A Field Test of a

Grade Severity Rating System

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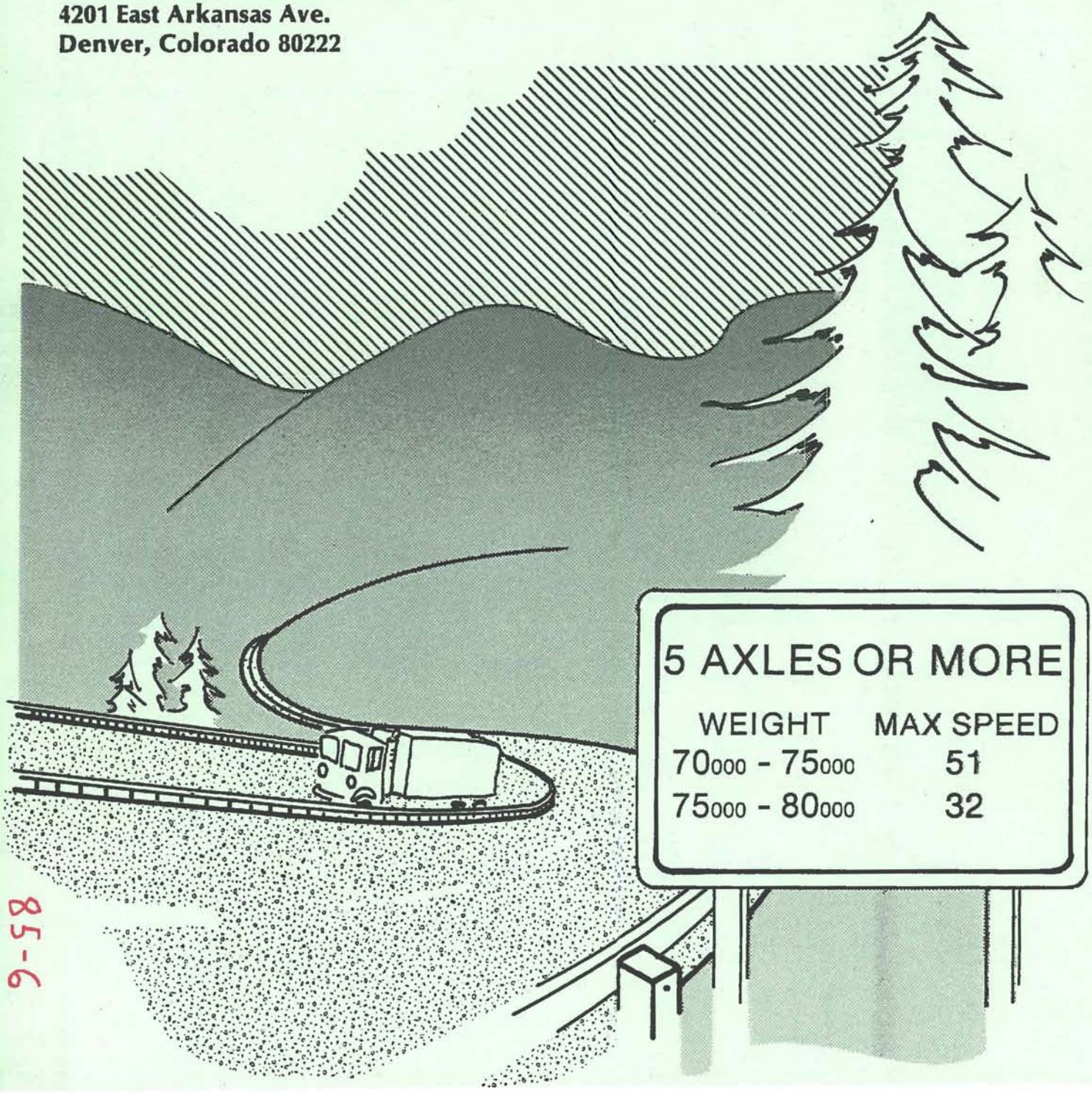

CDOH DTR R 85-6

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Raymond C. Erickson, Jr. P. E.

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Colorado Department of Highways or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOH DTR R 85-6		

4. Title and Subtitle	5. Report Date
A Field Test of a Grade Severity Rating System	April, 1985
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Raymond C. Erickson, Jr. P. E.	CDOH DTR R 85-6
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
State Department of Highways, Division of Highways, State of Colorado, Staff Traffic Engineering Branch, 4201 E. Arkansas Avenue, Denver, CO. 80222	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Interim 1983 - 1985
State Department of Highways 4201 E. Arkansas Avenue Denver, CO 80220	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U. S. Department of Transportation Federal Highway Administration

16. Abstract

A national research project has shown that truck brake temperature on grades is a major problem causing runaway trucks. Control of overheating of truck brakes can be achieved through correct speed. A truck brake heating model led to development of a Grade Severity Rating (GSR) System to be used with a Weight Specific Speed (WSS) sign.

The Colorado Department of Highways has cooperated with an FHWA contractor to test the GSR system and the WSS sign. Interim results of the test have been inconclusive as to the reduction of speed of heavy trucks.

Implementation

The WSS sign study should be extended for three years to permit additional study of the effectiveness of the signs. Before and after accident data will be submitted to FHWA to indicate the effect of these signs on driver response.

17. Key Words	18. Distribution Statement
Overheating of truck brake, downgrade truck braking Model, Weight Specific Speed, Grade Severity Rating System, effectiveness of WSS signs	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Acknowledgement

The author wishes to acknowledge research material used in this report from previous research accomplished by Walter A. Johnson, Systems Technology and Fred R. Hanscom, Director, Transportation Research Corporation.

Installation of the experimental Weight Specific Signs was made possible by P. R. McOllough, District Engineer, District I, Dale McCrumb, District I, Traffic Engineer and Maintenance Section I, Colorado Department of Highways.

This report would not have been possible without the valuable assistance and contributions of Engineering and clerical personnel of the Staff Traffic Engineering Branch.

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A Field Test
of
Grade Severity
Rating System

Objective of this Project

The objective of this project is to field test Weight Specific Speed (WSS) signs to determine if they provide an effective means of providing information to a driver of a heavy truck about the speed he should travel a grade in relation to the gross weight of his vehicle.

Background

Overheating of truck brakes on grades is a primary cause of runaway trucks. A national research project report number(FHWA RD-79-116) developed a truck downgrade braking model through instrumental field testing. Brake "fade" is primarily a brake temperature phenomenon, accordingly a brake temperature limit can be used to investigate potential downgrade problems. For a given speed the use of temperature to specify downhill braking requirements is equivalent to the use of stopping distance or deceleration. The report developed a grade severity rating (GSR) from the truck downgrade braking model. In conjunction with the GSR Weight Specific Speed (WSS) signs were formated to provide truck drivers a speed selection within acceptable brake temperature limits. These signs provide information about a speed that a vehicle driver should travel a downgrade in relation to gross weight of his vehicle.

In 1982 the Federal Highway Administration (FHWA) Office of Research awarded a research contract to field-test the effectiveness of an experimental advisory sign for trucks on downgrades. The Colorado Department of Highways agreed to participate in field-testing the WSS sign. Transportation Research Corporation of Haymarket, Virginia received the award from FHWA for the field test of the signs. In August of 1983

the FHWA Contracting Engineer and a Colorado Department of Highways Traffic Engineer made a field review of highway grades in Colorado with runaway truck incidents.

A site for field testing the WSS signs was selected on the eastbound lanes of I 70 between the east portal of the Eisenhower Tunnel and the Georgetown Interchange.

Field Test Before Data

For the period September 20, 1983 to September 24, 1983 data was collected by Transportation Research Corporation personnel for trucks traveling eastbound on I 70 at milepoint 228 between Silver Plume and Georgetown. Speeds of trucks were matched with visual descriptive information including: truck type, color, operator/company name and identification number. Positive matches were obtained for approximately ninety percent of the total truck sample. A total of 768 trucks were counted during the five-day study period. An 80% match of speed and weight data was obtained and, of the trucks counted, 173 had a gross vehicle weight exceeding 70,000 lbs.

Utilizing the truck downgrade braking model from FHWA Report Number RD-79-116, the April 1981 Draft Report, The Development and Evaluation of a Prototype Grade Severity Rating System, a program was written in BASIC to calculate final brake temperature given vehicle weight, speed, and slope data. Program outputs provide Weight Specific Speeds for desired weight classes.

From the east portal of the Eisenhower Tunnel to the Georgetown Exit I 70 descends from an elevation of 11,013 feet to 8,507, a decrease of 2,506 feet. The 12.6

mile section of roadway entails grades ranging from -6.9% to -1%, with the steeper grades in excess of -6% predominating the last 2.25 miles between the Silver Plume and Georgetown interchanges.

Variables used in the BASIC program for final brake temperature are as follows:

Variable/Unit		Basic Language
Slope	Radians	R
Initial brake temperature	^{o}F	T2
Speed	mph	S1
Final brake temperature	^{o}F	T9
Incremental increase in brake temperature during emergency stop	^{o}F	T8
Power absorbed by brakes	hp	H1
Maximum safe final brake temperature	^{o}F	T7

Exhibit 1 page 4 is a chart showing the Weight Specific Speeds generated by this program for I 70 eastbound (Georgetown Hill) between the Eisenhower Tunnel and Georgetown Interchange. The program calculated safe speeds for gross vehicle weight in 1,000 lbs. intervals between 70,000 and 80,000 lbs.

For Georgetown Hill a break point in speeds occurs at 74,000 lbs., and a maximum speed of 55 mph. Vehicles with a gross weight of 75,000 lbs. should travel the hill at 51 mph. Increased weight intervals of 1,000 lbs. result in a sequential reduction of safe speeds with the result that an 80,000 lb. vehicle should descend the hill at 32 mph.

◆ ◆ ◆ TRUCK DOWNGRADE BRAKING MODEL ◆ ◆ ◆
STAFF TRAFFIC AND SAFETY PROJECTS BRANCH

GEORGETOWN HILL

SPEED OF 32 MPH SAFE FOR WEIGHT OF 80000 POUNDS

SPEED OF 34 MPH SAFE FOR WEIGHT OF 79000 POUNDS

SPEED OF 37 MPH SAFE FOR WEIGHT OF 78000 POUNDS

SPEED OF 40 MPH SAFE FOR WEIGHT OF 77000 POUNDS

SPEED OF 44 MPH SAFE FOR WEIGHT OF 76000 POUNDS

SPEED OF 51 MPH SAFE FOR WEIGHT OF 75000 POUNDS

SPEED OF 55 MPH SAFE FOR WEIGHT OF 74000 POUNDS

SPEED OF 55 MPH SAFE FOR WEIGHT OF 73000 POUNDS

SPEED OF 55 MPH SAFE FOR WEIGHT OF 72000 POUNDS

SPEED OF 55 MPH SAFE FOR WEIGHT OF 71000 POUNDS

SPEED OF 55 MPH SAFE FOR WEIGHT OF 70000 POUNDS

AVG. GRADE OF THIS 12.93 MILE SLOPE IS 3.8 PERCENT

CP 1.510 SECS.

RUN COMPLETE.

Exhibit 1

The Truck Downgrade Braking Model[2.]

The Truck Downgrade Braking Model is based on a temperature limit concept. For a heavy truck traveling down a steep grade the maximum safe speed is defined as a speed that will not produce a brake temperature that will overheat the truck brakes. A truck on a grade should have enough braking capacity to maintain a steady descent speed and allow an emergency stop on the hill or at the bottom of the hill.

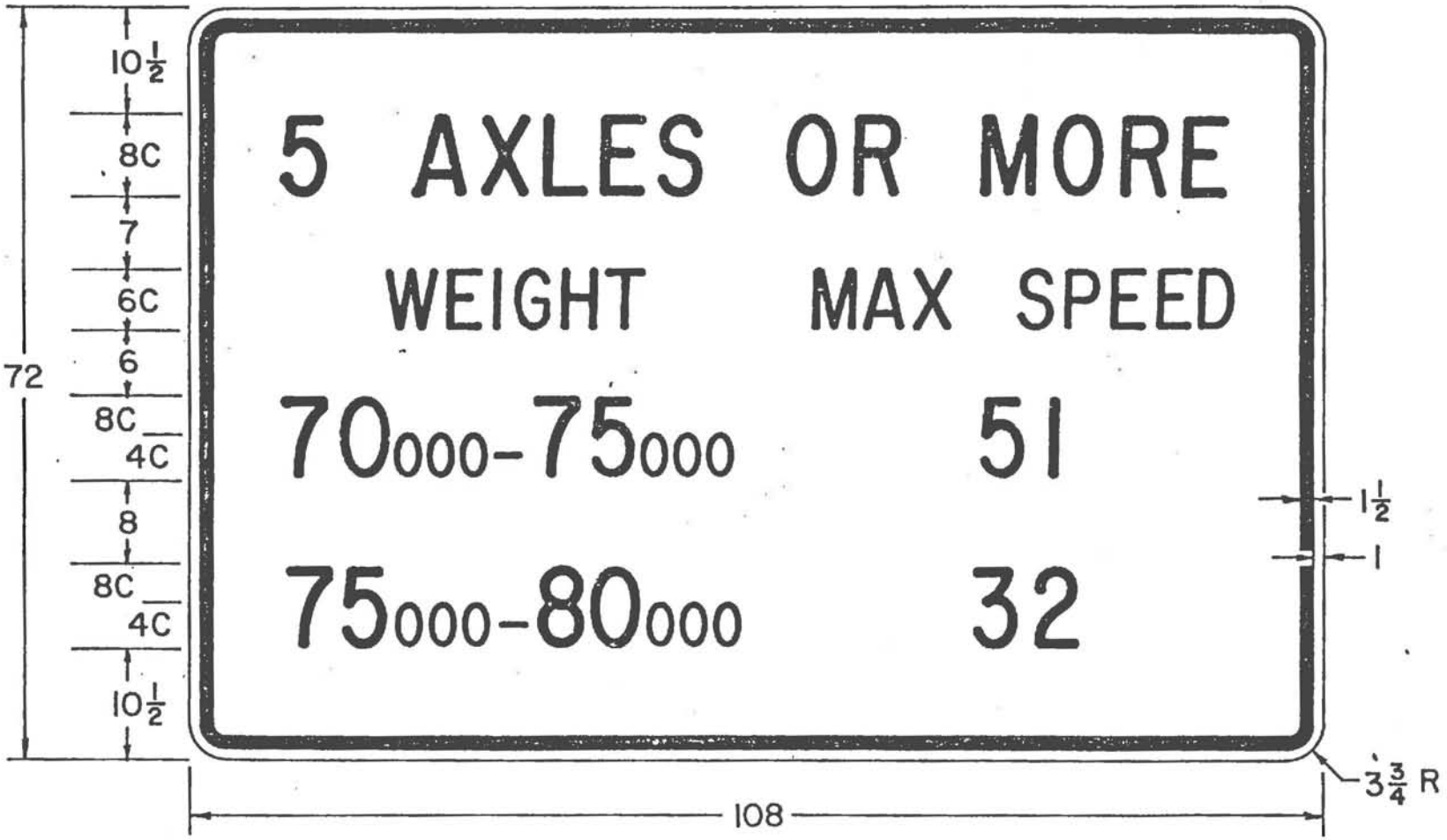
The maximum allowable final brake temperature (T_{lim}) is the sum of two sources of brake heating; one the heating from a steady grade descent at a speed V_o, the other resulting from a braked stop initiated at speed V_o.

The value of T_{lim} was selected to be 500°F. This is based on a range of brake temperatures at the start of fade for various linings, the typical degree of brake unbalance found on random trucks whose brake temperatures were measured.

Experimental Sign Format

In June of 1982 the Federal Highway Administration Office of Traffic Operation authorized field testing of the experimental WSS sign. Exhibit 2 shows a layout of the sign. For the signs to be installed on Georgetown Hill two weight intervals from the listing of the truck Downgrade Braking Model were selected for the sign message. A review of the weight class of vehicles entering the runaway truck ramps on Colorado Highways showed that 50% of the trucks using the ramps exceeded a gross vehicle weight of 70,000 lbs. Therefore, the two weight classes and speeds shown on the WSS sign are representative of the mix of truck weights found that have a significant history of brake failure on grades on Colorado Highways.

10/12/53



Advisory Speed Sign for the GSRS
WSS Sign No. II-72(E)

Stencil black legend and border
on reflectorized yellow background

Exhibit 2

After Data Collection 4.

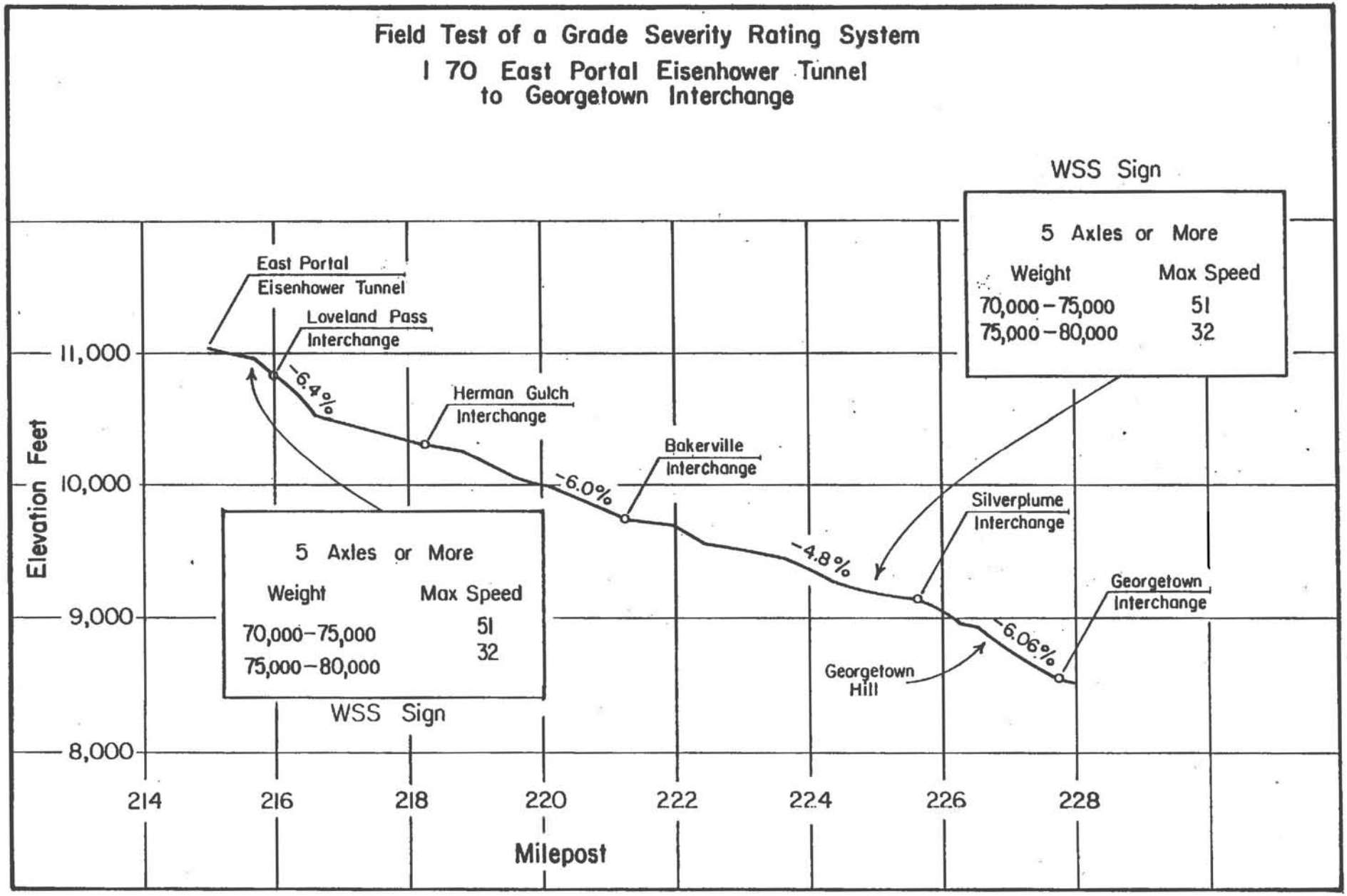
Two WSS signs were installed on I 70 during early November 1983. The first sign is located at milepoint 216, 0.7 miles east of the Eisenhower Tunnel and the second sign is at milepoint 225, 0.9 miles west of the Silver Plume exit. A profile of the grade with sign locations is shown on Exhibit 3.

During the week of November 7 the contractor collected "acclimation" data to determine if there was any adaptation on the part of truck drivers to the speed messages of the WSS signs.

Exhibit 4 from the Transportation Research Corporation report provides a preliminary analysis of before and after (acclimation) data.

Smaller samples of data for the after study were obtained due to the fact that snowfall limited data collection.

The contractors interim report found that the acclimation phase provided good statistical reliability with 95th percent confidence of the mean with a 2.0 mph accuracy. A conclusion of the contractor's interim report was that "little if any effect is realized from the presence of the Weight Specific Sign. While a slowing tendency is evident for the 75,000-80,000 pound trucks, as their observed mean speeds approached that posted on the Weight Specific Sign, this speed reduction is not statistically significant (nor is the 48 to 52 percent reduction which exceeded the posted speed). Virtually no mean speed difference is evident for the 70,000-75,000 pound trucks (as could be expected due to their slower-than-GSR speed in the before condition). A deceptively dramatic reduction (8 to 21 percent) in proportion of the trucks in this class exceeding the GSR speed is not statistically significant due to the small sample. Trucks lighter than 70,000 pounds exhibited a slight, but statistically non-significant, speed increase between the before


Field Test of a Grade Severity Rating System
I 70 East Portal Eisenhower Tunnel
to Georgetown Interchange
WSS Sign
5 Axles or More
Weight
Max Speed
70,000 – 75,000
51
75,000 – 80,000
32
East Portal
Eisenhower Tunnel
Loveland Pass
Interchange
-6.4%
Herman Gulch
Interchange
Bakerville
Interchange
-6.0%
-4.8%
Silverplume
Interchange
Georgetown
Interchange
-6.06%
Georgetown
Hill
5 Axles or More
Weight
Max Speed
70,000 – 75,000
51
75,000 – 80,000
32
WSS Sign
Elevation Feet
11,000
10,000
9,000
8,000
214
216
218
220
222
224
226
228
Milepost

GSR Category

	75-80,000 pounds 32 mph		70-75,000 pounds 51 mph		<70,000 pounds 55 mph	
	BEFORE	ACC	BEFORE	ACC	BEFORE	ACC
Sample Size	85	30	78	24	605	200
Mean Speed	35.1 mph	32.7 mph	35.7 mph	35.5 mph	53.6 mph	54.7 mph
(95% confidence)	$\pm$1.5 mph	$\pm$1.8 mph	$\pm$1.8 mph	$\pm$2.0 mph	$\pm$0.5 mph	$\pm$ .8 mph
% Exceeding GSR Speed	52	48	21	8	57	64

Table A - Preliminary Analysis of before versus acclimation data collected at the Colorado site

and acclimation condition.

In conclusion, comparison of before versus acclimation data revealed some minor (statistically non-significant) tendencies toward compliance with GSR-posted speeds. Slight speed reductions were noted for 75,000 to 80,000 lb. trucks, while a smaller proportion of the 70,000-75,000 lb. trucks exceeded the GSR-posted speed. These tendencies are insufficient to demonstrate a valid statistical effect. A comprehensive determination of sign effect will be undertaken during the "after" data collection this coming fall."

Preliminary Finding From the Contractor

On January 30, 1985 a copy of a preliminary finding in the FHWA study was transmitted to the Staff Traffic Engineering Branch by the contractor. Results of the study indicate generally poor compliance with posted speeds. Exhibit 5 shows data for six grades where experimental WSS signs were posted.

Conclusions and Recommendations

This report is a minute portion of the work that has been done to create an improvement in safety for trucks on highway grades. Ten states are participating in the overall program which should contribute to a more significant data base. The Weight Specific Speed sign is an alternative countermeasure to construction of runaway truck ramps and should be used as an adjunct or additive to the existing series of signs (W7-1 to 4) in Part II-C in the Manual on Uniform Traffic Control Devices (MUTCD). At the present time there are ten runaway truck escape ramps on mountain highway grades in Colorado with a recorded history of over 413 usages. A study of downhill grades where escape ramps are not in place showed that there are 14 locations where runaway truck accidents have occurred. The cost effectiveness of runaway ramp construction at these locations has not been investigated; however, installation

Site (Total Sample)	Weight Class (kips)	Posted Speed (mph)	Sample Size	Average Actual Speed (mph)	Proportion Exceeding Posted Speed
Cabbage Hill (N=1,253)	60	55	459	50.7	.37
	60-65	37	77	48.5	.69
	65-70	26	74	42.3	.90
	70-75	22	203	44.1	.97
	75-80	18	440	44.2	.98
Colorado (N=784)	70	55	588	52.2	.48
	70-75	51	85	38.0	.16
	75-80	32	111	36.5	.59
Imperial Grade (N=69)	65	55	53	50.3	.38
	65-70	45	3	45.4	.33
	70-75	30	6	27.1	.33
	75-80	20	7	32.0	1.00
Medford, Oregon (N=742)	60	55	200	50.7	.37
	60-65	44	39	48.5	.69
	65-70	30	42	42.3	.90
	70-75	23	139	44.1	.97
	75-80	18	322	44.2	.98
Siskyou County, CA (N=1,344)	75	55	826	55.4	.59
	75-80	45	523	53.3	.88
West Virginia (N=207)	74	55	198	56.8	.71
	74-80	40	9	56.5	1.00

Exhibit 5 - Compliance with GSR Posted Speeds

of the WSS signs at selected grades where the accident rate exceeds 1.0 per 100,000 downhill trucks might provide a low cost means of reducing accidents for heavy trucks.

So far the field test of the WSS sign has been inconclusive. Research in the field of sign recognition has shown that a high percentage of drivers do not recognize the intended meaning of many signs. However, given the fact that the WSS sign is intended to supply special information to a unique segment of the driving population it is possible that more widespread use of the sign would increase recognition and compliance by drivers of heavy vehicles.

There has been pressure by enforcement authorities to solve the runaway truck problem by means of speed enforcement of heavy vehicles. While this seems to be effective the fact remains that incidents of runaway vehicles are occurring on the Colorado I 70 grade where a 25 MPH speed limit is in place for all vehicles over 10,000 lbs., G.V.W.

The Colorado Truck Size and Weight Report shows that the average weight of an empty combination truck is in the range of 30 to 35 thousand pounds. Further, the report shows that 30 to 35% of combination trucks traveling Colorado highways are not loaded. A conclusion is that enforcement of a 25 MPH speed limit for vehicles over 10,000 G.V.W. is a severe restriction for drivers of unloaded trucks.

As a recommendation further study should be done to evaluate the WSS signs. The Colorado Study site at the I 70 Georgetown Hill should be utilized for further research since truck speed data can be correlated with truck weight data from the Dumont Weigh Station located 6 miles east of the Georgetown interchange.

An additional study site should be located on the westbound lane of I 70 on the west side of Vail Pass. The Vail Pass grade is steeper than the Georgetown Hill study site. The average grade for Georgetown Hill is 3.8 percent. The westbound I 70 Vail Pass Grade is 4.7 percent. There have been over 60 usages of the Vail Pass Truck Ramps which indicates that the steeper average grade creates a higher incidence of braking problems. A further reason for utilizing the Vail Pass grade for additional research for WSS signs is that before data has been collected by the contractor on this grade.

Implementation

Implementation of the WSS sign is dependent on the results of the field test authorized under the FHWA contract. The Colorado Department of Highways participation in the field test of the experimental signs was given impetus by the magnitude and severity of runaway truck accidents on grades in Colorado. As a result a program was initiated to construct runaway truck escape ramps at high truck accident locations. There are 10 runaway ramps located on State Highway grades in Colorado. For the period 1976 to 1984 there have been 413 usages of these ramps.

For runaway truck incidents where mechanical or equipment failures have occurred our reports show that 144 incidents of this type involved brake related problems with over 30 percent reporting overheating of brakes as the reason for utilizing the runaway ramp. As a result it is reasonable to believe that the present signing system for warning truck drivers about severe downgrades is not effective.

The WSS sign offers pertinent information to the driver that he may relate directly to his vehicle and the grade that he is traveling. It is recommended

that use of the WSS sign be extended to other grades where runaway truck accidents have occurred. There are thirteen such locations in Colorado. Posting of WSS signs on these grades should be considered under the experimental program. The sign locations would be monitored over the study period.

To provide additional information under the program, the Colorado State Highway Department would perform an accident study after the signs had been in place for three years and submit a report to FHWA of the accident history.

References

1. Thomas T. Myers, Irving L. Ashkenas, Walter A. Johnson, Feasibility of a Grade Severity Rating System FHWA-RD-116 August 1980 Final Report

2. Walter A. Johnson, R. Wade Allen, The Development and Evaluation of a Prototype Grade Severity Rating System Draft Report April, 1981 Contract DOT-FH-11-9336

3. A Report on Truck Escape Ramp Use in Colorado Revised April, 1983, State Department of Highways, Division of Highways, State of Colorado, Staff Traffic and Safety Projects Branch

4. Fred R. Hanscom, P. E. Director, Transportation Research Corporation, Interim Result a report on a Field Test of a Grade Severity Rating System August 7, 1984

5. Colorado Truck Size and Weight Study, 1979 Report State Department of Highways, State of Colorado, Division of Transportation Planning

6. Manual on Uniform Traffic Control Devices U. S. Department of Transportation, Federal Highway Administration.

Appendix A

Field Data Collection Procedures for Highway Grades [2]

Most of the mountain highway grades in Colorado are multiple grade hills. Grades vary sequentially according to the terrain traversed by the road. In many cases grade data is not available from roadway plans. The following is a procedure presented in reference number 2 for determining the value of R for the Truck Downgrade Braking Model for a specific grade; a driver and a recorder are required:

1. It is critical to determine the steepness and length of the grade quite accurately.

2. Use a car with a calibrated odometer and a sensitive hand-held altimeter.

3. Drive slowly down the grade with the car windows open so air pressure inside the car is the same as air pressure outside. Tap the altimeter frequently to counteract sticking in the instrument.

4. At each 20 feet of altitude change, the person holding the altimeter calls <u>now</u> and the driver estimates the odometer reading to the nearest hundredth of a mile.

5. The driver calls out the odometer reading to the recorder who records the mileage and the altitude.

6. This procedure is repeated several times, driving both uphill and downhill.

7. Using the altitude and distance data a grade profile is plotted for each run recorded.

8. An average of the individual profiles is used as the best estimate of the grade profile.

9. A straight line may be fitted between two points to determine the slope and percent of grade.

Appendix B

WEIGHT DISTRIBUTION OF TRUCKS ENTERING RUNAWAY TRUCK RAMPS IN COLORADO [3].

GVW Kips Class Interval	No.	%
20	15	49
20-25	10	
26-30	8	
31-35	8	
36-40	5	
41-45	4	
46-50	10	
51-55	4	
56-60	10	
61-65	16	06
66-70	35	14
71-75	53	20
76-80	77	30
81-85	3	01
TOTAL	258 *	

* Based on Revised April 1983 A Report on Truck Escape Ramp Use in Colorado

Appendix A Summary of Use, For 282 Usages Weight data was not available for 24 vehicles entering the ramps.

Appendix C

File No. 704.28

MEMORANDUM

DEPARTMENT OF HIGHWAYS
4201 East Arkansas Ave.
Denver, Colorado 80222

DATE: December 15, 1981

TO: Ray Erickson

DOH File 16-00

FROM: Matt Reay and Dan Lyons

SUBJECT: Computer Analysis of Weight Specific Speeds

As you know, the concept of a grade severity rating system (GSRS) has been studied extensively, and a workable example of such a system is described in Report No. FHWA-RD-79-116, Feasibility of a Grade Severity Rating System. Another report, entitled The Development and Evaluation of a Prototype Grade Severity Rating System,(April 1981) details the calculations and formulas established by the first, and presents a method for predicting final brake temperatures of 5 axle vehicles using a programmable calculator.

Shown here is a similar program, written in BASIC for a CDC 6400 computer. This program, like the HP67/97 program in the report, calculates final brake temperature given vehicle weight, speed, and slope data, but unlike the calculator program, our program outputs the Weight Specific Speeds in each case. This eliminates the need for the engineer to repeatedly enter data for each combination of weight and speed.

Attached is a program listing with a sample data list and sample output. The procedure is the same as that followed in Appendix C of the April 1981 document mentioned above, except that certain variables were renamed to accommodate the language used. Those changes are as follows:

FHWA Document	BASIC Program	Variable name, unit
θ	R	Slope, radians
T_o	T2	Initial brake temperature, ^oF
$\bar{V}$	S1	Speed, mph
T_f	T9	Final brake temperature, ^oF
ΔT_f	T8	Incremental increase in brake temperature during emergency stop, ^oF
HP_B	H1	Power absorbed by brakes, hp
T_{lim}	T7	Maximum safe final brake temperature, ^oF

Also attached is a chart showing the weight specific speeds (WSS) generated by this program for seven selected locations in Colorado. Note that this method ignores the effect of horizontal curvature in the roadway, as evidenced by a WSS of 55 mph for the lowest weight class on Rabbit Ears Pass. It should be emphasized that this method is only a tool, and that it cannot and should not replace good engineering judgment.

MATT REAY

DAN LYONS

MR/DL:bn

cc: File

BASIC Program to determine weight specific speeds

```
 81/12/15. 08.43.11.
PROGRAM    DAN1

00100 REM      PROGRAM DETERMINES VALUES FOR WEIGHT SPECIFIC SPEEDS
00200 REM           DATA CONSISTS OF INITIAL BRAKE TEMP FOLLOWED BY
00300 REM          "SLOPE IN RADIANS AND LENGTH IN MILES FOR EACH GRADE
00400 PRINT "ENTER GRADE IDENTIFIER IN QUOTES";
00500 INPUT A$
00600 PRINT
00700 PRINT
00800 PRINT
00900 PRINT "* * * TRUCK DOWNGRADE BRAKING MODEL * * *"
01000 PRINT
01100 PRINT TAB(15);A$
01200 PRINT
01300 FOR W=85000 TO 50000 STEP -5000
01400 FOR S1=55 TO 1 STEP -1
01500 READ T2,R,L
01600 K1=1.23+(.0256*S1)
01700 K2=1/(.1+.00208*S1)
01800 T8=(3.11*W*(S1**2))/10000000
01900 H1=(((W*R)-(450+17.25*S1))*(S1/375))-73
02000 E=(-1*K1*L)/S1
02100 E1=1-EXP(E)
02200 T9=T2+((90-T2+(K2*H1))*(E1))
02300 T7=T8+T9
02400 IF T7>500 THEN 02900
02500 T2=T9
02600 NODATA 03300
02700 READ R,L
02800 GO TO 01900
02900 RESTORE
03000 NEXT S1
03100 PRINT "NO SAFE SPEED FOR WEIGHT OF"W" POUNDS"
03200 GO TO 03400
03300 PRINT "SPEED OF"S1" MPH SAFE FOR WEIGHT OF"W" POUNDS"
03400 PRINT
03500 RESTORE
03600 NEXT W
03700 STOP
10000 DATA 150
10001 DATA .0692,2.3
10002 DATA .0685,1.95
10003 DATA .0636,3.2
10004 DATA .0430,.29
```

Sample run of BASIC Program

```
RUN

 81/12/15.  08.44.04.
PROGRAM    DAN1

ENTER GRADE IDENTIFIER IN QUOTES? "RABBIT EARS PASS"


* * * TRUCK DOWNGRADE BRAKING MODEL * * *

                RABBIT EARS PASS

SPEED OF 11   MPH SAFE FOR WEIGHT OF 85000   POUNDS

SPEED OF 12   MPH SAFE FOR WEIGHT OF 80000   POUNDS

SPEED OF 13   MPH SAFE FOR WEIGHT OF 75000   POUNDS

SPEED OF 16   MPH SAFE FOR WEIGHT OF 70000   POUNDS

SPEED OF 19   MPH SAFE FOR WEIGHT OF 65000   POUNDS

SPEED OF 23   MPH SAFE FOR WEIGHT OF 60000   POUNDS

SPEED OF 33   MPH SAFE FOR WEIGHT OF 55000   POUNDS

SPEED OF 55   MPH SAFE FOR WEIGHT OF 50000   POUNDS


CP          0.355 SECS.

RUN COMPLETE.
```

WEIGHT SPECIFIC SPEEDS FOR VARIOUS GRADES IN COLORADO

SPEED (MPH), BY LOCATION	LOCATION	VEHICLE WEIGHT (POUNDS) 85,000	80,000	75,000	70,000	65,000	60,000	55,000	50,000
	I-70 Eastbound, Mt. Vernon Canyon	25*	32	46	55	55	55	55	55
	I-70 Westbound, Straight Creek	14*	16	19	23	31	55	55	55
	I-70 Westbound, Vail Pass	17*	20	24	31	53	55	55	55
	I-70 Eastbound, Georgetown Hill	28*	36	55	55	55	55	55	55
	U.S. 40 Westbound, Rabbit Ears Pass	11	12	13	16	19	23	33	55
	U.S. 160 Westbound, Wolf Creek Pass	10	11	12	14	17	21	28	55
	S.H. 141 Northbound, Slick Rock Hill	13	15	18	23	31	55	55	55

*Vehicles in excess of 80,000 lbs. are not allowed on interstate highways, except by special permit.

```
TERMINAL - 037
FILE NAME: DAN
LAST CONTROL STATEMENT-
LAST COMMAND-RNH
SESSION STATUS -   0

 CYBER SYSTEM UP


 01/13/14. 09.22.15. CYBER  USER ID:H208,MATT
PROJECT:PHAP
TERMINAL:    15,TTY

PREVIOUS SESSION RECOVERED AT POINT OF INTERRUPTION:
TERMINAL - 037
FILE NAME: DAN
LAST CONTROL STATEMENT-
LAST COMMAND-RNH
SESSION STATUS -    WAITING FOR COMMAND.
ENTER (CR) TO CONTINUE.
ENTER  STOP  TO TERMINATE EXECUTION.

 IDLE.
LNH,10000
10000 DATA 75000,150,.0165,.16
10001 DATA .0662,.26
10002 DATA .0690,.15
0003 DATA  *INT*
$
 *TERM*
10000 DATA 100000,150,.0165,.16
RNH
HOW FAST YOU WANNA GO, HUH? 30
 27.99          148.163          176.153
 27.99          187.249          215.239
 27.99          210.864          238.854
 27.99          221.976          249.966
 27.99          224.646          252.636
 27.99          240.344          268.334
 27.99          247.642          275.632
 27.99          273.658          301.648
 27.99          285.778          313.768
 27.99          298.326          326.316
 27.99          313.253          341.243
 27.99          315.876          343.866
 27.99          338.494          366.484
 27.99          347.309          375.299
 27.99          364.496          392.486
 27.99          358.938          386.928
 27.99          381.805          409.795
 27.99          401.62           429.61
 27.99          389.128          417.118
 27.99          404.86           432.85
 27.99          437.659          465.649
 27.99          449.464          477.454
 27.99          465.392          493.382
 27.99          461.77           489.76
 27.99          450.997          478.997
 27.99          457.823          485.813
 27.99          442.361          470.351
 27.99          455.655          483.645
 27.99          450.809          478.799
 27.99          456.091          484.081
 27.99          450.472          478.462
 27.99          456.7            484.69
 27.99          440.348          468.338
 27.99          452.458          480.448
 27.99          453.495          481.485
 27.99          438.155          466.145
 27.99          480.93           508.92
TEMPERATURE EXCEEDED AT A SPEED OF 30  MPH
ABORT OCCURS IN .63  MILE SECTION
WITH A BRAKE TEMPERATURE OF 508.92  DEGREES


CP       0.332 SECS.
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Appendix D

STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS - STATE OF COLORADO
STAFF TRAFFIC AND SAFETY PROJECTS BRANCH

Runaway-Truck Accidents--Downhill Locations Where Escape Ramps Are Not in Place

September 1, 1978 - September 1, 1981

SH	Location	Total Truck Accs.	Fatal Truck Accs.	Injury Truck Accs.	No. of Downhill Trucks Per Day	Acc. * Rate
50 Ø	Monarch Pass EB MP 202-211	11	2	5	115	8.7
550 Ø	Coal Bank Hill SB MP 51-52	4	2	1	55	6.6
139	Douglas Pass NB MP 37-38	4	0	1	60	6.1
50	Monarch Pass WB MP 190-199	7	0	2	110	5.8
41	Nine-Mile Hill S. of Whitewater NB MP 149-151	4	1	3	105	3.5
6	Loveland Pass WB MP 216-218	2	1	1	55	3.3
141	N. of Gateway SB MP 116	3	0	2	105	2.6
25	Raton Pass NB MP 2-6	7	1	5	255	2.5
50	E. of Cimarron WB MP 117-118	3	1	1	115	2.4
50	W. of Canon City WB MP 268-269	3	0	1	125	2.2
19	W. of Boulder EB MP 34-35	2	0	0	100	1.8

Runaway-Truck Accidents--Downhill Locations (continued)

SH	Location	Total Truck Accs.	Fatal Truck Accs.	Injury Truck Accs.	Downhill Trucks Per Day	Acc. Rate *
285	**Crow Hill SB MP 222	3	1	1	135	1.2
70	Floyd Hill WB MP 244-245	6	2	3	680	0.8
160	Hesperus Hill, W. of Durango EB MP 77-78	2	1	1	235	0.8
91	Fremont Pass NB MP 17-19	1	0	1	110	0.8
70	Georgetown Hill EB MP 227-228	4	3	0	640	0.6

* Accident Rate = runaway-truck accidents per 100,000 downhill trucks

** Accident History 7/26/76 to 9/1/81

Ø Locations where Runaway Truck Ramps have recently been constructed