



AUTOMATIC REMOTE CONTROL
COUPLER FOR MINE CARS

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

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Automatic Remote Control
Coupler for Mine Cars

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16. Abstracts This report describes the Foster-Miller program that designed, developed, built, and tested an automatic, remote control mine car coupler. This new coupler gives the motorman the capability to selectively couple and uncouple cars from the locomotive, to transmit braking intelligence to the coupled cars, and to determine if the trip is intact. Hazards due to derailment and runaway cars will be reduced as the brakes are automatically applied in any uncoupled car. Laboratory tests described herein have been completed on the coupler set. Applications include, but are not limited to, the unit train system.			
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FOREWORD

This report was prepared by Foster-Miller Associates, Inc., 135 Second Avenue, Waltham, Massachusetts 02154 under USBM Contract Number H0346042. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PM&SRC with Mr. Kleysteuber acting as the Technical Project Officer. Mr. Dawkins was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period 14 June 1974 to 16 April 1976. This report was submitted by the authors on 16 April 1976.

DISCLAIMER NOTICE

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

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1. Introduction

Due to improvements in the safety of other aspects of mining (primarily in roof control), haulage related accidents, and in particular rail haulage accidents, are about to become the most common category of hazards causing death and injuries to underground coal miners. The major causes of these accidents are collisions between vehicles, men caught between rib and trip or between cars and/or the locomotive, derailments, and runaway cars. These hazards can be greatly reduced if the motorman has the capability to selectively couple and uncouple cars from the cab of the locomotive, to transmit braking intelligence to the coupled cars, to determine if the trip is intact, and if brakes are automatically applied in any uncoupled car. This capability for automatic uncoupling and coupling can be provided through the improved coupler system which has been designed and built by this program. Furthermore, this capability can be provided for lower capital and operating costs than conventional systems. This should hasten its utilization by industry.

This report describes the Foster-Miller program to design, develop, build and test an automatic, remote control mine car coupler. Using this coupler, the motorman can, from the locomotive:

- (a) Selectively uncouple any number of cars from the trip.
- (b) Couple cars to the trip without assistance.
- (c) Read the current number of cars in the trip on his control panel.

If a loss of cars occurs at any time other than during uncoupling, the coupler sends an alarm to the locomotive. In this case, the coupler would also provide signals to actuate an emergency braking system. The coupler provides power and signal transmission for both an electric braking system and running lights. The connections are automatically and safely made by the coupler system.

The program was organized into four phases:

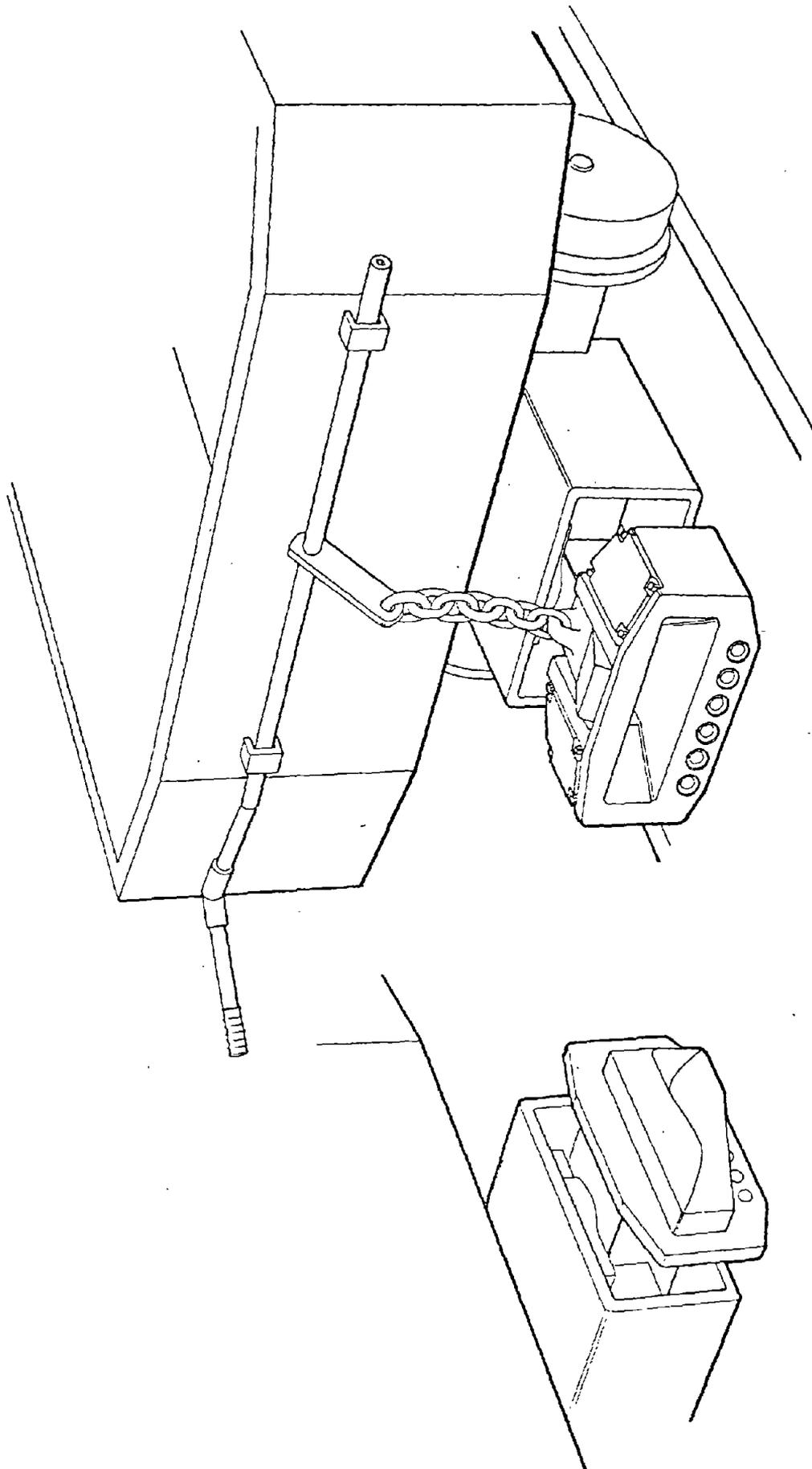
- Phase I - Preliminary Research
- Phase II - Specification Development
- Phase III - Design
- Phase IV - Fabrication and Test

During Phase I, an extensive survey of patent and trade literature was conducted. Manufacturers of mining, railway, and transit couplers, coupler components, mine cars, braking systems were reviewed. An engineering study was conducted of the performance required of the coupler, and how this performance could be achieved in the operating mine environment.

During Phase II, the information obtained during Phase I was used to prepare a detailed set of working specifications for the coupler.

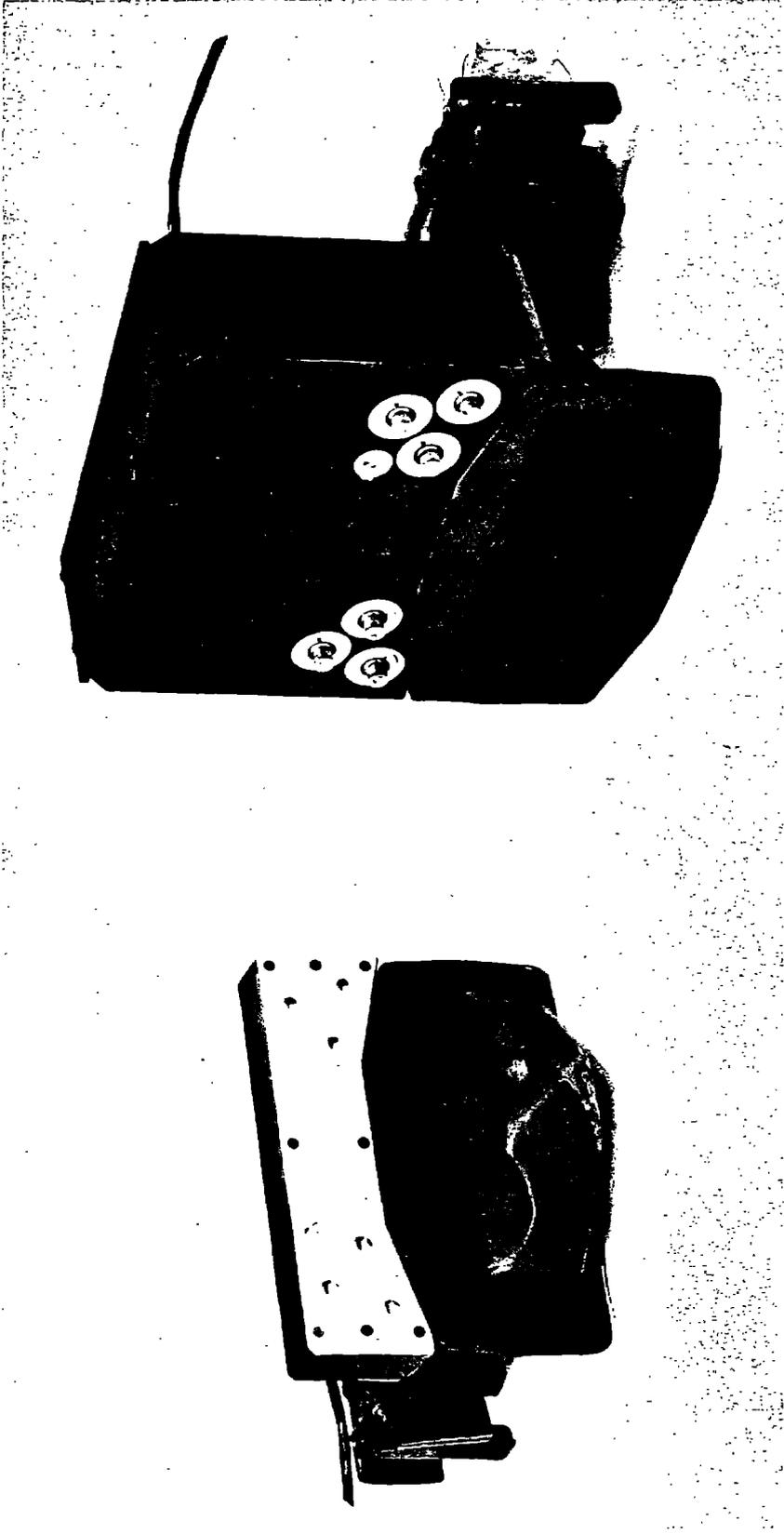
The detailed design of the coupler and associated control hardware was done during Phase III. Figure 1 -1 shows an artist's concept of the final production design. Figure 1 -2 shows a photograph of the unit that was fabricated and tested. To minimize program costs, the test unit was fabricated with no regard to aesthetics (only to performance) from readily available, proven components. The unit has the following features:

- (a) Six heavy mating contacts to transmit power and control signals. The contacts are designed to automatically wipe themselves clean as they mate.
- (b) A rugged mechanical switch which assures that the contacts are only energized when the coupler is engaged.
- (c) An improved draft gear which connects the coupler to the car truck (rather than to the car body as is done now). The FMA coupler will allow 26 foot cars to couple successfully on 25 foot radius reverse curves. Standard couplers generally have difficulty coupling on curves with a radius smaller than 120 feet. The ability to couple on curves can be improved, however, by changing the coupler mounting points. Other



Truck Mounted
Advanced Coupler Design

Figure 1-1



Male Coupler

Female Coupler

Remote Control Coupler Halves

Figure 1-2

factors that influence coupling include the distance between the centerlines of the trucks on each car, the distance from the axle to the pivot point of the coupler, pivot point to pivot point of couplers on adjacent cars and track gage.

Figure 1 -3 shows the control panel which was built and debugged. The motorman controls all functions as described previously from the panel which is situated in the locomotive.

The prototype coupler went through preliminary testing, minor design refinement, and then final testing. The coupler performed perfectly during 550 coupling-uncoupling cycles at speeds up to 3 mph. Electrical tests showed that the automatic contact cleaning system was successful, cleaning the contacts of even heavy dirt.

An economic evaluation of installing a coupler-braking system in a 1,000,000 ton per year mine was made. It showed that the net capital cost of the remote coupler system would be \$332,000 less (two locomotives can be eliminated), and manpower could be reduced by 3 men, resulting in an additional saving of \$100,000 per year.

The prototype coupler has proven itself in laboratory tests that were more severe than those used for normal testing of ordinary mine couplers. Normally, standard couplers are mounted on the test rack and subjected to a couple/uncouple sequence in order to check out the completed hardware. This testing is usually accomplished in the 1/2 to 3 mile per hour range. The newly designed portions of the coupler showed no adverse affects when the coupler was subjected to impacts of up to five miles per hour. We recommend that the coupler now go through underground testing.

The following sections describe the technology search and the development of the working specifications (Section 2), the mechanical and electrical design (Sections 3 and 4) and the coupler test program (Section 5). Section 6 presents the economic analysis, while Section 7 summarizes our conclusions and recommendations.

2. Development of the Coupler Specifications

The primary objective of Phases I and II of this program were to develop a set of coupler specifications which incorporated the new features contractually required by the Statement of Work, shown in Table 2-1.

To this end, Phase I was devoted to a thorough study of rail haulage and related patent literature, visiting mines to observe their current practice and to developing a list of vendors of relevant, presently available components. Each of these tasks was performed with an eye to locating subelements which would assist in achieving the Performance Requirements of Table 2-1.

During Phase II, the above data was assimilated. A number of alternate means of achieving the Performance Requirements were described, and tradeoffs among these were discussed with the Bureau. The work resulted in establishing a design baseline and generating a final set of working specifications.

The following sections contain a brief review of the Phase I and II effort. Section 2.1 discusses the subsystems which are implicitly needed to fulfill the contractual requirements, while Section 2.2 delineates the tradeoff areas where choices had to be made for the final hardware. Section 2.3 summarizes these hardware choices, defining the design baseline, while Section 2.4 presents the final, Working Specifications which resulted from the study.

2.1 Required Coupler Subsystems

The basic coupler system can be broken down into two groups of subsystems:

- (a) Car Hardware, consisting of:
 - i) The coupler itself
 - ii) The brakes, and
 - iii) The running lights.

TABLE 2-1

Performance Requirements

- (a) From the cab of the locomotive, the motorman shall be able to selectively uncouple any car or cars in a trip.
- (b) From the cab of the locomotive, the motorman shall be able to automatically couple a trip to the locomotive, or at the end of a partial trip already coupled to the locomotive he shall be able to couple the number of cars that are needed to make a full trip.
- (c) The coupling shall be capable of transmitting braking power through the coupling to all cars in the trip.
- (d) The coupling shall be interlocked in such a way that when a car or cars are uncoupled accidentally or by design, the car brakes will be automatically applied.
- (e) The coupling shall have the capability of transmitting braking control signals through the couplings of the trip so that the brakes on the cars on the trip can be operated from the cab of the locomotive.
- (f) The coupling shall be designed to transmit signals through the couplings so that the motorman can continuously verify that the trip is intact.
- (g) The coupling shall have the capability of transmitting power through the coupling to provide running light illumination on each car.
- (h) The coupling shall be sufficiently rugged, durable, and relatively maintenance free to meet the rigorous duty of underground coal mine haulage.

(b) Logic and Control Hardware, consisting of:

- i) The operator's control panel
- ii) The signal transmission hardware
- iii) The power transmission hardware.

The operating requirements for each of these subsystems is outlined below.

2.1.1 Car Hardware

A) The Coupler

The primary requirements placed on the coupler are:

1) Buff and Draft Loads

The coupler must transmit the pulling forces (draft) and pushing forces (buff) exerted by the locomotive.

We found, from our discussions with Bureau and mine operations personnel, that typical trip lengths are 30 to 40 cars, and that track grades often reach 6%.

A fully loaded mine car weighs about 26 tons, and on a 6% grade, 35 such cars will exert 54,500 pounds of drawbar pull on the coupler pair nearest the locomotive. A force of the same magnitude will be encountered in buffing a train up the 6% grade. In order to achieve the durability requirement (h) of Table 2-1, the working draft and buff ratings of the working coupler must exceed this value.

2) Automatic Coupling

The design of the coupler must be such that a pair will engage, without manual intervention, when they are moved together.

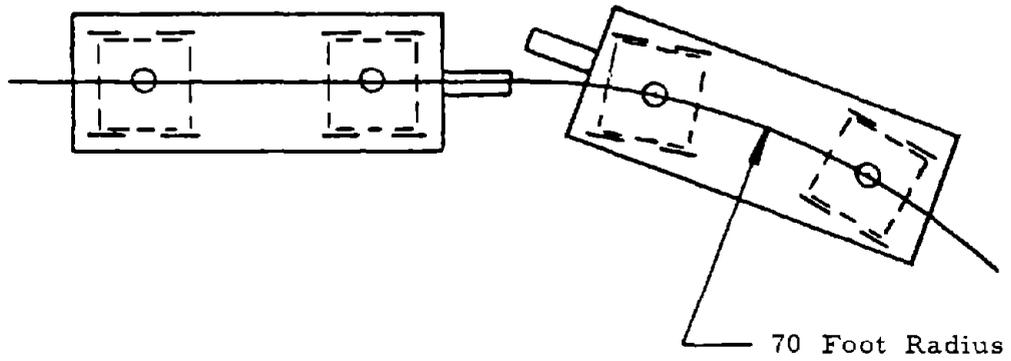
Without manual intervention, it is essential that the couplers always engage, independently of the misalignment caused by track curves of any possible configuration by vertical offsets or curvature in the track, and by any droop or lack of centration of the couplers.

The horizontal and vertical coupler displacements over which the pair will successfully engage are called the gathering range of the coupler. The gathering range required of the remote control coupler system is such that automatic coupling will be successful:

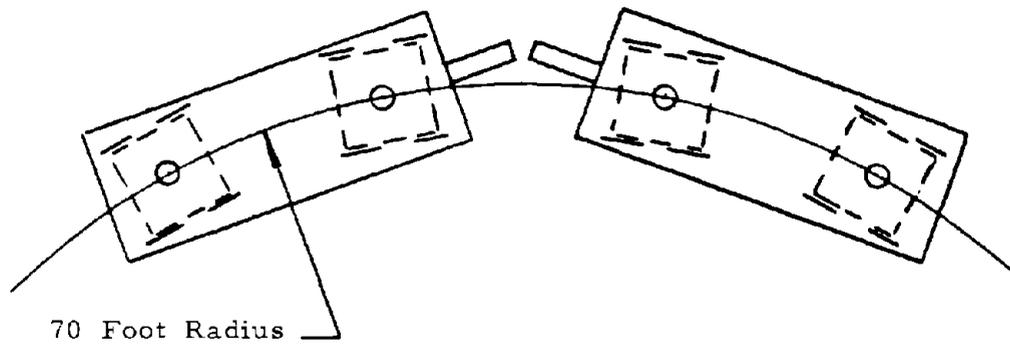
- a) On curved track of any configuration (see Figure 2-1) where the radius of curvature is 70 feet or more;
- b) On track having vertical curvature of 200 foot radius (see Figure 2-2); and
- c) On track containing vertical offsets of 2 inches.

3) Automatic Uncoupling

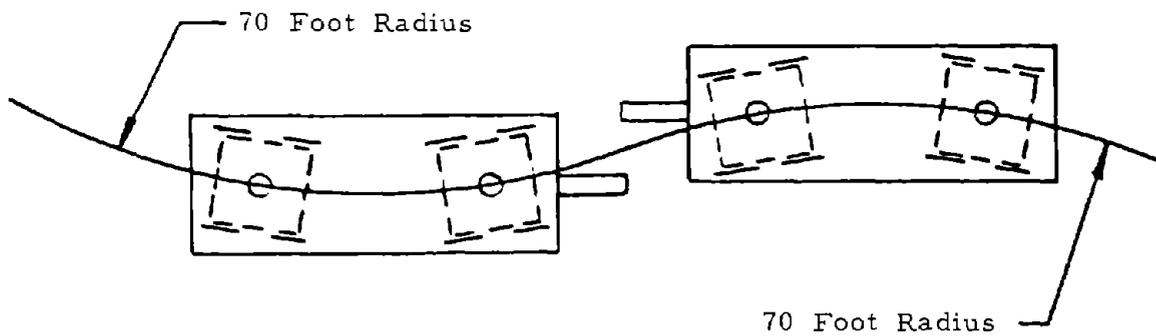
The design of the coupler must permit the addition of a remotely controlled actuator which will disengage the locking mechanism. Further, our analysis of the system requirements in light of current mining practice led to the conclusion that manual uncoupling would be required in the event of power loss during emergencies. A manual bypass of the uncoupler actuator must therefore be provided for this situation.



Straight to Curve Intersection



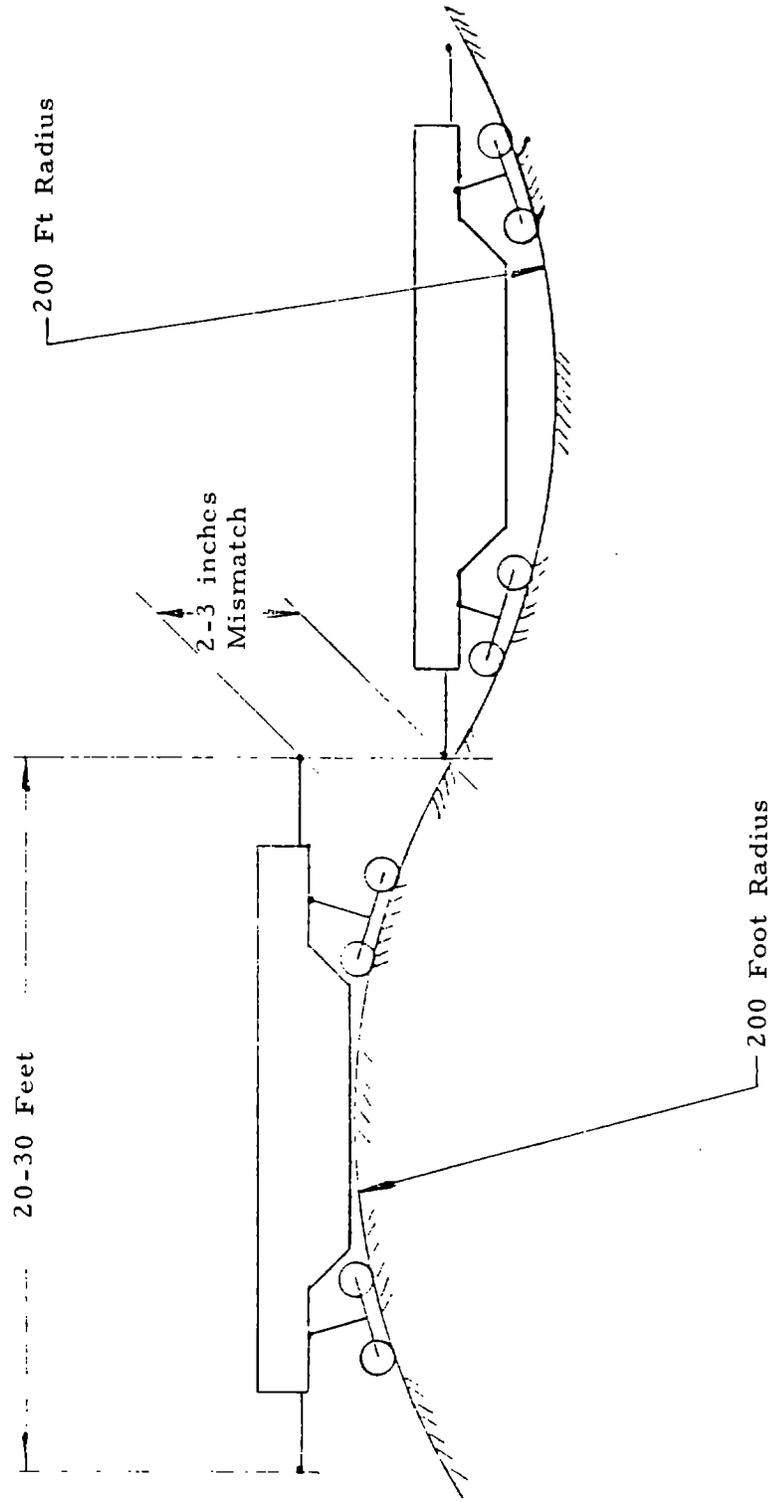
Continuous Curve



Reverse Curve Intersection

Various Curved Track Configurations

Figure 2-1



Coupler Displacement on Vertical Curves

Figure 2-2

4) Basis for the Transmission System

It is clear from the requirements of Table 2-1 that control signals and power for the brake and coupler actuators must pass through each coupler pair. An important requirement thus placed on the coupler design is that a foundation must be provided for mounting these transmission components. (Examples include pneumatic connectors or electrical contacts.)

B) The Brakes

Brakes on each car are explicitly required by Table 2-1. While they may be of any design in current use (shoe, disc or clasp) which can be adapted to the mine car trucks, it is essential that:

- 1) The brakes will be automatically applied upon intentional or unintentional uncoupling. This will prevent runaway cars.
- 2) The motorman can apply or release all car brakes in the trip simultaneously. (This can be easily implemented by interrupting the transmitted brake power required by (c) of Table 2-1 to apply the brakes.)

A detailed study of the brake system is left to a separate program, but provision for its implementation must be made.

C) The Running Lights

Lights are specified as replacements for the reflectors that are now installed on mine cars. As these are to be running lights and not to provide working illumination, significantly less light than is required for miners' cap lamps will be adequate. The lights will only operate when a car is connected to a locomotive, thus, reflectors would also be necessary in order to make cars more visible

on sidings. A light in two diagonally opposite outside corners of each car should provide adequate running illumination, requiring about 5 watts of electric power per car.

It must be noted that if illumination is to be required on runaway cars, each car would require a battery for this purpose.

2.1.2 Logic and Control System Hardware

A) Operator's Control Panel

The system control panel, located conveniently for the operator in the locomotive, must provide for the following functions:

- 1) Constant indication that the trip is intact and warning the operator if it is not;
- 2) Indication of successful coupling and uncoupling;
- 3) Selection of the car or cars to be uncoupled;
- 4) Uncoupling of the selected car;
- 5) Braking of all cars simultaneously.

B) The Signal Transmission System

The signal transmission system must carry information in both directions through the couplers:

- 1) From the locomotive to each car at the train
 - a) Uncouple signals
 - b) Brake signals
 - c) Car count initiation and reset signals.

- 2) From the train to the locomotive
 - a) Trip intact signals
 - b) Couple and uncouple successful operation signals.

C) The Power Transmission System

All power for coupler operations is derived from the 250 volt DC supply available at the locomotive. The power transmission system supplies each car in the train, through the couplers, with the energy necessary to:

- 1) Actuate the uncoupling mechanism when necessary,
- 2) Actuate the brakes, and
- 3) Activate the running lights.

Both power and signal transmission systems must pass information through the coupled interface by means of contacts or connectors mounted on each coupler. These connection components must be designed so that the integrity of the connection is maintained when:

- 1) The train negotiates horizontal curves of 70 foot radius; vertical curves of 200 foot radius; and track having vertical offsets of two inches.
- 2) The connectors are subjected to:
 - a) Humidity to 100%
 - b) Heavy dirt
 - c) Temperatures from -20°F to +100°F
 - d) Acidic Water
 - e) Impacts from falling rock, general physical abuse, and coupling.

Futher, the connection components must engage and disengage reliably and without damage during operation of the coupler over its full gathering range. The energy source must be disconnected from connectors or uncoupled ends of cars to prevent injury to tamperers.

2.2 Tradeoff Areas

There are several subelements of the remote control coupler system which can be implemented in more than one way. Trade-off analyses were conducted in the key areas described below.

2.2.1 Power and Signal Transmission Systems

Power for the actuation of the couplers and brakes can be transmitted to each car through

- a) Pneumatic connectors and hoses;
- b) Electrical contacts and cables;
- c) Locally generated power, either pneumatic or electric, on the car.

Power for the running lights must be electric.

Signals to control the operation of the coupler system can be transmitted through

- a) Pneumatic connectors and hoses;
- b) Electrical contacts and cables;
- c) Adjacent microwave antennas and cables through the car.

2.2.1.1 Pneumatic Systems

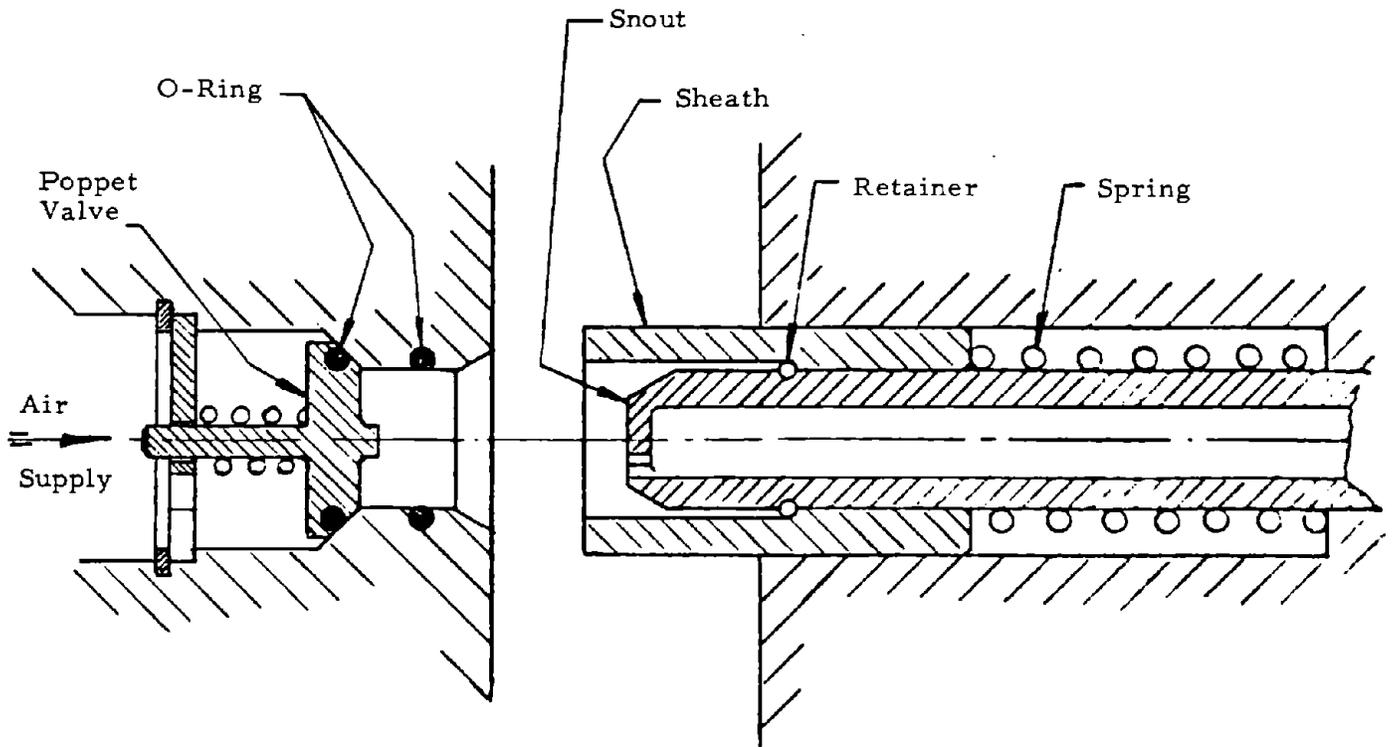
The biggest single difficulty in the implementation of pneumatic power or signal transmission systems is the development of a connector which will work with the remote control coupler. This connector must have the following properties:

- a) It must not leak air when the coupler is disengaged - a shutoff valve is needed. This valve must be tamper-proof to prevent injury;
- b) The connector must engage reliably over the full gathering range of the coupler;
- c) The shutoff valve must open freely when the coupler engages and the connector must not leak when engaged;
- d) The connector must be made impervious to dirt, moisture and corrosion;
- e) No fragile elements of the connector may be exposed outside the coupler housing.

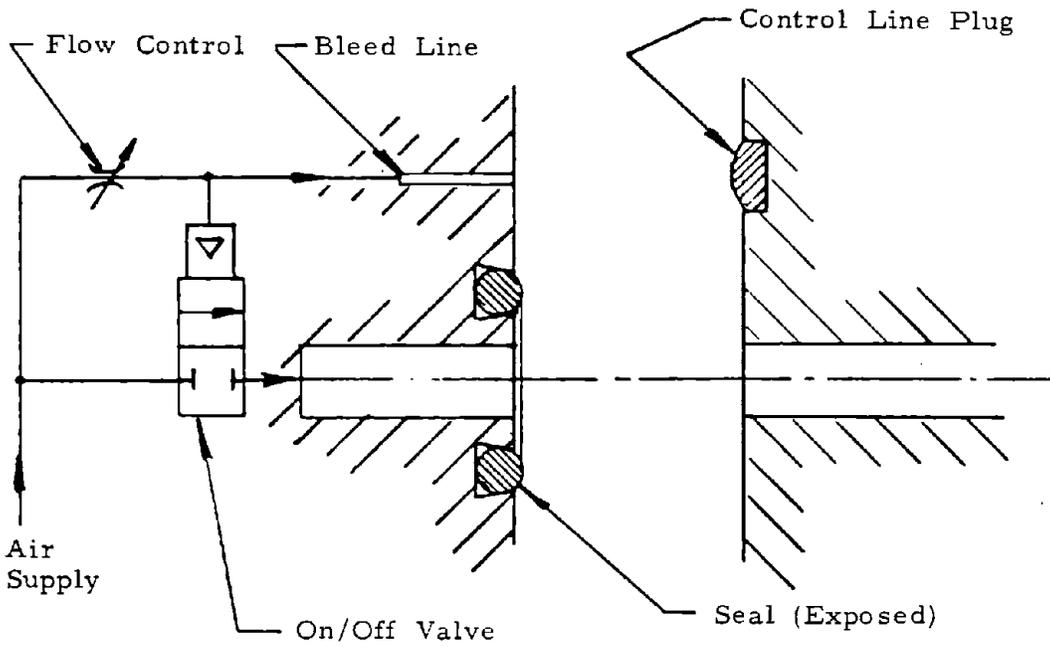
Two basic types of pneumatic connectors can be used in this application: Face sealing and Male-Female (see Figure 2-3).

1) Face Seal Connectors

The primary advantage of the face seal connector is that its alignment is not critical, as long as the axes of the connector are parallel.



(b) Male/Female



(a) Face Seal

Pneumatic Connectors

Figure 2-3

The disadvantages include:

- a) The seal faces and O-rings are exposed to damage from even minor abuse; small nicks will cause leakage.
- b) A shutoff contactor mechanism is required entailing extra components, although one contactor could operate more than one connector.
- c) Stringent coupler design is required to keep the axes of the connector halves parallel.

2) Male-Female Connectors

The advantages of this connector include:

- a) The seal faces can be protected (see Figure 2-3b);
- b) The shutoff feature is more simply implemented than with face sealing types.

The disadvantages include:

- a) Relatively precise alignment is required of the coupler before the connector halves can begin to mate - damage will result if design precautions are not observed. Note that several such connectors will be required on each coupler to implement the power and various signal transmission functions and that each of these connectors must align simultaneously.
- b) Dirt can be entrained in the mechanism, causing wear problems in the seal areas;
- c) The male half is fragile and exposed.

The design of this connector was seen as a primary difficulty with the use of pneumatic systems on the remote coupler. Significant design effort would be involved, and reliability and maintainability would always be in question.

Further considerations concerning pneumatic transmission systems are:

- (a) Pneumatic actuators for the couplers and brakes are readily available, and this is the prime advantage of pneumatic power transmission systems.
- (b) Pneumatic components to perform the required logic functions at each car are not readily available and require major design consideration. Candidate logic systems considered were:
 - . Fluidic logic, where air flows are switched similarly with digital electronic systems. Few of these logic modules are readily available and these can easily be made inoperable in the presence of dust or moisture.
 - . Pressure-volume-flow logic, where, for example, the number of cars newly coupled to the trip is determined by the flow of air from an accumulator on the locomotive into accumulators on the cars. The net flow is determined by knowledge of the instantaneous loss of pressure in the locomotive accumulator and its volume. The number of cars in a trip could be periodically monitored by depressurizing and then repressurizing the accumulators and measuring the net flow. This approach is slow when compared with an electronic system and very sensitive to leakage in the transmission system. The required pressure transducers are accurate, fragile and expensive.

Pneumatic logic is a high-maintenance, controlled environment approach.

In summary, the design and development of a pneumatic transmission system for the remote control coupler will be difficult and impractical, for in spite of the ready availability of the actuator components, the design of the connectors and logic system present significant design difficulty.

2.2.1.2 Electric Systems

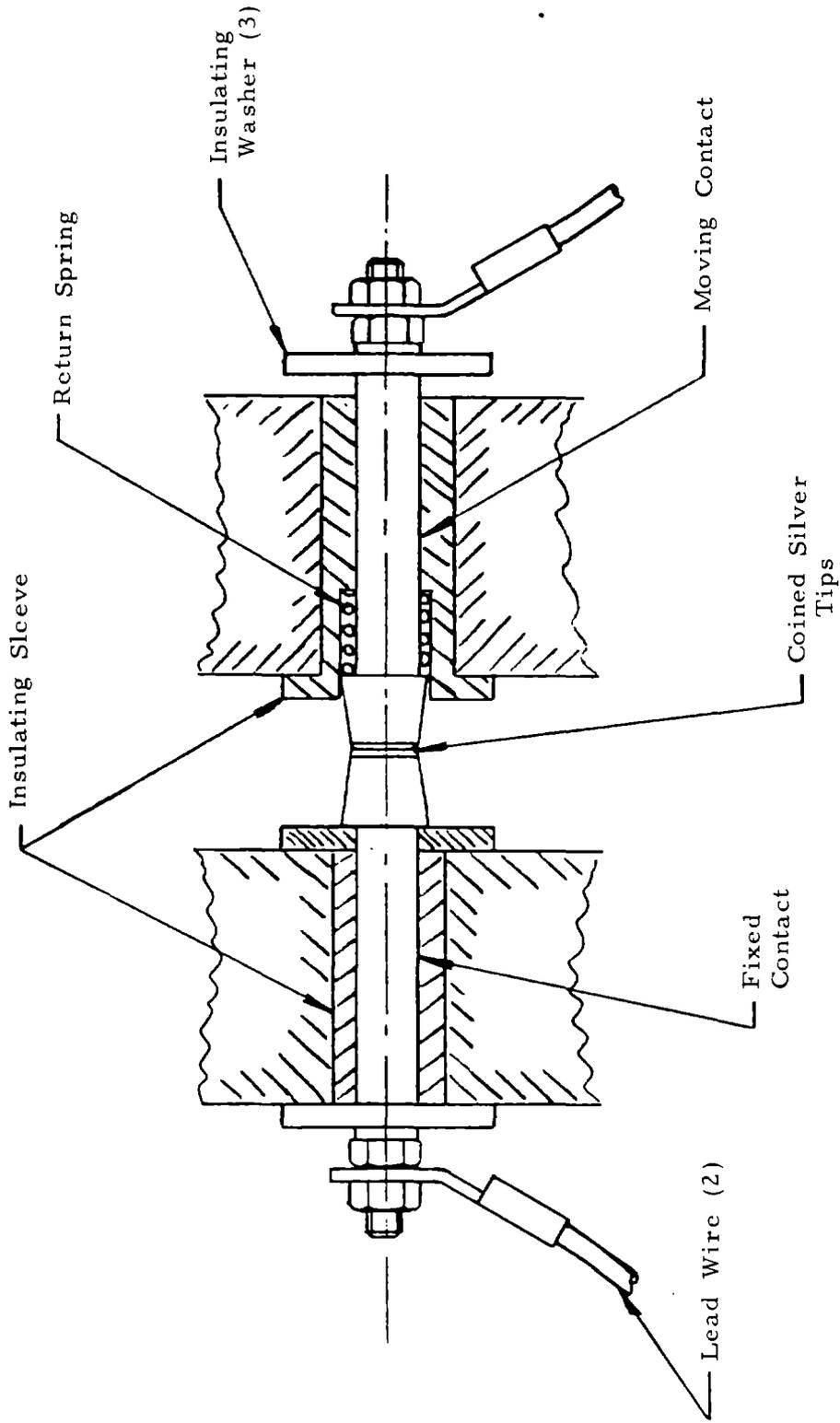
Coupler-mounted electrical contacts for the transmission of signals and power have been used in the surface rail transit industry for many years.

The design of a typical transit contact is shown in Figure 2-4. Its contacting face is clad with 1/32" thick fine silver for a longer service life than can be obtained with plating. The face is 1/2 inch in diameter, and the contact is rated at 15 amps.

Contacts for coupler mounting are not designed to open or close circuits under load. For this reason, the circuit must be switched with a suitable relay prior to the engagement of the contact.

The voltage drop across an engaged contact pair is sensitive to the presence of dirt. Transit system contacts are regularly cleaned to prevent unreliable train operation due to signal loss. Further precaution is taken by having one of the pair rotate during the engagement process, burnishing the faces together. Dirt will be an even more important problem, in underground haulage, where the environment is inherently dirtier than in surface transit, and where consistent maintenance cannot be expected.

Special design consideration must be given to the geometry of the faces and the material with which they are plated. The signal input and output circuits must be designed in anticipation of some signal loss through each contact pair along the length of the train.



Typical Rapid Transit Electrical Contact

Figure 2-4

Further considerations regarding electrical transmission systems are:

- (a) Actuators for the couplers and brakes, while available, have not been as extensively used in the surface rail industry as pneumatic components, and, as such, design effort will be required in their selection and development.

Electrical brakes are available from a number of manufacturers (Warner Brake and Clutch, FMC Stearns, Vickers, Trombetta and Facet), but these are primarily intended for industrial applications. Shoe brakes similar to those used in railroading can be actuated with large electrical solenoids.

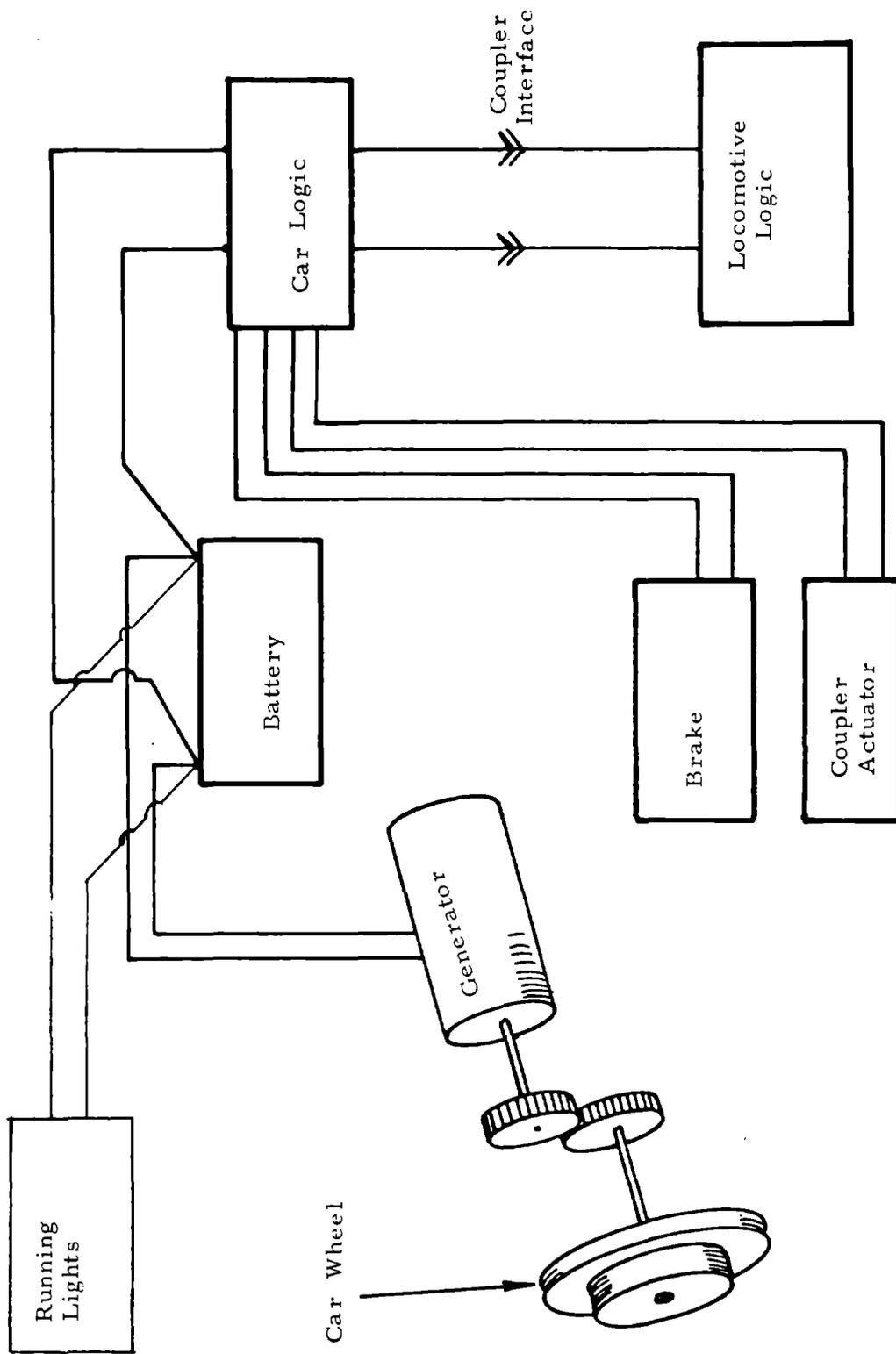
Couplers can be unlatched using rotary or linear solenoids, or with motor driven screws. Further consideration is given coupler actuators in Section 2.2.2.

- b) Electrically driven logic elements are readily available. This is the primary advantage of an electrical signal transmission system.

In summary, the design of an electrical signal and power transmission system will not present any major difficulty. Some development effort will be required to implement the contacts and brake and coupler actuators. Building blocks for the control logic are readily available.

2.2.1.3 Locally Generated Power

The power transmission system can be eliminated if electrical power for the brake and coupler actuators, the running lights, and the car logic is provided by a generator and storage battery on each car unit. A schematic of the concept is shown in Figure 2-5.



Block Diagram - Locally Generated Power

Figure 2-5

The advantages of this system include the elimination of power contacts and the availability of power to the running lights even when the car is uncoupled.

The disadvantages of this approach include:

- a) An axle-driven generator suitable for use in this application would cost about \$1500, exclusive of development costs. This would be a significant addition to the cost of implementing the coupler system. (See Section 6.0 - Cost Effectiveness.)
- b) Batteries for use in this application must be capable of being tipped upside-down, for rotary dump operation. Sealed batteries of sufficient power rating to handle the brakes, coupler actuator, electric logic and lights are only now being developed, and their operating reliability is, as yet, unspecified.
- c) In order to apply the brakes upon uncoupling, the car logic must sense the fact that it is no longer attached to a trip. This sensor is an extra component in the path of fail-safe operation. (In the power transmission approach, uncoupling automatically deprives the brakes of power, and they will be applied by spring forces.)
- d) Maintenance of a generator and battery on each car unit used in the mine is an additional operating cost.
- e) Haulage operations would require extra consideration to ensure that each car was moved often enough to maintain charge on the battery.
- f) Unless an elaborate contactless signalling approach is implemented, signal contacts are still required.

In summary, there are significant disadvantages to a locally generated power system which far outweigh the advantage gained by eliminating power contacts.

2.2.1.4 Microwave Signal Transmission System

Signal information can be passed back and forth along the train by means of three inch diameter microwave antennas, pairs of which are mounted facing each other on opposing coupler halves. The advantages of this approach include:

- a) Signal contacts are eliminated, and in conjunction with the locally generated power approach discussed above, remote control coupling can be implemented with no contacts or connectors on any coupler.
- b) The antennas can easily be made impervious to dust or moisture.
- c) The high frequencies used for signal transmission allow room for expansion of the signalling system: Trouble spots on each car unit could be monitored, and potential problems could be signalled to the locomotive. Additional antennas would not be required.

The disadvantages of the microwave approach include:

- a) All of the signalling components would require special development for this system, representing a significant expense.
- b) Maintenance of the microwave system will require skills not currently available in coal mines. Trouble-shooting of such systems can be subtle and time-consuming, even for skilled personnel.

In summary, a microwave system could be advantageous in the implementation of the remote control coupler, if the initial development and lifetime maintenance costs could be justified.

A paper design of one approach to the system is outlined in the Phase Reports of the program. In our discussions with Bureau and operating mine personnel, we determined that there was insufficient advantage to be gained by use of the microwave system to warrant the extra costs.

2.2.1.5 Transmission Systems - Summary

Having studied the available options for implementing the power and signal transmission systems of the remote control coupler, we concluded:

- a) Pneumatic power systems were inappropriate due to the difficulty of obtaining a reliable connector. Pneumatic signal systems were eliminated because of the lack of appropriate logic elements.
- b) Contactless systems - locally generated power and microwave signal transmission - involve too much development and life-cycle expense to be realistic in this application.
- c) An "all-electric" system, using electric power transmission through contacts, electric signal transmission through contacts and electronic logic and control elements offers the best all-around choice as a solution to the power and communication problems in the design of the remote control coupler.

2.2.2 Coupler Alternatives

2.2.2.1 Universal Vs. Male/Female Couplers

The investigations carried out during Phases I and II of this program uncovered many coupler configurations in use both on the surface and in mine haulage. The majority of mine car couplers are of the Universal type with 90 percent of the market being supplied by National Castings' Willison coupler. The second most

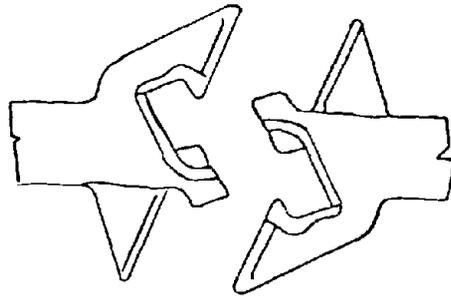
popular unit is the Ohio Brass Form 8, which is a male/female arrangement and has approximately 5 percent of the market. The balance are miscellaneous designs generally for special or utility vehicles. Figure 2 -6 shows typical coupler configurations.

A Universal coupler, as used on surface haulage systems does not discriminate between ends of a car. The coupler at each end is identical and because of this, each end of a particular car can couple with either end of any other car. This is a must in surface haulage situations where cars often run irregular routes and can be turned end for end before returning to their originating yard. This universality then dictates that both ends of a car must carry identical uncoupling mechanisms in order that the brakeman need not move from side to side of adjacent cars to uncouple.

A male/female coupler does not have this versatility. The couplers at each end of a car are dissimilar, one end male, the other female carrying the single uncoupling mechanism. This means that all cars in the system must maintain their end-to-end relationships throughout their travels within the system in order that the correct engagement of male to female always occurs.

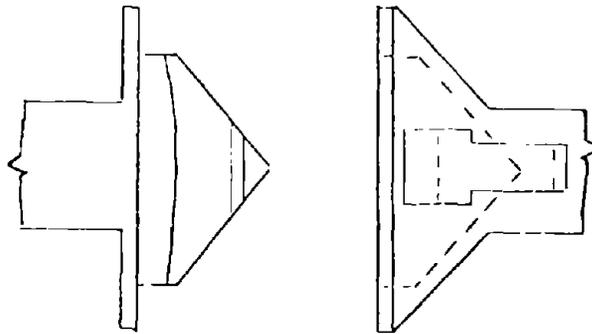
Mine layouts when compared to surface systems are relatively short, but more importantly are generally non-reversing arrangements where once a car is installed on the track, it maintains its end-to-end relationship with the other rolling stock. Therefore, a male/female coupler would be quite adequate for mine service operations.

Universal couplers are also known as slack couplers because of their loose coupled condition. There is as much as 4 inches of vertical play between mating halves of a Willison coupler and even with this wide deviation, the coupler will not disengage. In comparison, the male/female type couplers are generally called "Tight-lock" or rigid couplers as they typically have considerably less play between the mated halves when coupled.



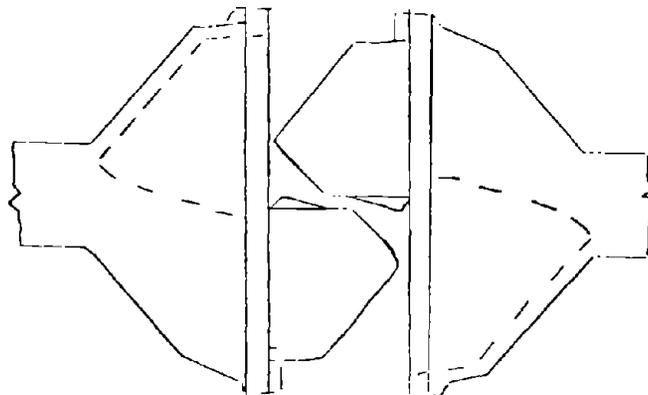
11" Horizontal Gathering Range

National Castings - Willison Coupler
 Universal - Slack



15" Horizontal Gathering Range

Ohio Brass - Form 8 Coupler
 Male/Female - Tightlock



11" Horizontal Gathering Range

American Steel Foundries Coupler
 Hook Type Universal - Tightlock

Figure 2-6. Standard Coupler Types

Any pneumatic or electrical transmission system across the coupler interface requires that an alignment condition exist between the two coupler halves in order to maintain the integrity of the pneumatic or electrical connection without submitting that connection to the forces transmitted by the coupler itself. This requirement cannot be met with stock universal couplers. Attempts to "rigidize" them in order to provide a stable base for transmission of power or signals have always restricted their degrees of coupling freedom and detracted from their simple, rugged operating advantages.

The male/female coupler inherently provides such a stable base which can be utilized effectively to provide adequate alignment of contacts during engagement and minimum play when in a fully engaged condition ensuring no break in continuity through the signal and power lines.

One other advantage of the male/female coupler is its greater horizontal gathering range which is most important when automatic coupling on curved track must be accomplished. The horizontal gathering range is 15 inches for the male/female coupler as compared to about 11 inches for both the Willison and the American Steel Foundries couplers. It should be noted that many design factors such as car design and coupler mounting influence the effective gathering range. For instance, as shank length decreases, the angle that the coupler must swing to make the same mating as with the longer shank increases. The vertical gathering range is also less on the Willison and the American Steel Foundries, about 5 inch allowable mismatch versus 6 inches for the male/female. Both of these figures are more than ample for conditions expected in the mine, but horizontal range should be as great as is physically attainable in order to compensate for the wide variation in track configurations.

Following is a list of couplers which are presently in use and were considered potentially applicable to the mine car coupler program (see Table 2 -2). It should be noted that the majority are of the Universal type, and the various modifications are intended to

apply automation to surface haulage. The Chio Brass Form 8, being a male/female type, was of particular interest because of the arguments previously stated and also the fact that it was the only such coupler specifically designed for mine service.

It can be readily seen that where universality is not an issue, but where gathering range and rigidity in the coupled state are of primary importance, the male/female style of coupler offers distinct advantages over the more widely used Universal design. All other parameters being equal, the choice was made to base the automated mine car coupler design for new mines on the male/female concept.

2.2.2.2 Coupler Mounting

Table 2 -1 stipulates that without manual intervention successful automatic coupling will take place in all of the following cases:

- a) On curved track of any configuration (see Figure 2-1) where the radius of curvature is 70 feet or more.
- b) On track having vertical curvature of 200 foot radius.
- c) On track containing vertical offsets of 2 inches.

Cases 'b' and 'c' present no problem with either the Universal or male/female style coupler discussed in Section 2.2.2.1. The cars on which these couplers are to be mounted range between 20-30 feet in length over the coupler ends and on a 200 foot vertical radius reverse curve, which represents the worst case condition, as depicted in Figure 2-2, car end mounted couplers would be displaced no more than 2-3 inches with respect to each other and be well within the vertical gathering range of either coupler type (see Section 2.2.2.1).

Horizontally curved track, as in case 'a' presents a greater problem for automatic coupling without manual intervention. It is presently common practice for the brakeman to kick adjacent coupler halves into a position where they will engage successfully on tight curves.

TABLE 2-2
LIST OF COUPLERS

WILLISON	basic railroad coupler - free type universal
UNICOUPLER	Willison modification to provide electrical and pneumatic connections through a rigid universal coupler - manually uncoupled
EUROCOUPLER	Willison modification similar to Unicoupler
ITALIAN WESTINGHOUSE	Willison modification similar to Unicoupler
SCHARFENBERG	recent design - rigid - universal - has multiple electrical contacts
OHIO BRASS	FCRM 8 mine car coupler - rigid, male/female - has been modified for electrical and pneumatic connections
CHIC BRASS	Hook type - rigid - universal - has multicontact capability - generally in rapid transit service
AMERICAN STEEL FOUNDRIES COUPLER	Hook type universal - tightlock

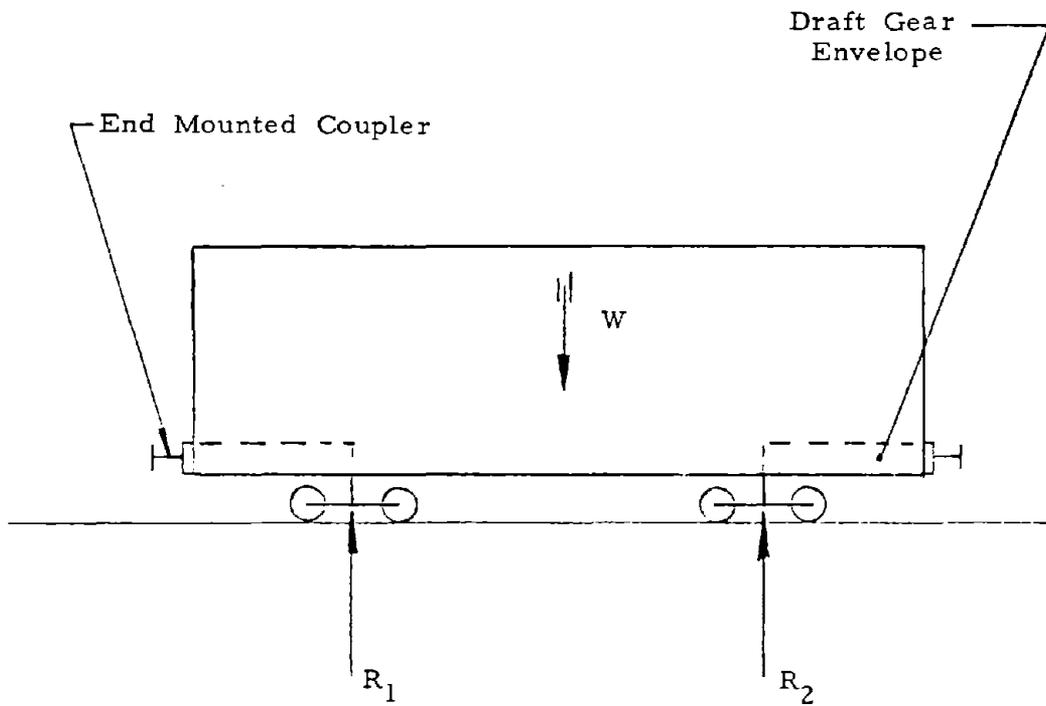
Typically, car end mounted couplers, as presently used, will not engage successfully on curves of less than 120 foot radius.

Car end mounting of the coupler is standard today and derives from common practice in the surface haulage field. There, length and height of cars is not restrictive on total volume of the car and these dimensions can be varied to assist in optimizing truck position and load support configuration. As can be seen in Figure 2-7(A), truck position on surface cars is determined by using simple, two support beam formulas to locate each truck at the optimum distance in from each end. Surface rail cars are in the order of 60-100 ft long and, therefore, the distance from the car end to its wheel truck is 10-20 feet. Horizontal curves on the surface are not as severe as those encountered in the mine, and there is less need for coupler adjustment prior to engagement.

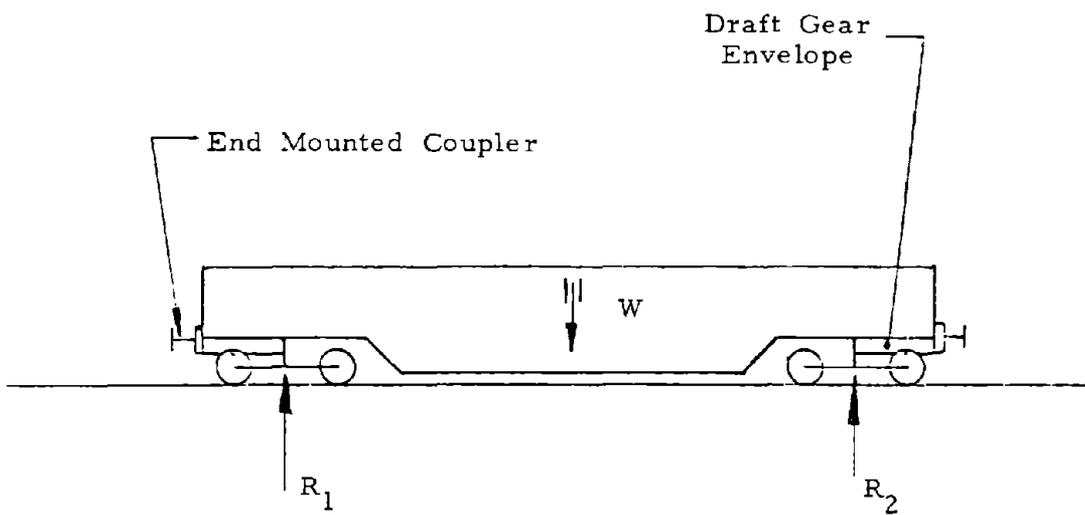
The long envelope available between the car end and the truck has provided room for sophisticated draft gear which cushions coupling and service load shocks, and for steering linkages which optimally position the coupler in a horizontal plane.

The general use of surface-style couplers and draft gear in mine car service has dictated car end mounting in all present systems. However, track curves are tighter and the car design is based on a different set of standards. The main concern is to pack the largest volume of coal into the most efficient envelope. Tight curves limit car length because of the car center bridging on corners, and car height is limited because a great deal of coal is mined in seams less than 5 ft high. Mine car designers have therefore positioned the trucks right at each end of the car with a depressed car floor between them in order to take advantage of all of the available volume in a car length. Figure 2-7(B) shows this typical configuration. Compromises have been made in draft gear design in order to fit within the restricted space at each end, but the basic surface techniques have been used in order to retain a coupler mounted directly to the car end.

However, if a valuable lesson is learned from surface railroad coupler steering designs, it is obvious that the truck



(A) Surface Car



(B) Mine Car

Comparison of Truck Position
on A Typical Surface Rail Haulage Car and A Mine Car

Figure 2-7

itself maintains a much closer in-line relationship to the track than the car body does. The adjacent trucks on two separate mine cars are always quite close to each other. The short, 3-4 ft wheel base on a four wheel truck and 2-3 ft projection of the coupler beyond the car end lend themselves to a small-span, two-link system which deviates only minimally from the track curve. Figure 2-8 illustrates this situation.

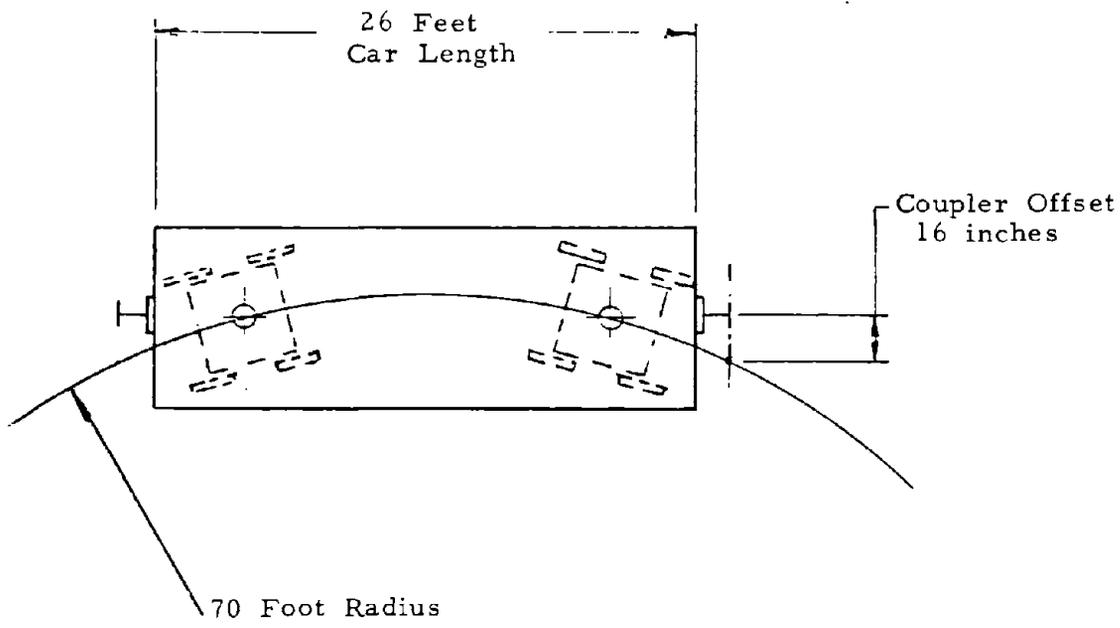
If a spring centering device is incorporated which aligns the coupler with the truck axis, rather than with the car axis (see Figure 2-9), the guidance obtained is more than sufficient to assure automatic coupling on all the track curves of Figure 2-1.

Since the trucks also tend to follow vertical curves, truck mounting also enhances the vertical gathering range of the couplers, reducing the 2 1/2 inch range required for 200 foot radius curves and 2 inch displacements in the track to 1 inch.

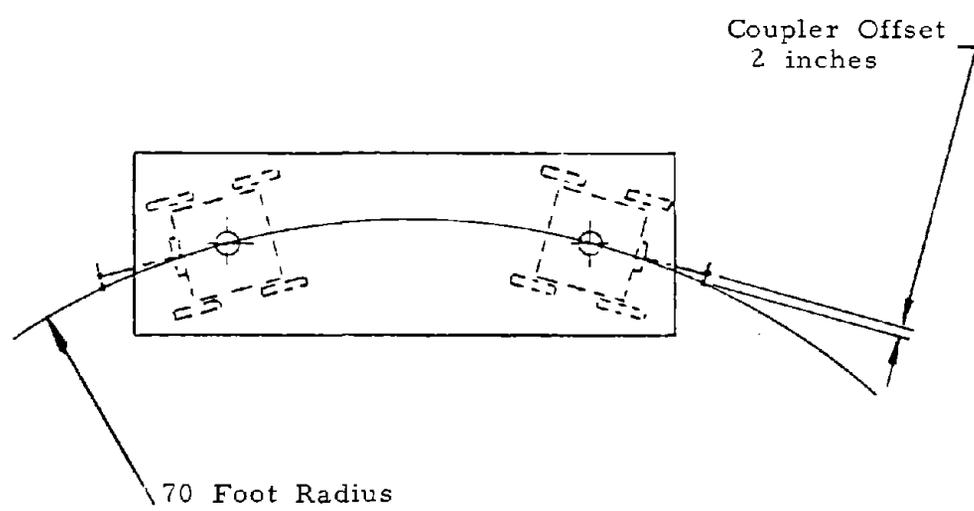
Truck-mounting of the couplers will require reinforcement of the trunion between truck and car. The effort involved in this reinforcement is approximately canceled by the elimination of the car-end coupler mount. The advantages of a truck mount for the coupler made it a clear choice for the remote control system.

2.2.2.3 Uncoupling Actuators

A significant source of danger in present mine haulage systems is the manual uncoupling lever at the end of each car. This lever typically is linked by a chain to the latch on the coupler and extends to the side of the car where it can be actuated by the brakeman. Due to a large tensile load on the coupler because the train has not been buffed, corrosion, foreign objects obstructing the linkage, and often crude bearing points, these levers are difficult to operate. Consequently, the brakeman is tempted to step between cars in order to obtain a better purchase and improve his mechanical advantage. Any movement of the



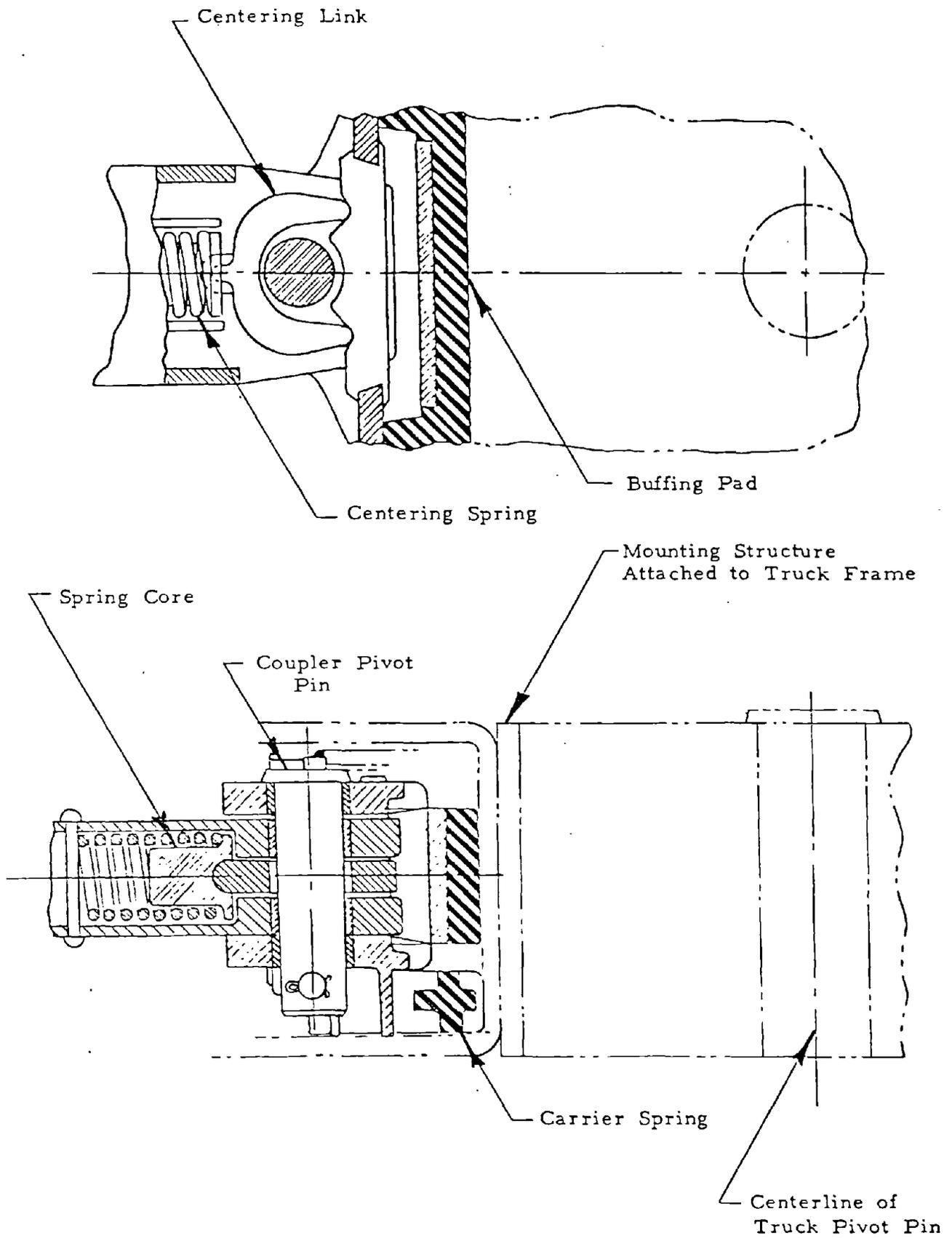
(A) Car End Mounting



(B) Truck Mounting

Coupler Deviation from Curved Track
for Car End and Truck Mounted Couplers

Figure 2-8



Centering Device

Figure 2-9

cars at this point, whether for buffing or by accident, will cause injury to the brakeman.

Automatic uncoupling of mine car couplers has been attempted previously, but none of the systems tried has been used extensively. Generally, they have been of a straightforward design with a pneumatic cylinder directly coupled to the latch. However, the tradeoff described in Section 2.2.1 shows that the use of air in the uncoupling system is ill-advised and advocates the use of electrically operated actuators. Consequently, the following devices were evaluated:

- a) Lead screw and nut
- b) Lead screw and ball nut
- c) Motor/gearbox with quadrant arm
- d) Rotary actuator - driven by locally generated air power
- e) Power cylinder - driven by locally generated air power
- f) Electro-thermal actuator
- g) Direct acting solenoid

When a, b, and c were examined further, it became apparent that a successful uncoupling mechanism based on one of these ideas would be complicated by the number of pieces involved and be inefficient because of the power drain those working parts represent.

Figure 2-10A shows the configuration of both the a and b approaches and the number of pieces involved in the power chain. The motor/gearbox would drive the lead screw and the nut would wind along the screw pulling the link and the uncouple latch out of engagement. The nut release actuator would be solenoid-operated and would hold the nut engaged with the screw only while power was available through the coupler contacts. As the coupler halves part, the nut would disengage and the return spring would recock the latch for the next couple operation, resetting the nut for the next uncouple operation. Figure 2-10(B) is similar

in operation with the worm rotating the wormwheel quadrant and disengaging the uncouple latch through the arm and link connection. As the coupler parts, the arm release actuator loses power as in the previous example, and the arm, link, and latch will all return to the cocked position ready for the next coupling. The one extra complication with this design is the necessity to reverse the worm and wormwheel upon coupling in order to re-engage the arm and the wormwheel.

Methods d and e are attempts to use direct acting components such as pneumatic cylinders even if air power were not available through the coupler. Previous automated uncouplers have used this approach and the actuators have proved adequate for the loads. However, with no air available from a central source, each car would be equipped with a wheel driven compressor and an accumulator. (A motor driven compressor could be used, but this is an extra complication.) The rolling car would drive the compressor which pressurizes the accumulator. An electrical signal from the locomotive would energize a solenoid operated valve retracting the cylinder and disengaging the latch. Figure 2-11 is a schematic of this system.

As in the previous example, a number of components were required in order to implement the power train and the compressors and accumulators available proved to be both expensive and too large for the space available under the car ends.

Electro-thermal actuators perform the same functions as a hydraulic or pneumatic cylinder, but the working fluid is self-contained and is either a hydrocarbon wax or a fluorocarbon fluid. If electric heat is added to the unit, the materials change phase either from solid to liquid in the case of the wax or from liquid to vapor in the case of the fluorocarbon. The high expansion rate results in movement of a piston actuator and generates large forces of up to 500 lbs. However, the high-powered units are slow in operation, and those which

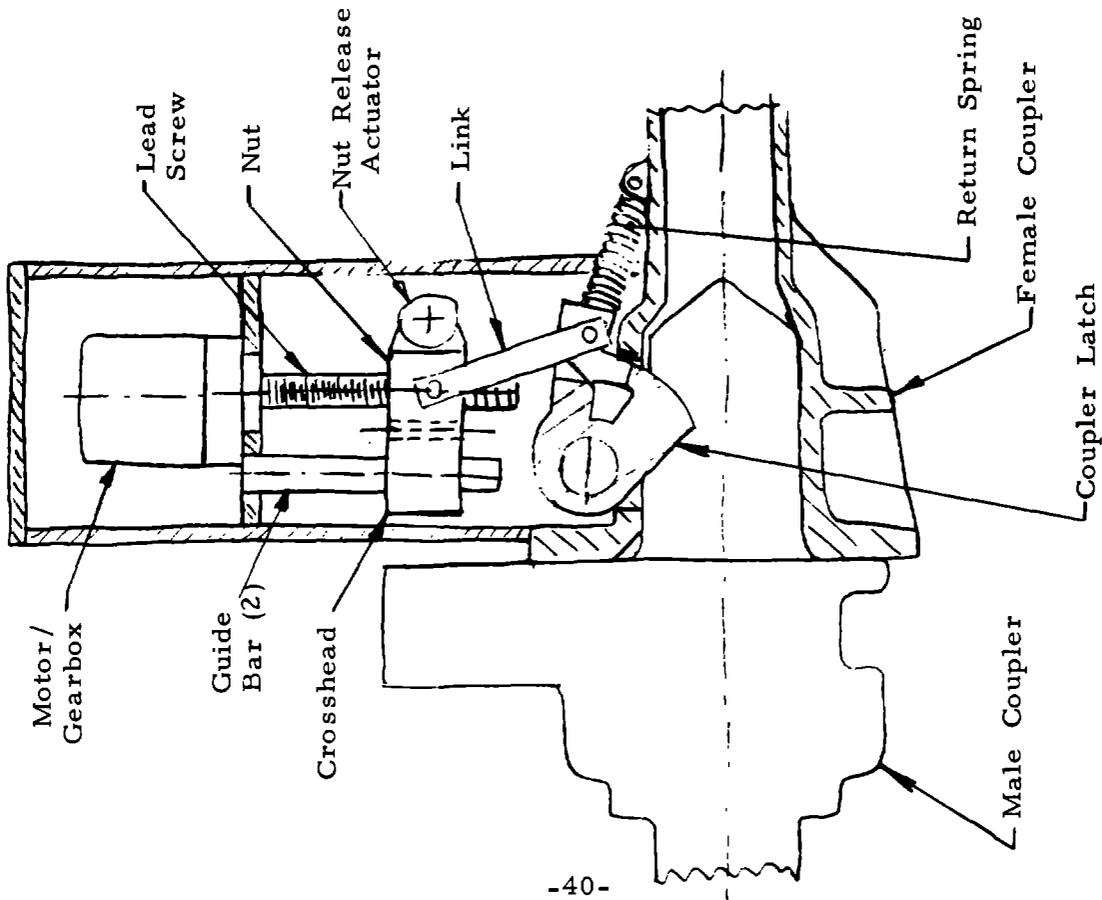


Fig. 2-10A. Lead Screw Uncouple Actuator

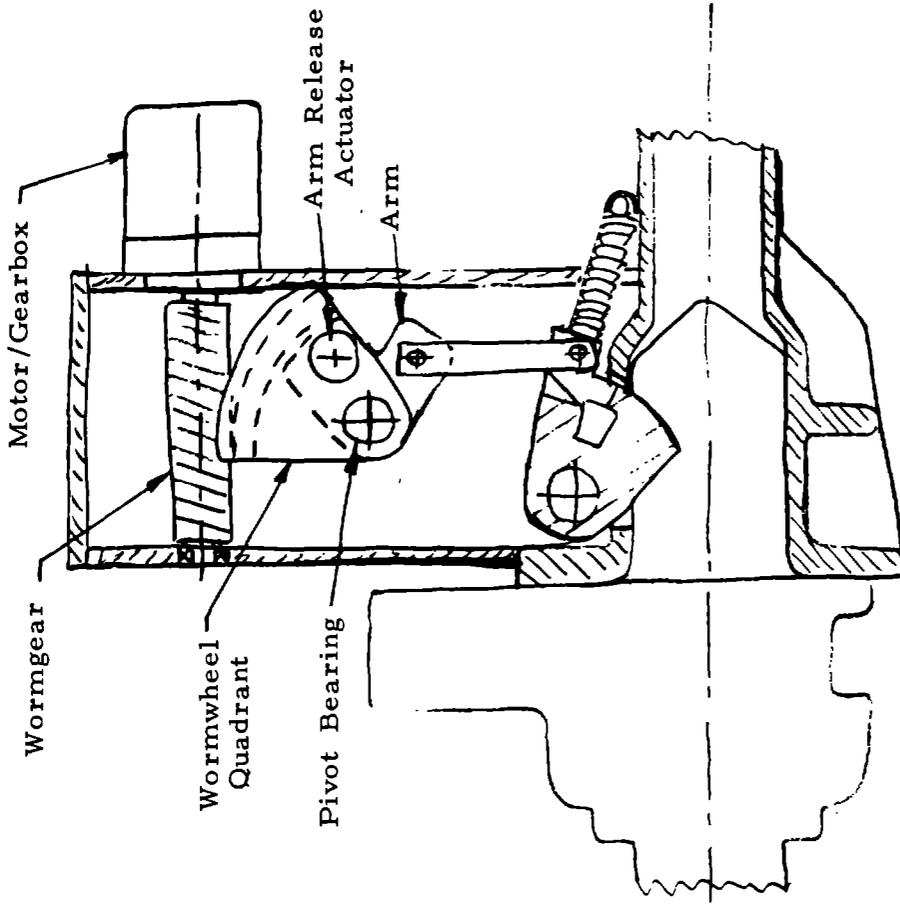
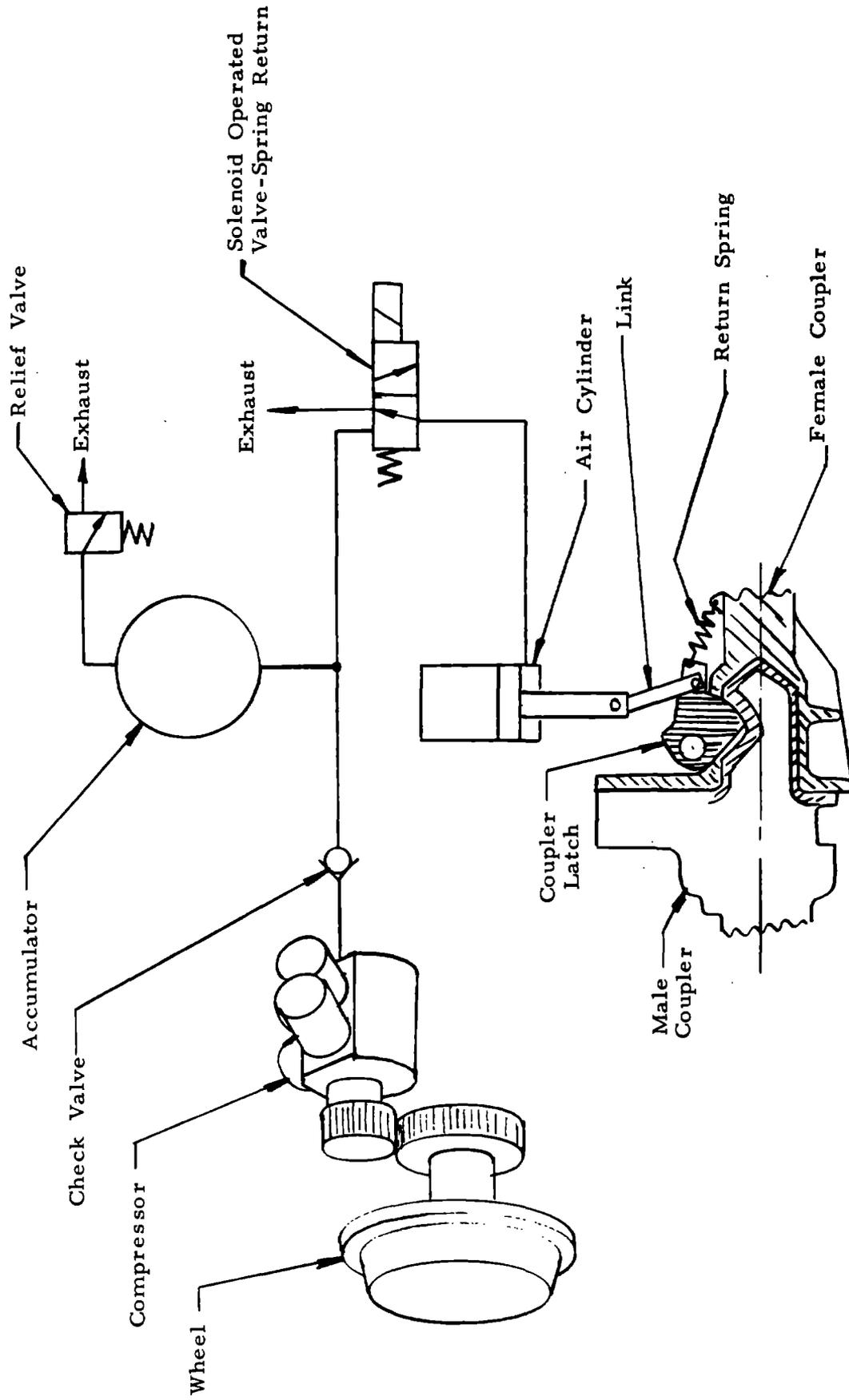


Fig. 2-10B. Quadrant Arm Uncouple Actuator

Figure 2-10. Uncouple Actuators



Gas Driven Actuator

Figure 2-11

are appropriately fast do not exert enough force to unlatch the coupler.

A direct acting D. C. solenoid was considered and finally selected as the best possible solution. Although these too are limited in actuator force to approximately 60 pounds for the size which would fit within the space available, 60 pounds is more than sufficient force for uncoupling if the load is buffed. (i. e., drawbar forces are reduced by backing the locomotive toward the cars to be uncoupled)

Figure 2-12 depicts the forces acting on the coupling and resisting unlatching. F_L is the total draft load on the coupler and it can be seen that the latch has been designed such that this load only serves to increase the locking force because of the moment arm at which it is applied. With the cars on a grade and full load across the coupler, the frictional resistance to unlatching F_F is of order 1500 pounds, and there is not sufficient space available for a direct actuator or geared system capable of exerting this force. Buffing momentarily relieves this load and reduces the force necessary to pull the latch. However, on an incline, buffing is useless unless the cars furthest from the locomotive are held stationary while the cars to remain are buffed against them. This leads to the requirement for selective braking of cars from the control box in the locomotive cab. Cars destined for uncoupling must be braked.

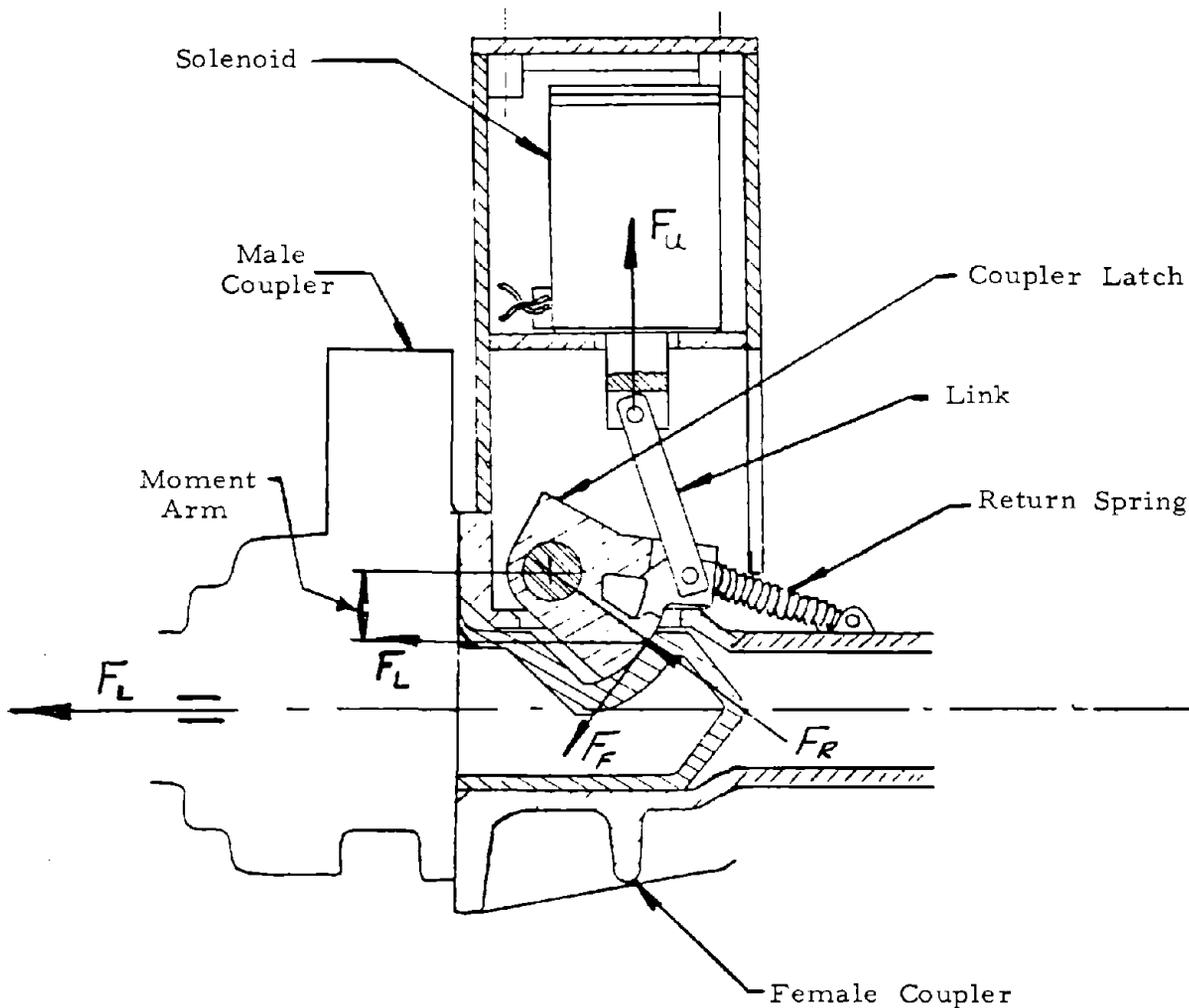
The direct-acting solenoid requires 25 watts of power during actuation, well within the capability of a contact power transmission system. It was selected as the most efficient, cost effective and reliable actuator available for the remote controlled coupler.

2.2.3

The Unit Train Concept

The cost of a coupler pair, including all necessary car logic, contacts, cables and actuators is estimated to be about \$3,900 in hundred quantities. This represents a significant investment

F_L = Coupler Load
 F_u = Uncouple Force
 F_R & F_F = Radial & Friction Resultants of Coupler Load Seen at Latch



Forces Resisting Uncoupling

Figure 2-12

when compared with the approximate \$3,000 cost of a suitable mine car, and could create industry resistance against implementing remote control coupler systems.

Employment of the unit-train concept can substantially reduce this difficulty. In this approach, a number of mine cars, say four, are connected together using a simple intermediate coupler, and these four cars remain coupled on a relatively permanent basis. The automated, remote control coupler halves are installed on the outside ends of the first and fourth cars.

In this way, the cost of the remote control coupler is shared over four operating mine cars, and the cost of equipping a mine with the system is significantly reduced. The design of the intermediate couplers is such that they can be parted only with special tools for maintenance or in emergencies. The temptation to use it as a manual coupler is minimized. (See Section 3.2.) The locomotive treats each car unit individually, counting, selectively braking and uncoupling in blocks of four. The number of cars per unit can be varied to suit the circumstances of a particular mine. If more cars can be used per section per trip, the unit size can be increased, and the capital cost of installing the system can be correspondingly reduced.

Implementing the unit train concept requires the design of a tamper-proof intermediate (fixed) coupler. This was pursued, and the design is described in detail in Section 3.2.1. The cost of the intermediate coupling, including an electrical junction box, is \$640.

2.3 Summary of Hardware Choices

The hardware choices made for implementing the remote control coupler system are:

- 1) The Primary Coupler: Ohio Brass Form 8A, Male/Female, tight

locking type.

The coupler will be truck-mounted to increase its effective gathering range.

- 2) The Uncoupling Actuator: Direct acting electrical solenoid.

The coupler will require buffing to assure operation of the actuator.

- 3) The Power Transmission System will be electrical, with power passed from the locomotive to each car unit by means of cables having mated contacts mounted on each primary coupler.

- 4) The Signal Transmission System will be electric, signals being passed along the trip by means of cables having mated contacts mounted on each primary coupler. All car and locomotive logic and control elements will be electrical.

- 5) Selective Braking of cars destined to be uncoupled will be implemented in the control system to facilitate buffing the trip on grades.

- 6) An intermediate Coupler will be used to connect cars within permanent units. A junction box containing a connector will be provided with each intermediate coupler to facilitate manual electrical connection of the cables.

2.4 Coupler Specifications

As a result of the above considerations, and discussion with Bureau, operating and manufacturing personnel, the following set of working specifications was developed:

- (a) General

- 1) The remote control coupler shall be installed at the ends of

car units approximately 100 ft long and shall be used for tracked haulage. Details of current design practice of mine cars need not be followed.

- 2) A car unit shall typically be composed of four cars, each 26 ft long. The couplers between cars of a unit may be of any suitable locked design requiring special tools for uncoupling. Eight units will make up a typical trip.
- 3) The full coupling of two vehicles shall be accomplished automatically, without assistance or supervision, as soon as the vehicles come into contact.
- 4) All operations concerning the action of the remote control coupler shall be undertaken from the cab of the front locomotive.
- 5) A universal type of coupler is not required.
- 6) There may be a locomotive on the front end or both ends of a trip.
- 7) Coupling must be feasible without damage to the couplers or the cars at impact speeds of up to 1 mph. (While this is the agreed upon specification, they were tested up to and including 3 mph.)
- 8) Chance or accidental separation of the couplers must not be possible without creating an alarm situation.
- 9) Pneumatics will not be used.

(b) Operation of the Coupler

- 10) It must be possible to uncouple selectively from the front locomotive.

- 11) When couplings are in the uncoupled position at points on the track where coupling must be possible (20), (21), they must never assume a position in which they and the vehicles are liable to be damaged in the event of an unsuccessful coupling operation. (No passed couplers).
- 12) A manual uncoupling capability is necessary as a safety consideration, at the automatic couplings only. Intermediate couplers are not intended for routine uncoupling.
- 13) It shall be possible to overcome the force exerted by the coupler centering device by directly applied manual effort.

(c) Coupling and Running over Curves and Ramps

- 14) On account of the horizontal field of action required by (20), vehicles fitted with the remote control coupler shall couple together in a sure and reliable manner, without manual assistance:
 - (i) on straight track;
 - (ii) At points where straight track meets curves of at least 70 ft radius;
 - (iii) on reverse curves without intervening straight section, of at least 70 ft radius (switches);
 - (iv) on curves with the same radius respectively.
- 15) Running of precoupled vehicles must be possible over reverse curves of at least 70 ft radius without intervening straight section and over curves of at least 70 ft radius.

- 16) As manually assisted coupling on curves is extremely dangerous, no provision is made for it.
- 17) It must be possible for precoupled vehicles to negotiate, without risk of uncoupling, vertical curves of minimum 200 ft radius and step changes of 2 inches.
- 18) It must be possible to uncouple vehicles on vertical curves and steps as defined in (17).
- 19) The construction and fitting of the coupler must be such that coupled vehicles are able to run on track with maximum torsion of 5° over a length of 75 ft.

(d) Coupling Head (Characteristics, Construction)

- 20) The horizontal field of action (gathering range) of the coupler on either side of the vehicle axis shall be large enough to permit coupling on the curves specified in (14).
- 21) The couplers must be capable of coupling in a sure and reliable manner when there is a difference in level between the axis of the coupler heads corresponding to vertical curves of 200 ft radius, or step changes of 2 inches.
- 22) The couplings must be capable of withstanding the following loads:
 - Maximum tensile load: Normal working load
55,000 lbs
(80,000 lb maximum draft rating)
 - Maximum compressive (buff) load: Normal working load
55,000 lbs.

- 23) The coupler shall be simple and robust in construction and of an inexpensive nature. The weight of the coupler shall be kept as low as possible and it shall operate in a reliable and sure manner, notwithstanding the influence of temperature and atmospheric agencies (frost, snow, dust, etc.).
- 24) The use of springs in the mechanism shall, as far as possible, be avoided. Fracture or fatigue of a spring shall not give rise to uncoupling.
- 25) Parts of the coupler particularly subject to wear shall be easily replaceable.

(e) Fitting of the Coupler on Vehicles

- 26) The height of the coupler axis, measured vertically from the top of the rails when in the position of rest, shall be compatible with good design practice of standard mine car, 4 wheel trucks.
- 27) The coupler shall be capable of transmitting both tractive and compressive efforts.
- 28) The coupler shall be capable of flexible movement on the vehicles, when in tension or under compression.
- 29) The maximum stroke of the draft gear shall be compatible with good mine practice.
- 30) The shank of the coupler shall be capable of 180° rotation for use in conjunction with a rotary dump.
- 31) The fitting of the coupler shall be such as to ensure that the lateral and vertical forces exerted on two coupled vehicles are kept as low as possible when conditions resulting from curves and differences in level are most unfavorable (as specified in (14) and (21)). The maximum resultant values for these forces are as follows:

- (i) 1/2 the weight of an empty car - vertical
- (ii) 5 tons pressure against the side of a rail - horizontal.

(f) Automatic Coupling of Electrical Circuits

- 32) The coupler shall provide for automatic coupling of electrical circuit connections. In the uncoupled position, the electrical contacts shall be disconnected from the train's power and signal lines to eliminate shock hazard and possible circuit damage.
- 33) One pair of electric power connectors is specified. The connectors shall be capable of transmitting 3200 watts DC continuously for brakes, electronics and running lights. 3825 watts will be required for 5 seconds intermittent duty to accommodate the coupler actuation.
- 34) Cables to the conductors shall be capable of twisting when passed through a 180° rotary dump.
- 35) Manual, intermediate electric connectors are required between cars of a unit so that the units may be separated for servicing.
- 36) An electrical switch shall be provided which indicates that the coupler latch is engaged with the mating coupler head.
- 37) An electric power line connector will be provided at load/unload points to permit brake release actuation for moving cars without the locomotive. Use of this

connector at points other than at the load/unload area should be restricted to an emergency condition. In any case, care and safety must be exercised with the use of this connector.

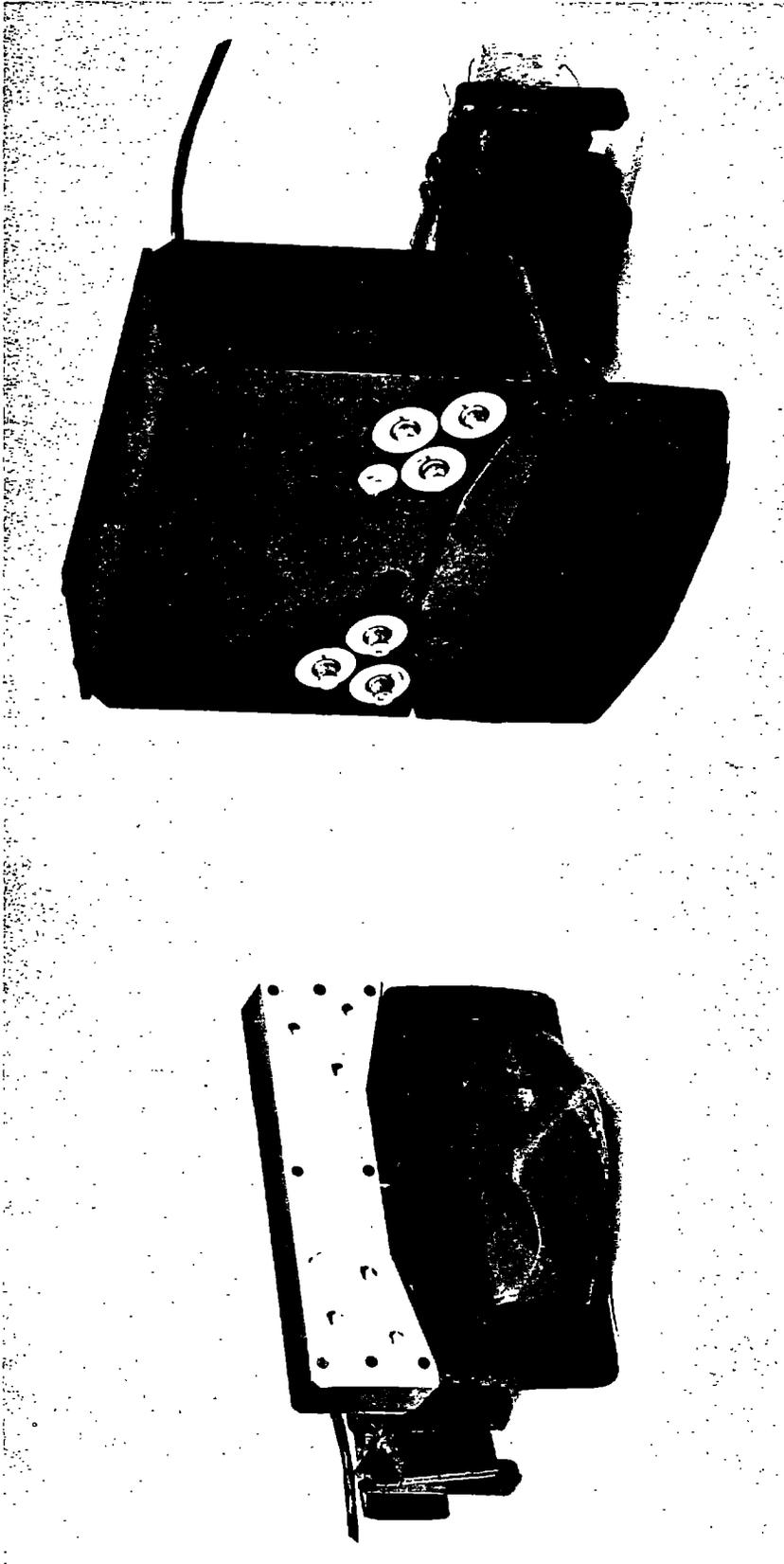
3. Mechanical Design

The automated coupler specifications which were developed during Phase II of this program were used as the basis for the design effort carried out in Phase III. The resulting configuration, as shown in Figure 3-1, is quite different from coupler systems currently used in the mines due to the addition of the automation features.

As discussed earlier in this report, the Ohio Brass Form 8A coupler was selected as the basis for the mechanical design. Its rigid male/female configuration provides an almost motion-free interface which is essential for the successful operation of the power and control connector unit. The short draft gear is compatible with a truck mounted system, so that coupling can be accomplished in a wide variety of curved track situations. The coupler has a 180° dump-rotation capability. A minimum number of parts and a horizontal gathering range of $\pm 7 \frac{1}{2}$ inches also proved to be advantageous.

The electrical and manual uncoupling features were designed to make use of the existing cam-type lock that is presently employed on the Ohio Brass coupler. The contact and actuator components which were added are mounted within a welded structure which is bolted to the female half of the coupler. (A production coupler would, of course, utilize a one piece casting for the complete structure.) The overall layout of the prototype coupler is shown in Figure 3-2.

The unit train concept, discussed in Section 2 and shown in Figure 3-3, requires a simple, permanent, intermediate coupling between cars within a unit. The intermediate coupler which was designed is simple, tamper-free and robust. This coupler combined with a newly designed junction box which is mounted on the back end (away from the locomotive) of the cars interconnected with intermediate couplers allows maintenance men to safely make or break the electrical circuit, completes the mechanical components required for an efficient unit train design.



Male Coupler

Female Coupler

Remote Control Coupler Halves

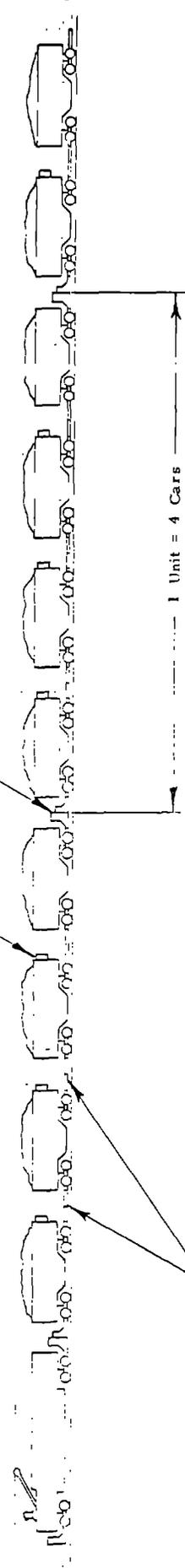
Figure 3-1

Junction Boxes
at Intermediate/End Couplers

Automatic Coupler Every 4th Car

1 Unit = 4 Cars

Intermediate Coupler
Within Units



A

Unit Train Concept

Figure 3-3

B

3.1 Primary Coupler

The primary coupler consists of the Ohio Brass Form 8A coupler with an electrical and an added manual uncoupling mechanism as well as power and signal connectors. The short draft gear of an Ohio Brass Form 8A coupler is of the energy absorbing type and will accept buff forces of up to 100,000 pounds and draft forces of up to 80,000 pounds. The broad bearing surfaces inherent in the design counteracts the offset moments developed in compression between the centerline pivot points of the two cars. This feature yields exceptional track stability in buffing.

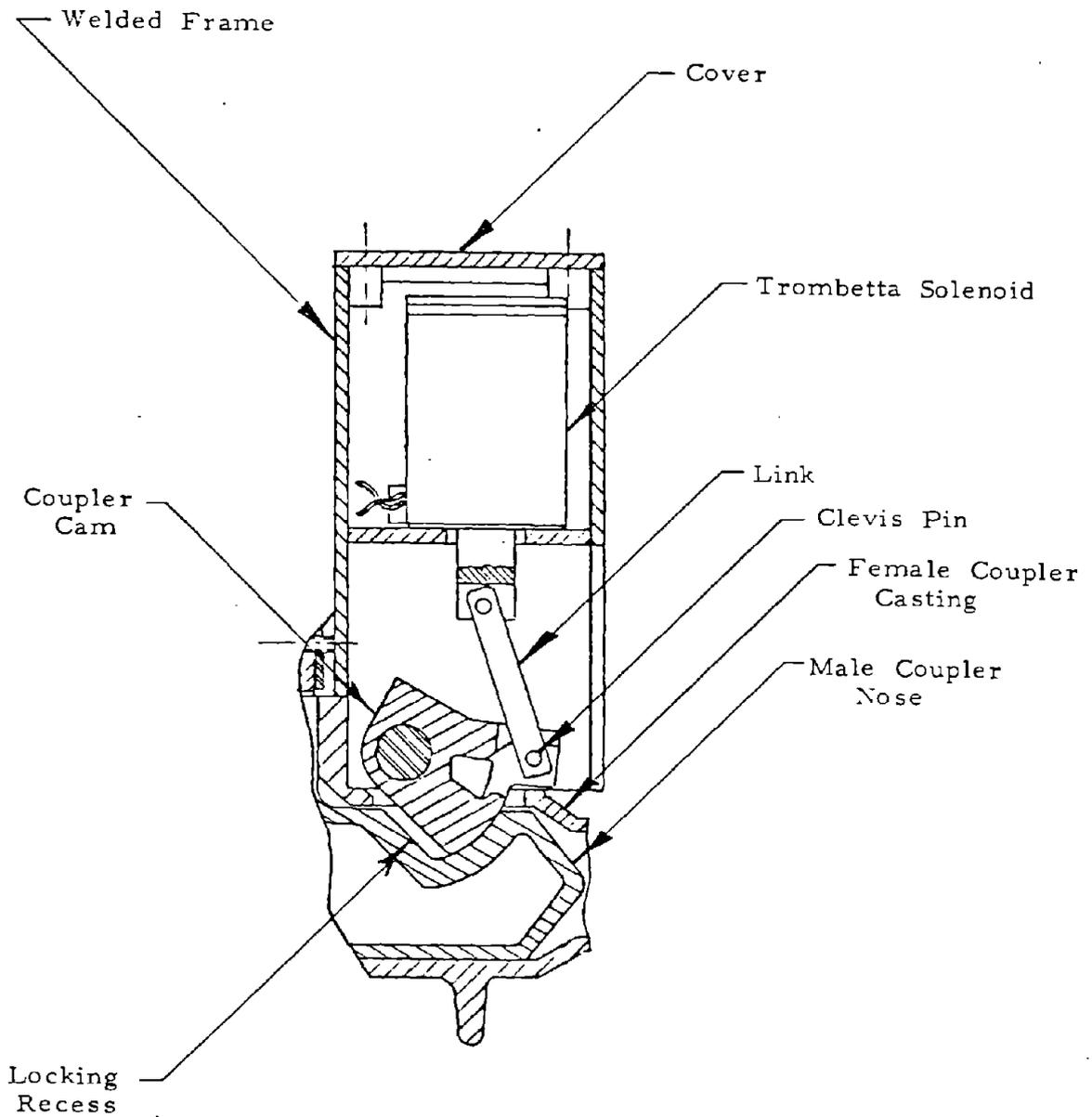
3.1.1 Electrical Uncoupling

Electrical uncoupling is accomplished by energizing a Trombetta solenoid which is connected to the coupler cam with a link. (See Figure 3-4.) Through this linkage, the coupler cam is rotated out of the locking recess located in the nose of the male coupler half. The standard Ohio Brass cam was modified by placing a clevis pin in a position so as to use the output force of the Trombetta solenoid in the most efficient manner. The solenoid is mounted within the welded frame which is located on the female coupler and can be easily serviced by removing the cover.

The Trombetta was chosen for this application for a variety of reasons. Beyond its obvious rugged construction, the Trombetta solenoid is the most simple and direct method of actuating the coupler release mechanism. All of its critical parts - coil, pole pieces, plunger, guides - can be replaced quickly which is a must for in-mine maintenance.

3.1.2 Manual Uncoupling

Manual uncoupling is initiated by placing a two foot long piece of pipe into a hole in the end of the release arm. (See



Uncoupling Mechanism

Figure 3-4

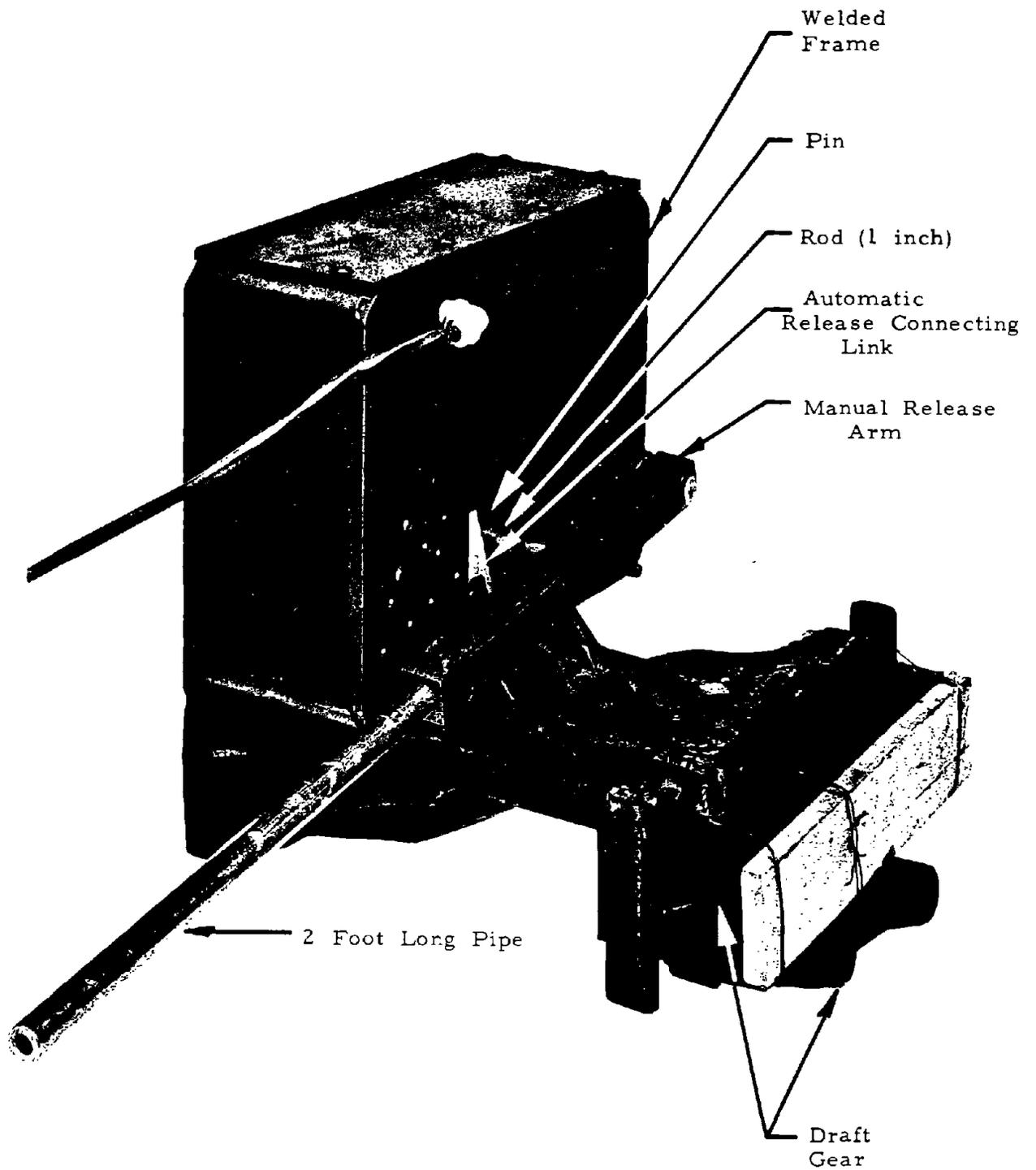
Figure 3-5.) A one inch diameter rod protruding from the release arm works against a pin which is part of the automatic connecting link. Thus, when an upward force is applied to the pipe, the automatic connecting link rotates the modified coupler cam out of its locking position. Once again, as in the case with the electrical uncoupling mechanism, the manual release arm is mounted directly to the welded frame. The pipe will normally be carried in the locomotive or on the cars and its two foot length will enable manual uncoupling without the need of having a man between the cars. However, the only reason for manual uncoupling should be the failure of automatic remote operation.

3.1.3 Coupling

As previously mentioned, the Ohio Brass coupler consists of a male and a female half, each of which has a heavy, flat face for buffing. The nose that extends from the male half guides the two halves during engagement and closely fits inside the female half when in a coupled condition so as to limit play.

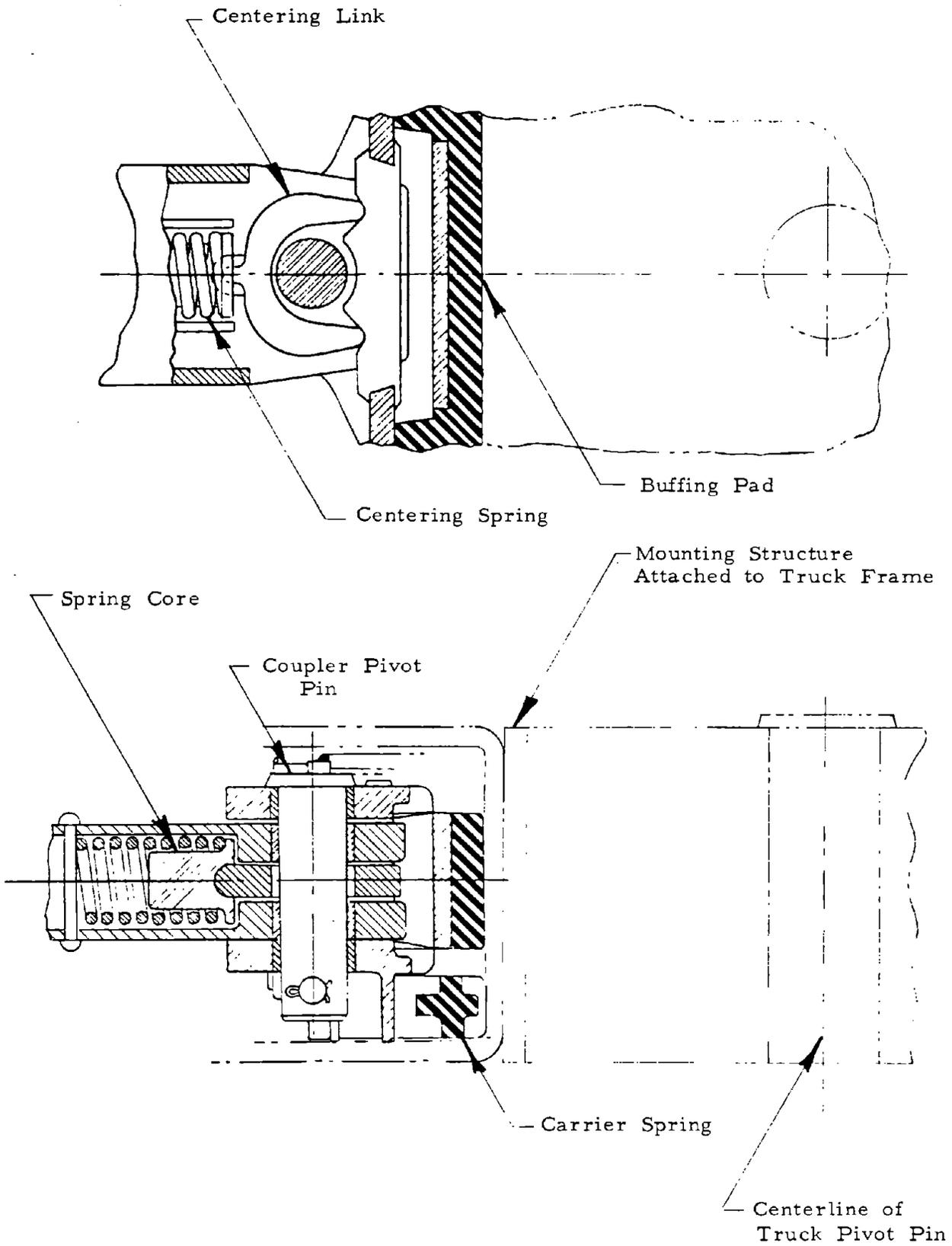
Each coupler half is equipped with a centering device and a carrier (see Figure 3-6). This combination serves to keep the heads centered with respect to the car centerline and in a horizontal plane when they are uncoupled, yet still allows movement both horizontally and vertically when they are coupled.

As the coupler halves begin to come together, the nose of the male coupler picks up the throat of the female and roughly aligns the two halves during initial engagement. The large areas of the buffing faces then contact on one of their sides, levering the coupler into a closer axial alignment at which time the coupler is forced together and the nose piece completes the final alignment. The nose of the male forces the cam to unlatch until the two halves are fully engaged and then the spring loaded cam, shown in Figure 3-4, snaps back into the recess in the nose of the male coupler, locking the halves together. The spring is needed to keep the cam in place when a car is upside down in a tipple.



Female Coupler

Figure 3-5



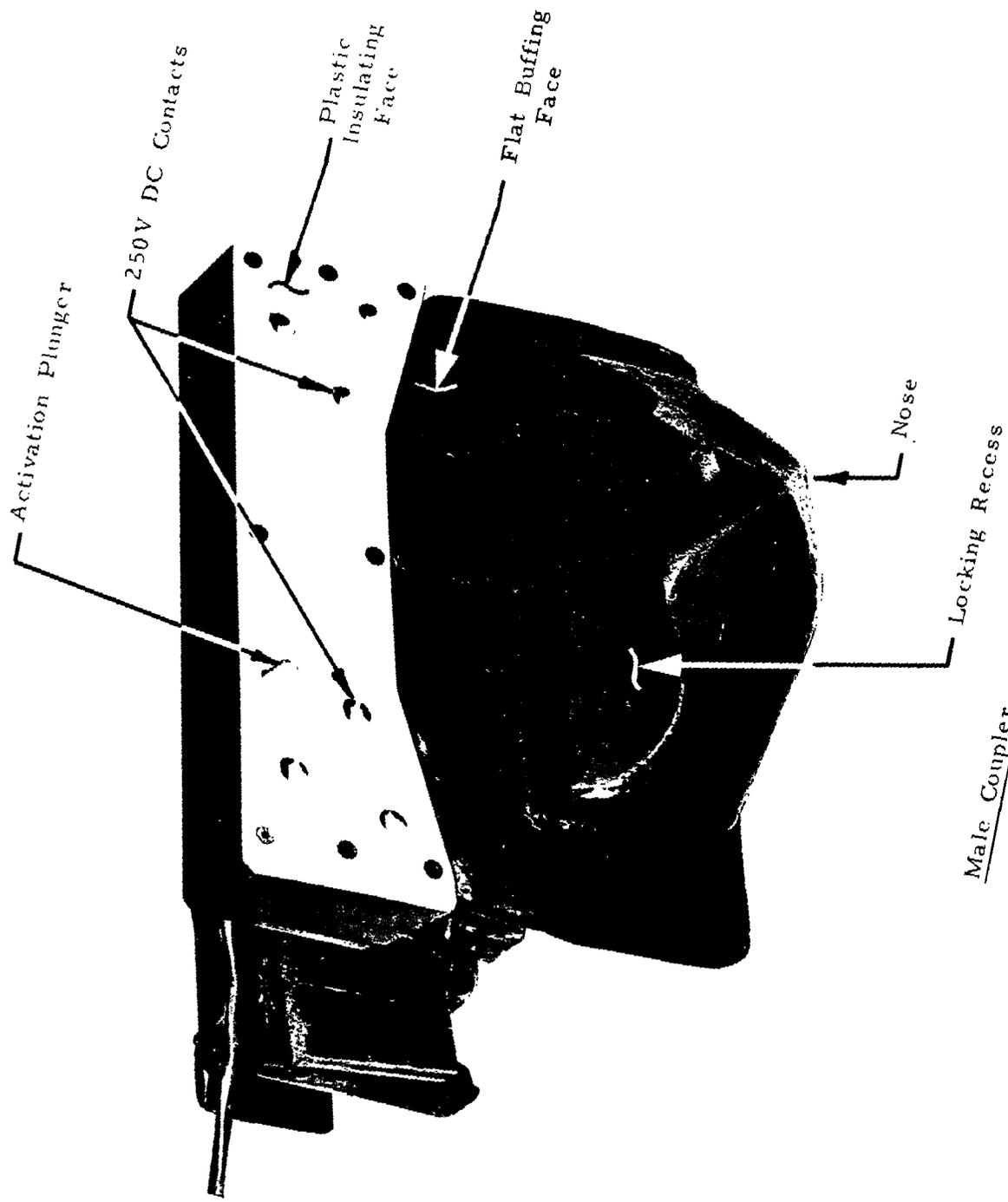
Centering Device

Figure 3-6

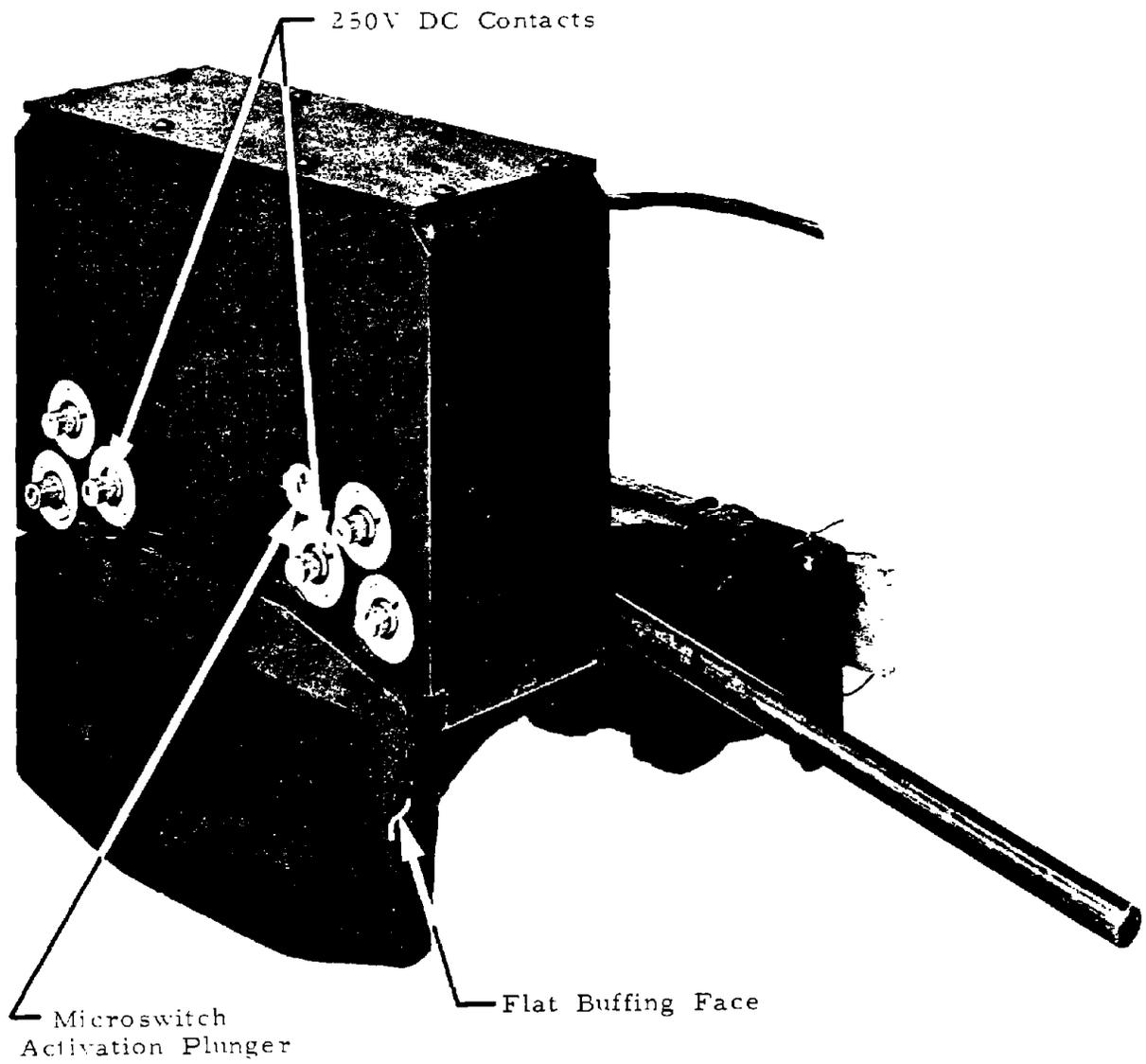
3.1.4 Coupler Contact System

As previously indicated, the Ohio Brass Form 8A coupler, because of its rigidity when coupled, provides an ideal base to which a contact system may be added. In order to ensure electrical continuity, there must be a minimum of movement between the coupler faces both along the axis of the train as well as parallel to the faces of the coupler. Referring to Figures 3-7 and 3-8, it is seen that the coupler has six contacts. The two innermost contacts transmit the 250V DC power, while the remaining four are concerned with the 12V DC logic system. Each of the contacts on the female side has a 3/4 inch diameter face. In the final stages of coupling, these contacts come face to face with the fixed contacts on the male side and as engagement proceeds the female side contacts rotate as they retreat. A detail of this moving contact is shown in Figure 3-9. As can be seen from the figure, the contact element slides within a threaded insert and is forced to rotate as the roll pin in the contact follows the helical track that is cut into the insert. This rotating action helps to clean the contact faces each time a coupling or uncoupling is completed. The spring located within this moving contact assembly serves two purposes. When the coupler is engaged, the spring is compressed and therefore provides a great deal of force to keep the contacts engaged. Secondly, an uncoupling occurs, the spring forces the contact element back into its initial position, preparing it for the next coupling event. A rod wiper has been designed into the forward portion of the assembly so as to clean the contact element as it moves back into the insert, thereby protecting the internal parts from damage due to foreign material. Electrical power or signal current, depending upon the particular contact in question, is carried from the moving element to its internal terminal by means of braided conductors.

The six contacts on the male side are flush with a plastic insulating face and have a contact face with a spherical radius. This design allows for a nearly point contact, which, when wiped by the rotating contact, will be cleaned. These contacts are mounted within the male housing.

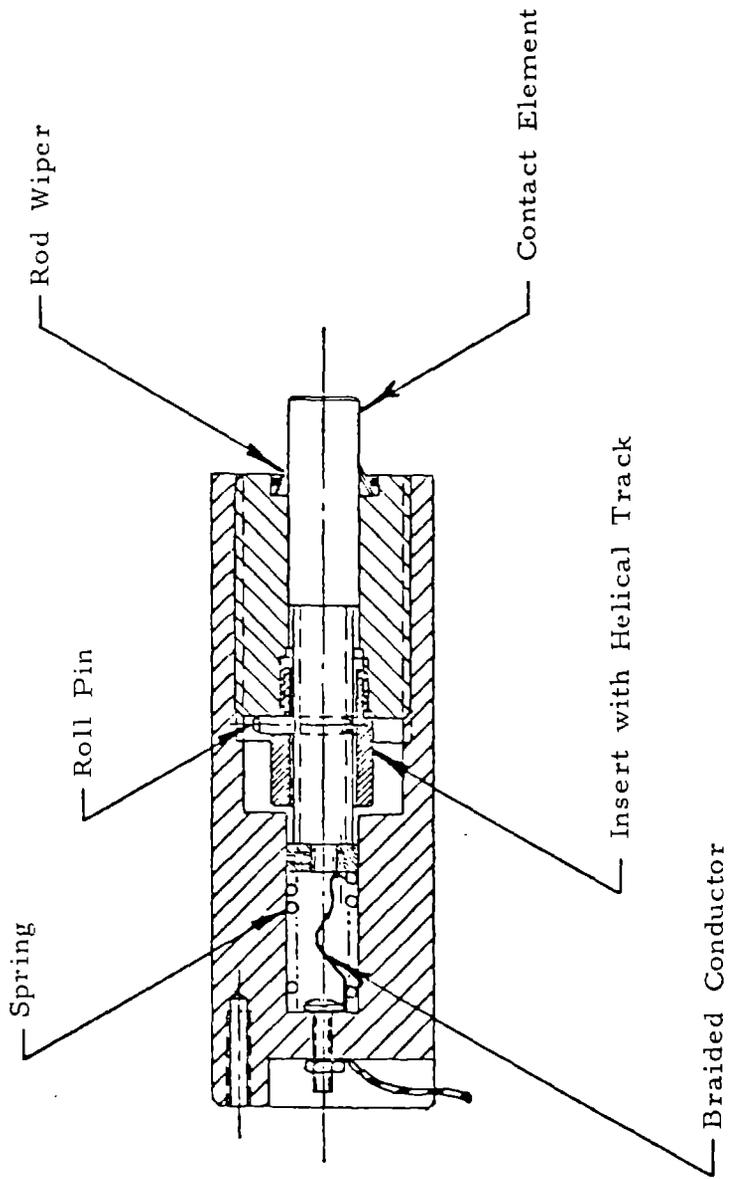


Male Coupler
Figure 3-7



Female Coupler

Figure 3-8



Moving Contact

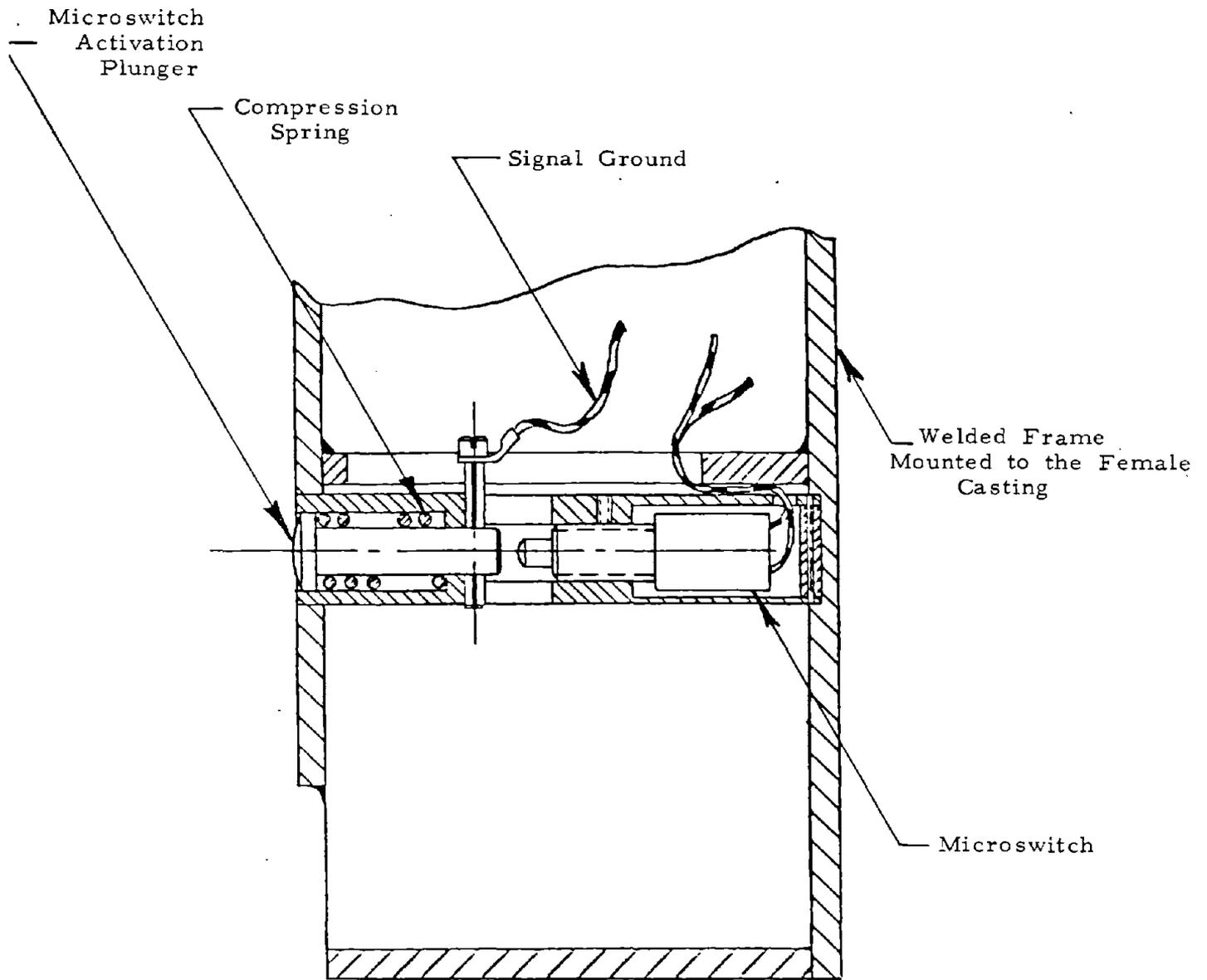
Figure 3-9

When the female coupler is not engaged, the power and signal contacts are decoupled from their respective lines by opening two relays, items 6 and 41 in Figure 3-2. These relays are pulled in by a microswitch arrangement mounted in the female half (see Figure 3-10). When the coupler halves are within 0.44 inch of each other, a fixed plunger on the male coupler (see Figure 3-7) will begin to move the microswitch activation plunger (see Figure 3-8) against the microswitch which will activate the relays thus completing the circuit. Note that the motion of the activation plunger is resisted by a large compression spring, which requires 45 lbs force to close the switch. This will prevent accidental activation, avoiding shock hazard. The microswitch assembly has been located with respect to the power contacts such that upon coupling the power contacts will be touching before the microswitch is activated. This is true even under the worst case situation, which is created when the coupler halves are offset by 7 1/2 inches horizontally and 2 inches vertically.

Provision has been made for the microswitch plunger and actuator to carry signal ground. This amounts to using it as a seventh contact should the electrical environment in the mine prove so noisy as to require a separate, clean ground for the logic signals.

As mentioned, the microswitch will pull in two relays. The first relay will close the two power contacts. This relay, which is a mercury displacement type, was chosen to enable switching of 250V DC, 15 ampere current within the physical size constraints of the welded housing. It is this constraint which precludes the use of a limit switch which, for this application, is too large.

Because these relays are currently used in Joy mining machinery, we expect they work satisfactorily. However, some underground testing will be required to prove proper mineworthiness. A problem could exist if the shock and vibration are sufficient to cause movement of the mercury in such a manner as to inadvertently open or close the circuit.



Microswitch Arrangement

Figure 3-10

The second relay will connect the four signal contacts to the control circuits. In an open state, it will prevent a short circuit of those contacts when the coupler halves are disengaged.

Due to the limited travel of the microswitch and the sliding contacts, the coupler castings will need a maintenance program to ensure that the faces of the couplings are never separated by more than 0.44 inch. If considerable wear has taken place, the couplers will show a gap at the bottom flanges under pull, and a program of rebuilding the couplers to their original specification is available from Ohio Brass. This rebuilding is accomplished by adding welding and wear plates at the suggested places. Under normal mine operating conditions, it is expected that a minimum of 5 years' service will be achieved before the coupler will need this maintenance.

3.2 Intermediate Coupler

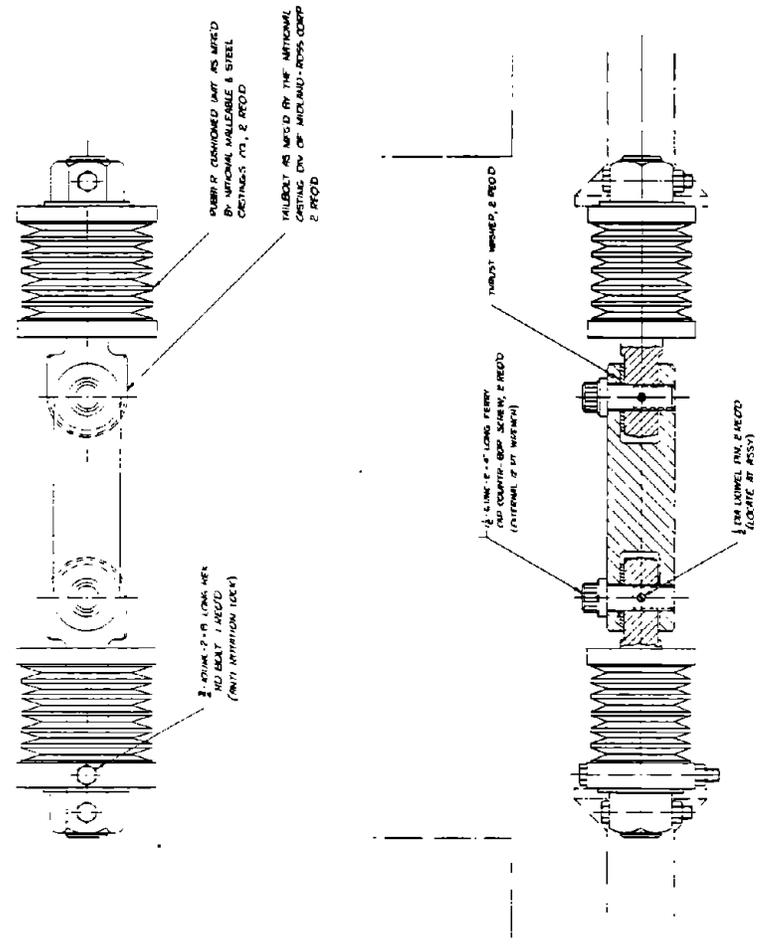
The intermediate coupler consists of a mechanical link coupler between cars and junction box, mounted on the car end nearest the locomotive, containing a limit switch and a cable connector.

3.2.1 Intermediate Mechanical Coupler

The design of the intermediate coupling has been kept simple and is of such a nature as to make it difficult, if not impossible, to dismantle inside a mine. The design, as depicted in Figure 3-11, consists of two sets of rubber cushion draft gear, two tailbolts with 1-1/2 inch bolts which require a 12 point external wrench to loosen, and which have been pinned to the tailbolts at assembly. One end of the assembly has been fitted with a 3/4 inch bolt which will act as an antirotation lock. This lock will keep the coupling in the proper orientation as the cars pass through the rotary tipple.

REV	DATE	BY	CHKD	DESCRIPTION
1				INTERMEDIATE COUPLER
2				REVISION
3				REVISION
4				REVISION
5				REVISION
6				REVISION
7				REVISION
8				REVISION
9				REVISION
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Figure 3-11



3.2.2 Junction Box-Intermediate Coupling

A junction box of the type shown in Figure 3-12 is to be used at each intermediate coupling in order to safely make or break the electrical circuit. The box is equipped with large mounting feet for easy attachment to the coal car nearest the locomotive. A Westinghouse limit switch has been placed so as to break the 250V DC power circuit upon removal of the cover, while not being overly accessible to accidental actuation by the serviceman. This eliminates the shock hazard during separation at intermediate cars for servicing. One end of the cable enters through the side of the box and the other end enters through the cover. The cover is equipped with an eye bolt so that it can be conveniently hung on a hook on the car near the junction box. This allows a man to have both hands free to connect or disconnect the Bendix QWLD connector. This rugged connector has recessed contacts which will stay clean during normal servicing operations, when the housing is open. The Bendix QWLD series of electrical connectors has been designed to meet the most rugged environmental conditions found in the power and control circuits of ground radar and missile launching equipment, as well as oil field, mining and other heavy duty industrial applications.

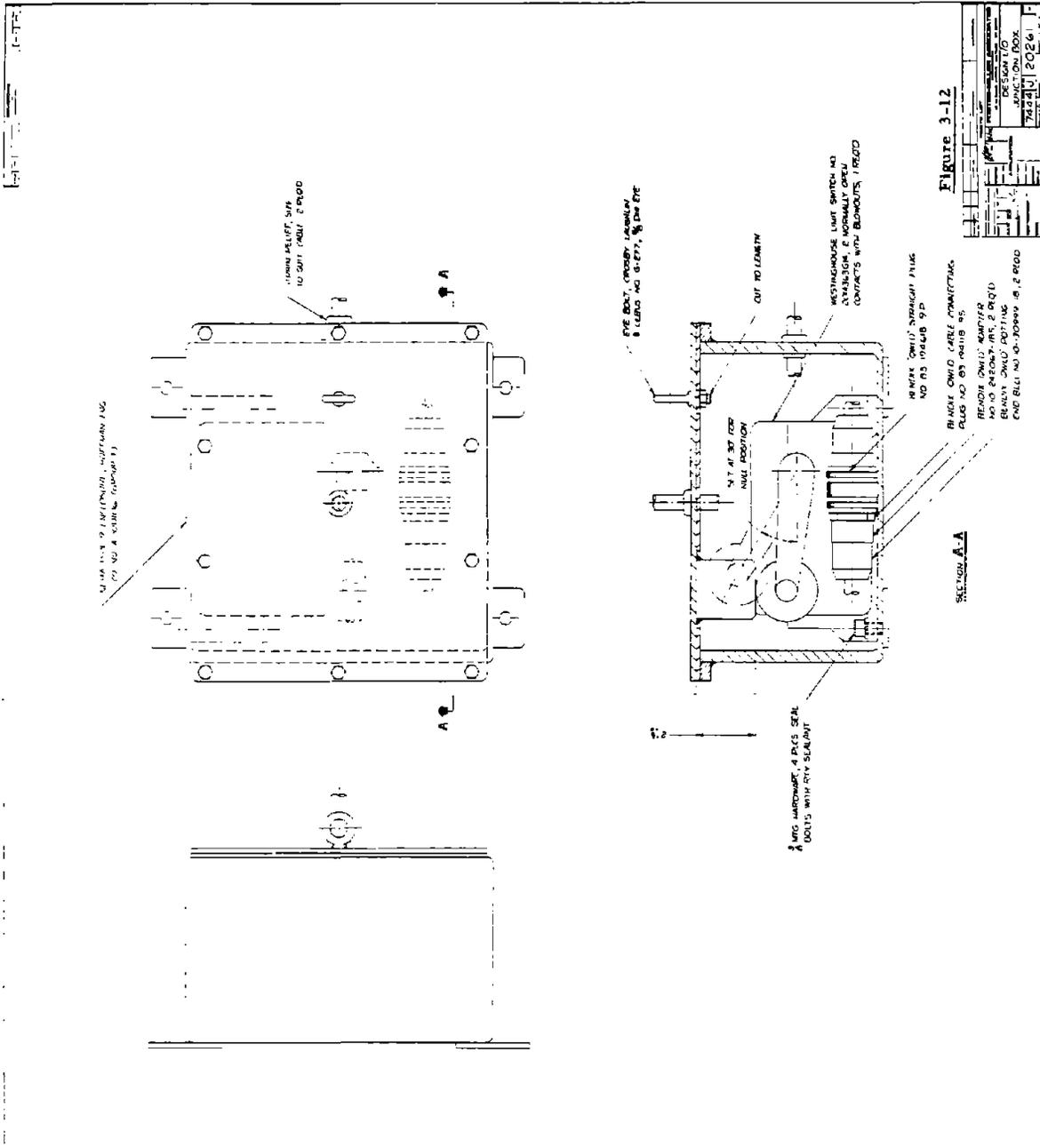


Figure 3-12

DESIGN NO.	7432811
REV.	1
DATE	2026
SECTION	SECTION BOX
PROJECT	7432811

B

A

4. Coupler Logic and Control System

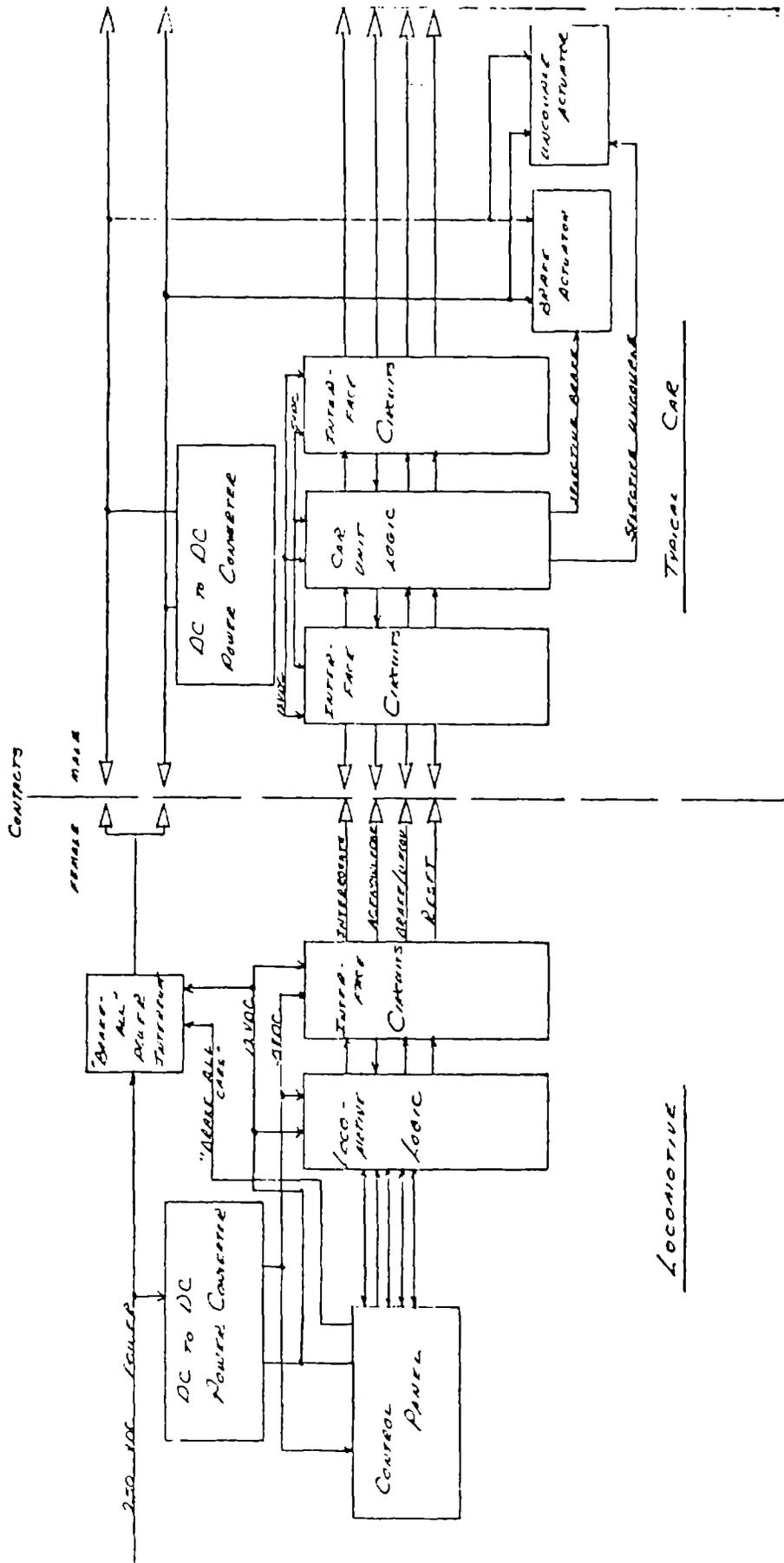
4.1 System Description

The coupler logic and control system consists of a locomotive control panel, a locomotive electronics module, and a mine car electronics module for each unit of intermediately coupled cars. All operator-train interactions are performed from the locomotive control panel. The locomotive electronics are electrically connected to the control panel, locomotive coupler (female), and the 250V DC locomotive power. The mine car electronics are connected to male and female couplers, respectively, located at the beginning and end of each car unit.

Signals and power are transmitted from locomotive to car units and between car units by means of six contacts mounted on each coupler. Four contacts are used for signal transmission, and two are used for the plus side of the 250V DC locomotive power. Signal ground between cars and locomotive is maintained by the rod and plunger of the coupler microswitch while the actuator power returns through the track as well as the coupler casting.

A diagram of the overall system is shown in Figure 4-1. The system logic is implemented using the very reliable 7400 N series Transistor-Transistor Logic Modules (TTL, commercial temperature range, 0° - 70° C).

The interface circuits, which consist of contact line drivers and receivers, are designed such that each receiver presents only 100 ohms impedance to its driver. Inasmuch as the driver operates at 12V, the signal through each contact is approximately 120 ma. The receiver design is such that it is immune to induced noise current of up to about 4 ma, or voltages up to 400 mv. Should the induced line noise exceed this value, simple frequency selective filter sections can be added to each receiver when the noise spectrum is determined.



Coupler Logic and Control System Diagram

Figure 4-1

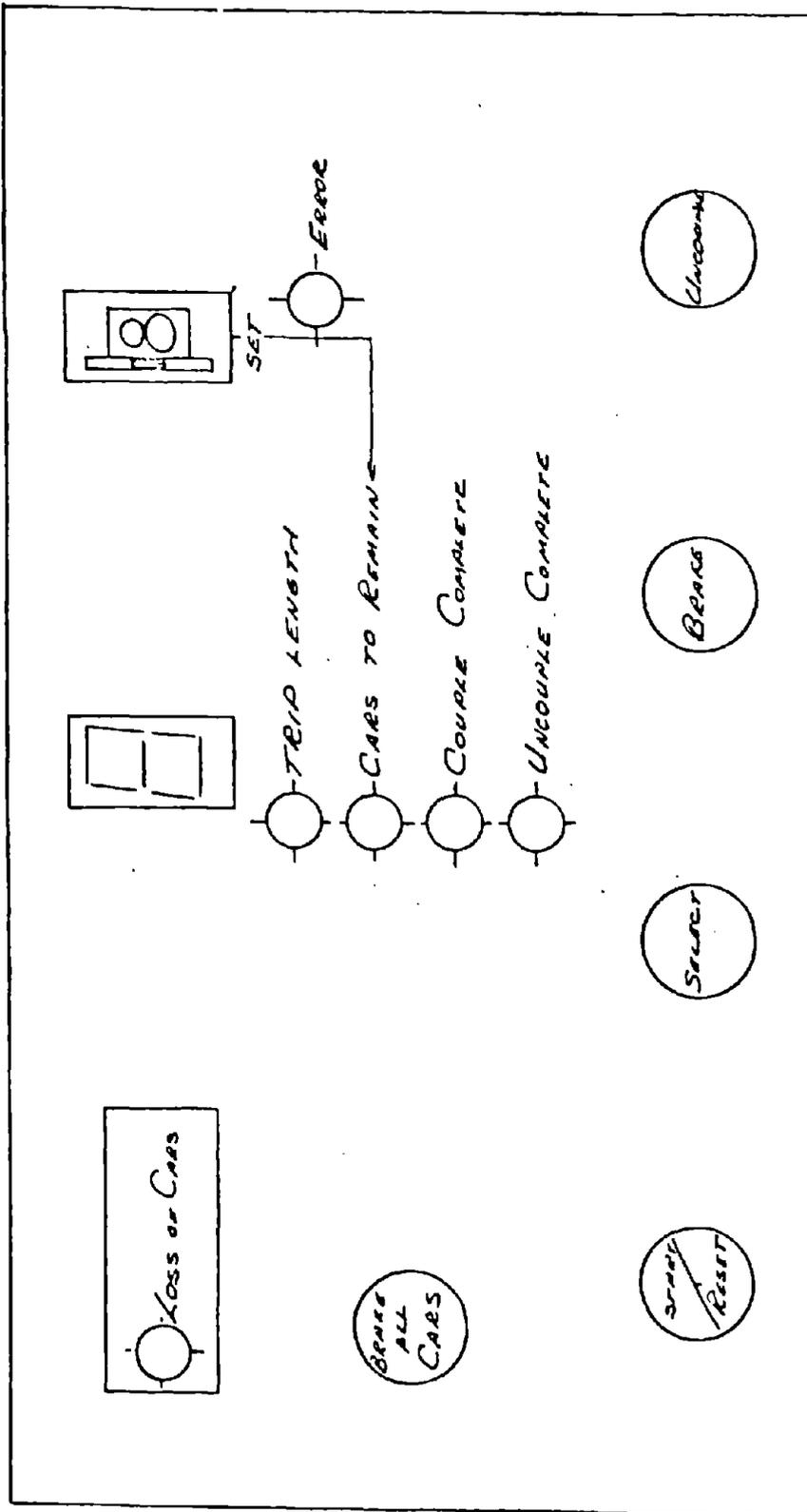
High power DC switching for brakes and coupler actuators is accomplished using Dura-kool Mercury Displacement Relays, similar to those used by Joy Manufacturing for power switching on their continuous miners. These are fully armored, steel encapsulated types, and switch up to 15 amps of 250 volts DC in a minimum of space and at minimum cost. They suffer from the disadvantage that their circuit can be opened by tipping them upside-down, but rotary dump operation of a train will not be adversely affected. The brakes on cars to the rear of the car in the dump will be applied, but only when this car is upside-down.

It is envisioned that the locomotive and car unit electronics be enclosed in durable, oil tight metal boxes and appropriate places be found for their mounting. The locomotive electronics and control panel may share the same enclosure, but due to the limited space accessible to the operator's vision, the control panel will probably have its own enclosure.

4.2 Control Panel Design

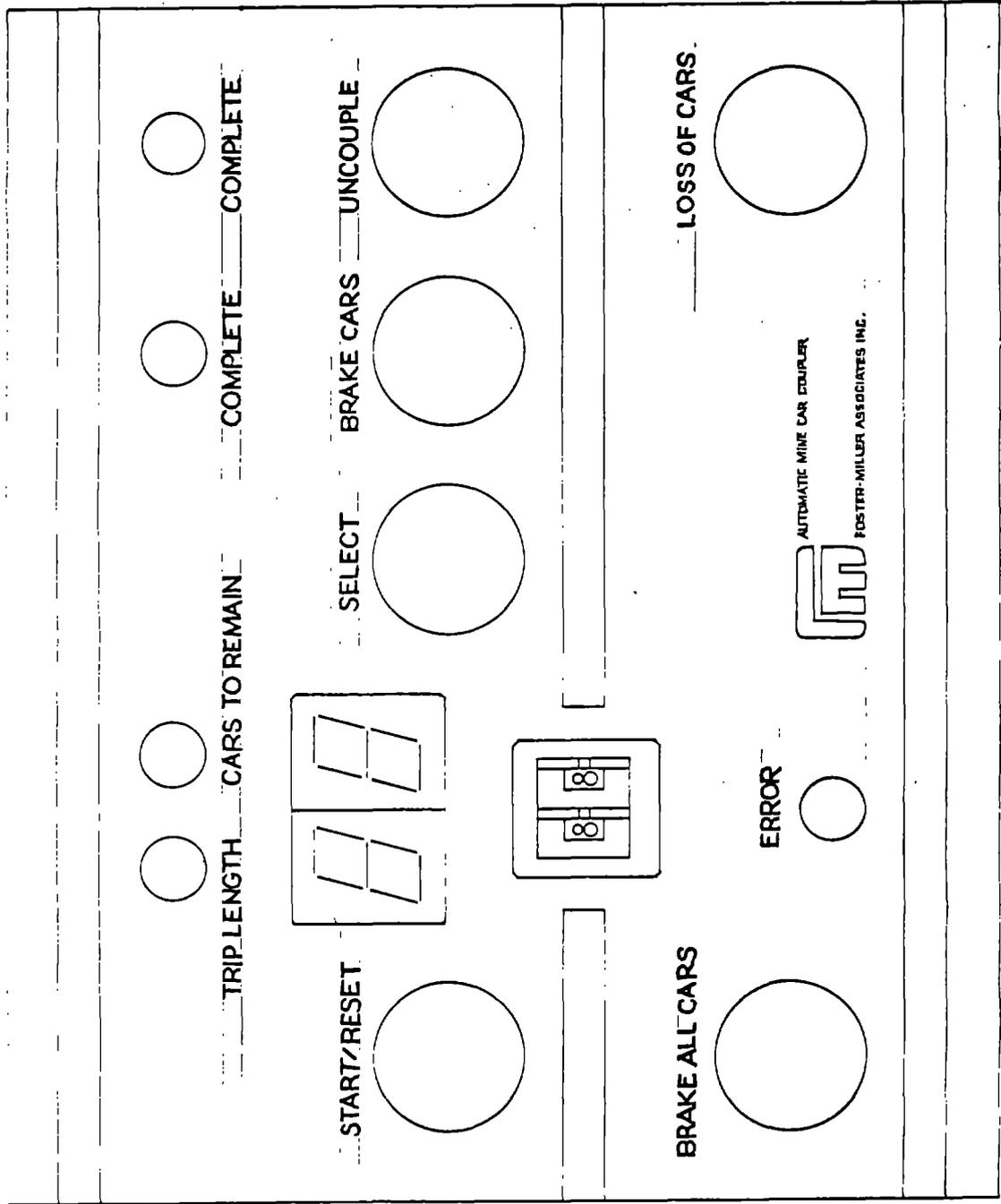
The control panel used in the "breadboarding" of the coupler logic and control system is shown in Figure 4-2. After the system was fully constructed, debugged, and operated, it became apparent that minor changes would improve the panel. (See Figure 4-3.)

In order to simplify the panel, the couple complete indicator was eliminated. The information that a car coupling operation was successful is now obtained by reading an increase in the car count display. The addition of a lighted "Uncouple" push-button indicating that the Trombetta solenoid is energized has eliminated the necessity of the operator being aware of the 5 second solenoid operation period. The addition of a lighted, "Brake All Cars", push button will remind the operator that he has pushed this button and the brakes of all the cars are engaged. The car count display and select switch have been changed from one digit to two digits. This allows the panel to operate a train of more than nine car units.



Breadboard Control Panel

Figure 4-2



Prototype Control Panel

Figure 4-3

A

B

The arrangement of panel components has also been changed from that shown in Figure 4-2. The push buttons are arranged in a horizontal row located mid-way down the panel. The row is arranged in a left-to-right sequence following the operating procedure of the panel. All indicators except "Error" have been located directly above the switch or display that they work with. The error indicator is located below the select switch. The car count display and select switch have been located respectively above and below the horizontal row at places that maintain the left-to-right operating sequence.

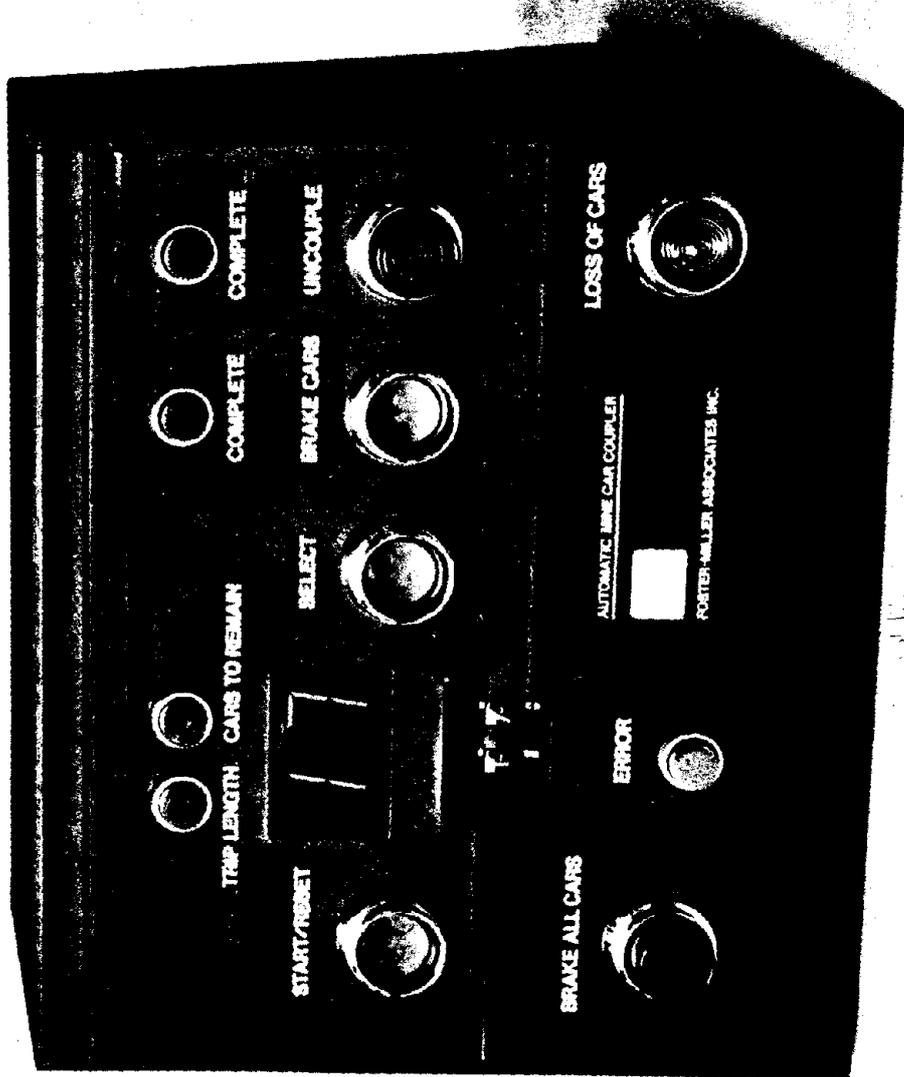
The "Brake All Cars" push button and the "Loss of Cars" indicator do not work with the other switches and indicators and have been located in bottom corners. The "Loss of Cars" indicator will work with an audible alarm. The type of alarm used in small, private aircraft to alert the pilot to the status of the landing gear will be ideal for this application. The "Brake All Cars" push button switch has been located in a very accessible position of the panel.

All components of the panel except the car count display are of the heavy-duty, oil tight, industrial type. Field service panels will have a fine steel mesh in front of the car count display for protection. Horizontal barrier bars and a recessed panel are features designed to give the panel durability. (See Figure 4-4.)

4.3 Control Panel Operation

The control panel of Figure 4-3 has the following indicators and switches:

- (1) Car Count Display - This is a two digit display indicating either the number of car units connected to the locomotive or the number of car units selected to remain after an uncoupling operation.



Control Panel

Figure 4-4

- (2) Trip Length Indicator - This indicates that the car count display is displaying the number of car units connected to the locomotive.
- (3) Cars to Remain Indicator - This indicates that the car count display is displaying the number of cars selected to remain after an uncoupling operation.
- (4) Start/Reset Switch - Pressing this switch commands the system into the monitor mode. The car count display will show the number of car units connected to the locomotive, and the trip length indicator will be activated. The switch is used to initially start the system after power has been applied and to reset the system to the monitor mode at any time during the uncouple mode.
- (5) Digital Switch - This is a two digit, thumb-wheel switch and allows the operator to select the number of car units desired to remain after an uncoupling operation.
- (6) Select Switch - Pressing this switch operates the system in the uncouple mode. The car count display will show the number of car units selected to remain after an uncouple operation and the cars to remain indicator will be on.
- (7) Error Indicator - This indicates to the operator that the number of car units selected to remain after an uncouple operation is greater than the number of car units connected to the locomotive, and that the system is automatically returning to the monitor mode. The indicator is on for four seconds.

- (8) Brake Cars Switch - The pressing of this switch has no effect unless the Select Switch has been pushed. This button is used to selectively engage the brakes of all cars of a train that are about to be uncoupled.
- (9) (Brake Cars) Complete Indicator - This indicates that the system is in an uncouple mode and the brake cars switch has been pushed.
- (10) Uncouple Switch - After the select and brake car switches have been pushed, the pressing of this switch will activate the Trombetta solenoid on the last car unit of the units desired to remain after an uncoupling operation. The solenoid will be energized for 5 seconds and an indication of this will be the lighted push button of this switch. The solenoid will be activated only once after pushing the button. In order to reactivate, the system must be returned to the monitor mode and the select and brake cars buttons must be pushed again.
- (11) (Uncouple) Complete Indicator - This indicates that an uncouple operation has been successful. It is displayed for 5 seconds and is activated as the system resets itself into the monitor mode.
- (12) Brake All Cars Switch - At any time, the operator may push this button and engage the brakes of all the cars. As an indication of this status, the button will be lighted. The brakes are disengaged by pushing the Start/Reset button.

- (13) Loss of Cars Indicator - If an unexpected loss of cars occurs while in the monitor mode, this indicator and an audible alarm are turned on. Pressing the reset button will turn off this indicator and the audible alarm.

- (14) Electric Light Test Switch - This switch is located on the side of the panel and pushing the switch in the down position causes all indicator lights and all character segments of the car count display to be lit.

Operation of the panel and system starts with the operator turning power on to the system. The mode and status of the system will be random, and it is now required that the operator push the Start/Reset switch. This action puts the system into the monitor mode and the Car Count Display will show the number of car units connected to the locomotive. The Trip Length indicator is on to indicate to the operator that the system is in the monitor mode and that the number on the Car Count Display is the trip length. If an unexpected loss of cars should occur, the Loss of Cars indicator and the audible alarm are activated. A loss of cars will also cause the Car Count Display to show the new trip length. The operator knows how many cars he has lost. The Loss of Cars indicator and audible alarm can be turned off by pressing the Start/Reset switch. The system continues in the monitor mode and any further loss of cars will cause the visual and audible indications to be given.

If at any time the operator desires to couple more car units to the train, the train is backed into the units. Since these units have no power connected to their coupler electronics, car brakes will be engaged. The operator will know if the coupling action is successful by noticing that the Car Count Display has changed to the new trip length. Each new car unit controller will automatically reset its electronics and remove the brakes as power is applied.

Uncoupling is accomplished by first setting the digital thumbwheel to the number of car units desired to remain. The Select switch is then pressed, and this changes the system from the monitor mode to the uncouple mode. The Car Count Display also changes to the number of cars desired to remain, and the Cars to Remain indicator is turned on to remind the operator of the new significance of the Car Count Display. If the number of cars desired to remain after uncoupling had been greater than the trip length number, the system would not have changed to the uncouple mode upon pressing the select button and an Error indication would have been given.

Pressing of the Select push button allows the uncouple operation to continue. The Brake Cars button is pushed and the brakes on all the cars that are to be uncoupled are engaged. To remind the operator that this operation has been accomplished, the (Brake Cars) Complete indicator is turned on. The operator will now buff the train against the braked cars and press the Uncouple push button. This action will energize the Trombetta solenoid on the coupler of the last car unit desired to remain. The solenoid will be energized for 5 seconds, and to remind the operator of this, the push button light will be on for the same duration. It is during this time period that the operator must "inch" the locomotive away from the uncoupled cars. The operator can now determine the success of the uncoupling operation by pressing the Reset button and observing the Car Count Display showing the trip length to be the desired length, and observing the (Uncouple) Complete indicator being on for 5 sec.

If the operation was not successful, the operator must go through the same sequence of pushing the Select push button, pushing the Brake Cars push button, buffing the train, pushing the Uncouple push button and inching the train forward away from the uncoupled car units.

At any time, the operator may engage the brakes on all the cars by pushing the Brake All Cars button. The push button will be lighted and the brakes may be disengaged by pushing the Start/Reset push button.

The system has been designed to by-pass all erroneous or inappropriate control panel operations. Selective Brake and Uncouple buttons have no effect unless the Select sequence has been executed. The thumbwheel switch has effect only during Select. Reset/Start, Select and Brake All Cars are always effective.

4.4 Electrical Design

The flow diagram of the coupler logic and control system are shown in Figure 4-5. The "monitor" mode of the system operations where the number of car units of the train are constantly being counted is shown on the right. Figure 4-6 is an electrical schematic of the locomotive logic, and Figure 4-7 is one of the car unit logic. The numbers within the device outline identify the particular dual in-line package that contains the logical elements. Since some packages contain a set of logical elements, the same package number may be used more than once. The package pins are identified by the numbers located next to the element connections.

Operation begins with the locomotive operator turning power on to the system. Since the mode and status of the system logic is random, it is now required that the operator push the Start/Reset switch. This button connects to a set-reset, flip-flop package number 53 which is used to eliminate the switch contact bounce. The reset signal now proceeds to reset all logic in the locomotive and car units via the reset contacts of each coupler. The system clock package 56 is inhibited by a 122.5 msec pulse which was triggered by the reset pulse. After the 122.5 msec delay, generation of three interrogation pulses proceeds by the clocking of the divider of package 46. The three interrogation pulses are sent to the first car unit and are not relayed to the second car unit due to the acknowledge gate being closed. The acknowledge gate (package 40, pins 1, 2 and 3 of the car logic) of the first car unit, and all other cars had been placed in the nonrelaying or closed position by the reset pulse. The three interrogation pulses are received by the first

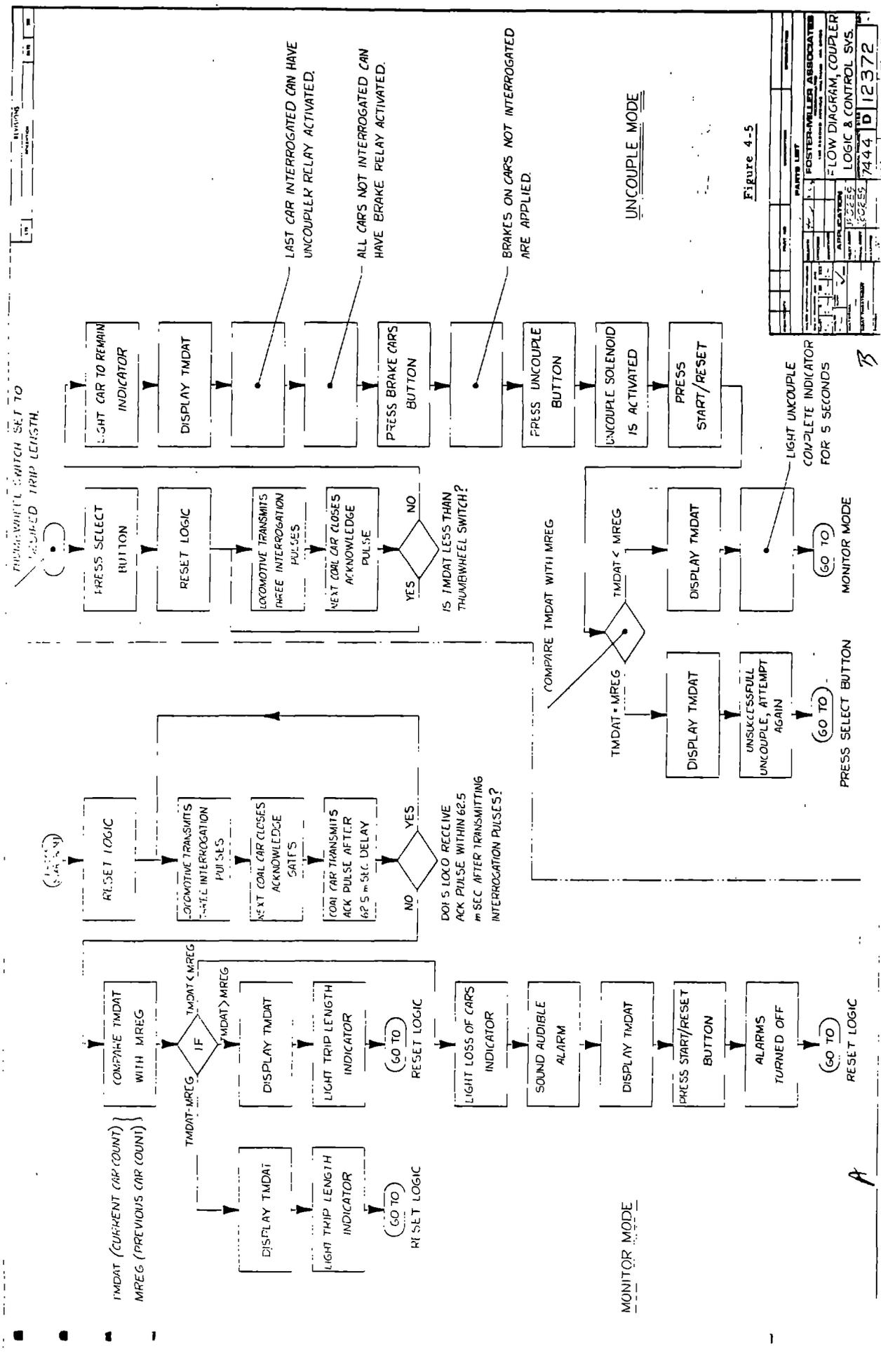


Figure 4-5

PARTS LIST	
FOSTER-MILLER ASSOCIATES	
LOW DIAGRAM, COUPLER	
LOGIC & CONTROL SYS	
7444	D 12372

3

A

car unit logic and are counted by the counter of package 31. The counter and the gate of package 50 send a pulse out to the D flip-flop of package 30. This flip-flop provides the acknowledge gate with a gating signal and any further interrogation pulses are relayed to the second car unit, and are not clocked into counter "31" of this car unit.

The D flip-flop of package 30 also gates the two one-shots of package 20. These one-shots provide a delay of 62.5 msec and emit a 1.3 msec acknowledge pulse. The acknowledge pulse which occurs 62.5 msec after the last interrogation pulse is sent to the locomotive logic. The counter, package 46, and the multiplexer, package 36, provide a gating pulse for the acknowledge pulse if it arrives between 62.5 msec and 125 msec after the last interrogation pulse. The duration of this gating signal is sufficient to allow the acknowledged pulse of a recently interrogated car to be gated to the TMDAT counter, package 27, of the locomotive and to reset the counter, 46, to begin a new cycle of interrogation pulses. The purpose of providing a definite time for allowing acknowledge pulses to be counted by the TMDAT counter minimizes false counts.

The interrogation cycle is repeated until there are no car units to transmit acknowledge pulses. At this time the counter of package 46 is not reset and the multiplexer of package 36 causes the D flip-flop of package 34 to be clocked and changes state. The D flip-flop of package 34 now allows the three outputs of the digital comparator of package 17 to be gated. The digital comparator constantly compares the TMDAT count (present car count) with the MREG count of counter 16. The MREG counter obtains its digital number from the TMDAT counter during a previous interrogation count. Therefore, at this time when all the cars connected to the locomotive have been counted, the system is comparing this count with the previous count to determine if there has been an addition or loss of cars. The three outputs of the comparator signify a loss of cars, a coupling of cars and no change in the number of cars connected to the locomotive. The three outputs are gated by the gates of package 38. Only one output will be active.

If there has been no change in the number of cars, the "no change" output will be active. The gating of this output to the D flip-flop of package 11 will cause the "Trip Length" indicator to be illuminated. The gating of this output is not connected to the latch of package 14 and hence the number displayed on the "Car Count Display" will not change.

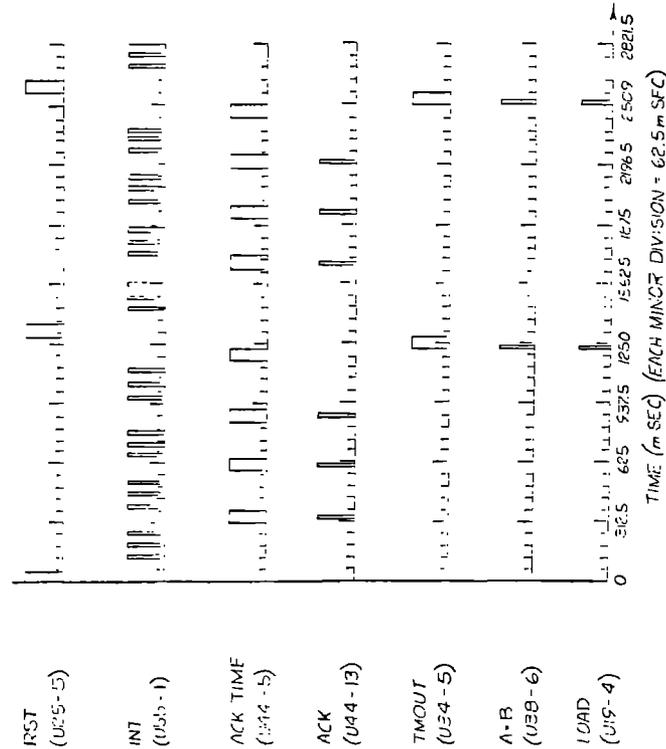
If the count of the TMDAT counter is greater than the count of the MREG, a different output of the digital comparator will be gated. This output would have been gated to illuminate the "Couple Complete" indicator by any of the 5 sec one-shot of package 58. (Note that the "Couple Complete" indicator has been eliminated from the final version of the control panel.) The one-shot would have illuminated the indicator for 5 sec. This output is also connected to the latch of package 14 and, hence, the count of the "Car Count Display" will change to the new value. The "Trip Length" indicator will always be on from previous interrogation counts.

If the count of the TMDAT counter is less than the MREG count, the third output of the digital comparator will be gated. This output is connected to the D flip-flop of package 34 and the "Loss of Cars" indicator will be illuminated. The output is also connected to the latch of package 14 and the count of the "Car Count Display" will change to the new value. All outputs of the digital counter are connected to the reset system and therefore, after the completion of one set of interrogation counts, all logic is reset and a new cycle is begun. Figure 4-8 shows the time relationship of the interrogation and acknowledge pulses for a locomotive connected to four cars.

Uncoupling of selected units is accomplished by setting the digital thumbwheel switch to the number of car units desired to remain and pressing the Select switch. The Select switch is connected to the set-reset, flip-flop of package 53. The flip-flop is connected to the D flip-flop of package 52. The D flip-flop stores the select command and provides a reset pulse to the locomotive and car unit logic. This D flip-flop is reset by pushing the Start/Reset switch.

SIGNAL (TEST POINT)

SIGNAL DESCRIPTION



A 60m SEC PULSE INITIATED BY THE START/RESET SWITCH OR AUTOMATICALLY AT THE START OF A NEW COUNTING PERIOD.

A GROUP OF THREE 1.5m SEC PULSES THAT INTERROGATE THE LOGIC OF SUCCESSIVELY COUPLED COAL CARS.

A PULSE THAT GATES ACKNOWLEDGE PULSES ALLOWING THESE PULSES TO BE COUNTED BY THE TMDAT COUNTER.

A PULSE GENERATED BY EACH COAL CAR AFTER RECEIVING A GROUP OF INTERROGATED PULSES.

A PULSE THAT OCCURS IF ACKNOWLEDGE PULSES ARE NOT RECEIVED 62.5m SEC AFTER A GROUP OF INTERROGATION PULSES.

A PULSE GENERATED AT THE END OF A COUNTING PERIOD WHEN TMDAT = MREG.

A PULSE THAT LOADS THE TMDAT INTO THE DIGITAL DISPLAY.

NOTE:
1. TIMING DIAGRAM: VARIOUS LOCOMOTIVE LOGIC SIGNALS, TRIP CONSISTS OF THREE CAR UNITS.

Figure 4-8

PARTS LIST	
POSTER-WILLER ASSOCIATED	
TIMING DIAGRAM	
COAL CAR COUPLER	
74 44	D 12373

A

8

The D flip-flop has its output connected to gates that redirect the returning acknowledge pulse to the SLCDAT counter of package 93. The normal interchange of interrogate and acknowledge pulses proceeds until the count of the SLCDAT counter equals the setting of the thumbwheel switch. This occurs due to a second digital comparator (package 23) which monitors the count of the SLCDAT counter and the setting of the thumbwheel switch. When the counts are equal, the clock is inhibited by the gate of package 57, the brake switch becomes operable due to gate 42, and the SLCDAT count is displayed on the Car Count Display.

The effect of interrogating a given number of car units is that the last car interrogated is susceptible to uncouple commands and all uninterrogated cars are susceptible to a selective brake command. The pushing of the brake switch clocks the D flip-flop connector to it, and the signal on all brake contacts is now active. This brake signal is gated in each car unit by the gate 40 which will not allow the brake signal to energize the brake relay unless the cars have not been interrogated. An interrogated car will not have brakes applied, while an uninterrogated car will be braked. An interrogated car will have its D flip-flop, package 30, output pins 9, 8 set. Once the brake switch has been pushed, the pushing of the uncouple switch will now activate a 2 KHz oscillator which energizes the brake/uncouple contacts on all cars. This signal is gated by the D flip-flop of package 30, output pin 5, which is set only on the last car interrogated. The uncouple solenoid, on this coupler alone, is energized for 5 seconds due to the one-shot of package 10, output pins 5, 12. Uncoupling is effected by braking the cars destined to be uncoupled and buffing the train against these cars. The Uncouple switch is then pushed and while the solenoid is energized, the train is moved forward, parting the cars.

4.5 Power Transmission System

The basic Power Transmission System for the coupler takes 250V DC power from the locomotive and transmits it, via two contacts on each coupler half to each car unit of the train. The return path is through the rails.

Power for the logic and interface circuits is derived from DC to DC converters located at each Logic Unit. Such converters are not, at present, available off-the-shelf for 250V DC input. They can be designed on special order and will cost in the neighborhood of \$300-\$500 in quantities of 100. They are conservatively estimated to be 50% efficient.

Shock and Short-Circuit hazard is eliminated through the use of a limit switch, mounted on the female half of each coupler, which, when the coupler is not engaged, opens the signal and power lines through relays. (See Figure 4-7.)

Power requirements for each element of the coupler system are shown in Table 4-1.

An analysis of the car unit requirements gives the contact ratings necessary for the various power interrupt relays and for the coupler contacts themselves.

Each contact must be rated to switch the worst-case load -- the running load of the whole train of car units -- since uncoupling could occur at the locomotive end of the train, and any car unit could be at this end. No limit switch relay or coupler contact need switch the uncoupling load because the uncouple actuator is on the female coupler half which remains with the train.

Even though uncoupling (and hence contact opening) occurs only when the brake power to the uncoupled portion of the train is off, coupling (hence, contact closure) causes immediate application of the brake power, and it must be assumed that this load is switched by the contacts.

Thus, for a train of eight car units, the worst-case running load is

$$8 \text{ units} \cdot (450 \text{ watts/unit}) = 3600 \text{ watts,}$$

or

$$\text{amps at 250 volts} = 14.40 \text{ amps.}$$

Table 4-1

Coupler System Power Requirements

Locomotive

Logic	5V	3.5 amp	
Interface	12V	2.0 amp	
"Brake All" Relay	12V	0.5 amp	
Total Converted Power	5V	3.5 amp	17.5 Watts
	12V	2.5 amp	<u>30.0 Watts</u>
			47.5 Watts
Allowance for 50% Conversion Efficiency			<u>47.5 Watts</u>
Total 250 Volt Power Required:			95 Watts

Car Unit

Converted Power:			
Logic	5V	2.0 amp	
Relay	12V	0.1 amp	
Brake Driver	12V	0.6 amp	
Limit Switch	12V	0.6 amp	
Total Converted Power	5V	2.0 amp	10 Watts
	12V	2.5 amp	<u>30 Watts</u>
			40 Watts
Allowance for 50% Conversion Efficiency			<u>40 Watts</u>
Total Converted Power			80 Watts

Direct 250V DC Power:		
Brakes (continuous)		360 Watts
Uncoupler (5 sec intermittent)		625 Watts
Lights		<u>10 Watts</u>
Total Direct Power - Running		370 Watts
- Uncoupling		995 Watts

Total 250 Volt Power Required:		
Per Four Car Unit, Running		450 Watts
Per Four Car Unit, Uncoupling		1075 Watts

The coupler contacts divide this load between two contact elements, and the "Brake All" and Limit Switch relays are double-pole; therefore, the worst-case contact rating is 7.20 amps at 250 volts. Since each of the two coupler contacts is rated at 15 amps, and each "Brake All" and Limit Switch Relay contacts is rated at 10 amps (Durakool Mercury Displacement Relay, ASX-series) at 250 volts, our specifications are conservative.

4.6 Summary

A breadboard version of the coupler logic and control system described early in the program has been fully constructed and debugged. The breadboard has demonstrated the following required capabilities:

- (a) In the monitor mode, the system constantly counts the number of car units in the train, and signals an alarm should an unexpected loss of cars occur.
- (b) In the uncouple mode, the system provides a means of selectively applying the brakes in the car units destined to be uncoupled, and then uncoupling these units.
- (c) The system provides a means of braking all cars at any time, if the need should arise.

Two improvements in the earlier design of the car logic were made as a result of the tests performed on the contacts system at Ohio Brass. Signal loss through very dirty contacts could have made operation of the logic package in the trailing cars marginal.

In the present system, signals are received and retransmitted by repeaters in each car unit, thereby limiting the voltage drop in any signal to the resistance of only one contact pair. In the prior system, there were no repeaters and signal level was reduced by the voltage drop of the series resistance of the number of contacts between the transmitter and receiver circuits.

The second improvement is that the mechanical acknowledge relay has been replaced by a solid-state 7400 series gate. This substitution has been made practical by the introduction of the repeaters. With the repeaters and the gate, the same logic is used, but at a reduced power level.

5. Testing of the Prototype Coupler

Two series of tests were performed on the test rack at the Ohio Brass Company in Mansfield, Ohio. The test rack (see Figure 5-1) is used by Ohio Brass to check proper coupler operation prior to the shipment of each new set, and is well suited for the purposes of our effort. The mechanical tests followed a test plan which was designed to simulate the different physical alignment situations which would be encountered when coupling and uncoupling a trip in a coal mine. Electrical contact operation was tested by applying liberal quantities of dirt to their faces, and checking the resultant loss of voltage at both the 12V and 250V levels. Further tests were performed to show that the contacts were closed before the microswitch connected them to active circuitry. The reverse operation was demonstrated in the uncoupling sequence.

Logic and control circuit breadboards were thoroughly tested at Foster-Miller Associates, and the results will be discussed in the following subsections.

5.1 The Test Program

Automatic coupling was tested by selecting the appropriate angles on the Ohio Brass test stand to meet the following conditions:

- (a) Straight track
- (b) Straight track meeting curves of at least 70 ft radius. One coupler set at $3^{\circ} 15'$ -- the other at 0° .
- (c) On reverse curves of at least 70 ft radius. One coupler set $3^{\circ} 15'$ to one side of center-line and the other 3° to opposite side of center-line ($6^{\circ} 15'$ total).



Ohio Brass Test Stand

Figure 5-1

- (d) On continuous curves
Both couplers set 3° 15' to one side of center-line.
- (e) Vertical step changes of 2 inches combined with conditions (c) and (d). Coupling under the above-mentioned conditions at speeds of up to 1 MPH (1.47 ft/sec).

5.1.1 Automatic Uncoupling

Uncoupling was initiated by pressing the "Uncouple" button on the operator's control panel and by simultaneously activating the test stand in such a way as to separate the coupler halves. Testing included conditions "a" through "e" as listed under the Automatic Coupling section.

5.1.2 Manual and Any Possible Accidental Uncoupling

Manual uncoupling was tested by exerting an upward force on a 2 ft long pipe which had been slipped over the pin on the release arm. The testing included conditions "a" through "e", as listed under the Automatic Coupling section.

5.1.3 Precoupled Tests

When the coupler halves are in a coupled condition, they must be capable of negotiating curves as described in conditions (a) through (e) under the Automatic Coupling section without uncoupling. The male shank was also rotated through a 180° angle to ensure compliance with rotary dump conditions at the tipple.

5.1.4 Strength Tests

The coupler was tested to withstand the following loads:

Maximum tensile load: Normal working load of 55,000 lbs (80,000 lb pull test).

Maximum compressive load: Normal working load of 55,000 lbs. (It should be noted that parts of the prototype coupler were made from the Ohio Brass Form 8 coupler which is made of a lower strength alloy and was available off-the-shelf.) As noted, this material is not guaranteed to achieve the strength specifications of the Form 8A and these tests were not performed. (The rated tensile load of the Form 8 prototype is 45,000 lbs; typical working load is 25,000 lbs.)

Production couplers intended for mine service would be made to the full strength specifications listed in the test plan.

5.1.5 Electrical Test

To ensure electrical continuity, the contacts were tested under severe environmental conditions. Prior to coupling, they were exposed to a combination of mud and water. This enabled the evaluation of the effectiveness of the contact wiping design and the durability of the contact itself.

5.2 Test Equipment

The primary piece of test equipment was the Ohio Brass coupler test stand, as shown in Figure 5-1. The test stand is a pneumatically operated device capable of simulating controlled coupling at

speeds well in excess of three miles per hour. The stationary, or right side of the stand has adjustment mechanisms built into it that allows vertical height, horizontal offset and angular adjustments in the horizontal plane to be made either separately or in conjunction with one another. The roller mounted table on the left side of the rack moves back and forth along the fixed bed by means of a large pneumatic cylinder. A roller type limit switch is mounted to the fixed bed of the test rack and is actuated by a 4 inch long ramp which is attached to the movable part of the rack. It is located so that the switch operation takes place near the forward end of the rack travel. Thus, the average velocity is obtained for the 4 inches of travel just before coupling takes place, by measuring the time between switch closure and reopening when the roller is passed by the ramp. The time interval was measured with a DuMont 304H oscilloscope which has a high-persistence phosphor.

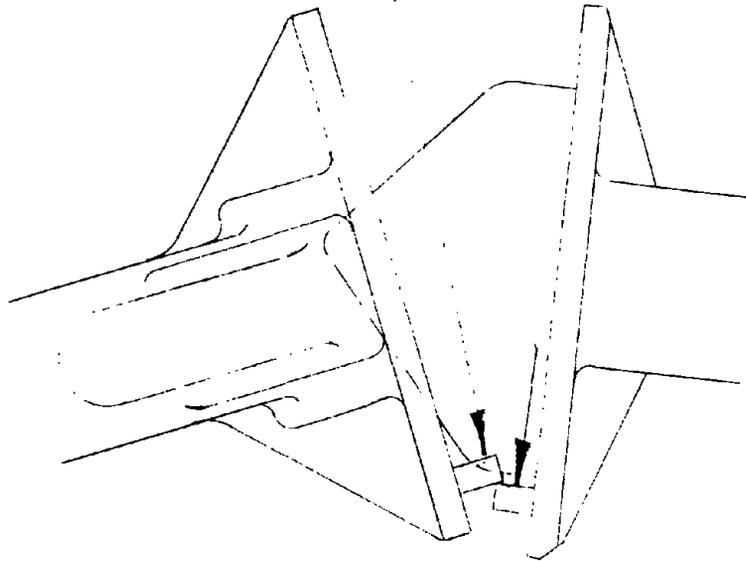
5.3 Preliminary Test

Preliminary testing was conducted at Ohio Brass in accordance with the above plan.

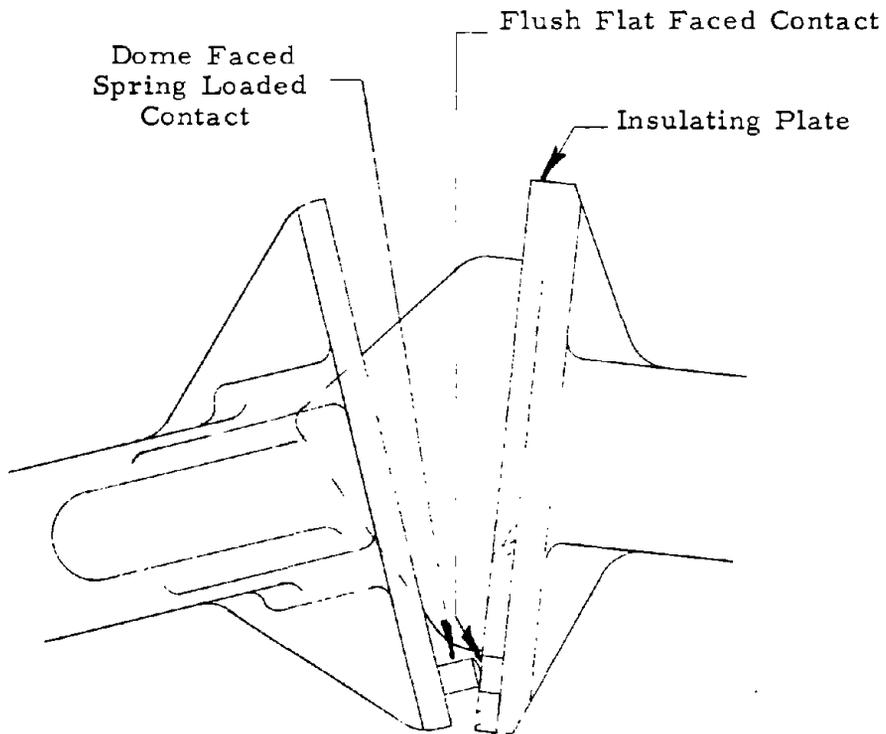
5.3.1 Test Results

During the preliminary test, successful couplings, automatic uncouplings and manual uncouplings were completed for a series of conditions at speeds of up to and including 1.5 MPH. These included straight track, straight track meeting curves of 70 ft radius, continuous curves of 70 ft radius and vertical displacements of 2 inches coupled with all of the above conditions. We were unable to couple on reverse curves of 70 ft radius as well as any condition that involved a horizontal offset. The contacts on both coupler halves projected out from the flange surface and mismatch of the contacts could occur when engaging at acute angles and the contacts would hit side to side as the main coupler halves were sliding face to face in the final stages of alignment (see Figure 5-2). This same condition also caused damage to the microswitch which was

Both Contacts Flat Faced
and Protruding



Possible Mismatch Resulting in Damaged Contacts



Successful Engagement at Any Angle

Contact Design Modification

Figure 5-2

mounted within the welded frame on the female coupler. The solenoid pull was marginal because of the strength of the coupler cam return spring. When this spring was removed, the Trombetta operated much more successfully.

An additional problem was the failure of the Trombetta solenoid after a total of about 300 operations, 114 of which were completed over about a one hour time span.

Electrical testing of the coupler confirmed that the sequencing of the microswitch opening the 250V DC power lines before the contacts separate worked during uncoupling. Oscilloscope measurements showed that a time separation of .1 sec occurs between the two above events. Testing also showed that during coupling, electrical contact is first made before the power is turned on.

Measurements were made of the voltage drops across the contacts at rated current. The drops across clean contacts were found to be less than 1 volt on the 250V DC power contacts, and less than .1 volt across the logic contacts. This is considered very satisfactory. However, a "mud"-like mixture of 30% coal, 30% limestone and 40% water was smeared across the contacts and voltage measurements were taken. The voltage drops were found to be as great as 50% of the applied voltage and not satisfactory.

5.3.2 Conclusions from Preliminary Test

The preliminary testing showed that the following would be needed:

- (a) Relocate the microswitch deep within the electrical compartment of the coupler and mount a separate, heavy switch plunger in such a manner as to preclude the possibility of it damaging the microswitch. This plunger was also designed to carry signal ground current.

- (b) Redesign the male side (fixed) electrical contacts so that they would have a spherical face. The resulting point contact should be less susceptible to interference from dirt.
- (c) Refit the welded frame on the male coupler with a plastic sheet of sufficient thickness such that the newly designed electrical contact would be flush with the surface. This allowed the coupler halves to align themselves from all angles without causing the contacts to hit from side to side.
- (d) Relocate both lead-in cable fittings to the back of the welded frames. This keeps cables out of the way and makes them less susceptible to damage.
- (e) Replace the coupler cam latching spring with one with a lower spring rate.
- (f) The Trombetta solenoid was returned to the manufacturer for a failure analysis which revealed that the failure was due to poor workmanship at the joint of the lead wires and the coil. There was no indication of overheating, thus indicating that the solenoid should have performed according to specifications. A further precaution was taken by putting a surge diode in parallel with the coil to quench its inductive "kick" upon switching.

The areas needing improvements were redesigned and subsequently the coupler assembly was refitted.

5.4 Final Test

A series of over 550 coupling/uncouplings were completed with one automatic uncoupling failure. This single failure was traced to a short in the surge diode caused by wires touching in the circuitry used to simulate the power load of a string of cars. There were no failures in the coupler circuitry.

The following conditions were tested at a speed that averaged over 1.2 MPH with a maximum speed of 3 MPH:

- (1) Straight track (tested 450 times).
- (2) On reverse curves of at least 70 ft radius.
(One coupler set $3^{\circ} 15'$ to one side of centerline and the other 3° to opposite side of centerline.) (Tested 10 times.)
- (3) On continuous curves (one coupler $3^{\circ} 15'$ to one side of centerline and the other 3° on the same side of centerline). (Tested 20 times.)
- (4) $6 \frac{3}{4}$ inches horizontal offset to one side (tested 10 times).
- (5) 3 inches to the opposite side of condition 4 (tested 10 times).
- (6) 2 inch vertical offset combined with $6 \frac{3}{4}$ inch horizontal offset (tested 10 times).
- (7) 2 inch horizontal offset with one coupler $3^{\circ} 15'$ to one side of centerline and the other 3° on the same side of the centerline (tested 10 times).
- (8) 2 inch horizontal offset with one coupler set $3^{\circ} 15'$ to one side of centerline and the other 3° to the opposite side of centerline (tested 10 times).
- (9) Same as condition (7) except 2 inch horizontal offset is to the opposite side (tested 10 times).

- (10) Same as condition (8) except 2 inch horizontal offset is to the opposite side (tested 10 times).

Manual uncouplings were completed for all of the conditions listed above.

Water was added to equal amounts of coal dust and crushed limestone to obtain a soupy mixture which was smeared across the female side contacts. Upon coupling, the logic voltage, which normally is 12 volts, was recorded at about 5V. At this point, a rocking motion which simulates coupler action during transit, was applied to the coupler and the voltage fluctuated between 9 and 12 volts. After the rocking motion was completed, the voltage remained between 11 and 12 volts in a steady state. Seven coupling/uncoupling sequences were followed and after final coupling, good contact was obtained after about 1 second. Apparently contact pressure squeezes the contaminant out over a short period of time. When the logic voltage is 12 volts, contact resistance is about 0.6 ohm.

A failure test consisting of activating the solenoid (already warm from 100 rapid coupling/uncoupling sequences) for 2 seconds and releasing for 1 second. This was repeated several times for various voltages ranging from 150 to 325V DC. With the exception of marginal uncoupling at 150 volts, the Trombetta acted normally at all other voltages.

5.5 Logic Testing

The logic system as described in Section 4 was bread-boarded and tested. A locomotive unit, control panel and three car units were built section by section, and debugging was completed on each section before proceeding to the next.

After the preliminary electrical contact tests were made at Ohio Brass, it became apparent that more immunity to signal loss caused by dirty contacts was needed. This led to implementation of the repeater feature (discussed in Section 4) in the Car Logic Units.

The breadboard was designed such that coupling and uncoupling of cars could be simulated by placing and removing appropriate clip leads. The principal system operations --

- (a) Coupling Cars
- (b) Selective Braking
- (c) Selective Uncoupling
- (d) Monitoring Car Count
- (e) Loss of Cars
- (f) Select Errors

were each thoroughly checked. In addition, the controls were operated by randomly selected FMA personnel with a minimum of verbal instructions, and the operation was observed to make sure no hang-ups or unforeseen logic states could be caused from the panel. None were discovered.

The operation of the system and the front panel arrangement was discussed with FMA and Bureau personnel, and with an industrial designer. As a result of these discussions, several changes to the control panel were made to make it easier to understand and operate. The changes are described in Section 4.2.

The schematics given in Figures 4-6 and 4-7 are the final result of the breadboard testing, debugging and control panel rearrangement operations.

It must be noted that further refinement of the panel and its associated circuitry will probably be required after discussing it with operating mine personnel. The logic, as designed, is sufficiently versatile to make incorporation of such changes a minor design task.

5.6 Test Summary

After correction of problems encountered in the preliminary test sequence, the automatic coal car coupler successfully completed the tests as outlined earlier in this report. All of the different coupling configurations have been met and in some cases exceeded by a great deal. Coupling/uncoupling sequences were easily met at a 2 inch vertical offset and a 6 3/4 inch horizontal offset which represent the limits of the test stand. Coupling velocity requirements were easily met during the course of the 550 cycle test.

The control signal voltage drop across excessively dirty contacts was reduced by the spherical contact design and will be less of a problem due to the implementation of the repeaters. The extent to which dirty contacts will hamper system operation can only be determined underground.

The logic breadboard demonstrated the full capability required of it. Bug-free schematics are available for implementation in whatever form is most appropriate for a specific underground test program.

6. Cost Effectiveness

In this section we examine the potential cost effectiveness of a fully implemented Remote Control Coupler System operating in a million ton per year mine. Present mine haulage systems use a locomotive at both the front and rear of the trip in order to provide failsafe operation in the event of coupler failure between any two cars. In this manner, both ends of the broken trip are still under the control of a locomotive and runaway cars are prevented. However, using an efficient braking system, any primary or intermediate coupler failure will, by depriving all detached cars of power, cause immediate application of the brakes. In this manner, control of the loose cars is maintained automatically and without compromising the safety of the haulageways, the second locomotive can be eliminated.

In our estimates of cost effectiveness, we have assumed the implementation of such automatic brakes on each car. The second locomotive on each trip (and its operator) will be eliminated. The brakeman, who normally must assist in coupling and uncoupling operations, will be freed for other work by the remote control nature of the couplers. Our cost estimates for the various subassemblies represent production quantity procurements, and are based on the stated quantities.

In a 1,000,000 ton per year mine, 1390 tons of coal must be moved by the haulage system per shift, assuming 240 working days per year and three working shifts per day.

A good working average for car usage is about one trip per shift. If we assume the mine uses cars similar to the Irwin MR354, 26 ton model, we can assume that about 20 tons of coal will be moved per car per shift. The mine will require 70 cars to accomplish this, most likely using two locomotives making one complete trip each, dropping off cars at each section and collecting them later.

If we employ the four-car unit train concept, two motormen and their locomotives would be responsible for the delivery and subsequent pickup of 9 units (36 cars) during every shift. Thus, allowing a small margin for inefficiency in car loading, 72 twenty-six ton cars will make the round trip each shift, and move the required 1390 tons of coal.

Table 6-1 compares the initial capital costs for implementing the Remote Control Couplers with those for a standard Willison system in current use. We have ignored costs common to both systems such as cars, track and power lines. It is seen that the savings of the extra two locomotives more than compensate for the addition of the remote control hardware.

Table 6-2 compares the operating costs associated with the two systems. The depreciation cost is based on a 10 year straight-line writeoff of the initial investment, assuming no end-of-life salvage value. The labor costs are based on union wages, including fringes. In the case of the remote control system, we have conservatively included the labor costs of a maintenance man who will work on the system one shift per day, and charged no maintenance whatever to the Willison system. Even under this assumption, it is seen that the remote control system is 13.2 cents per ton cheaper than the standard approach. The elimination of the extra locomotives and the two hazardous brakeman's jobs not only reduce costs, but will increase the safety of the operation by removing the occasion for accident.

Table 6-1

Comparison of Capital Costs

<u>Remote Control Coupler System</u>	<u>Standard Couplers</u>
Basis: 72 Cars - 18 Units	Basis: 72 Cars
Costs	
18 Coupler pairs including all car logic, cable and electrical components (Quantity 100 pairs), \$3900 each pair	72 Standard Willison coupler pairs (Quantity 100) \$500 per pair
\$ 70,200	\$ 36,000
72 Car Brake sets (Quantity 400 sets) \$1000 per set	4 Locomotive Couplers
72,000	1,000
54 Intermediate Couplers (Quantity 300) \$465 each	
25,110	
54 Intermediate Electrical Junction Boxes (Quantity 300) \$175 each	
9,450	
2 Locomotive Couplers - Female half only, including electrical components (Quantity 100) \$2500 each	
5,000	
2 Locomotive Control Stations (Quantity 10) \$1015 each	
2,030	
2 Locomotives, 27 ton, 13,500 lbs drawbar pull, all standard options (Quantity 2) \$235,000 each	4 Locomotives
<u>470,000</u>	<u>940,000</u>
Total Capital Costs	\$977,000

Table 6-2

Comparison of Operating Costs

	<u>Remote Control System</u>	<u>Standard System</u>
Depreciation of Capital Investment (10 years) per year	\$ 65,379	\$ 97,700
Labor:		
2 Motormen, 240 days 3 shifts per day, \$90 per shift	64,800	4 Motormen 129,600
1 Electronic/Electrical Maintenance Man, 240 days, 1 shift per day, \$125 per shift	<u>30,000</u>	2 Brakemen <u>64,800</u>
Labor and Depreciation Cost per year	\$160,179	\$292,100
Cost per ton	16.0 cents/ton	29.2 cents/ton

7. Conclusions

The primary result of the Remote Control Coupler Program has been to prove that a prototype coupler, with its associated power and control system, can be built which will satisfy all of the contractual performance requirements.

The mechanical aspects of the remote coupler design were proven feasible by building a prototype and testing in the laboratory. Coupling and uncoupling in the wide variety of vertical and horizontal misalignments required by the working specifications of Section 2.4 were repeatedly demonstrated.

The control aspects of the system design were proven by building and debugging an electronic breadboard and its associated control panel. The circuits performed all required functions, even when the controls were operated by people unfamiliar with them after minimal instruction. Bench tests of the final prototype coupler contacts demonstrated operation well within the capabilities of the logic and control system, even when these contacts were made excessively dirty. The mercury relays also performed without failure, including operation during shock tests.

The potential cost effectiveness of implementing a remote control coupler system in a working mine is described in Section 6. The remote control approach, with automatic braking upon uncoupling, offers a savings of 13.2 cents per ton hauled.

A realistic proof of the concepts developed during this program must await the results of rigorous in-mine testing. Weak areas in the mechanical design, and failure-prone electrical components can only be isolated by evaluating the system's performance on a day-by-day basis in an actual rail haulage operation.

A proposal for a phased approach to this testing is briefly described in Section 7.1, below. In Section 7.2, we describe how a production designed coupler would differ from the prototype tested during this program.

7.1 Proposed Future Work

The following represents a proposed series of operations which would continue evaluation and improvement of the automated car coupler in a logical sequence of steps.

7.1.1 Mine Evaluation of Single Unit

- (a) Ruggedize existing prototype equipment and assemble electronic controls into a mineworthy housing.
- (b) Install this unit on one car and one locomotive in an operating mine such that these units are always together in the mine.
- (c) Continual couple/uncouple tests occur at the tippie and underground, providing working information for further evaluation.
- (d) Carry out modifications, retest and finalize specifications for production design.
- (e) Prepare production design and detail drawings. Build several coupler sets.
- (f) Repeat previous tests using production coupler assembly, using one female on the locomotive and several cars with male couplers.

7.1.2 Full Scale Mine Operation

- (a) Equip a 1,000,000 ton per year mine with automatic coupler sets between each 4-car unit and intermediate couplers and connectors

between remaining cars. These would be installed on a logical, gradual basis, acceptable to the mine's management.

- (b) Run extended tests under basic operating conditions with particular attention to real and simulated problems. These tests should deal with gathering and coupling on small radius curves, uncoupling under both loaded and unloaded conditions, signal and power transmission through the coupler contacts in a mine environment, and man/machine interface with the multi-unit trips.

7.1.3 Expanded Use of Control System

The logic requirements of the basic system entail continuous trip length monitoring, trip state monitoring, uncouple command logic and braking control. The design that has evolved to encompass these functions has an inherent capability of controlling many more and once the basic system is operational, these other functions should be incorporated and evaluated to determine whether they are truly a viable accessory to efficient and safe operation.

These other control and operating functions which should be tried out include the following:

- (a) Brake failure sensing
- (b) Derail sensing
- (c) Intermediate coupler monitor
- (d) Lighting control
- (e) Proximity sensing for coupling.

There are undoubtedly other, more sophisticated functions which will be suggested as familiarity increases under mine conditions. The list above contains the items which are typically troublesome on existing equipment and which can be readily controlled from the central locomotive station already designed.

With a completely automated trip having couple/uncouple, braking, selection and trouble sensing capabilities, the next logical step would be to investigate the feasibility of the system for use with a central command station, eliminating the need for the motorman on the train itself.

7.2 The Production Coupler

The prototype couplers were based on the standard Ohio Brass Form 8A units, to which new hardware was added to implement the remote control functions and prove the utility of the system.

A production version of the coupler assembly should be designed, and it is proposed that this be pursued in two steps: First, an upgrading of the prototype to reflect standard mine practice; and, second, a redesign based upon in-mine test data and ideas for improving the basic design. These steps are described below.

7.2.1 Production Version of the Prototype

A production version of the coupler assembly would differ from the prototype in the following ways:

- (a) The actuator and contact housings would be made part of the casting - not a weldment.
- (b) The material used to cast the coupler would conform to the full-strength specifications of the Ohio Brass Form 8A (80,000 lbs. rated, 55,000 lbs working draft load).

The outward appearance of the production coupler would present a cleaner, more compact envelope, but the internal components would be identical with those used in the prototype. Savings in space will result from better component placement allowed by filling the

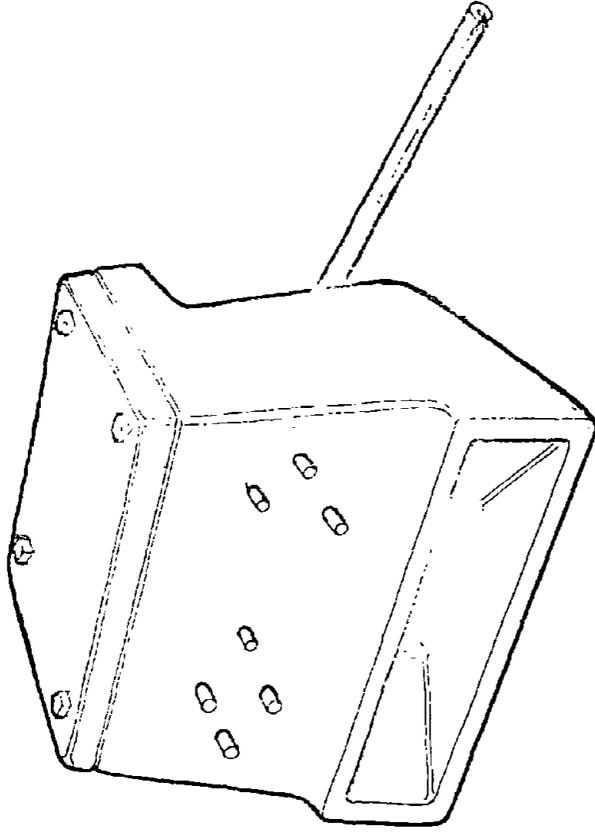
cast housing around the relays, actuator solenoid and wiring in a custom manner. Figure 7-1 shows an artist's concept of such a design. It is anticipated that about ten pairs of this version of the coupler would be produced for in-mine evaluation.

7.2.2 Advanced Production Coupler Design

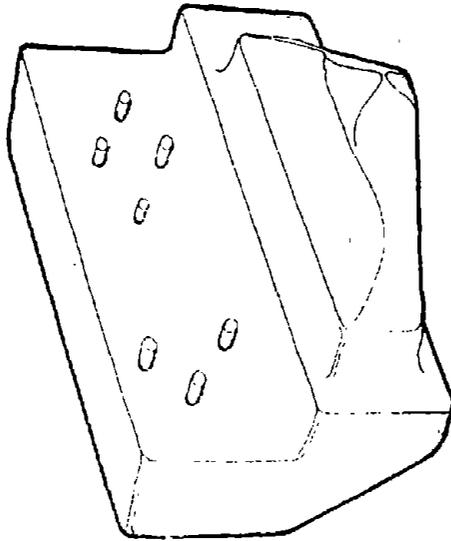
When the results of in-mine testing of the production prototype are available, a true production version of the coupler assembly can be developed. This design would eliminate the weak points of the prior version isolated by testing, as well as incorporate new ideas which would improve the utility of the coupler assembly.

By treating the female coupler assembly as a totally integrated system rather than an accumulation of add-on component parts and by introducing a high efficiency rotary solenoid for the unlatching operation, the entire female coupler profile can be lowered and simplified. This will result in a lighter, more compact and less expensive coupling system which will also be easier to service in the field. Furthermore, every effort has been made to eliminate external protrusions which could be hazardous to mine personnel.

As can be observed from Figures 7-2 and 7-3, all contacts including the microswitch plunger are located below, but very close to the coupler's horizontal axis. The mercury switching relays and the uncoupling solenoid are housed in separate and splashproof compartments integral with the female half of the coupler. A manual chain and lever operated coupling release is also provided which can only be activated with a special trip lever from either side of the coal car.



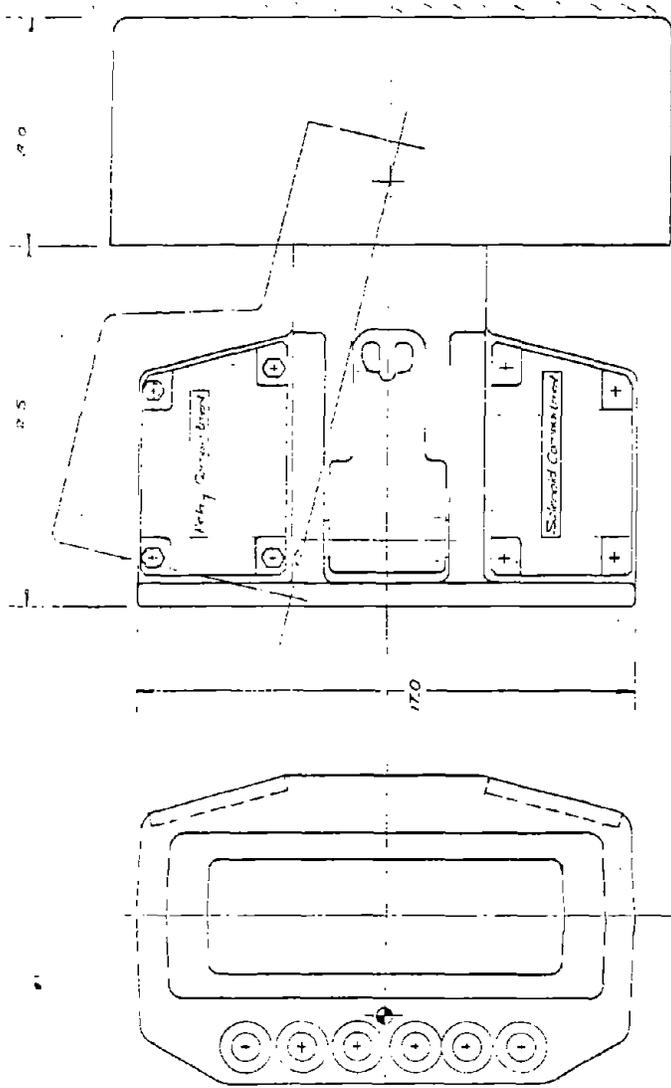
Female



Male

Production Version of Prototype Coupler

Figure 7-1



To manual Trip Release

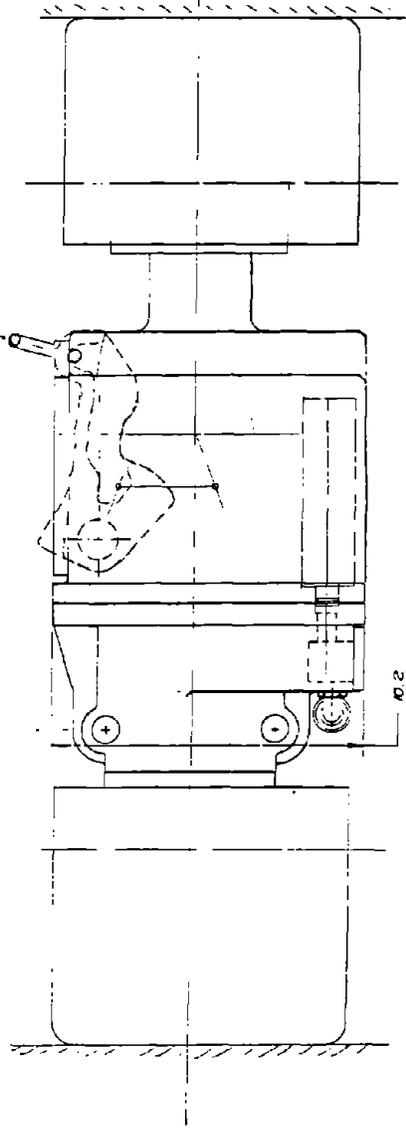
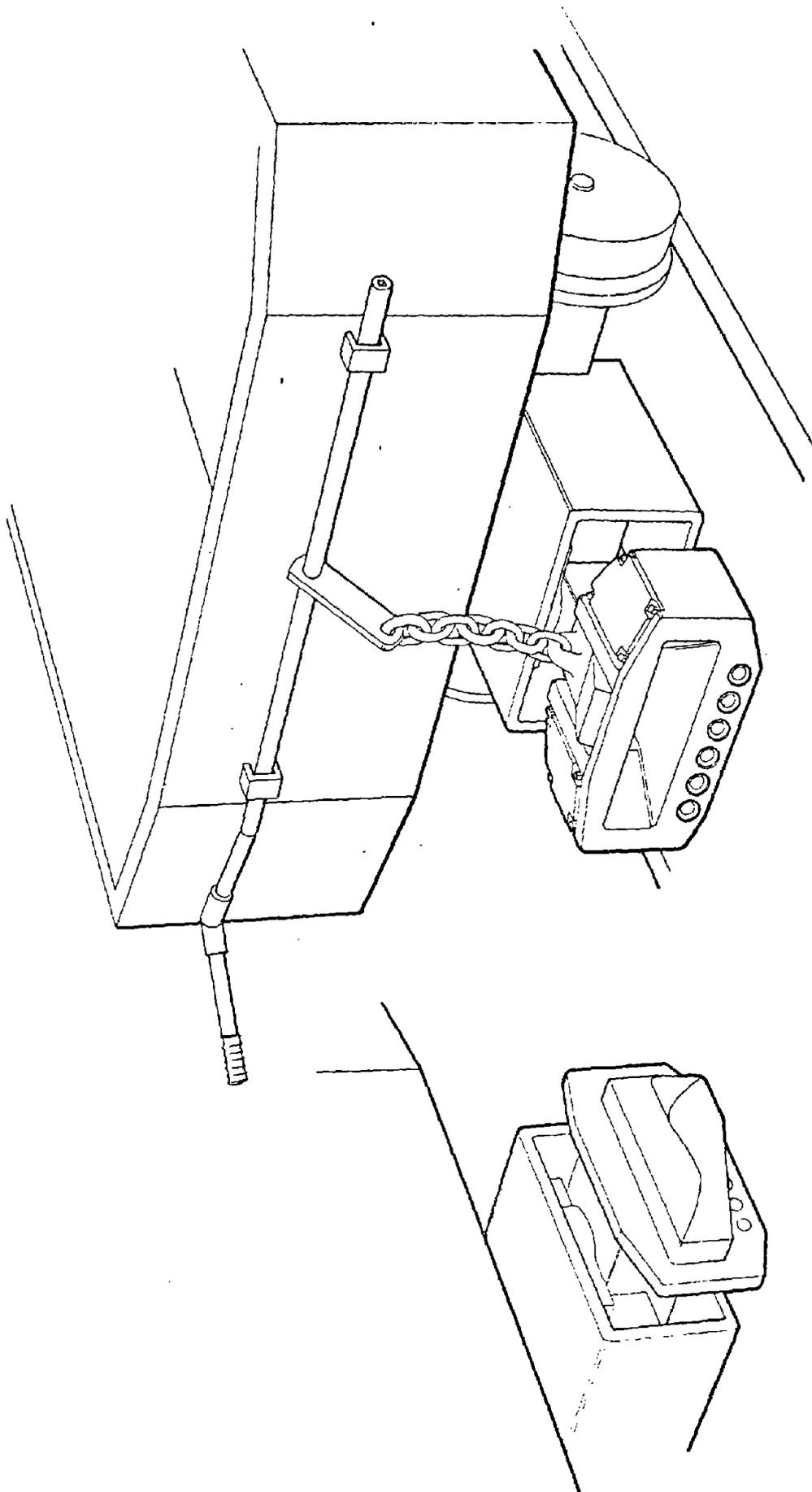


Figure 7-2

PROJECT NO.	12375
DATE	J 12 375
DESIGNED BY	
CHECKED BY	
APPROVED BY	
POSTER-MILLET ASSOCIATES	
Advanced Coupler Design	



Truck Mounted
Advanced Coupler Design

Figure 7-3

8. Subject Inventions

There were no subject inventions.