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REPORT NO. FRA/ORD-78/69

MEASUREMENT OF FRICTION SNUBBER FORCES IN FREIGHT CAR TRUCKS

WYLE LABORATORIES
SCIENTIFIC SERVICES AND SYSTEMS GROUP
7800 GOVERNORS DRIVE WEST
HUNTSVILLE, ALABAMA 35807

DECEMBER, 1978

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D.C. 20590

03 - Rail Vehicles & Components

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FRA/ORD-78-69		

4. Title and Subtitle	5. Report Date
MEASUREMENT OF FRICTION SNUBBER FORCES IN FREIGHT CAR TRUCKS Final Report	December 1978
	6. Performing Organization Code
7. Author(s) Klaus L. Cappel	8. Performing Organization Report No. ER-77-1
9. Performing Organization Name and Address Wyle Laboratories 7800 Governors Drive Huntsville, AL 35807	10. Work Unit No. (TRAIS) 11. Contract or Grant No. DOT-FR-T4263
12. Sponsoring Agency Name and Address Department of Transportation Federal Railroad Administration (FRA) Office of Research and Development Washington, D.C. 20590	13. Type of Report and Period Covered Final Report Nov. 1974 thru April 1977 14. Sponsoring Agency Code FRA/RRD-12

15. Supplementary Notes

Work on this project was initiated under TDOP Phase I.

16. Abstract

The report describes the design and construction of a set of transducers intended to measure the normal forces (column loads) and friction forces applied by the four friction shoes to the wear plates of a standard, three-piece freight car truck.

Two 70-ton trucks, an ASF Ride Control and a Barber S-2, were modified to accept the transducers. The functioning of the system was verified by shop tests in which the bolsters were translated vertically and laterally by hydraulic actuators, while all forces and displacements were recorded. Field tests of the instrumented trucks will be described in a future report.

Detailed knowledge of friction snubbing mechanics obtained from such tests is expected to aid the realistic modeling of truck behavior.

17. Key Words	18. Distribution Statement
Freight Car Trucks, Friction Snubbing, Truck Design Optimization Project (TDOP)	Document is available to the public through the National Technical Information Center, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	79	

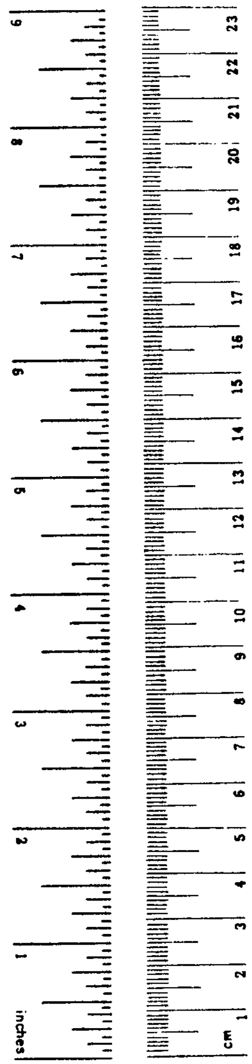
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

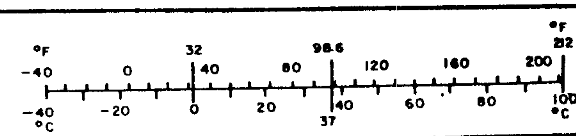
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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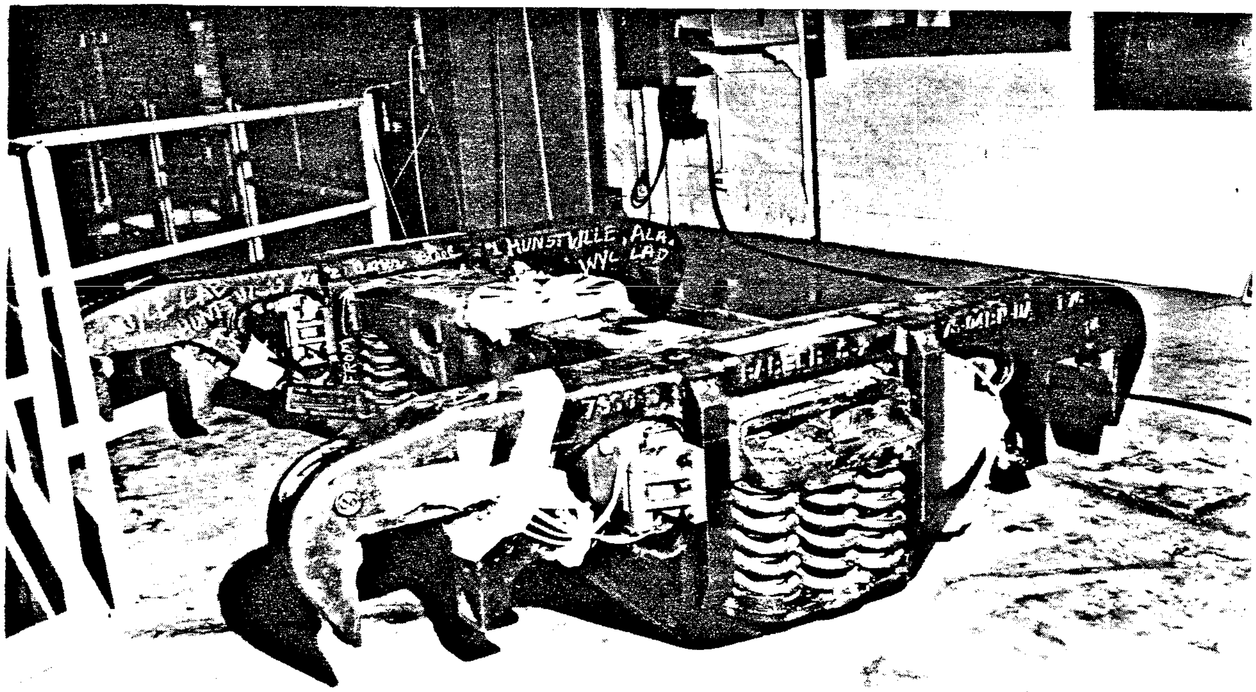
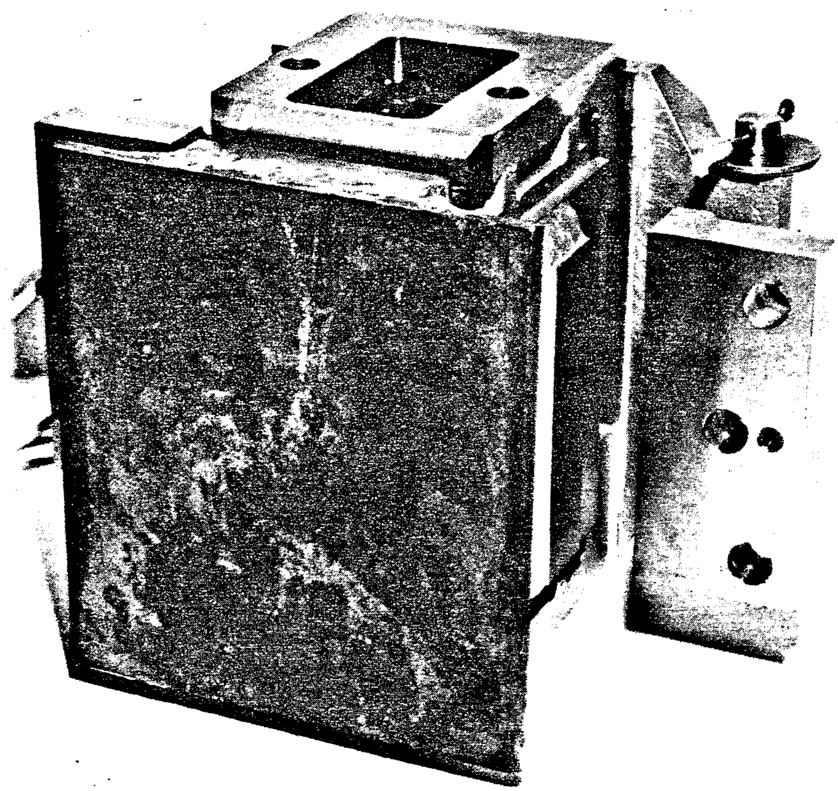


Instrumented Truck



Transducer Assembly

EXECUTIVE SUMMARY

A transducer system has been developed to measure the forces transmitted between each friction shoe and wear plate of a three-piece freightcar truck. Four transducer assemblies per truck are required. The transducer measures the normal column load, the vertical and lateral friction forces, the moments in the plane of the side frame, and the friction couple due to relative roll rotation between side frame and bolster. Space limitations precluded instrumentation to measure the yaw moments.

A set of transducers was installed in a Barber S-2 70-ton truck, and an ASF Ride Control 70-ton truck. The side frames were modified to allow support of the wear plates on the transducer assemblies. Lateral load tests showed the modified side frames to have adequate strength.

The operation of the transducer arose out of a need perceived during Phase I of the Truck Design Optimization Project. The work on the transducer was funded by the Federal Railroad Administration under a subcontract administered by Southern Pacific Transportation Company. At the end of Phase I, supervision of the work was taken over by the FRA.

Results?

SECTION 1 - BACKGROUND

1.1 IMPROVEMENTS IN TRUCK PERFORMANCE

During the past few years, an increasing amount of effort has been directed towards improving the performance of the freight car truck. Truck builders have proposed and constructed a number of new truck designs, as well as special components aimed at improving selected aspects of truck performance. Many railroads, as well as some suppliers, have conducted road tests with the purpose of evaluating the comparative advantages of the modified trucks, as well as the performance of the standard three-piece, friction-snubbed truck under a range of operating conditions.

While the conclusions drawn from test results were often contradictory, it is fair to state that methods of truck performance evaluation have steadily grown more scientific. This may in part be due to the concurrent development of mathematical modeling techniques and their associated computing procedures, which have shown increasing success in quantitatively explaining some important aspects of truck behavior. Much of this theoretical work necessarily dealt with idealized truck models, in which the behavior of components and their interaction was linearized in order to reduce computing time.

1.2 TRUCK DESIGN OPTIMIZATION PROJECT (TDOP) - PHASE I

In 1974, The Federal Railroad Administration commissioned a comprehensive project (TDOP) with the objective of quantitatively characterizing the performance of freight car trucks. The work in Phase I, for which the Southern Pacific Transportation Company was the prime contractor, was concerned with the evaluation of the two most commonly used types of standard, three-piece trucks: The American Steel Foundries "Ride Control" truck, and the Barber S-2 truck, the first incorporating constant snubbing friction, and the second, load-dependent snubbing friction.

Test trucks were instrumented to measure three types of phenomena: accelerations, normal contact forces (at the roller bearing adapters) and relative linear and angular displacements between side frames and bolster, as well as relative rotation between truck and carbody bolsters.

It was soon recognized that no instrumentation was available to measure the forces exerted between the side frames and bolster, which are transmitted through the spring-loaded friction shoes or wedges. It was suggested that it might be theoretically possible to determine the friction forces by computation. The friction force would appear as a deficit in a comparison of the forces applied to the truck with the resulting accelerations. However, it was obvious to everyone involved in the project that this approach would not only be cumbersome and expensive in computing time, but could not be expected to lead to accurate determination of friction forces. Inherent inaccuracies in measurement and the near-impossibility of taking into account every factor in the modeling of the truck would be certain to affect the magnitude of the "deficit" force to be determined.

It was concluded that the forces between side frames and bolster could only be measured by a transducer designed especially for the purpose. A preliminary design concept was drawn up in November 1974 and submitted for review to the FRA Office of Freight Systems.

SECTION 2 - ENGINEERING ASPECTS OF TRANSDUCER DESIGN

2.1 FORCE TRANSMISSION BETWEEN SIDE FRAME AND BOLSTER

Although the bolster-side frame connection is structurally and mechanically rather simple, it performs a multiplicity of functions, as follows:

a. Vertical support of the carbody weight through the spring nest.

b. Centering of the bolster between side frames through lateral spring forces ("flexicoil action").

c. Partial isolation of the carbody from shock and vibration through the springs in both vertical and lateral directions.

d. Dissipation of energy in both vertical and lateral directions, through the friction wedges and wear plates.

e. Equalization of wheel loads on uneven track, by permitting relative pitch and roll displacements.

f. Transmission of yaw torques between wheelsets and centerplate, required for curve negotiation, mainly through the friction shoes and wear plates.

g. Transmission of longitudinal braking forces, also through the friction shoes.

h. Limitation of excessive relative displacements through the bolster gibs. (This is especially important in the lateral direction, since buckling or overturning of springs must be prevented.)

It is important to note that, out of the three load paths -- springs, friction shoes and gibs — the friction shoes are involved in four of the eight interactions between side frame and bolster (d, e, f and g above).

The non-rigid connection between side frame and bolster permits relative motion in six degrees of freedom and consequently transmits six generalized forces - three forces and three moments - between the friction shoes and the wear plates. The tapered surface of the friction shoe is pressed against the mating surface of the bolster, and the wedge action results in a normal force between the vertical shoe surface and the wear plate, generally termed the column pressure. The two shoes at each bolster mutually load each other.

Relative vertical or lateral displacement of the bolster thus gives rise to corresponding friction forces. Braking forces are transmitted by increasing the normal load on the front shoe, as long as the column spring load is not exceeded. When it does, gib contact results.

Relative bolster roll, in which plane contact between friction shoe and wear plate is maintained, applies a roll friction moment on the side frame column.

The remaining two rotations, relative pitch and yaw, give rise to more complex interactions since both the slanting and vertical shoe surfaces can no longer remain in plane contact with the bolster and wear plate, respectively. The resulting edge-to-surface contact is probably an important cause of wear, both in the bolster pocket and at the upper and lower edges of the vertical shoe surface. It is well known that a worn friction shoe surface is slightly convex.

The relatively high restoring moment in yaw may be explained as follows. When the side frame is yawed with respect to the bolster, plane contact at either the sloping or vertical surfaces of the friction shoes changes to contact at diametrically opposite edges along a line that is longer than the distance between opposite wear plates (or contact points in the bolster pockets). Rotation of this diagonal into the center plane of the side frame thus requires that the distance between opposing friction shoes be shortened. The friction shoes thus move closer together, and in so doing slide inward along the slanted mating surfaces with the bolster. In the Barber truck, this causes additional compression on the snubber spring, and since the vertical load has not changed, there must be a slight rise in the bolster with respect to the side frame. The potential energy of elastic deformation is merely redistributed between the suspension and snubber springs. Thus, yaw rotation increases the potential energy of the system by raising the weight carried by the bolster. In the case of load-independent snubbing, as in the case of the ASF truck, where the snubber spring is based on the bolster, the entire added potential energy is stored in the snubber spring.

In either case, the reactions due to skew, applied at diagonally opposite edges of the side frame column, provide a yaw restoring couple. It may also be surmised that the column loads are increased by relative yaw between bolster and side frame. As will be discussed later, this was experimentally verified during tests of the transducer in the Barber S-2 truck.

2.2 SELECTION OF MANUFACTURING TECHNOLOGY AND CONCEPTUAL DESIGN OF TRANSDUCER

The manufacturing and instrumentation technology applicable to the Friction Snubber Force Measurement System was available in the field of towing tank testing, where the forces and moments applied between a moving carriage and a ship model towed by it are measured by so-called "force blocks". A force block is merely a roughly cubical, hollow block of alloy steel mounted at opposite sides to the objects between which forces are to be measured. The other four sides are machined so as to leave short cantilever beams which are instrumented with bonded strain gauges to measure bending stresses resulting from shears applied at the mounting surfaces. Additional strain gauges are provided for nulling out stresses due to normal forces applied between the mounting surfaces.

When forces in several degrees of freedom are to be measured, it is essential that the load path passes through each transducer in turn, i.e., the transducers are in series or cascaded. Spurious signals due to cross coupling are minimized by making the force blocks very stiff, in both shear and compression, along all axes not used for measurement. In the case of the Friction Snubber Force Measurement System, an additional requirement was symmetry of the load path, in order to preclude unsymmetrical deflections which would alter the contact geometry between the friction shoe and the wear plate. Also, all force blocks, interposed between the wear plate and the column had to fit into the envelope of the side frame, as did the reinforcement of the column required to make up for the material that had to be removed to permit attachment of the wear plate to the first transducer.

The original design concept is shown in Figure 1. The wear plate is welded to an adapter which in turn is bolted to a single vertical force block. The opposite face of the force block is bolted to an adapter to which a pair of lateral force blocks is mounted. Two normal force blocks are attached above and below, which are in turn bolted to an adapter rigidly mounted on the side frame. The adapter between the vertical and lateral force blocks thus divides the load path into two symmetrical sections which ensure that any tendency of the wear plate to tilt under unsymmetrical loading is minimized.

The five force blocks are capable of measuring two of the three moments applied by the friction shoes. The pitch moment is found from the differential loading of the

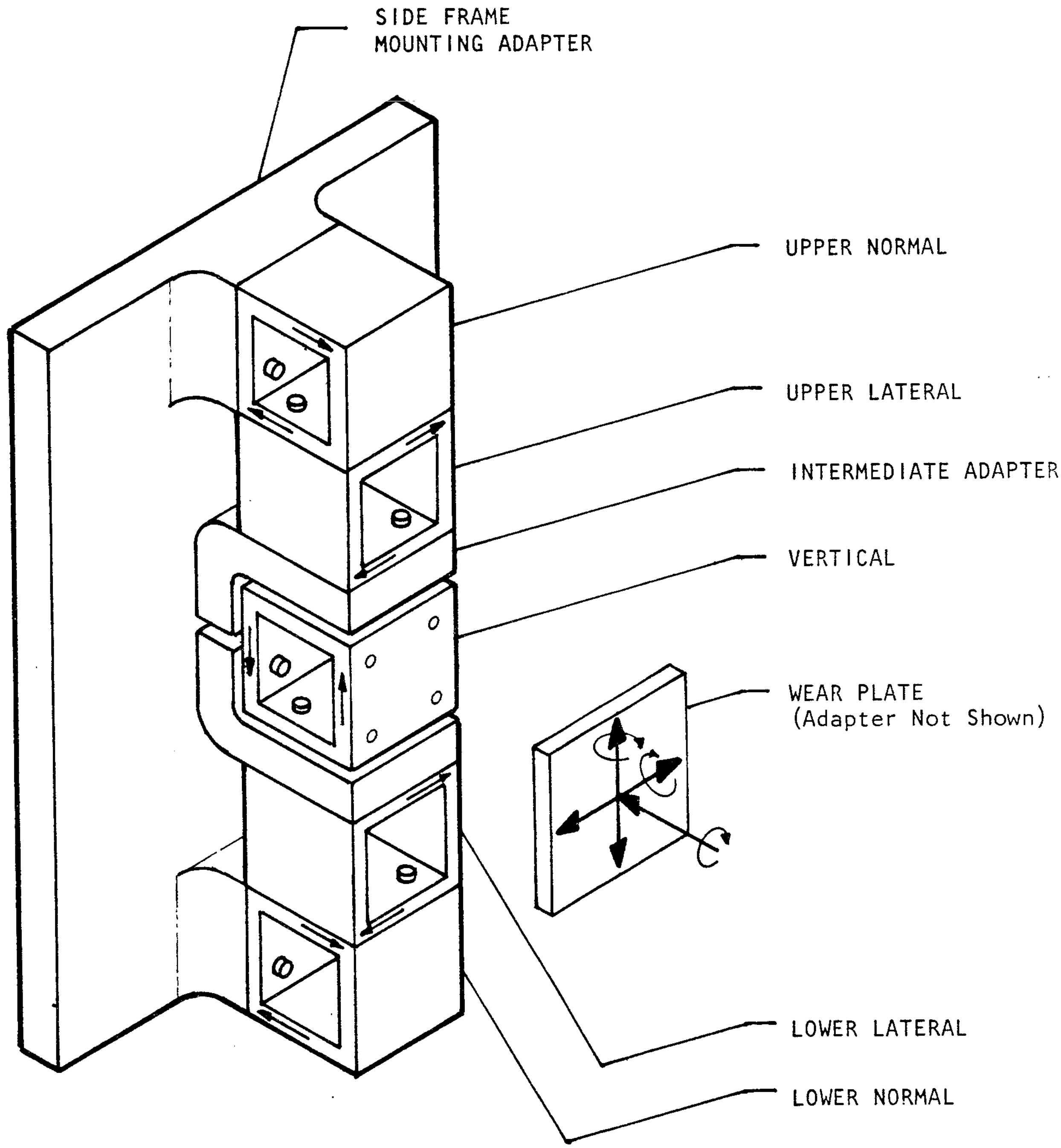


Figure 1. Basic Concept of Force Transducer

upper and lower normal transducers, and the roll friction moment, from the differential loading of the upper and lower lateral transducers. Space limitations precluded a transducer configuration capable of measuring a yaw moment; however, as already mentioned, the increased column load due to yaw can be measured.

The manufacturer chosen for the construction of the transducers was Modern Machine and Tool Company, Inc., of Newport News, Virginia. This company has designed, built and calibrated many multi-degree-of-freedom force measuring systems for use in towing tanks, to very exacting requirements of accuracy, reliability and space limitations.

An exploded view of the transducer assembly as built is shown in Figure 2. Space limitations in the side frame required that the normal and lateral force transducers be combined into a single unit.

While each individual transducer is compensated against cross-coupling, it is not possible to eliminate cross coupling between the vertical and normal transducers. This is due to the fact that the plane of the mounting adapter to which the lateral and normal force transducers are attached is offset from the plane of the wear plate adapter carried by the vertical transducer. A vertical friction force thus produces a moment which is resisted by equal and opposite normal forces. The forces making up this couple must be distinguished from unequal normal forces due to a vertical offset of the center of friction shoe pressure from the center of the wear plate which occurs with bolster displacement.

The correction factors required to distinguish the forces due to coupling via moments from those due to eccentric normal loading have been established for each transducer assembly by calibration and are listed in the instruction manuals. These factors must be utilized in the reduction of data collected in road tests. The specification is included as Appendix A, together with as-built drawings.

Assembly and calibration procedures, results of calibration, and wiring details are contained in Wyle Laboratories' Instruction Books. (Ref.)

why not here

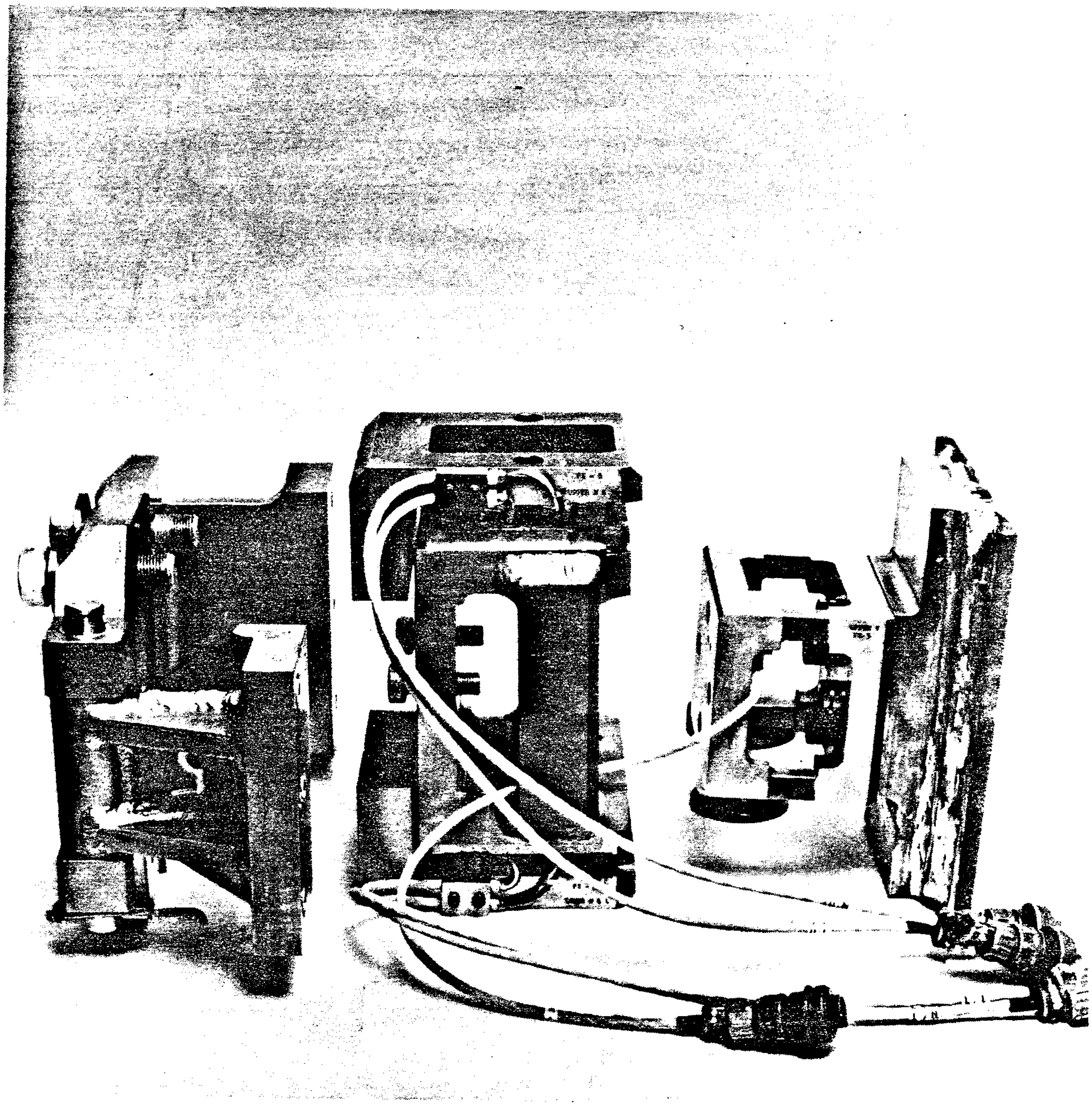


Figure 2. Exploded View of Transducer Assembly

SECTION 3

CONSTRUCTION OF TRANSDUCERS AND MODIFICATION OF SIDE FRAMES

3.1 CHANGES IN REQUIREMENTS

The original, unsolicited proposal was submitted to Southern Pacific Transportation Company, as the prime contractor for TDOP, on March 13, 1975. The proposal suggested instrumentation of a single, unspecified truck and was based on the assumption that the instrumented truck would be used in test operations only.

Before awarding a contract, on December 8, 1975, the following changes were made in the requirements:

a. Friction snubber instrumentation was to be provided for two trucks, one ASF Ride Control, and one Barber S-2, both 70-ton.

b. The instrumented trucks were to be capable of being run across the country under cars in a revenue service.

The second of these requirements implied that the modified, instrumented trucks had to be capable of withstanding normal shock loads, resulting in stresses below the fatigue limit, as specified in AAR M-203-65 which requires a side frame to be tested under a lateral load of 35,000 lb without exceeding listed deflections. This requirement led to the following modifications in the original design.

3.2 MODIFICATION OF SIDE FRAMES

The side frames, bolsters, friction shoes, brake beams and springs were purchased according to the directions, and from the suppliers, specified by Southern Pacific. The side frames required an opening in the center of each column, to accommodate the wear plate adapter by which the friction shoe forces are transmitted to the transducer assembly mounted behind it.

It had originally been intended to remove the entire column, and to replace it by two heavy welded steel bars which would serve the double purpose of providing reinforcement of the open center, and serving as mounting surfaces for the mounting adapter, a U-shaped flanged bracket carrying the vertical legs of the lateral and normal force transducers. American Steel Foundries had consented to stress-relieve the modified side frames under a subcontract.

Removal of the entire column might have caused more deformation in the side frame than could have been corrected. It was therefore decided to remove only the column web behind the location of the wear plate, after welding the reinforcing bars, which were cut from ASTM 515 GR70 steel. This steel is compatible for welding to the Grade B casting of the side frame. A modified side frame of the Barber truck is shown in Figure 3.

In order to preclude distortion during stress relieving, the center opening of each side frame was stabilized by a pair of diagonal braces on each side.

The critical dimension to be maintained in the modification of each side frame is the distance between wear plates, 17-3/4 in. in the ASF truck (Dwg. No. 7123, Rev. A5), and 17 in. in the Barber S-2 truck (Standard Car Truck Co. Dwg. No. 3741, Rev. M). This spacing determines the column load with the given bolster and friction shoe geometry, and the spring characteristics.

With the dimensions of the transducer stack between the wear plate and the mounting adapter flanges given, the offset between the face of the wear plate and the back surfaces of the reinforcing bars determines the spacing between wear plates. Since machining of these surfaces would have been costly, special care had to be taken in the fabrication to prevent distortion. Very little shimming was required to position the transducer assemblies correctly on the as-welded side frames.

A preliminary stress analysis indicated that the modified column, treated as a rigid frame with infinitely stiff girders, had ample strength to resist a concentrated transverse force of 17,500 lb (one-half of the specified 35,000 lb) applied at the center of one of the reinforcing bars. The calculated stresses are conservative since they were based on the reinforcing bars alone without consideration of the portions of the column left in place.

The weakest point in the modified column turned out to be the ledges surrounding the wear plate, at which the concentrated lateral force will be applied by one or the other bolster gibs. Removal of the column web deprives the lip of a backup and causes the gib force to be resisted by a portion of the lip in cantilever bending. A bar with tapered edges was welded to the inside of the cut to provide reinforcement, and the rear edges of the wear plate adapter were tapered to provide clearance in the reduced opening (see Figure 3).

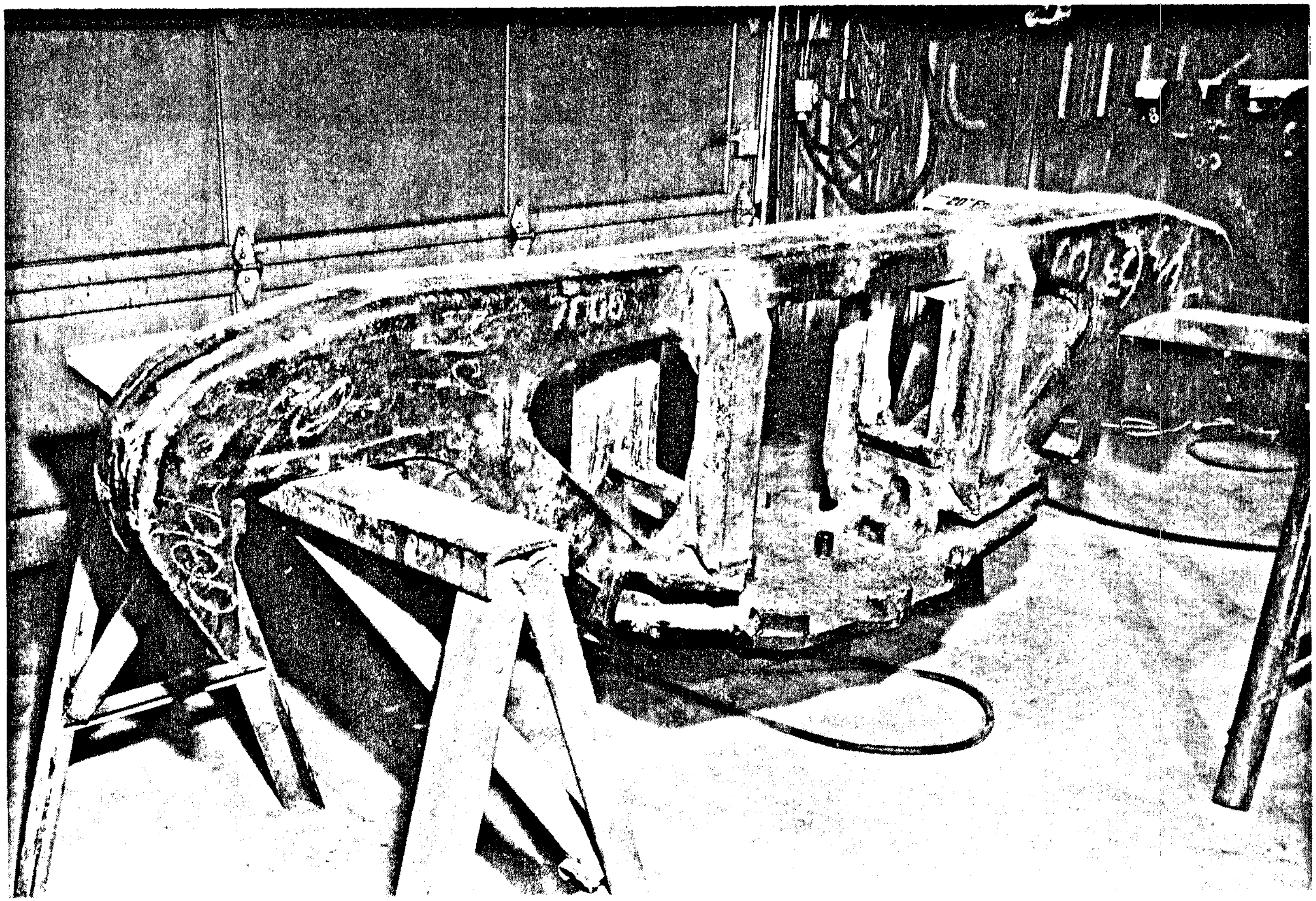


Figure 3. Modified Side Frame (Barber S-2 Truck)

The modified column is a highly indeterminate structure for which a complete and detailed stress analysis by finite element methods would have been time-consuming and costly. Instead, it was proposed to perform a lateral load test to AAR specifications, as a less expensive and more significant measure of the strength of the modified side frame. This test was carried out by American Steel Foundries on one of the Barber S-2 side frames.

Details and results of the test are given in Appendix B. The side frame was covered with Stresscoat, the side frame was loaded, areas of high stress were instrumented with strain gauges, and the load was again applied. The highest stresses occurred in areas other than those modified, and appear to be due to sharp changes in the directions of stresses, at the transition from the spring nest support to the column. In summary, the modified side frame can be declared safe for unrestricted service.

3.3 CONSTRUCTION AND MODIFICATION OF TRANSDUCERS

The transducer components were machined from 17-4 PH precipitation hardening steel, with a yield strength of 140,000 psi. Simultaneous application of a normal load of 6,000 lb, and vertical and horizontal friction forces of 3,000 lb each, are said by the manufacturer to produce stresses of only about 20,000 psi, so that an ample margin of safety is provided for unforeseen overloads.

The 35,000 lb lateral load posed no problem for the transducer since this load does not pass through the force blocks. However, a portion of this load would be resisted by the U-shaped mounting adapter that is flange mounted on the column reinforcing bars, and in effect forms a structural tie across the column opening. On account of the indeterminacy of the system, the stresses in the bracket and transducer mounting bolts are difficult to predict, but the arrangement was considered undesirable in any case because of the shock loads that would be transmitted to the transducer.

The stiffness of the lateral load path through the mounting adapter was therefore lowered in the following manner: As shown in Figure 4, the thickness of one web between the transducer mounting plate and its flange is reduced so that it will act as a flexure. The opposite bracket (Figure 5) is connected to the transducer mounting plate by a stainless steel pin assembled in self-lubricating bushings. This bracket transmits practically all lateral friction forces from the wear plate to one column reinforcing bar. Under a lateral impact force high enough to decrease the distance between the

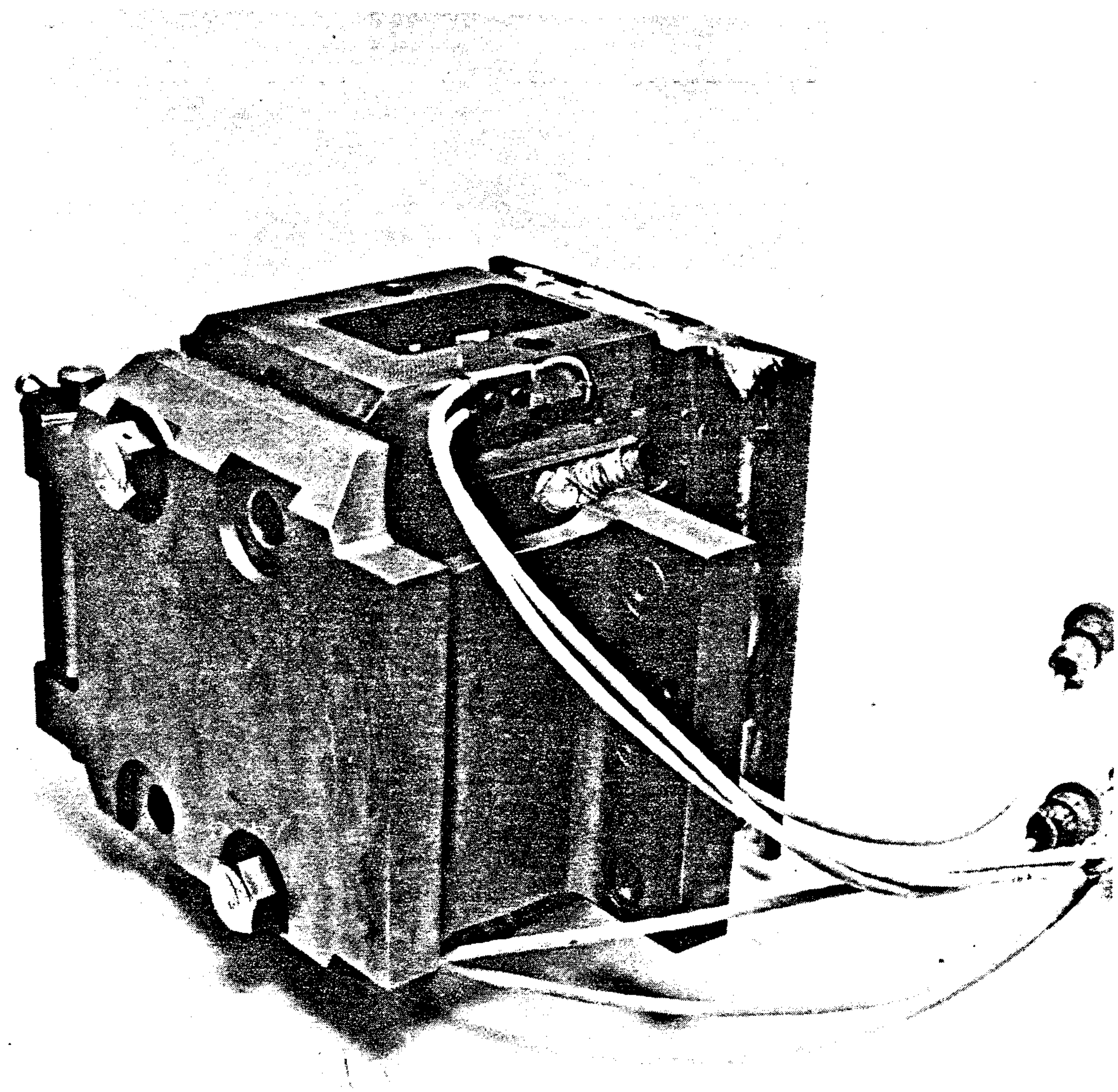


Figure 4. Transducer Assembly - Rear View

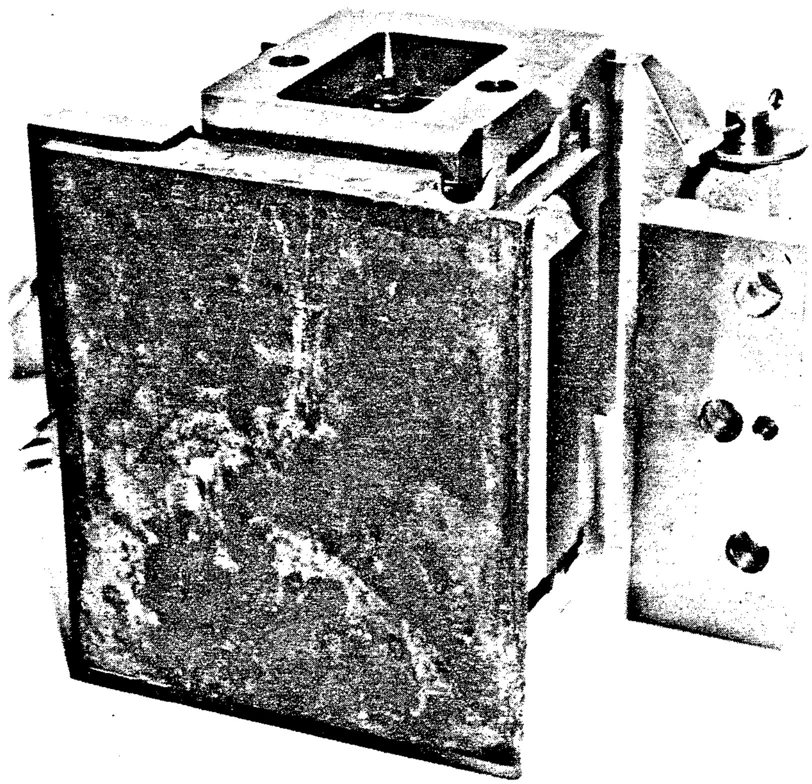


Figure 5. Transducer Assembly - Front View

reinforcing bars, the flexure will minimize the portion of the load transmitted through the mounting adapter. The adapter components are made from 1018 cold-finished steel.

The two-piece mounting adapter greatly eased the problem of assembling the transducers in the very confined space available in the side frames.

3.4 ASSEMBLY

Assembly of the transducers in the side frames turned out to be as difficult as was expected. Individual components must be introduced one by one, and inserted and tightened with a torque wrench in a tight space. The original specification called for lock-wiring of all bolts. However, this procedure was abandoned when a slipping tool damaged a lead wire. All bolts were subsequently installed with a thread-locking compound (Loktite).

In spite of careful measurements of the side frames, some interferences between transducers and fillets in the side frame castings were found, behind the column above and below the cutout. Some of these interferences were due to variations between castings. It was necessary to bevel the edges of the lateral and normal force transducers, and the rear edges of the cutout. Modifications also were required in the area of the lower two bolts of the mounting adapter in the case of the Barber truck, to provide space for assembly.

Partially assembled transducers in the Barber truck are shown in Figures 6 and 7, and completely assembled transducers in the ASF truck, in Figures 8 and 9.

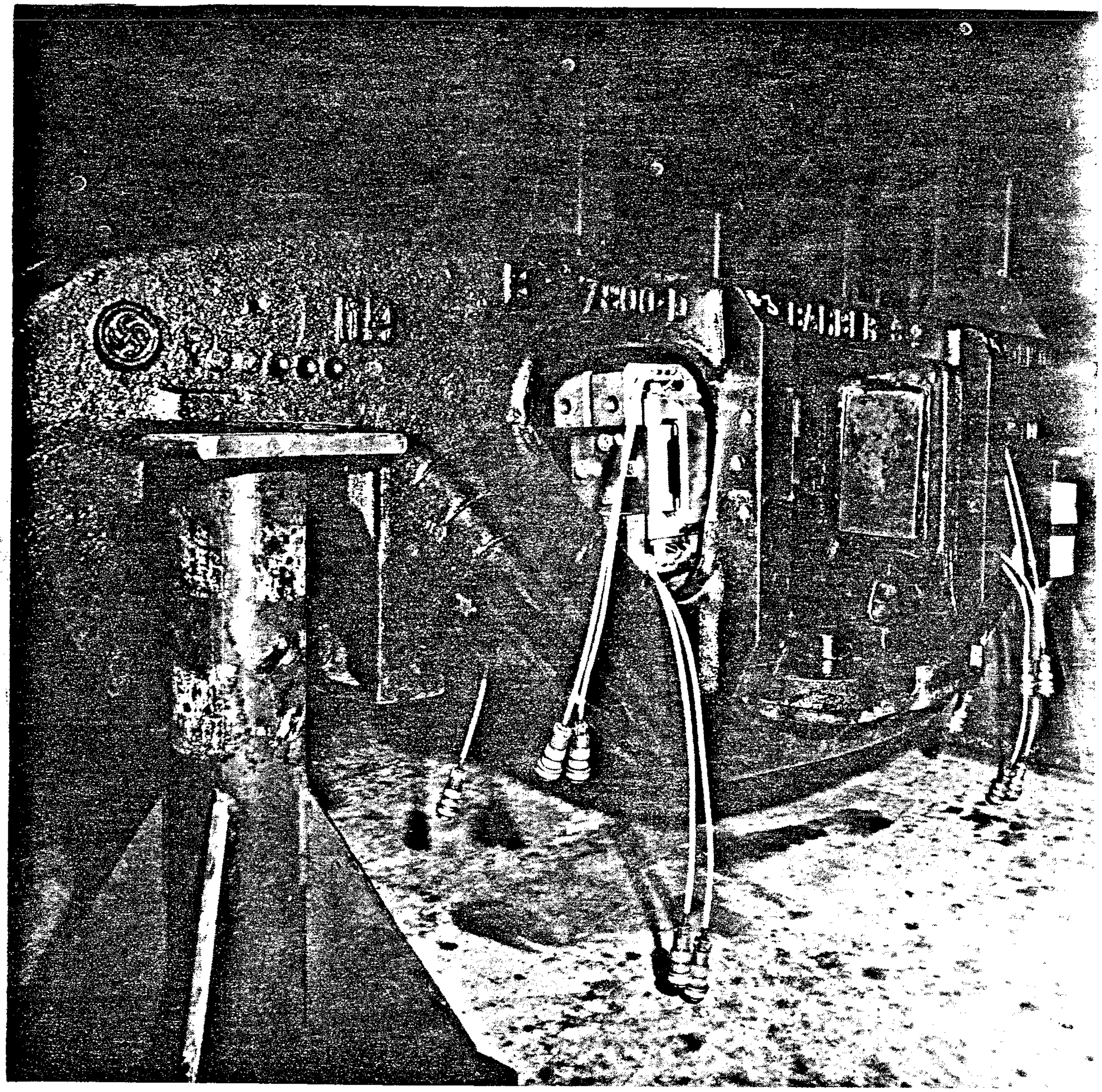


Figure 6. Close-up of Partially Assembled Transducers in Barber S-2 Truck

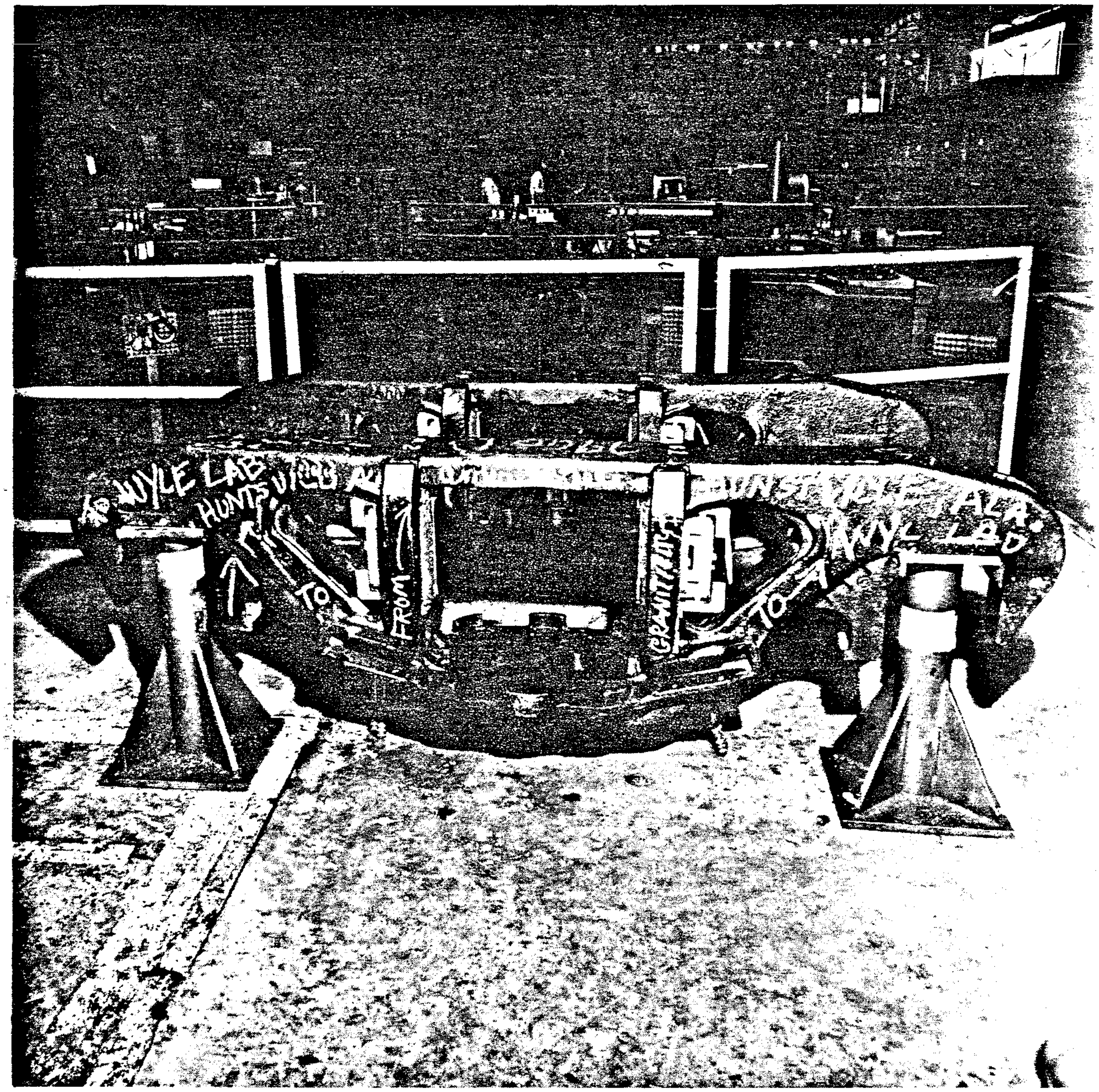


Figure 7. Transducers Partially Assembled in Barber S-2 Truck

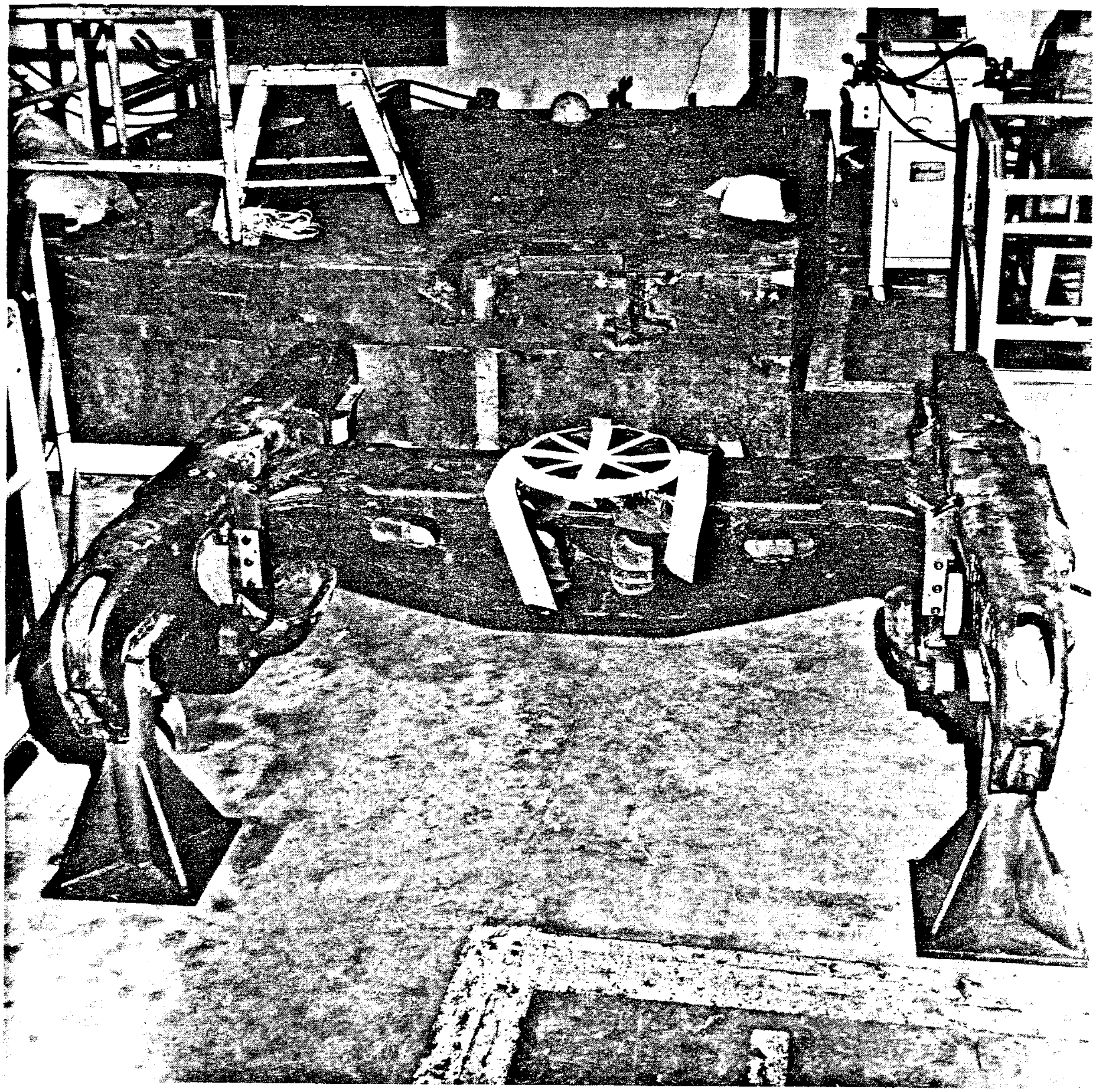


Figure 8. ASF Ride Control Truck with All Transducers Assembled

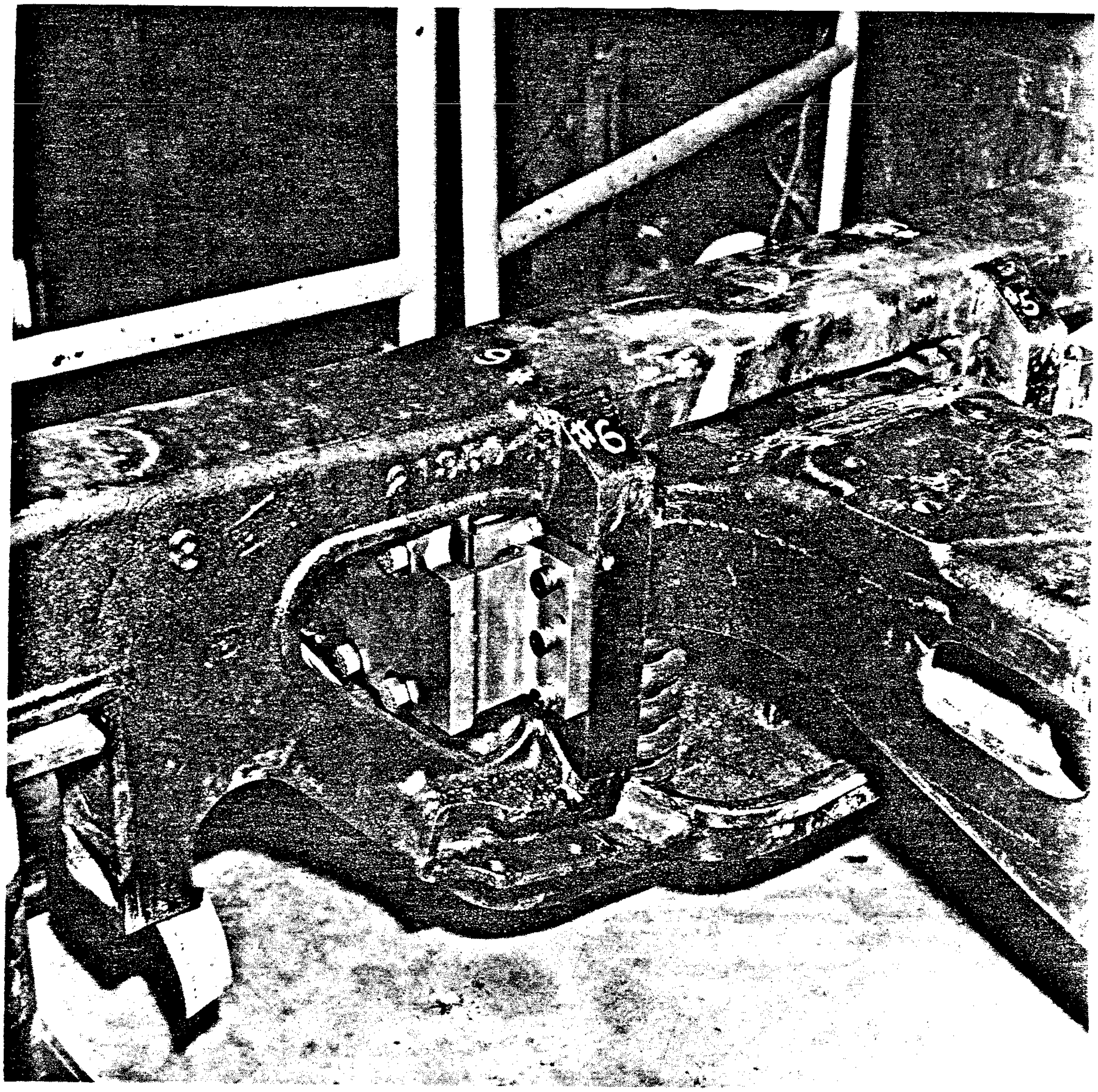


Figure 9. Detail of Transducers in ASF Truck

SECTION 4 - TESTING

4.1 TEST PHILOSOPHY

The in-plant testing of the Friction Snubber Force Measurement System was intended to demonstrate performance of the transducers in the truck under some simulated operating conditions, without reproducing all aspects of the rail environment which would have required much more complex and costly test equipment. Therefore, only simultaneous vertical and lateral movements of the bolster were produced in the tests. The lateral displacement was considered essential to prevent the formation of vertical grooves in the friction shoes.

In order to minimize the hydraulic power required to move the bolster, only two springs were installed in each side frame. In retrospect, it became apparent that more springs should have been used to prevent rocking of the side frames about their roll axes. However, this unplanned motion clearly demonstrated the capability of the transducer assembly to identify friction torques due to roll.

4.2 TEST SETUP

The test setup is shown in Figures 10 and 11, with the Barber and ASF trucks installed, respectively. An existing test frame was modified by the addition of four pedestals to support the pedestals of the side frames, and to restrain them laterally. A beam simulating the carbody bolster was nested by a center plate in the truck centerbowl. The beam was raised and lowered by a pair of double-ended, double-acting hydraulic actuators controlled by electrohydraulic servo valves. Linear Differential Voltage Transformers (LVDTs) mounted on the actuators provided position feedback.

A third horizontal hydraulic actuator mounted on a bracket atop the test frame provided lateral motion of the simulated carbody bolster. A central frame guided the bolster beam in a vertical plane through grease-lubricated rubbing plates.

Vertical and lateral relative displacements between the bolster and each side frame were measured by LVDTs as shown in Figure 12.

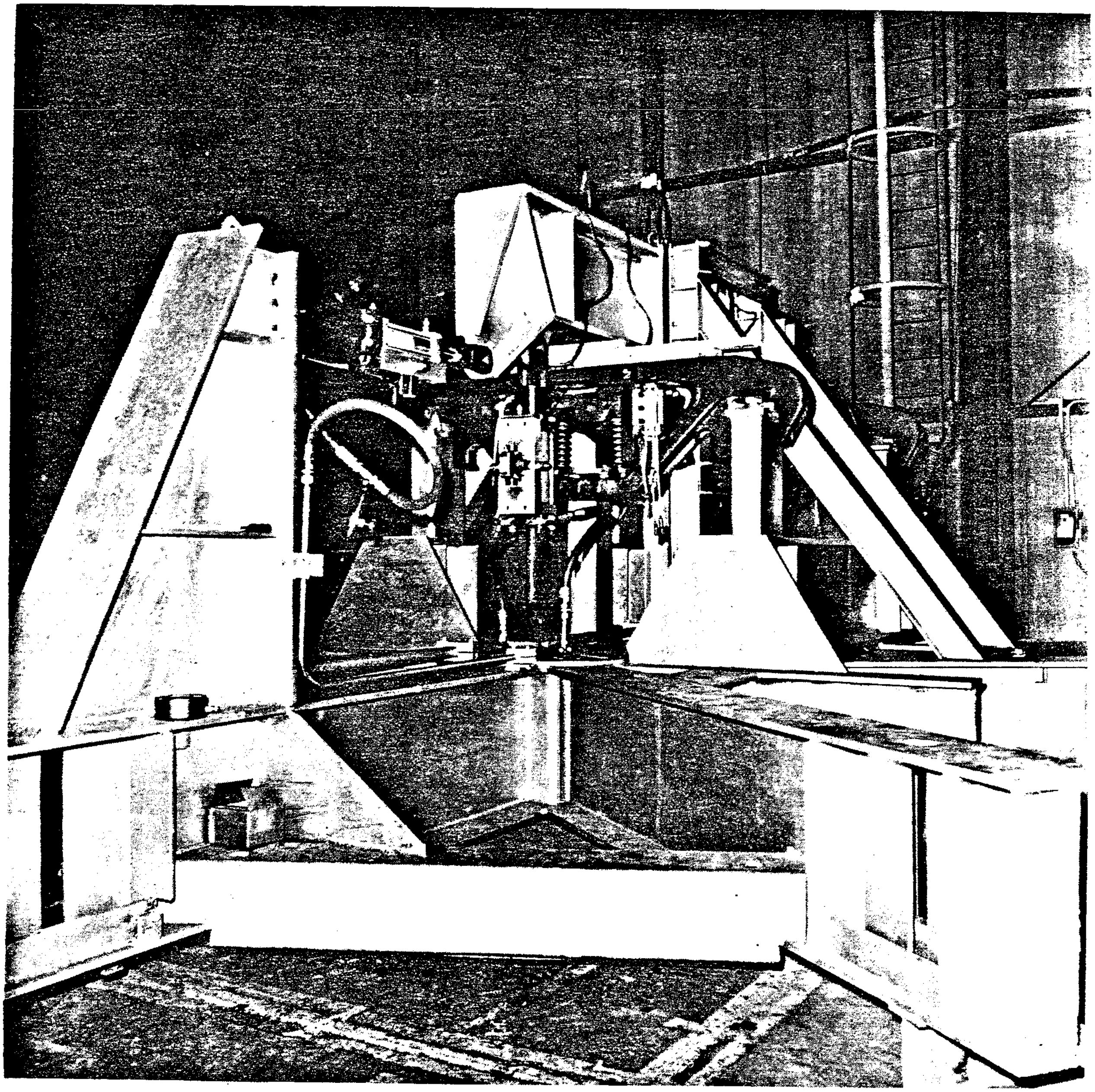


Figure 10. Barber S-2 Truck on Test Stand

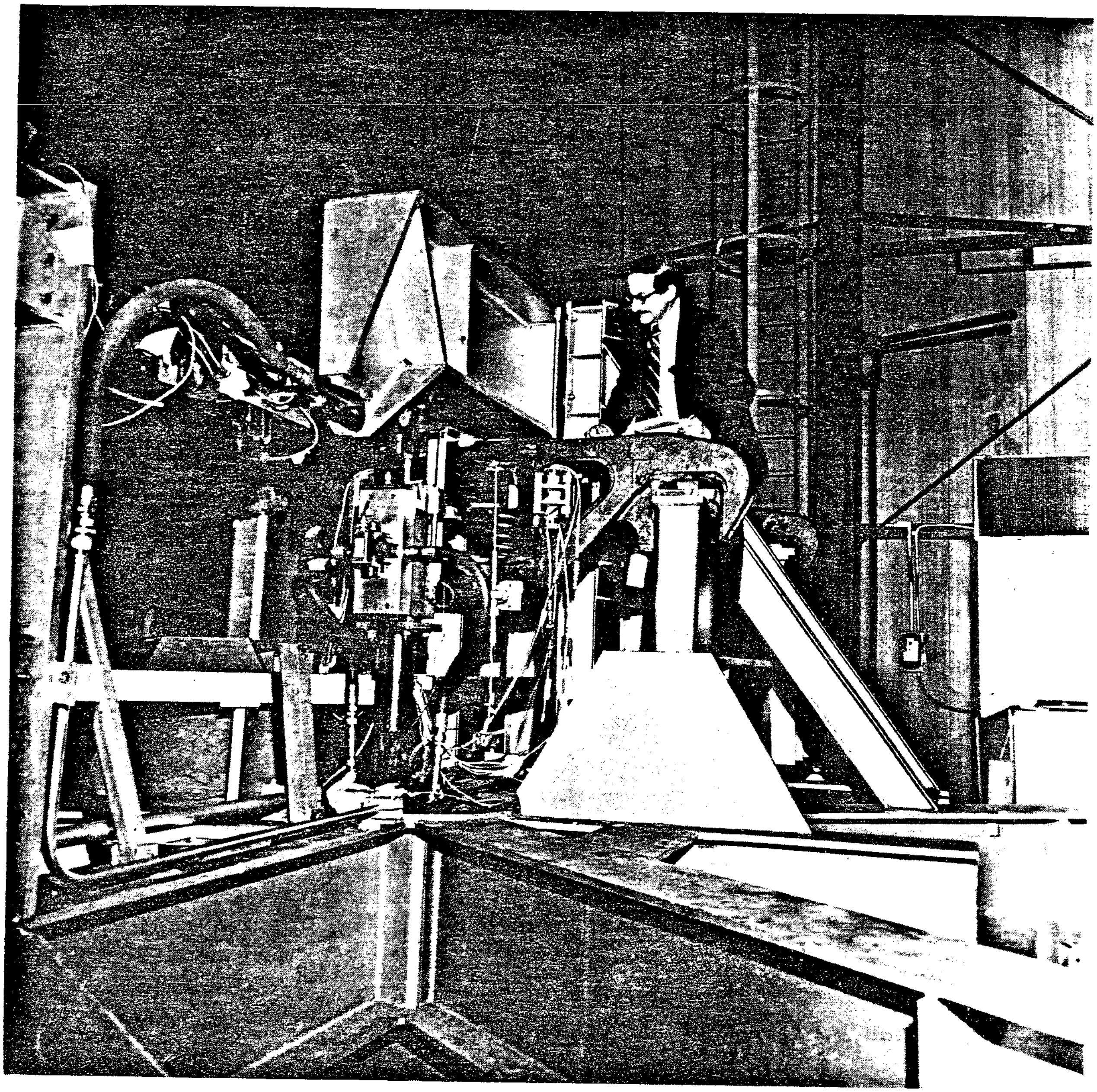


Figure 11. ASF Ride Control Truck on Test Stand

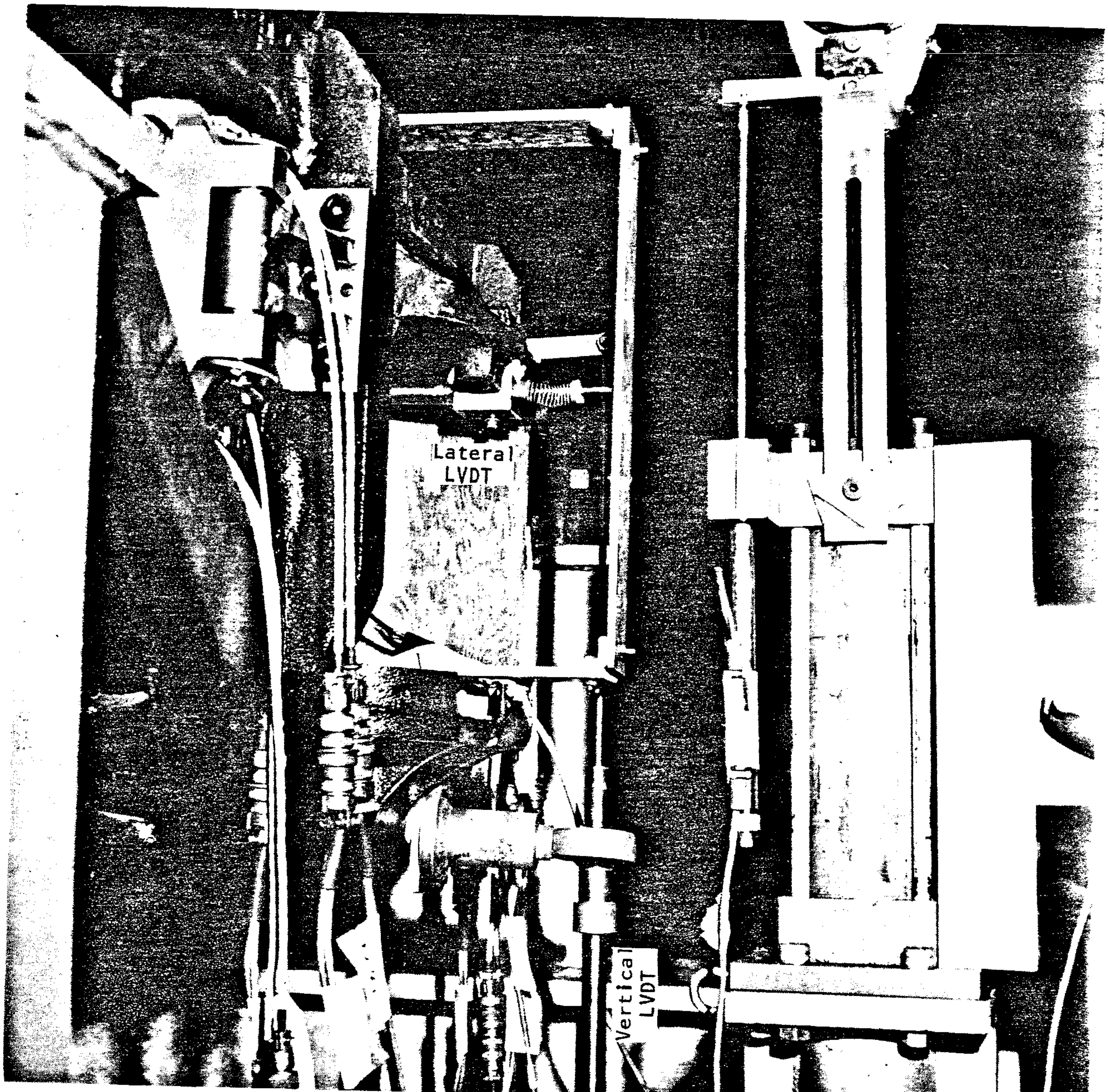


Figure 12. Instrumentation for Bolster/Side Frame Displacements

4.3 INSTRUMENTATION AND DATA RECORDING

Outputs of all 20 force transducers, the four bolster-side frame LVDTs, and the three actuator LVDTs were recorded on four oscillographs. In addition, all outputs as well as calibration and verbal comments were recorded on FM tape during the last two of the three test series.

A photograph showing most of the recording equipment is shown in Figure 13.

4.4 TESTING

All calibration factors for force transducers were established with the friction shoes out of contact with the wear plates. In the ASF truck, the pins that lock the shoes against the springs were left in place until after calibration was completed. In the case of the Barber truck, the bolster was lifted by the crane to unload the friction shoe springs to a point where the shoes could be moved manually away from the wear plates.

4.4.1 Preliminary Tests

A preliminary test of the Barber S-2 truck was conducted on February 25, 1977. The bolster was lowered until the springs were compressed to about half their travel, and then oscillated about this position through an amplitude of $\pm$3/4-inch, at a frequency of 0.1 Hz. Simultaneously, the bolster was displaced laterally through an amplitude of $\pm$1/4 inch at a frequency of one Hz.

Next, a sine sweep was performed, with the frequency gradually increasing, and the amplitude decreasing.

Considerable wear was taking place at the friction shoe-wear plate interface, as evidenced by black powdery debris. The normal forces measured by the transducers were increasing beyond the estimated levels, and some gouging of the wear plates was noted. It became evident that considerable time would be required to wear in the friction shoes.

The sine sweep test was therefore terminated at 8 Hz.

The vertical surfaces of the friction shoes of both trucks were lightly ground so as to remove the larger asperities, and to make the forces measured during the tests most representative of those occurring in service after wear-in.

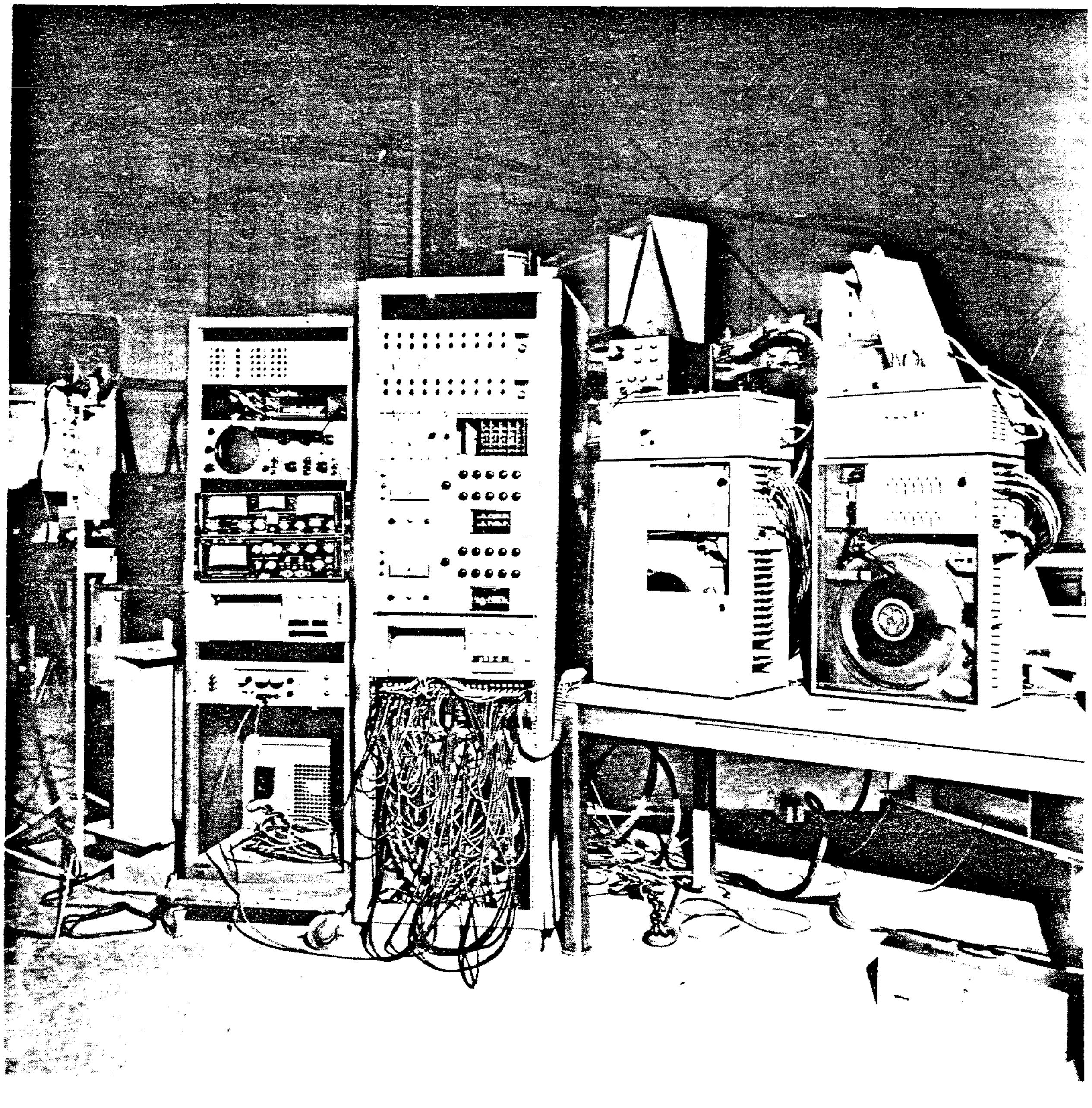


Figure 13. Recording Equipment

Before disassembling the truck, the adjacent pedestals of both side frames were displaced laterally through about 3/8 in. by means of set screws, thus forcing the truck out of tram. As will be discussed in the next section, the expected increase in the normal forces on the column was noted and recorded on the oscillogram.

4.4.2 Final Tests

The Barber truck, with friction shoes ground, was retested on March 7, and the ASF truck on March 10. The sine sweep test was eliminated mainly to prevent localized wear at small amplitudes. The sine dwell procedure was retained.

Measured normal forces were in the expected range for both trucks. Typical upper normal forces (always somewhat higher than lower normal forces) were between 6,000 and 7,000 lb, and accounted for most of the normal column load during the downstroke. Normal forces in the ASF truck were somewhat higher, but this is due to the fact that the Barber truck was tested in a condition equivalent to a light car. These results are discussed in detail in Section 5.

A successful attempt was made to demonstrate static friction in the snubber system. The bolster was very slowly moved one inch downward from the centered position with the hydraulic actuators under manual control. Typical lower normal forces rose to 8,000 lb on the Barber truck and 7,000 lb on the ASF truck. These forces immediately decreased to the lower values given above when the bolster was cycled at 0.1 Hz.

The only untoward event during these tests was the loss of one of the horizontal transducers between the side frame and bolster of the ASF truck, caused by parting of the cemented bracket connection. Since the opposite transducer remained, it was not considered worthwhile to interrupt the test.

SECTION 5 - DISCUSSION OF TEST RESULTS

5.1 TEST OBJECTIVES

The main objective of the in-plant tests was a final check on the proper operation of the transducer system in the trucks. This objective was achieved.

It was not intended to subject the truck to a full range of inputs such as would be observed on the track. In any case, the force distribution at the column is likely to change as the friction shoes wear in, and it is recommended that this process be monitored during future road tests.

The observations presented in the following should not be taken to imply endorsement or critique of either truck design.

5.2 BARBER S-2 TRUCK

An excerpt from the sine dwell test, measured by transducer no. FS-3, is shown in Figure 14. At a given instant, the following forces were recorded:

Upper plus lower normal	7200	lb
Vertical	1200	lb
Upper plus lower lateral	1200	lb

The significance of these data will be discussed in Section 5.4. It should be noted that the normal forces must be adjusted by adding and subtracting a correction to the values of the upper and lower measured normal forces to account for the moment applied by the vertical friction force, with the signs determined by the direction of vertical motion. Since equal and opposite corrections are applied, this does not affect the total normal force but serves to locate the center of pressure.

Some audible chatter was noted on the down stroke. It appears to be due to vertical stick-slip, and propagates in the other directions.

An attempt was made to measure the effect of forcing the truck out of tram, by means of set screws at two adjacent pedestals. As shown in Figure 15, the process is

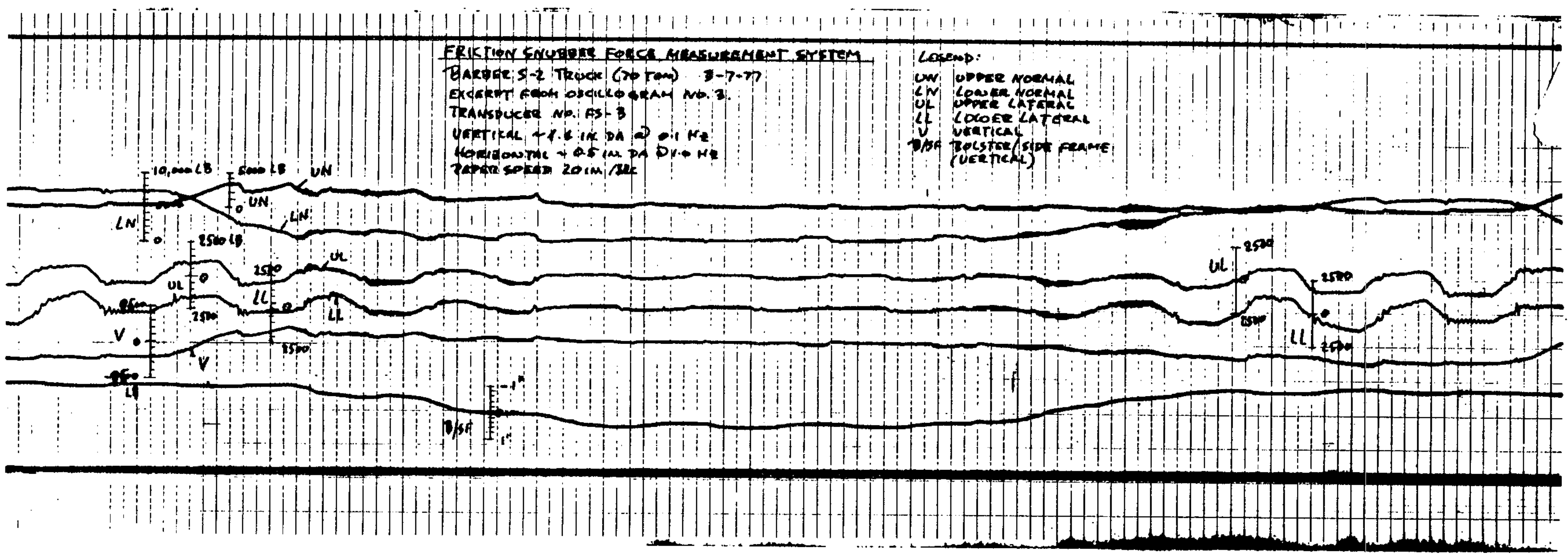


Figure 14. Sample of Test Data - Barber S-2 Truck

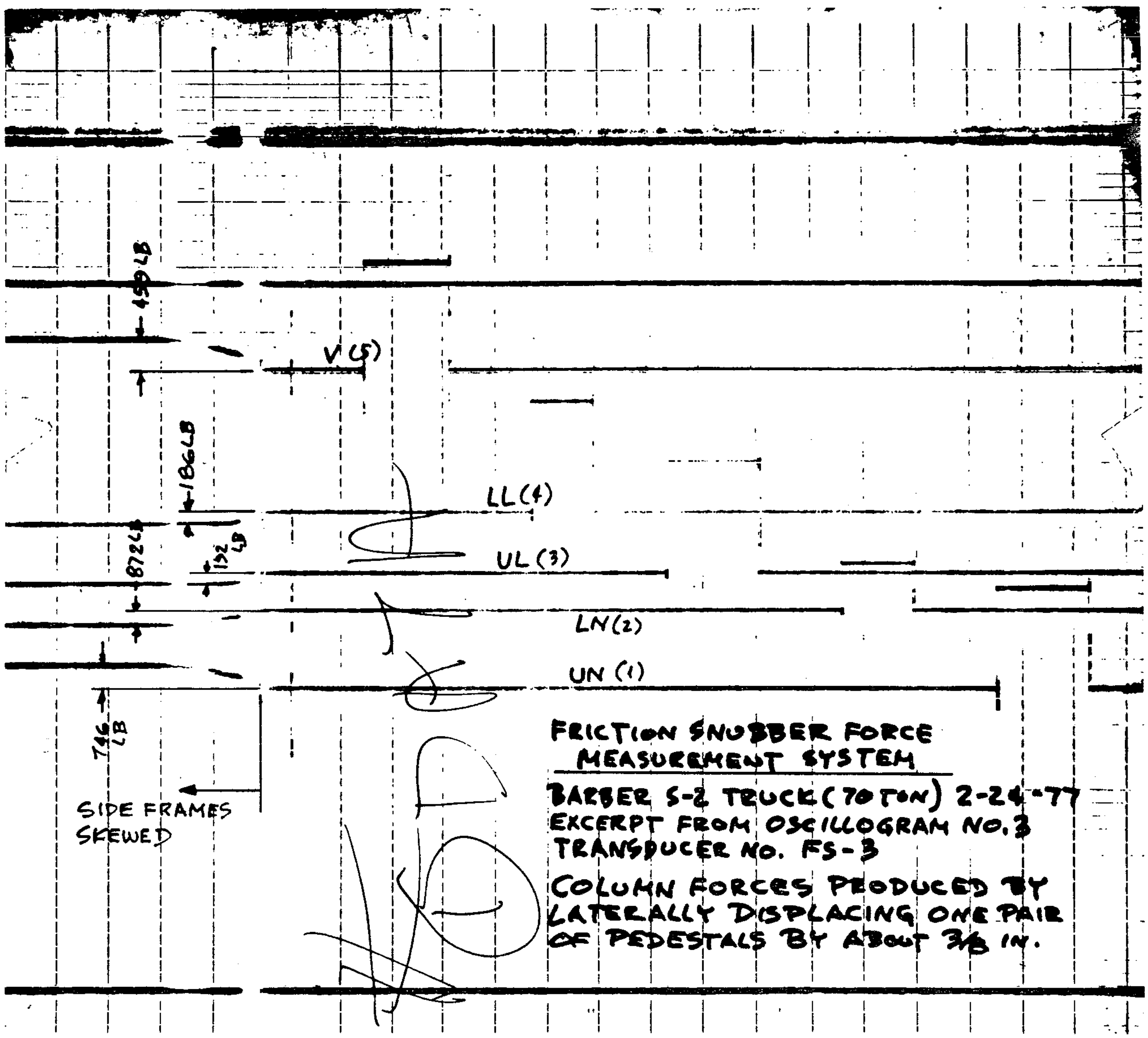


Figure 15. Effect of Truck Parallelogramming

more complex than had been assumed in the previous discussion. The normal column load is redistributed, increasing at the top and decreasing at the bottom.

The downward (positive) vertical friction force indicates that the friction shoe moves downward, as expected on the basis of the discussion in Section 2.1, since the bolster is restrained by the actuators from moving upward.

Because of the unsymmetrical distortion of the truck, there is some lateral sliding between bolster and side frames, as indicated by the lateral friction forces, of about 200 lb each.

5.3 ASF RIDE CONTROL TRUCK

An excerpt from the sine dwell test of the ASF Ride Control Truck, measured by transducer no. FS-7, is shown in Figure 16. At a given instant, the following forces were recorded:

Upper plus lower normal	10000 lb
Vertical	4200 lb
Upper plus lower lateral (approx)	1000 lb

These results are also discussed in Section 5.4.

There appears to be some rocking of the friction shoes, as indicated by the sharp rise in lower normal and vertical friction forces as the direction of vertical motion reverses at the beginning of the downstroke. There is also heavy (and very audible) chatter, which implies additional energy dissipation. The distribution of the normal load is highly unsymmetrical with respect to the center of the wear plate, as would be expected from the position of the bolster that simulated a lightly loaded car.

It should again be emphasized that the data discussed above are not necessarily typical of a friction snubber assembly worn in under actual operating conditions, but are presented mainly to illustrate the kind of information that can be obtained from the Friction Snubber Force Measurement System.

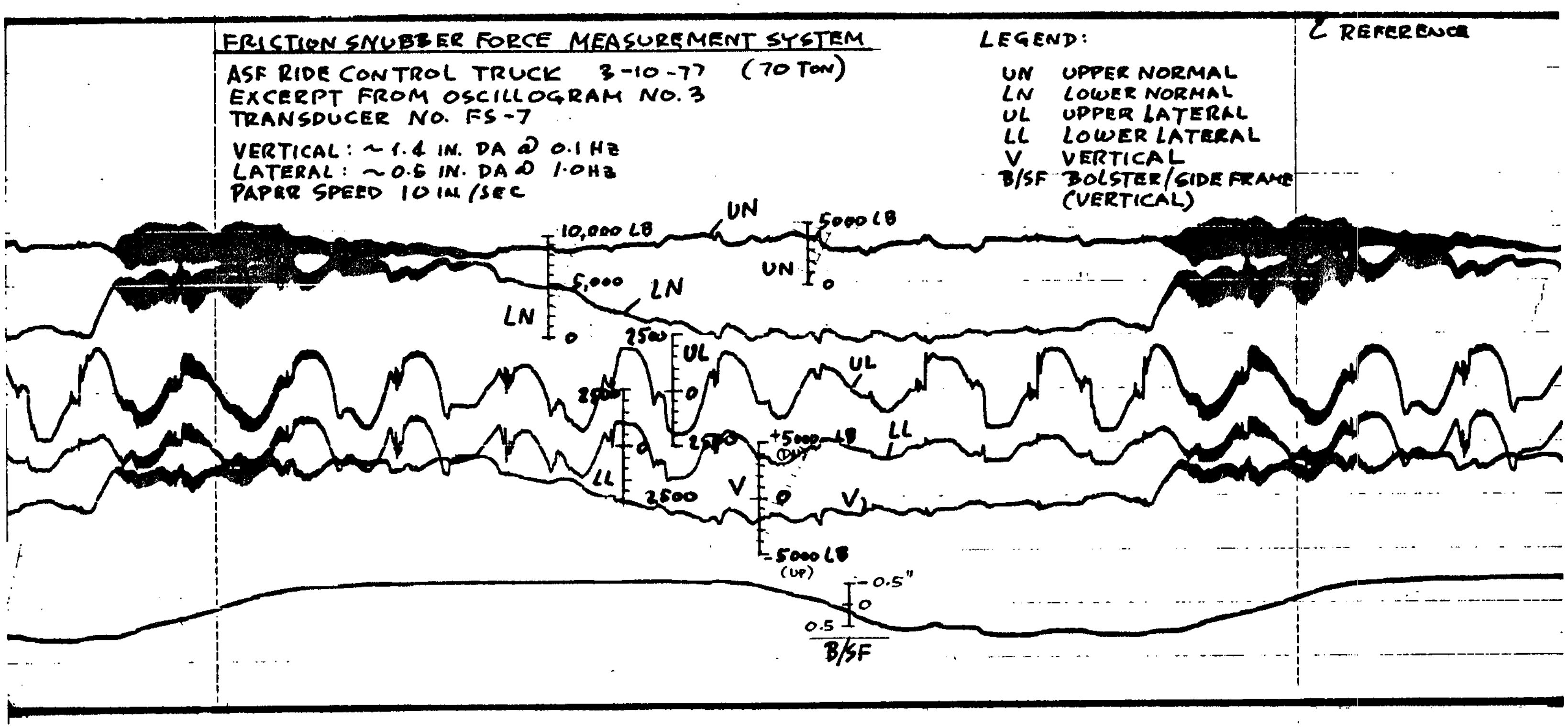


Figure 16. Sample of Test Data - ASF Ride Control Truck

5.4 PRELIMINARY ANALYSIS

While the tests described above demonstrated the proper functioning of the transducers, the conditions of the tests differed from those typical of actual operation sufficiently to require caution in the interpretation of results. For example, the light weight of the simulated car body bolster, combined with the low forces in the few suspension springs present in the trucks, the low level of exciting forces applied by the hydraulic actuators, and the low frequency of the motion may well have been responsible for more stick-slip behavior than would occur even in the snubbers of a lightly loaded car.

The raw data records give no indication of the repeatability of the tests. However, repeatability may be checked by calculating the work performed over several cycles. This work is the sum of the products of vertical friction force, and the absolute value of incremental displacement for one snubber.

Table 1 lists the results of this computation for five consecutive cycles, for both trucks, as well as the average work per cycle, and the variance.

Table 1. Friction Work for Five Cycles of Vertical Motion, lb/ft

Barber S2	ASF Ride Control
149.98	244.50
152.75	262.15
145.69	282.82
163.73	276.65
150.84	270.35
153.04 ± 7.7	267.29 ± 14.86

Since the bolsters were cycled about a position representing a light car, the work performed on the load-dependent friction snubbing system of the Barber truck is less than that for the ASF truck with its load-dependent friction snubbers. However, both sets of values are repeatable with a variance of about 5.5 percent. Of this, about one percent may be attributed to the known inaccuracy of the transducer. The remainder is most likely due to variation in the length of the stroke, which may not have been maintained within less than 1/64 in.

The simplest assumption to make in the computation of the material friction coefficient is that the resistance to sliding is the same regardless of the direction. This is illustrated in Figure 17. The resultant friction force is aligned in the direction of motion which is inclined at an angle θ with the vertical. The components along the vertical and lateral axes are $F_x = \mu F_N \cos\theta$ and $F_y = \mu F_N \sin\theta$, respectively where

F_N is the normal force, and $\theta = \tan^{-1} F_y/F_x$.

When these relations are applied to the test data given in the previous section, they lead to the following results:

For the Barber S-2 truck, $F_x = F_y = 1200$ lb, $\theta = 45^o$, $F_N = 7200$ lb.

Thus, $\mu = \frac{1200}{7200} \times \frac{1}{\cos 45^o} = 0.24.$ (0.167 paper)

For the ASF truck, $F_x = 4200$ lb, $F_y = 1000$ lb, $\theta = 13.4^o$,
$F_N = 10{,}000$ lb. $\mu = 0.43$. (0.45 paper)

The formulation of the friction process illustrated in Figure 17 implies that simultaneous vertical and lateral displacements of the friction shoe should modify the friction forces in the two directions, since they are components of the resultant friction force along the instantaneous and constantly changing direction of motion. As may be seen from Figures 14 and 16, the vertical friction force is perturbed by the lateral friction force which varies at ten times the frequency.

Since the work performed by the friction force is a scalar quantity, the work done along the two directions of motion must be added and must equal the work done along the direction of motion. From Figure 17:

$$dW = F_x dx + F_y dy$$

$$= \mu F_N \cos\theta \, ds \cos\theta + \mu F_N \sin\theta \, ds \sin\theta$$

$$= \mu F_N \, ds (\cos^2\theta + \sin^2\theta)$$

$$dW = \mu F_N \, ds.$$

The assumption of a constant friction coefficient is any direction of motion is not essential. However, if the friction coefficient varies in different directions of relative motion, as shown in Figure 18, the displacement is not in line with the direction of maximum force, except possibly in two orthogonal directions. In this case, too, it may be shown that the work done along the direction of resultant motion is equal to the sum of the work components along two orthogonal axes.

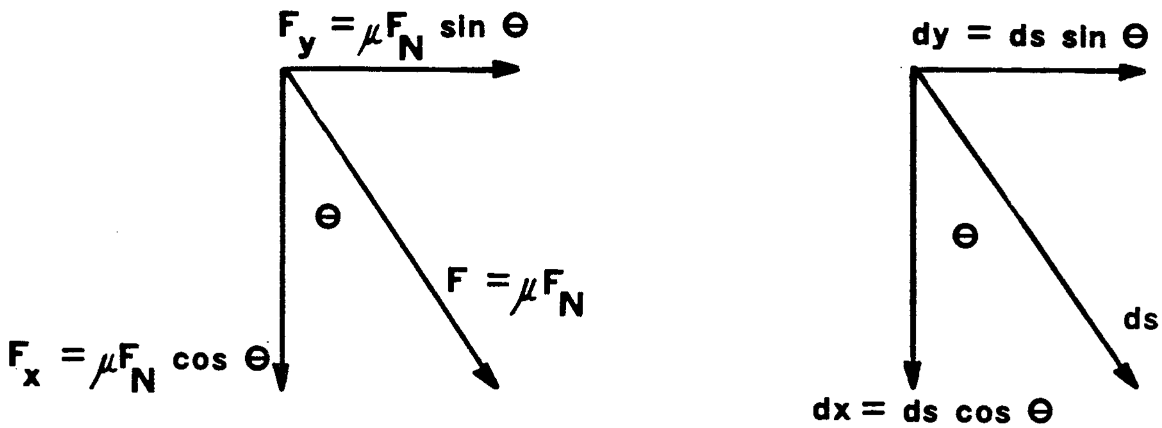


Figure 17. Forces and Displacements for Equal Vertical and Lateral Friction Coefficients

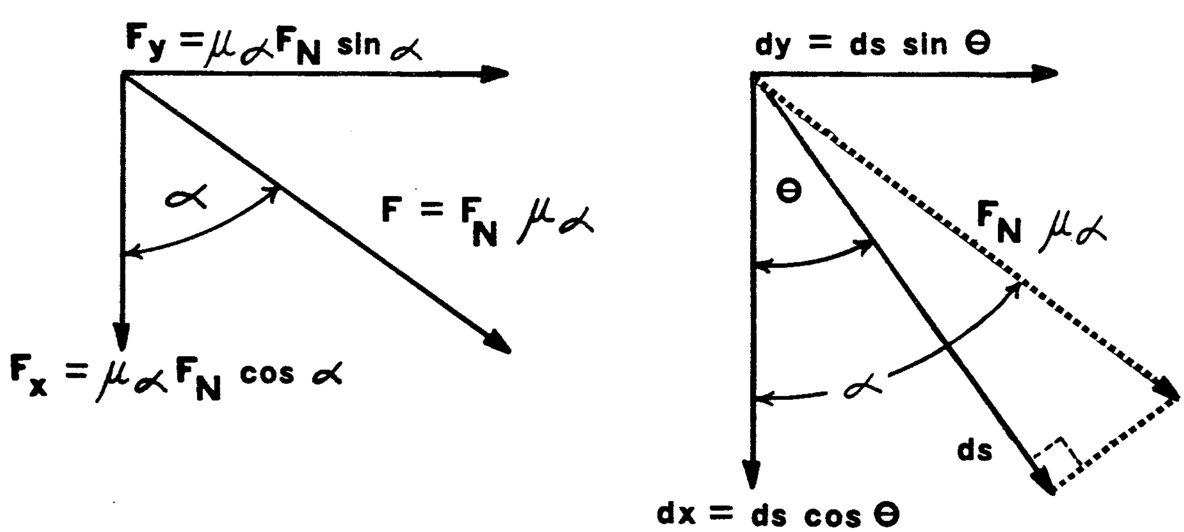


Figure 18. Forces and Displacements for Unequal Vertical and Lateral Friction Coefficients

5.4 CONCLUSIONS

The preceding review of limited test data justifies the provisional conclusion that the Friction Snubber Force Measurement System is capable of providing detailed information on the force environment in the bolster-side frame connection through the friction snubbers.

The main limitation of the transducer system is due to the fact that it could not be designed to be as stiff as the side frame column. As a result, the transition from static to sliding friction is not as abrupt during reversal of motion as one would expect, because of elastic deflections of the transducer elements during which the friction shoe and wear plate move together. This may account for the gradual rates of change in friction forces as well as for the rebound that appears to occur during breakout.

These shortcomings should not seriously impair the value of the information that can be obtained from the measuring system.

More extensive and detailed measurements of snubber friction will be obtained from road tests of the instrumented trucks ~~now in progress~~. Results of these tests will be presented and discussed in a future report.

SECTION 6

SUGGESTED UTILIZATION OF FRICTION SNUBBER FORCE MEASUREMENT SYSTEM

6.1 MEASUREMENT OF SIDE FRAME - BOLSTER INTERACTION UNDER SERVICE CONDITIONS

The capability to perform such measurements was the main objective of this endeavor. Until now, measurements of snubber friction have been performed only on stationary trucks, with instrumentation provided in fewer degrees of freedom.

As already mentioned, the transducer system was not completed in time to be utilized in Phase I of TDOP. However, the road test programs contemplated in Phase II provide an opportunity for testing the Friction Snubber Force Measurement System in the way originally intended. It will be essential to provide sufficient instrumentation on the modified trucks to ensure that a complete picture of the interaction between side frames and bolster can be reconstructed from the test data.

One additional use of the transducer not originally contemplated is the measurement of center plate friction torque during curve entry and exit. The truck bolster is slewed by a combination of longitudinal creep forces, and lateral creep and flange forces. The normal force transducers, which are in the load path between the wheelsets and the center plate, should respond to the longitudinal creep couples by a net increase in measured, forward normal force on the outside side frame, and in the rearward normal force on the inside side frame. The effect of lateral wheel loads, which force the truck out of tram, should result in an increase in the normal forces measured by all transducers, according to the reasoning presented above, as validated by the shop tests of the transducers.

Analogous results should be looked for during slow travel on tangent track when the truck travels along a sinusoidal path with a characteristic kinematic wavelength, and with a comparatively large amplitude. Because of the slow truck yaw velocity at low forward speed, center plate breakout friction will be observable, as was shown in records made during Phase I of TDOP, and should be measurable with the normal force transducers.

6.2 IMPROVED FRICTION DATA FOR MATHEMATICAL MODELS

The representation of damping has always been one of the less successful features in mathematical models of railway vehicles. This is demonstrated by the discrepancies, mentioned by a number of investigators, between predicted performance and actual test results.

There appears to be reasonable agreement concerning the material friction coefficients and overall snubber performance measured by energy dissipation under specified conditions typical of laboratory tests. However, current mathematical models do not include variations in the column load, and the consequent changes in friction forces, due to relative angular displacements between the side frame and bolster.

Results from road tests of the trucks instrumented with the Friction Snubber Force Measurement System offer the opportunity of replacing assumptions concerning snubber friction in mathematical models by realistic values that represent the full complexity of the snubbing system. This may serve to resolve some of the existing inconsistencies between predicted and measured performance and thus improve the predictive value of some mathematical models.

SECTION 7 - ACKNOWLEDGEMENTS

A number of individuals contributed to the successful completion of the project. Their support is gratefully acknowledged.

As Contracting Officer's Technical Representative (COTR) for Phase I of TDOP, Arne Bang, now Chief, Freight Services Division, Office of Freight Systems, FRA, not only supported the work, but broadened its scope to include both truck types, and specified that the trucks be modified to allow unrestricted use. In retrospect, these were wise decisions.

Mrs. Grace R. Fay, Research Manager, Office of Freight Systems, FRA, and COTR for Phase II of TDOP, saw the project to completion and began the arrangements for road testing of the instrumented trucks.

A number of Wyle Laboratories employees contributed significantly to the success of the project. The difficult modification of the side frames to close tolerances owes its success to the welding skill of Hoyt Brown. Bobby Davis solved the many assembly problems with patience and competence. Bruce Fowler acted as test engineer, and Bill Gray handled instrumentation and calibration.

Special thanks are due to Garth Tennikait, Manager of Test Engineering, American Steel Foundries, for his valuable advice and his readiness to accommodate the testing of a modified side frame in a crowded schedule.

Appreciation is also expressed to Robert Bullock, Manager of Research and Engineering, Standard Car Truck Company, for helpful discussion of load-dependent snubbing.

The writer is indebted to R.W. Radford, Chief Mechanical and Electrical Engineer, Canadian National Railway, for sharing his insights into the nature of the friction snubbing process.

APPENDIX A

SPECIFICATION AND AS-BUILT DRAWINGS

SPECIFICATION FOR A
FRICTION SNUBBER FORCE MEASUREMENT SYSTEM (FSFMS)

PREPARED FOR
SOUTHERN PACIFIC TRANSPORTATION COMPANY
UNDER CONTRACT 0302-94-171-91

BY
WYLE LABORATORIES
HUNTSVILLE, ALABAMA

WYLE JOB ORDER NO. 60400

1.0 SCOPE

1.1 Purpose

This specification covers the design, fabrication and calibration of eight triaxial force transducers, to be installed in the modified side frames of two freight car trucks, for the purpose of measuring normal and friction forces exerted between friction wedges and wear plates under operating conditions on the track.

1.2 Basis of Procurement

The transducers shall be procured on a sole source basis from Modern Machine and Tool Company, Inc. which was selected on the basis of its capabilities and experience in the development and construction of this type of equipment and has cooperated with Wyle Laboratories in the preliminary engineering required to fulfill the requirements. The system to be procured is identified by Modern Machine and Tool Company as FS-1-5.

2.0 CHARACTERISTICS, PERFORMANCE REQUIREMENTS AND ENVELOPE RESTRICTIONS

2.1 Type

The transducers shall be of the type in which bending strains due to imposed loads are transformed into proportional electrical signals by strain gauges. The internal construction of the transducer shall be such as to minimize out-of-plane deflections of the wedge-wear plate interface under loads applied centrally in any direction.

2.2 General Arrangement

Each transducer unit shall consist of two lateral force blocks, two normal force blocks, and one vertical force block, arranged substantially as shown in Modern Machine and Tool Company Drawing No. M750047, Rev. 1. The lateral and normal force blocks shall be combined into two units to minimize the envelope of the assembly within the restricted space available in the side frame. The permissible envelope of the assembly is shown in Wyle Laboratories Drawing No. E760038 (not included in this appendix).

2.3 Wear Plate Adapter

The wear plate shall be connected to the transducer assembly by the wear plate adapter, shown on Drawing No. E760038. The wear plate will be welded to the adapter by Wyle Laboratories. The material of the adapter shall be compatible with that of the wear plate (SAE 1095, Hardness 350-405 Brinell) to ensure a sound weld.

2.4 Mounting Adapter

A mounting adapter shall be provided to attach the transducer assembly to the modified column of the side frame, as shown in Drawing No. E760038. The mounting adapter shall have adequate strength and rigidity to support the loads given in paragraph 2.7 without excessive stress or deflection that might prejudice the function of the system. The mounting faces on the adapter, for the transducer and for attachment to the side frame, shall be plane and parallel.

2.5 Workmanship - Adapters

In order to protect personnel engaged in installing and servicing the FSFMS, all sharp edges and corners of the mounting and wear plate adapters shall be broken, and major surface irregularities such as burrs, flame-cut edges, and weld spatter, shall be smoothed by grinding.

2.6 Materials and Workmanship - Transducers

The transducers shall be built from materials, and to standards of workmanship, in accordance with the standards maintained by Modern Machine and Tool Company in equipment of this type.

2.7 Load Conditions

The transducers shall be designed to measure simultaneously the following loads applied simultaneously at the wear plate surface:

	Load Range	Overload
Normal:	±6000 lb	7500 lb
Lateral:	±3000 lb	4500 lb
Vertical:	±3000 lb	4500 lb

In view of the uncertainties inherent in the magnitudes of these loads (which the FSFMS is intended to resolve) the transducers shall be capable of supporting overloads of 400% without permanent set.

The material for the transducers shall be Armco 17-4 PH.

2.8 Strain Gauge Bridges

The strain gauge bridges shall have the following characteristics:

Signal	1 mv/v Nominal
Sensor	Four Arm Bonded Strain Gage Bridge
Bridge Resistor	350 ohms Nominal
Bridge Excitation	5 volts AC or DC
Compensated Temperature Range	30 F to 180 F
Non-Linearity	0.5% of Full Scale
Hysteresis	0.5% of Full Scale

The strain gauge assemblies shall be covered by a protective coating to provide protection against moisture and abrasion.

2.9 Electrical Connections

Each transducer assembly shall include five (5) cables, 18 in. long, terminating in A/N connectors, MS-3101A-14S-5S. Mating connectors shall be provided by Modern Machine and Tool Company.

3.0 MANUFACTURER, ACCEPTANCE AND SHIPMENT

3.1 Commencement of Work

Construction of the FSFMS shall be started upon approval of Southern Pacific Transportation Co., and issuance of notice to proceed from Wyle Laboratories.

3.2 Access

Representatives of Wyle Laboratories, Southern Pacific Transportation Company, and the Federal Railroad Administration shall have free access to inspect the work being performed for Wyle Laboratories, subject to reasonable notice being given of a planned visit.

3.3 Calibration

Each transducer assembly shall be calibrated by loading in all three axes, individually and simultaneously. The loads and outputs shall be recorded in a form making possible the determination of sensitivity, linearity and cross coupling. A brief outline of the test procedure, together with a copy of the form used to record performance shall be submitted at least one week prior to the calibration of the first transducer assembly, to enable Wyle representatives to comment, and allow time for preparing to witness the test.

3.4 Delivery

First Set of Four Transducers: No later than eight weeks A.R.O.
Second Set of Four Transducers: No later than 14 weeks A.R.O.

3.5 Shipment

When a group of four systems has been completed it shall be shipped to:

Wyle Laboratories
7800 Governors Drive West
Huntsville, AL 35807
Attn: K.L. Cappel

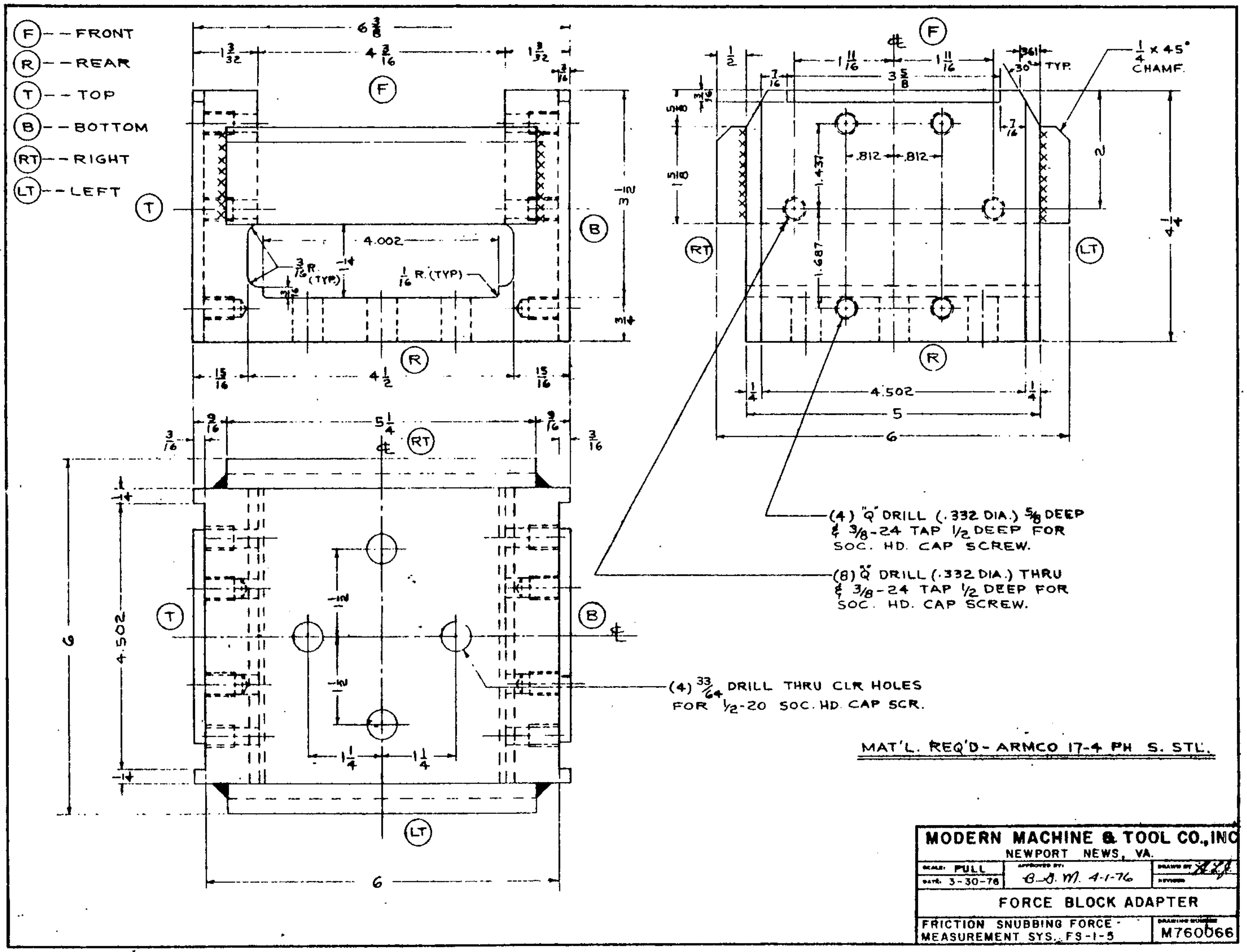
Packaging shall be adequate to preclude damage or deterioration during shipment.

3.6 Instrumentation Sheet(s)

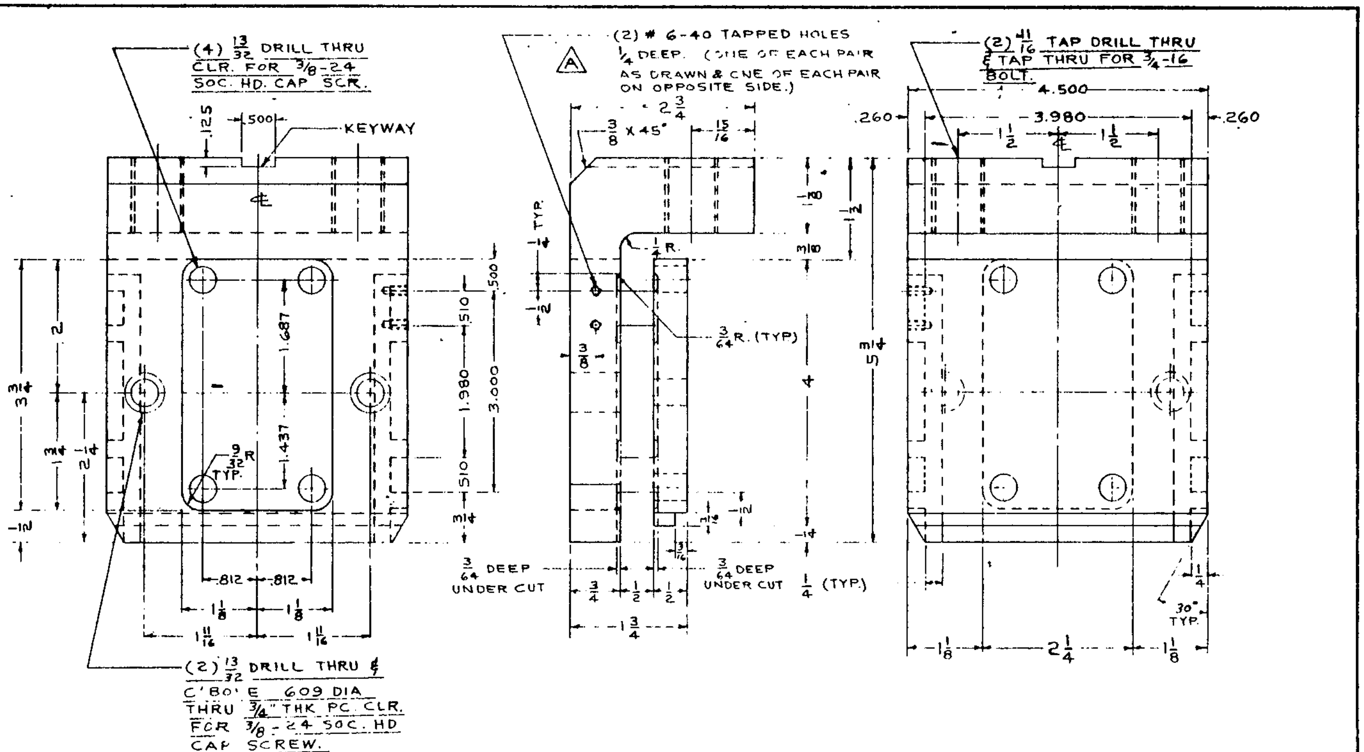
One reproducible and four (4) copies of an instruction sheet shall be provided to identify wiring, exciting voltage and any other data required to put the FSFMS into operation, and to preclude faulty handling.

3.7 As-Built Drawings

The final dimensions of the FSFMS shall be incorporated on the drawings. Alterations of drawings used for manufacture are acceptable. (The as-built drawings prepared by Modern Machine and Tool Company are shown on pp A-7 through A-10.)



F - - FRONT
R - - REAR
T - - TOP
B - - BOTTOM
RT - - RIGHT
LT - - LEFT
(4) "Q" DRILL (.332 DIA.) 5/8 DEEP & 3/8-24 TAP 1/2 DEEP FOR SOC. HD. CAP SCREW.
(8) "Q" DRILL (.332 DIA.) THRU & 3/8-24 TAP 1/2 DEEP FOR SOC. HD. CAP SCREW.
(4) 33/64 DRILL THRU CLR HOLES FOR 1/2-20 SOC. HD. CAP SCR.
1/4 x 45° CHAMF.
MAT'L. REQ'D - ARMCO 17-4 PH S. STL.
MODERN MACHINE & TOOL CO., INC
NEWPORT NEWS, VA.
SCALE: FULL
DATE: 3-30-76
FORCE BLOCK ADAPTER
FRICTION SNUBBING FORCE - MEASUREMENT SYS. FS-1-5
M760066

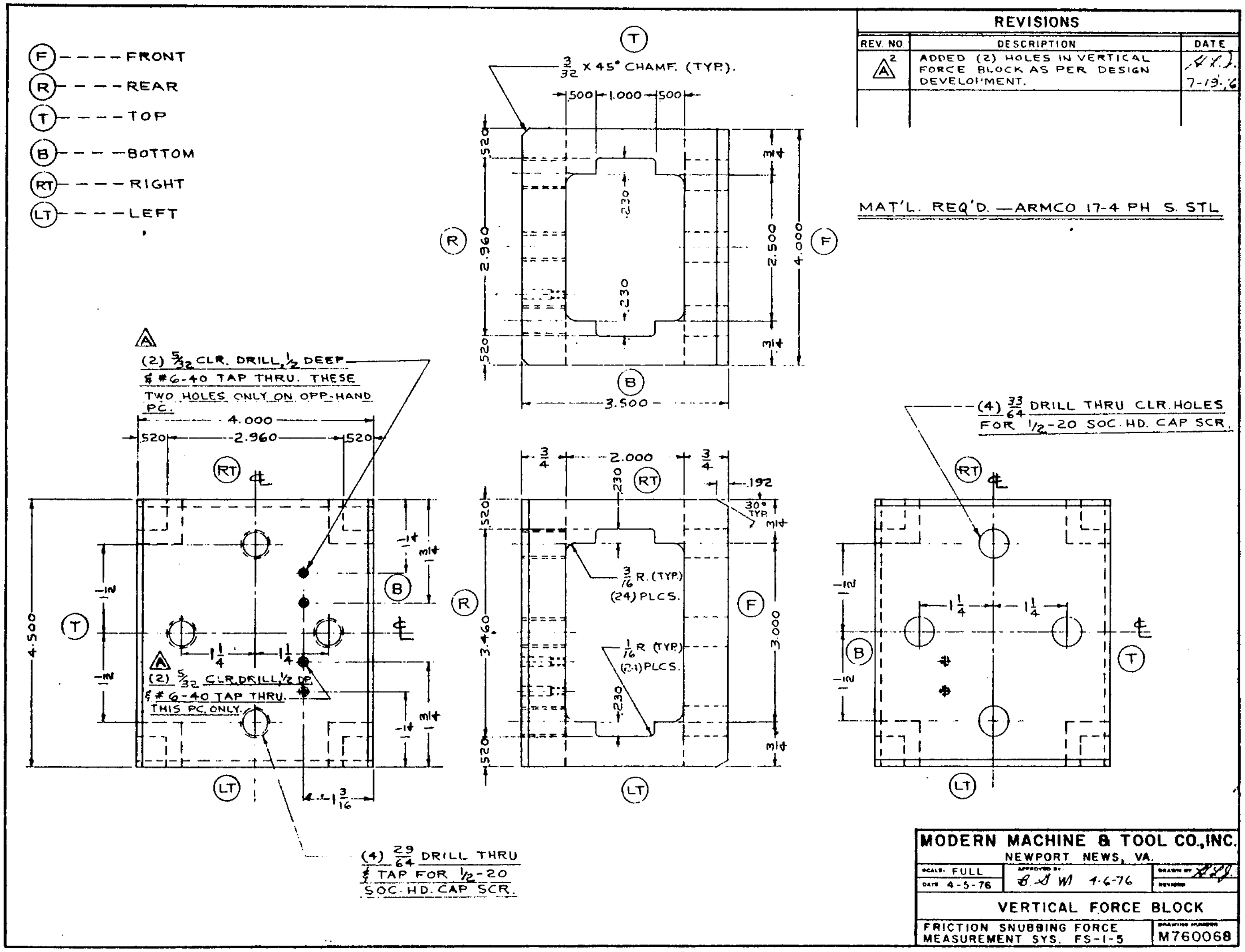


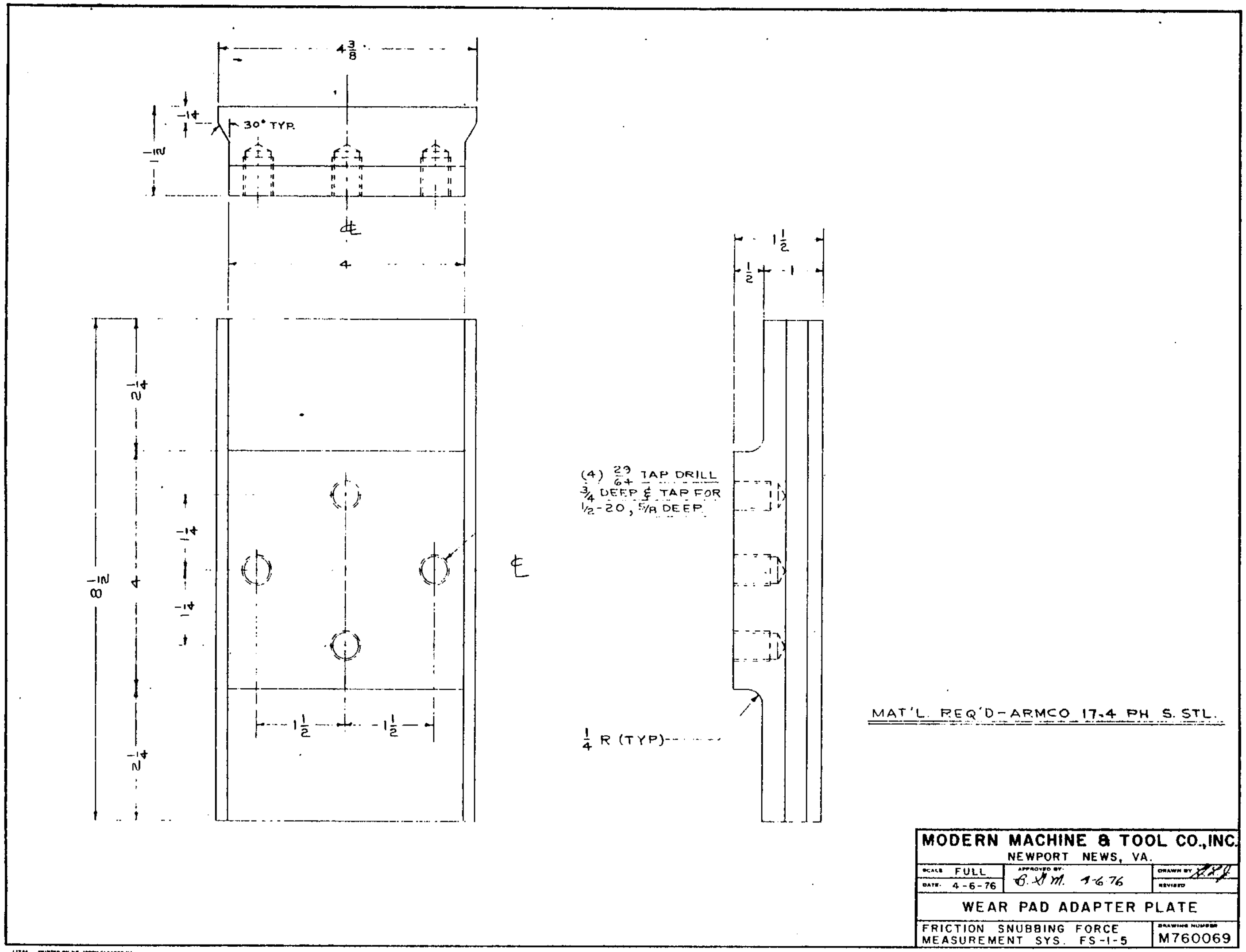
MAT'L. REQ'D. — ARMCO 17-4 PH S. STL.

(2) PCS. REQ'D. PER ASS'Y.

REVISIONS		
REV. NO	DESCRIPTION	DATE
A	ADDED (2) # 6-40 TAPPED HOLES TO FORCE BLOCK AS PER DESIGN DEVELOPMENT.	7-19-76

MODERN MACHINE & TOOL CO., INC. NEWPORT NEWS, VA.		
SCALE: FULL DATE: 4-1-76	APPROVED BY: B.J.M. 4-1-76	DRAWN BY
LATERAL & NORMAL FORCE BLOCK		
FRICTION SNUBBING FORCE MEASUREMENT SYS. FS-1-5		DRAWING NUMBER M760067


REVISIONS
REV. NO | DESCRIPTION | DATE
A2 | ADDED (2) HOLES IN VERTICAL FORCE BLOCK AS PER DESIGN DEVELOPMENT. | 7-19-76
F - - - - FRONT
R - - - - REAR
T - - - - TOP
B - - - - BOTTOM
RT - - - - RIGHT
LT - - - - LEFT
3/32 X 45° CHAMF. (TYP.)
MAT'L. REQ'D. — ARMCO 17-4 PH S. STL
(2) 5/32 CLR. DRILL, 1/2 DEEP & #6-40 TAP THRU. THESE TWO HOLES ONLY ON OPP-HAND PC.
(2) 5/32 CLR. DRILL 1/2 DP. & #6-40 TAP THRU. THIS PC. ONLY.
(4) 33/64 DRILL THRU CLR. HOLES FOR 1/2-20 SOC. HD. CAP SCR.
(4) 29/64 DRILL THRU & TAP FOR 1/2-20 SOC. HD. CAP SCR.
3/16 R. (TYP.) (24) PLCS.
1/16 R (TYP.) (24) PLCS.
30° TYP.
MODERN MACHINE & TOOL CO., INC.
NEWPORT NEWS, VA.
SCALE: FULL
DATE 4-5-76
APPROVED BY: B.S.W. 4-6-76
VERTICAL FORCE BLOCK
FRICTION SNUBBING FORCE MEASUREMENT SYS. FS-1-5
M760068


4 3/8
1/4
30° TYP.
1/2
℄
4
1 1/2
1/2
1
2 1/4
1 1/4
8 1/2
4
1 1/4
1 1/2
1 1/2
2 1/4
(4) 29/64 TAP DRILL 3/4 DEEP & TAP FOR 1/2-20, 5/8 DEEP
1/4 R (TYP)
MAT'L. REQ'D-ARMCO 17-4 PH S. STL.
MODERN MACHINE & TOOL CO., INC.
NEWPORT NEWS, VA.
SCALE FULL
DATE 4-6-76
APPROVED BY
4-6-76
DRAWN BY
REVISED
WEAR PAD ADAPTER PLATE
FRICTION SNUBBING FORCE MEASUREMENT SYS. FS-1-5
DRAWING NUMBER
M760069

APPENDIX B

RESULTS OF LATERAL LOAD TESTS

- need heading
for pictures

6"x11" SIDE FRAME MODIFIED BY WYLE LABORATORIES .... SER. NO. 14

STRESS (KSI) WITH TRANSVERSE LOADS OF 35 KIPS

GAGE NO.	LOCATION		DRAG SIDE UP	COPE SIDE UP	STRESS RANGE
1	SPRING SEAT RADIUS	COPE LEFT	23.7	-25.1	48.8
2		COPE RIGHT	23.6	-23.9	47.5
3		DRAG RIGHT	-28.9	30.9	59.8
4		DRAG LEFT	-33.0	34.1	67.1
* 5	COLUMN WALL OF LOWER BOLSTER OPENING	COPE RIGHT	-26.8	19.8	46.6
6		DRAG LEFT	12.2	-13.5	25.7
7	LOWER RADII IN MODIFIED COLUMN FACE OPENING	DRAG LEFT	-22.2	6.2	28.4
8		DRAG RIGHT	-23.7	5.2	28.9
9		COPE RIGHT	8.1	-9.8	17.9
10		COPE LEFT	3.9	-4.8	8.7
11	LOWER RADII OF WINDOW OPENING	COPE RIGHT	7.9	-9.4	17.3
12		DRAG RIGHT	-8.3	6.8	15.1
13		DRAG LEFT	-10.3	8.0	18.3
14		COPE LEFT	9.5	-12.8	22.3
15	VERT. INNER WELD AT JUNCTION OF COMPR. MEMBER & LARGE REINFORCEMENT BAR	DRAG LEFT	-15.8	14.8	30.6
16		DRAG RIGHT	-15.9	13.6	29.5
17		COPE RIGHT	18.9	-20.2	39.1
18		COPE LEFT	13.3	-15.1	28.4
19	SIDE WALL OF COMPRESSION MEMBER ABOVE WINDOW OPENING	COPE RIGHT	13.1	-13.9	27.0
20		COPE LEFT	11.6	-13.0	24.6
21		DRAG LEFT	-13.1	12.2	25.3
22		DRAG RIGHT	-12.8	11.5	24.3

* CORE SHIFT

9-7-76

Form 11-6-75

PROJECT NO. ______ DATE: 9-3-76

STRESS INVESTIGATION ON 6"X11" SIDE FRAME MODIFIED BY WYLE LABORATORIES - PATT. 7900D SERIAL NO. 14 TRANSVERSE LOADING - DRAG (INBOARD) SIDE UP

GAGE NO.	STRESS (KPSI) AT NET MACHINE LOAD (KIPS)					
	7	14	21	28	35	
1	4.7	9.6	14.3	18.9	23.7	
2	4.8	9.6	14.4	18.9	23.6	
3	-5.5	-11.3	-17.1	-23.0	-28.9	
4	-5.9	-12.5	-19.1	-25.9	-33.0	
5	-5.1	-10.4	-15.9	-21.3	-26.8	
6	2.6	5.1	7.4	9.8	12.2	
7	-3.8	-8.4	-12.8	-17.3	-22.2	
8	-4.7	-9.5	-14.3	-19.1	-23.7	
9	1.7	3.3	4.9	6.4	8.1	
10	1.0	1.7	2.5	3.1	3.9	
11	1.8	3.4	5.0	6.5	7.9	
12	-1.6	-3.2	-5.0	-6.7	-8.3	
13	-1.9	-4.2	-6.1	-8.2	-10.3	
14	2.2	4.1	5.9	7.7	9.5	
15	-3.0	-6.1	-9.4	-12.5	-15.8	
16	-3.1	-6.2	-9.5	-12.7	-15.9	
17	3.9	7.8	11.6	15.3	18.9	
18	2.9	5.6	8.2	10.8	13.3	
19	2.8	5.4	8.1	10.6	13.1	
20	3.0	5.1	7.4	9.4	11.6	
21	-2.7	-5.5	-8.0	-10.5	-13.1	
22	-2.5	-5.1	-7.8	-10.2	-12.8	

S-TD-37

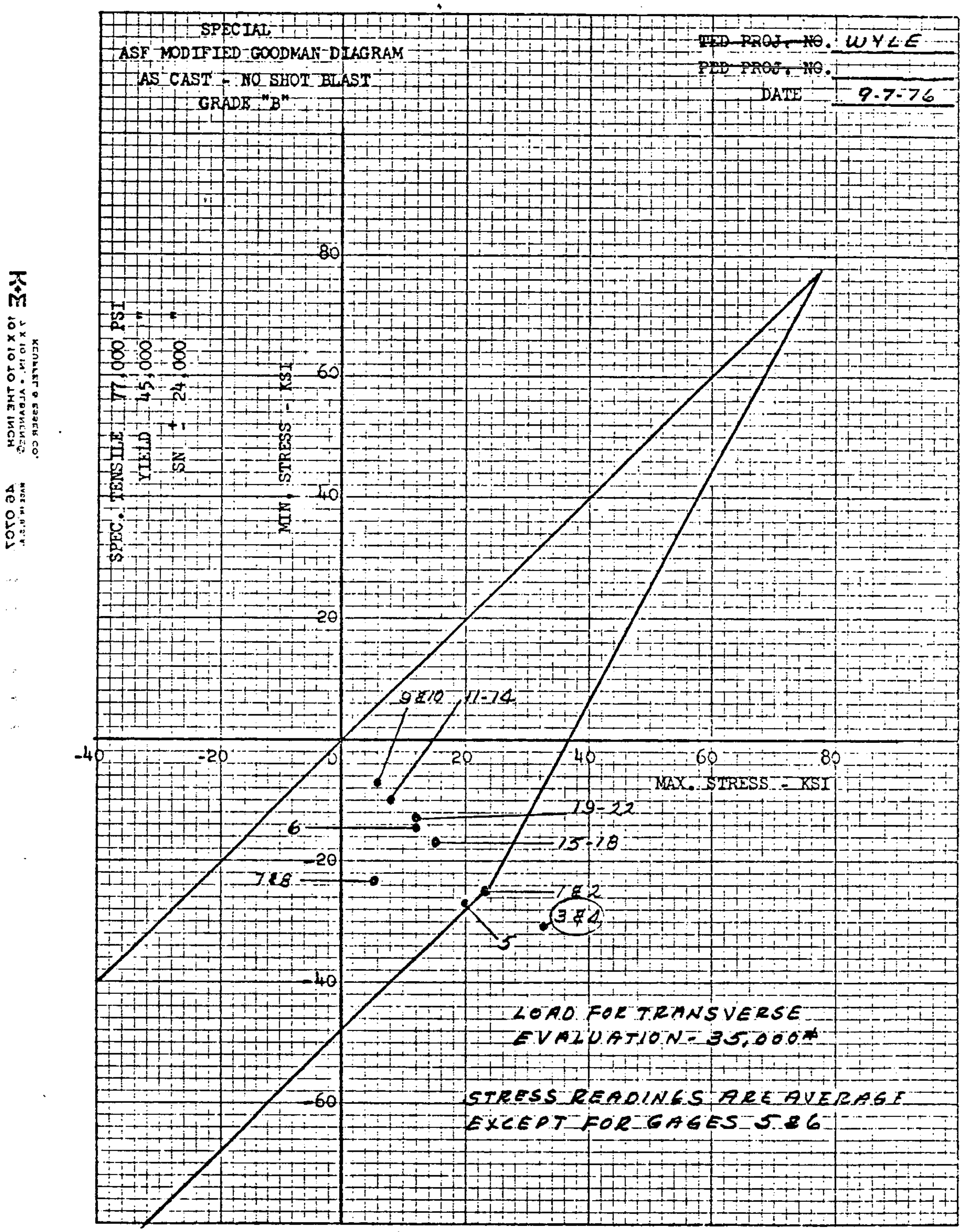
Form 11-6-75

PROJECT NO. ________ DATE: 9-7-76

STRESS INVESTIGATION ON 6"X11" SIDE FRAME MODIFIED BY WYLE LABORATORIES - PATT. 7900D SERIAL NO. 14 TRANSVERSE LOADING - COPE (OUTBOARD) SIDE UP

GAGE NO.	STRESS (KPSI) AT NET MACHINE LOAD (KIPS)					
	7	14	21	28	35	
1	-5.5	-10.3	-15.1	-20.3	-25.1	
2	-5.3	-10.1	-14.5	-19.4	-23.9	
3	7.0	13.1	19.0	25.1	30.9	
4	7.7	14.3	21.0	27.6	34.1	
5	4.3	8.1	11.8	15.9	19.8	
6	-3.0	-5.7	-8.2	-11.0	-13.5	
7	1.6	2.8	4.0	5.2	6.2	
8	1.5	2.4	3.3	4.3	5.2	
9	-2.7	-4.6	-6.4	-8.0	-9.8	
10	-1.2	-2.1	-2.9	-3.8	-4.8	
11	-2.2	-4.0	-5.7	-7.7	-9.4	
12	1.7	3.0	4.2	5.6	6.8	
13	2.1	3.7	5.0	6.6	8.0	
14	-2.5	-5.1	-7.7	-10.2	-12.8	
15	3.5	6.3	9.1	12.0	14.8	
16	3.3	5.9	8.4	11.2	13.6	
17	-4.7	-8.7	-12.4	-16.5	-20.2	
18	-3.4	-6.3	-9.1	-12.2	-15.1	
19	-3.2	-6.0	-8.5	-11.3	-13.9	
20	-2.9	-5.4	-7.8	-10.4	-13.0	
21	2.9	5.3	7.5	10.0	12.2	
22	2.9	5.2	7.4	9.4	11.5	

S-TD-37


SPECIAL
ASF MODIFIED GOODMAN DIAGRAM
AS CAST - NO SHOT BLAST
GRADE "B"
TED PROJ. NO. WYLE
PED PROJ. NO.
DATE 9-7-76
SPEC. TENSILE 77,000 PSI
YIELD 45,000 "
SN + - 24,000 "
MIN. STRESS - KSI
MAX. STRESS - KSI
80
60
40
20
-20
-40
-60
-40
-20
0
20
40
60
80
9 & 10
11-14
19-22
6
15-18
7 & 8
1 & 2
3 & 4
5
LOAD FOR TRANSVERSE EVALUATION - 35,000#
STRESS READINGS ARE AVERAGE EXCEPT FOR GAGES 5 & 6
K+E 10 X 10 TO THE INCH 46 0702
KEUFFEL & ESSER CO.

GRAPH -1

AMERICAN STEEL FOUNDRIES
PRODUCT DEVELOPMENT LABORATORY, GRANITE CITY, ILLINOIS
~~OFFICIAL A.A.R.~~ STATIC ~~APPROVAL~~ TEST
6" X 11" JOURNAL TRUCK SIDE FRAME

Test No._____ Date 9-3-76 Serial No. 14 Test Wt. _____ Est.Wt. _____

Patt.No. 7900D Drg. No._____ Manufactured by SCULLIN STEEL

Mfr'd. at _____ Type of Frame BARBER S-2

Grade Steel "B" Date Cast 1-76 Manufacturer's Witness _____

Heat No._____ Analysis: C._____ MN._____ SI._____ P._____ S._____

Physical: Yield _____ #/□" Tensile _____ #/□" Elong._____ % Red.in Area _____ %

COLUMNS MODIFIED BY WYLE LABORATORIES

TRANSVERSE TEST			
LOAD #	GAUGE 1	GAUGE 2	AVERAGE
5000	.000"	.000"	.000
15000	.0105	.015	.01275
25000	.020	.0315	.02575
5000	.002	.002	.002
*35000	.030	.0465	.03825
45000			
*60000			
SET 5000	.002	.002	.002

AAR SPECIFICATION M-203-76
GRADE "B" STEEL, WHEEL BASE,

TRANSVERSE
DEFL'N at 35,000# .070" Max.
SET after 60,000# _____" Max.

VERTICAL
DEFL'N at 117,500# _____" Max.
SET after 225,000# _____" Max.

ELASTIC LIMIT 212,500# Min.
Ultimate Load 625,000# Min.

*Specified Test Loads.

REMARKS:
AVERAGE DEFLECTION OF 6 DIFFERENT 6"X11" ASF PATTERNS TESTED IN THE PAST RANGED FROM .033" TO .044".

VERTICAL TEST			
LOAD #	GAUGE 1	GAUGE 2	AVERAGE
5000			
25000			
50000			
75000			
100000			
5000			
*117500			
125000			
150000			
175000			
200000			
*225000			
SET 5000			
250000			
275000			
300000			
325000			
350000			
375000			
400000			

ELASTIC LIMIT- #
LOAD (NOT ULTIMATE) (ULTIMATE)- #

OFFICIAL A.A.R. WITNESS: _____

Sheet 3 of 5 Sheets.

Form 11-6-75

PROJECT NO. ________________ DATE: 9-7-76

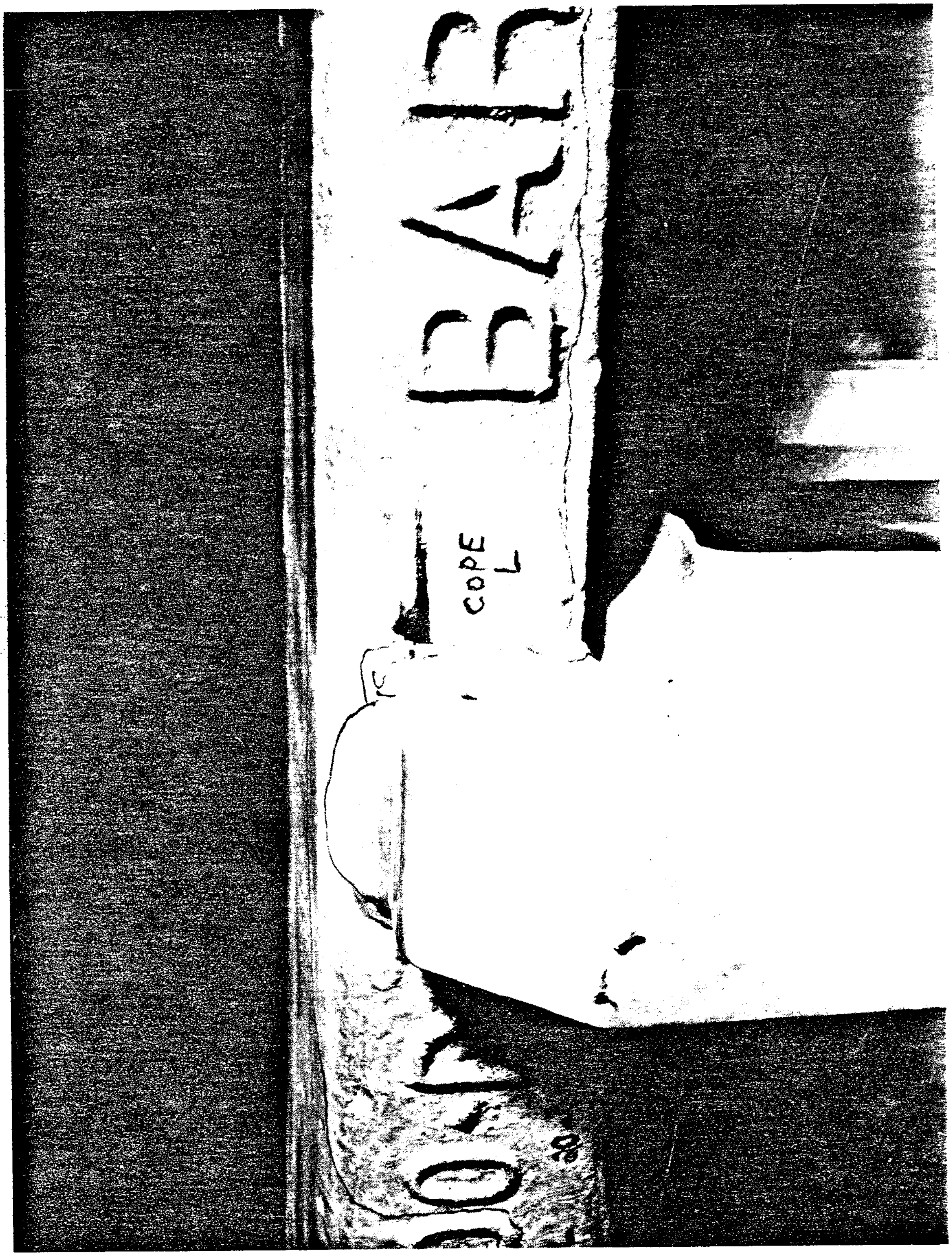
STRESS INVESTIGATION ON 6"X11" SIDE FRAME MODIFIED BY WYLE LABORATORIES - PATT 7900D SERIAL NO. 1A

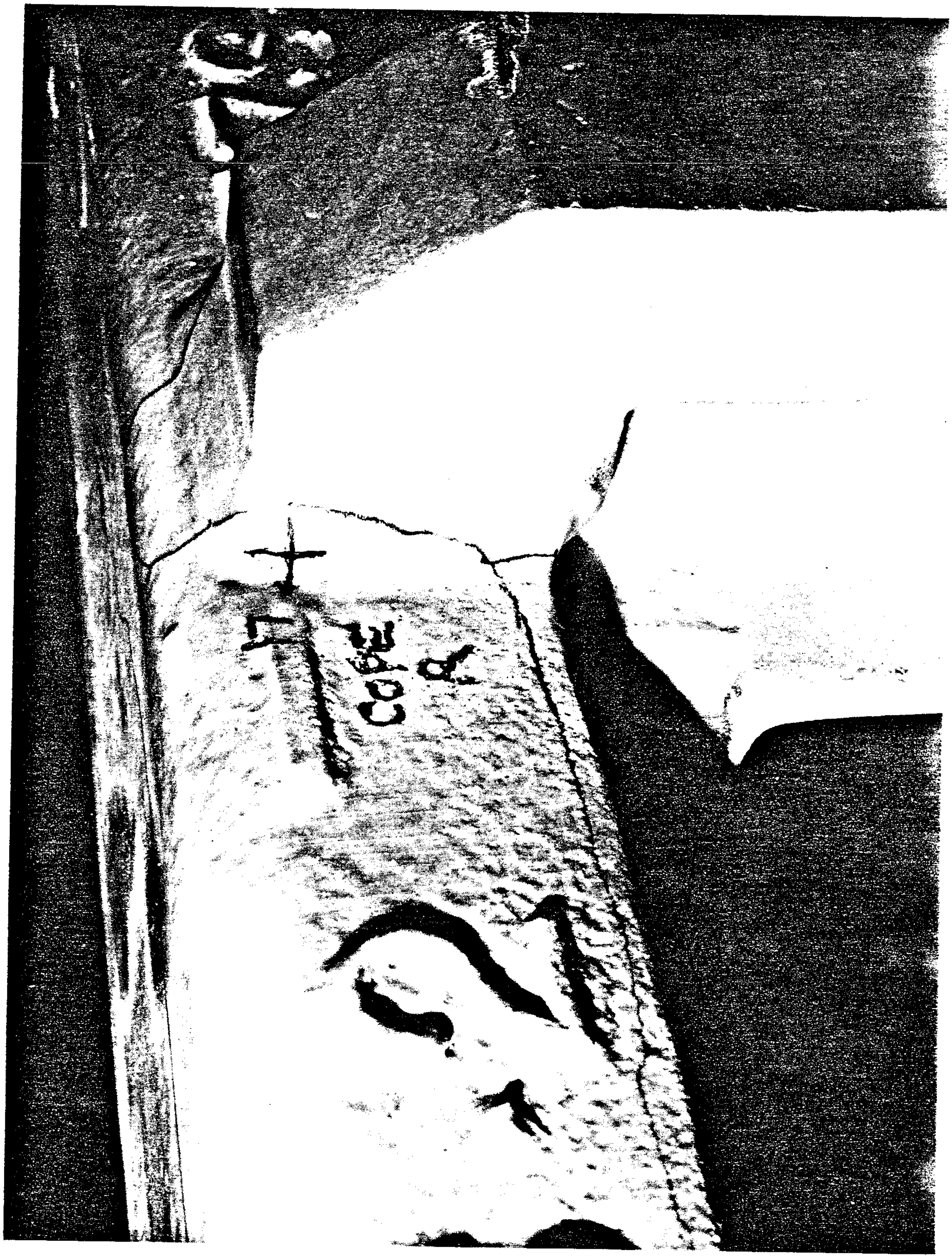
VERTICAL LOADING, SAME STRAIN GAUGES AS USED FOR THE TRANSVERSE LOAD INVESTIGATION

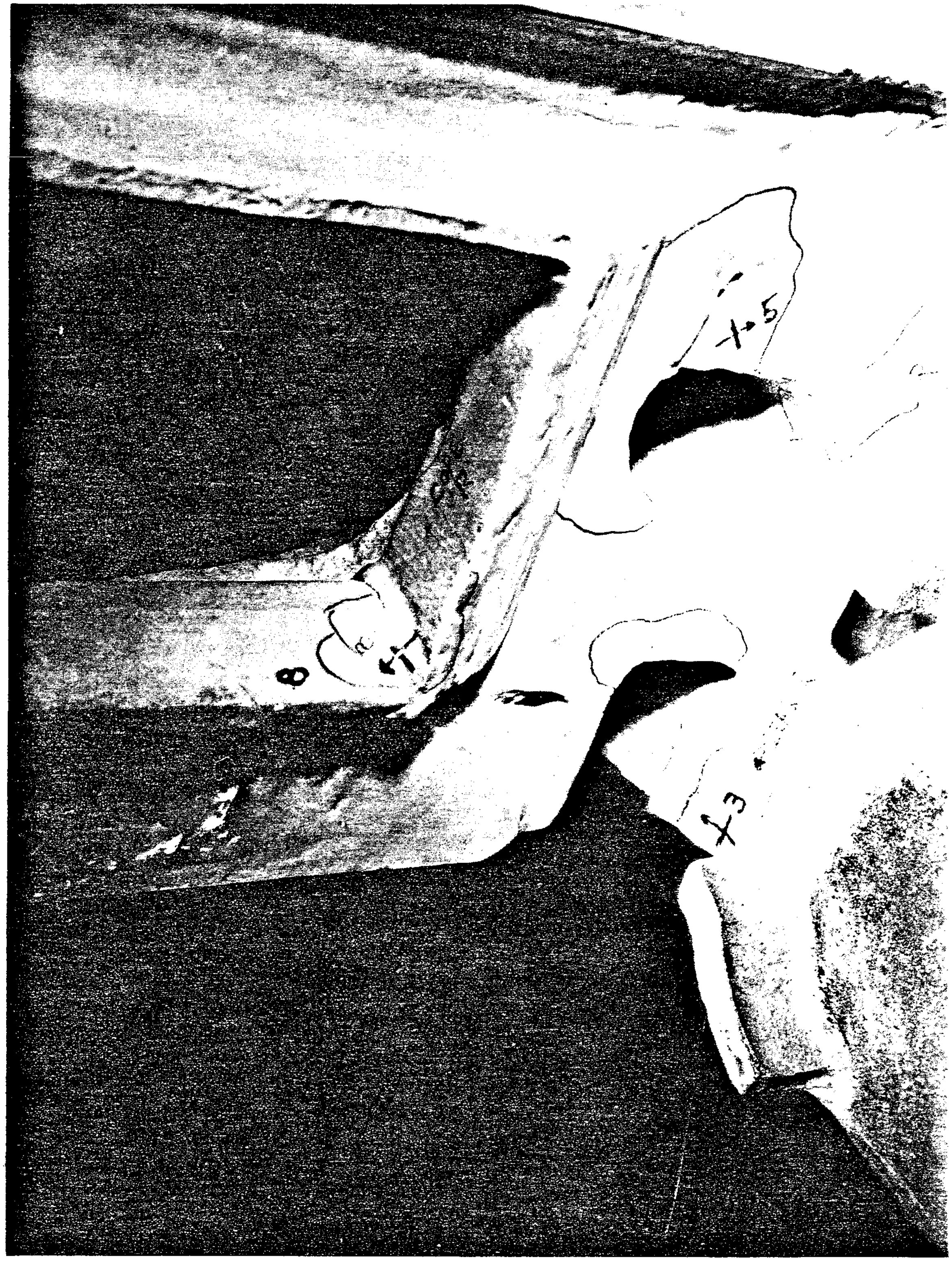
GAGE NO.	STRESS (KPSI) AT NET MACHINE LOAD (KIPS)					
	25	50	75	100	125	
1	6.8	12.9	19.1	25.4	31.7	
2	7.1	13.3	19.8	26.5	33.0	
3	3.5	7.2	11.2	16.0	21.2	
4	3.6	7.7	11.7	18.1	24.5	
5	0	.4	.8	1.2	1.8	
6	1.0	1.7	2.5	3.1	3.7	
7	.4	.7	1.1	1.5	1.9	
8	.7	1.0	1.5	2.0	2.8	
9	.7	1.4	2.2	2.9	3.6	
10	.7	1.2	1.7	2.1	2.6	
11	2.5	4.6	6.8	9.1	11.4	
12	1.5	2.7	3.9	4.9	6.0	
13	1.5	2.7	4.0	5.1	6.1	
14	2.8	5.0	7.2	9.5	11.7	
15	-2.2	-4.5	-6.5	-9.3	-12.1	
16	-2.3	-4.4	-6.3	-7.8	-9.3	
17	-2.3	-4.9	-7.2	-8.2	-9.4	
18	-1.6	-3.2	-4.7	-7.2	-9.7	
19	-1.1	-2.5	-3.8	-5.3	-6.9	
20	-1.2	-2.4	-3.4	-4.1	-4.9	
21	-2.0	-3.6	-5.2	-6.6	-8.0	
22	-1.9	-3.6	-5.2	-7.4	-9.6	

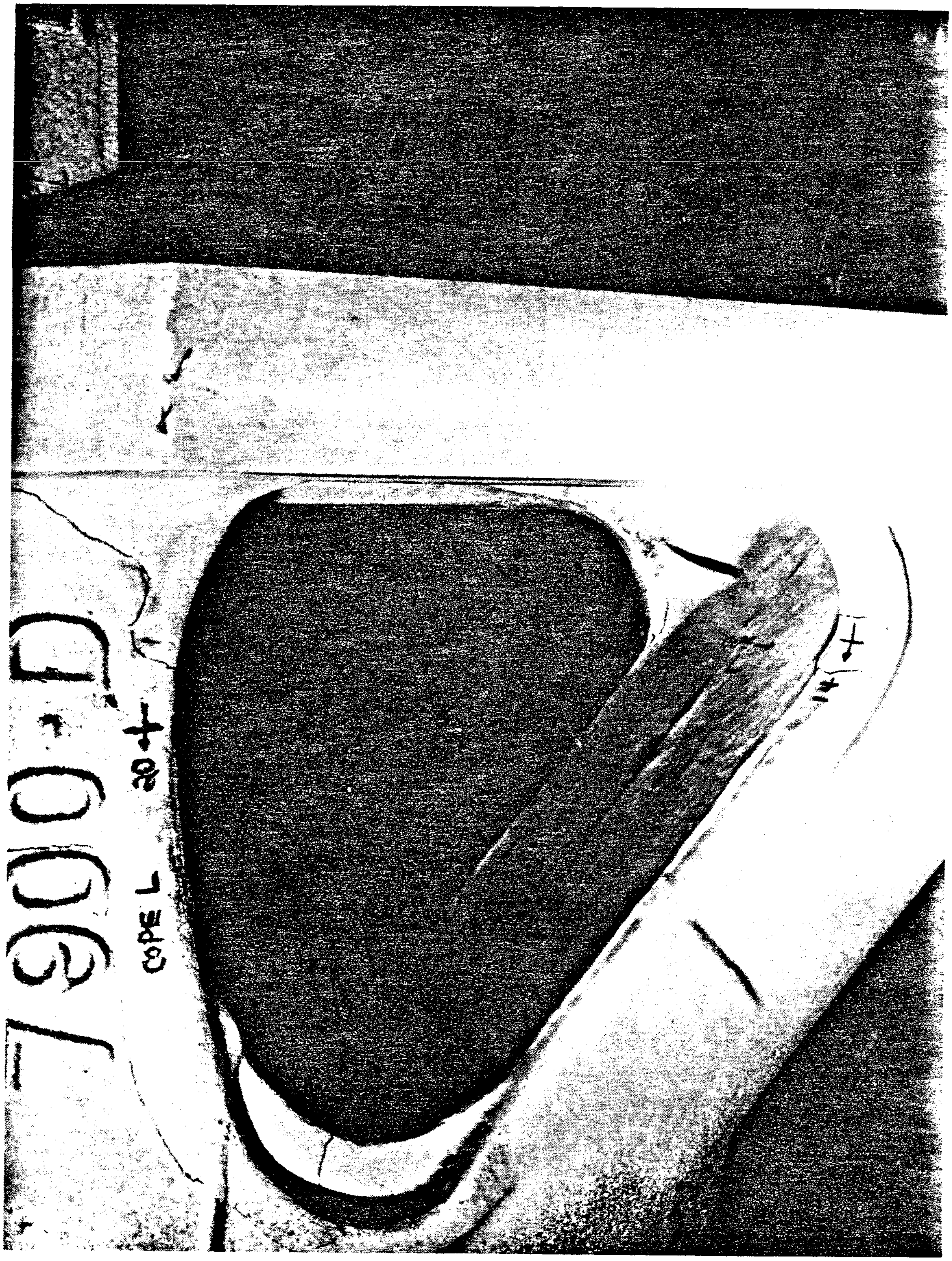
FOR ASF GRADE "B" STEEL "AS CAST - NO SHOT BLAST" THE FATIGUE LIMIT FOR ONE-WAY BENDING HAS BEEN DETERMINED AS 0-37,000 PSI ± 5000 PSI

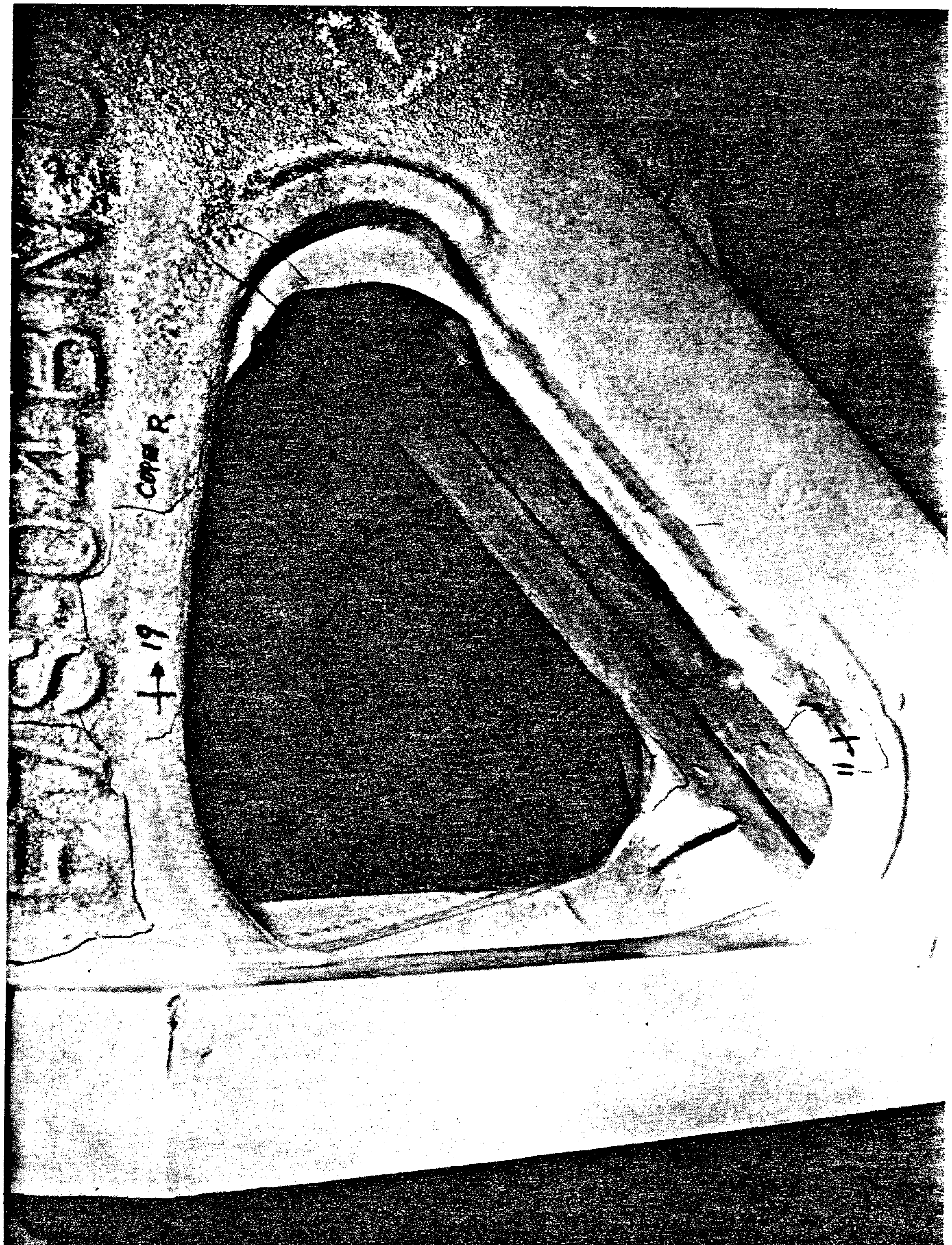
S-TD-37


BAR
COPE

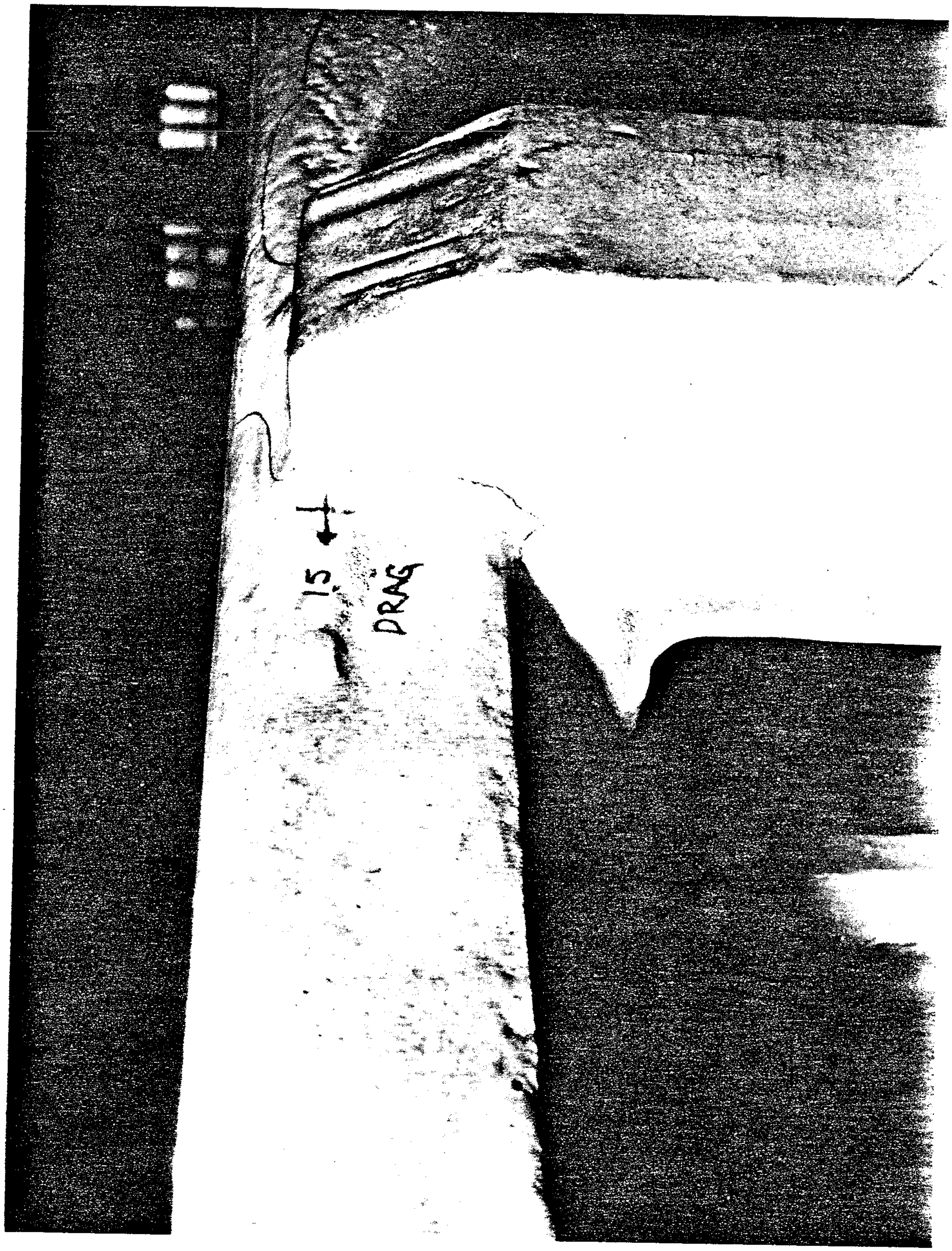





7900-D
COPE L




16
DRAG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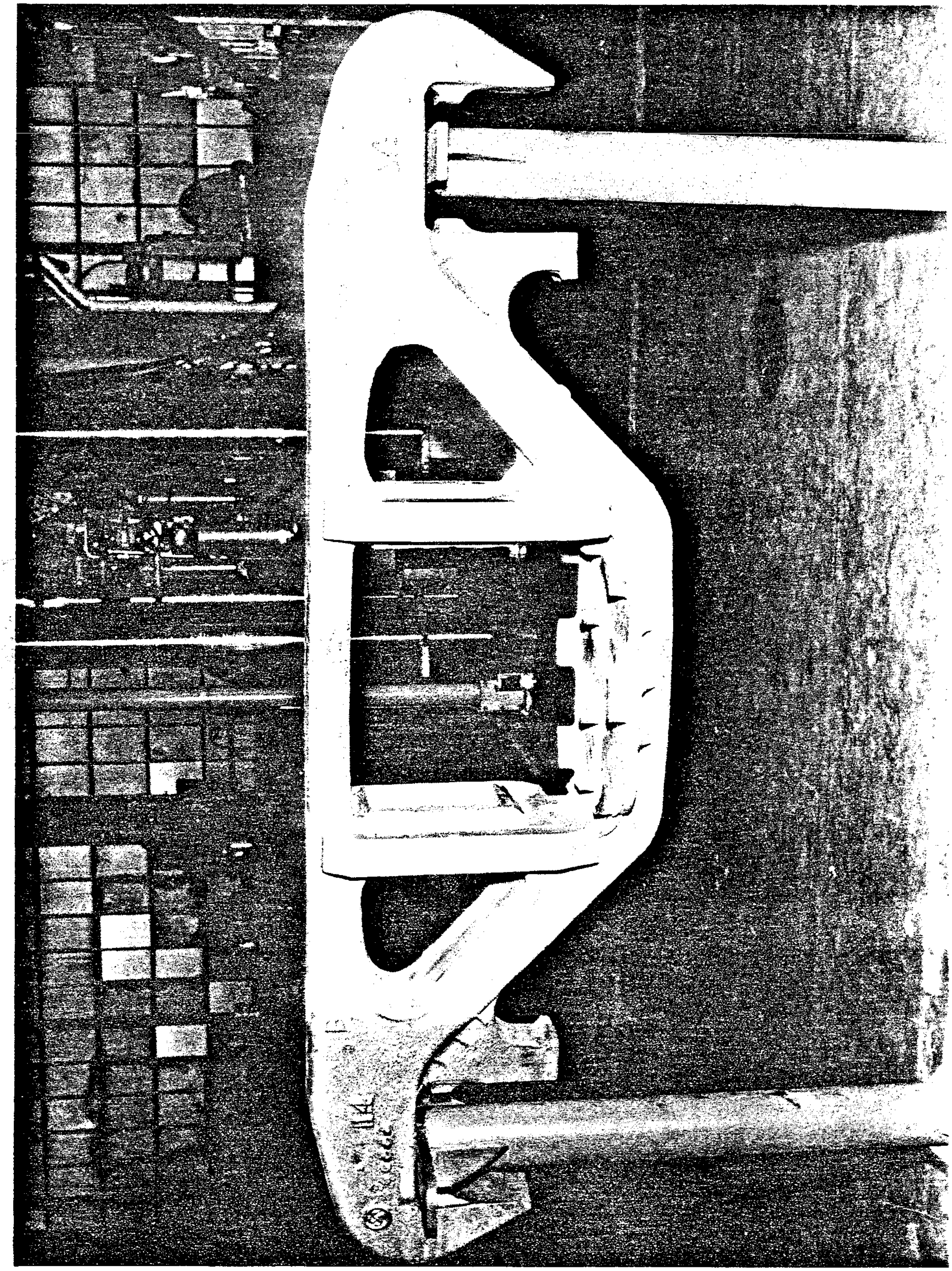
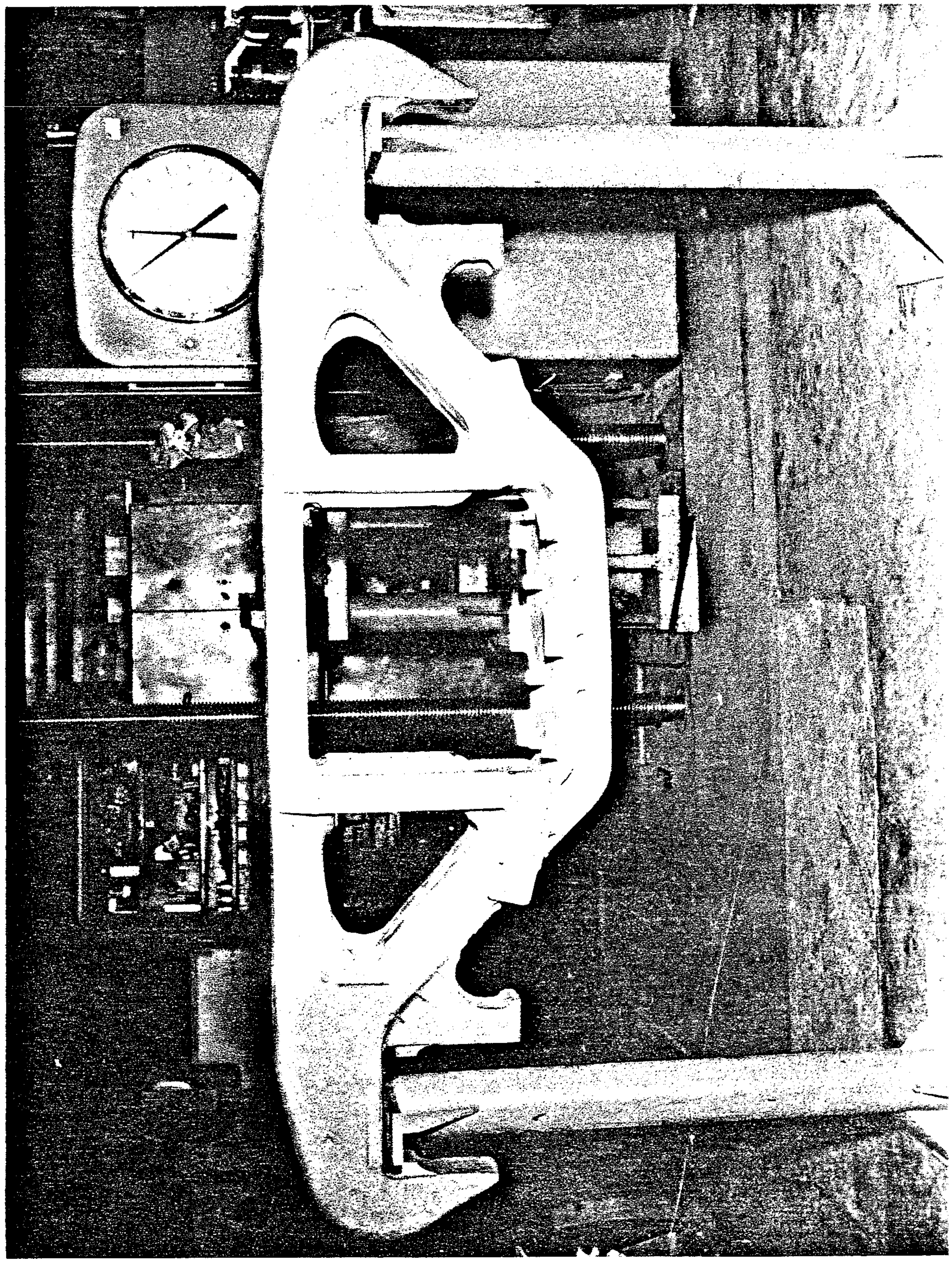
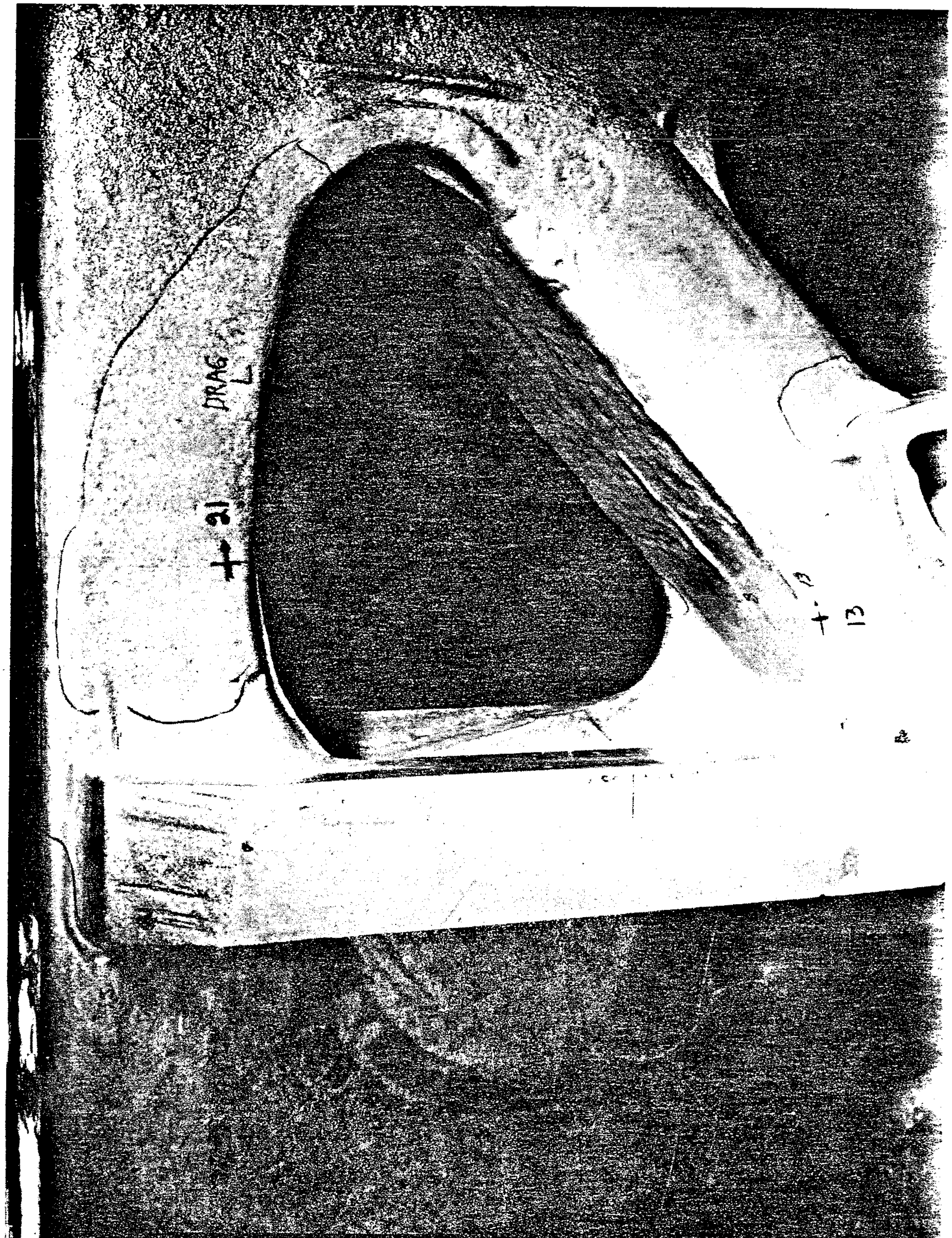
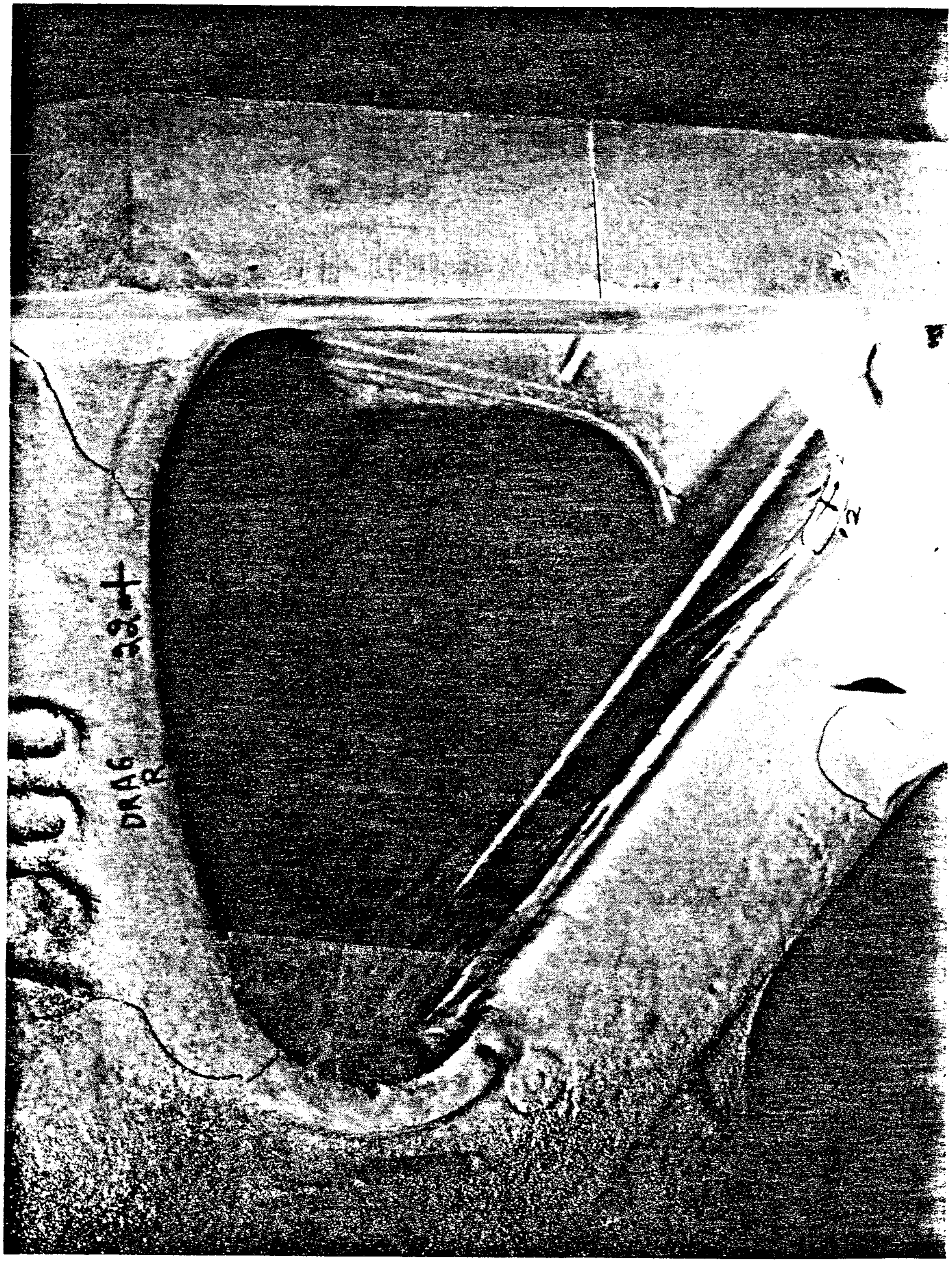
DRAG






DRAG
10


DRAG
21
13


DRAG