Report BRL TR-74-7173

AUTOMATIC BRAKES FOR MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES

FINAL REPORT

Contract H0110896

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February 1975

Prepared for

PITTSBURGH MINING and SAFETY RESEARCH CENTER
Bureau of Mines
U. S. Department of the Interior
Pittsburgh, Pennsylvania

FOREWORD

This final report was prepared by Bendix Research Laboratories, Bendix Center, Southfield, Michigan 48076, under USBM Contract H0110896. The contract was initiated under the Coal Mine Health and Safety Program. It was administrated under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. E. A. Curth acting as the Technical Project Officer. Mr. J. A. Herickes was the Contracting Officer for the Bureau of Mines.

This final report (BRL/TR-74-7173), Automatic Brakes for Mine-Track Transportation Systems in Underground Coal Mines, was prepared by A. M. Kiwior of the Applied Mechanics Department, under the direction of M. H. Cardon of the Automotive Program Management Center. Significant contributions to the investigations, design, development and system installation were made by A. Blatter, J. R. Lorraine, and D. R. Sproule. Consultation was provided by G. L. Judy of the mine consulting firm of George L. Judy Associates.

This final report is a summary of the work completed on this contract during the period of June 1971 to July 1974. This report was submitted by the author in December 1974.

TABLE OF CONTENTS

		Page
SECTION 1 - INTRODUCTION AND SUMMARY		1-1
1.1	Introduction	1-1
1.2	Summary	1-1
SECTION 2 - PREPARATION OF THE "STATE-OF-THE-ART" REPORT		2-1
SECTION 3 - PREPARATION OF THE "RECOMMENDED REGULATORY STANDARD"		3-1
SECTION 4 - DESIGN AND DEVELOPMENT OF THE BRAKE SYSTEM		4-1
4.1	Design Philosophy	4-1
4.1.1	Brake System Design	4-1
4.1.2	Permissibility	4-2
4.2	Locomotive Brake System Design	4-4
4.2.1	Operator Control	4-4
4.2.2	Electronic Controls	4-5
4.2.2.1	Speed Limit Control	4-11
4.2.2.2	Speed Sensor	4-11
4.2.2.3	Electronic Logic for Solenoid Control	4-15
4.2.2.4	Compressor Power Control	4-16
4.2.3	Brake System Power Source	4-18
4.2.4	Mechanical Brake Linkage	4-18
4.2.5	Locomotive Brakes Manual Override	4-19
4.3	Car Brake System Design	4-23
4.3.1	Car Brake Sub-Assembly	4-23
4.3.2	Automatic Latching Mechanism	4-32
4.3.3	Car Brakes Manual Override	4-34
4.3.4	Car Brake Air Cylinder Piston Seal Tests	4-35
4.3.5	Car Pneumatic Lines	4-35
4.3.6	Inter-Car Pneumatic Lines	4-35
SECTION 5 - BRAKE SYSTEM OPERATION		5-1
5.1	Locomotive Start-Up and Shut-Down Procedure	5-1
5.1.1	Locomotive Start-Up Procedure	5-1
5.1.2	Locomotive Shut-Down Procedure	5-2
5.2	Car Procedures	5-2
5.2.1	Car Coupling and Start-Up Procedure	5-2
5.2.2	Uncoupling Cars	5-3
5.3	Locomotive Service Brakes Manual Override	5-3

		Page
5.4	Car Service Brakes Override	5-4
	5.4.1 Manual Override	5-4
	5.4.2 Pneumatic Controlled Override	5-4
5.5	Overspeed	5-4
SECTION 6 - PREPARATION OF THE SYSTEM "MAINTENANCE MANUAL"		6-1
SECTION 7 - CONCLUSIONS AND RECOMMENDATIONS		7-1
7.1	Conclusions	7-1
7.2	Recommendations	7-1
SECTION 8 - PATENTS AND INVENTIONS		8-1
APPENDIX A - ASSEMBLY DRAWINGS		A-1
APPENDIX B - RECOMMENDED REGULATORY STANDARD FOR AUTOMATIC AIR-BRAKE SYSTEMS ON MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES		B-1

LIST OF ILLUSTRATIONS

Figure No.	Title	Page
1-1	View of Modified Bruceton Mine Electric Locomotive and Coal Cars	1-2
4-1	Schematic Diagram of Pneumatic System	4-6
4-2	Locomotive Cab	4-7
4-3	Brake Lever Positions	4-8
4-4	Pneumatic Brake Valve	4-8
4-5	Dead-Man Handle	4-9
4-6	Motor/Starter Box with Cover Removed	4-9
4-7	Wiring Diagram of Locomotive	4-10
4-8	Electronic Control Unit	4-12
4-9	Electronic Control Unit (E.C.U.) Schematic	4-13
4-10	Electronic Control Unit with Cover Removed	4-14
4-11	Electric Locomotive - Battery-Box End	4-17
4-12	Locomotive Chassis with Battery Box Removed	4-20
4-13	Locomotive Brake Mechanism	4-20
4-14	Locomotive Manual Brake Override	4-21
4-15	By-Pass Valve and Pump Wheel	4-22
4-16	Car Brake Assembly	4-35
4-17	Proposed Brake Sub-Assembly	4-27
4-18	Car Brake Linkage - Initial Design	4-29
4-19	Test Fixture - Brake Sub-Assembly	4-30
4-20	Test of Prototype Brake Linkage	4-31
4-21	Latching Mechanism Positions	4-33
4-22	Coal Car Manual Brake Lever Positions	4-36
4-23	Coal Cars - Manual Brake Lever End	4-36
4-24	Air Cylinder Assembly	4-37
4-25	Exploded View of Filter Assembly	4-37
4-26	Cars Pneumatically Coupled and Uncoupled	4-38

Table No.		
4-1	Solenoid Control Requirements	4-16

SECTION 1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

In 1969, the Congress of the United States declared that "the first priority and concern of all in the mining industry must be the health and safety of its most precious resource - the miner." Therefore, Public Law 91-173, Federal Coal Mine Health and Safety Act of 1969, was enacted.

Since haulage accidents account for a high percentage of coal mining accidents, Section 314e, "Hoisting and Mantrips," was included in the law. This section states: "Each locomotive and haulage car used in an underground coal mine shall be equipped with automatic brakes, when space permits. Where space does not permit automatic brakes, locomotive and haulage cars shall be subject to speed reduction gear, or similar devices approved by the Secretary which are designed to stop the locomotive and haulage cars with the proper margin of safety."

The contract "Automatic Brakes For Mine-Track Transportation Systems in Underground Coal Mines" was issued by the U.S. Bureau of Mines to Bendix Research Laboratories to further the development of such systems.

1.2 SUMMARY

The general scope of the work performed during this contract was the design and development of automatic braking gear and standards for use in coal-mine track haulage systems, equipping a battery-powered locomotive operating with five coal-haulage cars at the Bureau of Mines' Safety Research and Experimental Coal Mine with the system developed, and demonstrating the use and adequacy of the system.

Specifically, the following major tasks and this final report were completed:

- A report, "State of the Art of Underground Coal Mine Tracked Vehicle Brake Systems," was compiled and published. This report is a summary of information concerning coal mine trip practices and equipment used in United States and foreign mines.
- A fail-safe automatic braking system was designed and installed on the U.S. Bureau of Mines' Bruceton electric-powered locomotive (4 tons), and five 2-ton capacity coal haulage cars shown in Figure 1-1. The concept of the fail-safe brake system is that the brakes are applied at all times and can be released only if all the brake system components function properly. Thus, any brake system failure will result in a brake application. A speed sensor, controlled by the locomotive forward-axle

Figure 1-1 - View of Bruceton Mine Electric Locomotive and Coal Cars

drive chain, will limit the trip speed to 6 mph by applying the brakes if a speed over 6 mph occurs. If a trip separation occurs, the pneumatic intercar connection will automatically disconnect and brakes are applied. Also, a latching mechanism is provided so that the car brakes may be left inactive, thereby allowing the cars to be moved freely through dumping and loading areas.

- Maintenance of the modified Bruceton locomotive and five coal-haulage cars was conducted for a period of six months after the Bureau's acceptance of the braking system.
- A manual, "Maintenance Manual for the Bruceton Locomotive and Haulage Cars Modified under Contract H0110896," was prepared and published which serves as an all-inclusive brake system reference for the modified rolling stock.
- A report was prepared and published which contains a "Recommended Regulatory Standard for Automatic Air Brake Systems on Mine-Track Transportation Systems in Underground Coal Mines." This recommended regulatory standard establishes performance and equipment requirements.

The hardware feasibility of the automatic brake system has been demonstrated. The implementation of the hardware, an objective of this contract, has been successful. The next logical step is to modify and adapt this type of braking system to a larger, more conventional-sized locomotive and coal haulage cars, a task for a follow-on phase.

SECTION 2

PREPARATION OF THE "STATE-OF-THE-ART" REPORT

The objective of preparing this report was to gather information concerning coal mine trip practices and equipment used in United States and foreign mines. The information was gathered from literature published in this field, visits to typical United States production coal mines, and consultation with coal mining authorities. Included in this report are descriptions of existing brake systems used on tracked vehicles and the areas which will be affected by adding brakes to the cars.

Specific areas of interest were: brake systems, couplers, car trucks, and car handling procedures. Problems related to adding brakes to the haulage cars appear to be: the limited amount of space to mount the brakes on the cars, brake line connection between rotary dump cars, achieving desirable braking characteristics without over-complicating the system, and keeping the cost of installation reasonable.

In general, it is observed that existing mining equipment is rugged, simple, and effective, and any additional equipment should be designed accordingly.

Included in the state-of-the-art report is Appendix A, "Locomotive and Car Operation Requirements" which has data extracted from the report published by E. A. Curth of the USBM entitled "Causes and Prevention of Transportation Accidents in Bituminous Coal Mines;" Appendix B, "Tracked Vehicle Brake Practice," which has data extracted from the 1961 Car Builders Cyclopedia, published by Simmons Boardman; and Appendix C, "Electric Locomotive Brake Gear," which has data extracted from the report by L. M. Szklarski entitled "Underground Electric Haulage."

SECTION 3

PREPARATION OF THE "RECOMMENDED REGULATORY STANDARD"

The proposed regulations as set forth in the report "Recommended Regulatory Standard for Automatic Air-Brake Systems On Mine-Track Transportation Systems In Underground Coal Mines" are intended to change mining equipment and practices to provide safe working conditions for mine personnel. The recommended regulatory standard represents the accumulation of the best information available from discussions with mining consultants, observations made at representative mines; investigation of the state of the art of mine locomotive and haulage car brake systems; review of existing standards and practices; and the design, development and installation of automatic brakes on a mine electric locomotive and five coal haulage cars.

This regulatory standard is recommended as a guide in enforcing Public Law 91-173 "Federal Coal Mine Health and Safety Act of 1969." Its purpose is to insure safe braking performance of mine-track transportation systems in underground coal mines, under normal and emergency conditions, by defining safety-related functional and performance requirements for the brake system.

The complete report "Recommended Regulatory Standard for Automatic Air-Brake Systems on Mine-Track Transportation Systems in Underground Coal Mines" is included as Appendix B of this report.

SECTION 4

DESIGN AND DEVELOPMENT OF THE BRAKE SYSTEM

The design and development of this brake system was directed specifically to the modification of the rolling stock at the USBM's Bruceton facility. A four-ton locomotive, and 5 two-ton coal haulage cars were all modified and outfitted with a Bendix, custom-designed, fail-safe air-brake system.

The locomotive is a battery-operated electric type, manufactured by the National Mine Service Company. The end dump, four-wheeled coal haulage cars were manufactured by the Irvin-Sensenich Company.

4.1 DESIGN PHILOSOPHY

The brake system developed during this contract is designed for total braking, with a fail-safe operation. The concept of the fail-safe brake system is that the brakes are applied at all times and can be released only if all the brake system components function properly. Thus, any brake system failure will result in a brake application.

Also, a speed sensor, controlled by the locomotive foreward-axle drive chain, will limit the speed of the trip to 6 mph by applying the brakes if a speed over 6 mph occurs.

In the event of an accidental trip separation, the pneumatic inter-car connection will automatically disconnect and the brakes will be applied on all vehicles, thereby preventing runaways.

Although the primary advantage of this system is improved safety, the simplified operation and greater braking response should lead to greater productivity.

4.1.1 Brake System Design

The fail-safe brake system is implemented by mechanical springs which provide the brake application energy and a pneumatic system to release the brakes. An electric-powered compressor, along with its air reservoir and all pneumatic controls, is located in the locomotive battery box.

Also included in the brake system is an electronically controlled speed sensor and a runaway vehicle prevention.

Besides the automatic air brake, the locomotive retains an emergency, manual (hydraulic) brake-override system.

Each of the five coal cars has two sets of brake sub-systems, one for each side of the car. A latching mechanism, described in Section 4.3.2, is provided so that the car brakes may be left inactive, thereby allowing the cars to be moved freely through dumping and loading areas. The latching mechanism can be controlled pneumatically by the motorman from the locomotive cab or manually by the brakeman at the car.

4.1.2 Permissibility

During review meetings with the U.S. Bureau of Mines personnel, it was determined that the permissibility of the Bruceton locomotive be maintained under any modifications. This request was for compliance with mandatory standards under CFR 75.500(c): "All electric face equipment which is taken into or used inby the last open crosscut of any coal mine classified under any provision of law as a gassy mine prior to March 30, 1970, shall be permissible."

Bendix built the automatic brake system with all permissible components to ensure compliance with the mine regulations and allow unrestricted use of the equipment under all mine conditions. Building the locomotive electrical system consisted of purchasing permissible boxes within which the electrical components were mounted, purchasing permissible components, testing some components for intrinsic safety, and mounting the system in the locomotive.

"Permissible equipment" is defined by the U.S. Bureau of Mines in Schedule 2G as meaning "a completely assembled electrical machine or accessory for which a formal approval has been issued as authorized by the Director of the Bureau of Mines under Section 212(a) of the Federal Coal Mine Safety Act, as amended [66 Stat. 709; 30 U.S.C., Sec. 482(a)]."

Permissible boxes within which the electrical components were mounted were purchased with standard permissible stuffing boxes. Several switching components were tested by the U.S. Bureau of Mines for intrinsic safety. "Intrinsically safe" is defined as meaning "incapable of releasing enough electrical or thermal energy under normal or abnormal conditions to cause ignition of a flammable mixture of methane or natural gas and air of the most easily ignitible composition."

A listing of the major components and their permissibility status are as follows:

(See Table next page)

Component	Permissibility Status
Electrical Control Unit	Mounted in a permissible box.
Tie-Point Box	Used a permissible tie-in to the power source, and installed a permissible circuit-breaker box.
Connector Box	Mounted in a permissible box.
Motor	Permissible motor.
Solenoid Valves	Permissible valves.
Two Pressure Switches Logic Circuit	Tested for intrinsic safety.
Pressure Switch, Compressor Starter	Mounted in a permissible box.
Two Limit Switches	Switches mounted in permissible boxes.
Speed Sensor	Mounted in a permissible box.
Compressor Motor/Starter	Mounted in a permissible box.

The locomotive was inspected and approved as permissible by the U.S. Bureau of Mines before it was shipped to the Bruceton facility.

4.2 LOCOMOTIVE BRAKE SYSTEM DESIGN

The locomotive contains the motorman brake control, all of the electronic controls, the pneumatic power source, the locomotive brake linkage, and a manual (hydraulic) override brake. Each of these areas is described in the following sections.

A schematic drawing of the total pneumatic system with its list of materials is shown in Figure 4-1.

4.2.1 Operator Control

The brake system of the locomotive and the entire trip is controlled by a control valve located on the floor of the locomotive cab. This control valve, shown in Figure 4-2, is operated by a brake lever which is located for convenient use by the motorman. Originally, the handle of a mechanical rachet-type brake mechanism was located in this area. Pulling the brake lever to the BRAKES ON position vents the brake lines through the control valve and allows the brake springs to apply force to the brake shoes. When released, the lever is spring-returned to the BRAKES OFF position. Figure 4-3 shows the brake lever positions as limited by the control-valve selector plate. Pressures, as indicated on the brake pressure gage in the cab (P3), are 0 to 80 psi for proportional-force brake release, 110 psi for car brake latching, and 150 psi for car brake unlatching. These pressure levels may be adjusted by loosening the lock screw beneath the selector plate and sliding the stops to the desired new position.

An outline of the control valve and the location of the brake lever can be seen in BRL Drawing D-2176445 in Appendix A. A cross section of the control valve assembly is shown on BRL Drawing D-2176447. The control valve, shown schematically in Figure 4-4, is a pneumatic, spring-balanced spool valve, which controls the air pressure supplied to the brakes. The valve spool is 0.75 inch in diameter, and uses a line-on-line metering edge. Both spool travel-to-vent and travel-to-supply are 0.20 inch maximum. The output pressure is supplied through an orifice to one end of the spool. The pressure at one end of the spool is balanced by a spring at the other end of the spool and the spring is controlled by the brake handle. This valve gives a pressure directly related to the handle position. When the brake handle is in the normal operating position, air flows from the supply at the right to the brake line port. When the pressure in the brake line has built up, the spool is centered by the brake pressure feedback to the right side of the spool which is balanced by the spring at the left end. When the brake handle is moved, the spring force changes and the valve comes to rest at a new brake pressure.

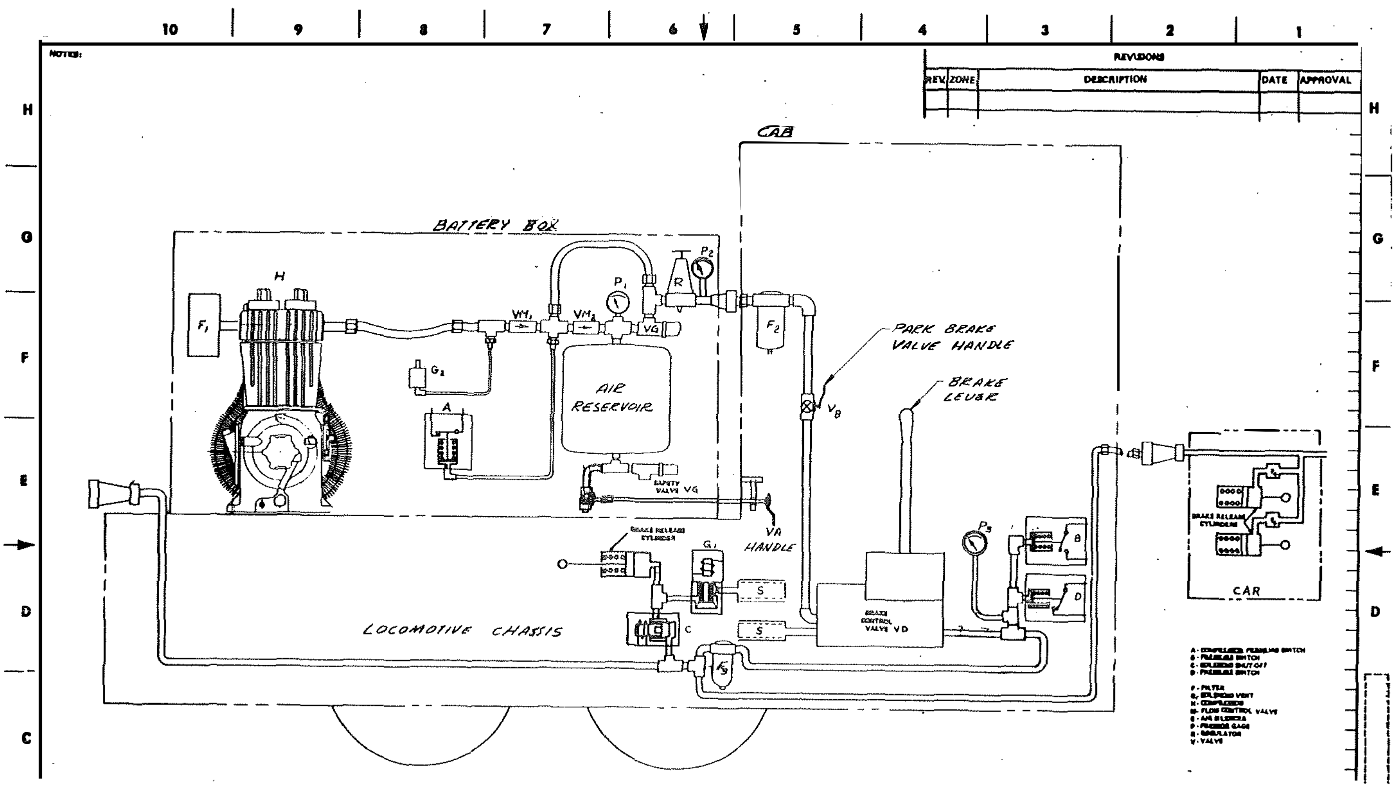
During development, tests were performed to determine an optimum orifice size and to insure valve stability. In order to optimize orifice size (to dampen flow between the brake line and spool back-pressure area), the orifice diameter was increased and the valve was tested to determine the rate at which the spool oscillation dampened. The orifice, shown in Figure 4-4, was initially drilled at 0.0145 inch diameter. Succeeding orifices were increased in diameter by increments of approximately 0.002 inch. For each orifice size, two supply pressures were tested. The brake line pressure was recorded as a function of time, showing damping rate as the oscillation went to zero. The final test was run with the orifice removed. It was noted that as the orifice diameter increased, the high and low pressures became more stable, and the amplitude of oscillation decreased. It was also noted that as the orifice size increased, it was more difficult to initiate the oscillation. In one test, with a 0.030-inch diameter orifice and a supply pressure of 120 psig, a vent was fully opened in the brake line to simulate a brake line loss. The valve showed no instability and could not be made to oscillate. As a result of these tests, the orifice screw was removed before the valve assembly was installed in the locomotive.

Initially, a dead-man handle and linkage, as shown on sheet 1 of BRL Drawing D-2176447, was designed, fabricated and tested as part of the control valve lever. However, after mine operation usage, the dead-man feature was removed at the request of the Bureau. During the initial program requirements review, the Bureau requested that a dead-man approach be utilized on the braking system. During operation using the original design, the dead-man handle was found to require too much force to hold it closed for long periods of time. One reason for this force was the misalignment of the handle with the cable at the end of the turnbuckle. For this reason, the turnbuckle was replaced with a thimble and wire-rope clamp, leaving the length adjustment to be done in the handle as shown in Figure 4-5. To reduce the force still further, the pivot point on the dead-man handle was moved closer to the cable to improve the mechanical advantage. In the final rework of the locomotive, the dead-man portion of the control was completely eliminated. Although the dead-man handle served a useful function, it was a nuisance to the locomotive operator and prevented him from using his hand to operate other controls.

4.2.2 Electronic Controls

The electronic controls for the brake system are all located on the locomotive. All electrical power, both 40 Vdc and 80 Vdc, is taken from the original four 20-Vdc Gould locomotive batteries.

The electronic control circuits associated with this brake system are protected by fuses located in the motor/starter box as shown in Figure 4-6. All four fuses in the box are 10-ampere regular-blow fuses (Limitron type KTK10 or equivalent). A schematic and wiring diagram of the compressor motor/starter is shown on Control Products, Inc., Drawing C-14538 which is included in Appendix A. Also, Figure 4-7, the wiring diagram of the locomotive, includes the motor/starter schematic.



	1	ONE WAY VALVE	PARKER #C-1200-S-10	VM1
	1	BALL VALVE ON-OFF	APOLLO # 70-103	VA
	1	REGULATOR	WILKERSON 2001-6H	R
	1	PRESSURE GAGE	MARSH INC. IDHC-2410U-E[illegible]	P1
	1	PRESSURE SWT.	CONTROL PROD. #D-12942	A
	2	ONE WAY VALVE	SERVICE MFG. 583-3/4/01	VM2
	1	SOLENOID VALVE	SKINNER # X5C56260	G2
	1	COMPRESSOR	QUINCY # 325P-25TG	H
	1/CAR	FILTER	WILKERSON #1117-2	F4
	1	COMPRESSOR FILTER	QUINCY # 7430 X	F1
	1	SOLENOID VALVE	SKINNER #XL2CX104	C
	1	SOLENOID VALVE	SKINNER #XLP1CX26	G1
	2	AIR SILENCER	WILKERSON AS-5311-6MD	S
	1	PRESSURE SWITCH	ALLEN-BRADLY #C7E	D
	1	PRESSURE SWITCH	ALLEN-BRADLY #C7E	B
*	1	PRESSURE GAGE	HYDRO PARK #102-0-200	P3
*	1	PRESSURE GAGE	HYDRO PARK #102-0-200	P2
*	1	BALL VALVE ON-OFF	WAVCO 600-5811 R	VB
*	1	FILTER	WILKERSON 1138-6-MF	F3
*	1	FILTER	WILKERSON 1138-6-MF	F2
QTY REQD	QTY REQD	DESCRIPTION	CODE IDENT / PART OR SPECIFICATION NO.	ITEM
*		LIST OF MATERIALS		

* PART IS DEFINED ONLY ON THIS PRINT

NEXT ASSY | FINAL ASSY
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAM. ± 10°
SURFACE FINISH MICROINCHES RHR
MATERIAL:

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SOUTHFIELD, MICHIGAN

TITLE
PNEUMATIC SCHEMATIC

SIZE C | CODE IDENT NO. 11272 | 2179324 | REV. X1
SCALE | WT | SHEET 2 OF 2
DEPT NO. 830

Figure 4-1 - Schematic Diagram of Pneumatic System

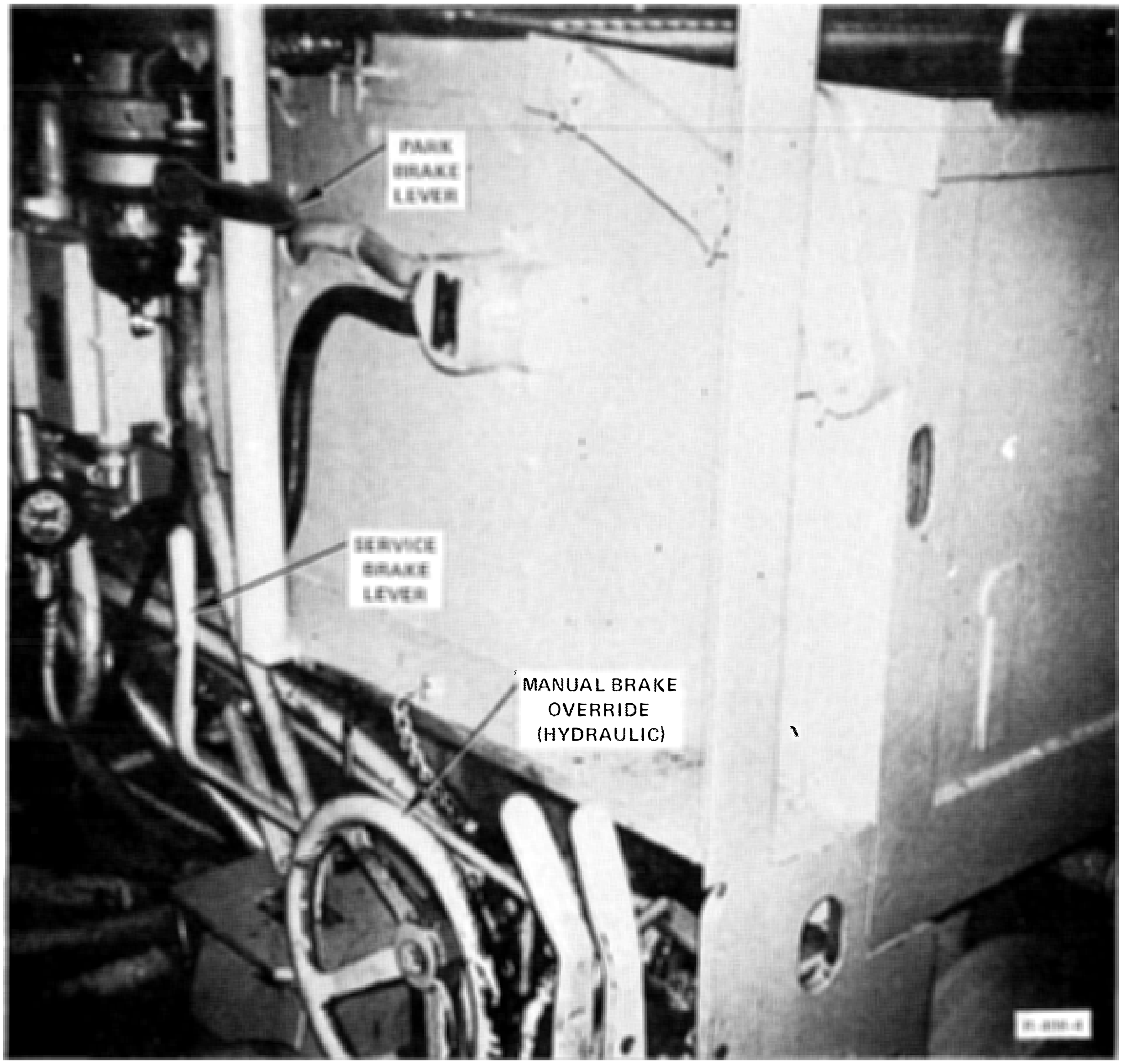


Figure 4-2 - Locomotive Cab

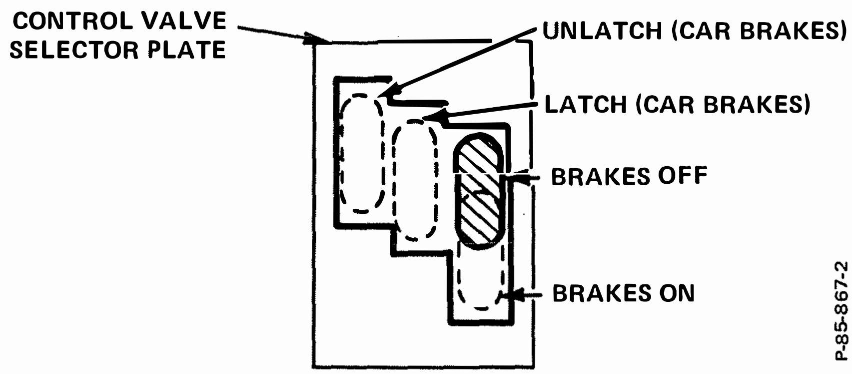


Figure 4-3 - Brake Lever Positions

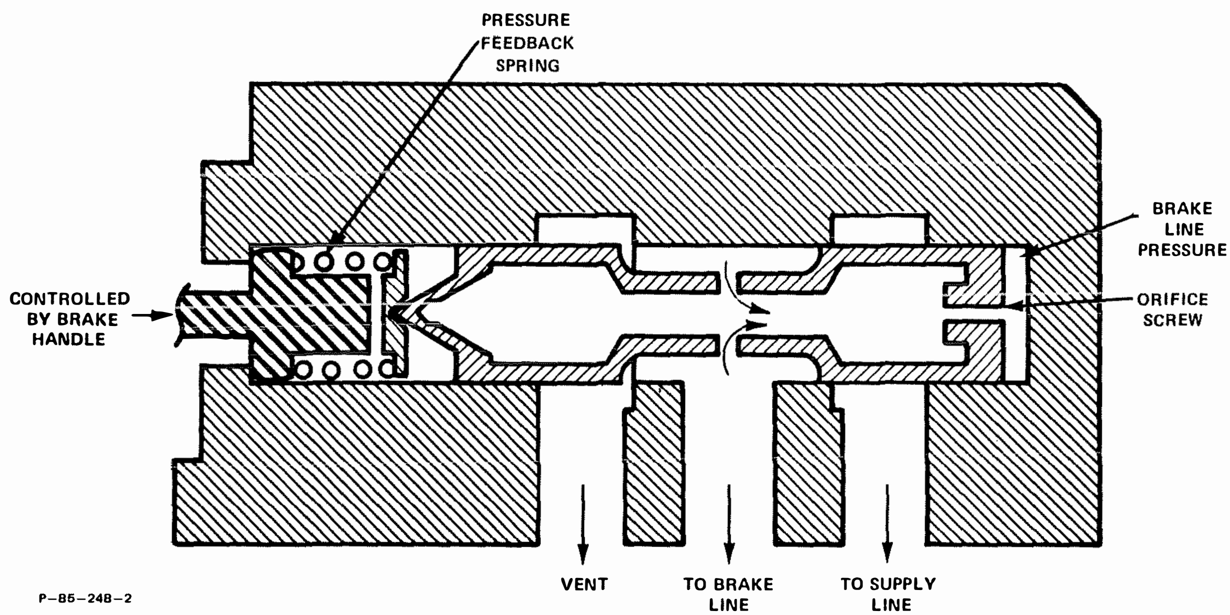


Figure 4-4 - Pneumatic Brake Valve

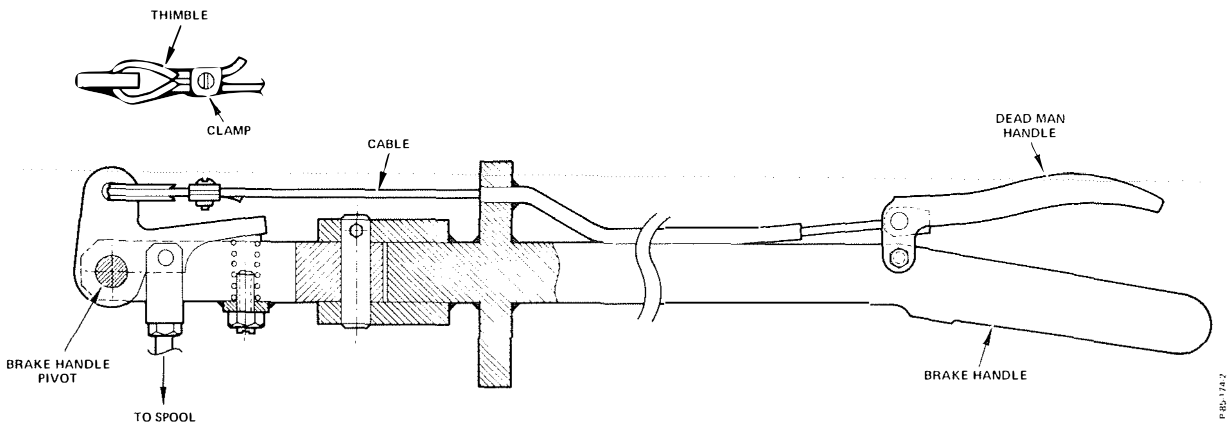


Figure 4-5 - Dead-Man Handle

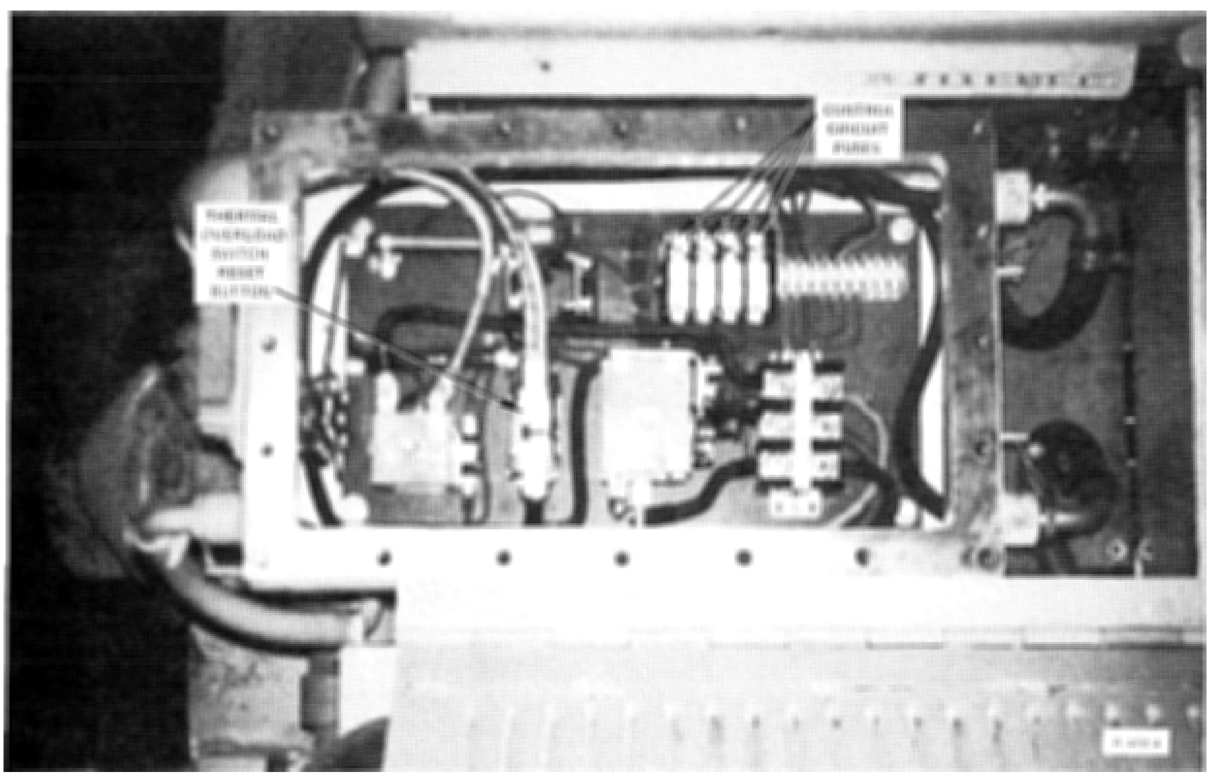


Figure 4-6 - Motor/Starter Box With Cover Removed

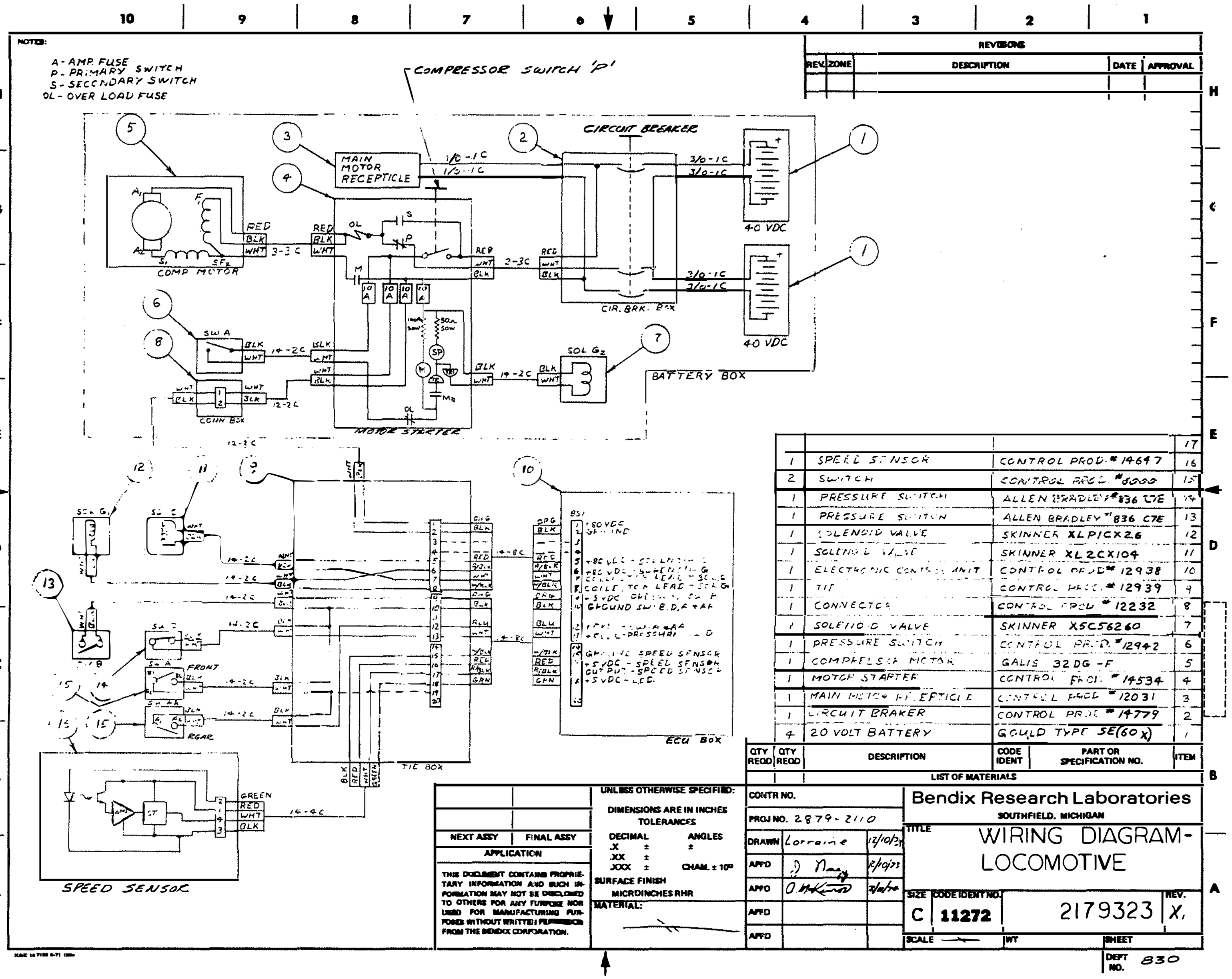


Figure 4-7 - Wiring Diagram of Locomotive

4.2.2.1 Speed Limit Control

The speed limit control senses excessive locomotive speed and applies the brakes in order to bring the trip under control. When the speed exceeds the set speed limit, solenoid G1, shown in Figures 4-1 and 4-7, is activated and vents the brake release pressure, thus applying the brakes. The brakes may be released when the speed has been reduced below the reset speed by pressing the OVERSPEED RESET button located on the electronic control unit panel. The electronic control unit, shown in Figure 4-8, is mounted in the locomotive cab, within convenient reach of the motorman. Figure 4-9 is the schematic for the electronic control unit (ECU) and Figure 4-10 shows the circuit boards inside the ECU.

In typical usage, when the locomotive speed reaches a preset speed (6 mph on the original system), the overspeed control activates the brake system. At this time, the OVERSPEED light on the ECU panel will light up to indicate that the set speed has been exceeded. When the locomotive speed is reduced below the set speed, the RESET light on the ECU panel will light up, and the brake system may be released by pushing the OVERSPEED RESET button. Each of the three lamps on the ECU panel incorporate a test feature. The bulbs may be checked by pressing the LAMP TEST button also located on the panel.

4.2.2.2 Speed Sensor

The final version of the speed sensor used in the speed limiting control system uses a photoelectric pickup with a tone wheel driven by the locomotive forward-axle drive chain. (As shown in Figure 4-12). The sensor is packaged in a permissible box that is mounted under the locomotive battery box. The assembly of the speed sensor is shown on BRL Drawing D-2179167, and its installation is shown on BRL Drawings D-2179312, D-2176445, and D-2179310 all included in Appendix A. As the pinwheel teeth pass the sensor, a square-wave signal is generated by each tooth. The frequency of the square wave is proportional to speed. The time period of the square wave is compared with a preset time interval. When the period of sensor signal equals the set standard, solenoid G1 and the reset system are activated and the brakes are applied by venting the brake lines. The photoelectric-type speed sensor was chosen because it does not require critical mounting tolerances and it is not speed limited. It produces a signal output down to zero velocity.

The early design proximity speed sensor, using an Airpax No. 14-0001 zero-velocity pickup, was abandoned when the brake system was reworked for permissibility. The output of this sensor was pulsed with a rate proportional to locomotive speed at approximately 6.3 pulses per second per mph. The sensor was mounted in a manner that placed its active end adjacent to the perimeter of the 18-tooth chain-drive sprocket on one of the locomotive axles. During usage of this original system, it proved difficult to maintain the necessary gap between the sensor and the sprocket (less than 0.030 inch).

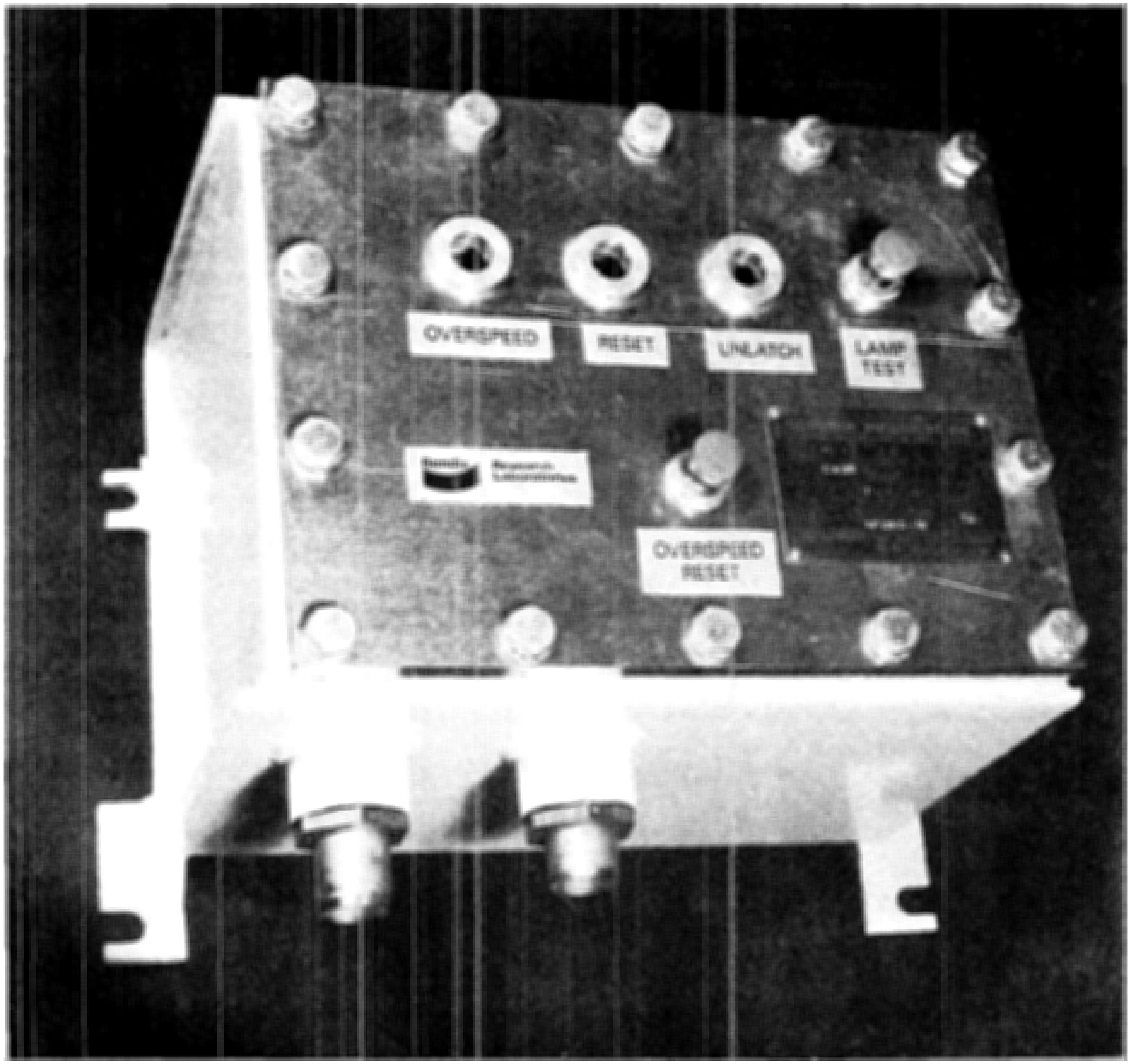


Figure 4-8 - Electronic Control Unit

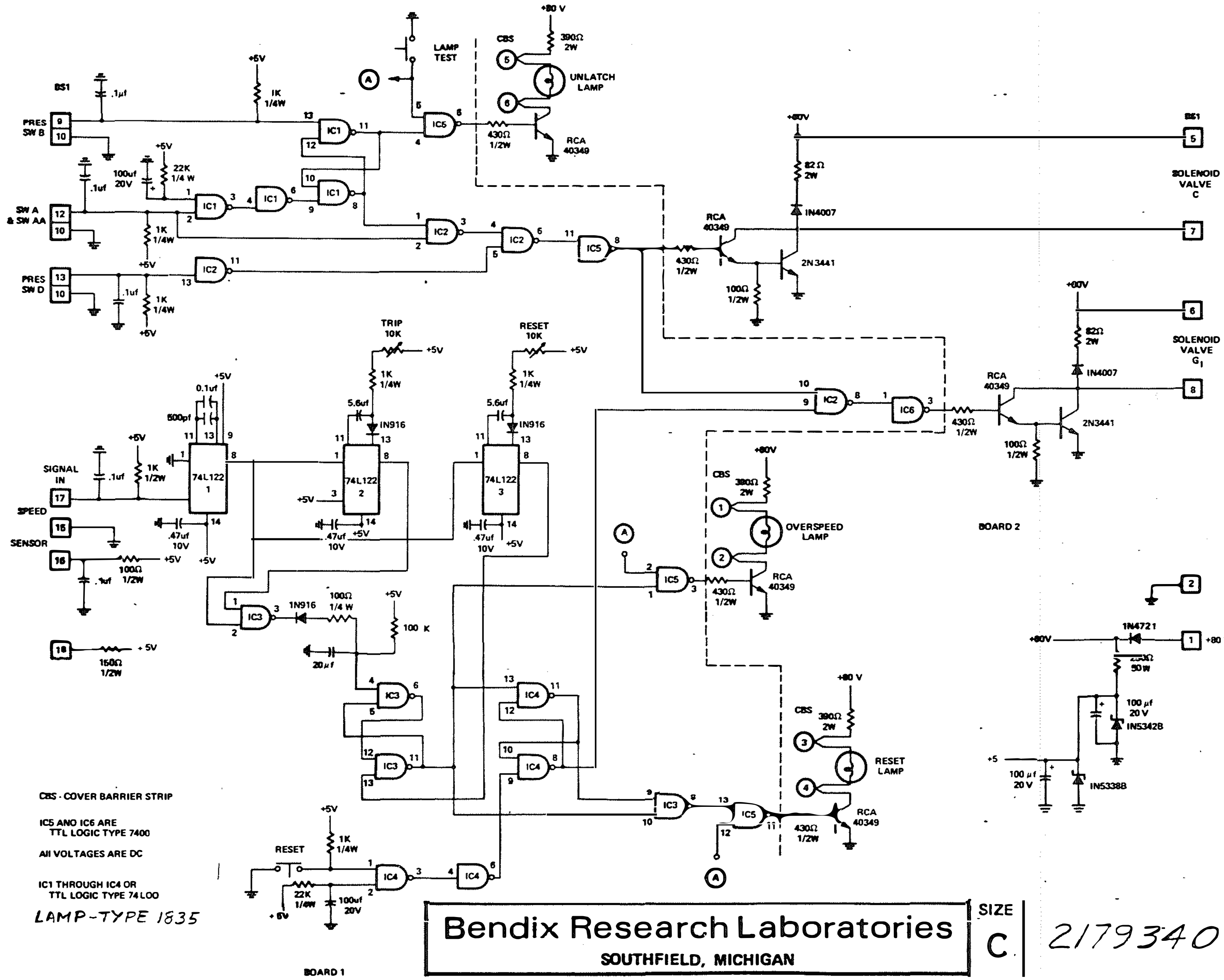


Figure 4-9 - Electronic Control Unit (E.C.U.) Schematic

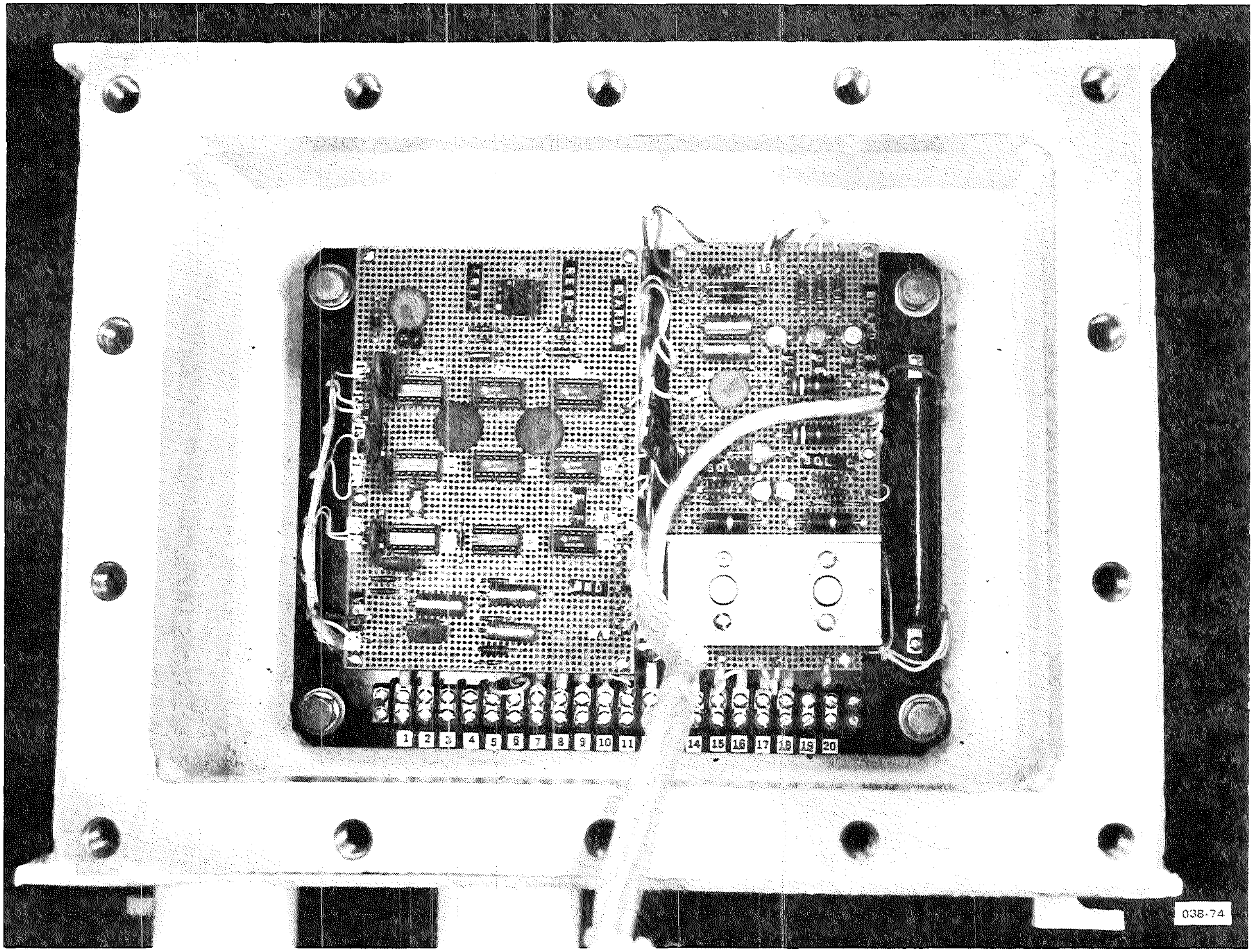


Figure 4-10 - Electronic Control Unit With Cover Removed

4.2.2.3 Electronic Logic for Solenoid Control

All solenoids, in accordance with the fail-safe design philosophy, are energized during normal operation of the system so that a power failure will de-energize the system, thus applying the brakes. A solenoid valve control sequence is shown in Table 4-1.

When the cars are coupled to the locomotive, it is necessary to unlatch the car automatic brake release mechanism. Unlatching the brakes is accomplished by supplying them with a high pressure. In order to ensure that an adequate pressure is supplied, pressure switch B (Figure 4-7) keeps the locomotive brakes applied while the cars are being unlatched. An UNLATCH light is located on the ECU panel which when lit indicates that the unlatch operation is required. This operation is performed by momentarily placing the brake lever in its unlatch position and then returning it to its normal brakes-off position.

The unlatching system has three sequencing switches which operate two solenoid valves:

Limit Switches A and AA - Open when car is connected, closed when no car is connected. (Located on each end of the locomotive, near the brake-line couplings. Switch AA is mounted on the cab end, and switch A is mounted to the battery box end.)

Pressure Switch B - Normally open. Closes when pressure is 150 psi or more.

Pressure Switch D - Normally closed. Opens when pressure is 80 psi or more.

Control Solenoids:

Solenoid Valve C - Normally closed; energize to open. When closed, isolates and prevents release of locomotive brakes, allowing the car brakes to be latched or unlatched. When open, allows release of locomotive brakes, permitting locomotive to be operated.

Solenoid Valve G1 - Normally open; energize to close. When open, vents system if Valve C is also open; vents locomotive brakes only if Valve C is closed. When closed, allows release of locomotive brakes.

Table 4-1 - Solenoid Control Requirements

Operation	Pressure Level (psi)	Condition of Switch			Required Solenoid Condition	
		Limit A & AA	Pressure B (NO)	Pressure D (NC)	Solenoid C (NC)	Solenoid G1 (NO)
1. Locomotive Coupled to Cars	0	Open	Open	Closed	Closed	Open
2. Unlatch Car Brakes	150	Open	Closed	Open	Closed	Open
3. Service Braking Locomotive and Cars	0 to 85	Open	Open	Closed	Open	Closed
4. Latching Car Brakes	110	Open	Open	Open	Closed	Open
5. Locomotive Operation Without Cars	0 to 85	Closed	Open	Closed	Open	Closed

R-498-4

Switches A & AA: Open = Cars connected; Closed = No cars
Pressure Switch B: NO; Closed if P is 150 psi
Pressure Switch D: NC; Open if P is over 85 psi
Solenoid Valve C: NC; Energize to open
Solenoid Valve G1: NO; Energize to close

4.2.2.4 Compressor Power Control

The compressor starter is activated automatically when the electrical system is turned on with switch P, located on the battery box end of the locomotive, shown in Figure 4-11, and shown schematically in Figure 4-7. The compressor starter is a parallel-series type, for the 5-hp, 80 Vdc, Galis motor. The motor is started using 40 Vdc from two batteries (one battery bank) for one second, then the power is switched to 80 Vdc from all four batteries (both battery banks) for continuous operation. This type of motor/starter eliminates the need for a large resistor and therefore minimizes the size of the electrical box.

When the air reservoir pressure reaches 300 psig, the compressor is automatically shut off. When the air reservoir pressure drops to 200 psig, the compressor is automatically started.

The compressor motor is protected by a thermal overload protector (shown schematically in Figure 4-7) located in the compressor motor/starter box. If the protector is tripped, it must be reset by removing the cover of the motor/starter, as shown in Figure 4-6, and pressing the reset button.

Figure 4-11 - Electric Locomotive - Battery Box End

4.2.3 Brake System Power Source

The brake system power source is a pneumatic supply contained within the locomotive battery box. Placement of specific components is shown on BRL Assembly Drawing E-2179177 in Appendix A. Before the locomotive was modified, the four Gould batteries were the only items in the box. Originally, the batteries were located near the center of the box but, during modification, they were relocated toward the outside walls to allow space for the pneumatic supply. The entire pneumatic supply was assembled in its own box, and then the box was installed in the battery box as a total subassembly. Also, during this modification, the original battery box covers were cut down in size so that they now only cover the battery area of the box. A new, separate hinged cover was installed to cover the pneumatic supply. The electric motor, motor/starter box, circuit breaker, pressure switch, and compressor-unloading solenoid valve are all permissible components. The battery cables are bolted to connectors within the circuit breaker and are cast in lead at the battery terminals. All electrical wiring was done according to U.S. Bureau of Mines Schedule 2G.

The compressor, a Quincy Model Number 325, produces 300 psig and has an output of 17.4 CFM at 0 psig. It is mounted in line with its electric drive motor. The motor is a Galis 5 hp, 900 rpm, 80 Vdc unit. Between the motor and the compressor is a speed-reducer gear box and a flexible coupling. The speed reducer is a Rotomission Model HA25-6-2-32-0 which reduces the motor speed from 900 rpm to 630 rpm. The flexible coupling is a Rex Tru-Flex No. 30 with a 1.375-inch-diameter bore. Bolted to the coupling is a custom-fabricated fan which cools the compressor heat exchanger. Also, the fan blows air across the entire compressor by drawing air from the front of the battery box and allowing it to exit through the louvered pneumatic supply cover. The system contains a pressure switch (Switch A of Figures 4-1 and 4-7) mounted to the front of the battery box, as shown in Figure 4-11, which turns the compressor on and off as demand requires. The compressor is shut down when a tank pressure of 300 psig is reached and is restarted automatically when the tank pressure drops to 200 psig. A solenoid valve (G2 in Figure 4-1) and an isolating one-way valve (VM1 in Figure 4-1) provide loadless starting and stopping of the compressor. The air reservoir, with a capacity of 13 gallons, has a safety valve connected at its base which is set to release pressures greater than 310 psig. Also, the reservoir has a manual condensate drain valve which is operated from the locomotive cab.

Both the compressor and the speed reducer have lubricating systems that must be maintained regularly. See the System Maintenance Manual for specific procedures.

4.2.4 Mechanical Brake Linkage

When the locomotive was modified, as much as possible of the original mechanical linkage was used as shown in Figure 4-12. The original main crossbar, as shown in Figure 4-12, and all of the brake subsystem located between the wheels was retained. (See Figure 4-13). The original hydraulic cylinder was removed, and a custom spring assembly was installed in its place. This spring provides a force that is transmitted through the linkage to the brake shoes, holding the shoes against the locomotive wheels.

A pneumatic cylinder with a 3.0-inch diameter bore was mounted to the bulkhead, on the centerline of the locomotive, in such a way that its output acts directly on the crossbar center. This is the cylinder which, when pressurized, counteracts the force of the brake spring, thereby releasing the brakes.

The original hydraulic cylinder was relocated in the system. It was originally mounted at tje center of the locomotive bulkhead. An auxiliary cross-member was added which, through its pivot arrangement, allows the force of the hydraulic cylinder to act through the center of the original brake crossbar. This hydraulic cylinder continues to serve as a manual override brake.

All components and links in the mechanical brake linkage were assembled using bolts. The total mechanical brake system is located below the bottom surface of the original battery box.

4.2.5 Locomotive Brakes Manual Override

The locomotive manual override brake should only be used in emergency situations. In case of a power or mechanical failure, where the automatic brake system is rendered inoperable, the manual override may be used to either release or apply the locomotive brakes.

The override brake consists of a hydraulic cylinder which, when pressurized by a hydraulic pump in the locomotive cab, will override the spring/pneumatic system and either apply or release the brakes, depending on the rotation of the wheel of the hydraulic pump. The parts of the manual brake override system are shown in Figure 4-14.

During normal locomotive operation, the override brake hydraulic bypass valve must be left open (turned 90 degrees counterclockwise) as shown in Figure 4-15(a).

To apply the brakes, the hydraulic bypass valve (valve handle is turned 90 degrees clockwise) located in the cab is closed as shown in Figure 4-15(b), and the pump wheel is rotated in a clockwise direction. To release the brakes, the hydraulic bypass valve is opened, and the pump wheel is rotated in a counterclockwise direction. Note that if the bypass valve is closed while releasing the brakes with the override pump wheel, the brakes will remain locked in the BRAKES OFF position. Such a condition would override the pneumatic fail-safe brake system.

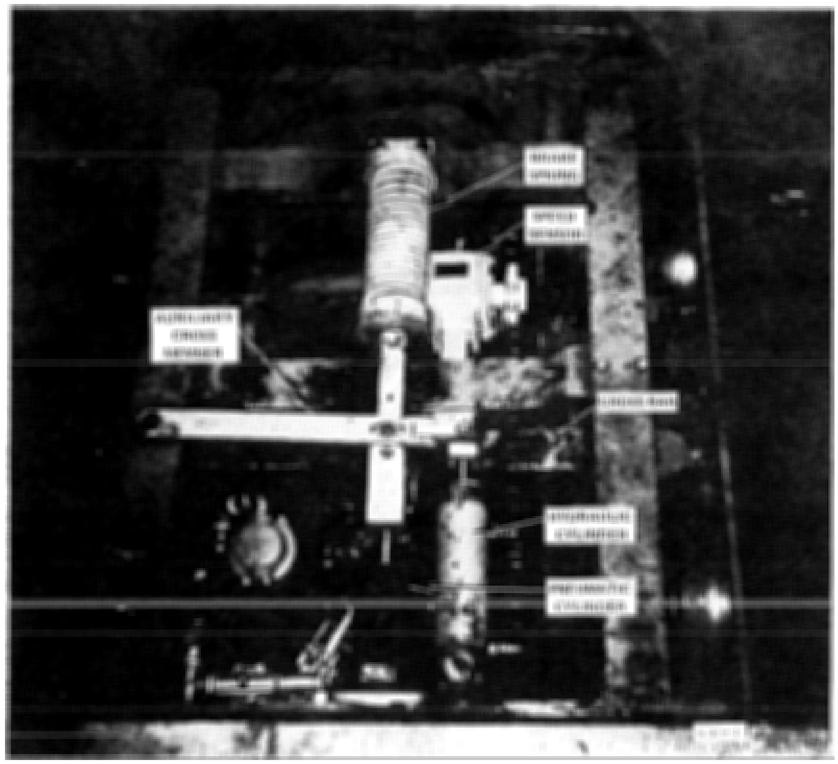


Figure 4-12 - Locomotive Chassis With Battery Box Removed

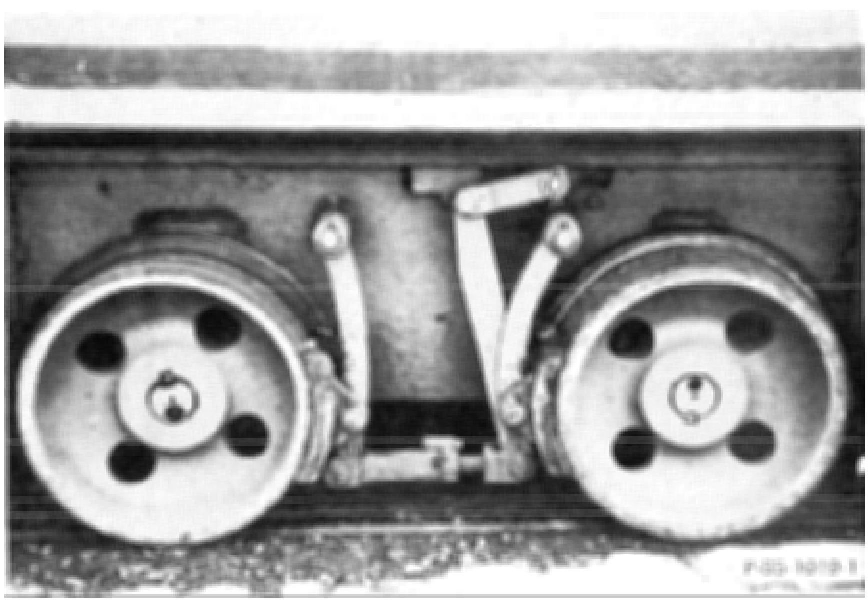


Figure 4-13 - Locomotive Brake Mechanism

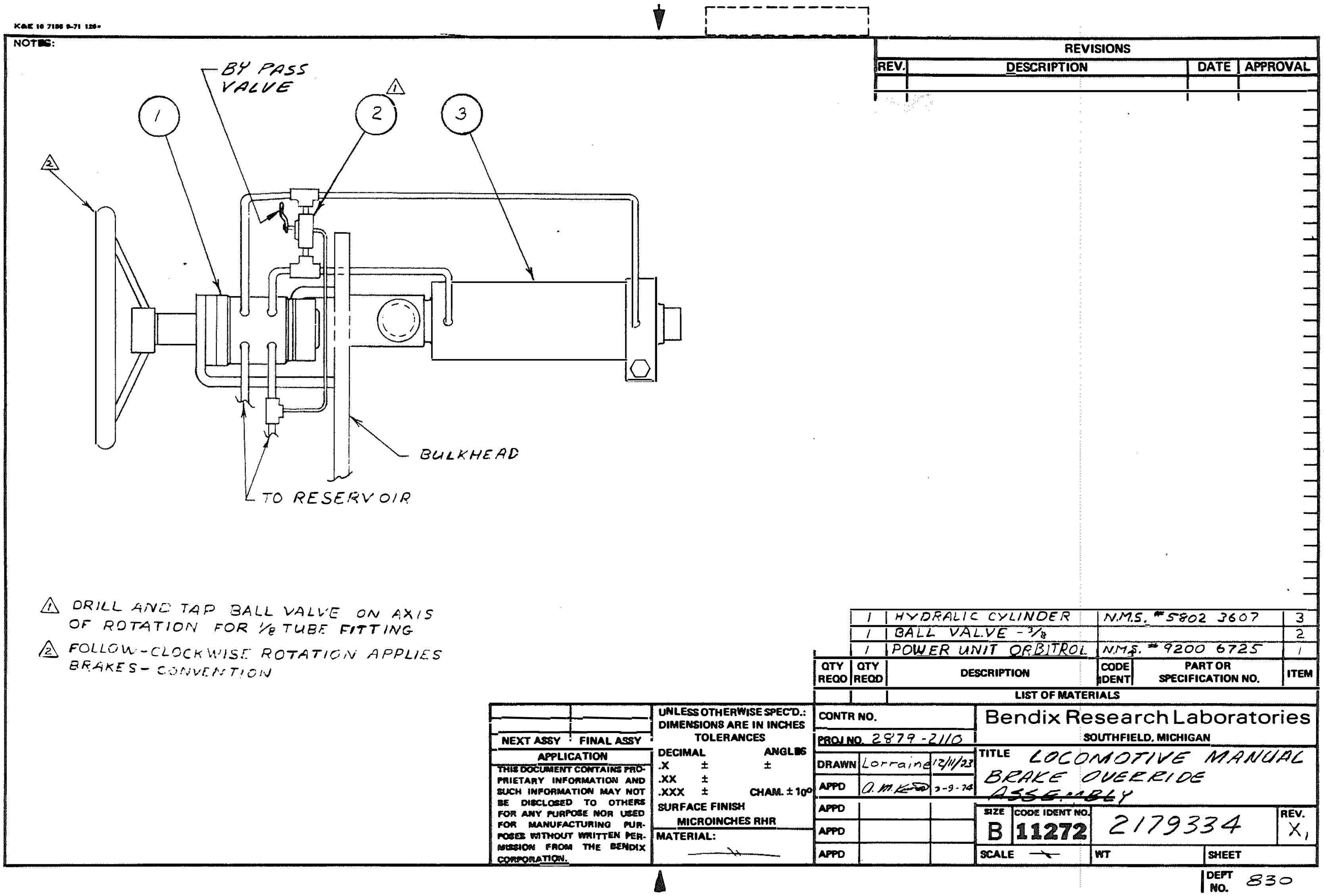
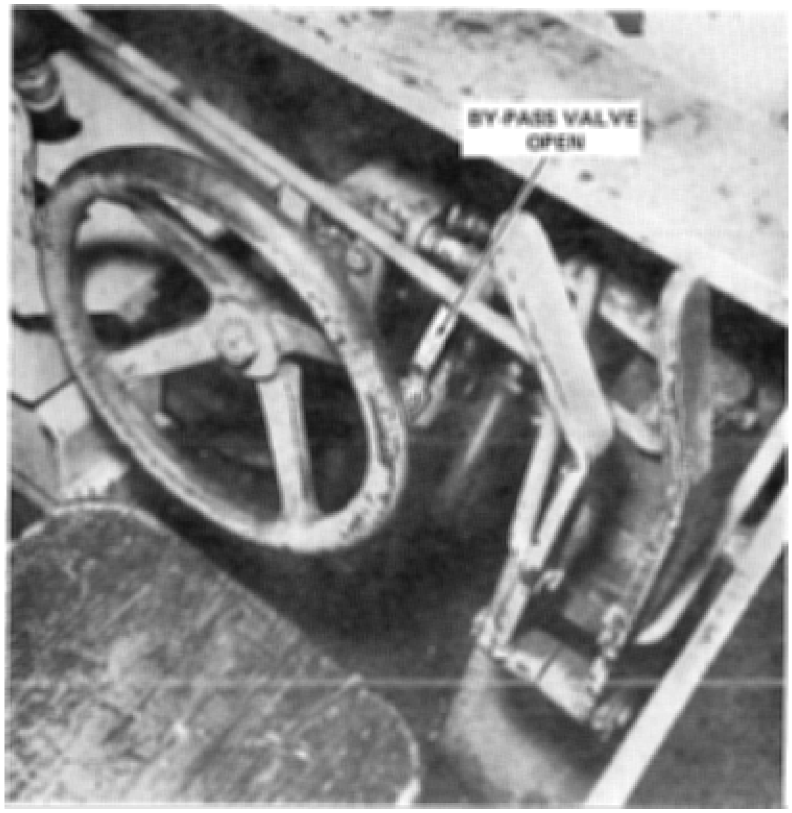
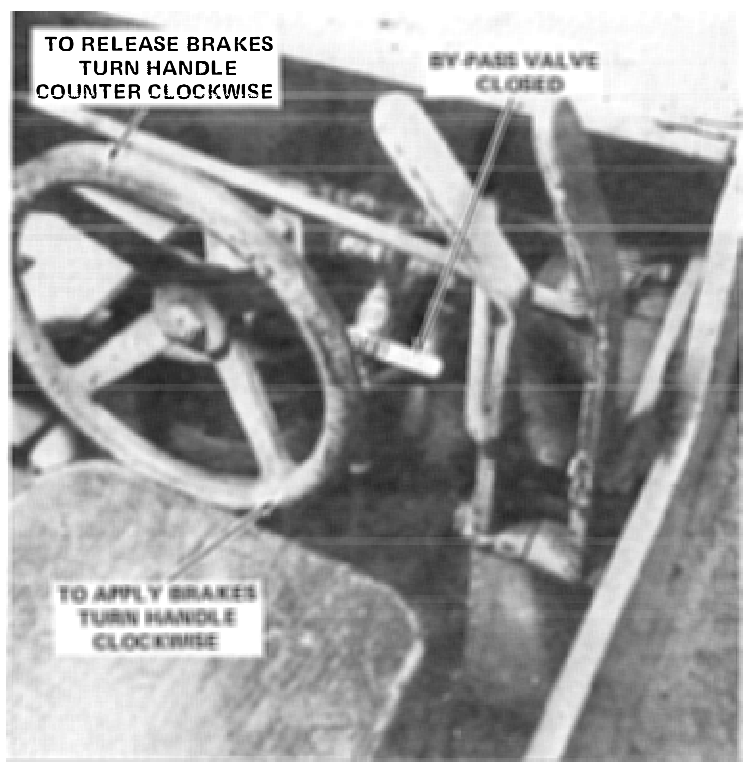


Figure 4-14 - Locomotive Manual Brake Override



(a) Hydraulic Brake Inactive



(b) Hydraulic Brake Active

Figure 4-15 - By-Pass Valve and Pump Wheel

The hydraulic manual override system was originally installed on the locomotive by the National Mine Service Company. Periodic maintenance and oil replacement should be continued in accordance with NMSC specifications.

The hydraulic cylinder, National Mine Service Company Part No. 5802-3607, has an approximately 4.0-inch diameter bore, approximately 6.0-inch stroke, and approximately 1.0-inch rod diameter. The hand pump is National Mine Service Company Part No. 9200-6725.

4.3 CAR BRAKE SYSTEM DESIGN

The car brake assembly, shown in Figure 4-16, is a spring-actuated, pneumatically released, brake system. Included in this system is a latching mechanism which, when operated by a pressure signal controlled by the motorman, mechanically holds the brake in the released position. Also, the brakeman has the ability to control the brakes on the cars without the use of the locomotive by use of a manual brake override designed into each car.

The pneumatic release of the car brakes is accomplished using a standard air cylinder as an actuator. Various cylinder seal combinations were tested and the best combination that produced a minimum amount of friction while maintaining a minimum leakage was used.

Both rigid pipe and flexible hose are used as pneumatic lines on the cars. Inter-car pneumatic connections are made with flexible hoses and quick-disconnect couplings.

A flexible rubber shield is bolted to each side of each car to keep coal out of the springs and linkages of the brake subsystem.

4.3.1 Car Brake Sub-Assembly

The car brake sub-assembly is a complete, self-contained unit which is bolted to the car structure. The original, simple, mechanical hand set brake with wooden shoes, which was installed on the cars during their original manufacture, was removed in its entirety. There are two brake sub-assemblies per car, located between the wheels on each side of the car. Figure 4-16 is a drawing of the final version of the car brake sub-assembly. Figure 4-17 shows a layout of a brake sub-assembly as originally proposed to the USBM.

As shown, the sub-assembly consists of a two-shoe system linkage with a spring located in such a way that the brake shoes are loaded against the wheel running surface. All linkage material is machined from cold-rolled steel stock. The spring force is designed to provide emergency braking without the wheels sliding when the coal car is empty. A pneumatic cylinder having a bore of 2.0-inch diameter and a stroke of 3.0 inches is used which pulls the brake release lever to overcome the brake spring force. When pressure is applied to the cylinder, the brake spring force is offset, causing a proportional decrease in brake shoe-to-wheel force. Further increase of pressure in the pneumatic cylinder will first cause the brake shoe-to-wheel force to become zero and finally, too, will retract the shoes from the wheels. An adjustment link located at the bottom of the linkage assembly is nominally set to allow the shoes to retract approximately 0.04 inch. Since this clearance will gradually increase as the shoes wear, an eccentric pivot is used for shoe mounting which can be adjusted to reset the clearance. This shoe-wear adjustment should be made according to the instructions given in the system Maintenance Manual, Bendix Report BRL/TR-74-7024. The eccentric pivot of each brake shoe may be adjusted two times, thereby permitting a total of four brake shoe adjustments during the usable life of a set of brake shoes.

The brake shoes described in the original proposal, and shown in Figure 4-17, were of the two-piece design. The initial design, as shown in Figure 4-18, had adjustment shims between the basic shoe and the shoe mounting support. Eventually, the brake shoes were redesigned as a one-piece casting with a centering guide groove to align the shoe with the wheel flange. The one-piece construction reduced the manufacturing cost per shoe and, at the same time, increased the operating efficiency. The material used in the brake shoes is cast iron, and is the same used in the manufacture of the original locomotive shoes.

In order to test the car brake sub-assembly, a test fixture, shown in Figure 4-19, was designed and fabricated. This fixture allows the installation of one complete car brake sub-assembly and provides means for measuring brake shoe/wheel force, brake cylinder pressure, simulated shoe wear and simulated brake system volume per car. Every car brake sub-assembly was operated in the Bendix Fluid Power Test Laboratory, and a graph showing pressure versus brake shoe application force was plotted. Also, the latching and unlatching sequence was tested to ensure smooth operation. All tests were performed to ensure that the linkage provided adequate shoe force, release at a minimum pressure, and performance of the latching and unlatching functions at the proper pressures. Each brake sub-assembly was mounted in the test fixture with the supply pressure connected as shown in Figure 4-19. A pressure regulator maintained the pressure to the control valve at 150 psig. This pressure was indicated on a supply pressure gage. Load cells were used to measure the forces at each brake linkage. Brake force versus cylinder pressure plots were taken for the prototype unit and each of the car brake sub-assemblies. Figure 4-20 shows the test results of the prototype sub-assembly. The maximum brake force is designed to be not less than 500 pounds and not greater than 600 pounds. A maximum brake force of less than 450 pounds or greater than 650 pounds was used as the tolerance range. Any subsystem with a brake force falling below 450 pounds or higher than 600 pounds was reworked to bring the force levels within the required range. The minimum pressure at which the brakes were released was set at 65 psig and was not allowed to be greater than 80 psig. The pressure-controlled latching mechanism would latch at not less than 90 psig, or more than 110 psig. The pressure-controlled unlatch mechanism would unlatch at not less than 120 psig or more than 130 psig. The unlatching pressure was controlled by controlling the torque on the nut which held this mechanism.

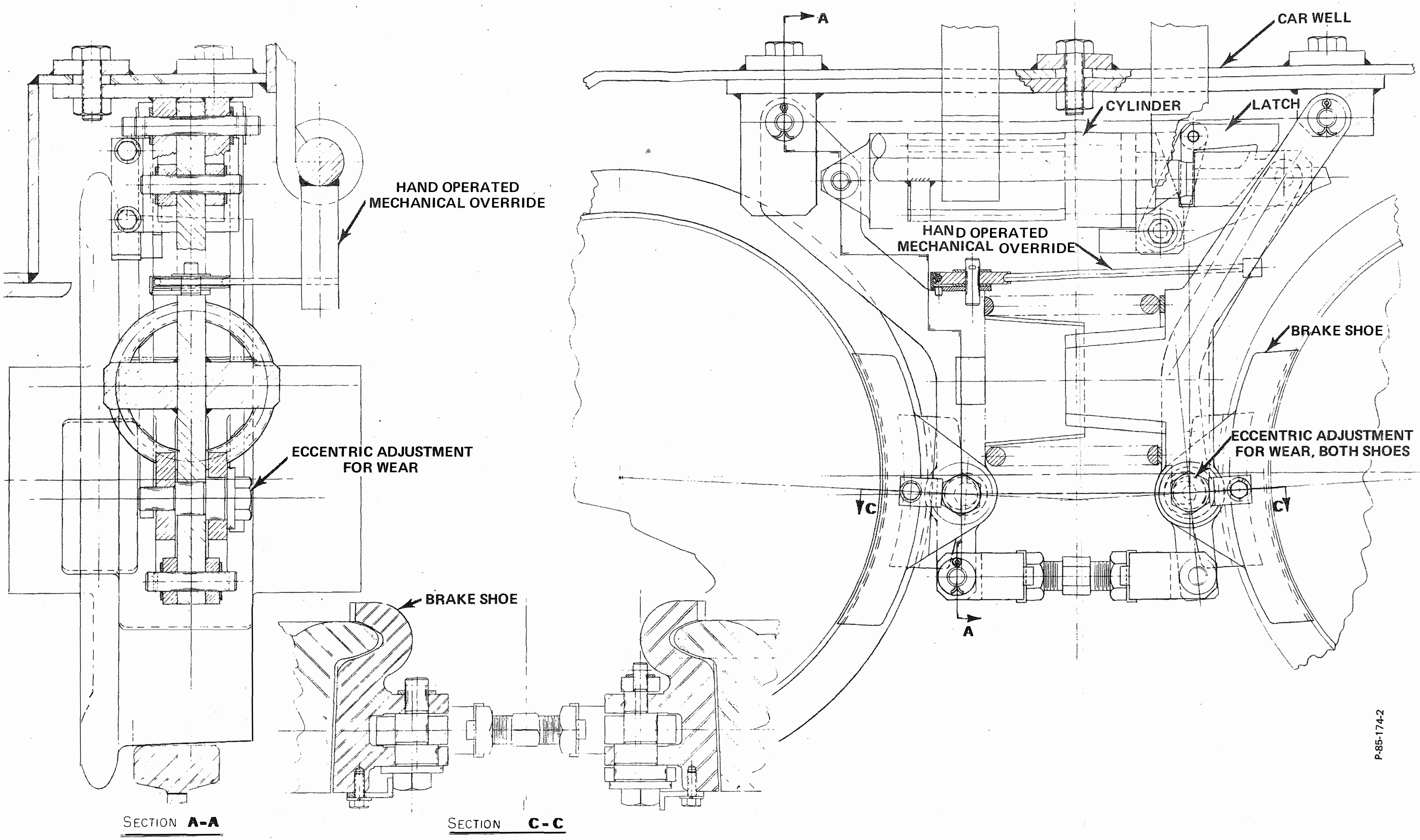


Figure 4-16 - Car Brake Assembly

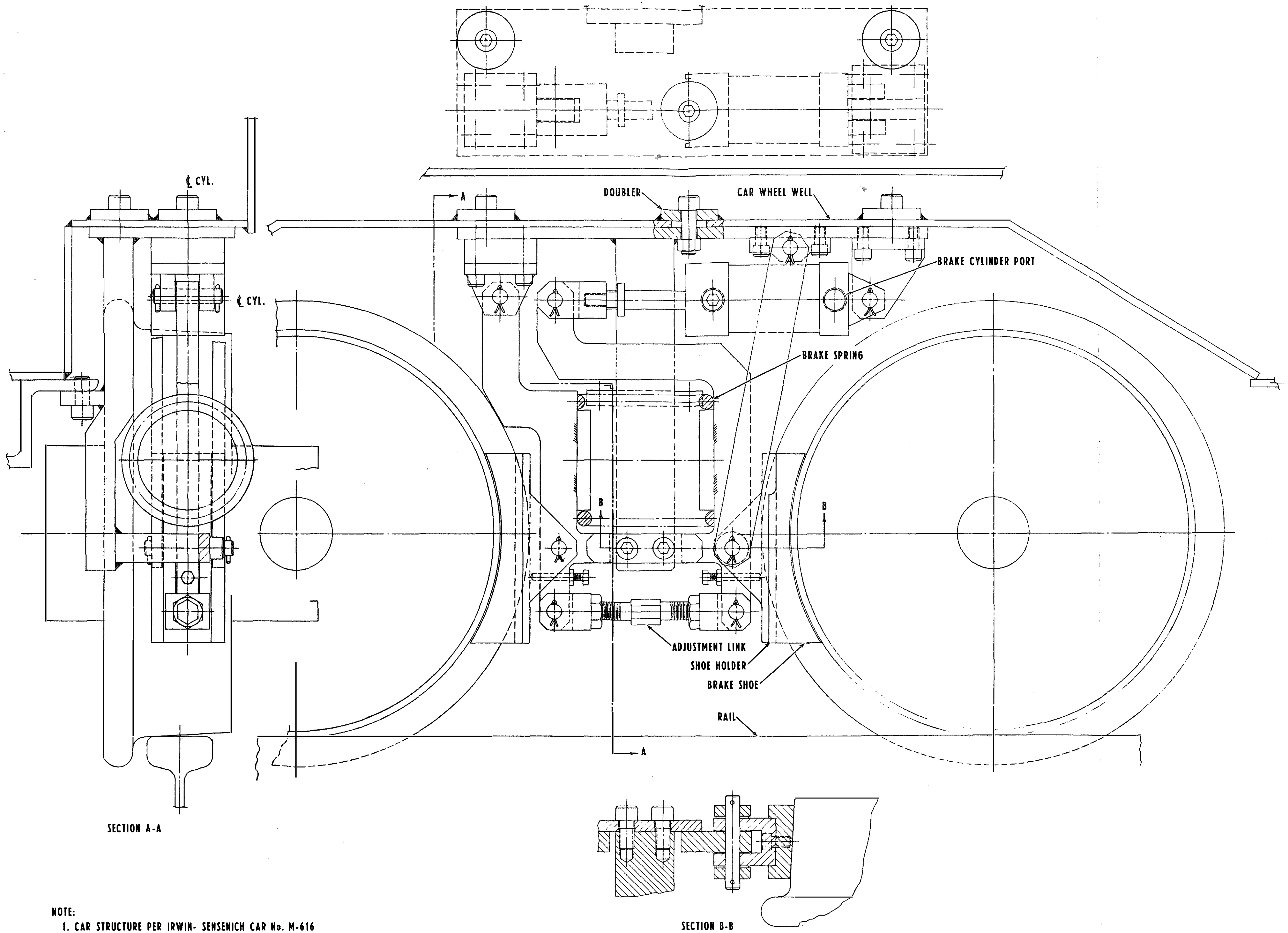


Figure 4-17 - Proposed Brake Sub-Assembly

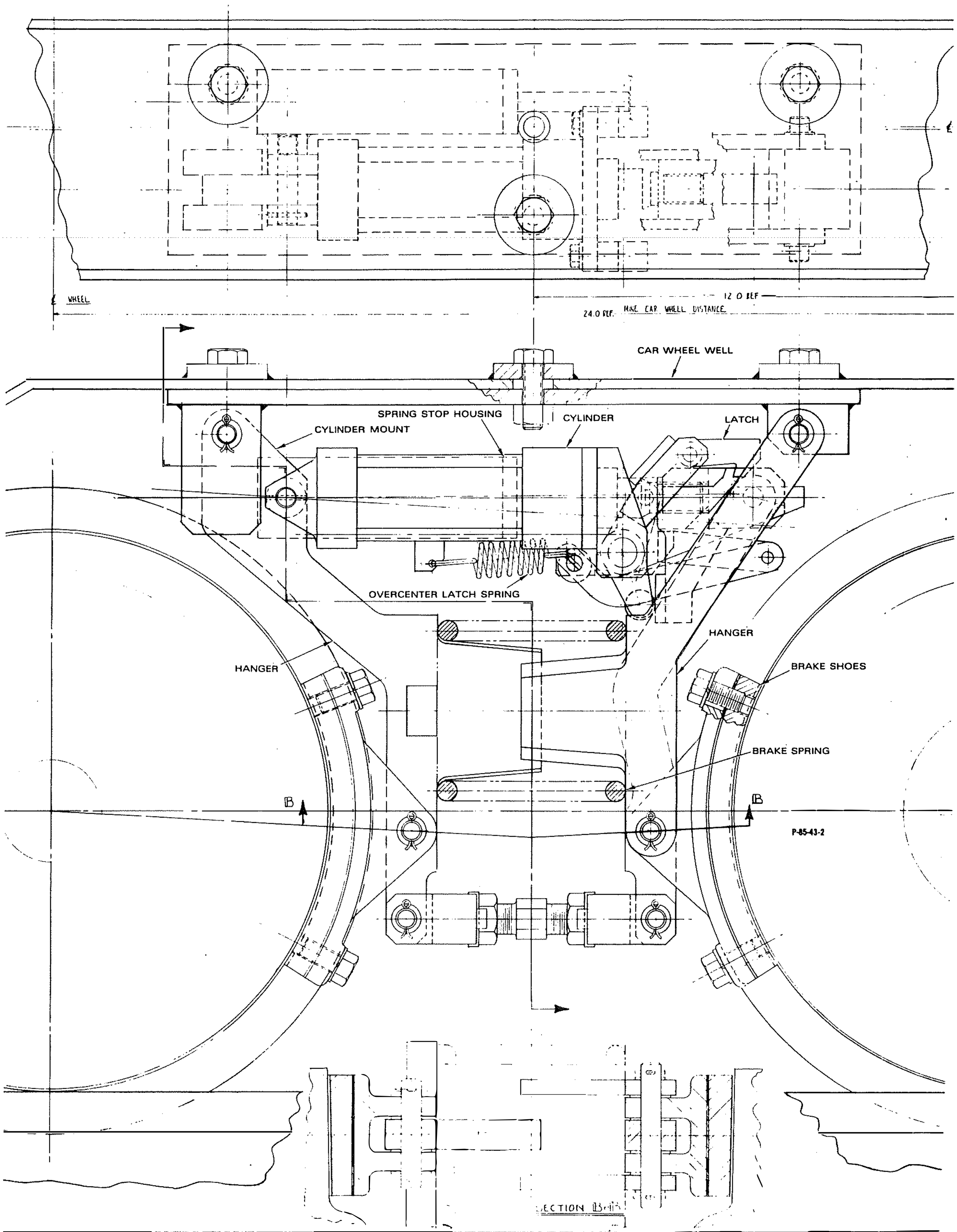


Figure 4-18 - Car Brake Linkage - Initial Design

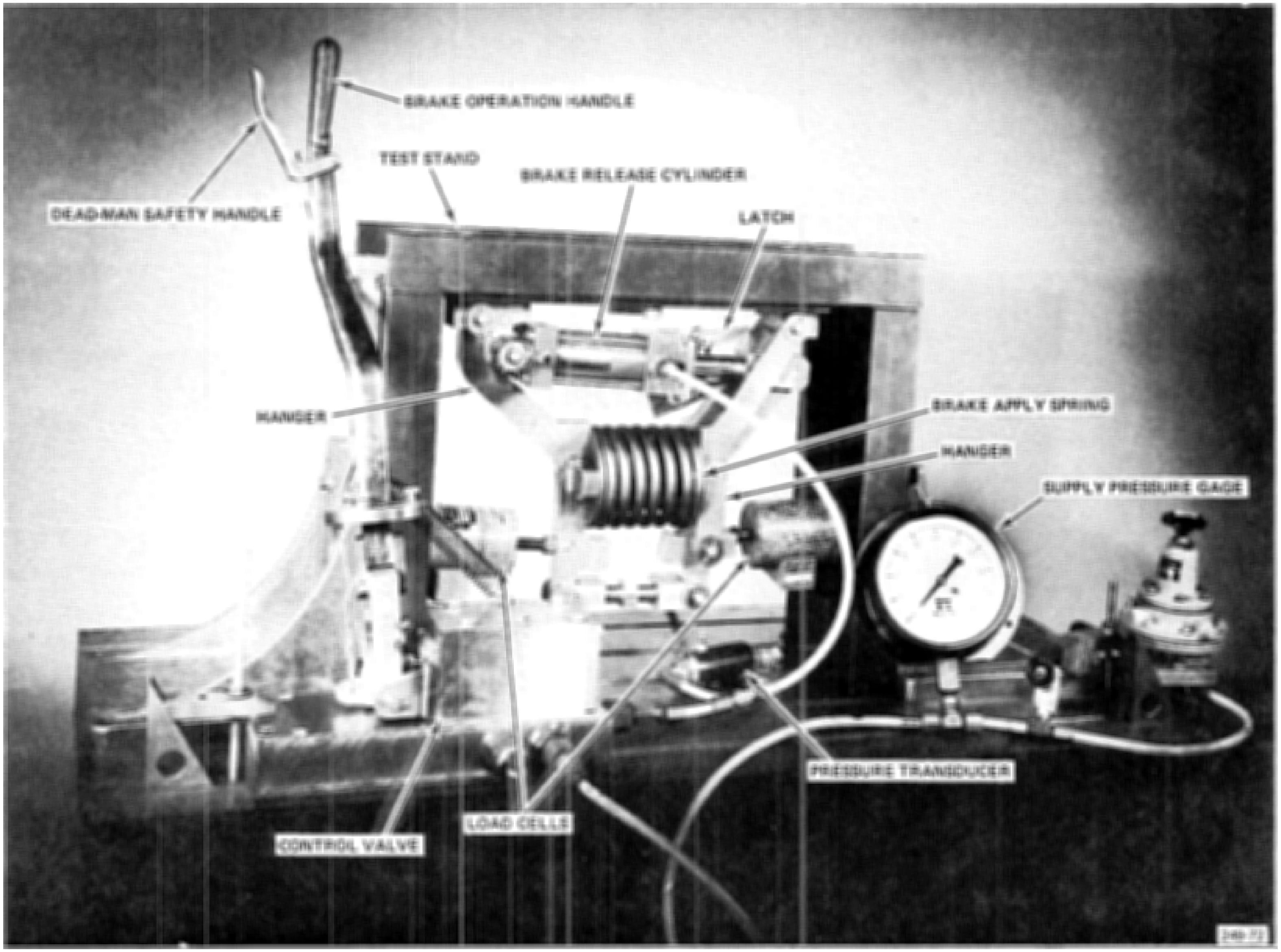


Figure 4-19 - Test Fixture - Brake Sub-Assembly

The load cell measures the brake shoe application force.
The control valve controls the cylinder pressure

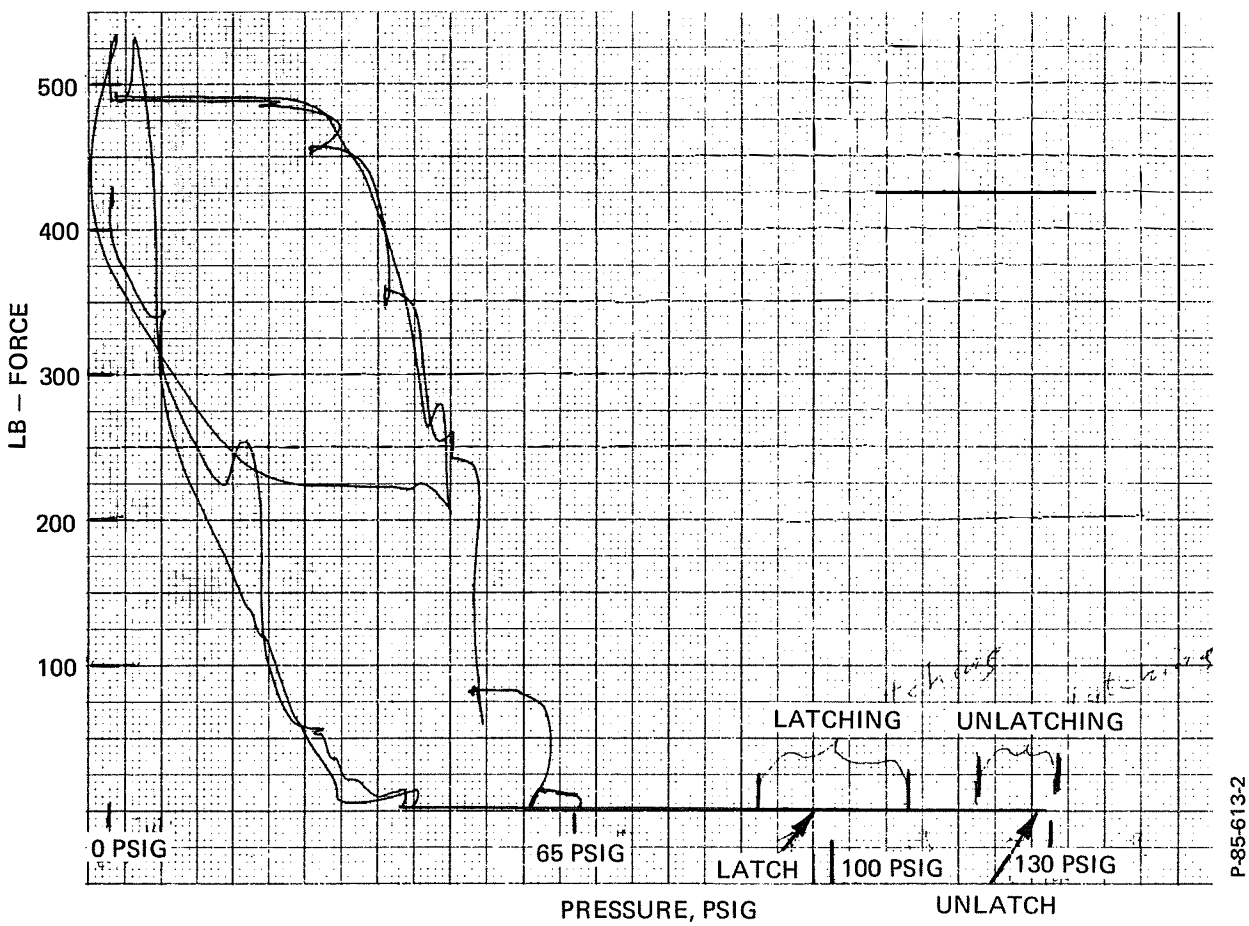


Figure 4-20 - Test of Prototype Brake Linkage

Installation of the brake sub-assembly was conducted by making moderate car body alterations and partially disassembling the brake linkage. Brackets, air lines and pneumatic couplers were installed, and all adjustments were made to ensure the functions of the brake system. Also at this time, flexible pneumatic lines on the cars were replaced with steel pipes.

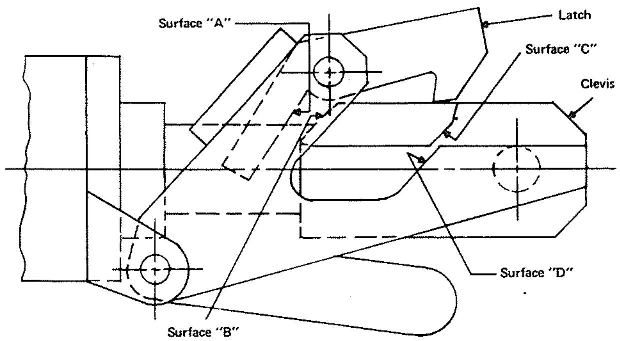
4.3.2 Automatic Latching Mechanism

A mechanical override latching mechanism was designed into the car brake linkage. The mechanism was included in order that the motorman may deliberately leave the cars with their brakes held in the released position. This is for the convenience of the operator when loading or unloading the coal cars. The latch is pneumatically controlled by a brake pressure signal above that of the normal operating level. In order to latch the car brakes, the motorman shifts the brake lever into the position which provides a line pressure above the normal operating pressure. To unlatch the brakes, he shifts the brake lever into another position, providing a still greater pressure which unlatches the brakes and prevents them from latching again until the brakes have operated in their normal position. Brake lever positions are shown in Figure 4-3. The high and low pressure limits for each of these lever positions can be varied by adjusting the stops built into the position plate.

Latching of the mechanism will only occur when the pressure is increased from its normal operating pressure of 80 psig to a pressure between 90 psig and 110 psig, as noted on the brake pressure gage P3 located in the locomotive cab. Unlatching of the latch mechanism will only occur when the pressure is increased to between 140 psig and 150 psig, as noted on the brake pressure gage P3. These pressure ranges are for both gradual and rapid applications of pressure. A sketch of the latching mechanism positions is shown in Figure 4-21.

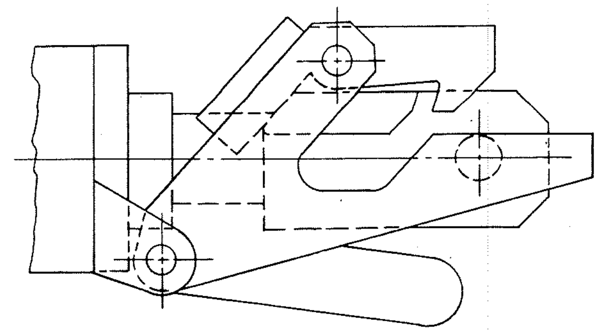
Position one shows the clevis at the end of the normal stroke, a spring-loaded stop limits further movement to the left. In position two, the first stop has been overpowered and the clevis has moved to the second spring-loaded stop. During the stroke from stop one to stop two, the latch was rotated down by contact between surface "A" of the latch and surface "B" of the clevis. In position three, the pressure has been released and the brakes are latched in the OFF position. Position four shows the clevis in the unlatch position where the second stop has been overpowered. The linkage is held in this position until a reduction in pressure moves the clevis to the right and surface "C" on the clevis meets surface "D" on the linkage which returns the linkage to position one.

Figure 4-16, Car Brake Assembly, and Reference Drawing E-2176031, Fail-Safe Brake Assembly, included in Appendix A, show the latching mechanism details.



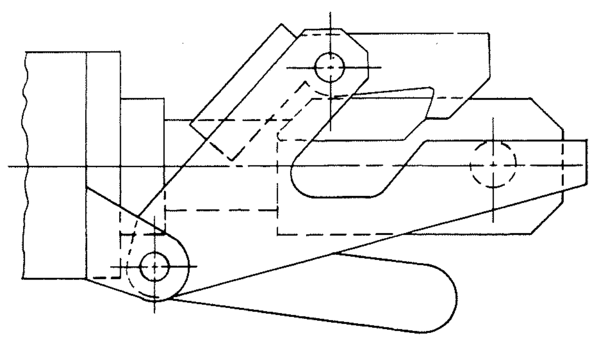
End of Normal Stroke

Position 1



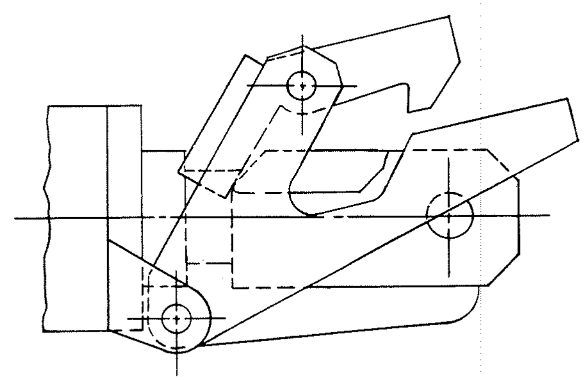
End of Latching Stroke

Position 2



Latched

Position 3



End of Unlatching Stroke

Position 4

Figure 4-21 - Latching Mechanism Positions

A brake lever positioning sensor (pressure switch) is included to apply the locomotive brakes when the car brakes are being latched or unlatched. An UNLATCH lamp is included on the electronic control unit panel which lights when the unlatch operation is required. This indicator is intended to reduce the chance of an oversight by the motorman in leaving the car brakes latched accidently when the cars are coupled to the locomotive.

4.3.3 Car Brakes Manual Override

The car brakes manual override is provided to give the brakeman the ability to control the brakes without the locomotive. The USBM requested this feature since the unloading of each coal car at the Bruceton facility necessitates releasing the brakes without the locomotive's air supply and manually pushing each car separately into the unloading station. Also, if the car brakes are LATCHED off, they may be unlatched manually by moving the car manual override lever from the normal operating position to the manual release position, then back to the normal operating position. These positions are shown in Figure 4-22. When the car is coupled to the locomotive, the car manual release lever must not be locked in the BRAKES OFF position. Such a condition would override the pneumatic fail-safe brake system.

The original Irwin Sensenich Company car brake linkage was utilized as much as possible in this manual override. Figure 4-16 (Car Brake Assembly), Reference Drawing E-2176031, (Fail-Safe Brake Assembly) and Reference Drawing #-2179018 (Mine Car, Modified W/Fail-Safe Brake System), included in Appendix A, show the override system. A lever (item No. 4 of Drawing #-2176031) was welded to the original torsion bar which runs along the side of the car as shown in Figure 4-23. This lever has a wire rope (item No. 26 of Drawing #-2176031) clamped to it. The wire rope passes over a sheave (item No. 25 of Drawing #-2176031) and is attached to the brake linkage righthand lever (item No. 19 of Drawing #-2176031). Pulling the brake lever pulls the wire rope which in turn pulls the brake linkage in such a manner to cause the brake spring to be compressed, thereby releasing the brakes.

On the hand lever, it was necessary to spread the original connector link mounting points to increase the lever throw and to increase the handle length in order to increase leverage. Originally, the new one-piece hand lever extended 12 inches above the car body when the manual release was on. The USBM approved of this extension as it was thought that the lever would not interfere with any mining operations. The portion of the handle which extended above the car had the advantage of being clearly visible to the motorman, thus reducing the chance of an oversight in leaving the manual override ON while the car was attached to the locomotive.

However, the hand lever was eventually redesigned and modified, incorporating a folding design. This modification was requested by the USBM because the handle interfered with the Bruceton coal-loading machine when the handle was up (BRAKES OFF position) during loading. Figures 4-22 and 4-23 show the final version of the folding handle.

4.3.4 Car Brake Air Cylinder Piston Seal Tests

During tests on the brake linkage, it was found that the air cylinder contributed about 75% of the system hysteresis. This caused the latching mechanism to function inconsistently. Therefore, a variety of seals were tested in order to determine the combination which would produce the lowest friction. Three types of seal combinations were tested. Seals, and their location in the air cylinder are shown in Figure 4-24. The first combination tested had two, flared-lip Buna-N piston seals backed with leather rings; one, flared-lip, polyurethane rod seal; and one, polyurethane rod wiper. The second combination tested had one, double, cast-iron piston ring and a more flexible, flared-lip, Buna-N rod seal. The third combination tested had a low-friction, Chemloy piston ring of both the solid and split design. The combination that produced minimum friction while maintaining minimum leakage was the Buna-N, flared-lip piston seal and the polyurethane, flared-lip rod seal. This combination was used in all the car air cylinders.

4.3.5 Car Pneumatic Lines

Both standard schedule 40 and 80 rigid galvanized pipe were used wherever possible as pneumatic lines on the coal haulage cars. Where flexibility is required, Parker high-pressure hose was used. Pneumatic line locations can be seen on BRL Drawing #-2179018 in Appendix A.

Each brake cylinder on the cars is protected from dirt in the lines by a filter which is connected between the air line and the cylinder. This filter, a Wilkerson No. A-117-2, contains a throwaway filter element as shown in the exploded view in Figure 4-25.

4.3.6 Inter-Car Pneumatic Lines

The pneumatic lines that couple one car to another and the locomotive to the first car are Parker 3/4-inch, high-pressure hose. Pneumatic coupling and uncoupling between vehicles is accomplished using quick-disconnect couplings. The inter-car air connection can be made or broken from one side of the car without going between the cars. The stationary portion of the quick disconnect coupling is a normally open Hansen socket, No. LL6-H-12-RC-VAA. The portion of the coupling that is connected to the disconnectable end of the flexible hose is a normally open Hansen plug, No. LL6-K31-VAA.

The last car of a series of cars can have its stationary socket plugged as shown in Figure 4-26(a) by using the Hansen plug, No. LL6-K-12, which is chained to the same car. Also, Figure 4-26(a) and Figure 4-23 show that when a car is not connected to another vehicle, the plug on the disconnectable end of the flexible hose is stored in a Hansen socket, No. LL6-H-12, mounted on the same car. Figure 4-26(b) shows two cars coupled and the chained plug stored in the connector bracket.

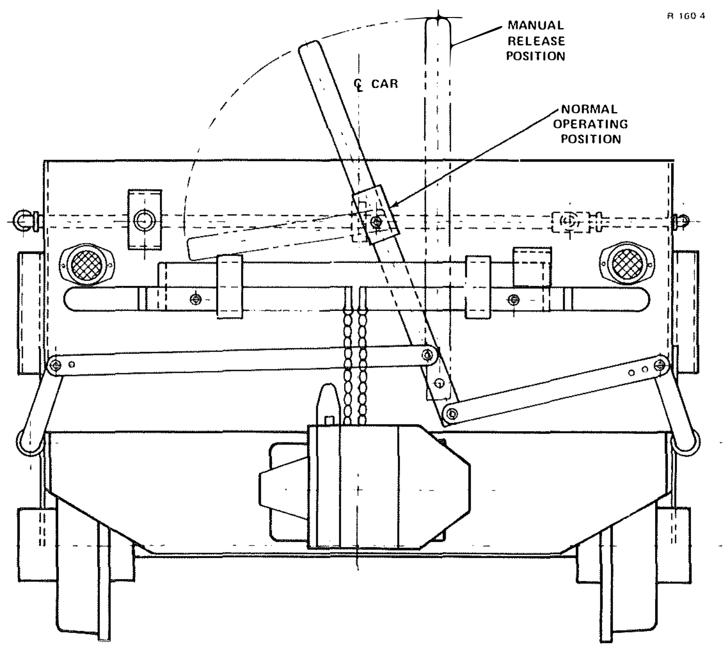


Figure 4-22 - Coal Car Manual Brake Lever Positions

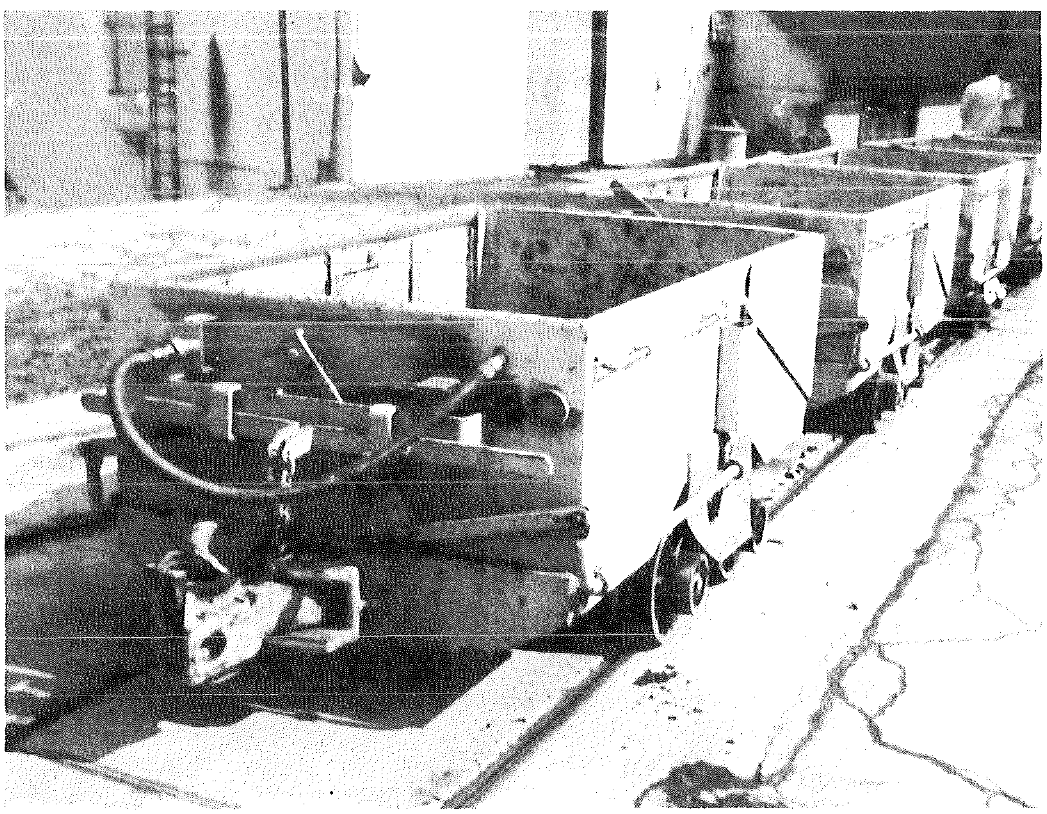


Figure 4-23 - Coal Cars - Manual Brake Lever End

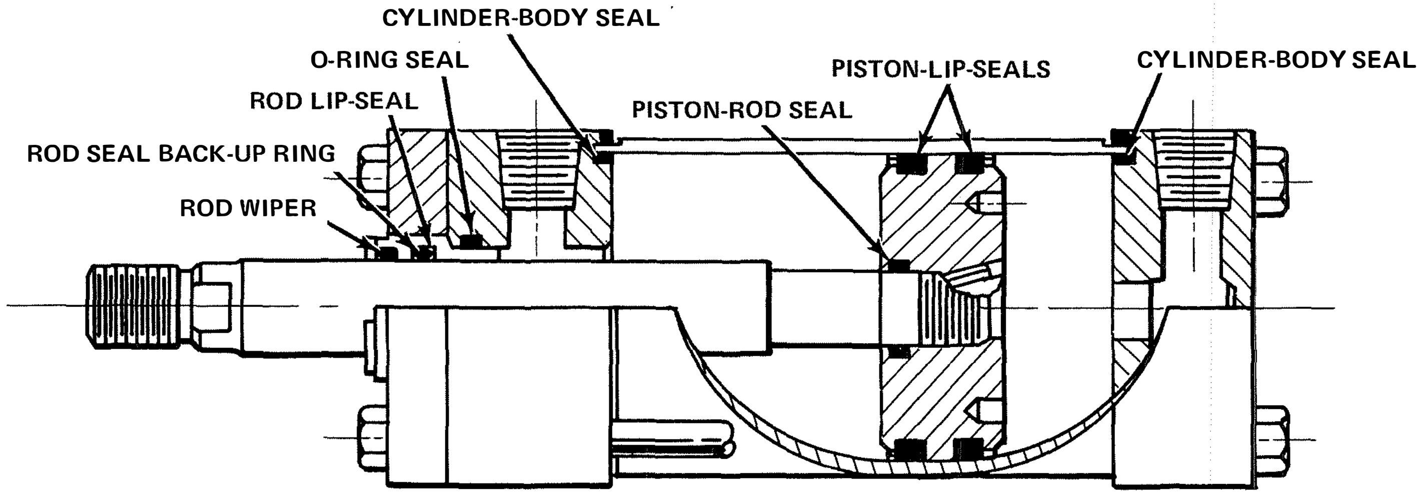


Figure 4-24 - Air Cylinder Assembly

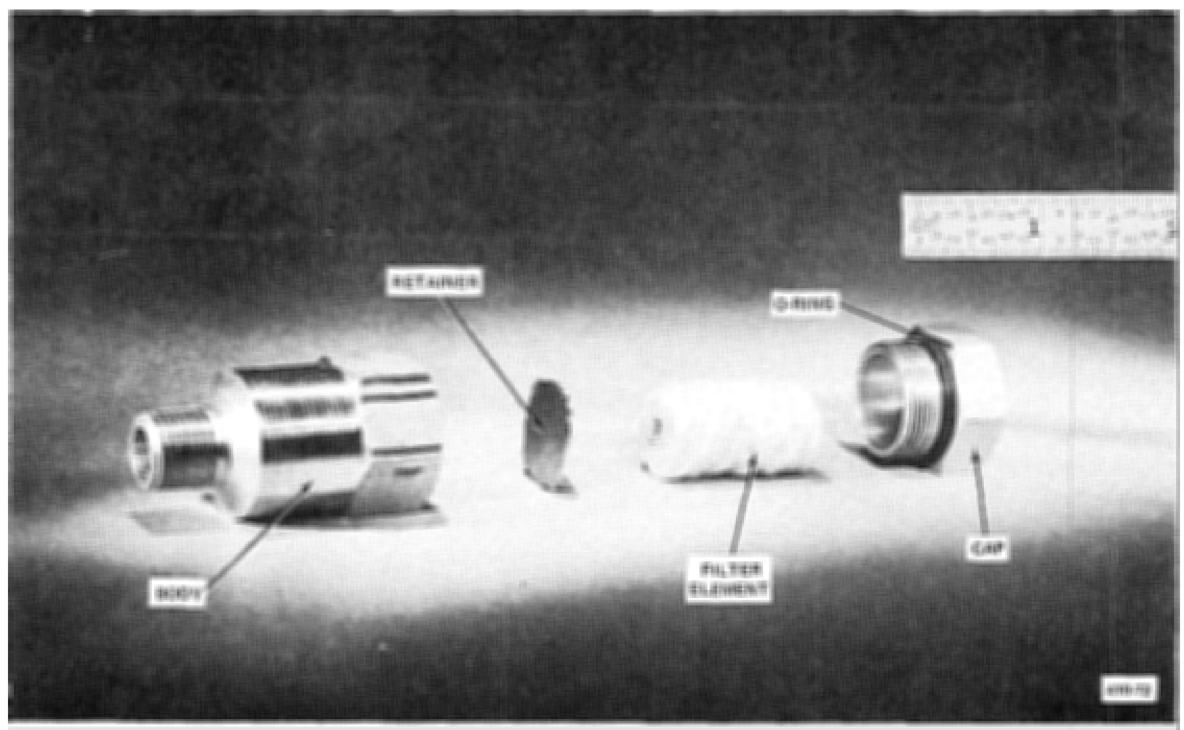
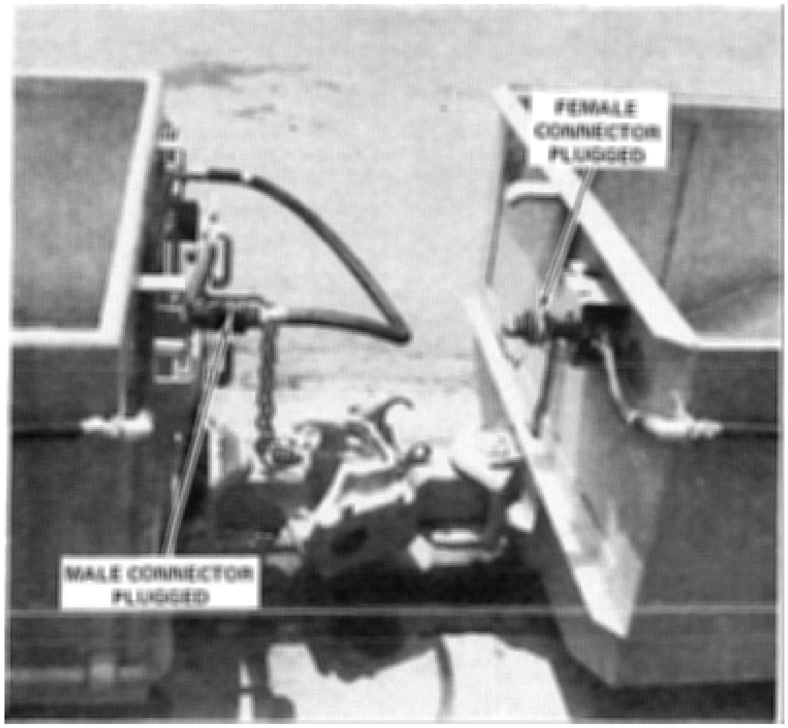
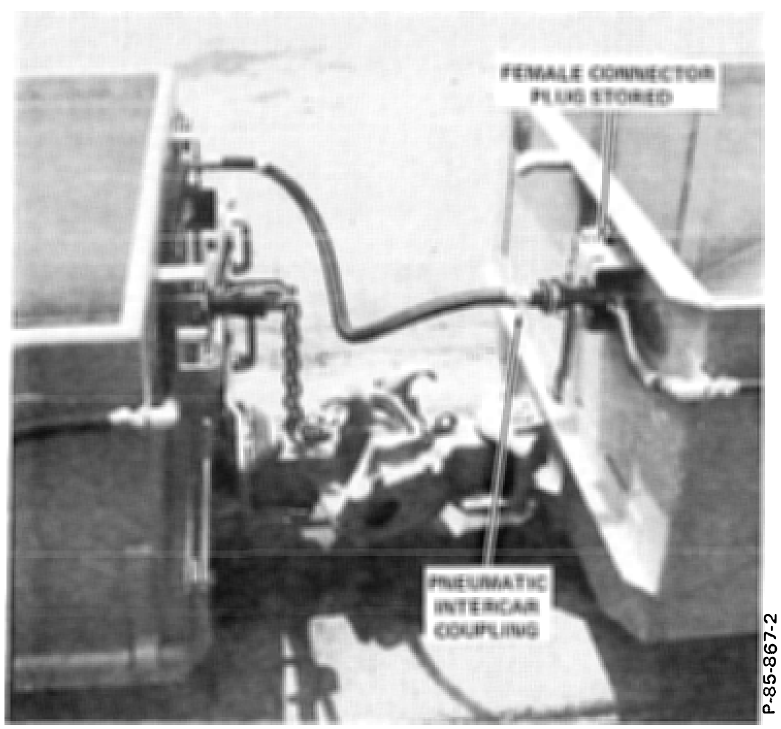


Figure 4-25 - Exploded View of Filter Assembly



(a) Position 1 - Pneumatically Uncoupled



(b) Position 2 - Pneumatically Coupled

Figure 4-26 - Cars Pneumatically Coupled and Uncoupled

SECTION 5

BRAKE SYSTEM OPERATION

The spring-brake system is normally applied and the pneumatic brake-release system must be activated before the locomotive or cars can be moved. The following paragraphs describe the operations necessary to activate the system and to shut the system down.

5.1 LOCOMOTIVE START-UP AND SHUT-DOWN PROCEDURE

5.1.1 Locomotive Start-Up Procedure

(a) Turn circuit breaker handle to ON position. (Handle located at the top center area of the battery box. Schematic shown in Figure 4-7.)

(b) Turn power switch [handle located on the front face of the battery box (shown in Figure 4-11)] to the ON position. (Switch is designated P on wiring diagram shown in Figure 4-7.) This switch energizes the electrical system and starts the compressor.

(c) When pressure gage P3 (shown on pneumatic schematic in Figure 4-1), located in the locomotive cab, reaches 80 psi or higher, place the park-brake valve handle in the BRAKES OFF position (rotate valve designated VB on pneumatic schematic shown in Figure 4-1 counterclockwise) releasing the brakes.

WARNING

The UNLATCH lamp on the electronic control panel, shown in Figure 4-8, indicates that the unlatch operation is required. If this lamp comes on after step (c) is complete, move the brake lever first to its UNLATCH position, as shown in Figure 4-3 (pressure gage P3 must reach 150 psi), then to the BRAKES OFF position to release the brakes.

(d) Check to see if the bypass valve on the locomotive override brake assembly (described in Section 5-3) is open.

The locomotive is now ready for operation.

5.1.2 Locomotive Shut-Down Procedure

(a) Park the locomotive by pulling the brake lever to the BRAKES ON position and hold in that position until park brake valve VB is closed and pressure shown on gage P3 drops to 0 psi. Park valve is designated as VB in pneumatic schematic shown in Figure 4-1. Rotate valve clockwise to close.

(b) Turn power switch (handle located on the front face of the battery box as shown in Figure 4-11) to the OFF position. (Switch is designated P on wiring diagram shown in Figure 4-7.) This switch de-energizes the electrical system and shuts off power to the compressor.

(c) Open air reservoir drain valve to drain any accumulated water. Close valve after all water is expelled. Handle for drain valve is located in the locomotive cab. (Valve is designated VA on the pneumatic schematic shown in Figure 4-1.)

(d) If the locomotive batteries are to be charged, the circuit breaker handle (located at the top center area of the battery box) must be left in the ON position to complete the circuit between the batteries and the charging unit.

5.2 CAR PROCEDURES

5.2.1 Car Coupling and Start-Up Procedure

(a) Mechanically couple the locomotive to the coal car.

(b) Connect the pneumatic couplers between the locomotive and the first coal car and between every additional coal car. The male plug should be stored within the coupler bracket when not in use. Refer to Figures 4-21 and 4-24.

(c) Visually check the cars to make sure that all of the manual brake-release levers are in the unlatched position. (Figure 4-20, normal operation position.)

(d) Place the brake lever in the UNLATCH position shown in Figure 4-3 even if the cars have not been left in the LATCHED position. Return the brake handle to BRAKES OFF operating position.

(e) To stop the trip, pull the brake lever to the BRAKES ON position.

(f) To park the trip, pull the brake lever to the BRAKES ON position and hold in that position until the park valve, VB, is closed (rotated clockwise) and pressure at gage P3 drops to 0 psi.

5.2.2 Upcoupling Cars

(a) Park the trip as described in step 5.1.2 (f), above. This operation will vent the air pressure from all of the brake lines, thereby applying the brakes on the locomotive and all of the coal cars.

WARNING

There are no automatic shutoff valves in the pneumatic couplings. Make sure that the brake pressure gage P3 (located in the cab) is at 0 psi before any of the pneumatic couplers are disconnected.

(b) Disconnect the pneumatic coupler between the locomotive and the coal cars, or between any or all of the coal cars.

(c) Connect the male fitting at the end of the pneumatic hose to the female plug on the same car.

(d) Plug the open female fitting with the male seal-off plug. The plug is chained to the coupler bracket, and is stored inside the bracket. Refer to Figure 4-26.

(e) Mechanically decouple either the locomotive from the first coal car, or any or all coal cars.

(f) To move any of the uncoupled coal cars manually, put the brake release lever shown in Figure 4-22 into the manual release (BRAKES OFF) position.

OPTION: The coal car brakes may be left with the brakes latched off pneumatically by placing the brake lever in the locomotive in the LATCH position before starting step (a), above.

5.3 LOCOMOTIVE SERVICE BRAKES MANUAL OVERRIDE

The locomotive manual override brake should only be applied in emergency situations. The override brake consists of a hydraulic cylinder which, when pressurized by the hydraulic pump in the locomotive cab, will override the spring/pneumatic system and apply the brakes. This brake should be applied as follows:

(a) Engage the hydraulic cylinder by closing the bypass valve (turn valve handle 90 degrees clockwise) located in the locomotive cab. The valve is shown in the hydraulic assembly shown in Figures 4-14 and 4-15.

(b) Apply the brakes by rotating the pump wheel in a clockwise direction. This motion pressurizes the hydraulic cylinder.

(c) The brakes may be released by opening the hydraulic bypass valve (Figure 4-15), rotating the pump wheel 90 degrees in a counterclockwise direction, or both.

WARNING

The manual override brake should never be locked in a brakes-off position. Such a condition would override the pneumatic fail-safe brake system. During normal locomotive operation, the override brake bypass valve shown in Figures 4-14 and 4-15 must be left open (turned 90 degress counterclockwise).

5.4 CAR SERVICE BRAKES OVERRIDE

5.4.1 Manual Override

The car brakes, if latched, may be unlatched manually by moving the coal car manual brake release lever from the normal operating position to the manual release position, then back to the normal operating position. Figure 4-2 shows these positions.

5.4.2 Pneumatic Controlled Override

An automatic latching mechanism was designed into the car brake linkage. The latch mechanism is pneumatically controlled by a brake pressure signal above that of the normal operating level. In order to latch the car brakes, the motorman shifts the brake lever into the LATCH position which provides a line pressure above the normal operating pressure causing the latch to catch in the clevis notch. To unlatch the brakes, he shifts the brake lever into the UNLATCH position, providing a still greater pressure which raises the latch out of the notch in the clevis which prevents it from latching again until the brakes have operated in their normal position.

5.5 OVERSPEED

(a) When the locomotive speed reaches 6 mph, the overspeed control will activate the brake system. The OVERSPEED light on the electronic control unit shown in Figure 4-8 will light to indicate that the speed has exceeded 6 mph.

(b) When the locomotive speed has been reduced below 6 mph, the RESET light, Figure 4-8, will light. At this time, the brake system may be released by pushing the OVERSPEED RESET button.

SECTION 6

PREPARATION OF THE SYSTEM "MAINTENANCE MANUAL"

A maintenance manual for the Bruceton locomotive and haulage cars modified under Contract H0110896 was prepared and delivered to the USBM.

This manual is intended to serve motormen and maintenance personnel as an all-inclusive brake system reference for the Bruceton fail-safe brake system. Therefore, the manual was divided into a description of the brake system for both motormen and maintenance personnel, an operation section for both motormen and maintenance personnel and two maintenance sections (scheduled and unscheduled) of interest to maintenance personnel.

In addition, Appendix A of the maintenance manual contains manufacturer's literature on the Quincy air compressor. This literature includes the instruction manual, service data, troubleshooting data, and parts lists.

Appendix B of the maintenance manual contains the manufacturer's literature on the Plessey Airborne Rotomission compressor motor-speed reducer. This literature includes the description, maintenance, and parts lists.

Appendix C of the maintenance manual contains selected engineering assembly drawings and a schematic, useful as references for troubleshooting and repair.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

All of the tasks in the scope of work for this contract have been completed. The special reports have been published, the Bruceton locomotive and its five coal haulage cars were modified and outfitted with an automatic braking system, and the system was maintained for the specified six-month period.

Thus, the hardware feasibility of the automatic brake system has been demonstrated. The implementation of the hardware, an objective of this contract, has been successful.

However, based on the practical experience obtained in installing this system, several areas worthy of review have been observed and are listed as part of the following recommendations section. In addition, experience has shown that transition into new braking systems must be slow and of such a design that it is readily accepted by the mine worker.

7.2 RECOMMENDATIONS

The major technical recommendation, based on the experience obtained in performing this contract, is that a redesign and adaptation of a pneumatic fail-safe braking system should be performed using a larger and more conventional-sized locomotive and coal haulage cars.

A configuration that should be considered, is one which would use only the locomotive brakes for service braking, and the combination of locomotive and haulage cars brakes for emergency braking. Such a system should be designed so that the locomotive braking response and performance is independent of car or cars coupled to the locomotive during all braking conditions. Likewise, each haulage car braking response and performance should be independent of any other car or the locomotive. The present system loses braking response time proportional to the amount of cars coupled to the locomotive since the air from all cars and the locomotive are collectively vented through the locomotive brake control valve. Since the brakes on all vehicles are applied at a rate proportional to the rate of increase of the force of the brake shoes against the wheels, and the brake spring force increase is proportional to the rate of decrease of spring compression by the air in the air cylinder, then it is readily seen that the rate of braking is proportional to rate of pressure decrease (venting speed) on the brake cylinders.

Such a system would have advantages other than performance. There would be a conservation of pneumatic supply since the amount of air vented during a normal service stop would only be the volume of the locomotive brakes rather than the locomotive and all the haulage cars. This would allow use of a smaller size compressor, along with a smaller size compressor motor to meet the air supply requirements. Besides the motor being smaller, it would also run less since it would be replacing a smaller quantity of air per braking operation. Therefore, the electrical power demands would decrease, resulting in a conservation of battery supply.

Implementation of this recommendation would however, result in two main differences. The first is that service braking performance with cars coupled would decrease, and the second is that the implementation of the brake control system would be more complex.

An area that could be investigated to improve the locomotive braking on the present system is the response of the locomotive pneumatic air cylinder. New techniques to reduce the friction in the pneumatic cylinder which holds the brake spring in the brakes-off position should be investigated. A possibility is the replacement of the cylinder seals with a new style that has lower breakaway friction when air is removed and the piston is moved by the brake spring force.

Both the force and time required to move the piston are directly subtracted from the force and response time of the brake system. An alternate solution to increase the speed of the retracting piston would be to use air pressure to assist the spring during the initial stroking of the piston. This alternate would require a more sophisticated system. Another alternative would be to use a long-stroke, rolling-diaphragm air cylinder such as the Bellofram style. These devices are virtually frictionless.

Another area that could be investigated to improve the braking response would be to modify the pneumatic logic in such a manner that control solenoid G1, shown in Table 4-1, is switched to be in the open position during service braking of the locomotive, with or without attached haulage cars, which would assist in dumping the line air pressure at a faster rate, thereby increasing brake response.

The following specific areas are being submitted for future braking system review.

(1) Out-of-Round Car Wheels - Use of cast iron car wheels as a contacting surface for the brake shoes is very difficult to accomplish in practice, since wheels used "as cast" are very much out of round. This condition causes each car wheel to lockup at a different force level as the braking force is applied. Only steel wheels should be considered.

(2) Car Axle Positioning - The high amount of front-to-back and axial clearance of the old type Bruceton mine car axles to their mounting require a high amount of flexibility and stroke provision to be designed into the brake mechanism. Only cars with limited axles motion should be considered for future braking systems.

(3) Spring-Applied Brake System - A spring-applied brake system is limited in performance since it can have a wide range of actual braking force caused by environmental conditions that can act on the linkages to reduce the effectiveness of the spring. However, such a system can be quite effective as a pure emergency system.

(4) Brake Surface Independent of Wheel Surface - A brake drum or brake disc attached to the vehicle axle for use only as a brake shoe contacting component would divorce the braking mechanism from the wheel problems.

(5) Brake Control Valve - A control valve, requiring lower component tolerances and clearances, would be more suitable to a mine environment.

(6) Latching Mechanism - A latching mechanism that must be designed to meet the requirements as specified for the Bruceton car is most difficult. Other types of systems should be considered, such as one that uses an auxiliary air supply for activation or one that uses pressure from the locomotive but can be isolated from the locomotive while maintaining pressure in its system.

(7) Cable Link in Mechanical Override - Cables have limitations in usage because of difficulty in attachment, and susceptibility to damage. Rigid steel links appear to be more suitable.

(8) Automatic Couplers - Automatic car couplers should include automatic air line coupling.

SECTION 8

PATENTS AND INVENTIONS

There were no patents or inventions made in the course of performing this contract.

APPENDIX A

ASSEMBLY DRAWINGS

Locomotive Assembly (Bendix Research Laboratories Drawings)

D2179310 - Outline and Installation Drawing, Locomotive Modifications

D2176445 - Locomotive Chassis Assembly

D2176447 - Fail-Safe Brake Control Valve Assembly (2 sheets)

D2179312 - Installation, Speed Sensor Assembly, Locomotive Modification

D2179167 - Speed Sensor Assembly

E2179177 - Battery Box Assembly

Mine Car Assembly (Bendix Research Laboratories Drawings)

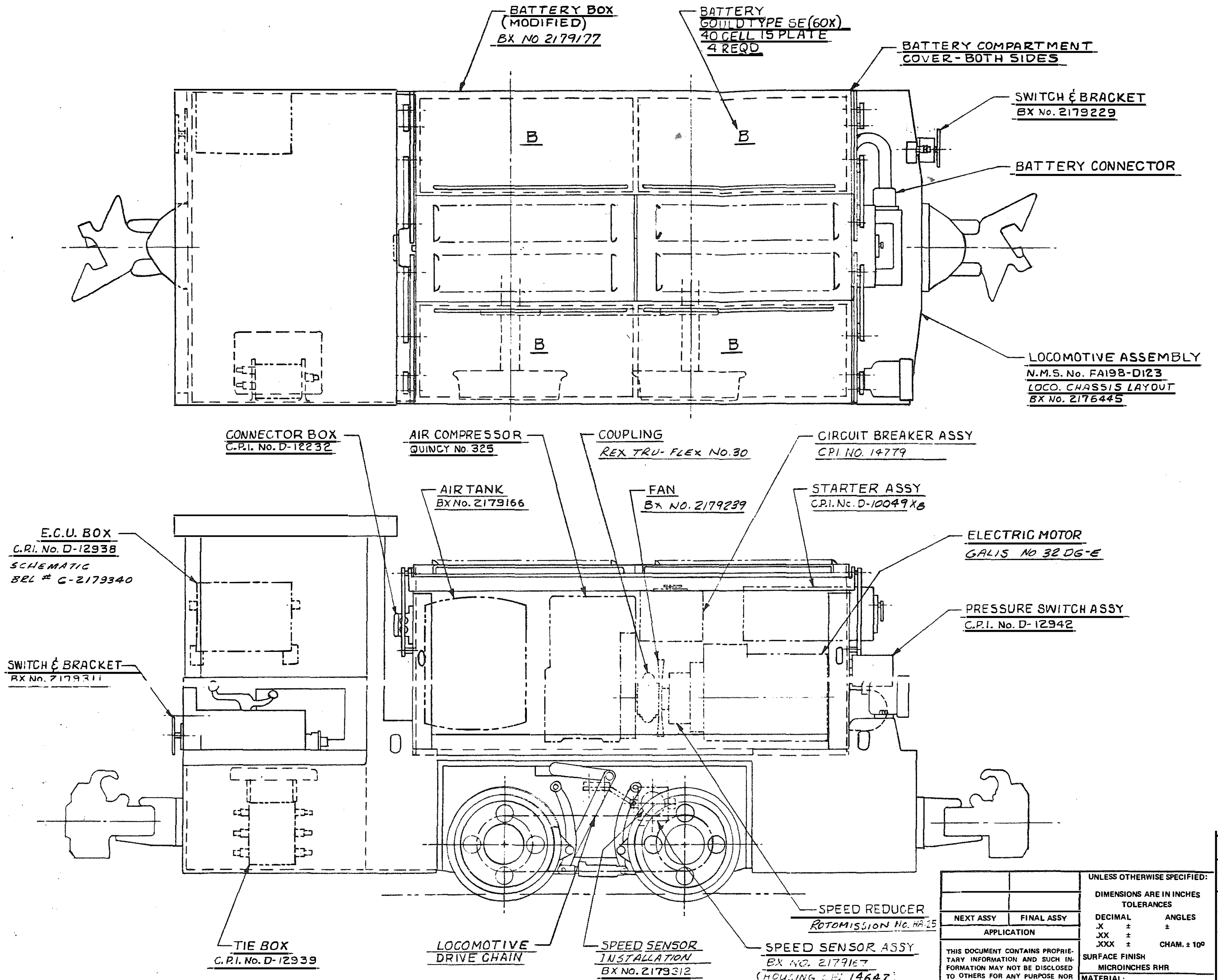
E2179018 - Mine Car Assembly

E2176031 - Fail-Safe Brake Assembly, Mine Car

D2177336 - Latch Mechanism Assembly

Locomotive Electronics (Control Products, Inc. Drawing)

C-14538 - Schematic and Actual Wiring, Compressor Starter



NOTES:

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REVISIONS

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LIST OF MATERIALS

NEXT ASSY	FINAL ASSY

APPLICATION

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAM. ± 10°
SURFACE FINISH MICROINCHES RHR
MATERIAL: —//—

CONTR NO.
PROJ NO. 2879-2110

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APPD	SPROULE	11-20-73
APPD	Lorraine	11/23/73
APPD	[illegible]	3-9-74
APPD		

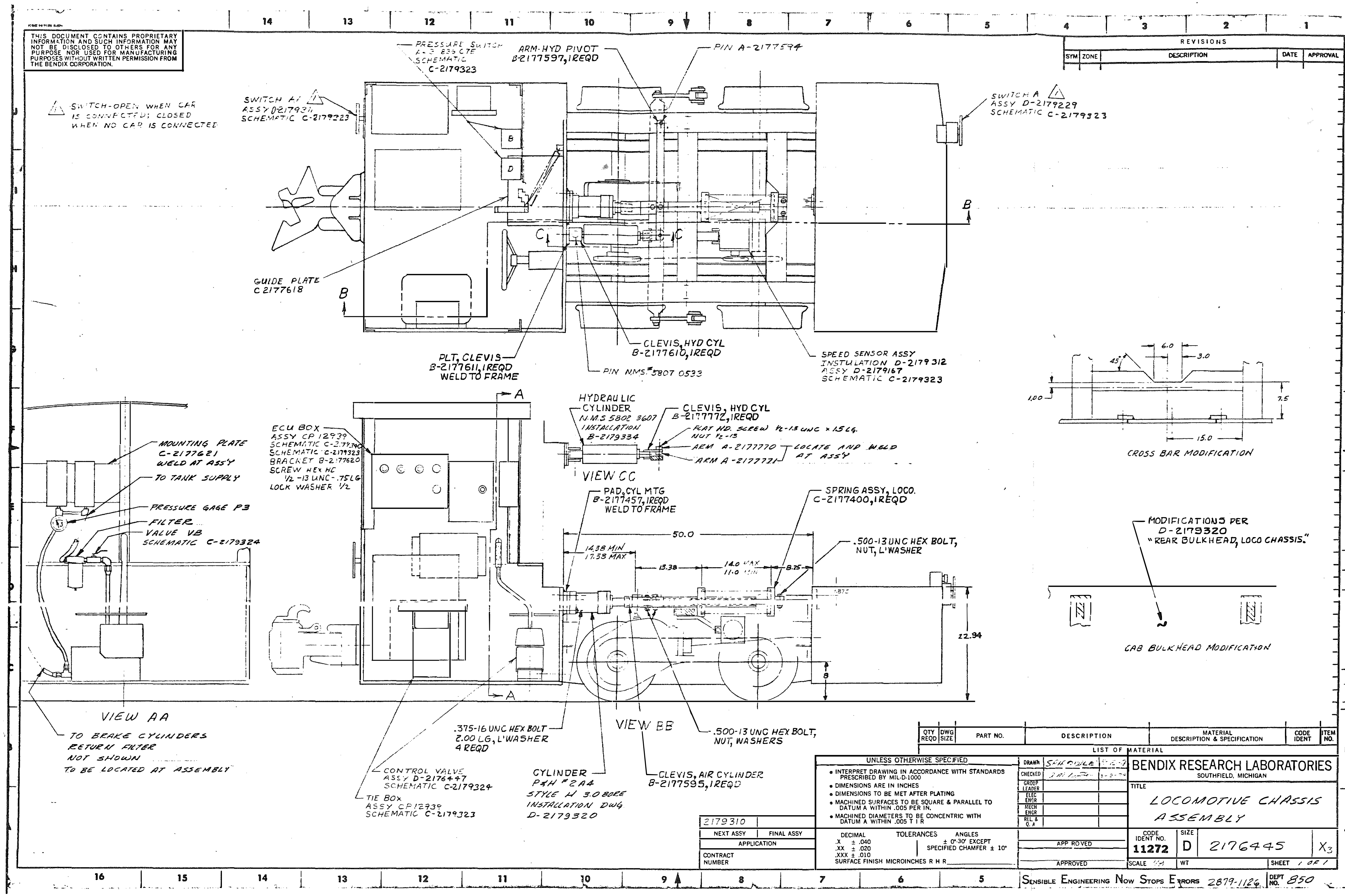
Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

TITLE: OUTLINE & INSTALLATION DWG, LOCOMOTIVE MODIFICATIONS

SIZE D | CODE IDENT NO. 11272 | 2179310 | REV. X2

SCALE — | WT | SHEET 1 OF 1

DEPT NO. 850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SWITCH-OPEN WHEN CAR IS CONNECTED; CLOSED WHEN NO CAR IS CONNECTED
PRESSURE SWITCH
SCHEMATIC C-2179323
ARM-HYD PIVOT B-2177597, 1 REQD
PIN A-2177594
SWITCH A ASSY D-2179229 SCHEMATIC C-2179323
SCHEMATIC C-2179223
GUIDE PLATE C 2177618
B
C
PLT, CLEVIS B-2177611, 1 REQD WELD TO FRAME
CLEVIS, HYD CYL B-2177610, 1 REQD
PIN NMS 5807 0533
SPEED SENSOR ASSY INSTULATION D-2179312 ASSY D-2179167 SCHEMATIC C-2179323
REVISIONS
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DESCRIPTION
DATE
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6.0
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7.5
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CROSS BAR MODIFICATION
A
ECU BOX ASSY CP 12939 SCHEMATIC C-2179323 BRACKET B-2177620 SCREW HEX HC 1/2-13 UNC-.75LG LOCK WASHER 1/2
HYDRAULIC CYLINDER N.M.S 5802 3607 INSTALLATION B-2179334
CLEVIS, HYD CYL B-2177772, 1 REQD
FLAT HD. SCREW 1/2-13 UNC x 1.5 LG.
NUT 1/2-13
ARM A-2177770
ARM A-2177771
LOCATE AND WELD AT ASSY
VIEW CC
MOUNTING PLATE C-2177621 WELD AT ASS'Y
TO TANK SUPPLY
PRESSURE GAGE P3
FILTER
VALVE VB SCHEMATIC C-2179324
PAD, CYL MTG B-2177457, 1 REQD WELD TO FRAME
SPRING ASSY, LOCO. C-2177400, 1 REQD
MODIFICATIONS PER D-2179320 "REAR BULKHEAD, LOCO CHASSIS."
50.0
14.38 MIN 17.38 MAX
13.38
14.0 MAX 11.0 MIN
8.75
.500-13 UNC HEX BOLT, NUT, L'WASHER
22.94
8
CAB BULKHEAD MODIFICATION
VIEW AA
VIEW BB
TO BRAKE CYLINDERS RETURN FILTER NOT SHOWN TO BE LOCATED AT ASSEMBLY
.375-16 UNC HEX BOLT 2.00 LG, L'WASHER 4 REQD
CONTROL VALVE ASSY D-2176447 SCHEMATIC C-2179324
TIE BOX ASSY CP12939 SCHEMATIC C-2179323
CYLINDER P&H #2A4 STYLE H 3.0 BORE INSTALLATION DWG D-2179320
CLEVIS, AIR CYLINDER B-2177595, 1 REQD
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QTY REQD
DWG SIZE
PART NO.
DESCRIPTION
MATERIAL DESCRIPTION & SPECIFICATION
CODE IDENT
ITEM NO.
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MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R
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TOLERANCES
ANGLES ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R
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FINAL ASSY
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DRAWN
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APPROVED
BENDIX RESEARCH LABORATORIES
SOUTHFIELD, MICHIGAN
TITLE
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CODE IDENT NO. 11272
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SHEET 1 OF 1
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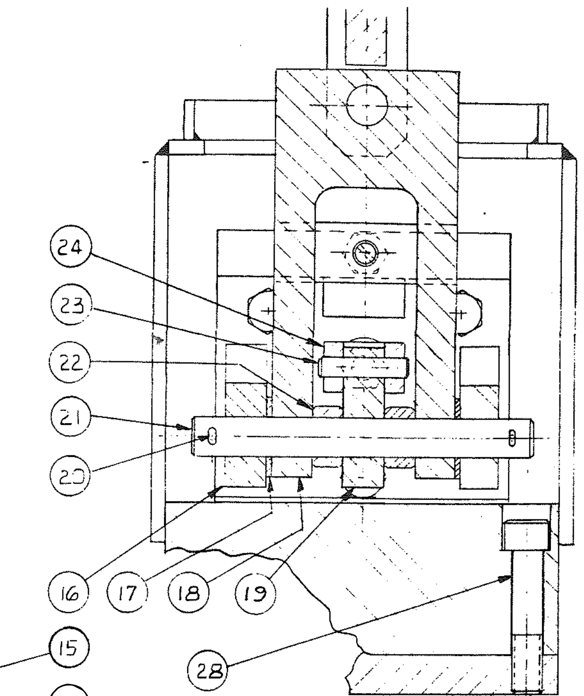

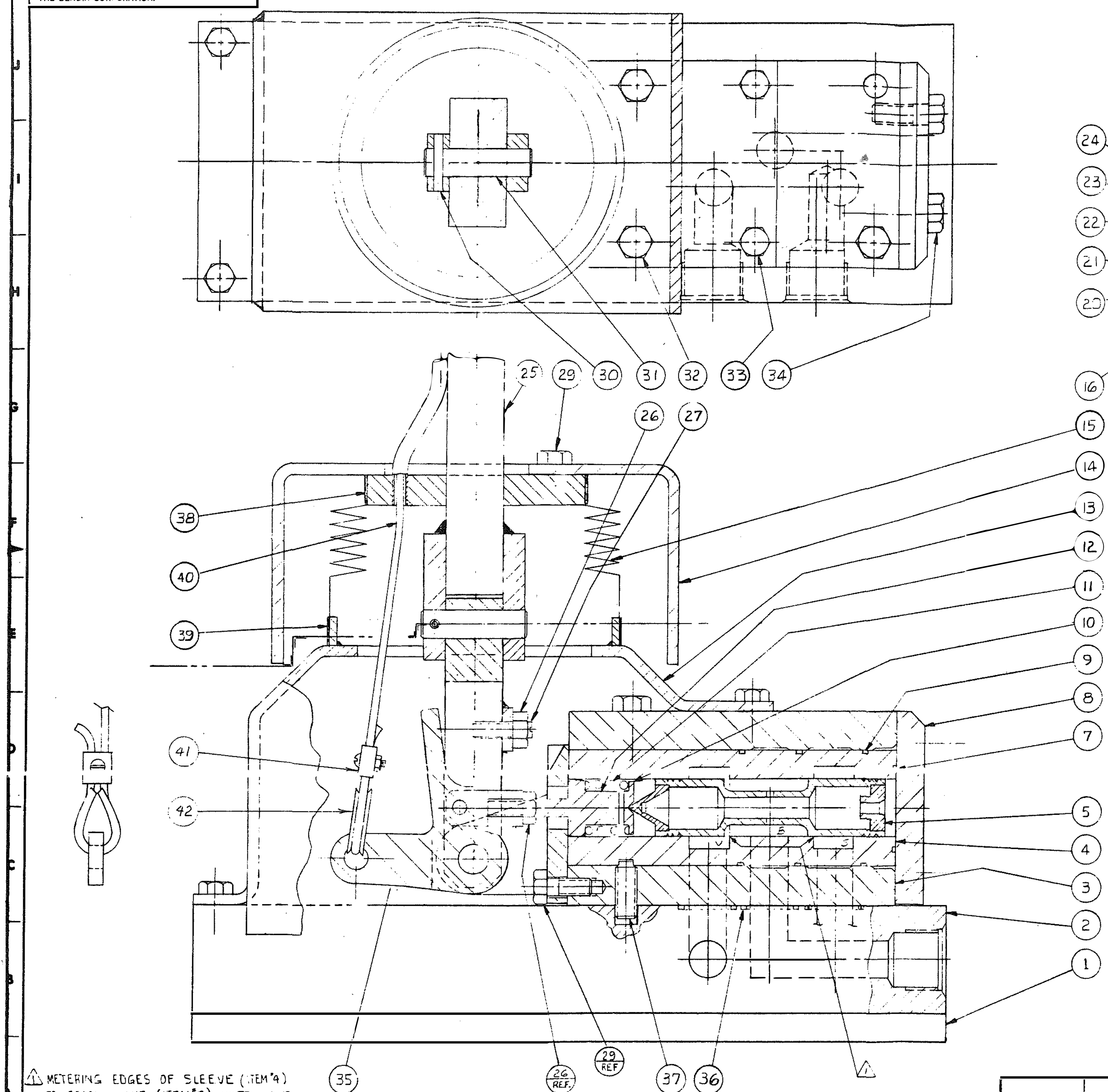

⚠ METERING EDGES OF SLEEVE (ITEM 4) TO SPOOL VALVE (ITEM 5) MUST HAVE A ZERO LAP CONDITION

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2	-	STOCK	NUT-HEX.	5/16-18 UNC-2B		26
1	D	2176248	HANDLE ASSY			25
1	B	2176878	CLEVIS			24
1	-	STOCK	DOWEL PIN .250 .0005 DIA	1.00 LG SST		23
2	-	STOCK	PLAIN BEARING - BRONZE	BUNTING No P52-3		22
1	B	2176877	SHAFT			21
2	-	STOCK	COTTER PIN	.093 DIA x 1.00 LG		20
1	C	2176881	LEVER - CONTROL VALVE			19
1	C	217688●	HANDLE EXTENSION			18
2	-	STOCK	WASHER	.56 I.D. 1.00 O.D. .050 THK.		17
1	C	2176875	RETAINER - PLATE			16
1	C	2176845	BELLOWS			15
1	C	2176885	COVER - HANDLE			14
1	D	2176884	COVER - LINKAGE			13
1	C	2176873	PLUNGER - SPRING			12
1	B	2176785	SPRING - SPOOL VALVE			11
1	B	2176871	CAP - SPRING			10
3	-	STOCK	O'RING	PARKER # 2-32		9
1	B	2176874	COVER - CONTROL VALVE			8
1	—	STOCK	O'RING	PARKER # 2-28		7
						6
1	C	2176870	SPOOL ASS'Y			5
1	D	2176869	SLEEVE - CONTROL VALVE			4
1	D	2176868	VALVE BODY			3
1	D	2176876	MANIFOLD & MOUNTING PLATE			2
1	C	2179879	BASE - CONTROL VALVE			1

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-1000
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040, .XX ± .020, .XXX ± .010

ANGLES: ± 0°-30′ EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

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MECH ENGR J Lorraine [illegible]
REL & Q.A.
APPROVED
APPROVED

BENDIX RESEARCH LABORATORIES
SOUTHFIELD, MICHIGAN

TITLE: FAIL SAFE BRAKE CONTROL VALVE ASSEMBLY

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SCALE FULL | WT | SHEET 1 OF 2

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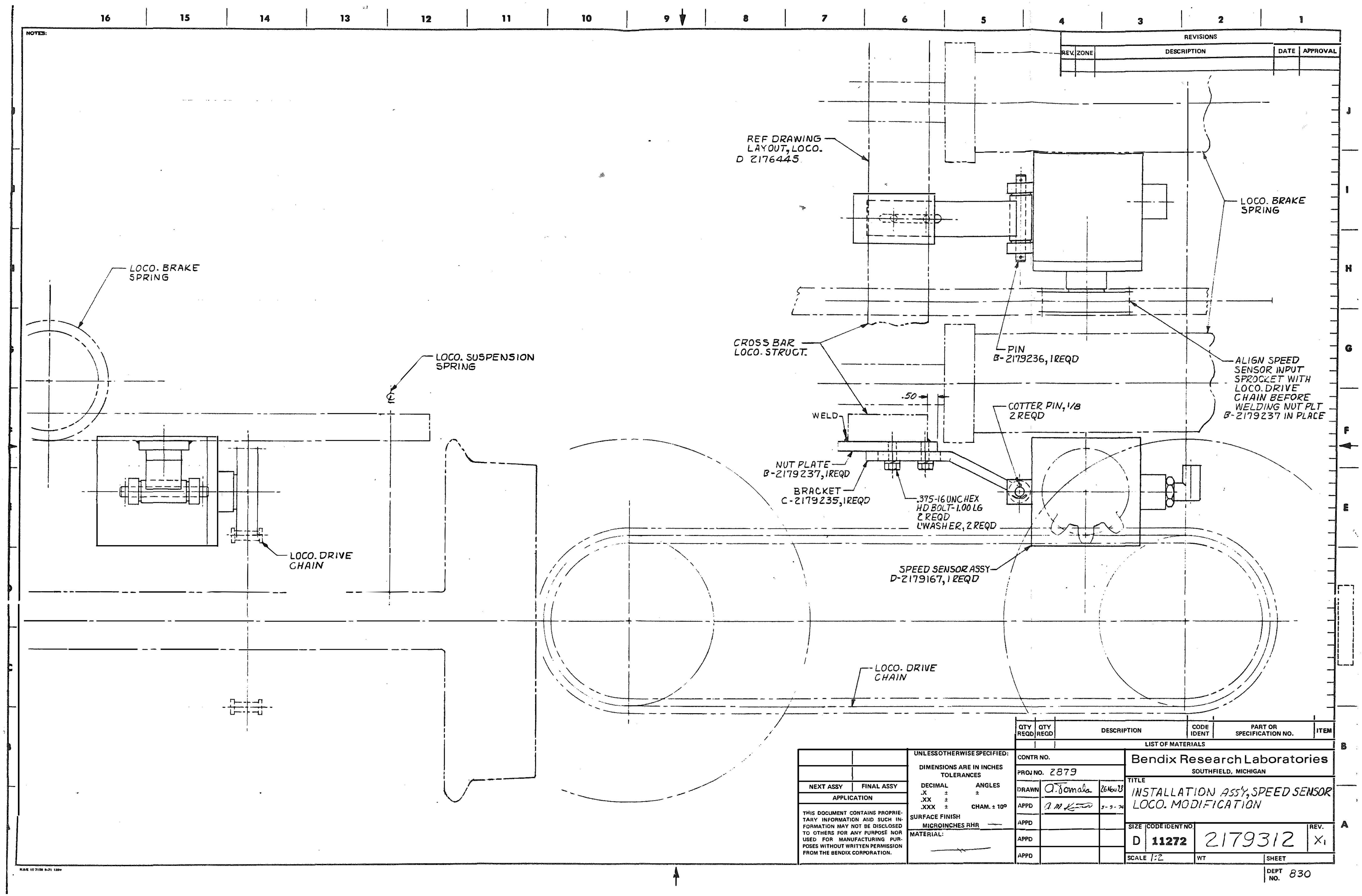

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LOCO. BRAKE SPRING
LOCO. SUSPENSION SPRING
CROSS BAR LOCO. STRUCT.
PIN B-2179236, 1 REQD
ALIGN SPEED SENSOR INPUT SPROCKET WITH LOCO. DRIVE CHAIN BEFORE WELDING NUT PLT B-2179237 IN PLACE
.50
WELD
COTTER PIN, 1/8 2 REQD
NUT PLATE B-2179237, 1 REQD
BRACKET C-2179235, 1 REQD
.375-16 UNC HEX HD BOLT-1.00 LG 2 REQD LWASHER, 2 REQD
LOCO. DRIVE CHAIN
SPEED SENSOR ASSY D-2179167, 1 REQD
LOCO. DRIVE CHAIN
QTY REQD QTY REQD DESCRIPTION CODE IDENT PART OR SPECIFICATION NO. ITEM
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DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ±
ANGLES ±
CHAM. ± 10°
SURFACE FINISH MICROINCHES RHR
MATERIAL:
CONTR NO.
PROJ NO. 2879
DRAWN 26 Nov 73
APPD
Bendix Research Laboratories
SOUTHFIELD, MICHIGAN
TITLE
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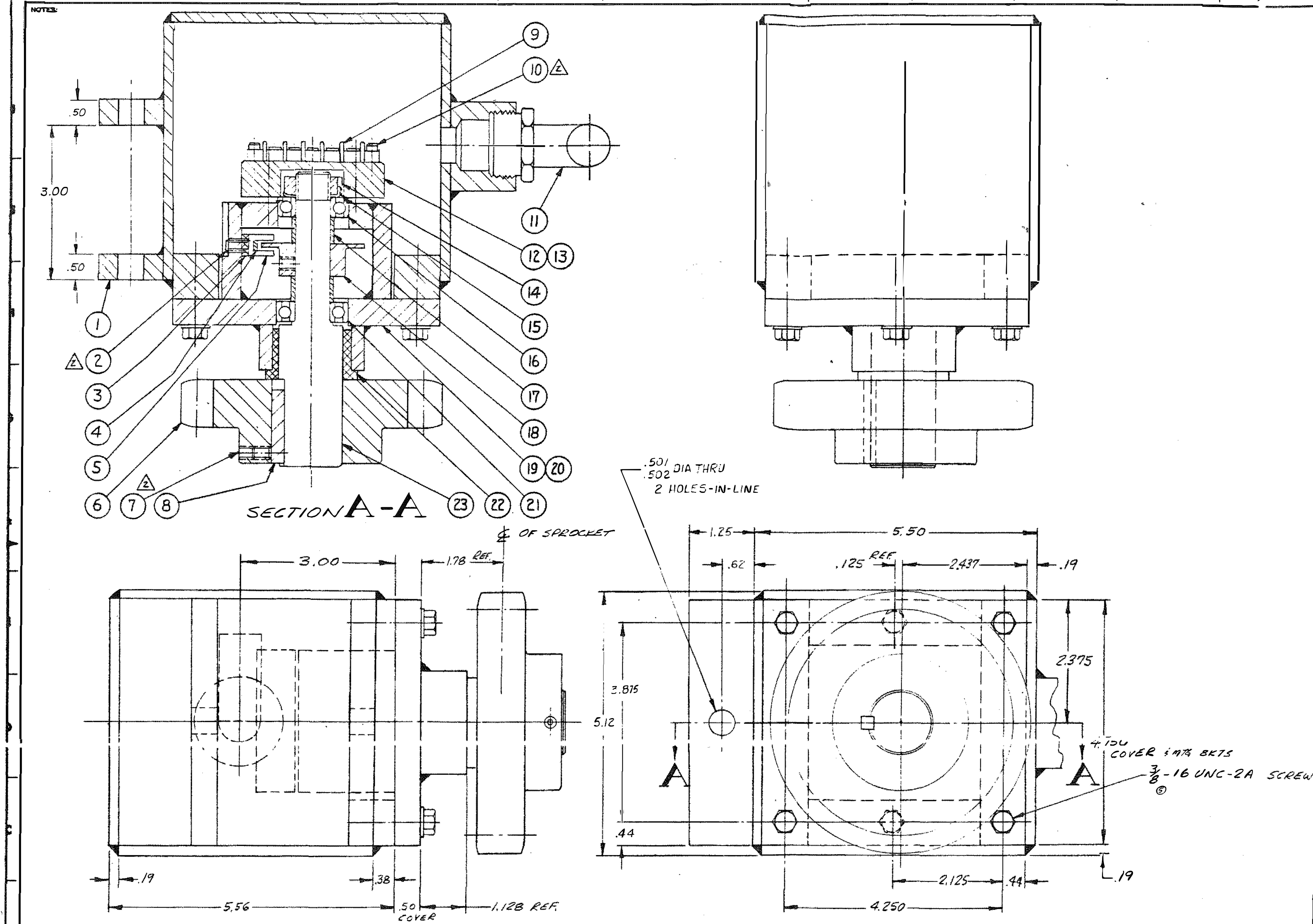

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	1	FLANGE BEARING		BUNTING No. FL-125-10	22
	1	BEARING, NEW DEPART.		No. Z4993L03	21
	6	SCR-.375-16UNC-2A×1.0LG		HEX HD.	20
	1	COVER	D	2179198	19
	1	PIN WHEEL	B	2179208	18
	2	SPACER	A	2179211	17
	1	BEARING, NEW DEPART.		No. Z393L03	16
	1	LOCKWASHER		A.B.E.C. STD W-03	15
	1	LOCKNUT		A.B.E.C. STD N-03	14
	4	SCR-.250-20UNC-2A×1.2LG		SOC HD CAP	13
	1	RETAINER, BEARING	B	2179210	12
	1	PACKING GLAND		No. 14-4 3/4 I.D.	11
	4	SCR-#5-40UNC-2A×.50LG		SOC HD CAP	10
	1	BARRIER STRIP, KULKA		No. 600A-C-5	9
	1	KEY-.250 SQ ×1.38LG			8
	3	SCR-.250-20UNC-2A×.25LG		SOC HD SET	7
	1	GEAR	B	2179207	6
	1	OPTICAL SWITCH, HEI INC		No OS-591S-200LW	5
	1	RETAINER	B	2179212	4
	1	SHOCK PAD	A	2179213	3
	2	SCR-#10-24UNC-2A×.38LG		SOC HD CAP	2
⚠1	1	CASE		CONT. PROD No. D-14647	1

LIST OF MATERIALS

NOTE:
⚠1 ITEMS (1) (11) PER CONTROL PRODUCTS DWG # D-14647
⚠2 APPLY LOCTITE "SCREWLOCK" AT ASSY.

NEXT ASSY	FINAL ASSY
2179312	2179310

APPLICATION

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TOLERANCES
DECIMAL: .X ±.03, .XX ±.02, .XXX ±.010
ANGLES ± — CHAM. ± 10°
SURFACE FINISH MICROINCHES RHR
MATERIAL:

CONTR NO.
PROJ NO. 2879-2110
DRAWN SPROULE 10-5-73
APPD Lorraine 11/27/73
APPD

Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

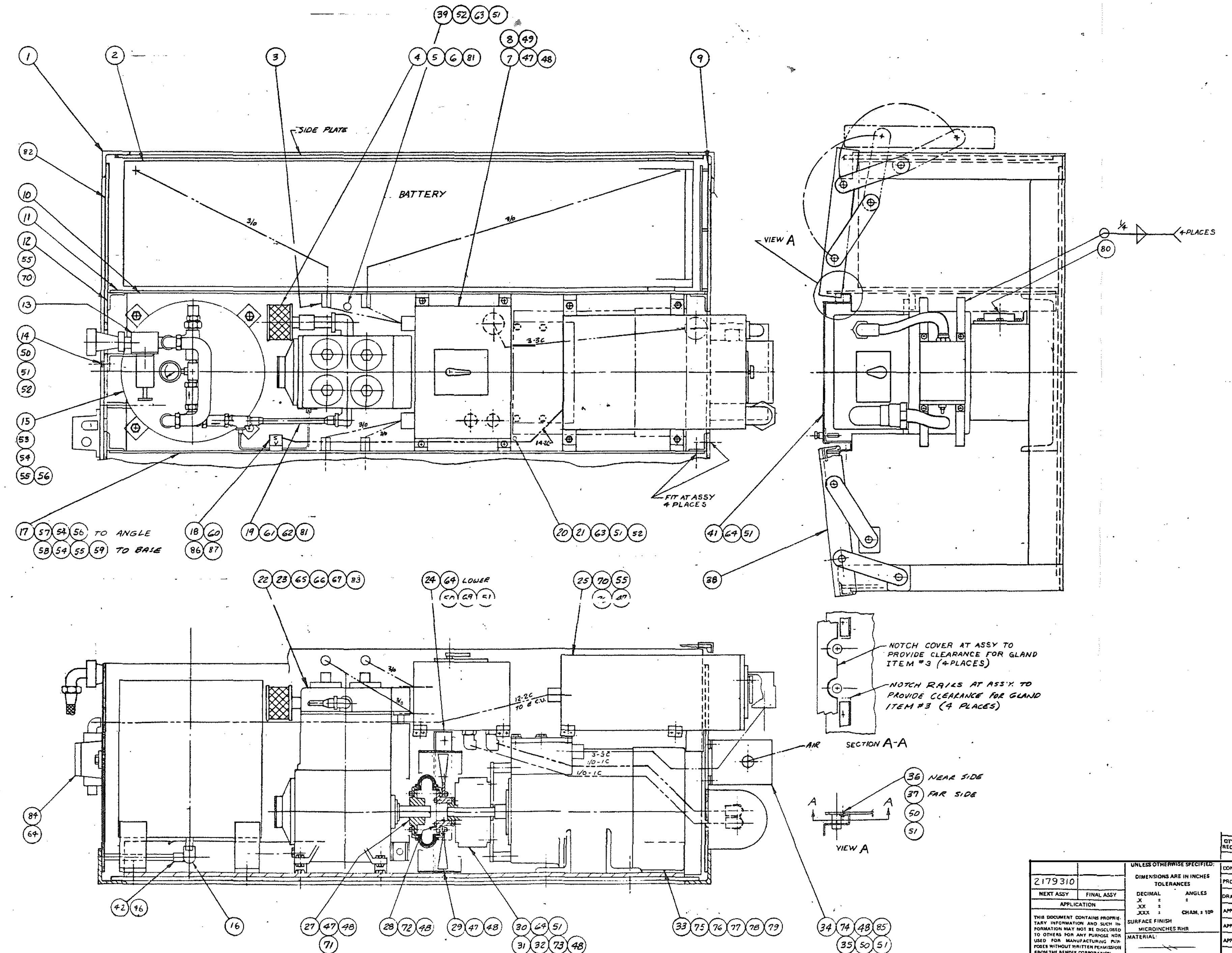
TITLE: ASSEMBLY – SPEED SENSOR

SIZE D | CODE IDENT NO. 11272 | 2179167 | REV. X5
SCALE FULL | WT | SHEET 1 OF 1
DEPT NO. 850

NOTES:

1. ALL ELECTRICAL COMPONENTS AND CABLES BETWEEN COMPONENTS SHALL BE IN ACCORDANCE WITH U.S. BUREAU OF MINES REGULATIONS: SCHEDULE 2G SPECIFICALLY SECTIONS 18.20, 18.36, 18.39 AND 18.44.

2. RETOUCH ANY UNPAINTED AREAS, COLOR: YELLOW #13655.



REVISIONS

REV.	ZONE	DESCRIPTION	DATE	APPROVAL

LIST OF MATERIALS

QTY REQD	QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM
	1	FITTING - TEE		PARKER # 4 9BTX	87
	1	TUBING		1/4 X 3'	86
	1	TUBING		3/8 X 7'	85
	1	CONNECTION BOX		CONTROL PROD. D 12232	84
	4	NUT - HEX		5/8 - 11 UNC	83
	1	REAR PLATE		C2179286	82
	2	PIPE ELBOW		PARKER # 1 CD - SS	81
	1	DISCONNECT RECEPTICLE		CONTROL PROD. # 12031	80
	4	NUT - HEX		1/2 - 13 UNC	79
	4	LOCKWASHER		1/2	78
	4	WASHER - PLAIN		1/2	77
	4	STUD		1/2 - 13 UNC x 2.0 LG.	76
	1	KEY		1/4 x 5/16 x 2.156	75
	4	SCREW - HEX. HD		5/16 - 18 UNC. x 75 LG.	74
	6	SCREW - HEX. HD.		5/16 - 18 UNC x 3.00 LG	73
	6	SCREW - HEX. HD		5/16 - 18 UNC x 2.25 LG	72
	1	KEY			71
	20	SCREW - HEX. HD.		5/8 - 16 UNC x 1.25 LG.	70
	4	SCREW - FL. HD 82°		1/4 - 20 UNC x 1.00 LG	69
					68
	4	NUT - HEX		7/16 - 14 UNC	67
	4	LOCKWASHER		7/16	66
	4	WASHER - PLAIN		7/16	65
	12	SCREW - HEX. HD.		1/4 - 20 UNC x .75 LG	64
	4	SCREW - FL. HD. 82°		1/4 - 20 UNC x 3.0 LG	63
	1	FITTING - HOSE		PARKER #	62
	2	FITTING - HOSE		PARKER #	61
	2	SCREW - FL. HD. 82°		10-32 UNF x .50 LG	60
	12	WASHER - BEVEL		3/8	59
	12	SCREW - FL. HD. 82°		3/8 - 16 UNC x 1.75	58
	20	SCREW - FL. HD 82°		3/8 - 16 UNC x 1.00 LG.	57
	24	NUT - HEX		3/8 - 16 UNC	56
	34	LOCKWASHER		3/8	55
	36	WASHER - PLAIN		3/8	54
	4	STUD		3/8 - 16 UNC x 2.00 LG	53
	6	NUT - HEX		1/4 - 20 UNC	52
	38	LOCKWASHER		1/4	51
	22	SCREW - HEX HD.		1/4 - 20 UNC x 1.00 LG.	50
	4	SCREW - FL. HD. 82°		5/16 - 18 UNC. x 62 LG	49
	32	LOCKWASHER		5/16	48
	20	SCREW - HEX HD.		5/16 - 18 UNC x 1.00 LG	47
	1	DRAIN VALVE HANDLE			46
					45
					44
					43
	7	DRAIN VALVE ASSY		C-2179330	42
	1	COVER		C 2179322	41
					40
	1	COMPRESSOR DIPSTICK ASS'Y		D-2179319	39
	2	COVER & HINGES		D-2179321	38
	1	RAIL - FAR		B-2179302-2	37
	1	RAIL - NEAR		B-2179302-1	36
	2	NUT PLATE PRESS. SW		B-2179238	35
	1	ASS'Y - PRESS. SWITCH		CONTROL PROD. # D-12942	34
	1	MOTOR		GALIS # 32 DG-E	33
	4	STANDOFF - MOTOR		C-2179226	32
	1	ADAPTER - MOTOR		D-2179227	31
	1	DRIVE - DIFFERENTIAL		ROTOMISSION HA-25-6-2.38-0	30
	1	FAN - COMPRESSOR		D-2179239	29
	1	ADAPTER - COUPLING		D-2179179	28
	1	COUPLING		REX TRU-FLEX #30-1.375 BORE	27
	4	BLOCK - MTG - STARTER		A 2179281	26
	1	ASSEMBLY - STARTER		CONTROL PROD # D-14534	25
	1	SHROUD - FAN		D-2179248	24
	4	STUD - COMPRESSOR		A-2179285	23
	1	[illegible]		QUINCY [illegible]	22
	1	CLAMP		A-2179279-2	21
	1	ASSEMBLY - DIP STICK TRANS.		D-2179318	20
	1	ASSEMBLY - HOSE			19
	1	SOLENOID VALVE		SKINNER X5C6260 N.O.	18
	1	PLATE - CONTROLS SUP. NEAR		C-2179247	17
	1	ASSEMBLY - DRAIN			16
	1	ASSEMBLY - TANK		C-2179166	15
	1	BRACKET -			14
	1	ASSEMBLY - SEQ. VALVES		D-2179317	13
	4	ANGLE - BATTERY BOX		B-2179282	12
	1	PLATE - CONTROL SUP. FAR		C-2179249	11
	1	BASE - PLATE		D-2179178	10
	1	FRONT PLATE		D-2179286	9
	4	BLOCK - MTG. CKT BRK.		A-2179280	8
	1	BOX - CIRCUIT BREAKER		CONTROL PROD. # 14779	7
	1	FILTER		QUINCY # 7430X	6
	1	COUPLING		1.0 I.P.S GALV.	5
	1	NIPPLE		1.0 I.P.S. x 3.7 LG. GALV.	4
	4	ASS'Y - GLAND		3/0 - 1 CABLE 1.00 I.D. COND	3
	2	BATTERY		NATIONAL MINE # 17720 B	2
	1	BATTERY ASY		NATIONAL MINE # F76697-D	1

2179177

2179310	
NEXT ASSY	FINAL ASSY
APPLICATION	

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ±
ANGLES ±
CHAM. ± 10°
SURFACE FINISH
MICROINCHES RHR
MATERIAL: —

CONTR NO.		
PROJ NO.	2972-210	
DRAWN	SPRAGLE	9-73
APPD	[illegible]	3-9-74
APPD		
APPD		
APPD		

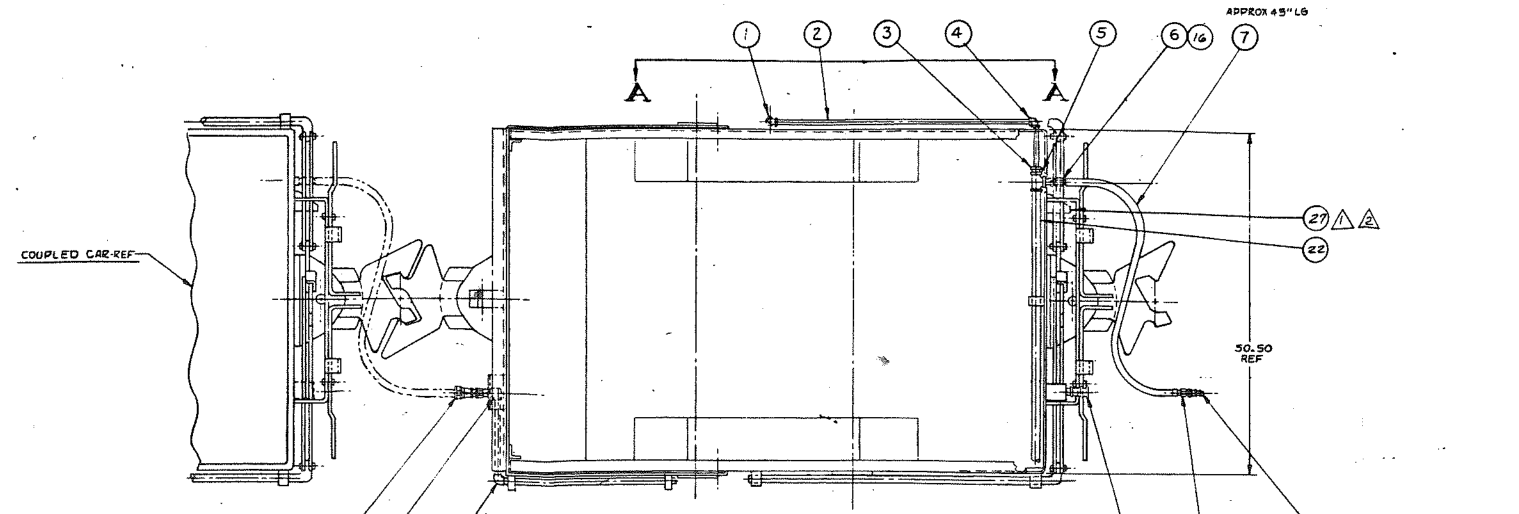
Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

TITLE: ASSEMBLY - BATTERY BOX

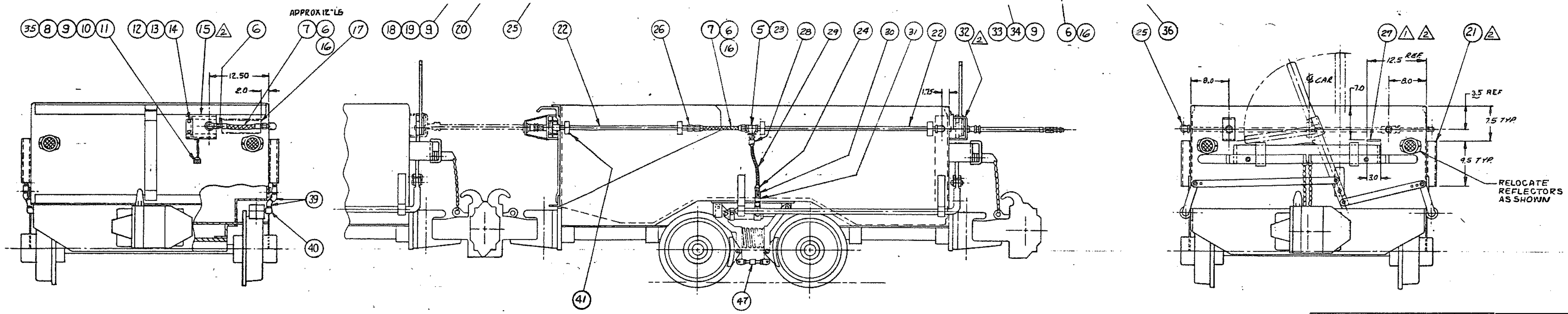
SIZE	CODE IDENT NO.		REV.
E	11272	2179177	X4
SCALE 1/4	WT	SHEET 1 OF 1	

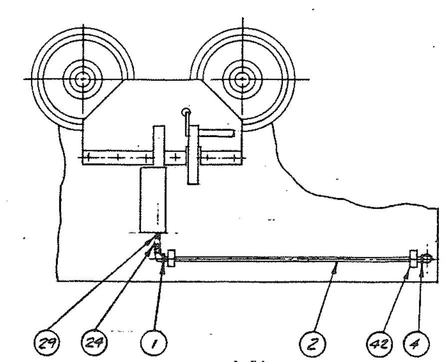
DEPT NO. 850

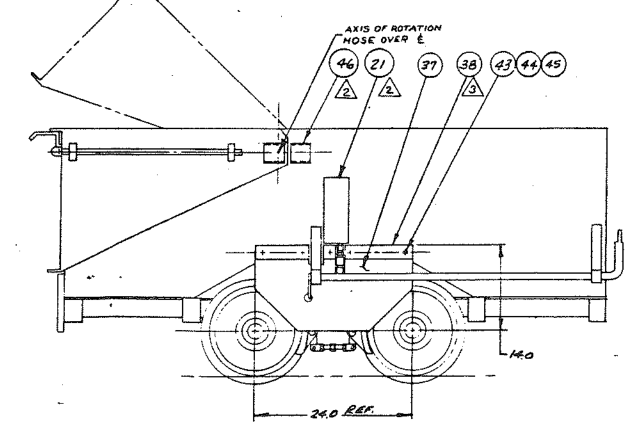
REV.	ZONE	DESCRIPTION	DATE	APPROVAL



2		FAIL SAFE BRAKE SYS.		E 2176031	47
2		GUARD - SQUARE TUBE		3.0/4.0 x 3.0 LG. OR EQUIV.	46
12		NUT - HEX 5/16-18 UNC-2B			45
12		WASHER - LOCK - 5/16			44
12		SCR. - 5/16 - 18 UNC-2A x 1.25 LG		ROUND HEAD	43
2		BRACKET-PIPE (1/4 I.P.S.)		C-2179160-2	42
5		BRACKET - PIPE (3/4 I.P.S.)		C-2179160-1	41
2		FITTING, STREET ELBOW		PARKER No. 1/4 CD-SS	40
4		FITTING, STREET EL. (45°)		PARKER No. 1/4 CD45-SS	39
A/R		STRIP		1/4 x 2.0 C.R.S.	38
A/R		GUARD - DIAPHRAGM RUBBER (1/4" THK)		BOSTON WOVEN HOSE # 3210	37
1		PLUG - HANSEN		NO. LL6-K31-VAA NO VALVE	36
1		PLUG - HANSEN		No. LL6-K-12	35







QTY REQD	QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM
1		PLUG COUPLING		B-2177775	34
1		SOCKET - HANSEN		No. LL6-H-12	33
1		BRACKET, END		B-2177110-1	32
2		FILTER		WILKERSON No. A-1117-Z	31
1		FITTING, MALE CONN.		PARKER No. 6 FTX-SS	30
A/R		HOSE, PARFLEX-PARKER		No. 821-6	29
2		FITTING, HOSE-PARKER		No. 30182-6-6	28
1		STOP		1/4 x 3 x 3 1/2 C.R.S.	27
1		FITTING, FEMALE CONN.		PARKER No. 12 GB-SS	26
2		FITTING, PIPE ELBOW		PARKER No. 3/4 DD-SS	25
2		FITTING - HOSE - PARKER		No 30682-6-6B	24
1		FITTING, REDUCER		PARKER No 3/4 x 3/8 PTR-SS	23
A/R		PIPE, 3/4 NOM. SCHED. 80		GALVENIZED	22
2		GUARD - SQUARE TUBE		3.0/4.0 x 9.5 LG. OR EQUIV.	21
1		FITTING, BULK-UNION ELBOW		PARKER No. 12 WEB-SS	20
2		WASHER, PLAIN		1.00 I.D. NOM.	19
1		SOCKET - HANSEN		NO. LL6-H-12-RC-VAA NO VALVE	18
1		GUARD - SQUARE TUBE		3.0/4.0 x 8.0 LG. OR EQUIV	17
4		FITTING, MALE CONN.		PARKER No 12 FTX-SS	16
1		BRACKET		B 2177111	15
2		SCR-.375-16 UNC-2A x .75 LG		HEX HD	14
1		SPRING		B-2177112	13
1		SCREW PLATE		B-2177113	12
4		SCR-#10-24 UNC-2A x .38 LG		RDHD	11
A/R		CHAIN			10
3		"O" RING		PARKER No 2-120	9
1		PLUG, COUPLING		B 2177382	8
A/R		HOSE, HIGH PRESS PARKER		No. 301-12 (SAE 100 R2 AT)	7
6		FITTING, HOSE - PARKER		No. 20630-12-12C	6
2		FITTING, PIPE TEE		PARKER No. 3/4 MMO-SS	5
1		FITTING, PIPE ELBOW		PARKER No 1/4 DD-SS	4
1		FITTING, REDUCER		PARKER No. 3/4 x 1/4 PTR-SS	3
A/R		PIPE, 1/4 NOM. SCHED. 80		GALVANIZED	2
1		FITTING, FEMALE ELBOW		PARKER No. 2 DB-SS	1

LIST OF MATERIALS

2179018

NOTES:

1. POSITION STOP TO GUIDE RELEASE LEVER INTO FIRST NOTCH
2. PAINT ALL WELDED PARTS AFTER WELDING
3. PAINT ALL ASSEMBLED PARTS BEFORE ASSY IF REQUIRED TO PREVENT CORROSION

NEXT ASSY	FINAL ASSY	
APPLICATION		

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES DECIMAL .X ±.04 .XX ±.02 .XXX ±.01 ANGLES ± CHAM. ± 10° SURFACE FINISH MICROINCHES RHR

MATERIAL: —//—

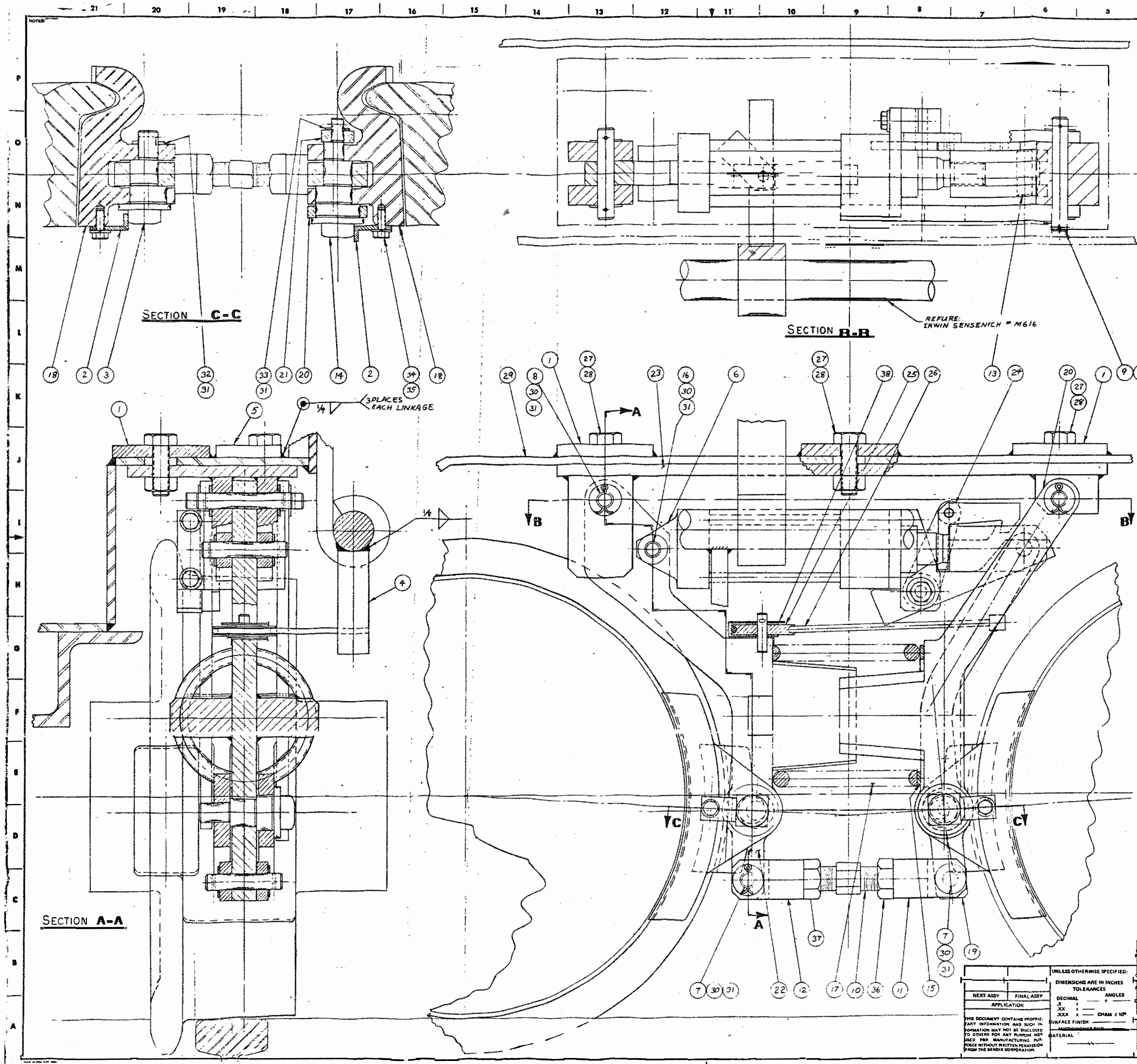
CONTR NO.		
PROJ NO.	2879-2110	
DRAWN	J. Tomalia	10/30/73
APPD	SPROULE	9-14-73
APPD	[illegible]	9/14/73
APPD	[illegible]	3-3-74
APPD		

Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

TITLE: MINE CAR, MODIFIED W/FAIL SAFE BRAKE SYSTEM

SIZE	CODE IDENT NO.		REV.
E	11272	2179018	X3
SCALE 1/8	WT	SHEET 1 OF 1	

DEPT NO. 850



QTY REQD	QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM
					50
					49
					48
					47
					46
					45
					44
					43
					42
					41
					40
					39
	1	CABLE GUIDE		A 2179336	38
	1	NUT		3/4-10UNC L.H.	37
	1	NUT		3/4-10UNC RH	36
	2	WASHER LOCK		1/4	35
	2	SCREW HEX. HD.		1/4-20UNC-3/4 LG.	34
	1	WASHER FLAT SS.		3/8"	33
	1	WASHER FLAT SS.		5/8"	32
	12	COTTER PIN		1/8 x 1"	31
	10	WASHER FLAT SS		1/2"	30
		MINE CAR		E 2179018	29
	3	NUT HEX.		1/2-13 UNC	28
	3	SCREW, HEX. HD		1/2-13UNC-1 3/4 LG.	27
	1	WIRE ROPE 7x19 SS. 3/16 DIA. 18" LONG 5/16 STOP			26
	1	SHEAVE-WILCOX-CRITTENDEN 8490			25
	1	LATCH MECH ASSY		D 2177776	24
	1	HANGER MOUNT		D 2176844	23
	1	LEVER L.H.		C 2176840	22
	1	LEVER REAR		C 2177375	21
	1	LEVER FRONT		C 2177374	20
	1	LEVER RH		C 2177373	19
	2	BRAKE SHOE		C 2177372	18
	1	SPRING		C 2176392	17
	1	PIN		B 2179146	16
	1	SHIM		B 2177377	15
	1	ECCENTRIC PIN RH		B 2177370	14
	1	PIN		B 2176966	13
	1	CLEVIS-ADJ. L.H.		B 2176828	12
	1	CLEVIS-ADJ. R.H.		B 2176827	11
	1	ADJUSTING SCREW		B 2176826	10
	1	PIN		B 2176824	9
	1	PIN		B 2176823	8
	2	PIN		B 2176822	7
	1	AIR CYLINDER		B 2176788	6
	1	MOUNTING SPACER		A 2179035	5
	1	LEVER		A 2177534	4
	1	ECCENTRIC PIN L.H		A 2177369	3
	2	STOP - BRAKE SHOE		A 2177368	2
	2	MOUNTING SPACER		A 2176831	1

LIST OF MATERIALS

NEXT ASSY | FINAL ASSY
APPLICATION

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DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± .XX ± .XXX ± ANGLES ± CHAM ± 10°
SURFACE FINISH
MICROINCHES RHR
MATERIAL

CONTR NO.
PROJ NO 273-1126
DRAWN 2-7-72
APPD 3-3-74
APPD
APPD
APPD

Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

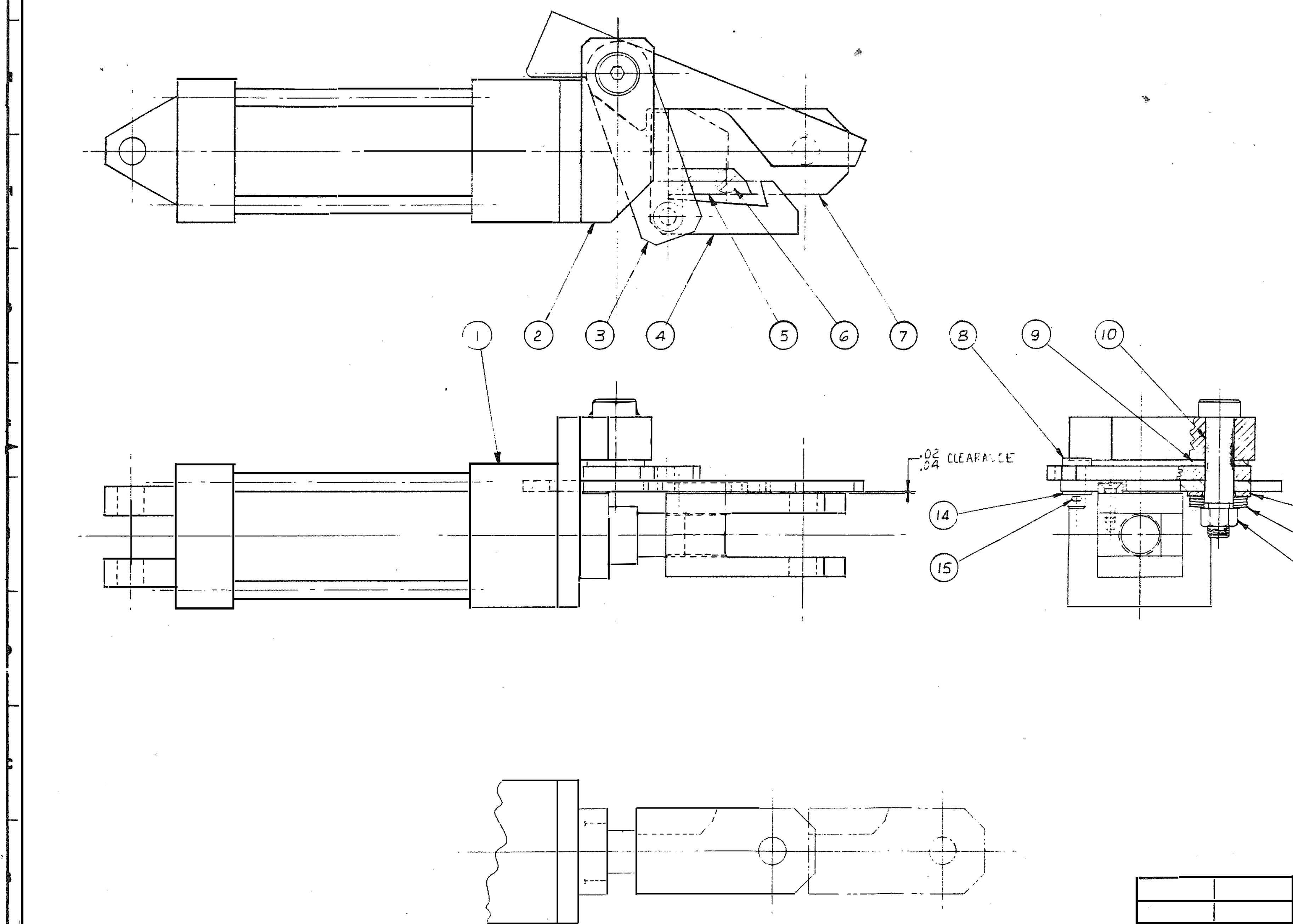
TITLE FAIL SAFE BRAKE ASS'Y MINE CAR

SIZE E | CODE IDENT NO 11272 | 2176031 | REV. X3

SCALE FULL | WT | SHEET 1 OF 1

DEPT NO. 850

2176031



REV.	ZONE	DESCRIPTION	DATE	APPROVAL

REVISIONS

QTY REQD	QTY REQD	DESCRIPTION	CODE IDENT	PART OR SPECIFICATION NO.	ITEM
	1	COTTER PIN .093 DIA X .62		STOCK	15
	1	WASHER-PLAIN O.D .56 I.D. .33 .062 THK		STOCK	14
	4	WASHER - SPRING, BELLEVILLE		STOCK DRIVE PRODUCTS #7X9-32050	13
	1	WASHER - PLAIN O.D. 1/2 I.D. .53 .08 THK		STOCK	12
	1	NUT - HEX. HEAVY 5/16-18UN-3B STAINLESS		ESNA #79NU-066	11
	1	SCREW SHOULDER .500 BODY DIA 1.50 LG.		STOCK	10
		BEARING - THRUST OIL IMPREGNATED BRONZE		BOSTON #TB-816	9
	1	PIN - LATCH		A 217734 3	8
	1	CLEVIS - LATCH		B 2177335	7
	2	SCREW FLAT HD 10-32 UNF-2A .62 LG.		STOCK	6
	1	STOP - LATCH		A 2177331	5
	1	LATCH		A 2177330	4
	1	SUB-ASS'Y LATCH RELEASE		B 2177334	3
	1	MOUNT - LATCH		A 2177329	2
	1	AIR CYLINDER		B 2176188	1

LIST OF MATERIALS

2177336

NEXT ASSY	FINAL ASSY

APPLICATION

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES
DECIMAL .X ± — .XX ± — .XXX ± —
ANGLES ± — CHAM. ± 10°
SURFACE FINISH
MICROINCHES RHR —
MATERIAL: —

CONTR NO.		
PROJ NO.	[illegible]	
DRAWN	[illegible]	1-24-72
APPD	SPROULE	2-11-72
APPD	[illegible]	3-5-74
APPD		
APPD		

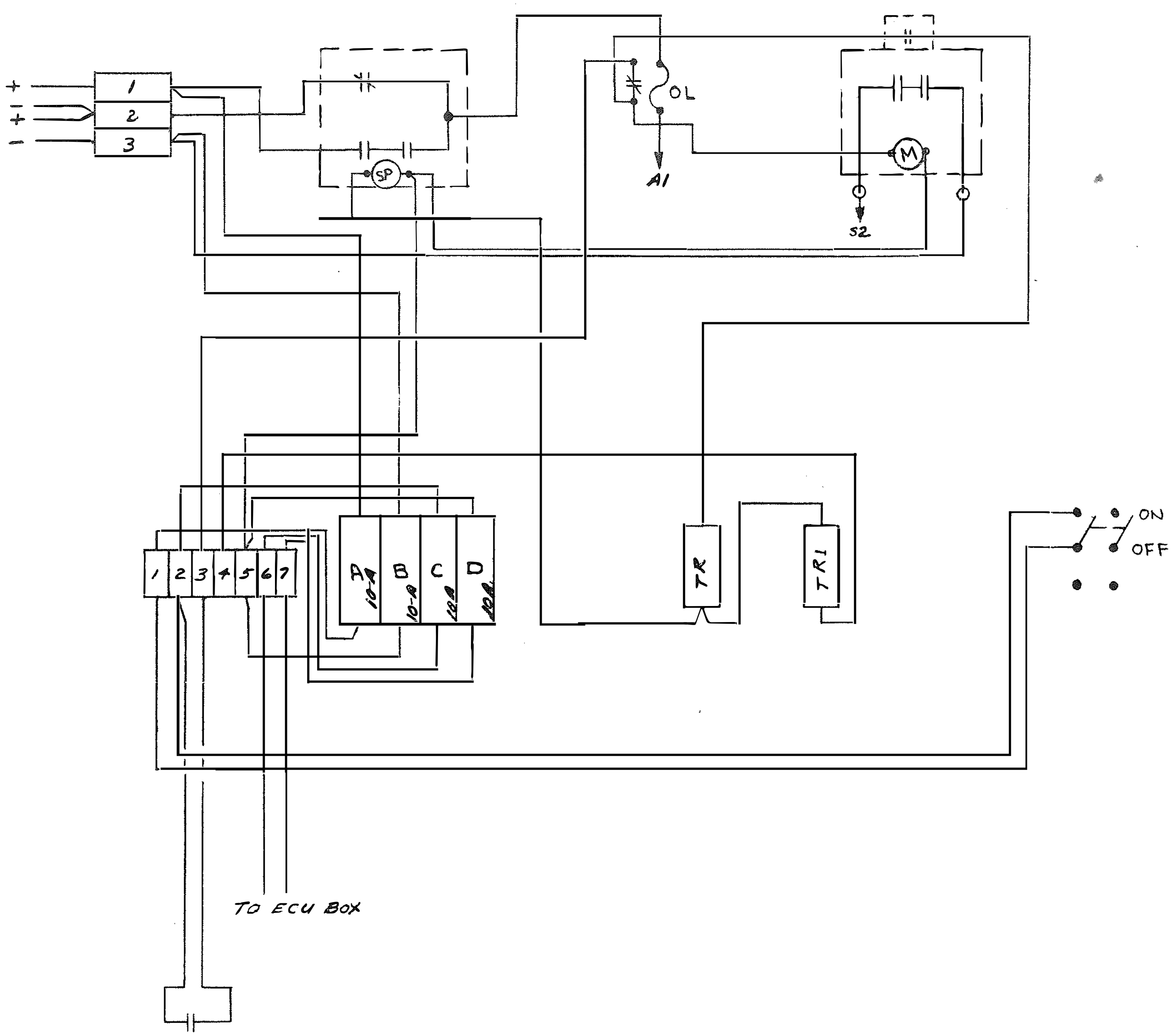
Bendix Research Laboratories
SOUTHFIELD, MICHIGAN

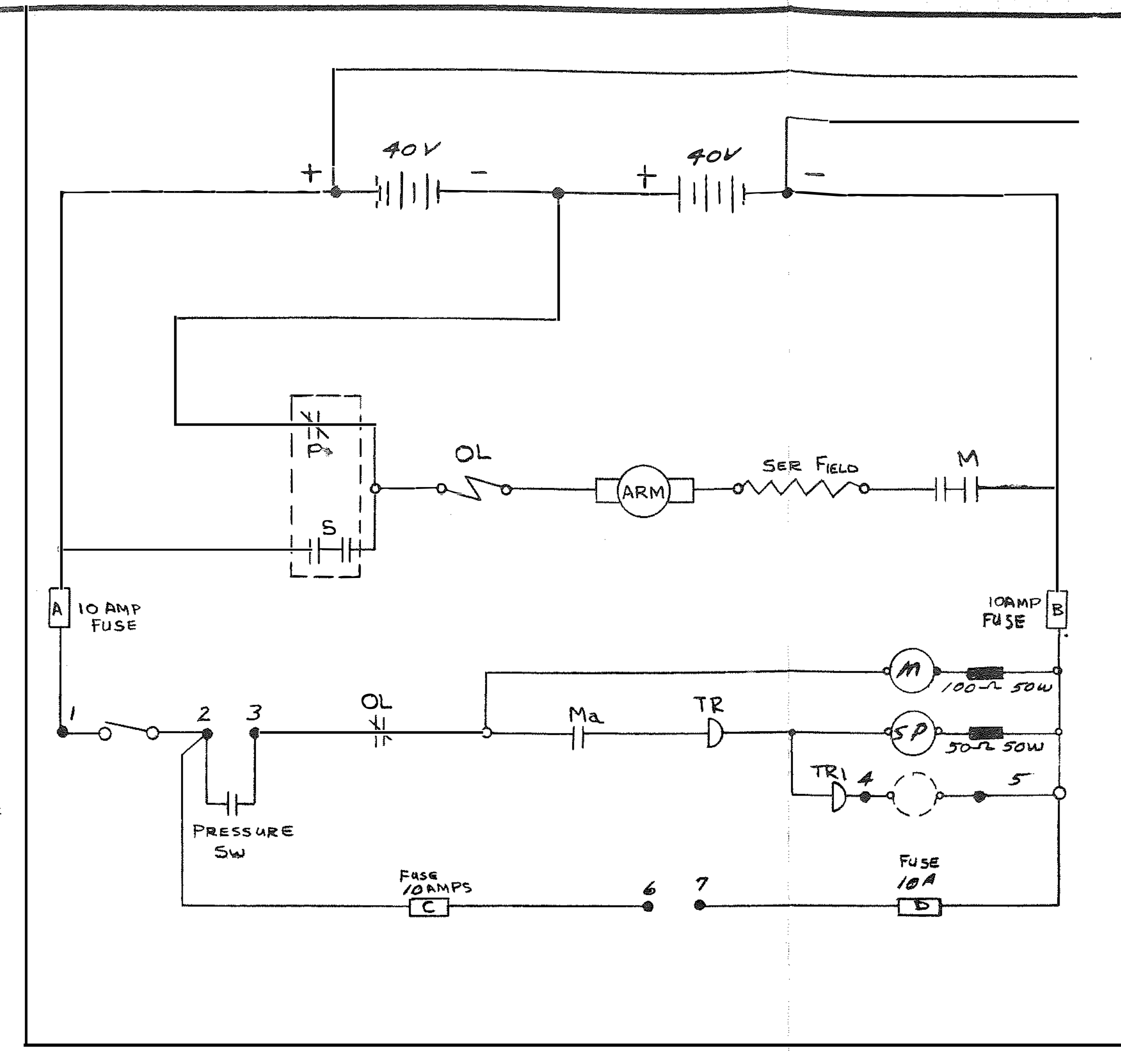
TITLE
ASSEMBLY
LATCH MECHANISM

SIZE	CODE IDENT NO.		REV.
D	11272	2177336	X.

SCALE — WT — SHEET 1 OF 1

DEPT NO. 850





			OVERLOAD PROTECTION THERMAL	
HP	VOLTS	RANGE	MFG. P/N	CPI P/N
5	80	62-67	H-85	10049X8

REVISIONS	BENDIX CONTROL PRODUCTS, INC. BECKLEY, W. VA
	SCHEMATIC & ACTUAL WIRING COMPRESSOR STARTER
	DRAWN — DATE 11-20 — APPROVED — SCALE —
	NO. C-14538

APPENDIX B

RECOMMENDED REGULATORY STANDARD FOR AUTOMATIC AIR-BRAKE SYSTEMS ON MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES

Report BRL/TR-74-7096

RECOMMENDED REGULATORY STANDARD FOR AUTOMATIC AIR-BRAKE SYSTEMS ON MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES

A. M. Kiwior

Bendix Research Laboratories
Bendix Center
Southfield, Michigan 48076

Submitted May 1974

Contract H0110896
Automatic Brakes for Mine-Track
Transportation Systems
in Underground Coal Mines

Prepared for

PITTSBURGH MINING and SAFETY RESEARCH CENTER
Bureau of Mines
U. S. Department of the Interior
Pittsburgh, Pennsylvania

FOREWORD

This report was prepared by Bendix Research Laboratories, Bendix Center, Southfield, Michigan 48076, under USBM Contract H0110896. The contract was initiated under the Coal Mine Health and Safety Program. It was administrated under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. E. A. Curth acting as the Technical Project Officer. Mr. J. A. Herickes was the Contracting Officer for the Bureau of Mines.

This report (BRL/TR-74-7096) contains a Recommended Regulatory Standard for Automatic Air-Brake Systems on Mine-Track Transportation Systems in Underground Coal Mines. The standard was prepared by Mr. A. M. Kiwior under the direction of Mr. M. H. Cardon of the Bendix Automotive Program Management Center. Consultation was provided by Mr. G. L. Judy of the mine consulting firm of George L. Judy Associates.

This report was completed as part of this contract during the period of June 1971 to May 1974 and was submitted by the author in May 1974.

PREAMBLE TO RECOMMENDED REGULATORY STANDARD FOR AUTOMATIC AIR-BRAKE SYSTEMS ON MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES

In 1969, the Congress of the United States declared that "the first priority and concern of all in the mining industry must be the health and safety of its most precious resource - the miner." Therefore, Public Law 91-173, "Federal Coal Mine Health and Safety Act of 1969," was enacted.

Since haulage accidents account for a high percentage of coal mining accidents, Section 314e, "Hoisting and Mantrips," was included in the law. This section states: "Each locomotive and haulage car used in an underground coal mine shall be equipped with automatic brakes, when space permits. Where space does not permit automatic brakes, locomotive and haulage cars shall be subject to speed reduction gear, or similar devices approved by the Secretary which are designed to stop the locomotive and haulage cars with the proper margin of safety."

The regulations in this Recommended Regulatory Standard are intended to change mining equipment and practices to provide safe working conditions for mine personnel. These recommended regulatory standards represent the accumulation of the best information available from discussions with mining consultants; observations made at representative mines; investigation of the state of the art of mine locomotive and haulage car brake systems; review of existing standards and practices; and the design, development and installation of automatic brakes on a mine locomotive and five haulage cars.

This recommended standard was prepared under Contract H0010896 with the U. S. Bureau of Mines titled "Automatic Brakes for Mine-Track Transportation Systems in Underground Coal Mines." A locomotive and five coal haulage cars were equipped with an automatic brake system and delivered to the U.S. Bureau of Mines, Bruceton, Pennsylvania, for use in mining operations.

RECOMMENDED REGULATORY STANDARD FOR AUTOMATIC AIR-BRAKE SYSTEMS ON MINE-TRACK TRANSPORTATION SYSTEMS IN UNDERGROUND COAL MINES

TABLE OF CONTENTS

		Page
SECTION 1 - SCOPE		1
SECTION 2 - PURPOSE		1
SECTION 3 - APPLICATION		1
SECTION 4 - DEFINITIONS		1
SECTION 5 - REQUIREMENTS		2
5.1	Required Equipment	3
5.1.1	Braking Mechanism	3
5.1.2	Air Compressor	3
5.1.3	Reservoirs	3
5.1.3.1	Volume	3
5.1.3.2	Construction	3
5.1.3.3	Leakage	
5.1.3.4	Condensate Drain	4
5.1.4	Pressure Gauge	4
5.1.5	Safety Valves	4
5.2	Service Brake System	4
5.2.1	Testing	4
5.2.2	Stopping - Locomotive and Haulage Cars	4
5.3	Parking Brake System - Locomotive and Haulage Cars	6
5.3.1	Application and Holding	6
5.3.2	Parking Brake Control - Locomotive with Haulage Cars Coupled	6
5.3.3	Parking Brake Control - Haulage Cars	6
5.4	Emergency Braking System	6
5.4.1	Breakaway Cars	6
5.4.2	Operation of Emergency Brake System	6
5.4.2.1	Automatic Application	6
5.4.2.2	Automatic Braking Performance	6
5.4.2.3	Release After Automatic Application	7
5.4.2.4	Manual Operation	7
5.4.3	Emergency Braking System Failure	7
5.4.4	Emergency Braking Stopping	7
5.4.5	Speed Limit Control	7

Page

5.5	Mechanical Override	7
5.6	System Environment	8
5.7	Safety	8
SECTION 6 - CONDITIONS		8
6.1	Test Conditions	8
	6.1.1 Loading	8
	6.1.2 Controller Handle	8
	6.1.3 Vehicle Openings	8
	6.1.4 Brake Wear-In	8

1. SCOPE

This standard establishes performance and equipment requirements for automatic air-brake systems on mine-track transportation systems in underground coal mines.

2. PURPOSE

The purpose of this standard is to insure safe braking performance of mine-track transportation systems in underground coal mines, under normal and emergency conditions, by defining safety-related functional and performance requirements for the brake system.

3. APPLICATION

This standard applies to locomotive and haulage cars used in underground coal mines.

The brake system of the locomotive and the entire trip shall be controlled by the motorman. Brake application should be a smooth, continuous force, proportional to the brake control command of the motorman.

4. DEFINITIONS

The subject regulations will be interpreted by the following definitions of certain terms.

Air-Brake System - A system that uses air as a medium for transmitting pressure or force from the operator's control to the brakes.

Automatic Braking System - The brakes on a locomotive and haulage cars of a trip so interconnected that they can be operated together and by means of which the motion of the trip may be retarded or arrested. Braking is comprised of "service braking", "emergency braking" and "breakaway" protection.

Brake Chamber - Housing cavity where air pressure is converted to mechanical force.

Brake Effort - The force which presses the brake shoe(s) to the wheel friction surface to cause a retardation of the wheel motion. In the case of rail brakes, the force of the shoe(s) against the rail.

Brake Pipe - The line of pipe and hose extending throughout the length of the trip by means of which compressed air is supplied to the brake devices on the vehicles and the pressures so controlled as to effect the application and release of the brakes.

Brake Valve - The valve located in the locomotive by means of which operation of the brake system is controlled.

Breakaway - Non-intended trip separations.

Emergency Braking - The application of maximum braking effort.

Fail-Safe - An automatic braking system that will provide emergency braking in the event of failure or malfunction within the braking system.

Leakage Rate - The change or loss in pressure which occurs in an isolated pressurized system because of leaks in that system. The leakage rate is the pressure change, in pounds per square inch, which occurs in one minute.

Maximum Speed - The velocity which should not be exceeded by the locomotive and/or haulage cars.

Maximum Trip Load - The allowable gross weight of each haulage car (empty car tare plus weight of load material) multiplied by the number of cars in the trip.

Mechanical Override - A mechanism essentially separate from the air-brake system capable of holding the brakes in the "off" and "on" positions.

Parking Brake - A mechanism which will hold a vehicle stationary.

Power Brake - A combination of parts operated by compressed air and controlled manually, pneumatically, or electrically by means of which the motion of a car or locomotive is retarded or arrested.

Secretary - Secretary of the Interior or his delegate.

Service Brake - A mechanism which will retard or arrest the motion of a vehicle under normal service operating conditions.

Terminal - A loading, unloading, or haulage-car storage area.

Trip - The cars hauled at one time by a locomotive.

5. REQUIREMENTS

All vehicles shall meet the following requirements under the conditions specified in Section 6.

The automatic brake system controls are considered part of the locomotive and must be located on the locomotive. When used by itself, the locomotive must meet all the requirements of this standard.

Brake system leaks, such as cylinder, brake pipe, valves, and connection leaks, should only prevent release of the brakes. The total system leakage of maximum trip load conditions must not exceed the capability of the brake system air compressor to maintain continuously the highest pressure required for normal brake system operation. Individual locomotive and haulage car system leakage rates should not produce a significant pressure drop when the system has been pressurized and isolated at the maximum operating pressure.

5.1 Required Equipment

5.1.1 Braking Mechanism

Each locomotive and haulage car used in an underground coal mine shall be equipped with automatic brakes when space permits. When space does not permit the installation of automatic brakes, the locomotive and haulage cars shall be subject to speed reduction gear, or similar devices approved by the Secretary, which are designed to stop the locomotive and haulage cars with the proper margin of safety for the mine haulage way.

5.1.2 Air Compressor

An air compressor of sufficient capacity to maintain operating air pressure in the brake system during normal operation of the vehicle shall be a part of the brake system. A suitable pressure control shall be provided that will maintain a safe operating pressure.

5.1.3 Reservoirs

One or more service reservoir systems, from which air is delivered to the brake chambers, shall be part of the brake system.

5.1.3.1 Volume

The combined volume of all service reservoirs and supply reservoirs shall be at least twelve times the combined volume of all service brake chambers at maximum travel of the brake pistons or diaphragms.

5.1.3.2 Construction

All pressure vessels shall be constructed, installed, and maintained in accordance with the standards and specifications of the American Society of Mechanical Engineers, Boiler and Pressure Vessel Codes.

5.1.3.3 Leakage

Each service reservoir shall be protected against loss of air pressure caused by failure or leakage in the system between the reservoir and the source of air pressure by check valves or equivalent devices whose proper functioning can be verified without disconnecting any air line or fitting. Each service reservoir must be equipped with at least one safety valve, set to vent the reservoir at a pressure of ten pounds per square inch above the maximum setting of the compressor pressure control.

5.1.3.4 Condensate Drain

Each reservoir shall have a condensate drain valve that can be manually operated. The drain valve must be checked on a regular basis to make certain it is functioning, but not less than once each day that the vehicle is operated.

5.1.4 Pressure Gauge

A pressure gauge in the service brake system, readily visible to the motorman seated in the normal operating position, that indicates the brake line air pressure shall be a part of the brake system.

5.1.5 Safety Valves

Safety valves must be provided in the system and must be set to allow no more than 10 pounds per square inch pressure above maximum operating pressure of the protected device.

5.2 Service Brake System

5.2.1 Testing

The service brake system on each locomotive and each haulage car shall, under the conditions of Section 6, meet the requirements of paragraph 5.2.2 when tested without adjustments other than those specified in this standard.

5.2.2 Stopping - Locomotive and Haulage Cars

The braking system shall stop the locomotive and trip from the maximum allowable speed specified by mine management without any part of the locomotive leaving the track.

The locomotive and trip shall be capable of being stopped on a dry level track in not more than the distance specified by curve 'A' in Figure 5-1, measured from the point at which movement of the service brake control begins.

The service brake shall hold the locomotive and haulage cars stationary, facing uphill and facing downhill, on a dry track at the maximum grade of the mine haulage way, when loaded to the gross vehicle weight rating, under the conditions of Section 6.

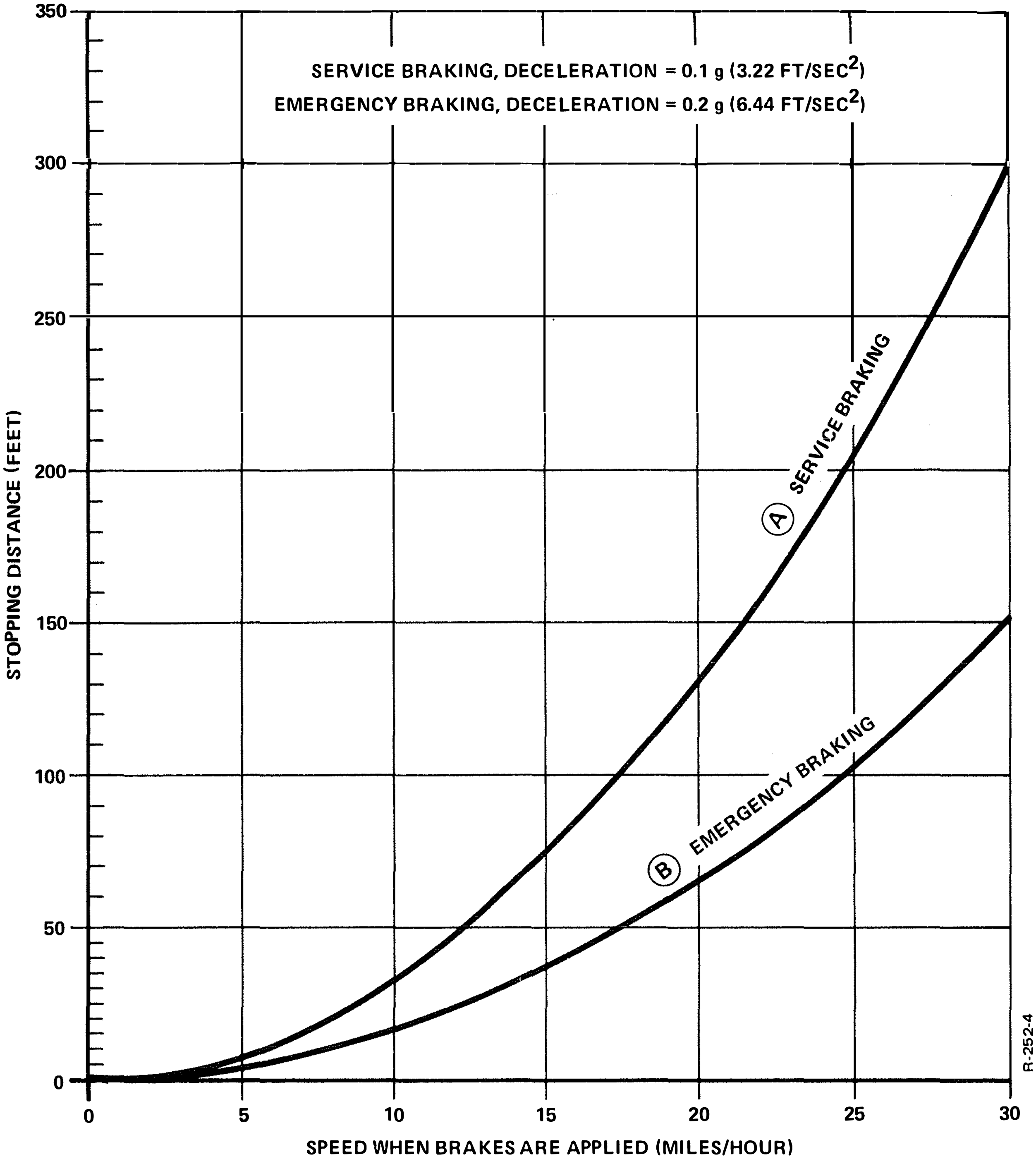


Figure 5-1 - Maximum Stopping Distance Versus Speed on a Dry Level Track

5.3 Parking Brake System - Locomotive and Haulage Cars

Each vehicle shall have a brake system that under the conditions of Section 6 will hold the vehicle stationary, facing uphill and facing downhill, on a dry track at the maximum grade of the mine haulage way, when loaded to the gross vehicle weight rating.

5.3.1 Application and Holding

The parking brakes shall be applied by an energy source that is not affected by loss of air pressure or brake fluid pressure in the service brake system. Once applied, the parking brakes shall be held in the applied position solely by mechanical means.

5.3.2 Parking Brake Control - Locomotive with Haulage Cars Coupled

The parking brake control shall be operable by a motorman in the normal operator's position in the locomotive. The control shall be identified in a manner that specifies the method of control operation. The parking brake control shall control the parking brake of the locomotive and of all haulage cars that it is designed to tow.

5.3.3 Parking Brake Control - Haulage Cars

When haulage cars are uncoupled from the locomotive or from each other, the haulage car brakes automatically shall be applied.

5.4 Emergency Braking System

The locomotive and haulage cars shall have a braking system with emergency braking capability meeting the following requirements.

5.4.1 Breakaway Cars

In the event of an accidental separation, the brakes of the separated cars, the remaining trip and the locomotive shall be applied. The brakes on the separated cars shall remain applied until intentionally released.

5.4.2 Operation of Emergency Brake System

5.4.2.1 Automatic Application

The emergency brakes shall be applied automatically when the air pressure in the service brake air lines is less than that required to operate the service brakes.

5.4.2.2 Automatic Braking Performance

With the brakes automatically applied, a locomotive shall be capable of meeting the requirements of paragraph 5.4.2.3.

5.4.2.3 Release After Automatic Application

After automatic application, the brakes shall be releasable only if they can be automatically reapplied and exert the force required by paragraph 5.4.4.

5.4.2.4 Manual Operation

The emergency brakes may be manually operable; however, they shall not be capable of being locked in the brakes-off position.

5.4.3 Emergency Braking System Failure

In the event of a failure of a brake pipe, valve, or brake cylinder housing that is common to the service brake and emergency braking systems, loss of air shall cause the brakes to be applied.

5.4.4 Stopping - Locomotive and Haulage Cars

The braking system shall stop the locomotive and trip from the maximum allowable speed as specified by mine management without any part of the locomotive leaving the track.

The locomotive and trip shall be capable of being stopped on a dry level track in not more than the distance specified by curve 'B' in Figure 5-1, measured from the point at which movement of the emergency brake control begins.

The emergency brake shall hold the locomotive and haulage cars stationary, facing uphill and facing downhill, on a dry track at the maximum grade of the mine haulage way, when loaded to the gross vehicle weight rating, under the conditions of Section 6.

5.4.5 Speed Limit Control

A speed limit control shall sense the locomotive speed. When the speed exceeds the set speed limit, the emergency brakes shall be applied. The speed limit control shall be set to apply the brakes at a speed of 1 MPH faster than any speed setting between 0 and 10 MPH, 2 MPH above any speed setting between 10 and 20 MPH, and 3 MPH above any speed setting between 20 and 30 MPH.

The brakes shall be releasable by activating a reset control when the speed of the locomotive has been reduced below the reset speed.

5.5 Mechanical Override

Haulage cars may have a mechanical override latching device to release the brakes at loading or dumping areas. When the haulage cars are recoupled to the locomotive, the overriding latching device shall be made inoperable either automatically or by the motorman from the normal operator's position.

5.6 System Environment

The automatic brake system must be capable of operation as specified herein when exposed to any of the environmental conditions of the mine.

5.7 Safety

Brake components must not protrude beyond the car body in such a way as to be a danger to mine personnel. In the case of component failure, system energies must not result in flying debris. System assembly and disassembly procedures must be such that they may be conducted without danger to persons involved.

6. CONDITIONS

The requirements of Section 5 shall be met under the conditions specified below. Where a range of conditions is specified, the vehicle must be capable of meeting the requirements at all points within the range.

6.1 Test Conditions

6.1.1 Loading

As specified in paragraphs 5.2 and 5.3, the vehicle will be loaded to its gross vehicle weight rating, distributed proportionally to its gross axle weight ratings.

6.1.2 Controller Handle

Unless otherwise specified, the locomotive controller handle will be in the "off" position during all deceleration and static parking-brake tests.

6.1.3 Vehicle Openings

All vehicle openings, such as compressor hood and battery covers, will be in the closed positions during all tests.

6.1.4 Brake Wear-In

Brakes shall be worn-in and adjusted before tests are conducted.