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LOFT TECHNICAL REPORT LTR 1326-1
MAY 9, 1978

KAISER ENGINEERS RAILROAD TRACTIVE EFFORT TEST,
LOFT - A&M TRACK

E. R. White

MASTER

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DEPARTMENT OF ENERGY

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LOFT TECHNICAL REPORT
LOFT PROGRAM

EGG/LTR--1326-1

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TITLE Kaiser Engineers Railroad Tractive Effort Test,		REPORT NO. LTR 1326-1
LOFT - A&M Track		
AUTHOR E. R. White <i>E.R. White 2/17/78</i>	GWA NO.	
PERFORMING ORGANIZATION LOFT	DATE May 9, 1978 <i>sh</i>	
LOFT APPROVAL PSB Mgr. <i>[Signature]</i> RSB Mgr. <i>ECQ</i> P&CSB Mgr. <i>[Signature]</i>		

SUMMARY

This LTR contains the original results of the Railroad Locomotive Tractive Effort Test performed by Kaiser Engineers on July 29, 1965, using an existing 24-wheel 500-ton dolly and the existing shielded locomotive. The test was conducted to confirm calculations of the tractive effort required to move the LOFT dolly (MTA) through the four-rail high bay curve and the curve into the LOFT containment vessel.

This document was originally Appendix A-6 to SDD 1.3.26B.

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APPENDIX A-6

TRACTIVE EFFORT TEST - LOFT-A&M TRACK

This appendix presents the results of the tractive effort test performed by Kaiser Engineers on July 29, 1965, at the NRTS using an existing 24-wheel, 500-ton dolly and the existing 400-hp shielded locomotive. The test was conducted to confirm calculations of the tractive effort required to move the future LOFT dolly through the four-rail high bay curve and the future LOFT curve.

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TRACTIVE EFFORT
TEST
LOFT-A&M TRACK

A. INTRODUCTION

A tractive effort test using an existing 24 wheel, 500 ton dolly and the existing 400 HP shielded locomotive was run on July 29, 1965, at the A&M area, NRTS, Idaho. The purpose of the test was to confirm theoretical calculations of the tractive effort needed to move the future LOFT dolly through the 4-rail High Bay curve and the future LOFT curve.

Observations were also made of track action under the influence of the dolly and locomotive.

B. CONCLUSIONS

1. The tractive effort required to move the LOFT dolly through the curves, estimated on the basis of this test, is within the "continuous operation" range of the locomotive.
2. Roadbed deflections under the test dolly wheel loads are not excessive.
3. Although the High Bay curve rail was doubtless overstressed during the test it is probable that a few trips by the LOFT dolly will not cause failure of the track under load.

C. RECOMMENDATIONS

1. Restrict LOFT dolly speed to 1 mph at the High Bay curve.
2. Grease the contact rail heads at the High Bay curve before passage of the LOFT dolly.

D. TEST PREPARATIONS BY PPCo

1. AMMETERS: The locomotive ammeters were removed and shop-adjusted to provide true current readings.
2. SPEEDOMETER: The locomotive speedometer was calibrated with a stop watch over a measured course. The calibration curve is shown on sheet 8.
3. DOLLY WEIGHT: The test dolly was weighed by means of a simultaneous lift by four 100 ton hydraulic jacks. The jacks with their pressure gages had previously been calibrated using a 60,000 pound compression tester as a source of known load. The calibration curve is shown on sheet 9 .

The jacks would not hold pressure beyond 8,000 psi and were not able to lift the full 100 tons apiece. When the dolly was lifted to the 8,000 psi capacity of the jacks, the four 6 wheel trucks were not lifted from the rails. The four jacks at 8,000 psi corresponded to a total weight of 315 tons. The four trucks would weigh at least 3 tons. A weight of 318 tons was used in the calculations.

4. ADDITIONAL WEIGHTS ON DOLLY:

Four additional storage casks weighing a total of 72.25 tons were placed on the dolly. Their weight was determined with a 100,000 lb Dillon dynamometer placed between the cask and the hook of the High Bay crane.

Three known steel and concrete weights of 60, 25, and 25 tons were obtained from General Electric Company at NRTS and placed on the dolly. Since they had been weighed previously by GE and the tonnage marked on the weights, they were not reweighed for this test.

The total weight of the loaded dolly was thus taken as:

Dolly	318	tons
Casks	72.25	tons
GE Weights	110	
	<u>500.25</u>	tons

E. TESTS AND OBSERVATIONS:

1. RUN NO. 1

At approximately 1:00 PM the test train was driven from the High Bay to the turntable, with both observers in the locomotive cab. The locomotive was in a pulling position. The instrument readings are shown on sheet 10. The rail head was not greased on this run.

At no time during this run did the ammeters read beyond the green or "continuous operation" zone of the dial.

No lifting of the locomotive was felt as the curve was traversed. According to the locomotive engineer this lifting had actually been felt, as well as observed from outside when the locomotive was first run on this curve several years ago.

2. RUN NO. 2

After the first run, the train was reversed and run back to the High Bay. The locomotive was in a pushing position. The track was ungreased. No instrument readings were taken. Both observers walked alongside and ahead of the dolly in order to observe the action of the track and wheels. The following observations were noted.

- A. The wheels of the dolly and locomotive did not noticeably rise from the rail. This was confirmed by observing the crushing of a coin under the wheels of the train. The width of bearing measured from the side of the rail head to the demarcation between the crushed and uncrushed portions of the coin was $1 \frac{13}{16}$ inches.
- B. The rails were observed to rotate due to the lateral force of the wheels. The lateral movement of the rail head was on the order of $\frac{3}{32}$ " to $\frac{1}{4}$ ". All of the spikes on the inside of the rail had been loosened and pulled up by the passage of trains previous to this test.
- C. The trucks proceeded around the curve in a series of chords relieved by jumps to the next position. A series of loud snaps were heard as the wheels jumped to the new alignment. The jump of the wheels to the next alignment was a visible lateral motion. This sudden skidding left burn marks on the tops of the rail heads. These burn marks may be seen in one of the photos in the appendix.

3. RUN NO. 3

After greasing the inside of the rail heads the train was run out onto the turntable. One observer was in the cab and one outside. This run was noticeably much smoother, both in the marked reduction in the wheel snapping action and also in the reduced ampere readings. The instrument readings are shown on sheet 11.

4. RUN NO. 4

The train was run west on the tangent track towards LOFT to the crossing of the overhead 13.8 kv transmission line which supplies power to the existing LOFT wells. Both observers were outside the locomotive observing vertical rail and tie deflections. Little deflection was observed at 90% of the ties. At 3 points of the greatest observed deflections, the train was stopped and level shots taken with a surveyors transit and a 6 inch machinists rule. Three shots were taken: with the tie unloaded; loaded with the

55,000 lb axle load at the rear of the locomotive; and loaded with the heavy interior axle of the dolly. It may be assumed for a rough estimate that the depression under the locomotive wheel load took up most of the play between the rail, tie plate, tie and roadbed and that most of the added deflection under the heavy dolly axle load may be ascribed to the deflection of the ballast and subgrade. The 3 bad ties deflected $3/32$ " (avg) under the light load and $21/32$ " under the heavy load. The other 90% of the ties deflected from a quarter to a half of this deflection. The average roadbed deflection then would be $(21/32 - 3/32)/2$ or $9/32$ which agrees quite closely with the estimated deflection of 0.33 inches. (Sheets 22 and 23) In other words, the roadbed appears to be in satisfactory condition.

This run was stopped at the 13.8 kv transmission line because the clearance between the top of the dolly and the power line was too small to permit safe passage.

5. RUN NO. 5

The locomotive was reversed and run back to the A & M area at 5 mph. The instrument readings are shown on sheet 12.

F. DISCUSSION AND CALCULATIONS

1. TRACTIVE EFFORT

A multiplying factor of 1.13 was obtained between the theoretical dolly running resistance and the running resistance corresponding to the 1 mph ammeter readings at the ungreased 455' radius curve. The projection of the theoretical calculations for the LOFT dolly using this factor gives a maximum estimated effort within the "continuous running" zone of the locomotive. Sheets 13 to 21. This projection of the maximum effort is based on journal bearings. The roller bearings to be used on the LOFT dolly will reduce the effort below the estimated values given by 10% to 50% at speeds of 5 mph to 1 mph respectively.

2. RAIL STRESS AT HIGH BAY CURVE

Combined stress at the lower web fillets is doubtless high due to the outward leaning of the rails. The outward deflection of the rails though prevents the extremely high stress which would be experienced in the "wedging up" of the wheel flanges. Methods for calculating the magnitude of the stress have not been developed since the railroads have been in the habit of using strain gauges whenever a rail stress determination was needed.

It is felt however, that there is a low probability of rail fracture under the few load cycles to be imposed by the LOFT trains.

The stresses may be minimized by restricting train speed at the High Bay curve to 1 mph, and by greasing the inside of the rail heads at this curve.

3. The photographs taken during the running of the test can be obtained from the PPCo photographer, Mr. J.C. Pruden.

G. ACKNOWLEDGEMENT

The assistance and cooperation of John C. Pruden, Harold Petty, Daryl Hanni and their staff, all of Phillips Petroleum Company, were greatly appreciated.

AXLE LOADS

400 HP GE LOCOMOTIVE
SN 32027

LTR 1326-1
Appendix A-6

Driving Axle
Idle Axle

Fig. VI-31 - View of Shielded Locomotive

Driving Axle
Idle Axle

AXLE LOADS
POUNDS
WHEEL
LOADS, LBS.

55,000	27,500	90,500	45,250	55,000	27,500	57,400	28,700	114,700	57,350	57,400	28,700
--------	--------	--------	--------	--------	--------	--------	--------	---------	--------	--------	--------

TOTAL = 430,000
LOCO.

TOTAL = 224,800
ON
DRIVERS

Test Dolly Diagram

Total wt.: 500 tons.

Overall Length: 50'-0"

32 Wheel LIFT Dolly Landing Diagram

LTR 1326-1
Appendix A-6

Load On 100 Ton Jacks, Ton

V_s
Jack Gage Pressure, PSIG

Simplex Hydraulic Jack No. 109 HJ
Ashcroft Dregage Type 1279D (41500 psi range)

Jack Gage Pressure, PSIG

16000
14000
12000
10000
8000
6000
4000
2000
0

25 Ton 50 000 lb 50 100 000 75 150 000 100 200 000 125 250 000

Weight

78.75 TONS
157,500 lb

TRACTIVE EFFORT TEST RECORD

LTR 1326-1
Appendix A-6
Date: 7-29-65
Recorder: Pruden

BY PHILLIPS PETROLEUM COMPANY
Witnessed by Kaiser Engineers

FOR

U. S. ATOMIC ENERGY COMMISSION
Idaho Operations Office
Idaho Falls, Idaho

This test was conducted using 500 ton test dolly and GE shielded locomotive Serial No. 32027, 400 HP.

Test Run No. 1 Wind Speed, MPH 12.5

Location of Run 455' Hi Bay Curve Wind Direction 225° Az.

Direction of Run Out (North) Ambient Temperature 93°F

Track Grade Level % Track Dry or Wet? Dry

Remarks on Other Track Conditions Rail Head Ungreased

Test Personnel: PPCo J. Pruden Locomotive Engineer D. Hanni

KE H. Thayer

SPEED - AMPERE RECORD					
Speed			Amperes		
Reading	Correction	True	Reading	Correction	True
.5	+ .05	.55	149	NONE	
.5	+ .05	.55	150		
.5	+ .05	.55	150		
.75	-	.75	150		
.5	-	.5	175		
.5	-	.5	150		
.25	-	.25	200		
.75	-	.75	200		
.75	-	.75	200		
.75	-	.75	200		
1.0	-	1.0	200		
1.25	-	1.25	275		
1.0	-	1.0	175		
1.25	-	1.25	210		
1.75	-	1.75	300		

TRACTIVE EFFORT TEST RECORD

LIK 1326-1

Appendix A-6

Date: 7-29-65

Recorder: Pruden

BY PETROLEUM COMPANY
Witnessed by Kaiser Engineers

FOR

U. S. ATOMIC ENERGY COMMISSION
Idaho Operations Office
Idaho Falls, Idaho

This test was conducted using 500 ton test dolly and GE shielded locomotive Serial No. 32027, 400 HP.

Test Run No. 3 Wind Speed, MPH 12.5

Location of Run 555' Hi Pay Curve Wind Direction 225° Az.

Direction of Run Out (North) Ambient Temperature 82° F

Track Grade Level % Track Dry or Wet? Dry

Remarks on Other Track Conditions Rail Head Greased

Test Personnel: PPCo J. Pruden Locomotive Engineer J. Hammi

KE N. Thayer

SPEED - AMPERE RECORD					
Speed			Amperes		
Reading	Correction	True	Reading	Correction	True
<u>.75</u>	<u>NONE</u>		<u>170</u>	<u>NONE</u>	
<u>1.0</u>			<u>200</u>		
<u>1.0</u>			<u>175</u>		
<u>1.0</u>			<u>170</u>		
<u>1.0</u>			<u>160</u>		
<u>1.0</u>			<u>160</u>		
<u>1.0</u>			<u>160</u>		
<u>1.0</u>			<u>175</u>		
<u>1.0</u>			<u>170</u>		
<u>1.0</u>			<u>165</u>		
<u>1.25</u>			<u>150</u>		
<u>1.25</u>			<u>150</u>		

Date: 7-29-65
Recorder: Pruden

U. S. ATOMIC ENERGY COMMISSION
Idaho Operations Office
Idaho Falls, Idaho

KE N. Thayer

.13

Theoretical Tractive Effort
Locomotive and test Dolly

90 F, 1 mph train speed, zero wind, level grade
 455' radius (12.6°) level curve & 736' r. (7.8°) curve; $S = .00752$

Locomotive Running Resistance

455' R 12.6° level	736' R 7.8° S = .00752	
2170	1340	
450	450	
—	—	
—	—	
—	—	
—	—	
—	3080	

1. Curve resistance

$$0.8 \text{ lb/ton} \times 215 T \times 12.6^\circ$$

$$0.8 \times 215 \times 7.8$$

2. Journal resistance

$$R_j = \left(1.3 + \frac{29}{w}\right) \times 215 T \times \text{Temp factor}$$

$w = \text{avg. axle load, tons}$
 At normal temperatures, temp factor is 1.0

$$R_j = \left(1.3 + \frac{29}{215/6}\right) \times 215 T \times 1.0$$

$$= (1.3 + 1.81) \times 215 \times 1.0$$

3. Flange resistance

$$R_f = b V W$$

$b = .03 \text{ flange factor}$
 $V = 1.0 \text{ mph}$
 $W = 215 T$
 $= .03 \times 1.0 \times 215 \rightarrow \text{negligible}$

4. Air resistance5. Internal resistance: none for diesel6. Wind resistance: none7. Grade resistance: $20 \text{ lb/ton} \times 215 T \times 0.752$

Total locomotive running resistance, lbs

2620 4850

say

2600 4900

Theoretical Tractive Effort
Locomotive and test Dolly

90F, 1mph train speed, zero wind, level grade
 455' r. (12.6°) level curve & 736' r (7.8°) curve $s = .00752$

<u>Test Dolly Resistance</u>	455' R 12.6° level	736' R 7.8° $s = .00752$
1. <u>Curve Resistance</u> use 0.8 lb/ton and obtain correction factor from test results $0.8 \times 500 T \times 12.6^\circ$ $0.8 \times 500 T \times 7.8^\circ$	5100	3120
2. <u>Journal resistance</u> $R_j = (1.3 + \frac{29}{500/12}) \times 500 T \times 1.0 \text{ Temp. Factor}$ $= (1.3 + .70) \times 500 \times 1.0$	1000	1000
3. <u>Flange resistance</u> $R_f = b v w$ $R_f = .045 \times 1 \times 500 = \text{negligible}$	—	—
4. <u>Air resistance</u>	—	—
5. <u>Wind resistance</u> : none	—	—
6. <u>Grade resistance</u> : $20 \text{ lb/T} \times 500 T \times .752$		7520
<u>Total Dolly Running Resistance, lbs</u>	6100	11,640

Traction Effort Test
Wind Effect

Av. Velocity 1:30 - 3:00

MPH
12
15
12
11
<u>4150</u>
12.5 mph

Av. Azimuth 1:30 - 3:00

243
207
270
180
<u>4900</u>
225°

from NRTS
weather
records
for Ag. M. area
150' level
7-29-65

Dynamic Pressure ASCE Paper #3269 "Wind Force on Structures"
 $= .0026 V^2 = .0026 \times 12.5^2 = .406 \text{ lb/ft}^2$

With 225° Wind & avg. dolly orientation of 158°, the
 component opposing motion is $\frac{67}{4.35} \times .406 = .159 \text{ lb/ft}^2$

Use $C_p = 0.9$

$$0.9 \times .159 = .14 \text{ lb/ft}^2$$

Use Area = 30' x 16' (end section)
 = 480 sf

$$\text{Force} = 480 \times .14 \text{ lb/ft}^2 = 67 \text{ lbs}$$

negligible

Note: lateral wind force producing pressure of
 flanges against rails has been neglected
 because of great weight of dolly + locomotive.

Traction Effort Correction Factor to correct theoretical calculations

from test run #1, use the 1 mph reading which drew the maximum current, i.e. - 200 amps (Sheet 10)

This corresponds to a traction effort of 9500 lbs. (Sh. 29) which is the total force required to move dolly and locomotive through the level 455' radius curve in an average 12.5 mph wind

To find the effort necessary to move dolly:

1. Deduct total calculated locomotive resistance. Since loco is a conventional 2-rail vehicle, the Davis formulas will give a legitimate value (Sh. 13) - 2600
2. Wind force - negligible: See Sh. 15 -

total deduction: - 2600 lbs

$$\begin{aligned} \text{Effort to move dolly} &= \text{Total Effort less deductions} \\ &= 9500 \text{ lbs} - 2600 \text{ lbs} = 6900 \text{ lbs} \end{aligned}$$

This compares with theoretical calculation of 6100 lbs or 13% greater

Apply correction factor of 1.13 to theoretical calculation of dolly resistance at LOFT curve and Hi-bay curve.

Also correct journal resistance value for greater number of axles on LOFT dolly.

Estimate of LOFT Dolly running resistance

DATE

7-8-65

BY

HT

90°F; 1 mph; wind 0-20 mph; 455' R (12.6°) level; and
736' R (7.8°) $s = .00752$

1. Curve Resistance

$$0.8 \times 500T \times 12.6^\circ \times 1.13$$

$$0.8 \times 500T \times 7.8^\circ \times 1.13$$

2. Journal resistance

$$R_j = \left(1.3 + \frac{29}{500/16}\right) \times 500T \times 1.0 \times 1.13$$

$$= (1.3 + .93) \times 500 \times 1.13$$

3. Flange resistance - negligible

4. Air resistance - negligible

5. Wind resistance - negligible

6. Grade resistance - $20 \text{ lb/T} \times 500T \times .752$

Total estimated LOFT dolly running resistance (lbs)

Say

455' R 12.6° level	736' R 7.8° $s = .00752$	
5720	3530	
1260	1260	
—	—	
—	—	
—	—	
	7520	
6960	12310	
7000	12300	

Estimate of total Tractive Effort required of
locomotive using LOFT dolly

DATE 9-8-65

BY HT

90 F; 1 mph; wind 0-20 mph, 455' R & 736' R curves

	455' R 12.6° level	736' R 7.8° S = .00152
LOFT Dolly: estimate of resistance, lbs	7000	12,300
Locomotive	2600	4900
Estimate of total train <u>running</u> resist. lbs	9600	17,200
per motor lbs	2400	4300
requiring current of (from "Tractive Effort" curve FS-1, Sheet 20)	200 amps	280 amps

These values are within the "continuous
operation" range of the locomotive.

USE "TRACTION EFFORT CURVE" FS-1.

100X140 7/100 I.

GENERAL ELECTRIC COMPANY SCHENECTADY, N. Y., U.S.A.

8-50)

FN:

July 8, 1955 mb

H-8888552

H-8888552

Locomotive & LOTT Dolly
Estimated additions to tractive effort
for cold weather and for starting
on curves. This will be the extreme condition.

1. Cold weather

Apply a temperature factor of 2 to
journal resistance for operation at -20F

Locomotive: Sh. 13

Dolly: Sh. 18

455' R	736' R
750	450
1260	1260

2. Starting on curve

Apply a factor of 2 to curve resistance
for starting on curve

Locomotive: Sh. 13

Dolly: Sh. 18

2170	1340
5700	3530

Total Increase for -20F and for
starting on curve

Say

9580	6580
9600	6600

Total train running resistance, Sh. 19

9600	17200
------	-------

TOTAL TRAIN RESISTANCE FOR COLD WEATHER
START ON CURVE, LBS.

19200	23800
-------	-------

per motor, lbs

4800	5950
------	------

Requiring a current of
(Sheet 20)

300A	350A
------	------

Both of these current values are within the
"continuous operation" range of the locomotive

Estimated Roadbed Deflection under Test Dolly wheel load.

The exact wheel loads of the test dolly are not known. The interior wheel loads are heavier as would be expected from the sketch. That they are heavier was confirmed during the test by observing that the greatest track deflection occurred under the interior wheels.

Assume that the interior wheels would be the average wheel load plus 10% :

$$1.10 \times \frac{500 \text{ tons} \times 2000}{24} = 46,000 \text{ lbs per wheel}$$

Pressure distribution under ties shown in Hay p.304

1. Pressure under tie at top of ballast = 160% of average tie.

$$\frac{1.6 \times 4 \text{ wheels} \times 46000}{10'' \times 20' \times 12'' \times 3 \text{ ties/wheel}} = 40.9 \text{ psi}$$

2. Pressure at bottom of 8" ballast layer = 103% of average tie pressure.

$$\frac{1.03}{1.60} \times 40.9 = 26.4 \text{ psi}$$

3. Pressure at bottom of 8" select = 46% of avg.

$$\frac{.46}{1.60} \times 40.9 = 11.8 \text{ psi}$$

4. Pressure at bottom of 6" compacted scarified = 39% of average.

$$\frac{.39}{1.60} \times 40.9 = 10.0 \text{ psi}$$

Estimated Roadbed Deflection under Test Dolly Wheel Load

5. Subgrade deflection factors, "k" lb/in²/in of Δ

ballast	400	KE soils report	p	19
select fill	290	estimated		
compacted unclassified	115	KE soils	p	8
in-situ upper silty clay	250	KE soils	p	8

6. ESTIMATED Δ:

ballast:	$\frac{40.9}{400} \times 1"$	=	.10"
select:	$\frac{26.4}{290} \times 1"$	=	.09"
compacted unclas:	$\frac{11.8}{115} \times 1"$	=	.10"
in-situ:	$\frac{10.0}{250} \times 1"$	=	.04"

TOTAL ESTIMATED 4-RAIL Δ = .33"

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