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DRAGLINE ROLLER TRACK IMPROVEMENT

Field Measurement of Dragline Roller Circle Loading

Final Report
Contractor The Franklin Research Center

Contract No. AC01-76ET-12502

U. S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Coal Mining

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DRAGLINE ROLLER TRACK IMPROVEMENT

VOLUME II
FIELD MEASUREMENT OF DRAGLINE
ROLLER CIRCLE LOADING

FINAL REPORT VOLUME II
FOR CONTRACT PERIOD
SEPTEMBER 30, 1976-JULY 30, 1980

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PREPARED FOR THE
U. S. DEPARTMENT OF ENERGY
CARBONDALE MINING TECHNOLOGY CENTER
UNDER CONTRACT NO. ET-76-C-01-9121

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ABSTRACT

The Franklin Research Center (FRC), a Division of the Franklin Institute, was contracted by the Bureau of Mines to improve walking dragline roller tracks. The contract was subsequently transferred to the Department of Energy.

The period from September 1977 to September 1978 covered laboratory rolling contact rig tests to evaluate typical low hardness dragline track materials. The results of this work are covered by DOE/ET/9121-1 Final Report, Volume I.

The period from September 1978 to July 1980 covered field measurements of dragline roller circle loadings. The results of this work are covered by DOE/ET/9121-2 Final Report, Volume II.

During May 1979, a field test group visited the Beltona Mines in Warrior, Alabama, for the purpose of instrumenting and testing dragline roller circle loading. This testing was done both before and after the introduction of elastomeric padding between the upper track and rotating frame.

The data collected indicates installation of an elastomeric pad between the rotation frame and the upper track reduced the strain in the upper track. The primary reason for these load and strain reductions was added flexibility provided by the elastomeric pad coupled with redistribution of local loads. Installation of the elastomeric pad also reduced the peak roller loads resulting from "hard" spots due to dragline construction.

More field data is necessary to fully appreciate the positive and negative effects of elastomeric pad on roller track loading. This information can be obtained through more thorough testing and instrumentation program.

ACKNOWLEDGEMENTS

FRC is grateful to the various mining engineers and maintenance men who assisted with their advice and encouragement.

FRC appreciates the key contribution of the Bureau of Mines cognizant engineer Mr. Randall Conolly, Spokane Mining Research Center and later Mr. Howard Parkinson, Carbondale Mining Technology Center, DOE.

Finally FRC acknowledges the contributions and encouragement of Mr. Hamilton B. Reese, U.S. Department of Energy.

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1. INTRODUCTION

The subject of this report, the field measurement of dragline roller circle loading, was a continuation of a project* to study roller-and-track materials and life which Franklin Research Center (FRC) had performed for the U. S. Department of Energy (DOE).

The field measurements were used to determine dragline roller circle loading both before and after an elastomeric pad was inserted to provide upper track flexibility. The measurements were made on a Bucyrus-Erie Model 1300 dragline with the cooperation of the Drummond Coal Co., Jasper, Alabama at the Beltona Mine in Warrior, AL.

This report will describe the following:

- Problem areas which contributed to short roller life.
- Roller loads before and after the installation of an elastomeric pad between the upper track and the rotating frame.
- Track support, rotating frame and track stresses before and after addition of an elastomeric pad.
- Upper and lower track geometry before and after addition of an elastomeric pad.
- Test instrumentation, apparatus, and procedures used for making the field measurements.
- Recommendations for further investigation of the effects of the elastomeric pad on roller loading.

*See Franklin Research Center Interim Report I-C4569, "Evaluation of Low Hardness Dragline Track Materials in Rolling Contact," dated August, 1979.

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2. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

2.1 SUMMARY OF RESULTS*

The test data showed that, before the elastomeric was installed:

- Average roller loads were about 240 kips.
- There were non-uniform roller loads due to "hard" (rigid) spots in the dragline frame.

After the elastomeric pad was installed, the following results were observed:

- Average roller loads were about 200 kips, which is about 20% less than the average roller loads were before the addition of the elastomeric pad.
- Peak upper track stresses were reduced by an average of approximately 40% (4100 psi to 2500 psi).
- Peak roller loads on the outboard portion of the rollers were reduced by an average of approximately 15% (250 kips to 230 kips).
- Peak Roller loads on the inboard portion of the rollers were reduced by an average of approximately 25% (245 kips to 195 kips).
- The upper track could move up and down by as much as 0.030 in. thus allowing redistribution of local loading.
- Peak rotating frame principal stress was increased, in general, by an average of approximately 5% (4850 psi to 5100 psi).
- Peak lower-track-support (tub diaphragm) principal stress was reduced, in general, by an average of approximately 40% (7800 psi to 4600 psi).
- Peak roller loads were more uniform after installation of the elastomeric pad, indicating a leveling of the upper track.

* NOTE: Measured values for roller loads (kips), track stresses (psi), and track-support diaphragm stresses (psi) are contained in Section 7.

2.2 CONCLUSIONS

Installation of an elastomeric pad between the rotating frame and the upper track, as shown in Figure 2-1, reduced the strain in the upper track. The chief reason for these load and strain reductions was the additional flexibility provided by the elastomeric pad which allowed redistribution of local loads.

Installation of the elastomeric pad also reduced the peak roller loads which resulted from "hard" (rigid) spots due to dragline construction (e.g., the rotating frame is rigid where the boom feet are connected to the deck).

More field data is required to fully gage the effects of the elastomeric pad on roller track loading. The following section outlines some proposed improvements to the existing method of gathering data from the instrumented dragline.

2.3 PROPOSED IMPROVEMENTS FOR APPLICATION IN FUTURE DRAGLINE ROLLER LOAD TESTING

During the analysis of the data from the May 1979 dragline test at the Beltona Mine and in discussions with Department of Energy representatives, it became apparent that several improvements could be made which would provide more conclusive information about the effectiveness of the elastomeric pad to reduce roller loads.

The following ideas should be considered for future dragline tests:

- Locate the strain gages closer to the top and bottom edges of the outer circumference of the upper track (as shown in Figure 2-1) to emphasize bending stresses and minimize noise. Use rosettes instead of uni-axial strain gages so the maximum stress and the principalaxis of stress can be determined.
- Incorporate a rotary encoder to provide a signal proportional to rotating-frame angular position which is useful in relating roller position to "hard spots" as well as certain information from one test to another. Rotating frame direction is indeterminable from the May 1979 test data.

Figure 2-1. Proposed Location of Rectangular Strain Rosettes on the Upper Track for Future Tests

- Calibrate the LVDT's in the instrumented roller pin from 120 kips (which is the maximum capacity of FRC's compression machine) to 500 kips (which is the highest roller load measured during the May 1979 test). The calibration for the roller load LVDT's was extrapolated from 120 kips to 500 kips).
- Apply strain rosettes to the surfaces where the boom feet abruptly end at the rotating frame.
- Apply more strain rosettes to the upper and lower track-support diaphragms.
- Provide a reliable source (e.g., a gasoline-engine-driven AC generator) for powering the data acquisition instruments. Power interruptions, which caused data to be lost, were common during the May 1979 test.
- Design an improved bearing and seal for the instrumented roller pin. The original bearing and seal failed during the May 1979 test causing malfunctions in several roller LVDT's.
- Record a time reference on the magnetic data-tape.
- Measure roller loads when (1) the bucket is loaded, causing the rotating frame to tilt over the rollers under the fore track; (2) when the bucket is unloaded and the rollers under the fore and aft tracks are carrying a uniform load; and (3) when the rollers are not under a track.
- Measure the load on the rollers while rotating the upper frame two complete revolutions in one direction (720°). The roller circle will move through one complete revolution (360°) in the time the upper frame moves through 720° (in one direction).
- Check the kinematic correctness of the slew bearing taper.
- Keep a record of roller bearing failure over a period of time to determine the long-term effect of the addition of the elastomeric pad to the upper track.
- Apply strain rosettes to the root of the necked region shown in Section A-A of Figure 2-1. The necking will generate stress concentrations which should be investigated.

3. PROGRAM DESCRIPTION

One of the most critical mechanical components of a walking dragline, illustrated in Figure 3-1, is the main roller (slew) bearing which consists of a lower roller track attached to the dragline base structure (tub), an upper roller track bolted to the rotating frame (with the boom, machinery house and associated supporting structure) and large cylindrical rollers pinned between inner and outer cages, as shown in Figures 2-1, 3-2 and 4-3.

During a 5-year period, over 200 rollers had failed in the machine described in Table 3-1. Repair of these rollers is an expensive, time consuming process with subsequent loss of coal production.

The objective of this program was to obtain field measurements of actual dragline roller bearing loadings, upper track strains, upper and lower track geometry, rotating frame strains, and lower (tub) track-support (diaphragm) strains. These measurements were made both before and after installation of an elastomeric pad.

Drummond Coal Co. planned to use an elastomeric material (in the form of a Fabreeka® pad*) between the upper rotating deck and the upper track as shown in Figures 2-1, 3-3 and 4-3. The purpose of the elastomeric pad is to cushion peak roller loadings when the roller passed under "hard" points in the upper rotating deck (e.g., where the mast and boom feet connected to the deck). These hard points result in greatly increased roller loadings, which lead to individual roller failure, track failures, and upper structure and tub diaphragm weld failures. Thus, any procedure that would reduce the roller loadings can have significant long-term cost savings. Drummond Coal Company (Jasper, Alabama) personnel installed the elastomeric pad as FRC observed and documented the procedure.**

*The Fabreeka® pad was a 11/32-in-thick, 21-ply, fabric (cotton and polyester blend) and rubber (Goodyear Chemigum®) composite manufactured by Fabreeka Products Co., in Boston, Mass. A plan view of the Fabreeka® pad is presented in Figure 3-3.

**A slide presentation, with instructions on a cassette tape, of the Fabreeka® pad installation was produced by FRC.

Figure 3-1. Typical Walking Dragline Configuration

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Figure 3-2. Sketch of the Major Components of a Dragline Roller Bearing

Table 3-1. Walking Dragline/Roller Track Summary

GENERAL DATA

Rotating Frame Weight (lbs)	3.0×10^6
Bucket Capacity (yd ³)	40

ROLLER TRACK DATA

Pitch Dia. of Track (ft)	34
Upper Rail Track	120° FWD (3 segments - 40° each segment) 120° AFT (3 segments - 40° each segment)
Track Width (in)	8.5
Track Depth (in)	5.25 (average)
Dia. of Tapered Rollers (in)	8.5 (smaller end) and 8.9 (larger end)
Dia. of Roller Pin (in)	3.6
Dia. of Roller Flange (in)	9.9
Total Number of Rollers	116
Number of Rollers under the Front Track	38
Number of Rollers under the Rear Track	38

Notes:

1. Predicted roller loads = $\frac{3 \times 10^6}{76} = 39$ kips if rollers were in even contact with both fore and aft tracks.
Peak roller loads can be expected to be higher due to eccentricity of the rotating frame weight with respect to the center of rotation.

2. The dragline used for this study was a Bucyrus-Erie 1300 machine at Drummond Coal Co.'s Beltona Mine, Warrior, Alabama.

NOTE: Approximate area of the elastomeric pad = 5500 in^2 (38 ft^2).
 Thickness of the pad = 0.34 in (uncompressed).

Figure 3-3. Plan view of the Elastomeric Pad.

To the best of our knowledge, this report is the first literature which describes measured results of the application of an elastomeric pad to a roller track on a dragline.

Failure of a slew bearing can be caused by a number of factors and several types of conditions can combine to fail a bearing. Poor lubrication, excessive roller loads, static overload resulting in Brinell marks (plastic indentations) and rolling over foreign objects causing denting are some of the physical conditions that can be encountered. In addition, it has been reported that roller life* decreases exponentially with the inverse of roller load or,

$$L \propto \left(\frac{1}{P} \right)^4$$

where

L = roller life, and

P = roller load.

The FRC team designed, fabricated and calibrated instrumentation capable of measuring actual dragline roller loads, roller position relative to the upper rotating deck, track geometry and strains, and track-support (diaphragm) strains. This instrumentation was used at the Beltona Mine (Warrior, Alabama) of Drummond Coal Company to measure and record data under a number of operating (digging, swinging and dumping) conditions. After installation of the elastomeric cushioning material, the FRC field instrumentation team again measured roller loads and roller positions under a number of operating conditions. Thus, a direct comparison on the same machine and pit, under similar digging conditions, was accomplished both before and after installation of the elastomeric pad to determine the effectiveness of this type of material.

*Refer to the paper, "Dragline Slew Bearings: Factors Affecting Their Life and Operation," by W. R. B. Morrison, Director, Winders Barlow and Morrison Pty. Ltd., and R. F. Beale, Chief Mechanical Engineer, Utah Development Company. This paper was presented at the International Conference on Mining and Machinery, 1979 at Brisbane, Australia, 2-6 July. (ISBN 0 85825 1132).

4. DATA ACQUISITION EQUIPMENT

4.1 MEASUREMENT OF ROLLER LOADS (RLD)

In order to estimate roller loads, FRC used LVDT's (linear variable differential transformers) to measure the vertical reduction in the bore diameter of the roller (in two places) when a load was applied. The correlation between roller deflection (LVDT output) and roller load is discussed in Section 5.

FRC fabricated four instrumented roller pins, each with two LVDT's as shown in Figure 4-1, which were assembled into four rollers (one pin per roller) as shown in Figure 4-2.

FRC's approach was a modified version of the one-LVDT-per-roller-pin method discussed in the paper referenced in Section 3.

4.2 MEASUREMENT OF TRACK GEOMETRY (TCG)

Geometrical imperfections in the tracks and/or track distortion are usually the factors that result in the largest increases in roller loads during the life of the machine. Distortion can be caused by initial manufacture, but is usually the result of rewelding when repairing or modifying the machine.

A "rat trap" device was designed and installed to measure imperfections in the geometries of both upper and lower tracks of the roller bearing. The "rat trap" design, shown in Figures 4-2, 4-3, and 4-4, utilized two individual LVDT's attached to spring-loaded levers with hardened contoured points that contacted the central portion of the upper and lower tracks. The assembly was attached to the outside of the roller pin cage, which rides in a reference plane established by the average rolling height of the pins in that section. Thus, traces of the deviations from an average plane for each of the upper and lower tracks was obtained and is presented in Section 7, Test Results. The track geometry data was useful for determining the effectiveness of the elastomeric pad in providing flexibility for the upper track.

Figure 4-1. Cross-Section of Roller Pin Showing the Inboard and Outboard LVDT's

Figure 4-2. Plan view (Schematic) of Roller Circle Showing the Location of LVDT's for Roller Loads (RLD 1 through 8) and Track Geometry (TCG 1 and 2) as well as Other Data Sensors

Note 1. The meaning of the abbreviations used in Figure -3 are:

- RCPS - Roller Cage Position (Inductance PU)
- RFPS - Rotating Frame Position (Inductance PU)
- RDS - Rotating Frame Diaphragm Strain Rosette
- RLD - Roller Load (LVDT)
- TCG - Track-to-Cage Geometry (LVDT) - Nicknamed "Rat Trap"
- TDS - Tub Diaphragm Strain Rosette
- UTS - Upper Track Strain

Figure 4-3. Cross-Section (Schematic) of the Bottom Portion of the Dragline Showing Major Roller Circle Components and Test Instrumentation

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Figure 4-4. Photograph of Track Geometry Transducer (RAT TRAP)

4.3 MEASUREMENT OF UPPER TRACK STRESS (UTS)

Eight single strain gages were applied to the upper track as typified in Figures 2-1 and 4-3.

4.4 MEASUREMENT OF LOWER TRACK SUPPORT (DIAPHRAGM) STRESS (TDS)

One rectangular strain rosette was applied to the diaphragm below the lower track (see Figures 4-2 and 4-3).

4.5 MEASUREMENT OF ROTATING FRAME STRESS (RDS)

Two rectangular strain rosettes were applied to the rotating frame (see Figure 4-3).

4.6 DETECTION OF ROLLER CAGE POSITION (RCPS)

A roller counter, in the form of a displacement measuring probe, was used to reference roller position (see Figure 4-3). The drawback of this method was insensitivity to roller direction.

4.7 DETECTION OF ROTATING FRAME POSITION (RFPS)

A displacement measuring probe, aimed at the swingrack, was used to reference the position of the rotating frame (see Figure 4-3). However, this method was insensitive to rotating frame direction.

4.8 DATA ACQUISITION INSTRUMENTATION

Table 4-1 contains a list of data acquisition instrumentation and Figure 4-5 contains a block diagram which details the relation among the data acquisition equipment.

Table 4-1. Data Acquisition Equipment

<u>Function*</u>	<u>Quantity</u>	<u>Description</u>
TDS & RDS	3	BLH 3-axis rectangular-rosette type (350 Ω) strain gage (1mV = 30 psi)
UTS	8	BLH single-axis type (350 Ω) strain gage (1mV = 30 psi)
TCG	2	Schaevitz model PCA-116-200 linear measurement gage heads** (22.5 mv = 0.001 in)
RLD	8	Schaevitz model 100-MHR LVDTs** (100 mv = 0.001 in)
RCPS and RFPS	2	Kaman model KD-2300-10C displacement measuring systems
Gage Conditioner	14	Vishay model 2120 strain gage conditioners & power supply

- Notes:
1. Data was recorded on an Ampex Model 2200 14-channel recorder and a Brush 2-channel strip chart.
 2. Data going in and coming out of the recorder was monitored on a Nicolet model 444 spectrum analyzer.
 3. Also used were a Data Precision digital multimeter and a Vu-data dual-channel miniscope for trouble shooting and spot-checking data.

*See Figure 4-3 for a key to the acronyms in this column.

**All LVDTs and gage heads were powered and conditioned by a Schaevitz self-contained, 10-channel PCB conditioning system. It consists of a power supply and an oscillator/demodulator to supply a regulated excitation voltage at a set frequency to each LVDT. Mechanical movement of the LVDT will result in a proportional analog output from the Schaevitz PCB system.

Figure 4-5. Block Diagram Showing Data Acquisition System

5. CALIBRATION OF ROLLER PIN LVDT'S FOR MEASURING ROLLER LOADS

Prior to the field test, a Baldwin compression testing machine, shown in Figure 5-1, was used to apply a variable load from 50,000 to 100,000 lb to a single roller which contained a roller pin with two LVDT's, as shown schematically in Figure 5-2. Steel plates had been machined to fit on the top and bottom of the roller so the load from the testing machine would be applied to horizontal surfaces. The millivolt outputs from each of the two LVDT's in each roller pin were measured and found to be approximately equal when the load was applied as shown in Figure 5-1 and 5-2. The millivolt output of each LVDT was related to the total load indicated by the gage on the testing machine, as shown in Figure 5-3, where it can be seen that the average roller loads measured on the BE 1300 dragline are above the limit of the actual calibration at 100 kips.

An average of the two LVDT outputs for each roller was used to arrive at the approximate total load.

Figure 5-1. View of Calibrated Roller Pin and Roller in Baldwin Compression Machine

Figure 5-2. Representation of Method of Calibration of Roller Load LVDT's

Figure 5-3. Results of Calibration of a Typical LVDT Installed in a Typical Roller Which was Compressed with Loads up to 100 kips in Compression Machine. (Note: LVDT may be non-linear in the extrapolated region).

6. TEST IMPLEMENTATION

A summary of the tests implemented during May 1979 and the type of data taken during the tests is contained in Table 6-1.

A listing of all tests implemented during May 1979 is contained in Table 6-2.

TABLE 6-1. Summary of Tests Implementation on a Bucyrus-Erie 1300 Dragline at Drummond Coal Company's Beltona Mine (Warrior, Alabama) in May 1979

	← 0 TO 360° ROLLER CAGE ROTATION				← 0° TO 45° TO 0° ROLLER CAGE ROTATION (DIG, SLEW, & DUMP)			
TEST NO. (BEFORE PAD)	1*	2	3	4*	5	6	7†	8
TEST NO. (AFTER PAD)	9*	10	11	12*	13	14	15†	16
ROTATING FRAME & LOWER-TRACK-SUPPORT (DIAPHRAGM) STRESSES [RDS AND TDS]Δ								
TRACK GEOMETRY [TCG]Δ								
ROLLER LOADS (RLD)Δ								
TRACK STRESSES (UTS)Δ								

* - Test deleted

† - Data was of poor quality

Δ - See Figure 4-3 for meaning of abbreviations

Table 6-2. Test Sequence Prior to Installation of the
Elastomeric Pad (week of 5/18/79)

TEST #1 - Recorded data included diaphragm loads, track geometry, and
tub/cage position

Transducers Position Recorded

- 2 - Position Transducers
- 3 - Tub Strains
- 6 - Rotating Frame Strains
- 2 - Track Geometry LVDT
- 1 - Track Strain

14 - Channels on tape recorder

Conditions: 2 - 360° rotation upper frame for

1 - 360° roll cage rotation with the bucket empty

TEST #2 - Diaphragm loads. Track geometry, tub/cage position

Transducers Recorded

Same as Test #1

Conditions: 2 - 360° upper frame rotations for

1 - 360° roll cage rotation with the bucket full

TEST #3 - Diaphragm loads, track strains, tub/cage position

Transducers to be Recorded

- 2 - Position Xders
- 8 - Track Strains
- 4 - Rotating Frame Strains 1-3 axis rosette, 1-single axis gage
- 14 - Channels

Conditions: 2 360° upper frame rotation for

1 360° roll cage rotation with the bucket full

TEST #4 - Same as Test #3 except the bucket was empty

Table 6-2. Test Sequence Prior to Installation of the
Elastomeric Pad (week of 5/18/79)(Cont'd)

TEST #5 - Roller loads, track strains, tub/cage position

Transducers to be Recorded

- 2 - Position Xdcrs
- 8 - Roll pin LVDT's
- 4 - Track Strains
- 14 - Channels

Conditions: Normal Dragline Operation (dig and dump) with a 160° rotation.

Record data for approximately 1 hour

TEST #6 - Roller loads, track strains, tub/cage position

Transducers to be Recorded

- 2 - Position Xdcrs
- 4 - Roll Pin LVDT's (2 rolls-inboard & outboard LVDT's)
- 8 - Track Strains
- 14 - Channels

Conditions: Normal Dragline Operation (dig and dump) with a 160° rotation.

Record data for approximately 1 hour.

TEST #7 - Roller loads, track strains, tub/cage position

Transducers to be Recorded

- 2 - Position Xdcrs
- 4 - Roll Pin LVDT's (4 roll-outboard LVDT's)
- 8 - Track Strains
- 14 - Channels

Conditions: Same as Test #6

TEST #8 - Same as Test #7 except record inboard roll pin LVDT's.

Table 6-2. Test Sequence After Installation of the
Elastomeric Pad (week of 5/25/79) (Cont'd)

TEST #9 - Same as Test #1 with elastomeric pad installed.

TEST #10 - Same as Test #2 with elastomeric pad installed.

TEST #11 - Same as Test #3 with elastomeric pad installed.

TEST #12 - Same as Test #4 with elastomeric pad installed.

TEST #13 - Same as Test #5 with elastomeric pad installed.

TEST #13a - Same as Test #6 with elastomeric pad installed.

TEST #15 - Same as Test #7 with elastomeric pad installed.

TEST #16 - Same as Test #8 with elastomeric pad installed.

7. TEST RESULTS

The following test results are presented in this section:

- Table 7-1 - Peak Roller Loads
- Table 7-2 - Peak Upper Track Stresses
- Table 7-3 - Peak Rotating Frame Stresses
- Table 7-4 - Peak Lower-Track-Support (Diaphragm) Stresses
- Figure 7-1 - Principal Stress and Axis of Stress
- Figure 7-2 - Upper and Lower Track Geometry
- Figure 7-3 - Typical Data Trace: Peak Roller Loads
- Figure 7-4 - Typical Data Trace: Peak Upper Track Stresses
- Figure 7-5 - Typical Data Trace: Peak Rotating Frame Stresses
- Figure 7-6 - Typical Data Trace: Peak Lower-Track-Support Stresses

Table 7-1. Peak Roller Loads During "Dig, Slew and Dump" Operation

LVDT Designation (see Figure 5-1)	Percent Change from Test 5 to Test 13 [†]			Percent Change from Test 6 to Test 14 [†]			Percent Change from Test 8 to Test 16 [†]		
	Test 5 (KIPS)	Test 13 [†] (KIPS)	(%)	Test 6 (KIPS)	Test 14 [†] (KIPS)	(%)	Test 8 (KIPS)	Test 16 [†] (KIPS)	(%)
RLD 1 (OUTBD)	*	*	*	*	*	*	Δ	Δ	Δ
RLD 2 (INBD)	200	180	-11%	260	230	-13%	290	210	-38%
RLD 3 (OUTBD)	105**	*	*	130	*	*	Δ	Δ	Δ
RLD 4 (INBD)	200	180	-11%	230	195	-18%	235	195	-20%
RLD 5 (OUTBD)	50**	45**	**	Δ	Δ	Δ	Δ	Δ	Δ
RLD 6 (INBD)	235	195	-20%	Δ	Δ	Δ	290	220	-32%
RLD 7 (OUTBD)	250	90**	**	Δ	Δ	Δ	Δ	Δ	Δ
RLD 8 (INBD)	240	160	-50%	Δ	Δ	Δ	170	160	-8%

Notes:

- The average load of the rollers before the elastomeric pad was installed was 240 KIPS while the average load of the rollers after installation of the elastomeric pad was 190 KIPS.
- All loads were measured in the vertical direction.
- Predicted roller loads were about 39 to 78 KIPS.

[†]Elastomeric pad had been installed.

*Data could not be obtained due to a faulty sensor.

ΔData was not recorded due to an insufficient number of available tape recorder tracks.

**Data is questionable.

Table 7-2. Peak Upper Track Stresses

	TEST 3 (PSI)	TEST 11 (PSI)	PERCENT CHANGE FROM TEST 3 TO TEST 11 (%)	TEST 5 (PSI)	TEST 13 (PSI)	PERCENT CHANGE FROM TEST 5 TO TEST 13 (%)	TEST 6 (PSI)	TEST 14† (PSI)	PERCENT CHANGE FROM TEST 6 TO TEST 14 (%)	TEST 8 (PSI)	TEST 16† (PSI)	PERCENT CHANGE FROM TEST 8 TO TEST 16 (%)
UTS 1	5400	3900	-27	6000	2100	-65	5400	2900	-47	4800	2100	-56
UTS 2	4500	4350	- 3	3000	2400	-20	4100	2100	-48	3900	1800	-50
UTS 3	7800	3000	-62	2100	1800	-14	3300	2000	-41	2400	2100	-12.5
UTS 4	9900	2400	-76	2700	1500	-44	2900	1500	-47	9000	*	*
UTS 5	3900	2900	-26	Δ	Δ	Δ	*	2400	*	*	2400	*
UTS 6	*	13500	*	Δ	Δ	Δ	3200	2100	-33	2400	1500	-37
UTS 7	4500	4200	- 6	Δ	Δ	Δ	4100	3000	-26	3000	1650	-45
UTS 8	*	3900	*	Δ	Δ	Δ	3600	3300	- 8	2100	1650	-45

†Elastomeric pad had been installed.

*Data could not be obtained due to a faulty sensor.

ΔData was not recorded because of an insufficient number of available tape recorder tracks.

Notes:

1. All stresses were measured in the horizontal direction.
2. These stresses were the peak values observed from the recorded data.
3. See Figure 4-3 for the approximate location of UTS 1 through 8.

Table 7-3. Peak Rotating Frame Stresses

ROSETTE IDENTI- FICATION	IDENTI- FICATION FOR DATA MEASUREMENT	TEST 2 (PSI)	TEST 10 [†] (PSI)	PERCENT CHANGE FROM TEST 2 TO TEST 10 [†] (%)	TEST 3 (PSI)	TEST 11 [†] (PSI)	PERCENT CHANGE FROM TEST 3 TO TEST 11 [†] (%)
A-Horiz	RDS 1	1800	1400	- 25	1800	1200	-33
A-45°	RDS 2	2100	200	- 93	2400	3900	+62
A-Vert	RDS 3	3600	3600	0	3600	3300	-8
B-Horiz	RDS 4	300	300	0	3600	1200	-67
B-45°	RDS 5	*	1800	*	Δ	Δ	Δ
B-Vert	RDS 6	600	1200	+100	Δ	Δ	Δ

[†]Elastomeric pad had been installed.

*Data could not be obtained due to a faulty sensor.

Δ Data was not recorded because of an insufficient number of available tape recorder tracks.

- Notes:
- See Figure 4-3 for the approximate location of rectangular strain gages RDS 1-3 and RDS 4-6.
 - See Figure 7-1 for a graphical presentation of the principal stress and axis of stress.

Table 7-4. Peak Lower-Track-Support (Diaphragm) Stresses

ROSETTE IDENTI- FICATION	IDENTI- FICATION FOR DATA MEASUREMENT	TEST 2 (PSI)	TEST 10 [†] (PSI)	PERCENT CHANGE FROM TEST 2 TO TEST 10 [†] (%)	TEST 3 (PSI)	TEST 11 [†] (PSI)	PERCENT CHANGE FROM TEST 3 TO TEST 11 [†] (%)
C-Horiz	TDS 1	3000	3000	0	Δ	Δ	Δ
C-45°	TDS 2	6900	3600	-48	Δ	Δ	Δ
C-Vert	TDS 3	4300	2500	-42	Δ	Δ	Δ

[†]Elastomeric pad had been installed.

*Data could not be obtained due to a faulty sensor.

ΔData was not recorded because of an insufficient number of available tape recorder tracks.

NOTE: • See Figures 4-2 and 4-3 for the approximate location of rectangular strain gage TDS 1-3.

- See Figure 7-1 for a graphical presentation of the principal stress and axis of stress.

ROTATING FRAME STRESS

LOWER TRACK SUPPORT (DIAPHRAGM) STRESS

- Note:
- Dashed arrow indicates direction of principal axis of stress
 - RDS means rotating frame stress
 - TDS means lower track support stress

Figure 7-1. Diagrams Showing the Principal Stress and Axis of the Principal Stress for the Rotating Frame and the Lower Track Support

Commentary on Figure 7-2

The following comments apply to the track geometry traces shown on Figure 7-2:

- As shown in the trace for Test 10, upper track, the track could move up and down as much as 0.031 in.
- The rollers "float" when they are in the gap between the fore and aft tracks due to the non-existent section of upper track in the gap.
- There appears to be an 8 mil "bump" in the aft section of the lower track. This bump may lead to increased stress levels at this point.

Figure 7-2. Upper and Lower Track Geometry Profiles: Before Addition of the Elastomeric Pad (Test 2) and After Addition of the Elastomeric Pad (Test 10)

Figure 7-3. Typical Data Trace for Roller Loads

Figure 7-4. Typical Data Trace for Upper Track Stresses

Figure 7-5. Typical Data Trace for Rotating Frame Stresses

Figure 7-6. Typical Data Trace for Lower Track-Support Stresses