avg total loss of moisture (lb.)
A	156.9	12.5	144.4	7.3	-	-	137.1	2.2	134.9	5	22.0
B	172.7	21.4	151.3	2.6	-	-	148.7**	6.6	142.1	5	30.6
C	-	-	-	-	165.1	18.4	146.7	8.1	138.6	3	26.5

*Loss of weight between two weighings.

**Average weight exceptionally high owing to rainy period prior to weighing.

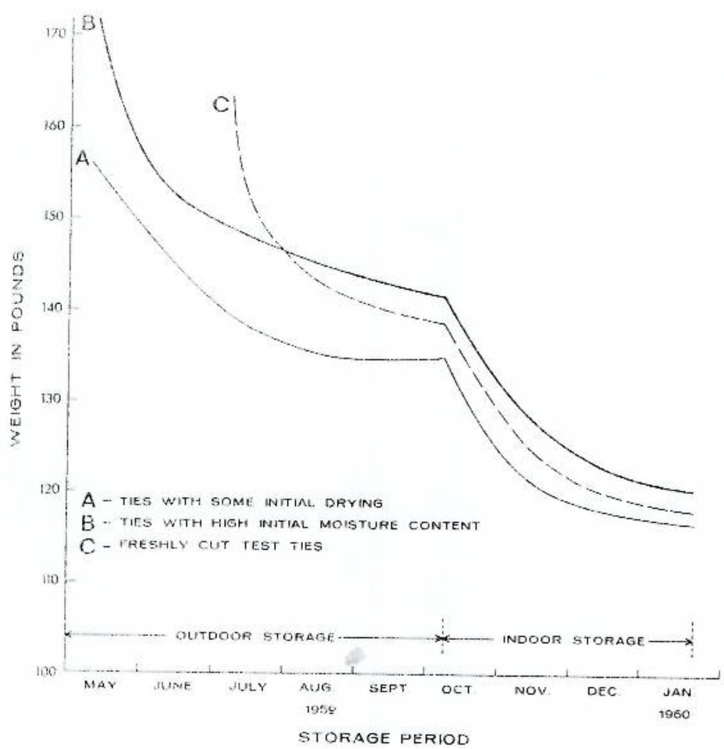

Figure 1. Changes of weight of the test ties during seasoning.

The 4-month period of indoor storage (average temperature 72 F, average relative humidity 22%) reduced the weight of the ties drastically; the average loss per tie was approximately 20 pounds. Owing to the higher initial MC of end-coated ties, somewhat greater loss of moisture was recorded for this category. The average MC of all ties at the end of indoor storage was approximately 16%.

Moisture Distribution in Test Ties at Different Stages of Seasoning

At the end of each stage of seasoning one untreated test tie was dissected into test specimens in such a way that observations of moisture gradients could be made along the length of the tie by layers 1/2 inch thick across the grain, from shell to core.

The MC values at different locations within the test ties at four stages of seasoning are recorded in Table 3. In Figure 2 moisture gradients occurring in the ties from one end to the other (a symmetrical pattern of moisture distribution being assumed to exist in both halves of the tie) are shown at different stages of seasoning.

The ties dissected after the outdoor seasoning period (October 5) showed a relatively uniform average MC (28 to 29%) throughout the length of the tie, with the exception of the few inches of wood at the ends, where a somewhat lower MC (23 to 26%) was recorded. It is of interest to note the relatively high average MC of the cross sections with the first foot from

TABLE 3. MOISTURE CONTENT DISTRIBUTION IN TEST TIES (%)

A. At commencement of observations (May 1959)
(Tie belonging to Group B)

Distance from tie surface	Distance from end of tie				
	1 inch	1 foot	2 feet	3 feet	4 feet
Outer 1/2 inch	32	48	51	52	51
1/2 to 1 inch	39	51	52	54	52
1 to 1-1/2 inches	43	66	67	70	69
1-1/2 to 2 inches	45	67	67	70	73
2 to 2-1/2 inches	46	67	70	72	74
Core	51	74	88	87	80

B. In June 1959 after 5 weeks of air seasoning
(Tie belonging to Group A)

Distance from tie surface	Distance from end of tie						
	1 inch	2 inches	5 inches	1 foot	2 feet	3 feet	4 feet
Outer 1/2 inch	17	21	26	27	28	29	30
1/2 to 1 inch	21	31	35	36	37	38	37
1 to 1-1/2 inches	25	36	41	45	42	43	42
1-1/2 to 2 inches	29	41	47	53	49	49	52
2 to 2-1/2 inches	33	44	52	58	56	51	63
Core	33	45	54	62	66	58	62

TABLE 3 (CONTINUED)

C. In October 1959 after approximately 5 months of air seasoning (Tie belonging to Group A)

Distance from tie surface	Distance from end of tie						
	1 inch	2 inches	5 inches	1 foot	2 feet	3 feet	4 feet
Outer 1/2 inch	21	21	21	21	21	21	21
1/2 to 1 inch	24	25	29	29	28	28	27
1 to 1-1/2 inches	25	27	33	32	31	31	30
1-1/2 to 2 inches	25	30	35	33	32	33	31
2 to 2-1/2 inches	24	31	36	34	33	33	31
Core	24	32	36	35	33	33	32

D. In January 1960 after 16 weeks of indoor storage

Distance from tie surface	Distance from end of tie						
	1 inch	2 inches	5 inches	1 foot	2 feet	3 feet	4 feet
Outer 1/2 inch	7	7	8	10	10	11	11
1/2 to 1 inch	7	8	11	13	14	16	16
1 to 1-1/2 inches	7	9	10	15	19	21	20
1-1/2 to 2 inches	7	9	13	18	21	23	23
2 to 2-1/2 inches	7	9	14	19	22	24	24
Core	7	10	14	20	22	25	25

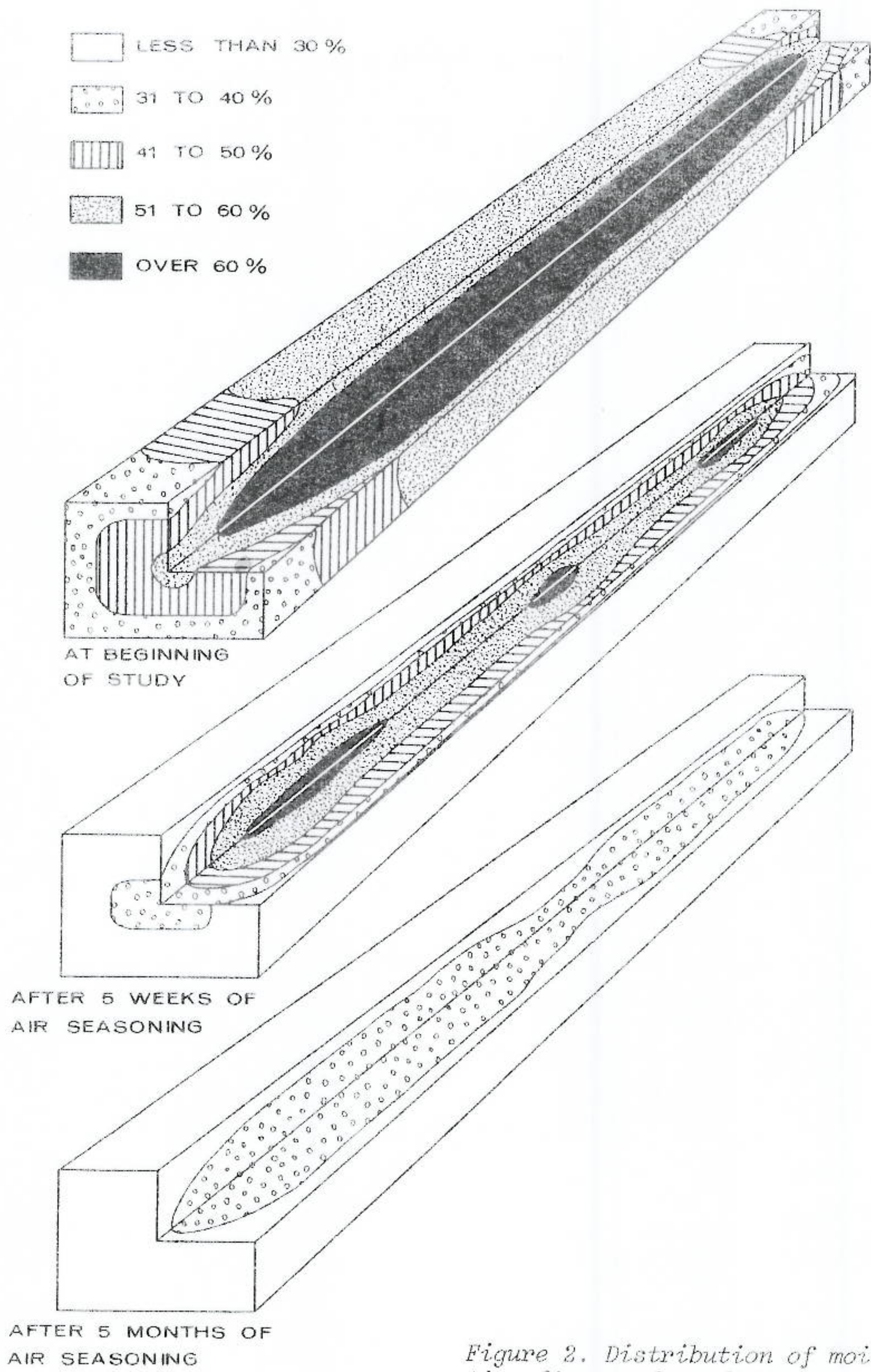

Figure 2. Distribution of moisture in ties dissected at different stages of air seasoning.

the ends of the tie. This phenomenon may be partly explained by the fact that the end portions of tie were in direct contact with the cross-piled ties employed as stringers and illustrates a possible favorable effect of stringer ties in retarding drying at areas of contact and thereby reducing the moisture gradients along the length of the ties.

If it is assumed that an MC of 30% (approximate value for MC at fiber saturation point) or less is desirable for successful preservative treatment, and that a preservative penetration of approximately 1 inch into the outer shell gives adequate protection to ties in service, the regional distribution of moisture in the test ties indicates that ties in the experimental piles had attained at the end of the outdoor seasoning period a degree of seasoning beyond the stage required for preservative treatment. Figure 3 illustrates the moisture distribution in the outer 1-inch shell of the test ties at the different stages of experiment. The variation of the average MC along the length of the test ties, dissected at different stages of seasoning, is illustrated on the same graph.

Occurrence of Checks in the Test Ties

Very small seasoning checks had started to develop on the ends of the test ties at the beginning of the test. All checks observed at the initial weighing of the ties were marked with colored crayons for future reference. As a rule, the checks on the end surfaces were small but numerous. Checks that started at the edges of the end surfaces did not extend more than a few inches along the faces of the ties. At a somewhat more advanced stage of drying the principal checks in the ends of the ties became conspicuous (Figure 4). A principal check generally began to form on the broad face nearest the pith, gradually extending toward the pith from this external origin by following the plane of the rays. Simultaneously with the development of principal checks, a number of small checks on the end surfaces closed.

Heart checks (also known as "heart shakes" or "star shakes") that were present in green condition frequently closed as the V-shaped seasoning checks began to develop in the periphery of the ties. The presence of heart checks, which are formed either when the tree is growing or when the growth stresses are released by felling and bucking, tends to aggravate the danger of splitting in seasoning and in service. If the plane of the principal check coincides approximately with that of a heart check, a deep separation, usually extending across the pith to the other side of the cross section, develops in the tie. Such separations may easily split the ties either during subsequent seasoning or in service when the tie is exposed to conditions of repeated drying and rewetting and to conditions of mechanical stress and wear.

Another minor implication of the presence of heart checks should be mentioned. Rail ties are, as a rule, S-ironed before piling and before much drying has occurred. Since heart checks may be present, however, it is considered desirable to place the S-irons across such separations (in order to prevent their widening) so that the position of heart checks directs the

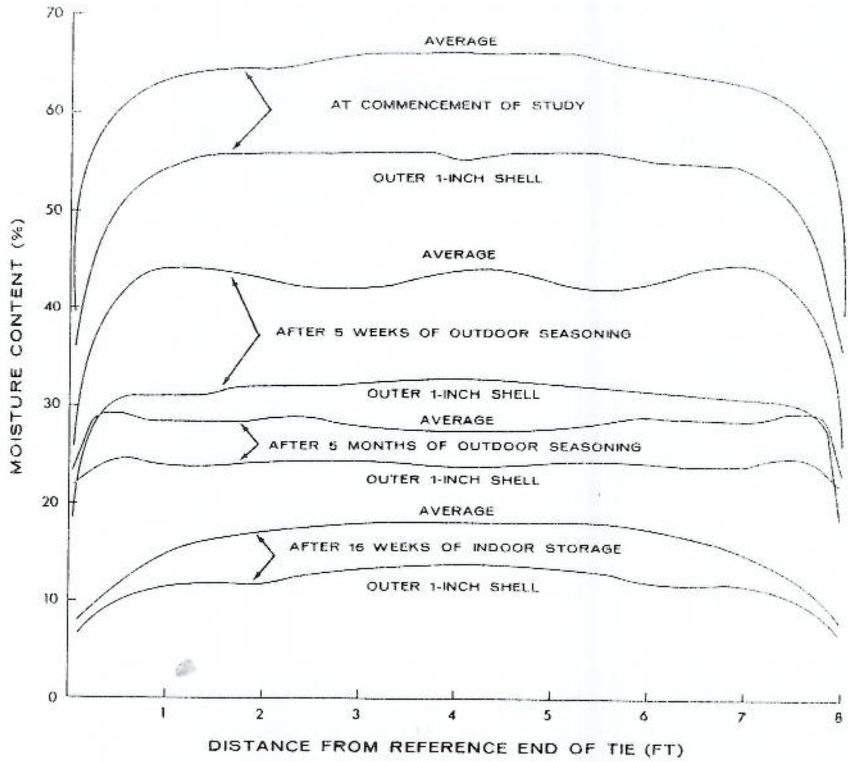

Figure 3. Variation of the average moisture content and the moisture content of the outer 1-inch shell of the test ties along the length of the ties at different stages of drying and seasoning.

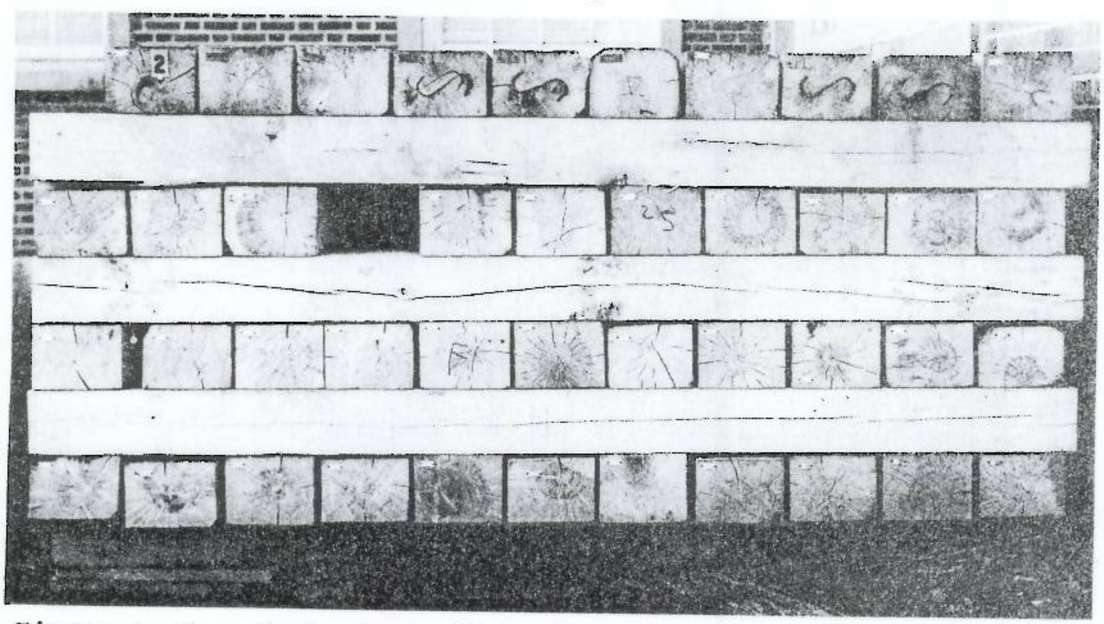

Figure 4. One of the test piles after approximately 1 month of air seasoning. The formation of principal seasoning checks is beginning in the ties.

location of S-irons often across the pith, where, generally, no noteworthy drying stresses develop. The expected useful service of an S-iron intended to counteract the drying stresses therefore becomes improbable. However, provided that the direction of heart checks does not coincide with the preferred direction of the principal seasoning checks, the heart checks may remain closed throughout the seasoning period, and this is sometimes taken as an indication of the check-preventative action of the S-irons.

Detailed measurement of checks in the test ties was carried out at the end of the indoor storage period, when the development of checks was at its maximum. During the measurements all checks 0.1 inch wide or wider were recorded with notation of their width, length, and position in the ties. In addition, separate records were kept for checks 0.3 inch wide or wider. The measurements are recorded in Table 4. In general, checking in the test ties was less severe than had been expected, the majority of the principal checks being less than 0.3 inch in maximum width. None of the seasoning checks appeared severe enough to cause rejection of a tie. In a number of ties that showed cross grain or spiral grain, severe warping and twisting were observed. Little difference was found in the extent of check development on the faces of the different groups of ties (untreated, S-ironed, and end-coated). The average area of small checks per tie tended to be somewhat greater for untreated ties than for S-ironed or end-coated ties, but the frequency of occurrence and the dimensions of large checks in the untreated ties were comparable to those of S-ironed ties.

The average area of the large checks per tie was practically equal for all three groups of ties, indicating that no drastic reduction in formation of major checks was brought about by application of S-irons on the ends of test ties or by the use of end-coatings on the ties.

Because of the expected interrelation between the occurrence of a major check on a face of the tie and the relative distance of this face (as compared with other faces) from the pith, the occurrence of principal

TABLE 4. CHECKS IN TEST TIES AFTER APPROXIMATELY 16 WEEKS OF INDOOR STORAGE

Treatment	Number of ties	All checks (0.1 inch wide or wider)		Large checks only (0.3 inch wide or wider)		
		Avg length per tie (ft)	Avg area per tie (sq inches)	Avg number per tie	Avg length per tie (ft)	Avg area per tie (sq inches)
Untreated	11	26.3	60.3	1.9	6.2	22.5
S-ironed	17	21.9	47.1	2.3	5.2	22.6
End-coated	31	25.4	53.6	2.1	5.6	23.5
All ties	59	24.5	53.0	2.1	5.6	23.1

checks in the test ties was analyzed according to the faces in which the checks occurred. Of the 236 faces of 59 maple ties in which the checks were recorded after 16 weeks of indoor storage, 76 (approximately one-third) had at least one large check 0.3 inch wide or wider. Most of the large checks were on the broad faces (upper and lower) of the ties. Approximately 55% of all broad faces had one or more major checks, as compared with only 9% of all narrow faces (side faces). The average length of larger checks per broad face was 2.5 feet, compared with an average length of 0.3 foot of large checks for each narrow face. More severe checking of the broad faces, as compared with the sides of the ties, is due to a combination of two factors: (a) the average distance of the pith to the narrow face is greater than the average distance to the broad face, and (b) fewer rays reach the narrow face than the broad face.

Dimensions of the large checks on the broad faces of test ties of different treatment groups are recorded in Table 5 by grouping the faces on the basis of their average distance from the pith. In Figure 5 the same data are shown graphically. It is apparent from the table and the graph that the distance of the face of the tie from the pith has a decided effect on the development of major checks in a tie with a boxed heart. The fact that a broad face close to the pith represents an approximately radial plane of the stem cross section while the opposite face is nearly tangential, causes the pith side to become convex in seasoning, and this in turn causes principal checks to widen excessively. Comparison of the effect of dif-

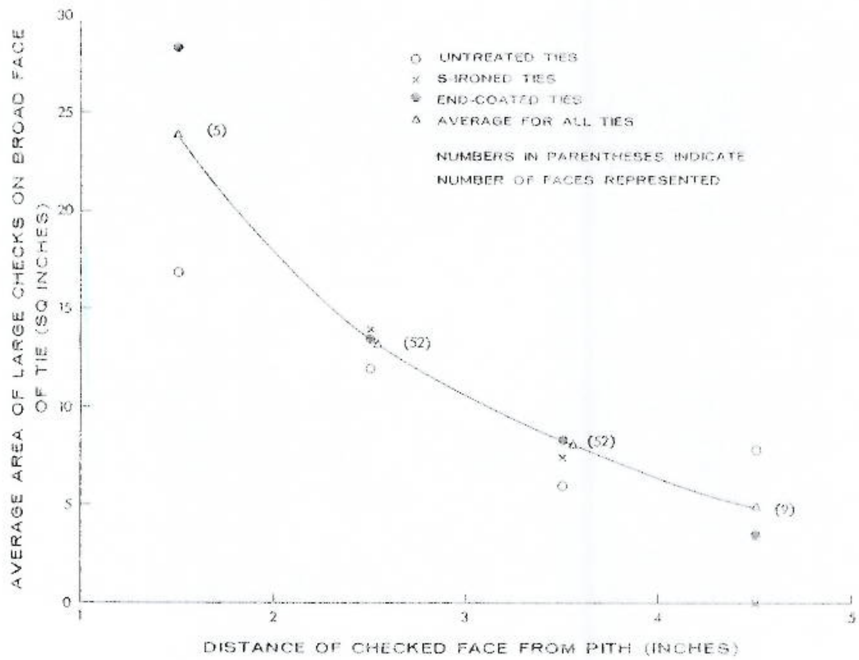

Figure 5. The average area of large checks on the broad faces of ties in relation to the distance of the face from the pith after 16 weeks of indoor storage.

TABLE 5. LARGE CHECKS (0.3 INCH WIDE OR WIDER) ON BROAD FACES OF TEST TIES AS RELATED TO DISTANCE OF FACES FROM PITH

Distance of face from pith	Treatment	Number of faces under observation	Percentage of faces with large checks	Avg length of large checks per face (ft)	Avg area of large checks per face (sq inches)
1 to 2 inches	Untreated	2	100	4.7	16.8
	S-ironed	0	-	-	-
	End-coated	3	67	5.4	28.3
	All ties	5	80	5.1	24.0
2 to 3 inches	Untreated	8	63	2.5	11.8
	S-ironed	16	69	3.2	13.7
	End-coated	28	64	3.3	13.4
	All ties	52	65	3.1	13.2
3 to 4 inches	Untreated	9	33	1.5	5.8
	S-ironed	17	47	1.9	7.4
	End-coated	26	50	2.1	8.5
	All ties	52	46	2.0	8.0
Over 4 inches	Untreated	3	33	2.2	7.9
	S-ironed	1	0	0.0	0.0
	End-coated	5	40	0.8	3.3
	All ties	9	33	1.2	4.5

ferent treatments, therefore, requires observations on the checking of the faces of ties that are similar as regards their distance from the pith. When the check formations in the different groups of ties (untreated, S-ironed, end-coated) are compared on this basis, it is apparent that none of the treatments applied reduced the formation of large checks appreciably.

Although the principal checks are typically formed at the broad face nearest the pith, there are occasional exceptions to this rule. A common reason for the formation of a principal check on some face of a tie other than that nearest the pith is the more rapid drying at the checked surface. Since sapwood seasons more rapidly than heartwood, the part of a tie most remote from the pith, which is likely to have the most sapwood, may dry more rapidly and therefore develop shrinkage stresses before noticeable shrinkage has occurred in the rest of the tie. Similarly a face exposed on the outside of the pile to the rapid drying effect of freely circulating air, undergoes shrinkage stresses in advance of other less exposed faces. Figure 6 shows the ends of the test ties piled outdoors after completion of the tests. The tendency toward principal check formation on the broad face nearest the pith is recognizable in the photographs. In Figure 7 two methods of placing the S-irons in the ends of ties are illustrated. In one, the S-irons are placed more or less in the center of the cross section of the ties (common industrial practice); in the other method, used by the Laboratory, S-irons are placed across the radial plane extending from the pith to the nearest broad face of the tie. No significant difference in the efficacy of the two methods was observed. It should be emphasized that an inspection confined only to the ends of a tie will not reveal the full condition of the tie. To establish the extent of checking and its possible effect on utility, the condition of the faces, particularly the broad faces, has to be examined critically.

B. OBSERVATIONS OF THE CHECKING OF HARD MAPLE RAIL TIES IN COMMERCIAL SEASONING PILES

Test Material

Development of seasoning checks in boxed-heart hard maple ties in seasoning piles of commercial size was observed near Montreal. One thousand one hundred and twenty-three ties, each with an identification number, were piled for seasoning in four test piles representing two different methods of piling (Figures 8 and 9). Two test piles were piled according to the method known as 1 x 11 (all ties, with the exception of stringers, at a slight angle to the horizontal plane), and two piles according to the method 2 x 11 (all ties horizontal). Half of the ties in each test pile were S-ironed in the checkerboard pattern in such a way that both ends of each tie were either S-ironed or not S-ironed.

The green test ties were piled in August 1959 for observation during the following summer. The test piles were close together and close to other piles in the seasoning yard to retard drying. Almost no seasoning checks developed in the ties during the fall of 1959.

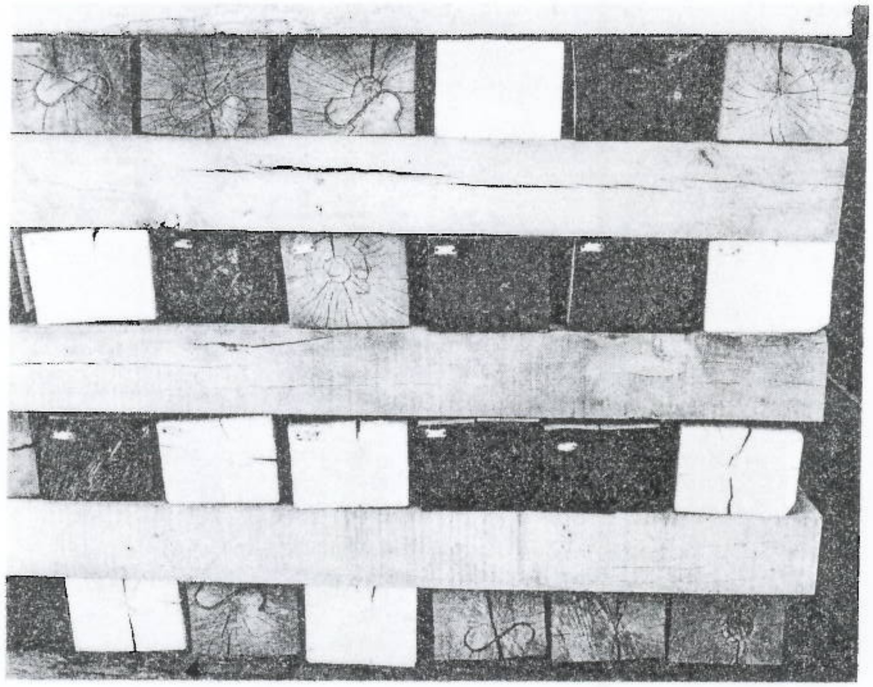

Figure 6. A closeup view of the end surfaces of some of the test ties after completion of the tests. The tendency toward principal check formation on the broad face nearest the pith is recognizable.

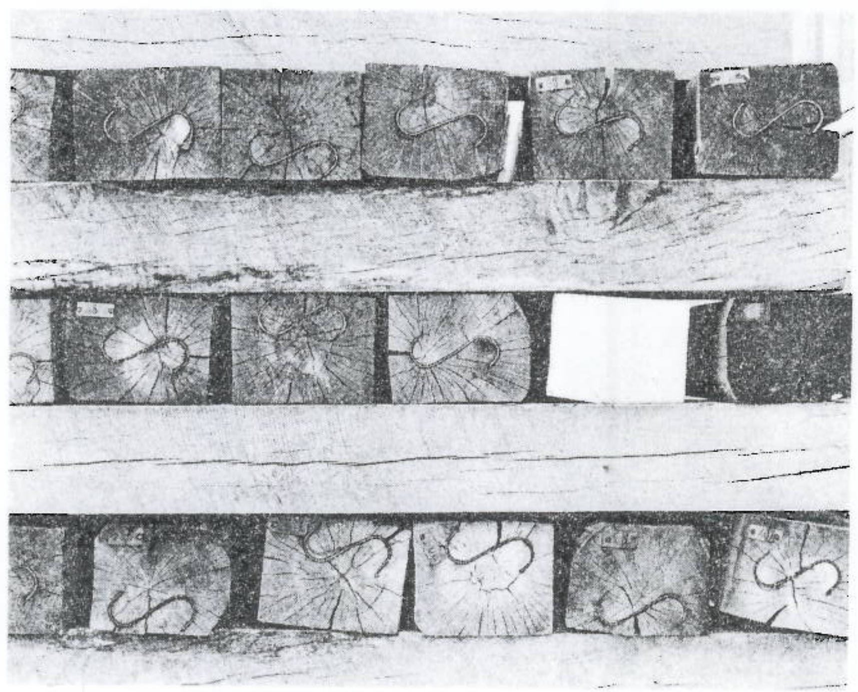

Figure 7. Two methods of placing S-irons in the ends of ties. In some test ties S-irons were placed more or less in the center of the cross section of the tie (common industrial practice); in others S-irons were placed across the radial plane extending from the pith to the nearest broad face of the tie.

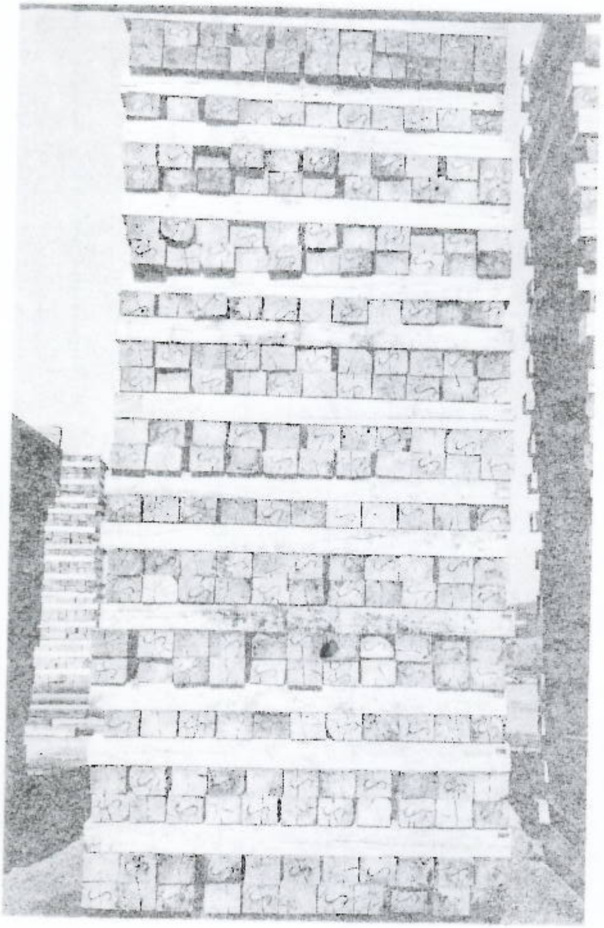

Figure 8. A test pile representing the 1 x 11 method of piling. The ties are S-ironed in checkerboard pattern.

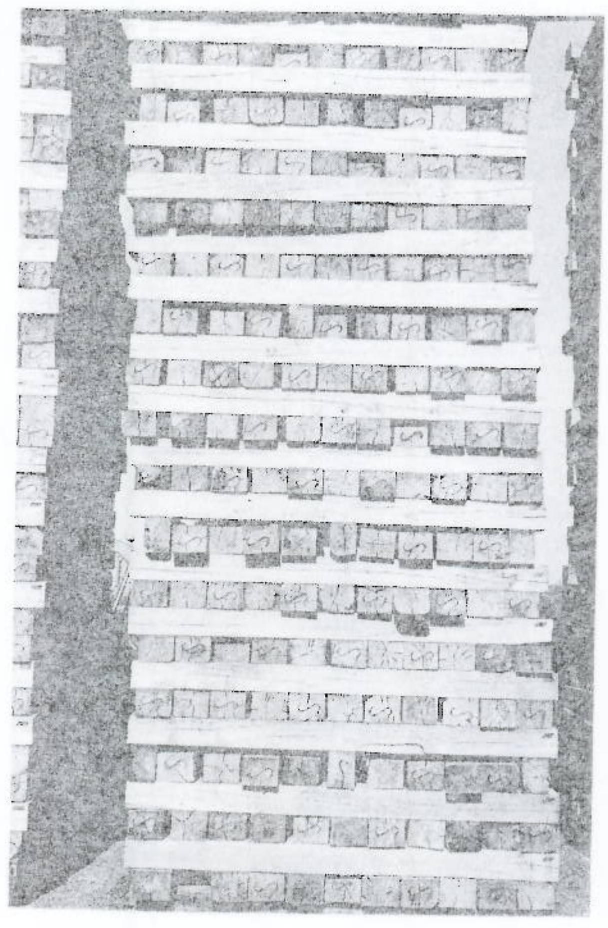

Figure 9. A test pile representing the 2 x 11 method of piling.

The seasoning and observation of check formation was completed in 1960. The ties were pressure-treated with preservative and placed in a test track in 1961.

Occurrence of Checks in Seasoned Ties

In two test piles (one piled according to method 1 x 11, the other according to method 2 x 11) detailed measurements of checks were made late in August 1960. Six hundred and three ties were subjected to these measurements, 327 with S-irons on both ends and 276 without S-irons.

All checks 1/8 inch wide or wider were recorded as regards their position, length, and width on all four faces. Most of the checks were small, very few having a width of 1/2 inch or more. No splitting had occurred in the test ties during seasoning. The distribution of the checks by width was as follows:

1/8" to 1/4" wide	-	76.5%
1/4" to 3/8" wide	-	21.4%
3/8" to 1/2" wide	-	2.0%
1/2" wide or wider	-	0.1%

The ties of the 2 x 11 pile ("flat-piled") developed longer seasoning checks than the ties in the 1 x 11 pile ("angle-piled").

Method of piling	Average number of checks per tie	Average length of checks per tie (ft)
1 x 11	9.0	19.2
2 x 11	9.1	25.0

The measurements showed also that checking had progressed at different rates within a pile depending on the position of the tie in the pile. While no clear pattern of variation existed in the ties of the same horizontal row, there was a definite decrease in checking going from the top of the pile to the bottom. The checks in the ties of the top five rows were, however, partially closed owing to a short rainy period prior to measurement. The average length and area of checks per tie in the different rows of a 1 x 11 pile were as follows:

Rows	Average length of checks per tie (ft)	Average area of checks per tie (sq inches)
Top five rows (1-5)	5.6	17.8
Rows 6 to 10	3.8	30.7
Rows 11 to 15	3.8	12.2
Rows 16 to 20	2.9	8.6
Rows 21 to 24	1.9	5.5

As expected, the principal seasoning checks had formed predominantly on the broad faces that were closest to the pith. The average length and area of checks 1/4 inch wide or wider on the broad faces closest to the pith and farthest from the pith were as follows:

	Average length (ft)	Average area (sq inches)
Broad faces closest to the pith (pith distance < 3 inches)	2.65	7.99
Broad faces farthest from the pith (pith distance > 3 inches)	1.37	4.36

To evaluate the merits of S-irons in preventing the development of major checks, the relative occurrence of checks 3/8 inch wide or wider was compared in the ties with S-irons and in those without S-irons (Table 6). The S-irons had no apparent beneficial effect in preventing the formation of major seasoning checks during seasoning.

TABLE 6. OCCURRENCE OF WIDE CHECKS (3/8 INCH WIDE OR WIDER) IN COMMERCIAL TIE PILES AFTER SEASONING

Treatment	Number of ties	Avg length (ft)	Avg area (sq inches)
Ties with S-irons	327	0.79	3.70
Ties without S-irons	276	0.77	3.46

C. OBSERVATIONS OF THE CHECKING AND SPLITTING OF TEST TIES AFTER AN INITIAL PERIOD OF SERVICE IN A TEST TRACK

Test Material

The air-seasoned hard maple ties were not pressure-treated with creosote until the summer of 1961, and thus they had probably developed more seasoning checks at the time of preservative treatment than they would have normally. The ties, installed near Drummondville, Que., in the usual manner in the summer of 1961, will form the basis of the long-term study concerning the checking and splitting of boxed-heart maple rail ties and the efficacy of S-irons in preventing checking and splitting. Inspection of the ties is to be carried out periodically, and three inspections have been performed to date (in 1962, 1965, and 1967).

During the first inspection, 1 year after installation, the position of the pith in relation to the upper face was recorded for each tie (Table 7). One thousand and eighty-three of the original 1,123 air-seasoned ties were installed in the test track. Of these, 638 had S-irons in the ends, while 445 were without S-irons. The relative proportions of the different pith-position groups were comparable in ties with and without S-irons, and this simplifies the evaluation of the merits of S-irons. Sixty-five percent of the ties were placed with the pith side up, which suggests that such positioning was done intentionally in some cases.

Occurrence of Checks in Ties in the Test Track

The 1962 inspection (1 year after installation) revealed that checking degrade was relatively minor. The average length of checks 1/2 inch wide or wider per tie was 1.8 feet; and the average area was 10.7 square inches. By 1965 the average length and area of major checks had almost doubled to 3.4 feet and 21.2 square inches. In 1967 the amount of apparent checking had decreased to 3.1 feet and 18.5 square feet, and the decrease was associated with a rainy period prior to the 1967 inspection.

To determine whether there was any correlation between the extent of checking in the ties during seasoning and the extent of checking in the ties after 4 years of service, the area of checks (1/4 inch wide or wider) of the broad faces of 568 ties after seasoning was compared with the area of checks (1/2 inch wide or wider) on the same broad faces after 4 years of service (Table 8). The correlation was low (although statistically significant), indicating that only 7 to 14% of the variation in checking shown after 4 years of service would be explained by the variation in checking present immediately after seasoning.

The Effect of S-irons on the Checking of Ties in the Test Track

As expected on the basis of observations made during the other phases of the study, no changes were observed in the checking pattern due to the presence of S-irons in the ends of ties. The average length and area of major checks (1/2 inch wide or wider) of S-ironed and not S-ironed ties, recorded during the three inspections, were much the same (Table 9).

The Effect of the Position of the Pith on the Checking of Ties in the Test Track

The observations made during the seasoning experiments showed that the important variable that determines the extent of checking in the broad face of a boxed-heart tie is the position of the pith in relation to the face. In seasoning, a simple relationship existed between the distance of the face from the pith on one hand, and the length and area of major checks on the other hand. The closer the pith was to the broad face, the more severe was the checking (Figure 5). In the newly established test track,

TABLE 7. DISTRIBUTION OF TIES IN TEST TRACK BY PITH POSITION GROUPS AND BY S-IRONING

Pith position (distance of pith from upper face)	Ties without S-irons		Ties with S-irons		All ties	
	Number	%	Number	%	Number	%
0 to 1 inch	3	0.6	1	0.2	4	0.4
1 to 2 inches	84	18.9	73	11.4	157	14.5
2 to 3 inches	215	48.3	331	51.9	546	50.4
3 to 4 inches	131	29.5	209	32.7	340	31.4
4 to 5 inches	12	2.7	24	3.8	36	3.3
5 to 6 inches	0	0.0	0	0.0	0	0.0
Total	445	100	638	100	1,083	100

TABLE 8. EFFECT OF 4 YEARS OF SERVICE ON AREA OF MAJOR CHECKS ON UPPER FACES OF TIES

Type of ties	Number of ties	Area of major checks per tie		Coefficient of correlation	Level of significance
		After seasoning* (sq inches)	After 4 years of service** (sq inches)		
Without S-irons	263	7.96	30.44	+ 0.368	99%
With S-irons	305	6.38	30.19	+ 0.265	99%

*Including all checks 1/4 inch wide or wider.

**Including all checks 1/2 inch wide or wider.

TABLE 9. COMPARISON OF AVERAGE LENGTH AND AREA OF MAJOR CHECKS (1/2 INCH WIDE OR WIDER) IN TIES WITH AND WITHOUT S-IRONS DURING THREE INSPECTIONS

Year of inspection	Ties without S-irons		Ties with S-irons	
	Avg length (ft)	Avg area (sq inches)	Avg length (ft)	Avg area (sq inches)
1962	1.86	11.07	1.79	10.51
1965	3.52	21.91	3.38	20.68
1967	3.00	18.20	3.12	18.80

the most severe checking after an initial service period was recorded in the ties in which the pith was 1 inch to 2 inches from the upper face (Table 10 and Figure 10). The ties in which the pith was approximately midway between the two broad faces (2 to 4 inches from upper face) showed, when assessed on the basis of recorded average values, relatively moderate check development. It was observed, however, during the last inspection of the test track that it was characteristic of the ties in this group to show either complete absence of major checks or severe checking, the intermediate types of check development being relatively rare. It is reasonable to assume that the proportions of badly checked ties will increase rapidly in this pith-position group.

When the 1,083 ties in the test track were divided into two groups —(a) ties placed in track with the pith up, and (b) ties placed in track with the pith side down—the average length and area of the large checks in the upper faces proved to be less in ties in which the pith side was down.

Position of tie in track	Average length of large checks per tie (ft)	Average area of large checks per tie (sq inches)
Pith side up	3.93	24.32
Pith side down	2.53	15.30

It is expected that the apparent better performance of ties installed pith side down will become less pronounced with time.

TABLE 10. LENGTH AND AREA OF MAJOR CHECKS (1/2 INCH WIDE OR WIDER) IN TIES IN NEW TEST TRACK, GROUPED ON BASIS OF AVERAGE DISTANCE OF PITH FROM UPPER FACE

Distance of pith from upper face	Number of ties	1962		1965		1967	
		Avg length (ft)	Avg area (sq inches)	Avg length (ft)	Avg area (sq inches)	Avg length (ft)	Avg area (sq inches)
Less than 1 inch	4	2.0	6.0	2.6	15.7	2.6	15.7
1 to 2 inches	157	2.4	14.7	4.1	25.9	3.9	23.6
2 to 3 inches	546	1.8	10.9	3.9	23.9	3.9	20.2
3 to 4 inches	340	1.7	9.8	2.6	15.9	2.4	14.2
4 to 5 inches	36	0.1	0.9	1.5	9.1	1.7	10.1

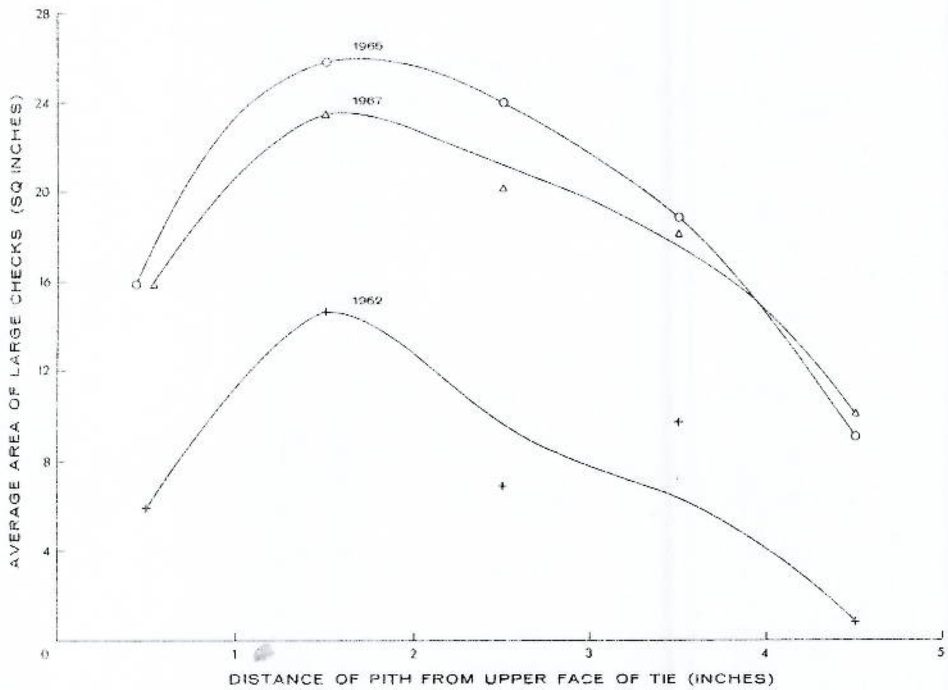

Figure 10. The occurrence of major checks (1/2 inch wide or (wider) in the upper faces of ties in the test track in relation to the distance from the pith to the upper face.

D. OBSERVATIONS OF THE CHECKING AND SPLITTING OF HARDWOOD RAIL TIES AFTER LONG SERVICE IN A TEST TRACK

The occurrence of checking and splitting in hardwood rail ties after long service was observed to determine the effect of S-irons in preventing the checking and splitting of ties in service. The ties were installed in a test track at Lac Mercier, Que., in 1930 and 1931 for a study concerning the effect of incising on service life, but since one-third of the ties had been provided with S-irons, the Joint Committee on Checking and Splitting of Cross Ties believed that useful information on the merits of S-irons could be obtained by detailed inspection of this test track. The inspection was made in June 1962.

Test Material under Observation and the Method of Appraisal of the Condition of Ties

Eight hundred and twenty-nine ties treated with a mixture of creosote oil (70%) and coal tar (30%) were installed in the track in 1930 and 1931 (Krzyzewski, 1969). At the time of the 1962 inspection 508 (61.3%) of the original ties were still in service. All ties were 6" x 8" x 8'. The distribution of the 508 ties by species is shown in Table 11.

TABLE 11. DISTRIBUTION OF TEST TIES IN OLD TRACK, BY SPECIES

Species	Number of ties installed in 1930-31	Ties in service at time of 1962 inspection	
		Number	%
Birch	304	247	81.3
Maple	314	204	65.0
Beech	211	57	27.0
All species	829	508	61.3

The presence of S-irons in the ends of test ties at the time of the 1962 inspection is shown in Table 12. One hundred and sixty-one (31.7%) of the 508 ties inspected had S-irons in one or both ends.

Since most of the S-ironed ties had S-irons in one end only, and since the effect of S-irons, if any, on the development of checks is likely to be limited to half of the total length of the tie, the recorded data were analyzed on the basis of half-ties. In Table 13 the number of half-ties under observation is shown by different categories.

During the 1962 inspection all checks 1/2 inch wide or wider were recorded for each test tie with notation of width, length, and position of the check. The ballast covering was removed from both ends of the ties and the position of the pith in relation to the upper face of the tie was recorded.

The Effect of S-irons

In Table 14 the average length and average area of checks per half-tie are recorded for the two types of ties. It is evident from the table that more checking occurred in S-ironed half-ties than in half-ties without S-irons.

Since it is not likely that the presence of S-irons is a cause of increased checking of ties, it seems reasonable to assume that the ties provided with S-irons were more susceptible to checking and that they showed major checks at the time of S-ironing. In Table 15 half-ties without S-irons from ties which had S-irons in the other half are compared with half-ties from not S-ironed ties. Considerably fewer wide checks were present in those half-ties which originated from not S-ironed ties, and the checking of not S-ironed half-ties from S-ironed ties was comparable to the checking of the S-ironed halves.

Since the two groups of ties (ties with S-irons and ties without S-irons) apparently differed from each other with regard to the likelihood of developing major checks and splits, and since the ratio of S-ironed ties

TABLE 12. PRESENCE OF S-IRONS IN TEST TIES AT TIME OF 1962 INSPECTION

Species	Ties without S-irons		Ties with S-irons					
			On both ends		On one end only		Total of S-ironed ties	
	Number	%	Number	%	Number	%	Number	%
Birch	132	38.0	42	79.2	73	67.6	115	71.4
Maple	178	51.3	4	7.6	22	20.4	26	16.2
Beech	37	10.7	7	13.2	13	12.0	20	12.4
All species	347	100	53	100	108	100	161	100

TABLE 13. SUMMARY OF HALF-TIES IN OLD TEST TRACK UNDER OBSERVATION

Category of half-ties	Birch		Maple		Beech		All species	
	Number	%	Number	%	Number	%	Number	%
Number of half-ties without S-irons								
Ties without S-irons	264	53.4	356	87.2	74	64.9	694	68.3
Ties in which other half had been S-ironed	73	14.8	22	5.4	13	11.4	108	10.6
Number of half-ties with S-irons								
Ties with S-irons on both ends	84	17.0	8	2.0	14	12.3	106	10.5
Ties in which other half had no S-iron	73	14.8	22	5.4	13	11.4	108	10.6
All categories	494	100	408	100	114	100	1,016	100

TABLE 14. OCCURRENCE OF CHECKS IN S-IRONED AND NOT S-IRONED HALF-TIES

Treatment	Species	Number of half-ties	All checks (1/4 inch wide or wider)		Major checks only (1/2 inch wide or wider)	
			Avg length per half-tie (ft)	Avg area per half-tie (sq inches)	Avg length per half-tie (ft)	Avg area per half-tie (sq inches)
S-ironed	Birch	157	4.5	21.1	2.4	14.8
	Maple	30	5.1	26.5	3.3	21.1
	Beech	27	4.6	25.7	3.0	20.5
Not S-ironed	Birch	337	4.3	18.5	1.3	9.5
	Maple	378	5.0	26.3	2.7	19.4
	Beech	87	5.0	29.0	2.9	22.7

TABLE 15. CHECKING OF HALF-TIES LACKING S-IRONS

Origin of half-ties lacking S-irons	Species	Number of half-ties	Major checks (1/2 inch wide or wider)	
			Avg length per half-tie (ft)	Avg area per half-tie (sq inches)
From ties in which the other half was S-ironed	Birch	73	2.1	14.2
	Maple	22	3.2	20.3
	Beech	13	3.9	29.7
From ties without S-irons	Birch	264	1.1	8.3
	Maple	356	2.7	19.3
	Beech	74	2.7	21.4

to not S-ironed ties—among the ties removed from the track during the period of 31 to 32 years in service—was not known, no conclusive evidence could be obtained from this phase of the study on the role of S-irons in preventing checking and splitting of ties in service. However, no indication of any beneficial effect due to S-irons was apparent in the test material.

The Checking of Ties as Related to Species

The three species of wood used for test ties—birch, maple, and beech—showed considerable differences with respect to the development of checking. Checking was much less in birch ties than in maple and beech. The checks in beech were, as a rule, wider than in maple. In Table 16, the average length and area of checks per tie is shown for each species.

The fact that only 18.7% of the birch ties were removed from service, compared with 35% for maple and 73% for beech, is consistent with the relatively low incidence of large checks in birch ties. There is no record of the principal reasons that caused the removal of ties from the test track. The prevailing opinion among experts associated with the maintenance of railroads is that the main cause of removal is deterioration due to splitting and other mechanical failures rather than to decay. It is likely however, that the extension of seasoning checks—due to stresses in service—exposed areas of untreated wood to decay organisms, and that this contributed to the failure of some ties.

The less severe checking of birch ties, compared with maple and beech, is undoubtedly associated with the low shrinkage differentials and corresponding low seasoning stresses in birch. The average ratio of tangential shrinkage to radial shrinkage of yellow birch is 122:100; the average ratio is 191:100 for sugar maple and 194:100 for beech

The Effect of the Position of the Pith (in Relation to the Upper Face of the Tie) on the Checking of Ties

As already indicated, the location of the principal seasoning checks and the extent of checking in boxed-heart ties are strongly influenced by the position of the pith in relation to the broad faces of the tie. As a rule, the major checks develop on the broad face of the tie closest to the pith. Since such seasoning checks could have a permanent effect on the behavior of ties in service, and since further formation of major checks is expected to occur in service as a result of seasonal moisture movement through the upper face of the ties, the occurrence of checks and the position of the pith were observed in the test ties.

In Table 17 the average length and area of large checks (1/2 inch wide or wider) per tie are recorded by groups of ties characterized by different average distance of the pith from the upper face of the tie. In Figure 11 the average area of large checks in ties of the three species is represented graphically for each of the groups. Sixty-five test ties were

TABLE 16. OCCURRENCE OF CHECKS IN TIES, BY SPECIES

Species	Number of ties	All checks (1/4 inch wide or wider)		Major checks only (1/2 inch wide or wider)	
		Avg length per tie (ft)	Avg area per tie (sq inches)	Avg length per tie (ft)	Avg area per tie (sq inches)
Birch	247	8.7	38.6	3.4	22.7
Maple	204	10.0	52.6	5.6	39.4
Beech	57	9.8	56.4	5.8	46.4

TABLE 17. CHECKING OF HALF-TIES GROUPED ON BASIS OF AVERAGE DISTANCE OF PITH FROM UPPER FACE

Distance of pith from upper face	Species	Number of half-ties in group	Avg length of major checks (ft)	Avg area of major checks (sq inches)
Non-boxed-heart ties	Birch	36	0.5	4.3
	Maple	74	1.6	12.4
	Beech	20	0.9	8.3
Less than 1 inch	Birch	16	0.6	3.9
	Maple	53	2.9	19.9
	Beech	8	2.8	25.7
1 to 2 inches	Birch	29	1.0	6.9
	Maple	22	3.2	21.8
	Beech	8	4.0	25.0
2 to 3 inches	Birch	181	2.1	12.7
	Maple	59	3.1	22.2
	Beech	36	3.2	23.2
3 to 4 inches	Birch	174	1.9	13.6
	Maple	86	3.4	24.3
	Beech	29	3.7	27.6
4 to 5 inches	Birch	34	1.2	8.1
	Maple	47	3.1	21.3
	Beech	8	3.2	22.5
5 to 6 inches	Birch	24	1.0	6.8
	Maple	61	2.6	17.3
	Beech	5	2.6	18.0

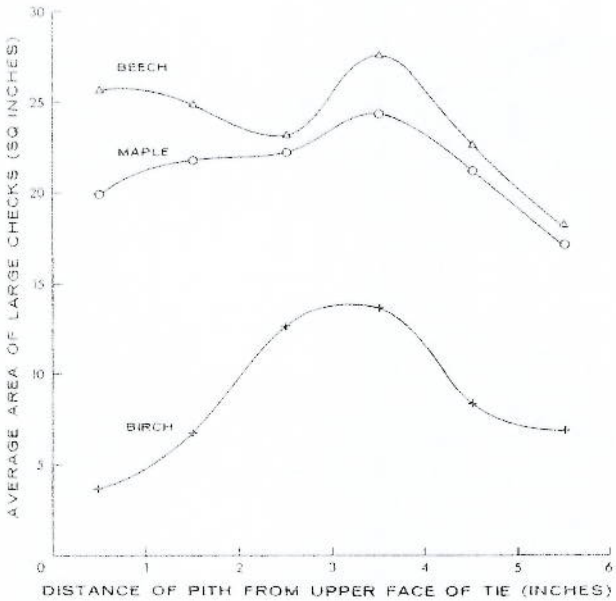

Figure 11. The occurrence of major checks (1/2 inch wide or wider) in rail ties of different species after long service in a test track in relation to the distance of the pith from the upper face of the tie.

not of the boxed-heart type and these are shown separately in the table. Both S-ironed half-ties and half-ties without S-irons are included.

It is evident that the occurrence of large checks in the test ties is related to the position of the pith in the cross section of the tie. In the 130 half-ties that were not of the boxed-heart type, checking was significantly less than in ties that contained the pith. In boxed-heart ties, the least checking was recorded for those in which the pith was less than 1 inch from either the upper or the lower face of the tie. Ties in which the pith was approximately halfway between the two broad faces showed the most severe check development.

This pattern of occurrence of principal checks after long service differs considerably from the pattern of development of seasoning checks described earlier, where the most severe checking was observed in ties in which the pith was close to a broad face. From a practical point of view it is only the check development after long service that is important. An increase in the development of major checks after a long period of service in those ties in which the pith is about halfway between the two broad faces is to be expected. Even a narrow seasoning check extending halfway through the cross section at the time of track installation creates a definite plane of weakness in the tie. Under repeated loading in service the separation progresses along this plane of weakness, causing the check to widen and deepen and leading ultimately to the splitting of the tie. In ties with the pith close to a broad face, the depth of the principal seasoning check is usually limited, and a well-defined plane of excessive weakness may not exist.

In this connection, it would be of considerable interest to have information available on the proportion of ties of the different pith-distance groups removed from the old test track. Since no such records exist,

TABLE 18. DISTRIBUTION OF DIFFERENT PITH-DISTANCE GROUPS OF TIES IN OLD (30 YEARS) TEST TRACK AND IN RECENTLY ESTABLISHED TEST TRACK

Distance of pith from upper face	After 30 to 31 years of service		Newly established track
	Maple (%)	Birch (%)	Maple (%)
Less than 1 inch	15.7	3.5	0.4
1 to 2 inches	6.7	6.6	14.5
2 to 3 inches	18.2	39.3	50.4
3 to 4 inches	26.6	38.0	31.4
4 to 5 inches	14.6	7.4	3.3
5 to 6 inches	18.2	5.2	0.0

an attempt was made to estimate indirectly the distribution of ties by pith-distance groups that had been removed during the 32 years of service. For this purpose the percent distribution of 1,083 hard maple ties among the different groups was first established for the new test track at Ste. Germaine, Que. (Table 18 and Figure 12). Since this new track of maple ties may not represent the conditions that existed in the old track at the time of its establishment—the use of boxed-heart ties and the method of placement of ties in the track (pith side up or down)—a distribution curve for the birch ties of the old track (of which only 18.7% had been removed during service) is shown for comparison (Curve C, Figure 12). The similarity of the two curves is apparent, even though the proportion of the ties with the pith approximately halfway between the broad faces was less in the birch ties of the old test track. (From Figure 12 it can be assumed that most of the birch ties that had been removed were of the halfway type.)

A comparison of Curve B with Curves A and C suggests that halfway ties have a much shorter service life expectancy than ties in which the pith is located close to one of the two broad surfaces. The curves also indicate that, of the ties in which the pith was more than 1 inch but less than 2 inches from a broad face, those placed in the track with the pith side down survived better than the ones placed in the track pith side up.

CONCLUSIONS

1. In seasoning boxed-heart maple rail ties, the major seasoning checks form, as a rule, on the broad faces nearest the pith and extend toward the pith by following the plane of rays.
2. The frequency and dimensions of major checks are not reduced either in seasoning or in service by embedding S-irons in the ends of ties before seasoning.

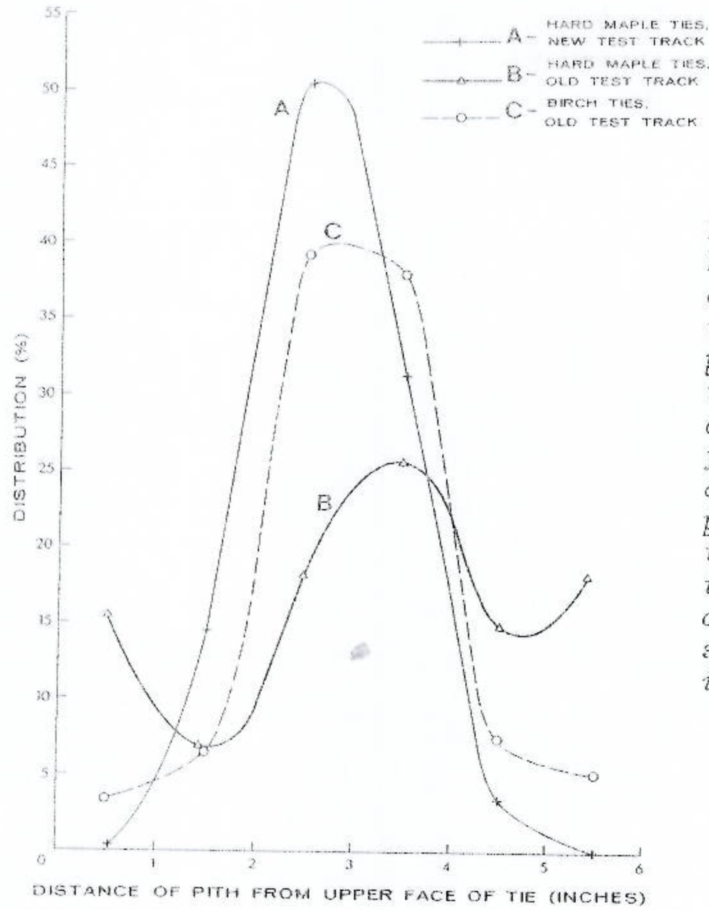

Figure 12. Distribution of boxed-heart maple ties of the old track and of a newly established test track among the different pith-position groups. The distribution curve for birch ties of the old track is also shown to justify the assumption that a normal distribution among the pith-position groups is applicable to the ties of the old track at the time of its establishment (most of the original birch ties were still in service at the time of inspection).

3. The position of the pith in the boxed-heart tie strongly influences the extent of check development and the susceptibility of the tie to splitting.

4. The extent of checking and the risk of splitting in service is least in boxed-heart ties in which the pith is less than 1 inch from a broad face, whether the tie is placed in the track with the pith side up or down.

5. The risk of splitting in service is greatest in ties where the pith is approximately halfway between the two broad faces.

6. Ties with a 6" x 8" cross section, in which the pith is more than 1 inch but less than 2 inches from a broad face, appear less vulnerable to splitting in service when they are placed in the track with the pith side down.

7. The fact that major seasoning checks tend to extend with time into the pith, thereby exposing the untreated interior of the tie to fungal attack, undoubtedly contributes to failure of the tie in service.

8. The study indicates that the expense of providing boxed-heart hardwood ties with S-irons is unwarranted, and that the average service life of hardwood ties could be improved by the adoption of tie specifications in which allowance is made for the location of the pith.

ACKNOWLEDGMENTS

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