DS

REPORT

First Semiannual Progress Report

Investigation of Wheel Conditions

To

Federal Railroad Administration

U.S. Department of Transportation

JANUARY 13, 1989

Battelle

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January 13, 1989

Mr. Cliff Gannett, RRS-32
Federal Railroad Administration
Office of Research and Development
Washington, D.C. 20590

Dear Mr. Gannett:

Enclosed are five copies of our First Semiannual Progress Report on our Investigation of Wheel Conditions. This activity is being addressed under Technical Task Directive No. 5 of Contract No. DTFR53-86-C-00006.

If you have any questions or comments, please call me at (614) 424-4433.

Very truly yours,

Richard C Rice

Richard C. Rice
Manager,
Structural Integrity Projects Office
Mechanics Section

RCR:lma

Enclosures (5)

cc Mr. Garold Thomas, RRS-32 (letter only)
Ms. Susie A. Bolling, RAD-30

FIRST SEMIANNUAL PROGRESS REPORT

TECHNICAL TASK DIRECTIVE NO. 5
CONTRACT NO. DTFR53-86-C-00006

on

INVESTIGATION OF WHEEL CONDITIONS

to

FEDERAL RAILROAD ADMINISTRATION
U.S. DEPARTMENT OF TRANSPORTATION

January 13, 1989

by

R. C. Rice and S. W. Rust

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SUMMARY

Approval of this task was confirmed on March 21, 1988, and it is currently scheduled for completion on December 20, 1989. The objective of this task is to ensure the validity of wheel discoloration test data developed with the cooperation of the American Association of Railroads (AAR) and to provide an analysis of these data so that the Federal Railroad Administration (FRA) Office of Safety can make technically sound decisions concerning the safety of operating discolored curved plate wheels in normal railroad service.

This report summarizes Battelle's activities on this task to date. Progress on the FRA/AAR wheel discoloration program has lagged behind the expectations of nearly everyone involved, because there is still some disagreement concerning the details of the AAR test plan and, therefore, the nature of a waiver that the FRA should grant to allow the AAR to develop the necessary discolored wheel service data. As a result, the majority of Battelle's efforts to date have been devoted to a critique of the American Association of Railroad's (AAR's) most recent implementation proposal for the discolored wheel study. Areas of concern with this plan are identified in this report and alternative approaches and analyses are offered for consideration by the FRA. Anticipated activities for the next 6 months are reviewed. Conclusions and recommendations for FRA action are also provided.

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INTRODUCTION

The Association of American Railroads (AAR) and several major railroads have petitioned the Federal Railroad Administration (FRA) Office of Safety to permit discolored curved plate wheels to remain in service. Presently, Statute 49 CFR 215.101(h) requires that wheels thermally discolored 4 inches or more on both sides be removed from service. To assist the FRA in making a decision on this petition, a test program ~~has been~~ was proposed by the AAR to determine the rates at which thermal/mechanical damage is accrued on a sample of discolored curved plate wheels and an equal size sample of nondiscolored curved plate wheels as a control.

Originally, the test program was to include a population of 60,000 thermally discolored wheels on 30,000 representative carsets run in revenue service on railroads in all parts of the country (as described in the original AAR test plan- see Reference 1). The test was to begin only when 60,000 discolored curved plate wheels had been identified, and was to continue for a one-year period. At the end of this time, rates at which discolored and nondiscolored wheels were removed from the test population was to be established. Thermal cracking was to be the primary criterion for wheel removal in these tests.

Since that initial proposal, several iterations have taken place between the AAR and the FRA, culminating in the AAR's revised implementation proposal, included in this report as Appendix A. Battelle's first item of

work on this task was to review the test plan and to provide input to the AAR and the FRA concerning the utility of the plan. Specifically, the matter of concern has been whether the test plan is sufficiently detailed to allow the FRA to eventually make a decision, with high statistical confidence, whether to permanently void the discoloration removal statute for curved plate heat treated wheels.

PLANNED VERSUS ACTUAL TECHNICAL ACTIVITY

According to the current agreement for this task, Task Item 1 was to be completed by September 20, 1988. Battelle's review of the test plan was completed by early October, and it was discussed by Richard Rice with the FRA on October 13, 1988, and the AAR on October 14, 1988. (A copy of the test plan review is included in Appendix B.) It was immediately obvious from these discussions that there were some basic points of disagreement between the FRA and the AAR that were not yet resolved. Clearly, additional work had to be done to address these issues before the FRA waiver could be approved and the wheel discoloration test program could begin.

Since the meeting with Tom Guins of the AAR in October, Richard Rice and Steve Rust of Battelle have had several additional conversations with him. These conversations have helped clarify the AAR's perspective and have helped Battelle identify specific issues that could be addressed quantitatively. These issues are reviewed in the next section.

In regard to the schedule for the remainder of the task, it is apparent that it will have to be modified to reflect the delays in initiating the wheel discoloration test program. However, it is premature to suggest an altered schedule until the FRA waiver has been signed, and an official start date for the test program has been established by the AAR. Once these things have been accomplished, Battelle will submit a suggested revision to the schedule (and deliverables as necessary). In the meantime, Battelle will continue to work, at the direction of the FRA, to help resolve remaining points of disagreement concerning the wheel discoloration test plan.

ITEM 1 - REVIEW OF TEST PLAN

We have reviewed each comment made in October on the original test plan (see Appendix B) and have identified whether we believe the issue is still unresolved and significant (implying the need for additional activity or resolution) or whether the issue has been resolved or now appears to be insignificant.

At the direction of the FRA, Battelle provided a copy of the comments included in Appendix B to Tom Guins of the AAR for review. He did review Battelle's comments, and discussed his views (over the phone) on each point. The following is an attempt to summarize that input.

1. Mr. Guins indicated that there is an extensive database available for the national fleet (Rumler file), but the number of curved plate, heat treated wheels currently in service is still rather limited. This limitation should not be of great concern if the primary objective of the study is to evaluate the performance of discolored vs. nondiscolored curved plate, heat treated wheels. (It does appear unlikely that it will be possible to make a statistically sound comparison between discolored wheels in the test fleet and nondiscolored wheels in the national fleet, because of the multitude of uncontrolled variables.)

   Status: No further action required, if it is agreed that the primary objective of the study will be to evaluate the performance of discolored vs. nondiscolored curved plate, heat treated wheels.

2. Tom said that it was unrealistic to expect to define wheel years of service explicitly. This is because he feels that wheel specific data cannot reliably be collected on a regular basis. The only reliable check point will be when a periodic inspection reveals a wheel that must be retired according to Form B. This wheel, and the other wheels on the car that remain in service, will have their wheel years of service identified.

He expressed concern about activating the trigger mechanism before 50,000 wheel years of service. He fears that a few early, and aberrant results might put the entire study in jeopardy, if they are factored into the analysis from the very beginning. We have evaluated this issue further, and we have convinced ourselves that the only appropriate approach is to employ a trigger mechanism from the very beginning. However, the trigger mechanism that we feel is appropriate is somewhat different than the one proposed by the AAR. (See the following section for further discussion of this trigger mechanism, and the basis for it.)

Status: Both issues just discussed are still significant concerns. Recommendations regarding data gathering procedures and the trigger mechanism are presented later in this report.

3. Tom pointed out that their reporting plans were covered on page 6 of their March 29, 1988 proposal.

   Status: No further action required.

4. Tom indicated that most of the details about the cars and their service conditions could be obtained directly, or at least inferred, from the car identification.

   Status: Recommendations regarding car documentation are presented later in this report.

5. The AAR plans to complete Form B only when a wheel is removed from service. The number of wheel years up to and after the point of discoloration will not be documented explicitly.

   Status: This item relates directly to Item 2, discussed earlier.

6. The types of wheel defects are adequately addressed in the AAR's coding scheme on the modified Form B.

   Status: No further action required.

7. The exact procedure that the AAR intends to use to analyze their data is still unclear.

   Status: Recommendations regarding data analysis are presented later in this report.

8. It is the AAR's plan to collect data on the number of discolored and nondiscolored wheel months of service primarily through the use of Form B at the time of a wheel's removal. This would be supplemented with periodic (non-wheel-specific) samplings of the fleet.

   Status: This item again relates to Item 2, discussed earlier.

9. The data for the national fleet will be derived from the Rumler file.

   Status: This item bears further scrutiny only if emphasis in the study will be placed on the performance of the test fleet relative to the national fleet (rather than on the performance of heat treated, curved plate nondiscolored wheels relative to discolored wheels).

10. Mr. Guins agrees that it would be reasonable to place the primary emphasis on the comparative performance of heat treated, curved plate discolored and nondiscolored wheels.

    Status: This item relates directly to Item 9, just discussed.

11. The form of trigger mechanism proposed by the AAR requires the specification of an expected proportion of wheel removals due to thermal cracks

without indicating how this value will be determined. This could be a significant issue because of the known seasonal variations in rate of wheel removals.

Status: Recommendations concerning the trigger mechanism are presented later in this report.

12. It appears likely that the expected 50,000 discolored wheel years of service per study year is optimistic, especially in the beginning of the test program. The AAR (logically) plans to move test cars into the national fleet gradually and, therefore, the number of cars fully equipped with heat treated, curved plate wheels will increase over the first few years of the test program.

Status: The only issue raised by this item is that the test program is likely to take more than 5 years to complete (if the 250,000 wheel years goal is maintained).

13. Regular monitoring of the trigger mechanism is possible (and recommended) once a limited number of wheels are retired. It will not be necessary to wait until 50,000 wheel years of service are accumulated.

Status: This item relates to Items 2 and 11.

14. Discoloration that is observed predominately on one side of the wheel is generally considered insignificant because it is believed to be the result of corrosion (due to exposure of that surface during wheel storage) rather than wheel heating.

Status: No further action required.

15. The AAR uses a standard nomenclature for wheel location.

Status: No further action required.

16. The finger gages are designed to minimize variations in wheel measurements by different inspectors.

Status: No further action required.

Trigger Mechanism Analyses

The form of trigger mechanism proposed for use in the implementation proposal dated 3/29/88 is to consider terminating the study if

$$X > X_{UL} \qquad (1)$$

where

X = the number of wheel removals due to thermal damage for discolored wheels

X_{UL} = the allowable upper limit on the number of wheel removals due to thermal damage for discolored wheels

$= NP + 1.645\ (NP)^{1/2}$

N = the number of wheel years for discolored wheels

P = the expected proportion of all wheels to be removed due to thermal damage (removals/wheel year)

This trigger mechanism appears to be based on a statistical model which assumes that X has a Poisson distribution with mean $\mu = NP$. It is further assumed that μ is large enough so that this Poisson distribution is well approximated by the normal distribution with mean $\mu = NP$ and standard deviation $\sigma = (NP)^{1/2}$. This normal distribution is employed to determine X_{UL}, an upper 95 percent prediction bound for X. If both N and P are known constants and $\mu = NP$ is large enough so that the normal approximation to the Poisson distribution is adequate, this is a reasonable trigger mechanism.

However, there is no indication of how either P or N will be determined. Let us assume for now that N is a known constant. If P is to be

determined from historical data, seasonal variation in removal rates could cause the study to be terminated during months for which the removal rate is characteristically higher.[2] On the other hand, if P is to be determined from current study data, the equation for the upper limit is not adequate since it considers P to be a fixed but unknown constant.

To avoid these problems, three recommendations are made. First, P should be set equal to the observed proportion of wheel removals due to thermal damage for discolored and nondiscolored wheels combined on test cars. Second, the assumed variance of X should be changed from NP to NP(1-R) where R is the ratio of wheel years of service for discolored wheels on test cars to wheel years of service for both discolored and nondiscolored wheels on test cars. This change (reduction in variance) is necessary because of the correlation between the observed number of wheel removals for discolored wheels which is being tested and the specific form of P which is being employed as a result of the first recommendation. Third, the trigger mechanism should be stated in terms of the observed significance level (OSL) of a test of the hypothesis that the removal rates due to thermal damage are the same for discolored and nondiscolored wheels.

Combining the three recommendations from above, a new trigger mechanism is developed as follows. Let

N_1 = the number of wheel years of service for discolored wheels

X_1 = the number of wheel removals due to thermal damage for discolored wheels

P_1 = the true (unknown) rate of wheel removals due to thermal damage for discolored wheels (removals/wheel year)

N_2 = the number of wheel years of service for nondiscolored wheels

X_2 = the number of wheel removals due to thermal damage for nondiscolored wheels

P_2 = the true (unknown) rate of wheel removals due to thermal damage for nondiscolored wheels (removals/wheel year)

$R = N_1 / (N_1 + N_2)$

= the ratio of wheel years of service for discolored wheels to wheel years of service for both discolored and nondiscolored wheels

$X = X_1 + X_2$

= the number of wheel removals due to thermal damage for both discolored and nondiscolored wheels

Assume that X_1 has a Poisson distribution with mean $\mu_1 = N_1P_1$, that X_2 has a Poisson distribution with mean $\mu_2 = N_2P_2$, and that X_1 and X_2 are independently distributed. Then X has a Poisson distribution with mean $\mu = \mu_1 + \mu_2 = N_1P_1 + N_2P_2$ and the conditional distribution of X_1 given X is binomial with X trials and probability of success

$$P^* = \frac{N_1P_1}{N_1P_1 + N_2P_2} . \tag{2}$$

Under the assumption that $P_1 = P_2$, the conditional distribution of X_1 given X is binomial with X trials and probability of success R. Using this distribution, a statistical test of the null hypothesis H_0: $P_1=P_2$ versus the alternative hypothesis H_1: $P_1>P_2$ can be conducted by rejecting the null hypothesis in favor of the alternative hypothesis if X_1 is too large. The observed significance level (OSL) of this test (for $X_1>0$) is

$$OSL(X_1) = 1 - \sum_{i=0}^{X_1-1} \binom{X}{i} R^i (1-R)^{(X-i)} \tag{3}$$

The proposed trigger mechanism is to consider terminating the study if

$$OSL(X_1) \leq 0.05. \tag{4}$$

This trigger mechanism can also be stated in terms of a 95 percent upper prediction bound for X_1 as follows. Let X_{UL} be the smallest integer such that $OSL(X_{UL}+1) \leq 0.05$. Then X_{UL} is a 95 percent upper prediction bound for the number of wheel removals due to thermal damage for discolored wheels, under the assumption that $P_1 = P_2$. An equivalent statement of the proposed trigger mechanism is to consider terminating the study if

$$X > X_{UL}. \tag{5}$$

Determining X_{UL} for given values of X and R can be accomplished in an iterative fashion. Begin with the value

$$X_{UL} = XR + 1.645\ (XR(1-R))^{1/2} \tag{6}$$

rounded to the nearest integer and evaluate $OSL(X_{UL+1})$.

(1) If $OSL(X_{UL}+1) > 0.05$, repeatedly add one to X_{UL} and reevaluate $OSL(X_{UL}+1)$. Let X_{UL} be the first value encountered for which $OSL(X_{UL}+1) \leq 0.05$.

(2) If $OSL(X_{UL}+1) = 0.05$, no modification to the value of X_{UL} is necessary.

(3) If $OSL(X_{UL}+1) < 0.05$, repeatedly subtract one from X_{UL} and reevaluate $OSL(X_{UL}+1)$. Let X_{UL} be the last value encountered for which $OSL(X_{UL}+1) \leq 0.05$.

Note that the recursion relationship

$$OSL(X_{UL}+1) = OSL(X_{UL}) - \binom{X}{X_{UL}} R^{(X_{UL})}\ (1-R)^{(X-X_{UL})} \tag{7}$$

is useful in (1) and (3) above. Since XR is expected to be small, the number of iterations required in (1) and/or (3) should also be small.

To compare the recommended trigger mechanism back to the trigger mechanism proposed for use in the implementation proposal dated 3/29/88, the starting value in equation (6) can be restated as

$$X_{UL} = N_1P + 1.645\ (N_1P(1-R))^{1/2} \qquad (8)$$

where

$$P = X\ /\ (N_1 + N_2)$$

= the observed proportion of all wheels removed due to thermal damage (removals/wheel year),

since $XR = N_1P$. However, in addition to recommending an appropriate value for P and making the corresponding correction to the variance in the normal approximation, the recommended trigger mechanism of Equation (4) or (5) above does not employ a normal approximation, but is based on exact binomial distribution theory. While based on exact distribution theory, it is easily implemented through the use of a simple computer program.

Given the availability of the trigger mechanism developed above, waiting until 50,000 wheel years of service to monitor the trigger mechanism is not necessary. A continuous monitoring of the recommended trigger mechanism is possible and preferable, beginning after a small number of wheel removals have been observed for either discolored or nondiscolored wheels on test cars.

Also, the statistical theory and procedures described above are applicable to the statistical analysis of the study data in general and not simply to a trigger mechanism. It is recommended that the primary data comparison be between discolored and nondiscolored wheels in the test fleet. Otherwise, the test may be confounded with uncontrolled variables such as type of cars, age of cars, age of wheels, type of brake system, and type of service. If the comparison between the removal rate for test cars and that for the national fleet is to be made, analyses should be performed to characterize the differences between the test cars and the national fleet in terms of these and any other potentially important variables. It should then be pointed out

in summary reports that any of these factors could contribute to the observed difference in removal rates. Specific recommendations on general data analysis procedures can be developed if so desired.

Finally, the recommendations above were made under the assumption that the number of wheel years of service for both discolored and nondiscolored wheels can be accurately and precisely estimated and, therefore, can be assumed to be known constants. Apparently, this will not be the case for the discolored wheel study and the AAR is currently developing a protocol for estimating these quantities. When this protocol is finalized, modifications to the recommended trigger mechanism and general data analysis procedures are likely to be required.

ANTICIPATED ACTIVITIES OVER NEXT 6 MONTHS

It is difficult to anticipate Battelle's activities on this task over the next 6 months because of the uncertainty regarding the start of the wheel discoloration test program. Over the next few months it is expected that Battelle will continue to work with the FRA to resolve issues concerning the trigger mechanism, and other details regarding the AAR test plan. In essence, this means that Battelle's activities on Task Item 1 will continue until the FRA negotiates a revised test plan with the AAR and approves a waiver that will allow the test program to begin. At that time, Battelle will review the requirements of the program with the FRA and submit a plan for completion of activities on this task.

CONCLUSIONS AND RECOMMENDATIONS

Based on Battelle's review of the AAR test plan for the wheel discoloration test program, and subsequent discussions with the AAR and the FRA, the following conclusions and recommendations have been developed.

1. The primary focus of the study should be on the relative performance of discolored and nondiscolored, heat treated curved plate wheels. Only secondary emphasis should be placed on the performance of discolored wheels relative to the national fleet. Otherwise, the test may be confounded with uncontrolled variables such as type of cars, age of cars, age of wheels, type of brake system, and type of service. If the comparison between the removal rate for test cars and that for the national fleet is to be made, analyses should be performed to characterize the differences between the test cars and the national fleet in terms of these and any other potentially important variables.

2. Recommendations concerning a trigger mechanism were made under the assumption that the number of wheel years of service for both discolored and nondiscolored wheels would be measured at regular intervals on a wheel specific basis and, therefore, the relative percentages of discolored and nondiscolored wheel years could be assumed to be known parameters. Apparently, this will not be the case for the discolored wheel study, since the AAR favors a periodic non-wheel-specific sampling procedure. The AAR is currently developing a protocol for estimating the number of discolored and nondiscolored wheel years. When this protocol is finalized, modifications to the recommended trigger mechanism and general data analysis procedures are likely to be required.

3. The information available in the AAR database based on car ID should be reviewed (for a realistic sampling of cases) so that it can be

verified that the key variables of interest to the FRA can be identified, or at least strongly inferred, from the car ID.

4. If the trigger mechanism described earlier is utilized, waiting until 50,000 wheel years of service to monitor the trigger mechanism is not necessary. A continuous monitoring of the recommended trigger mechanism is not only possible, but preferable, beginning after a small number of wheel removals have been observed for either discolored or nondiscolored wheels on test cars.

5. The statistical theory and procedures described earlier are applicable to the statistical analysis of the study data in general, and not simply to a trigger mechanism. Once the AAR protocol for estimating the number of discolored and nondiscolored wheel years is finalized, a protocol for the statistical analysis of the study data should be developed. The statistical model developed for the trigger mechanism should be generalized to take into account the uncertainties in estimating the discolored and nondiscolored wheel years of service. A new trigger mechanism and general data analysis procedures should be developed based on this model.

REFERENCES

1. Anon., "Experimental Plan FRA/AAR Discolored Wheel Study with Waiver for Sample Cars", August 21, 1986.

2. Rahkumar, B. R., and Stone, D. H., "Wheel Failure Mechanisms of Railroad Rails", Association of American Railroads, Report No. R-679, November 1987.

APPENDIX A

March 29, 1988

IMPLEMENTATION PROPOSAL
FRA/AAR DISCOLORED WHEEL STUDY
WITH WAIVER FOR EQUIPPED CARS

3/29/88

IMPLEMENTATION PROPOSAL
FRA/AAR DISCOLORED WHEEL STUDY
WITH WAIVER FOR EQUIPPED CARS

PURPOSE:

The purpose of this document is to provide more detailed information on how the AAR intends to implement the field test to facilitate an industry changeover to heat treated, curved plate wheels under controlled and documented conditions. The implementation procedure planned will permit the FRA/AAR Review Committee to verify the degree of expected improvement in wheel performance resulting from voluntary adoption of heat treated, curved plate wheels as the industry standard. Most importantly, the test will assess the strength of correlation (or lack of correlation) of discoloration with adverse thermal damage in heat treated, curved plate wheels.

IMPLEMENTATION PLAN:

Test Duration:

As described in the FRA test outline, the full test will be conducted for up to a five year period after a sufficient number of cars have entered into the test and the data collection system has been verified.

There will be a start-up period as cars that have all heat treated, curved plate wheels are identified and marked. Cars will be identified and marked for inclusion in the test by several means including: 1. New and rebuilt cars added to fleet after the test begins, 2. cars which have under gone extensive repairs including replacement of all wheels with heat treated, curved plate wheels and 3. existing cars with all wheel changed to the standard heat treated, curved plate design by the car owner or existing cars inspected and found to have all heat treated curved plate wheels. As stenciled/marked cars operate in service, discoloration of wheels will be identified on these cars. When the number of discolored wheel years of service on the test cars reaches 50,000, full analysis and monitoring of the trigger mechanism will begin. However, the performance of all wheels on test cars will be continuously monitored and periodic status reports completed and filed with the FRA.

(1) (2) (3)

Selection of Cars:

Individual cars will be selected stenciled/marked and initial data entered for inclusion in the test and exemption under the waiver as each meets all test criteria without regard to the existing state of wheel discoloration.

No cars will be stenciled that 1. carry hazardous materials, 2. have any straight plate wheels or 3. have any non-heat treated wheels.

MINIMUM REPORTING REQUIREMENTS:

Initial Wheel Inventory:

When the cars are entered into the test, the following information will be collected and reported for each car using form A (attachment). (4)

1. Car Initial
2. Car Number
3. Car Type
4. Built Date
5. Inches of discoloration on each wheel by location (R1, L1....).
6. Certification that all wheels on the car are heat treated, low stress, curved plate wheels.
7. Date the car is stenciled/marked.
8. The SPLC of the location where the car is stenciled/marked.
9. Stencilling Entity

At Time Of Wheel Removal:

When any wheel is removed from the test car for any reason, the following information will be required using form B (attachment): (5)

1. Car Initial
2. Car Number
3. Car Type
4. Built Date
5. Inches of discoloration for each wheel by location (R1, L1....).
6. The why made code (except code 23) for removal of the wheel.
7. The location of the wheel removed and the wheel applied.
8. Date of removal
9. Size and location of spalls, shells, flat spots or other rim and flange surface flaws whether within or beyond condemning limits. (6)
10. SPLC of the location of removal
11. Repairing road

12. If a wheel on a test car is removed due to thermal damage (codes 66,68,71,74 and 83), the AAR will be notified and both that wheel and the mate wheel will be held for disposition, for closer examination and for possible laboratory analysis.

SPECIAL REQUIREMENTS:

Each participating road will be required to designate at least one location where test cars will receive intensified inspection.

All railroads will be alerted to ensure intensified efforts to find thermal damage on any wheel.

All test cars will be stenciled or marked on both sides to say:

AAR TESTS
FORM B
HEAT TREATED
CURVED PLATE
WHEELS ONLY

Trains containing test cars shall be routed to avoid operation on the NEC between Washington and New York to the extent possible or shall be operated during the hours of 11 p.m. to 6 a.m.

The replacement of a heat treated, curved plate wheel with a non heat treated curved plate or straight plate wheel will not be permitted. This prohibition will be included in the interchange rules.

WAIVER SIZE:

All cars meeting the requirements may be stenciled/marked for inclusion in the test.

RESPONSE VARIABLE:

The response variable for this experiment is the number of wheels experiencing thermal damage (codes 66, 68, 71, 74 and 83) per wheel year of service. This accounting will allow determination of the rate of removal of damaged wheels for discolored wheels and comparison to that for non-discolored wheels based on the average number of thermally damaged wheels for the fleet as a whole. The number of wheel-months in the test over the test period will be determined separately for both discolored and non-discolored test wheels and for the fleet as a whole, and these will be utilized in calculating the expected number of failures in each case.

(7)

EXPERIMENTAL RESULT:

At the conclusion of each reporting period during the test, six calculations will be made as follows:

1. The number of wheel months of service for all discolored wheels in the test fleet from the start of the test to the present.

2. The number of wheel months of service for all non-discolored wheels in the test fleet from the start of the test to the present.

3. The number of wheel months of service for all wheels in the national fleet from the start of the test to the present.

4. The number of wheels removed due to thermal damage (codes 66,68,71,74 and 83) reported for discolored wheels in the test fleet from the time the test started to the present.

5. The number of wheels removed due to thermal damage reported for non-discolored wheels in the test fleet from the time the test started to the present.

6. The number of wheels removed due to thermal damage reported for all wheels in the national fleet from the time the test started to the present.

The total number of wheel months of service in each category will be tallied. As wheels become discolored during the test, months of service will be adjusted to reflect the number of months in each category. Wheels removed during the test for causes other than thermal damage (codes 66,68,71,74 and 83) will have the number of months in the test credited to their proper category. If a wheel is lost due to error in reporting, the wheel will not be counted in any category.

The overall result of the experiment is the comparison of the rate of wheels removed due to thermal damage for discolored wheels on test cars with the rate of removals due to thermal damage for the national fleet. If the number of wheel removals due to thermal damage for test cars falls within a 95%, one sided confidence interval about the expected number given the rate experienced in the national fleet, the hypotheses of no difference between discolored and non-discolored wheel will be accepted.

A secondary result of the experiment is the comparison of the rate of wheels removed due to thermal damage for discolored wheels on test cars with the rate of removals due to thermal damage for the non-discolored wheels on the test cars. If the number of wheel removals due to thermal damage for test cars falls within a 95%, one sided confidence interval about the expected number given the rate experienced for the non-discolored wheels on the test cars fleet, the hypotheses of no difference between discolored and non-discolored heat treated curved plate wheels will be accepted.

This upper limit of this interval has been calculated below:

$$N_{\text{UPPER LIMIT}} = NP + Z_a [NP]^{1/2} \quad (11)$$

Where;

Z_a	is normal deviate for 95%, one sided confidence - 1.64
N	is the number of wheel years for discolored, curved plate, heat treated wheels in the test.
P	is the expected proportion of all wheels removed due to thermal cracks
a	is equal to 1 - the confidence level (.05)

For the assumed (based on current CRB data) values of P=.001 and N=250,000, the 95%, upper limit on the one sided confidence around the proportion (rate) of wheel removed due to thermal damage will be 276 at the end of the test. If the actual rate of wheel removal due to thermal damage is not .001 per wheel year, the 95%, one sided confidence interval will change as indicated by the above formula. (12)

TRIGGER MECHANISM:

Results from the recently completed FRA/AAR Wheel Safety Research Program indicate a significant safety improvement is to be expected from the adoption of curved plate, heat treated wheels as the industry standard. The purpose of the field test is to allow the FRA/AAR Review Committee to monitor the railroads voluntary change over to an improved design for an unexpected adverse impact on safety. The trigger mechanism is intended to alert the Review Committee in the event that there is a likelihood that the performance of the new standard wheel does not meet the current expectations.

Heat treated, curved plate wheels have demonstrated extremely high resistance to thermal damage in the form of stress reversal of the hoop stress from compressive to tensile It is this stress reversal that creates a dangerous state in the wheel which can cause a wheel to fail catastrophically in the event a small crack develops in the wheel.

The trigger mechanism proposed is based on wheel thermal damage, and as time passes, the increase in experience and thus the number of wheels removed due to thermal damage expands the allowable number (but not the rate) removed due to thermal damage. Figure 1 shows the limits for the expected sample sizes from 50,000 (when the trigger should begin) to 250,000 discolored wheel years. (13)

If at any time during the test the number of discolored wheels removed due to thermal damage exceeds the established statistical bounds, a careful examination is called for to determine if there is a basis for the test to be safely continued, i.e., by more stringent inspection requirements or removal criteria.

We must recognize that if an FRA reportable accident is caused by the thermal failure of a waivered wheel (discolored wheel on a test car), a full analysis of the data will conducted and forwarded to the FRA to facilitate an immediate review of the test results to date to determine if there is a basis for the test to be safely continued.

DATA BASE ADMINISTRATION:

The data base associated with this waiver will be administered by the AAR Research and Test Department. The administration will consist of the following:

1. The collecting of the initial car/wheel inventory.
2. The collecting of wheel removal reports.
3. The editing of all reports for accuracy/consistency.
4. The comparing of reported removals with other available sources (CRB and CMC Data Bases) for completeness of reporting.
5. The monthly reporting to the FRA/AAR Review Committee on all activity occurring during the month. This will include the number of cars added to the test, the number of discolored wheels added to the test, the number of wheels removed by cause and discoloration, and a summary of all data problems encountered.
6. The reporting to the FRA of data summaries upon request.
7. The annual reporting to the FRA/AAR Review Committee containing the number of thermal failures, a plot of the number of thermal failures on the trigger mechanism control chart, and a list of data reporting or other problems encountered during the year.

The participating owners will be required to submit the initial car/wheel inventory in the detail specified by form A. Subsequent wheel removal reports will be submitted directly to the AAR R & T Department within five days with the comprehensive information specified by form B.

FIGURE 1
EXAMPLE CONTROL CHART LIMITS
FOR THE FRA/AAR WHEEL WAIVER
BASED ON ASSUMED FLEET EXPERIENCE

ACCUMULATED TEST CAR DISCOLORED WHEEL YEARS	UPPER 95% CONFIDENCE* LIMIT ON THERMAL FAILURES
50,000	62
100,000	116
150,000	170
200,000	223
250,000	276

* The number of wheel removed due to thermal damage must exceed this number to indicate an exception.

FORM A

ASSOCIATION OF AMERICAN RAILROADS

REPORT ON CARS IDENTIFIED FOR THE DISCOLORED WHEEL WAIVER PROJECT

CAR INITIAL	CAR NUMBER	DATE CAR BUILT MONTH	DATE CAR BUILT YEAR	STENCILLING ROAD	DATE OF STENCILLING MONTH	DATE OF STENCILLING DAY	DATE OF STENCILLING YEAR	SPLC	CAR TYPE
☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐☐	☐☐	☐☐	☐☐	☐☐☐☐	☐

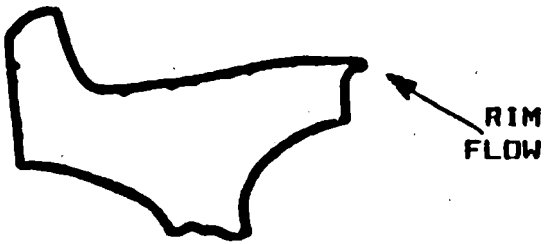
PLEASE COMPLETE THE FOLLOWING FOR EACH WHEEL:
SPECIFY INCHES OF DISCOLORATION ON THE FRONT PLATE OF THE WHEEL ONLY WHEN BOTH FRONT AND BACK FACE SHOW DISCOLORATION TO SUBSTANTIALLY EQUAL EXTENT, OTHERWISE SPECIFY ZERO. (14)

RIM FLOW IS NOT A DEFECT. THE PRESENCE OF RIM FLOW IS REQUESTED AS INFORMATION ONLY

WHEEL LOCATION	INCHES OF DISCOLORATION	RIM FLOW (Y/N)	FINGER GAGE READING
R1	☐☐	☐	☐☐
L1	☐☐	☐	☐☐
R2	☐☐	☐	☐☐
L2	☐☐	☐	☐☐
R3	☐☐	☐	☐☐
L3	☐☐	☐	☐☐
R4	☐☐	☐	☐☐
L4	☐☐	☐	☐☐

(15) (16)

DIAGRAM SHOWING RIM FLOW



I CERTIFY THAT THIS CAR IS FULLY EQUIPPED WITH CURVED PLATE, HEAT TREATED WHEELS (NAME) _____

PHONE NUMBER ( )_____

COMPLETED FORM SHOULD BE SENT TO:
T. S. GUINS
ASSOCIATION OF AMERICAN RAILROADS
50 F STREET NW, WASHINGTON, DC 20001

FORM A (NEW OR REBUILT CARS)
ASSOCIATION OF AMERICAN RAILROADS

REPORT ON NEW CARS IDENTIFIED FOR THE DISCOLORED WHEEL WAIVER PROJECT
THIS FORM IS TO USED FOR CARS REPORTED IN A SERIES HAVING ALL NEW
HEAT TREATED, CURVED PLATE WHEELS

CAR INITIAL	FIRST CAR NUMBER	LAST CAR NUMBER	NUMBER OF CARS	DATE CAR BUILT MONTH	DATE CAR BUILT YEAR	STENCILLING ROAD	DATE OF STENCILLING MONTH	DATE OF STENCILLING DAY	DATE OF STENCILLING YEAR
☐☐☐☐	☐☐☐☐☐☐	☐☐☐☐☐☐	☐☐☐☐	☐☐	☐☐	☐☐☐☐	☐☐	☐☐	☐☐

SPLC	CAR TYPE
☐☐☐☐☐☐	☐

I CERTIFY THAT THIS CAR IS FULLY EQUIPPED
WITH CURVED PLATE, HEAT TREATED WHEELS (NAME) _____

PHONE NUMBER ( )_____

COMPLETED FORM SHOULD BE SENT TO:
T. S. GUINS
ASSOCIATION OF AMERICAN RAILROADS
50 F STREET, NW, WASHINGTON, DC 20001

F___ B

ASSOCIATION OF AMERICAN RAILROADS
DISCOLORED WHEEL WAIVER PROJECT
REPORT AT TIME OF WHEEL REMOVAL

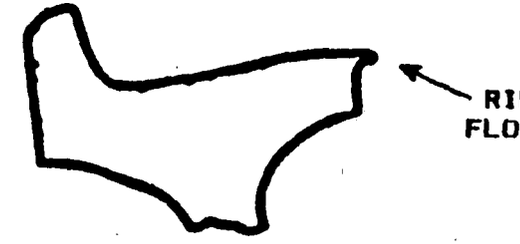
CAR INITIAL	CAR NUMBER	DATE CAR BUILT MONTH	DATE CAR BUILT YEAR	REPAIRING ROAD	DATE OF WHEEL REMOVAL MONTH	DATE OF WHEEL REMOVAL DAY	DATE OF WHEEL REMOVAL YEAR	SPLC	CAR TYPE
☐☐☐☐	☐☐☐☐☐☐	☐☐	☐☐	☐☐☐☐	☐☐	☐☐	☐☐	☐☐☐☐☐☐	☐

PLEASE COMPLETE THE FOLLOWING FOR EACH WHEEL:
SPECIFY INCHES OF DISCOLORATION ON THE FRONT PLATE
OF THE WHEEL ONLY WHEN BOTH FRONT AND BACK FACE SHOW
DISCOLORATION TO SUBSTANTIALLY EQUAL EXTENT, OTHERWISE SPECIFY ZERO.

RIM FLOW IS NOT A DEFECT. THE PRESENCE OF RIM FLOW IS REQUESTED AS INFORMATION ONLY.

FOR WHEELS REMOVED DURING THIS REPAIR			FOR THE WHEELS AS THE CAR LEFT THE SHOP/REPAIR TRACK		
INCHES OF DISCOLORATION	WHYMADE CODE**	WHEEL LOCATION	INCHES OF DISCOLORATION	RIM FLOW (Y/N)	FINGER GAGE READING
☐☐	☐☐	R1	☐☐	☐	☐☐
☐☐	☐☐	L1	☐☐	☐	☐☐
☐☐	☐☐	R2	☐☐	☐	☐☐
☐☐	☐☐	L2	☐☐	☐	☐☐
☐☐	☐☐	R3	☐☐	☐	☐☐
☐☐	☐☐	L3	☐☐	☐	☐☐
☐☐	☐☐	R4	☐☐	☐	☐☐
☐☐	☐☐	L4	☐☐	☐	☐☐

DIAGRAM SHOWING RIM FLOW



** IF ANY WHEEL IS REMOVED FOR WHY MADE CODES 66,68,71,74,78 OR 83, THAT WHEEL AND THE MATE WHEEL MUST BE HELD FOR DISPOSITION.

I CERTIFY THAT THIS CAR IS FULLY EQUIPPED
WITH CURVED PLATE HEAT TREAT WHEELS (NAME) _____
PHONE NUMBER ( ) _____

REMARKS _____

COMPLETED FORM SHOULD BE SENT TO:
T. S. GUINS
ASSOCIATION OF AMERICAN RAILROADS
50 F STREET, NW, WASHINGTON, DC 20001

FI C

ASSOCIATION OF AMERICAN RAILROADS

REPORT ON CARS REMOVED FROM THE DISCOLORED WHEEL WAIVER PROJECT

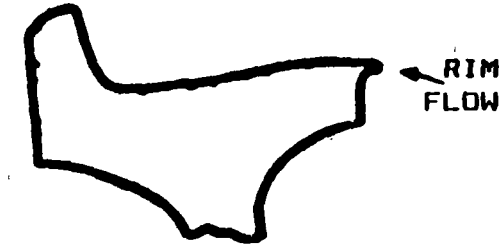
CAR INITIAL	CAR NUMBER	DATE CAR BUILT MONTH	DATE CAR BUILT YEAR	REMOVING ROAD	DATE OF CAR REMOVED MONTH	DATE OF CAR REMOVED DAY	DATE OF CAR REMOVED YEAR	SPLC	CAR TYPE
☐☐☐	☐☐☐☐☐	☐☐	☐☐	☐☐☐☐	☐☐	☐☐	☐☐	☐☐☐☐☐☐	☐

PLEASE COMPLETE THE FOLLOWING FOR EACH WHEEL AS THE CAR ARRIVED, BEFORE REMOVAL FROM TEST:
SPECIFY INCHES OF DISCOLORATION ON THE FRONT PLATE
OF THE WHEEL ONLY WHEN BOTH FRONT AND BACK FACE SHOW
DISCOLORATION TO SUBSTANTIALLY EQUAL EXTENT, OTHERWISE SPECIFY ZERO.

RIM FLOW IS NOT A DEFECT. THE PRESENCE OF RIM LOW IS REQUESTED AS INFORMATION ONLY.

WHEEL LOCATION	INCHES OF DISCOLORATION	RIM FLOW (Y/N)	FINGER GAGE READING
R1	☐☐	☐	☐☐
L1	☐☐	☐	☐☐
R2	☐☐	☐	☐☐
L2	☐☐	☐	☐☐
R3	☐☐	☐	☐☐
L3	☐☐	☐	☐☐
R4	☐☐	☐	☐☐
L4	☐☐	☐	☐☐

DIAGRAM SHOWING RIM FLOW



I CERTIFY THAT THE STENCIL HAS BEEN REMOVED
FROM THIS CAR (NAME) _____

PHONE NUMBER (___)_____

REMARKS_____
_____
_____

COMPLETED FORM SHOULD BE SENT TO:
T. S. GUINS
ASSOCIATION OF AMERICAN RAILROADS
50 F STREET, NW, WASHINGTON, DC 20001

APPENDIX B

October 17, 1988

INITIAL BATTELLE COMMENTS ON AAR IMPLEMENTATION PROPOSAL

APPENDIX B

Comments on AAR Implementation Proposal

1. Because of the systematic manner in which the test cars are to be selected, any comparison between the test cars and the national fleet will be confounded with uncontrolled variables such as type of cars, age of cars, age of wheels, type of brake system, and type of service. Any observed difference in the removal rates for test cars and the national fleet could be attributable to any of the differences between the distribution of test cars and the distribution of cars in the national fleet, only one of which is type of wheel. Thus, comparisons between test cars and the national fleet must be made carefully and corresponding conclusions drawn cautiously. See Comment 10.

2. Wheel years of service should be defined explicitly. Waiting until 50,000 wheel years of service to monitor the trigger mechanism is not necessary. Monitoring of the trigger mechanism can begin after a small number of wheel removals have been observed for either discolored or nondiscolored wheels on test cars. See Comment 11 for a recommended trigger mechanism which will facilitate early monitoring.

3. How often will periodic status reports be filed with the FRA? Be specific.

4. There are no plans to collect certain information about the cars (Form A) that may prove to be very important as explanatory variables when the data are analyzed. Examples of such items are car condition (new/rebuilt/extensively repaired), car capacity, brake characteristics (brake shoe type, air valve characteristics), specific wheel characteristics (new/used, type, design, diameter, class), and type of service anticipated. Shouldn't such information be requested on Form A?

5. Will Form B be completed only when a wheel is removed from a car? In order to determine when a wheel "crosses over" from nondiscolored to discolored with any precision, it will be necessary to obtain Form B

information more often. In fact, it may be advantageous to have Form B filled out every time a car is inspected.

6. Where and how will the "size and location of spalls, shells, flat spots, or other rim and flange surface flaws" (Item 9) be included on Form B? These items were included on previous forms but are not included on the latest revised forms. Shouldn't this information be requested in addition to the rim flow and flange width information that is now being requested? If not, what is the justification for excluding these items from Form B?

7. "This accounting will allow determination of the rate of removal of damaged wheels for discolored wheels and comparison to that for non-discolored wheels based on the average number of thermally damaged wheels for the fleet as a whole. The number of wheel-months in the test over the test period will be determined separately for both discolored and nondiscolored test wheels and for the fleet as a whole, and these will be utilized in calculating the expected number of failures in each case." What does this mean? It appears to be a very important passage explaining precisely how the data will be analyzed. However, it is not clear from the passage how the data analysis will be carried out. This explanation should be expanded to include specific details.

8. How will the "number of wheel months of service" be determined in Items 1 and 2? Particularly, how is a nondiscolored wheel that becomes discolored handled in terms of crediting the correct total with (1) the wheel months prior to the last report received characterizing the wheel as nondiscolored, (2) the wheel months between the last report received characterizing the wheel as nondiscolored and the first report received characterizing the wheel as discolored, and (3) the wheel months after the first report received characterizing the wheel as discolored? Also, how will the number of months in category (2) be minimized since these months are difficult to characterize in terms of discoloration?

9. How will the data for the national fleet be identified, obtained, and verified for accuracy?

10. Shouldn't the primary comparison be between discolored and nondiscolored wheels in the test fleet? Otherwise the test may be confounded with uncontrolled variables such as type of cars, age of cars, age of wheels, type of brake system, and type of service. If the comparison between the removal rate for test cars and that for the national fleet is to be made, analyses should be performed to characterize the differences between the test cars and the national fleet in terms of these and any other potentially important variables. It should then be pointed out in summary reports that any of these factors could contribute to the observed difference in removal rates.

11. The form of trigger mechanism planned for use requires the specification of an "expected proportion of wheel removals due to thermal cracks" (P) without indicating how this value should be determined. If P is determined from historical data, seasonal variation in removal rates could cause the study to be terminated during months for which the removal rate is characteristically higher. If P is to be determined from test car data, the equation is not adequate since it considers P to be a fixed but unknown constant.

    To avoid these problems, two recommendations are offered. First, P should be set equal to the observed proportion of wheel removals due to thermal damage for discolored and nondiscolored wheels combined on test cars. Second, the term inside the square root [NP] should be changed to [NP(1-R)] where R is the ratio of wheel months of service for discolored wheels on test cars to wheel months of service for both discolored and nondiscolored wheels on test cars. This change (reduction in variance) is necessary because of the correlation between the observed number of wheel removals for discolored wheels which is being tested and the specific form of P which is being employed as a result of the first recommendation.

A justification for this recommended trigger mechanism is provided in Appendix C. The justification is based on a Poisson model for wheel removals and based specifically on the conditional distribution of the number of wheel removals due to thermal damage for discolored wheels (X_1) given the total number of wheel removals due to thermal damage for both discolored and nondiscolored wheels (X). Under the hypothesis that the rate of removal is the same for discolored and nondiscolored wheels, this conditional distribution is binomial with X trials and probability of success R as defined above. Noting that XR is equal to NP with P as defined above leads to these recommendations.

12. How is the expected 50,000 discolored wheel years of service per study year for test cars going to be attained? There are no details given under "car selection" as to an adequate number of test cars and the expected rate at which wheels will become discolored. Specific plans should be described for assuring that a minimum number of wheel years will be attained.

13. A continuous monitoring of the trigger mechanism is possible and preferable and the "P" value used in these calculations is critical. See Comment 8 regarding the choice of a specific trigger mechanism. If the recommended trigger mechanism is employed, monitoring of the trigger mechanism can begin after a small number of wheel removals have been observed for either discolored or nondiscolored wheels on test cars.

14. The message following "Please complete the following for each wheel:" is confusing. Why not report inches of discoloration on both sides and perform calculations later. Also, how is the inches of discoloration to be measured? Shouldn't repeatability of the measurement process be examined?

15. A diagram illustrating wheel location would be helpful to avoid any possibility of confusion.

16. How are the finger gage readings to be performed for "flange width" in order to obtain consistent readings?

TRIGGER MECHANISM

Notation

M_1 = Wheel months of service for discolored wheels

X_1 = Wheel removals due to thermal damage for discolored wheels

β_1 = True (unknown) rate of wheel removals due to thermal damage for discolored wheels

M_2 = Wheel months of service for nondiscolored wheels

X_2 = Wheel removals due to thermal damage for nondiscolored wheels

β_2 = True (unknown) rate of wheel removals due to thermal damage for nondiscolored wheels

$R = M_1 / (M_1 + M_2)$

= Ratio of wheel months of service for discolored wheels to wheel months of service for both discolored and nondiscolored wheels

$X = X_1 + X_2$

= Wheel removals due to thermal damage for both discolored and nondiscolored wheels

X_{UL} = Upper limit on allowable number of wheel removals due to thermal damage for discolored wheels

Z = Value such that the area under the standard normal curve to the left of Z is equal to the desired confidence level

Model

$$X_1 \sim \text{Poisson } (M_1\beta_1)$$

$$X_2 \sim \text{Poisson } (M_2\beta_2)$$

$$X \sim \text{Poisson } (M_1\beta_1 + M_2\beta_2)$$

$$X_1 \mid X \sim \text{Binomial } \left(X, \frac{M_1\beta_1}{M_1\beta_1 + M_2\beta_2}\right)$$

$$X_1 \mid X \sim \text{Binomial } (X, R) \quad \text{if } \beta_1 = \beta_2$$

Trigger

$$X_{UL} = XR + Z\,[XR(1-R)]^{1/2}$$

First Semiannual Progress Report: Investigation of Wheel Conditions, 1989, R.C. Rice, S.W. Rust, 1

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