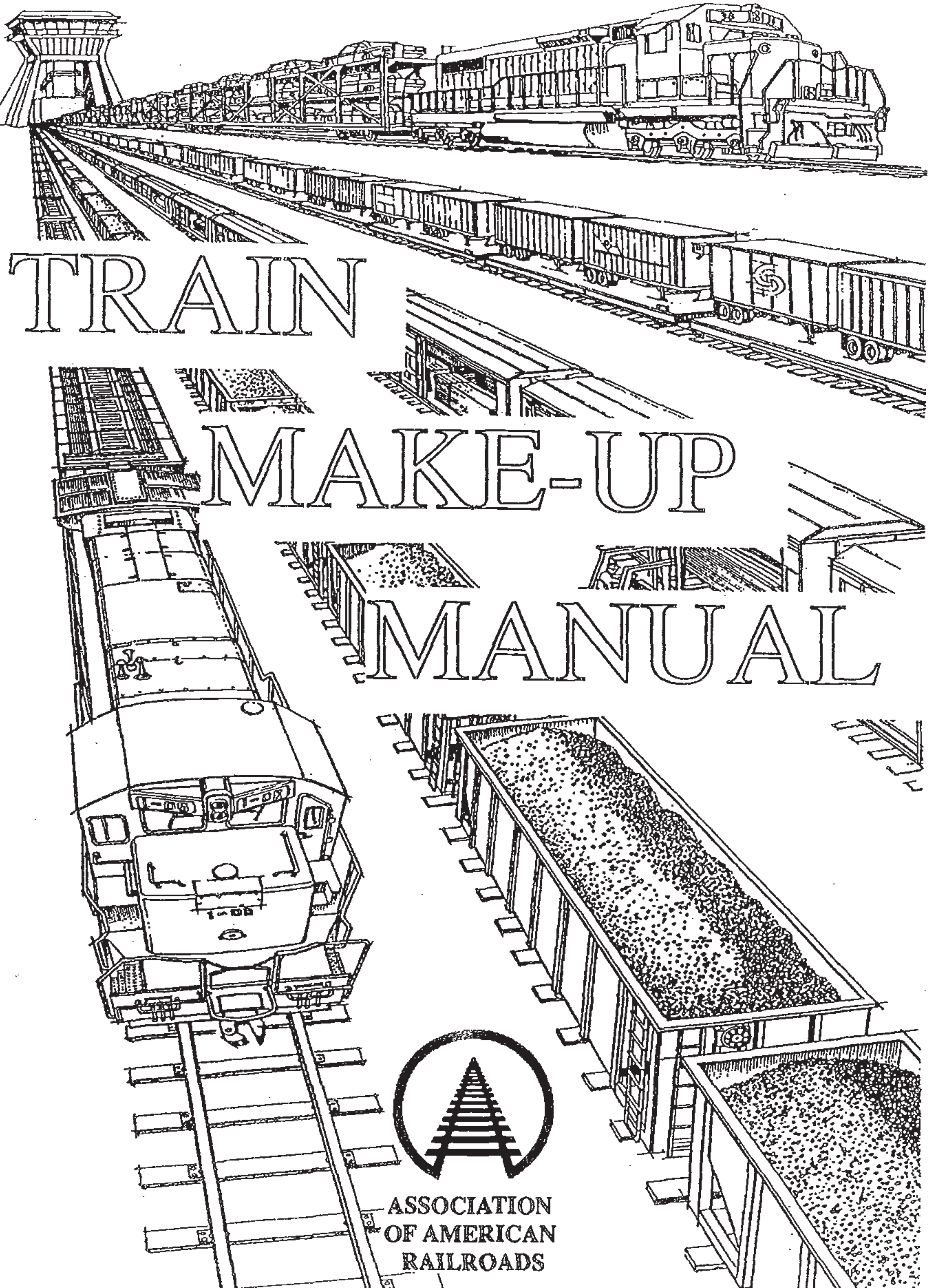
TRAIN MAKE-UP MANUAL



ASSOCIATION
OF AMERICAN
RAILROADS

R-802

ASSOCIATION OF AMERICAN RAILROADS
Research and Test Department

TRAIN MAKE-UP MANUAL

Report No. R-802

Vehicle Track Systems TTD
Implementation Officers

January 1992

AAR Technical Center
Chicago, Illinois

DISCLAIMER

This report is disseminated by the AAR for informational purposes only and is given to, and accepted by, the recipient at its sole risk. The AAR makes no representations or warranties, either express or implied, with respect to the report or its contents. The AAR assumes no liability to anyone for special, collateral, exemplary, indirect, incidental, consequential or any other kind of damage resulting from the use or application of this report or its content. Any attempt to apply the information contained in this paper is done at the recipient's own risk.

1. REPORT NO. R-802	2. REPORT DATE January 1992	3. PERIOD COVERED -

4. TITLE AND SUBTITLE

Train Make-up Manual

5. AUTHOR(S)
P. M. Lovette, Conrail
J. Thivierge, Canadian National
Implementation Officers Train Make-up Manual Subcommittee

6. PERFORMING ORGANIZATION NAME AND ADDRESS Association of American Railroads Technical Center 3140 South Federal Street Chicago, Illinois 60616	7. TYPE OF REPORT Manual 8. CONTRACT OR GRANT NO. --
9. SPONSORING AGENCY NAME AND ADDRESS Association of American Railroads Technical Center 3140 South Federal Street Chicago, Illinois 60616	10. NO. OF PAGES 57 11. NO. OF REFERENCES 14

12. SUPPLEMENTARY NOTES

13. ABSTRACT

This self contained manual represents an updated version of the Train Make-up guidelines contained in Chapter 3 of AAR Report R-185, "Track Train Dynamics-To Improve Freight Train Performance - 2nd Edition" published under the Track Train Dynamics Program in 1979. It is intended to serve as a source of information for considerations such as train size and car placement, that relate to the make-up of trains.

This manual suggests that for trains under 4000 tons total train weight (TTW), no special consideration is required. However, for trains of mixed cars over 4000 tons TTW, the manual suggests that the placement of long car/short car combinations be restricted within the consist, so as not to exceed a suggested maximum trailing tonnage for the ruling grade and curve combination for a particular route. The suggested values are obtained from either tables or curves presented in this manual. For special cars or car combinations the best current practice is described. The detailed calculation procedure for estimating the maximum trailing tonnage is included in Section 10.

14. SUBJECT TERMS Train Make-up, Train Forces, Stringlining, Jackknifing, Harmonic Motion, Trailing Tonnage, Train Handling, Curves.	15. AVAILABILITY STATEMENT Document Distribution Center Association of American Railroads Technical Center 3140 South Federal Street Chicago, Illinois 60616

20 = Grade Resistance Constant (lb/ton/% grade)

% Grade = Grade (1% = 1.0, .5% = 0.5, 0% = 0.0 etc)

4.5 = Rolling Resistance Constant - Assumes train is in motion (lb/ton)

0.8/2 = Curve Resistance Constant - Assumes half of Trailing Cars are on Curve (lb x min)/(ton x mph)

Curve = Degree of Curvature (deg)

1.52 = Conversion Constant (lb x min)/(ton x mph)

A = Acceleration (mph/min)
- Positive if speed is increasing
- Zero if speed is constant
- Negative if speed is decreasing

Safe lateral wheel load:

For the purposes of this manual, if the L/V ratio exceeds 0.82[2] there is a possibility that the wheel may climb. In other words, the vertical load (mainly the car weight) may not be sufficient to prevent the wheel from climbing under the effect of the lateral load.

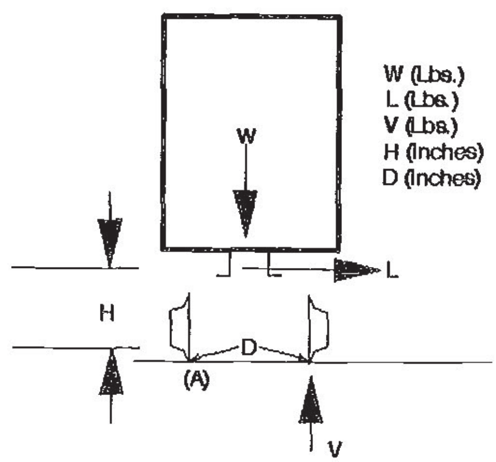
Therefore, if at the wheel,

$$L = 0.82 \times V \qquad (1)$$

there may exist a potential for derailment. The lateral wheel load of interest, in this analysis, originates at the coupler. The free body diagram below can represent all the forces involved.

Summing moments about point (A) (see diagram):

$$V \times D = \frac{W}{2} \times \frac{D}{2} + L \times H \qquad (2)$$



where:

W = Weight of Car (lbs.)

L = Lateral Load (lbs.)

D = Track Gage (inches)

[2] A more conservative value of 0.75 may be used, if desired.

H = Coupler Height (inches)

V = Vertical Reaction (lbs.)

$$V = \frac{W}{4} + L \times \frac{H}{D} \qquad (3)$$

replacing V in equation (1) with (3):

$$L = 0.82\ (\frac{W}{4} + L \times \frac{H}{D}) \qquad (4)$$

rearranging equation (4) and substituting their values:

$$L = \frac{0.82 \times W/4}{1 - 0.82 \times 34/59}$$

$$L = 0.389 \times W \qquad (5)$$

Therefore, the maximum lateral bolster load (lateral component of coupler load) for safety against wheel climb situations will be equal to 0.389 times the car weight in pounds.

Maximum DBF and consequently trailing tonnage may be calculated by:

DBF = 0.389 x Weight/Sin(Angle)

where:

DBF = Allowable Drawbar Force based on Truck Side L/V ratio of 0.82 (lbs.)

0.389 = Physical Ratio

Weight = Weight of Long Car (lbs.)

Angle = Coupler Angle of the Long Car (deg)

Coupler angles can be calculated from the formulas shown in Exhibit 10.1. If multi-unit cars are in the consist, special consideration must be given to the end and intermediate platforms; that is, to the coupler connection between intermediate units and the coupler connection between end units, or the connection of an end unit to a conventional freight car. These special considerations for estimating the coupler angle are discussed below.

Multi-Platform Cars - Two Trucks-Solid Connection (drawbar)

End Platforms - Use equations provided in Exhibit 10.1. Consider the outboard half of the end platform and use dimensions based on this as if it represented a fully symmetric car of these dimensions. This is the case whether coupled to a like end platform or a conventional car.

Intermediate Platforms - Evaluate like a conventional car having a coupler length equal to one-half of the drawbar length. Coupler contour angle must be set at zero.

Multi-Platform Cars - Shared Articulated Truck Type

End Platforms - Consider the half of the platform on the outboard end and use dimensions based on this as though it represented a fully symmetric car of these dimensions. Use equations in Exhibit 10.1 as with a conventional car of these dimensions. This is the case whether coupled to a like end platform or to a conventional car.

Intermediate Platforms - To obtain the angle formed between the inboard half of the end platform and the adjacent articulated platform or between two articulated intermediate platforms, the following relationship must be used:

$$\text{Angle} = 180 - \text{Arccos}(A1/(R+E)) - \text{Arccos}(A2/(R+E))$$

Where:

Angle = Small angle formed between platforms at articulated connection (deg)

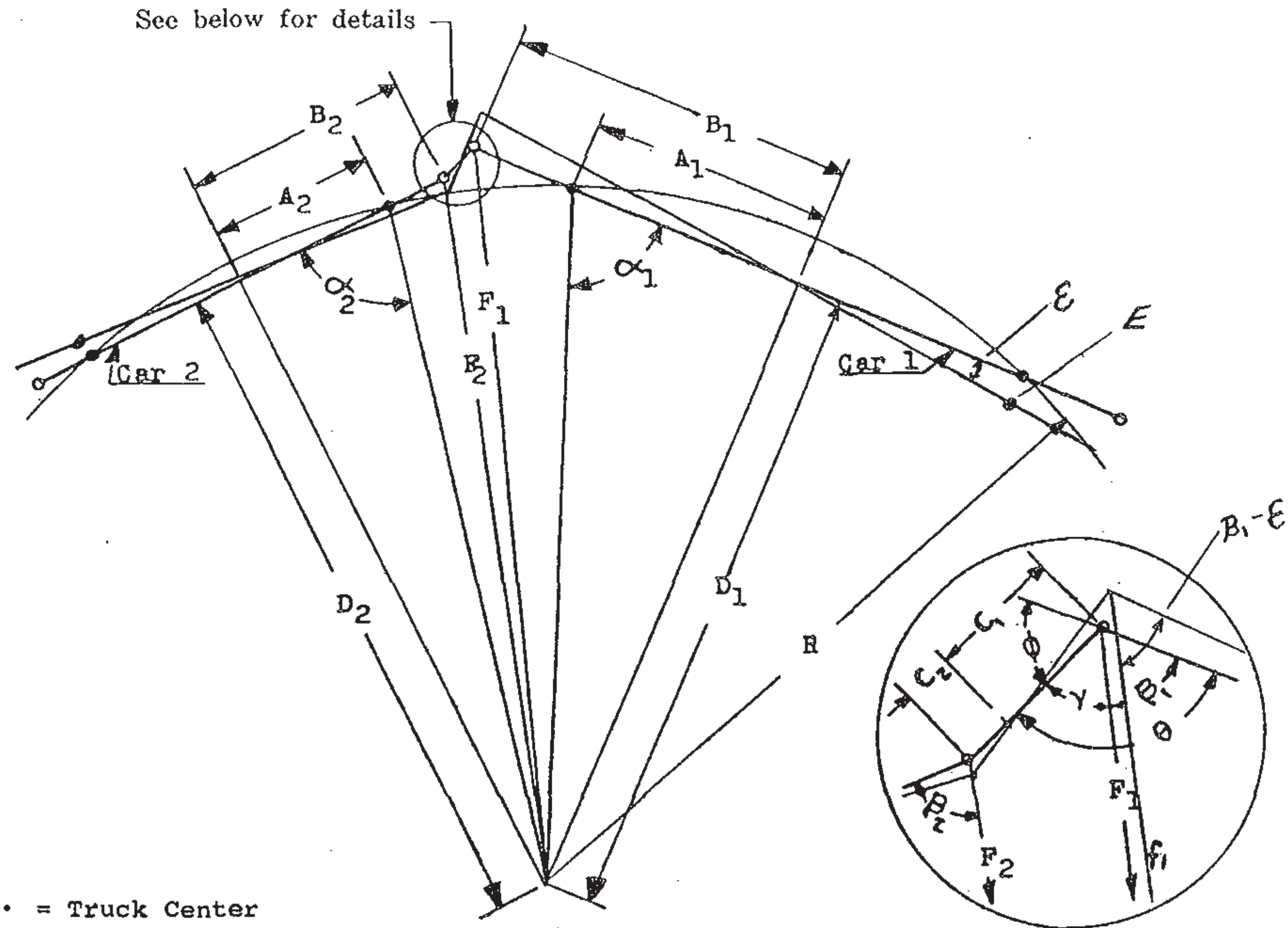
A1 = Half of Truck Center of Platform 1 (ft)

A2 = Half of Truck Center of Platform 2 (ft)

R = Radius of Curve (ft)

E = Lateral Bolster/Track Play (ft)

As can be seen from the above, these cases are not likely to be the limiting condition based on geometry. However, multi-platform cars with very light tare weight may represent the limiting condition based on the lower vertical loads.



• = Truck Center
° = Coupler Pivot Point
C = Coupler Length
A = Truck Center Distance /2
B = [Length Over Pulling Faces of Couplers -2 (Coupler Length)]/2
E = Lateral Bolster/Track Play
R = Radius of Curve = 50 / sin(track curvature in degrees /2)
α = Arc cos(A/R)
ϵ = Arc sin(E/A)
D = R sin(α)

$F = (B^2 + D^2)^{1/2}$ or $F = B/\cos(\beta)$
β = Arc cot (B/D)

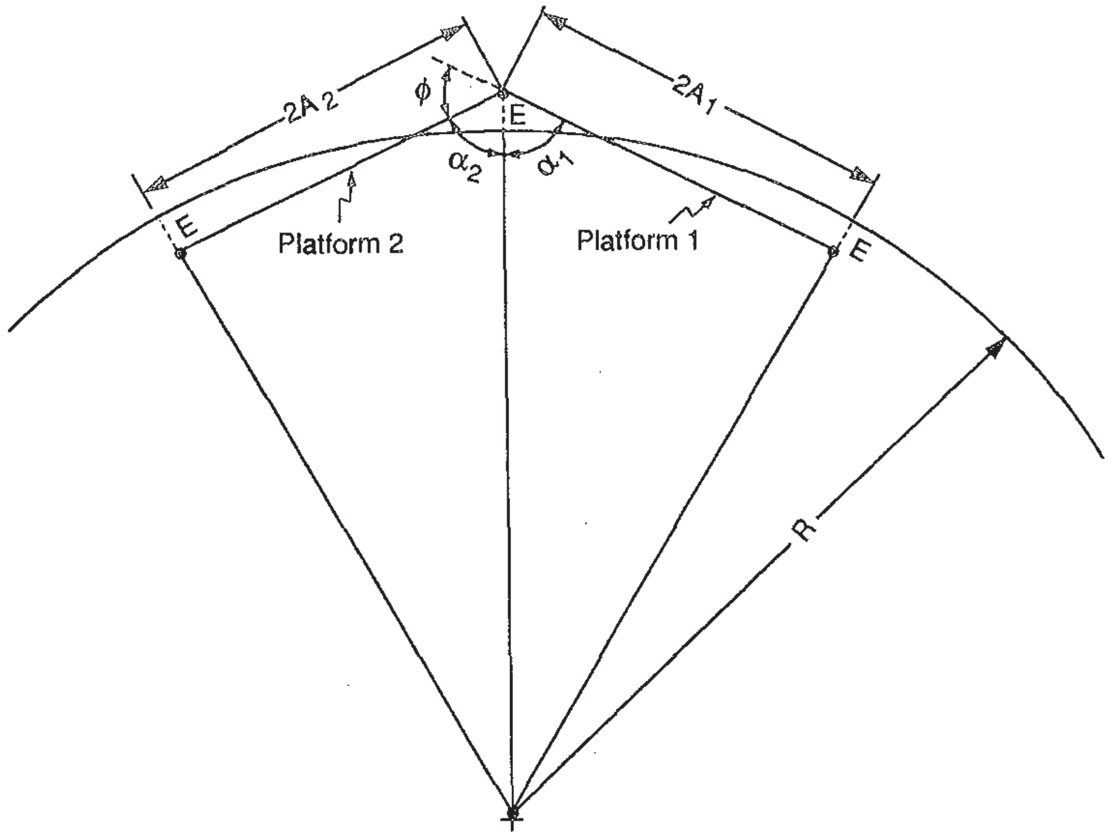
$$Y = \text{Arc Cos}\ \frac{(C_1 + C_2)^2 + F_1^2 - F_2^2}{2\ (C_1 + C_2)\ F_1}$$

Introducing Bolster/Track Plan
$f_1 = F_1 - E_1 \times B_1/A_1$ and $f_2 = F_2 + E_2 \times B_2/A_2$

$$\gamma = \text{Arc Cos}\ \frac{(C_1 + C_2)^2 + f_1^2 - f_2^2}{2\ (C_1 + C_2)\ f_1}$$

$\Theta = \beta_1 - \epsilon + \gamma$
Φ = Coupler Angle = 180 - Θ
P = Coupler Force
L = Lateral Component of Coupler Force = P sin(Φ)

Exhibit 10.1



A = Truck Center Distance/2
E = Lateral Bolster/Track Play
R = Radius of Curve = 50/sin (Track Curvature in Degrees/2)

$$\alpha_1 = \text{ARCCOS}\left[\frac{(2A_1)^2+(R+E)^2-(R-E)^2}{2(2A_1)\ (R+E)}\right]$$

$$= \text{ARCCOS}\left[\frac{A_1^2+ ER}{A_1\ (R+E)}\right] \approx \text{ARCCOS}\left[\frac{A_1}{R}+\frac{E}{A_1}\right]$$

$$\alpha_2 = \text{ARCCOS}\left[\frac{(2A_2)^2+(R+E)^2-(R-E)^2}{2(2A_2)\ (R+E)}\right]$$

$$= \text{ARCCOS}\left[\frac{A_2^2+ ER}{A_2\ (R+E)}\right] \approx \text{ARCCOS}\left[\frac{A_2}{R}+\frac{E}{A_2}\right]$$

$$\phi = \text{PLATFORM ANGLE} = 180 - \alpha_1 - \alpha_2$$

EXHIBIT 10.2