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J0377057

TROLLEY LINE POWER TRANSFER TO VEHICLES

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

MBAssociates
Bollinger Canyon Road
San Ramon, California 94583



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Final Report

Contract No. J0377057
Trolley Line Power Transfer to Vehicles

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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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FOREWORD

This report was prepared by MBAssociates under USEM Contract No. J0377057. The contract was initiated under the Coal Mine H&S/Safety Program. It was administered under the technical direction of Pittsburgh/Bruceton Administration Office with George J. Conroy acting as Technical Project Officer. Alan G. Bolton, Jr. was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 1977 to September 1979. This report was submitted by the author Andrew St.Amant on July 31, 1980.

In accordance with the requirements as set forth in Section 8 of "Requirements for Preparing and Submitting Contract and Grant Reports to the Bureau of Mines," this is to certify that there are no known patentable designs or features in the trolley pole control system which is comprised of an RCB, RCL and SAU.

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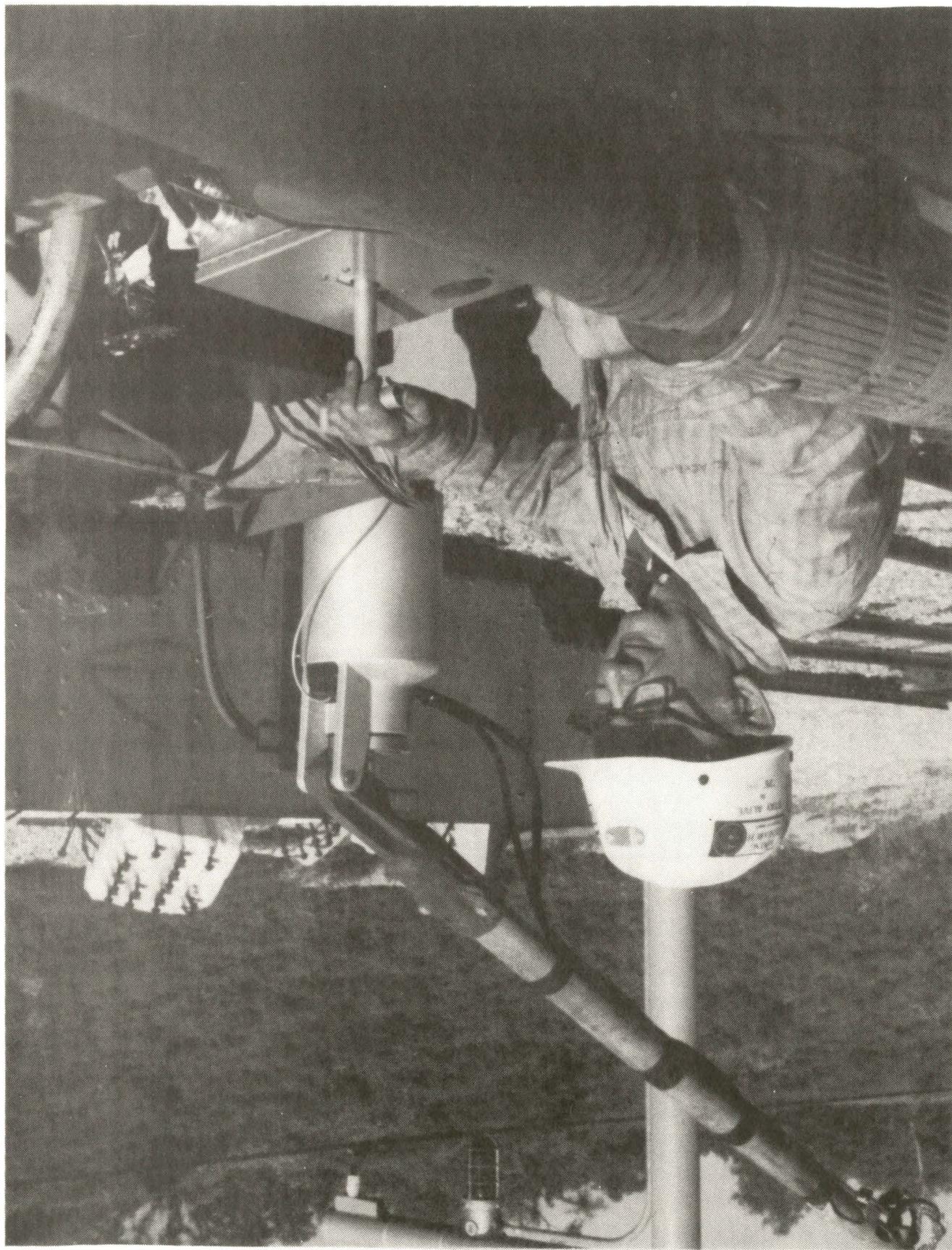
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1.0 INTRODUCTION

1.1 Topic

This Task Completion Report on the investigation of "Trolley Line Power Transfer to Vehicles" is submitted by MBAssociates in accordance with the provisions of U.S. Bureau of Mines Contract No. J0377057, and covers the period of 1 January 1979 through 30 September 1979, Phase IV.

1.2 Summary

This report reviews the tasks performed during Phase I - Improved Pole Tracking, Phase II - Rapid Pole Retraction, and Phase III - Remote Pole Repositioning. Section 2.0 of this report details task performance during Phase IV Design, Manufacture and Testing, and Section 3.0 deals with recommendations for further development by way of design improvement of the RCB (Remotely Controlled Base) and its control, further development of an improved trolley pole Harp and Shoe Assembly, and the initial investigation and concepts generation for an Automatic Guidance System to control the RCB during rewiring of the trolley pole.

2.0 REPORT OF TASKS PERFORMED

2.1 Review of Phase I - Improved Trolley Pole Tracking

The tasks which were performed during the first part of Phase I (October through December 1977) were telephone contacts and personal visits with data sources in three categories. Phone calls and visits were made to equipment manufacturers, visits were made to underground coal mines, and phone calls to MSHA personnel were followed up by personal visits. The purpose of these contacts was to obtain detailed data on the manufacturers' design specifications for presently used trolley poles and wire; the historic and contemporary in-mine performance of the trolley systems; and the recent history of accidents involving trolley power transfer to mine vehicles.

Trolley literature and design drawings were obtained from fifteen manufacturers, and standards applicable to trolley systems were obtained from two standards associations.

The trolley equipment manufacturer information detailed several types of trolley pole base assemblies; a few differing harp assemblies; and two types of pole, wood (ash or poplar) and plastic (PVC).

Product specifications and design details for hardware items such as trolley wire, hangers, splicers, insulators, switches, etc., were obtained from most of the firms and associations.

2.1.1 Underground Coal Mine Data

Eight mine visits were accomplished during the Phase I effort to the Powhatan, Valley Camp, Nemaquin, Sunnyside, Eagle, and Bear underground coal mines.

Color slides and prints (35mm) and motion picture films (8mm) were produced on six of the mine trips. MBA also secured the consulting services of the Ohio Brass Company design and management engineers during the second month of Phase I with formal meetings at the O-B plant at Mansfield, Ohio.

Ohio Brass furnished engineering reports and other information to MBA. These were most helpful in showing not only what avenues of design improvement had been conceived and implemented, but also of great importance, the possible improvement areas which had not been explored by experiment or practice. Included in this last category is forced air cooling of the harp assembly, surface area increase (fins), and construction materials which are high in thermal conductivity.

MBA obtained print-outs from HSAC of all accidents associated with trolley wire or trolley poles. We found that, out of the total of about 6,500 listings for the years 1972 through 1977, only 231 injuries and two deaths were definitely caused by wire or poles. Both of the fatal accidents involved electricution and apparently not any "mechanical" injury from the pole.

Section 2.1.5 of MBA Annual Report No. MB-R-78/52 details the results of the Analysis and Evaluation of Data obtained during the first part of Phase I.

2.1.2 Concept Development

Two harp concepts were developed as a natural consequence of the evaluation showing the need for improvement of the upper end of the trolley pole, even though not required by the Contract and Program Plan. Final detailing of these three concepts occurred during the Phase I Review in September 1978.

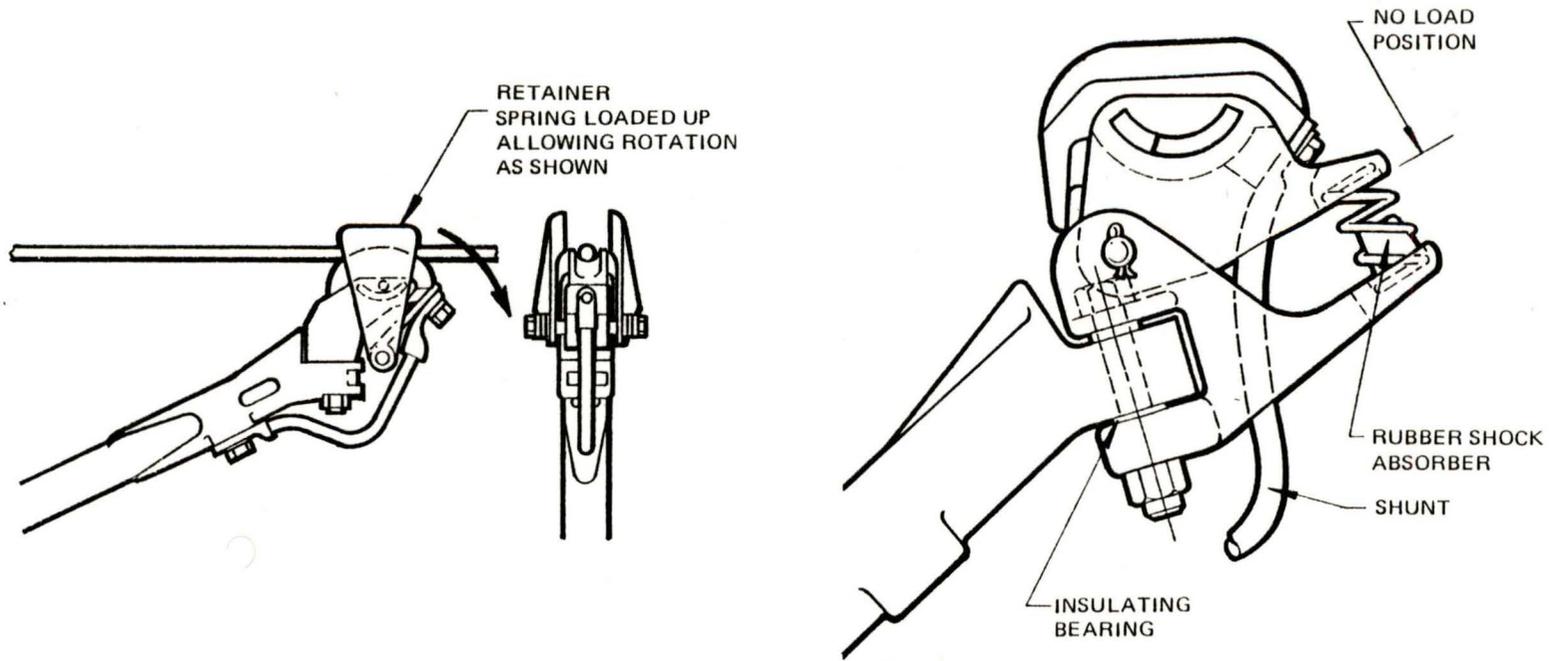
2.1.2.1 Low Inertia Trolley Wire Retainer

Figure 2.1-1A shows a Low Inertia Retainer concept. This design requires no modified hardware such as a modified harp. The retrofitable hardware bracket is fastened by the same bolt used presently for the shoe end of the shunt. The device functions as follows: "The spring loaded ears, one pivoting on each side of the harp, and (in normal guidance position) extending one or two inches above the top of the shoe, will easily swing down when encountering any trolley wire support or connecting hardware such as frogs, unusually wide clamps, or switches. When the shoe has passed the projecting hardware, the spring loading immediately returns the ears to the active guidance position. In this position most dewirements will be avoided as our data (motion pictures) shows downward excursions of the shoe to be quite small during typical dewirements."

2.1.2.2 Retrofit Trolley Shoe Suspension

Figure 2.1-1B shows a variation (reduction of size) of the design submitted in Monthly Report No. 6. This improvement in shoe suspension reduces the mass acting at the shoe for all vertical shoe movement except when there is extreme excursion. The spring suspension is damped by a built-in bumper.

The hardware should be manufactured from machined or cast aluminum wherever possible. This will foster a further improvement by the reduction of mass to the lowest that is practicable.



A. LOW INERTIA TROLLEY WIRE RETAINER

B. RETROFIT TROLLEY SHOE SUSPENSION

FIGURE 2.1-1

2.1.2.3 Other Concepts Originated During Phase I

In addition to the harp improvement concepts described above, five other design improvement areas were suggested by the Phase I Data Evaluation. They are as follows:

- Pole Snubber - Shock absorbers which act only when the shoe or the pole moves downward quickly. This increases shoe force when needed.
- Low Mass Pole - Except for the contact area of the shoe, strong lightweight materials are available. A rubber shield would protect the pole from impacts.
- Improved Bases - Friction in the base is reduced by designs with low friction bearings and spring housings. This was implemented with the RCB design during Phase IV.
- Wire Guides - Insulating extrusions mounted on the wire to make dewirement very improbable. A contractor is investigating this approach for USBM at the present time.
- Wire Straightening Tools - A hand held tool to straightening small sections of wire quickly. A wire straightening die for straightening 500 to 1,000 foot section of wire by pulling it with a rail vehicle. Figure 2.1-2 shows a concept tool design.

2.1.2.4 Other Recommendations

The following system concepts are recommended for development to improve tracking:

- Low mass pole (complete pole system redesign)
- Shoe suspension system (retrofit)
- Wire mounted or shoe guides (retrofit or new design)
- Wire straightening tools
- Improved pole base

Standards for trolley systems would be effective if applied to installation alignment and allowable hardware wear. Trolley wire straightness conditions are a matter of judgement with varying requirements for safe usage, depending on location, wire tension and pole variations.

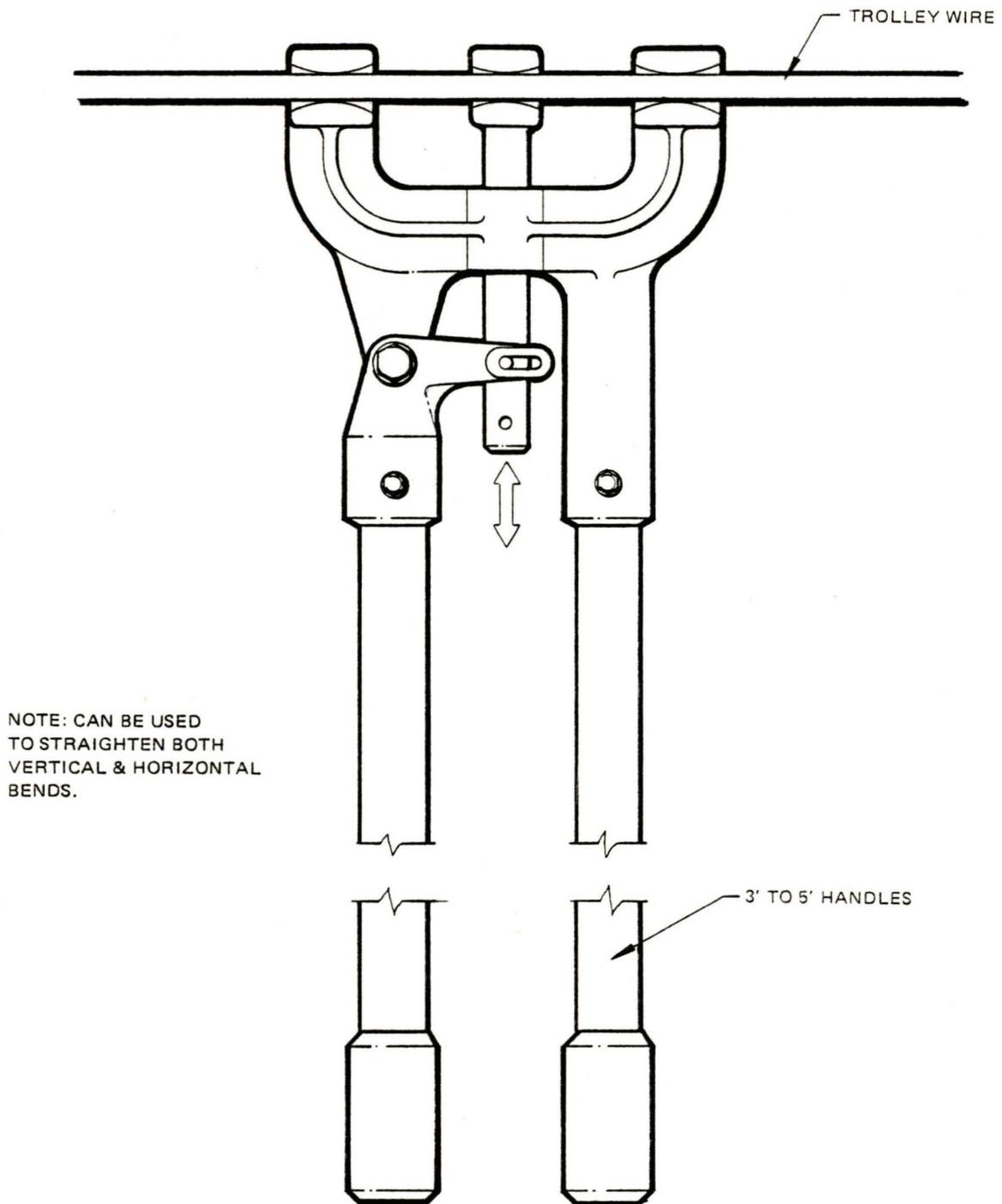


FIGURE 2.1-2
TROLLEY WIRE STRAIGHTENING TOOL



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2.2 Review of Phase II - Rapid Trolley Pole Retraction

The Phase II tasks included a survey and analysis of all types of retraction systems, manufacturer contacts regarding commercially available pole bases with retraction devices for coal mine vehicles, and development and evaluation of retraction concepts.

2.2.1 Concept "A" Base Mechanism

A concept which is similar to typical existing manually operating hardware, but with an added one-way shock absorber, to help maintain the shoe on the wire, electric linear actuator and Gel-Cell battery is shown in the Figure 2.2-1 section view. The essential parts of the mechanism are specified on this figure and its operation is entirely by way of switching control of electric power.

2.2.2 Concept "B" Base Mechanism

Figure 2.2-2 shows a section view of a compact mechanism which accomplishes both required functions; resistance to dewirement by way of a one-way (compression) shock absorber, and capture of the pole in its position of maximum downward deflection by way of a rotary-solenoid actuated cam.

2.2.3 Concept "C" Base Mechanism

This hydraulic mechanism, Figure 2.2-3, will operate in a manner somewhat similar to Concept "A", as far as external observation is concerned. The exception is the resetting of the main spring. This is accomplished manually by use of an integral hydraulic pump part of this device similar to an automobile jack.

2.2.4 Concept "D" Base Mechanism

This concept is illustrated in Figure 2.2-4 and uses a solenoid released tilt-lock mechanism to capture the main spring at the extreme of compression. This locking of the pole in the extreme of downward travel would only occur with loss of trolley power and after a capacitor controlled time delay of a few hundred milliseconds.

2.2.5 Concept "E" Base Mechanism

Concept "E" shown in Figure 2.2-5 is quite similar in pole-capture function to Concept "D", but has the considerable advantage of a one-way shock absorber of the same type used for Concepts "B" and "C". This is accomplished without significantly increasing the mechanism size because of the use of a unique substitute for either a ratchet and pawl or a tilt-lock. The capturing device is a flexible stainless steel braided sleeve which operates according to the same principle as the ancient woven straw toy called a Finger-Puzzle.

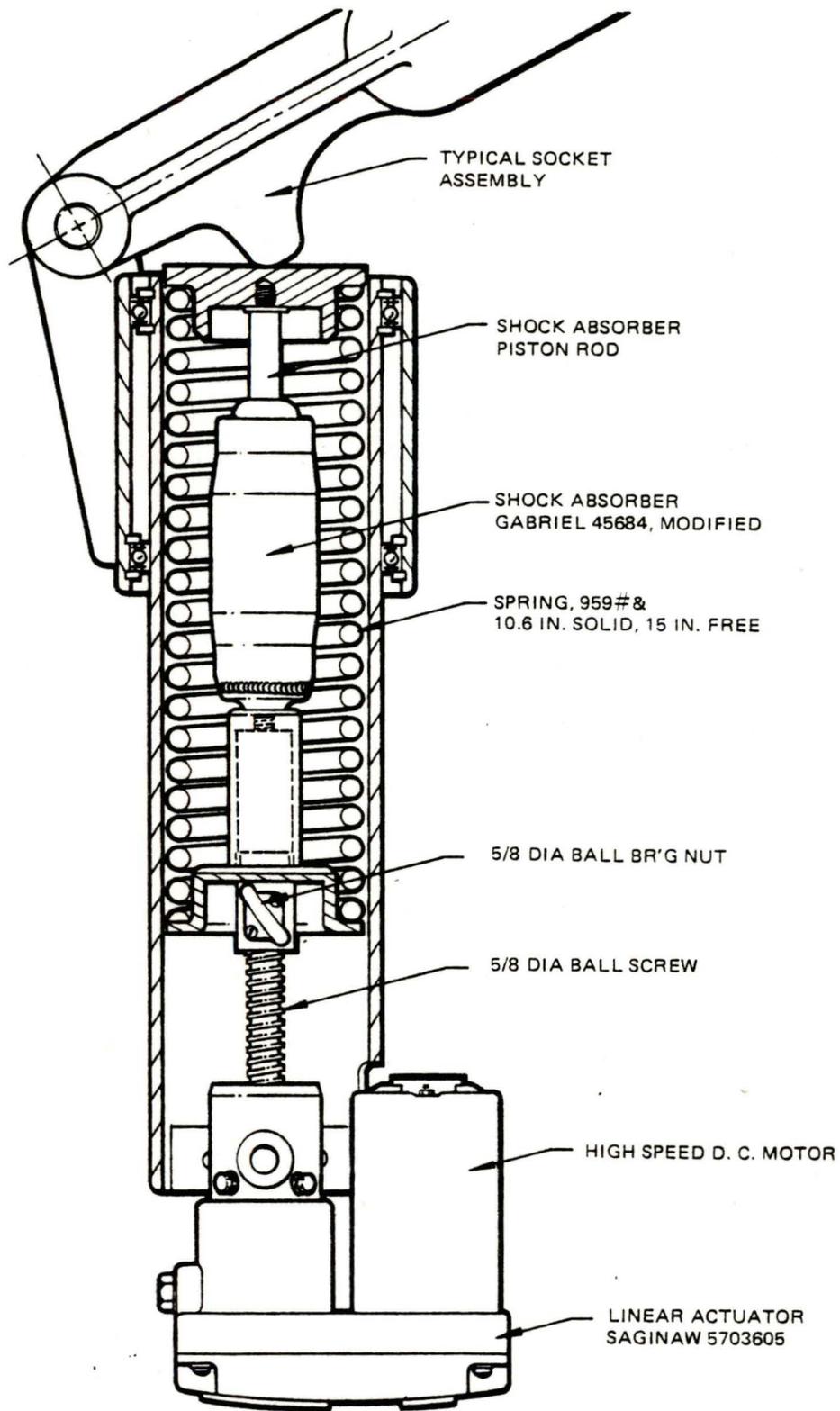


FIGURE 2.2-1
CONCEPT "A" BASE MECHANISM



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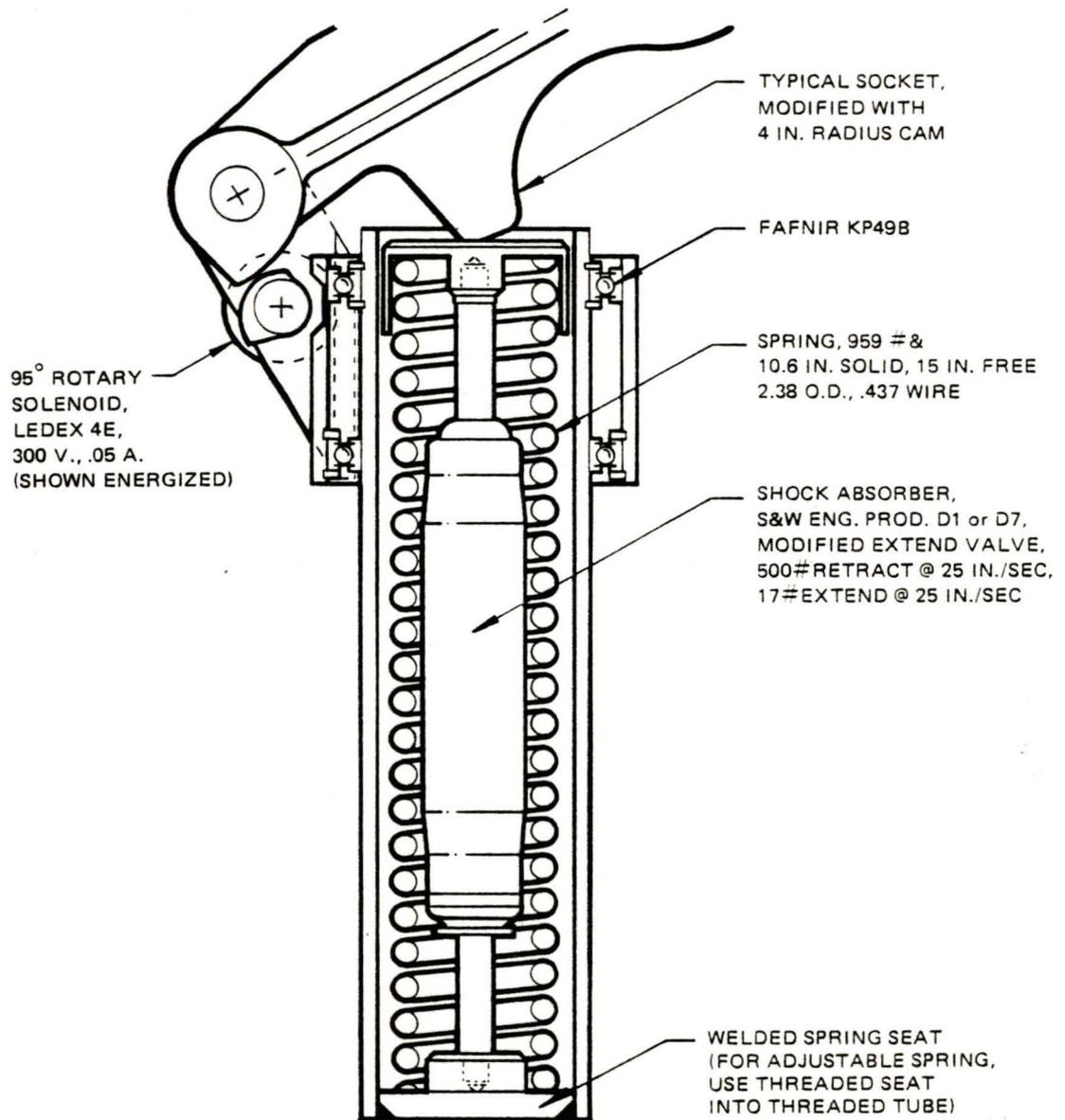


FIGURE 2.2-2
CONCEPT "B" BASE MECHANISM

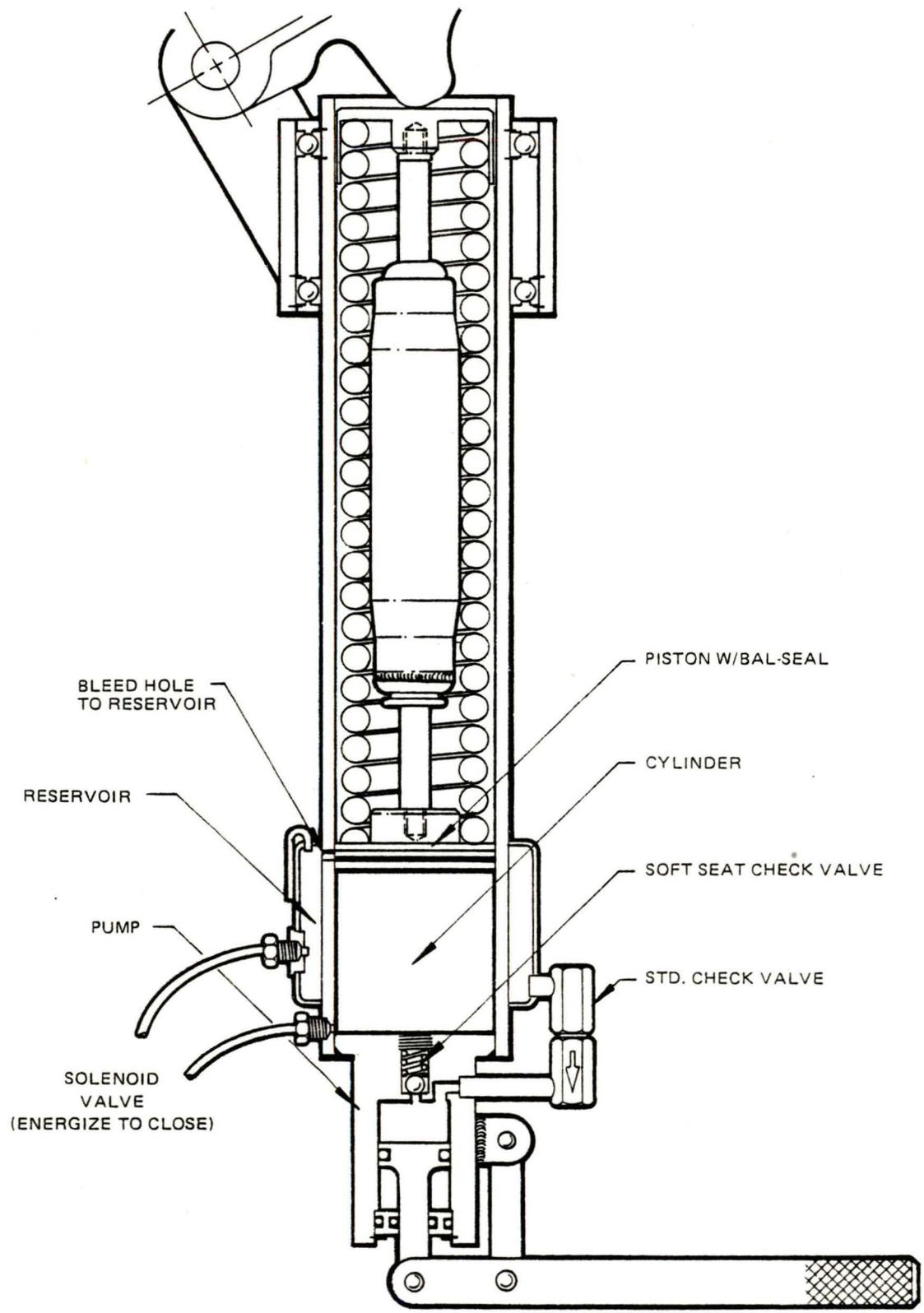


FIGURE 2.2-3
CONCEPT "C" BASE MECHANISM



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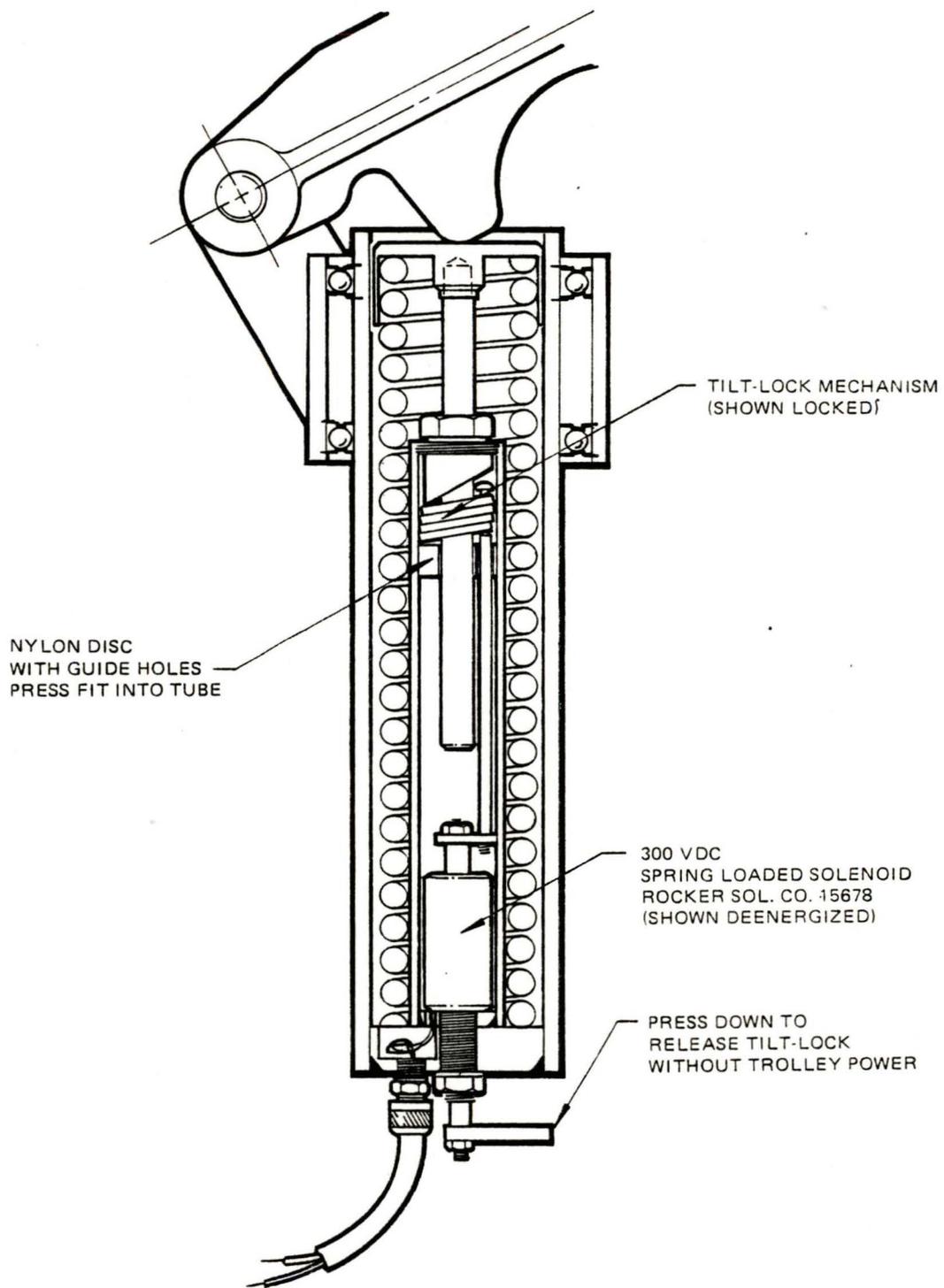


FIGURE 2.2-4
CONCEPT "D" BASE MECHANISM



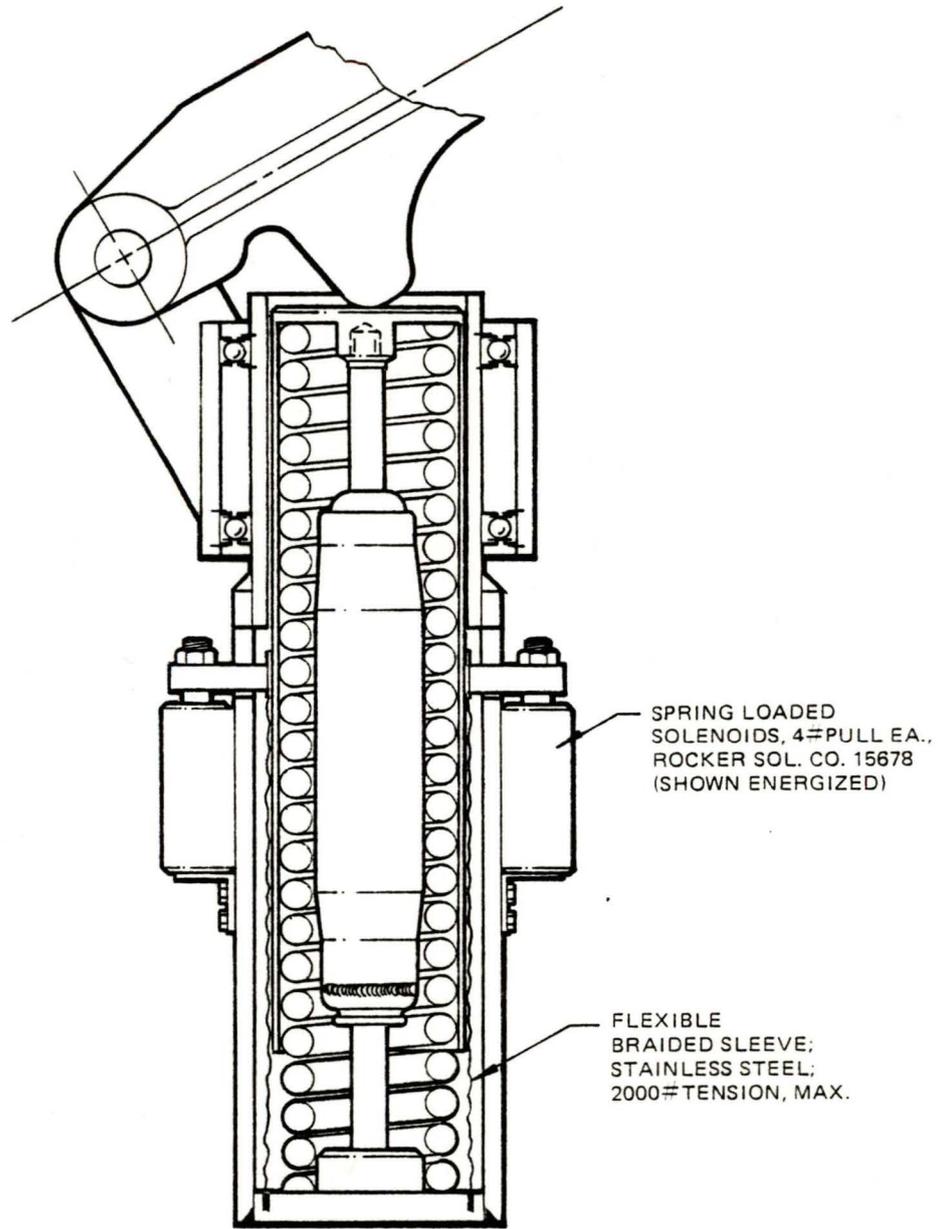


FIGURE 2.2-5
CONCEPT "E" BASE MECHANISM

2.2.6 Concept "F" Base Mechanism

Figure 2.2-6 shows the last of this series of concepts. A circuit similar to that used for Concept "A" can be used to control the operation of the linear actuator. Only the relay and switch contact wiring would require changes. The charger and Gel-Cell circuit would be identical.

This concept mechanism uses energy stored in a spring to overpower the main operating spring by the release of the larger diameter spring. The illustration shows the mechanism in its normal "trolley on the wire" condition. Operation of this unit is described in a Phase I monthly report.

2.2.7 Analysis

After a thorough and independent analysis performed by six engineers, it was quite evident that the summary score for the Concept "B" was the highest with "E" in second place. This result was in keeping with previous comments by various engineers, both at Bruceton and at San Ramon.

2.3 Review of Phase III - Remote Trolley Pole Repositioning

MBAssociates developed four concepts to integrate the three functions of tracking improvement, rapid retraction and remote repositioning in a compact trolley pole base mechanism. For the azimuth and elevation functions, the first (AA) is an electro/hydraulic design; the second (BB) is entirely hydraulic; the third (CC) is entirely mechanical, and the fourth (DD) is electro/mechanical. All four concepts make use of the hydraulic shock absorber damping and the electrical rotary solenoid pole retraction concepts (Phase II, Concept B).

2.3.1 Concept AA Base Mechanism

The concept is illustrated by Figure 2.3-1 titled Concept AA Base Assembly, and also by the hydraulic diagram and other motor design information in the Appendix of this Report.

This mechanism used the shock absorber and rotary solenoid concepts; for elevation, a modification of the shock absorber to include a linear actuator (hydraulic cylinder) function; and for azimuth, an electric torque motor.

2.3.2 Concept BB Base Mechanism

The base assembly as shown in Figure 2.3-2 titled Concept BB Base Assembly uses a modified shock absorber for both the pole damping and elevation actuator functions. The hydraulic lines to the shock absorber, and their function, are similar to those shown by the Concept AA illustration. They are omitted on the BB illustration for purpose of clear presentation of the vane actuator azimuth drive concept.

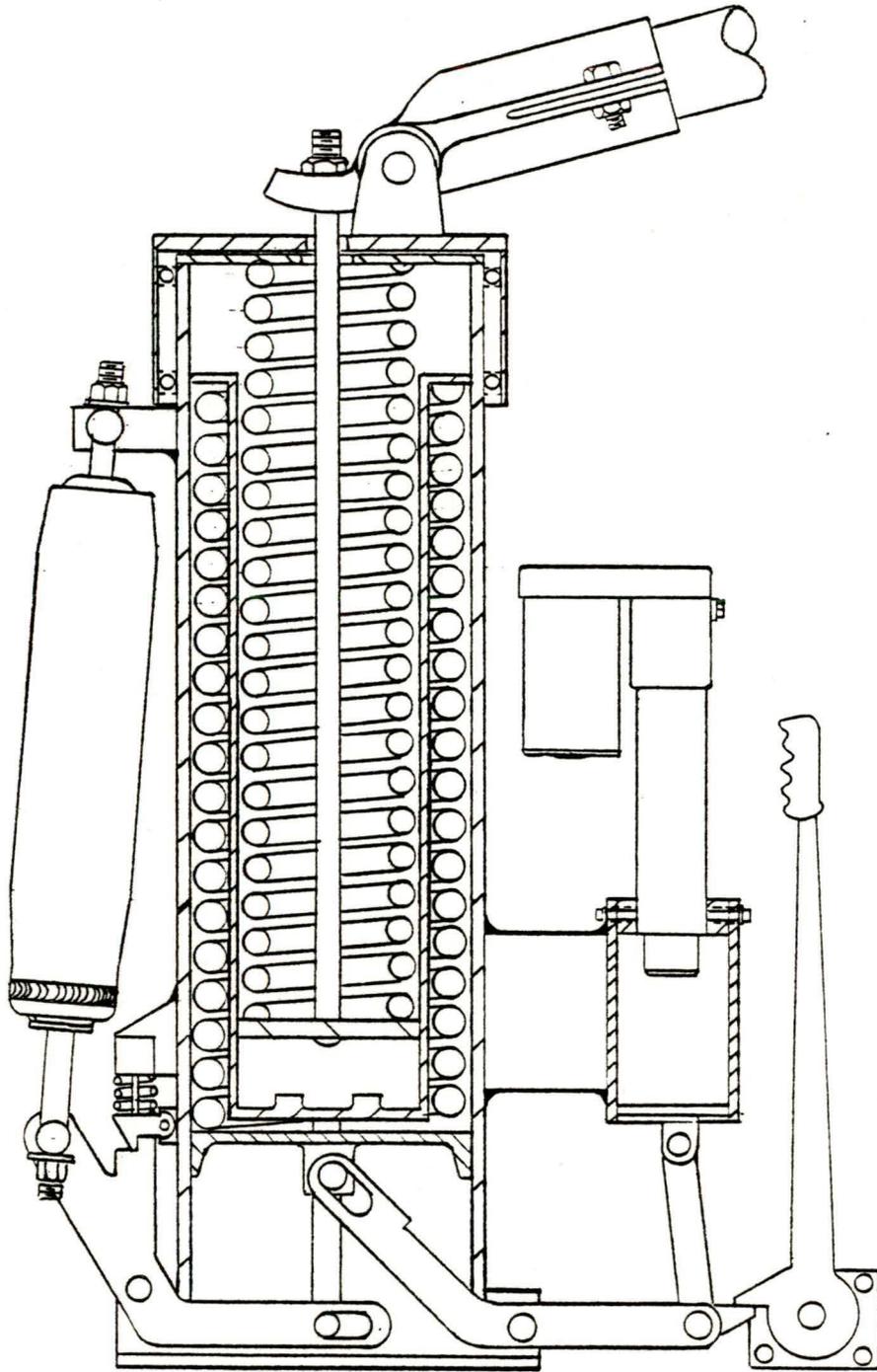


FIGURE 2.2-6
CONCEPT "F" BASE MECHANISM

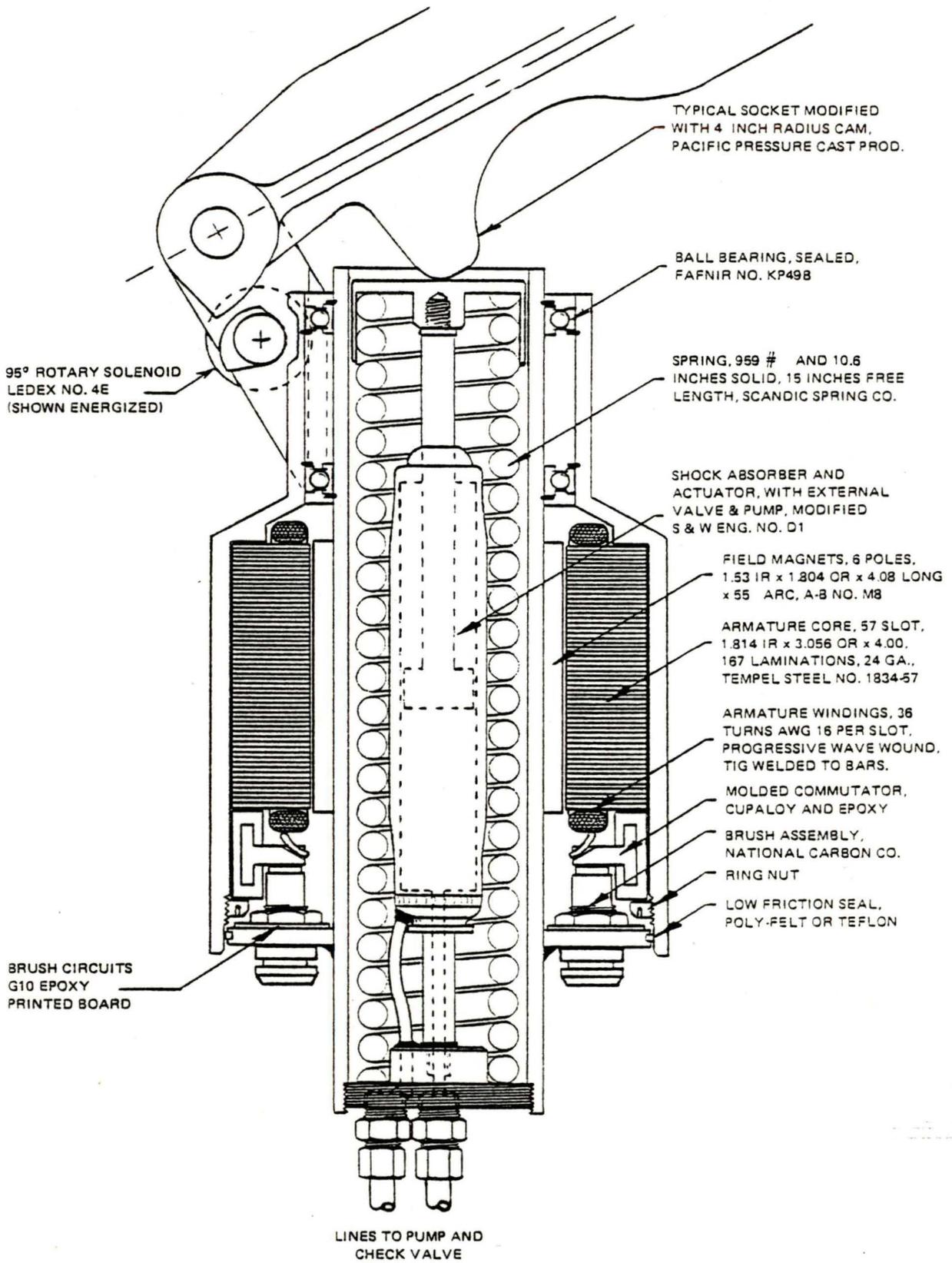


FIGURE 2.3-1
CONCEPT AA BASE ASSEMBLY

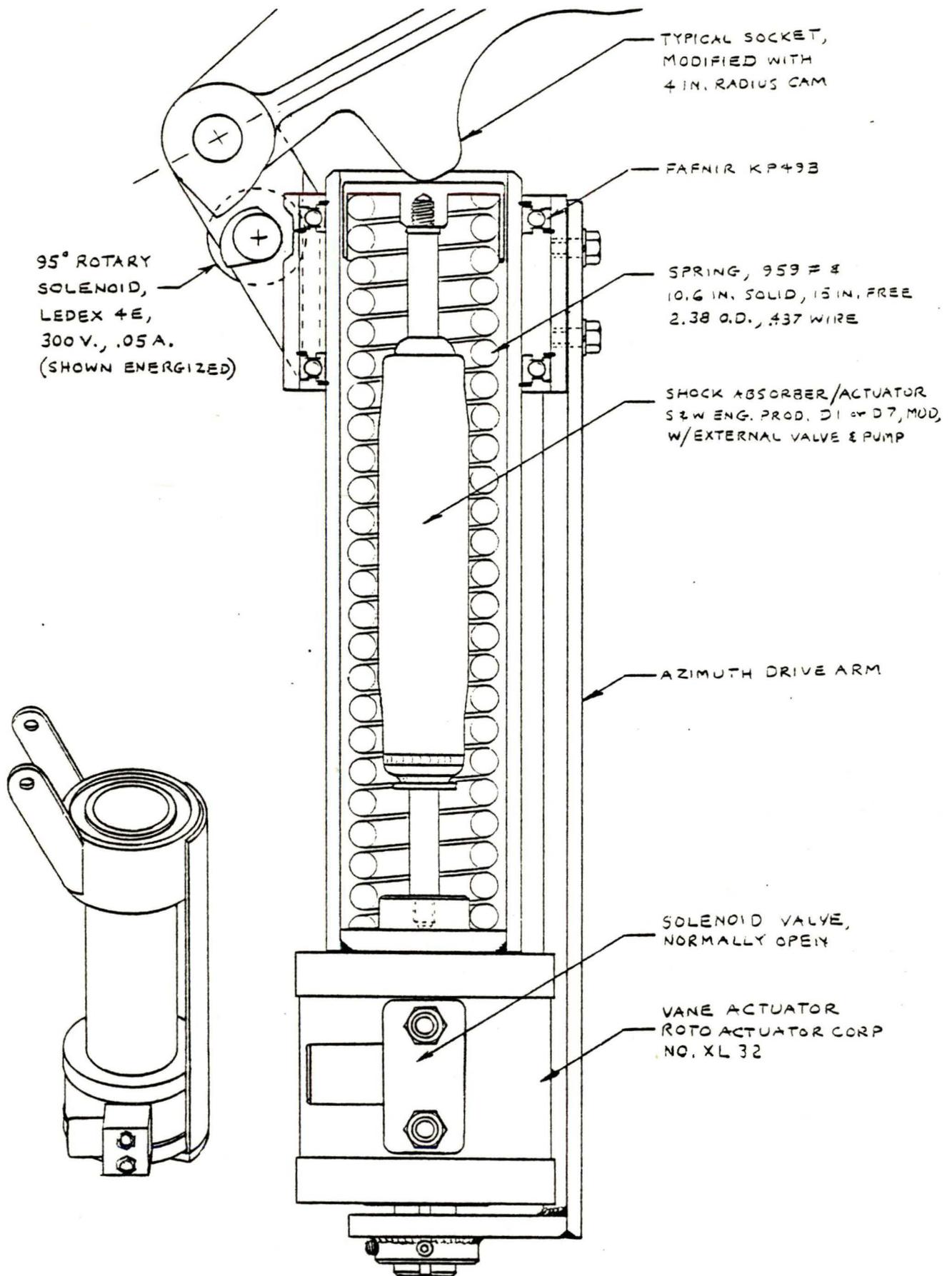


FIGURE 2.3-2
CONCEPT BB BASE ASSEMBLY

The azimuth vane actuator is not driven by a hydraulic pump. It is a slave unit direct coupled by two hydraulic tubing lines to an identical master unit located within easy manual operating reach of the motorman. The master unit is operated by a lever.

2.3.3 Concept CC Base Mechanism

This is a very simple all-mechanical (except for the rotary solenoid) azimuth and elevation control concept. The Figure 2.3-3 Concept CC Base Assembly illustration shows a V-belt drive for both functions. A toothed belt or roller chain could be used for the elevation drive with no other changes, but for the azimuth drive the inertia and friction of the hand-wheel and sprockets might be difficult to decouple without the additional complication of a remotely operated clutch between the driven sprocket and the sleeve which supports the trolley pole. A V-belt which is completely loosened from the driven pulley by a lever is, therefore, more simple and lower in cost.

2.3.4 Concept DD Base Mechanism

This concept for azimuth and elevation drive, as shown by Figure 2.3-4, Concept DD illustration, uses two similar gear motors and an electric clutch. It can be D.C. servo amplifier controlled (by motorman operated potentiometer) or, as is probably preferable due to cost, the motors can each be operated by three-position spring-return lever switches for energizing and direction control. The electric clutch is energized simultaneously with the azimuth motor so that it is only engaged when the motor is rotating.

2.3.5 Concept Evaluation

Seven MBA engineering program managers reviewed the above four concepts and submitted their assessment of which Phase III concept was the most promising. On the basis of an overall quick analysis of each concept, the trend seemed to be in favor of AA and BB.

This preliminary analysis proved to be correct in the case of AA; there seemed to be a decided preference for this concept. All rated Concept AA in first or second place.

A more thorough analysis was subsequently conducted by the same group during September 1978, with the best rating given to Concepts AA and CC.

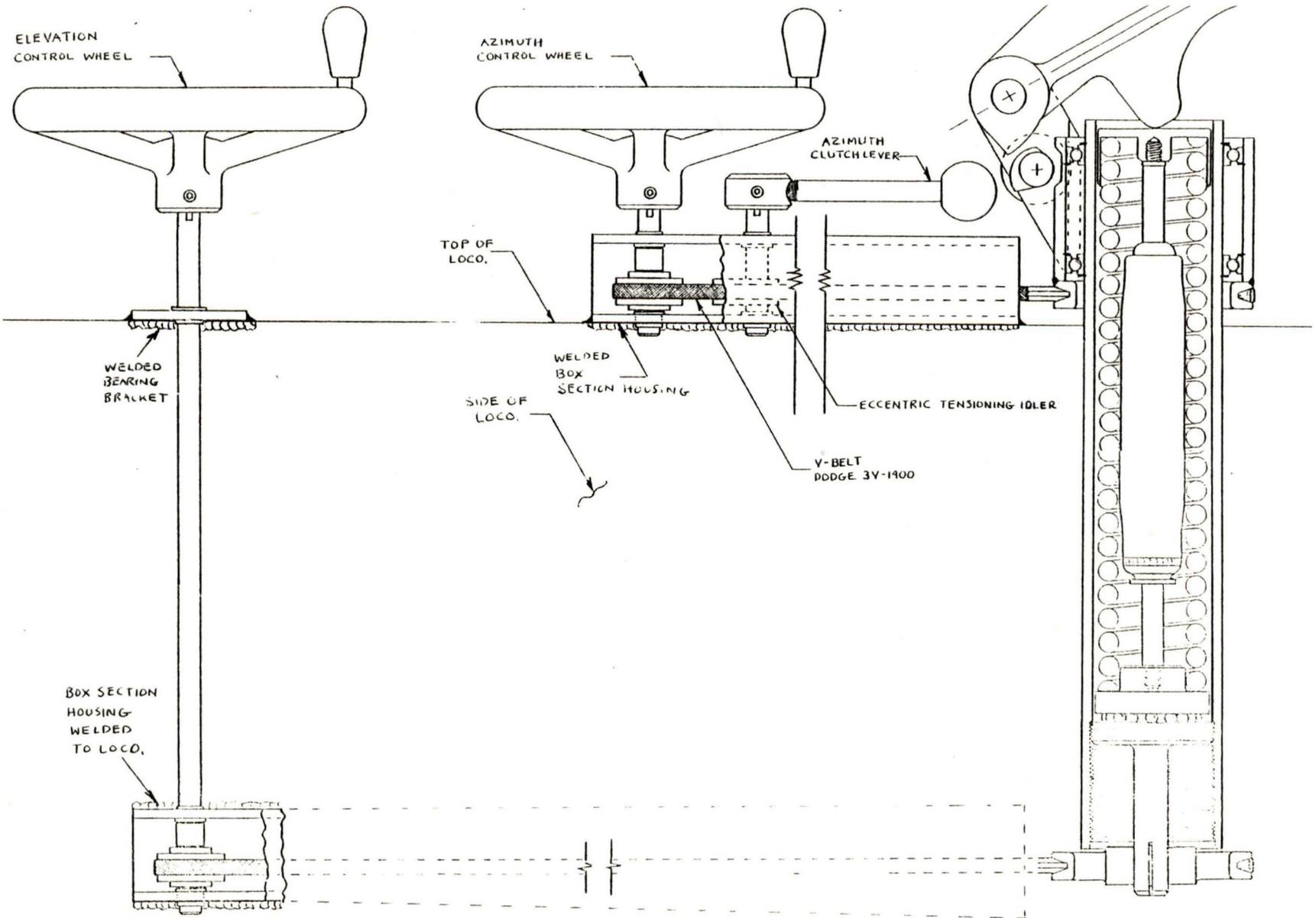


FIGURE 2.3-3
CONCEPT CC BASE ASSEMBLY

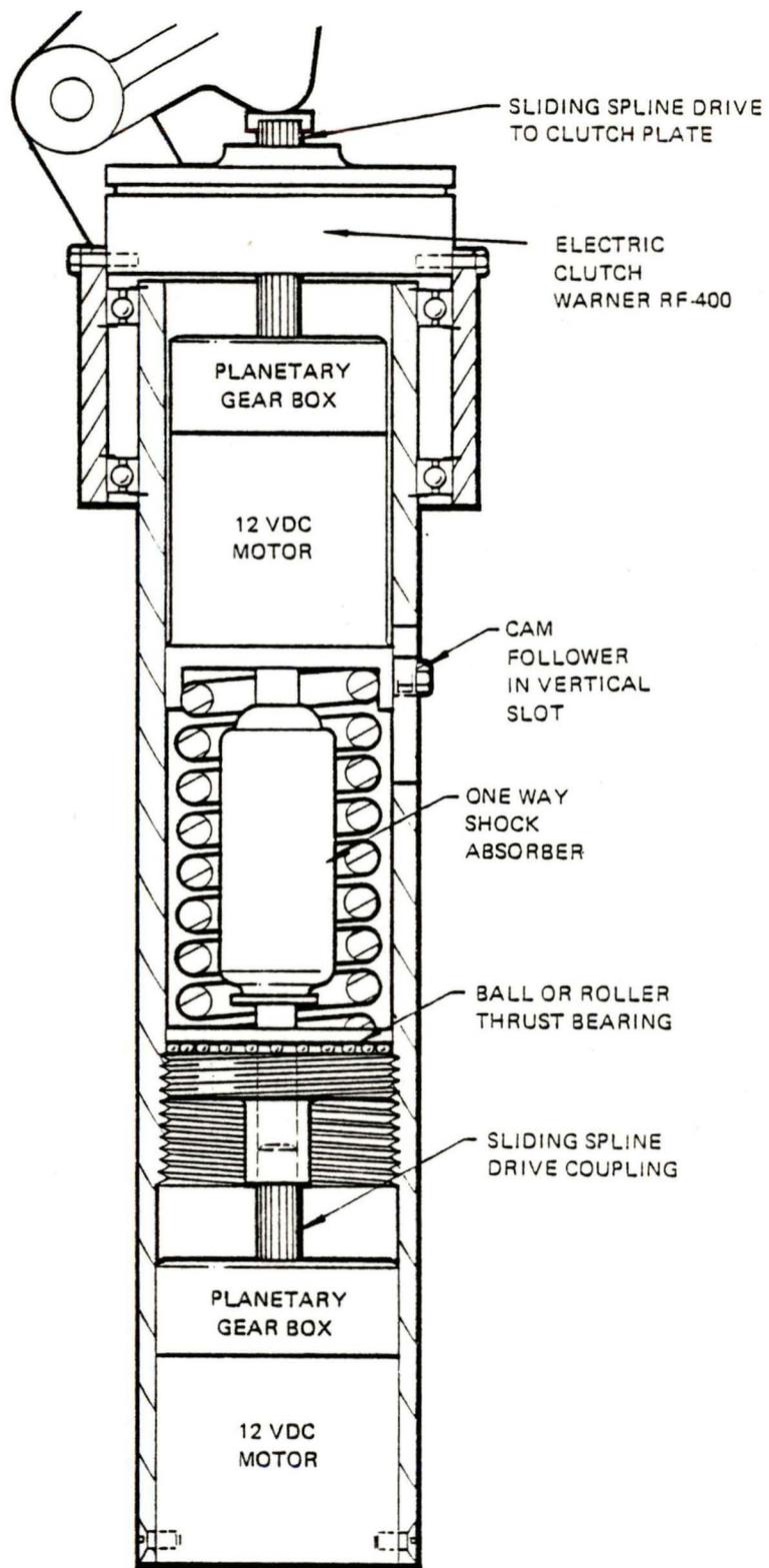


FIGURE 2.3-4
CONCEPT DD BASE ASSEMBLY

2.4 Phase IV Task Performance

2.4.1 Task Plan

On 23 February 1979, MBAssociates submitted the Phase IV Task Plan, the schedule for which is shown in Figure 2.4-1. This plan was for performance of the review, lab testing, design, manufacturing and testing of prototype concepts for an innovative trolley-pole base assembly which functions to (1) improve shoe tracking on the wire using a hydraulic shock absorber, (2) automatically retract pole upon dewirement of the shoe, and (3) allow remote operation of elevation and azimuth of the pole by the motorman so as to allow present locations of the trolley pole, or the option of relocation to a position not hazardous to the motorman.

2.4.2 Concept Review

The first of Phase IV was devoted to a review of Concepts AA and CC. Even though AA showed the most promise, all USBM and MBA engineers concerned with the correct final choice wanted to be certain that AA was the best choice. We, therefore, constructed a working model of Concept CC in our laboratory (see Figures 2.4-2 and 2.4-3). It included the shoe, harp, wood pole, pole socket, and a standard West Virginia Armature base assembly mounted on a pair of ball bearings and driven by a sprocket, toothed-belt and hand-wheel arrangement. It did not include the elevation control for the pole, as we were most concerned with the speed of azimuth motion which would be practicable when "human arm powered."

The CC azimuth tests, including harps of two weights, showed that the all-mechanical manual system would indeed be simple, but considering the requirement for two-handed operation (elevation and azimuth hand-wheels), and the large human powered torque required, we concluded that this type of design would probably be unacceptable to the coal mine personnel. (See Table 2.4-1).

Concept AA was given a final evaluation and found to be better than thought at the end of Phase III. This was due to the fact that the assembly could be simplified by removing the rotary solenoid and cam mechanism and substituting an additional automatic (upon loss of 300V trolley power) function of the hydraulic cylinder elevation device. The detailed design was, therefore, immediately initiated with long-lead-time items designed first.

Also investigated was the make, size, and quantity of coal mine locomotives now in use in the United States (see Appendix).

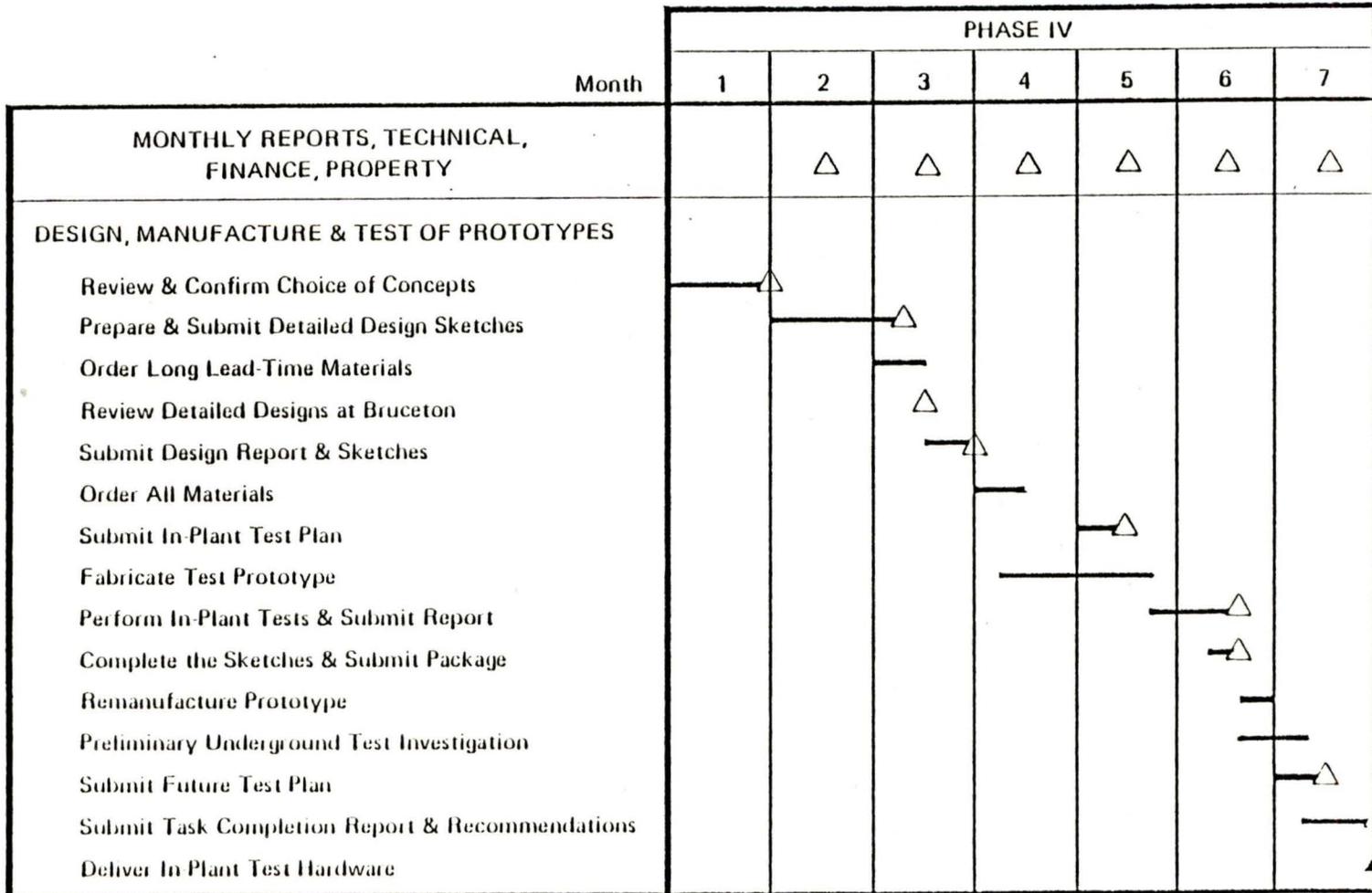


Figure 2.4-1
PROGRAM SCHEDULE & MILESTONES

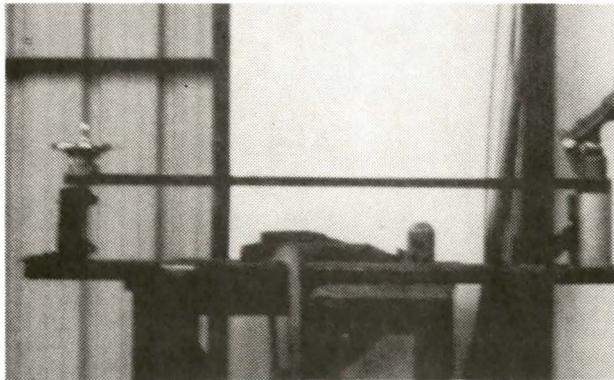
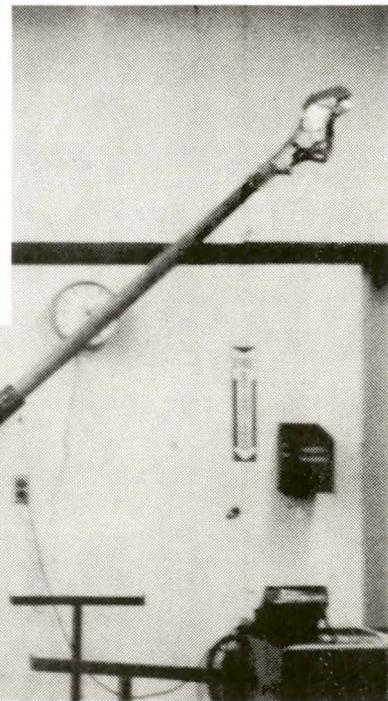
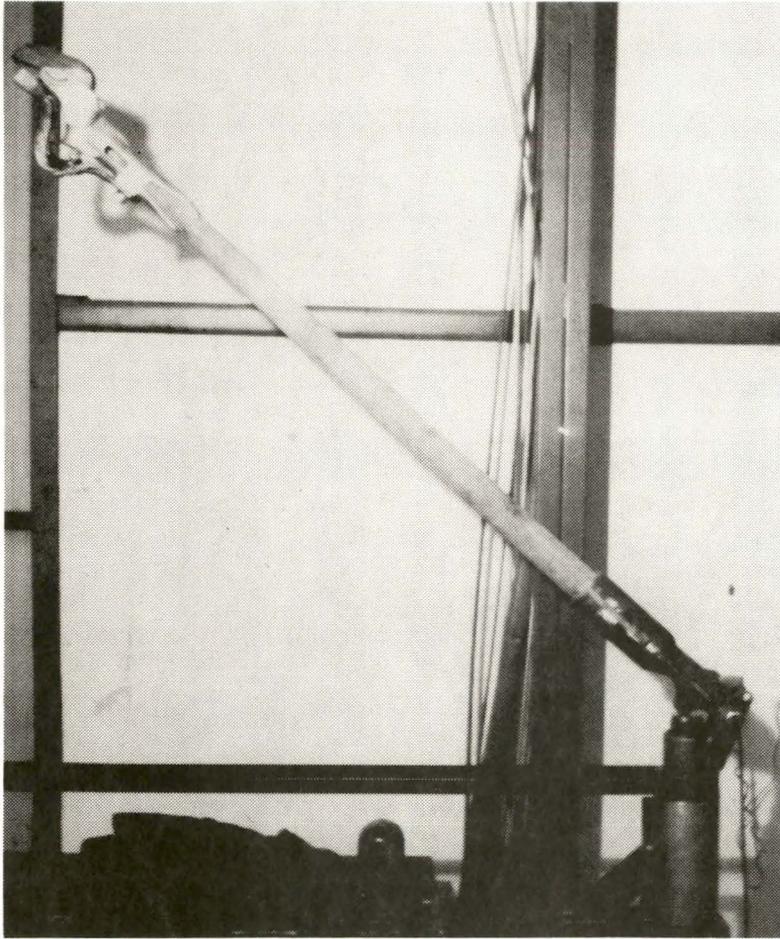


FIGURE 2.4-2
CONCEPT "CC" - BREADBOARD TEST SETUP

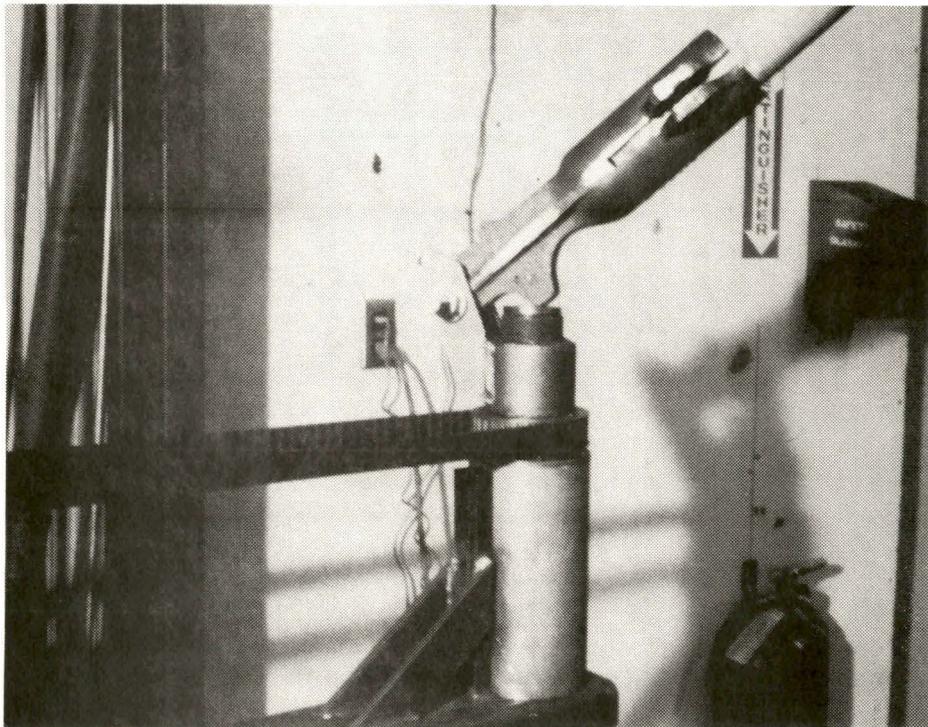
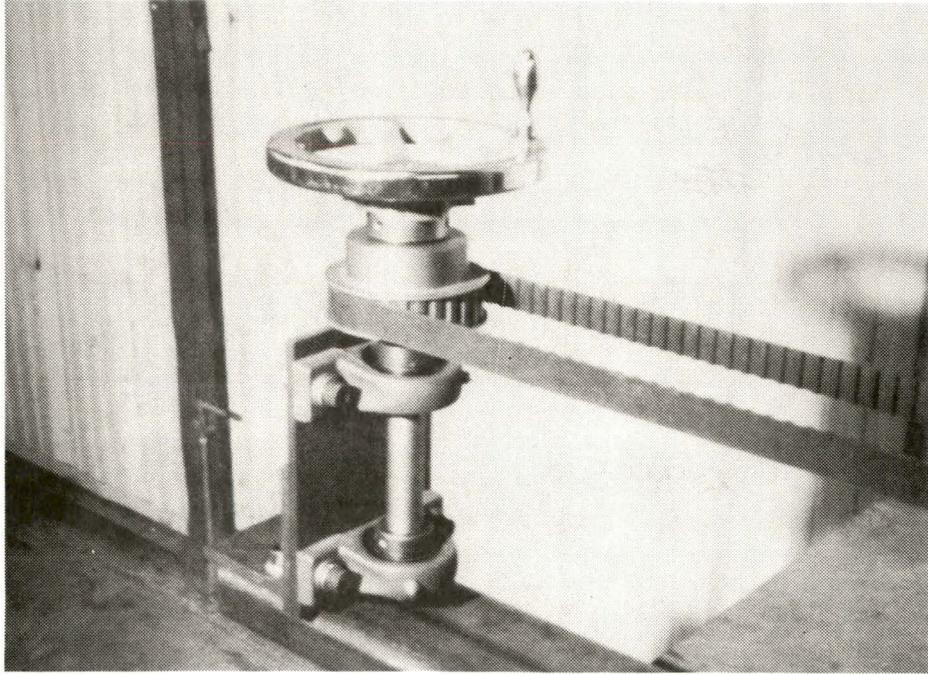


FIGURE 2.4-3
CONCEPT "CC" - BREADBOARD TEST SETUP
CLOSEUP VIEW OF DRIVE AND DRIVEN ENDS



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2.4.3

Concept AA Prototype Design

Almost all of the long-lead-time items required were for the azimuth torque motor part of the prototype. These included laminations, brushes, magnets, etc. Therefore, the calculations and sketches (see Appendix) for the motor were produced as soon as possible and all long-lead items ordered immediately thereafter. The bearings were ordered from Kaydon, the spring from Scandic, the shock absorber from Koni, laminations from Fotofabrication Corporation, magnets from Allen-Bradley, commutator materials from American Brass and Copper, bus-bars from Essex Wire, seals from Minnesota Rubber, and the hydraulic pump unit (without reservoir) from John S. Barnes Company.

As soon as the critical parts were ordered, the sketches required to manufacture the remaining parts in the MBA shop were continued to completion, and the parts made in our shop as soon as approved by the TPO. (Note that the above infers some of the sketches were semi-complete. This was true and was done to enable the earliest ordering of parts which MBA does not manufacture such as laminations, brushes, brush holders and magnets. All were "specials," the particular designs never having existed before, and not available "off-the-shelf" or catalogued by any manufacturer).

Portions of the design package were submitted to the TPO with each monthly report as the various sketches were completed.

2.4.4

Design Review at Bruceton

On 25 April 1979, the MBA Program Manager visited the TPO at Bruce, Pennsylvania. All of the design sketches and drawings produced to that date were reviewed by the TPO. All progress to date was explained by MBA's Program Manager, and in the afternoon the USBM locomotive was inspected, measured, and photographed. We discussed and planned the installation of "defective" trolley wire parallel to the existing conductor, and also an MBA-supplied special mounting bracket to interface between the prototype Trolley Pole Base Assembly and the external end of the locomotive. This bracket was completed and shipped to the TPO on 10 July 1979.

2.4.5

Completion of FCB Design Details

Upon approval by the TPO, MBA produced the additional tooling sketches for manufacture of the armature and commutator. These were not design specification drawings, but instead were manufacturing instructions, etc. Typical is the mold sketch (see Appendix) for casting the commutator bars within an epoxy ring.

2.4.6 Nomenclature

At approximately this point in time the design was firm enough to develop nomenclature for the base assembly and other units which complete the system. We, therefore, have since that time consistently used the following designations:

- RCB (Remotely Controlled Base Assembly)
- RCL (Remote Control Lever)
- SAU (Servo Amplifier Unit)
- Battery (small 36 volt lead-acid storage battery)
- RCB System (the RCB, RCL, SAU and Battery cabled together)

The above designations will be used in all the following text of this report.

2.4.7 Fabrication of Prototype RCB

2.4.7.1 Stator

The tubular non-rotating support which houses the main spring, shock absorber, hydraulic cylinder, ball bearings, field magnets and brush rigging plate was manufactured first. As soon as cadmium plated per Federal Specification QQ-P-416, Type II, Class 3, the stator was shipped to Allen-Bradley for bonding of the field magnets to the outside surface.

Allen-Bradley did a very superior job, and when returned to MBA, the magnets proved to measure within .001 inches of concentricity with the outside diameter of the tube and its bearing mounting surface.

The main spring, shock absorbers, bearings, spacers, and the potentiometer drive gear were then assembled to the upper part of the stator tube, and the brush hangers to the lower part, thus completing this subassembly. (See Appendix for assembly sketches.)

2.4.7.2 Rotor

The cast aluminum (Consolidated Alloy 201-T7 at 68,000 to 78,000 psi, tensile) housing was produced for MBA by Pacific Pressure Cast Products, and then machined to its final inside diameter and outside diameter at MBA. The laminations produced by Fotofabrication to our special design were bonded together at MBA, using 3-M #2290 epoxy which was developed especially for this use, and along with the commutator made by MBA from epoxy-encapsulated machined copper, was sent to Advance Electric for winding and assembly of the two pieces into the finished armature subassembly. (See Figures 2.4-4, -5 and -6.)

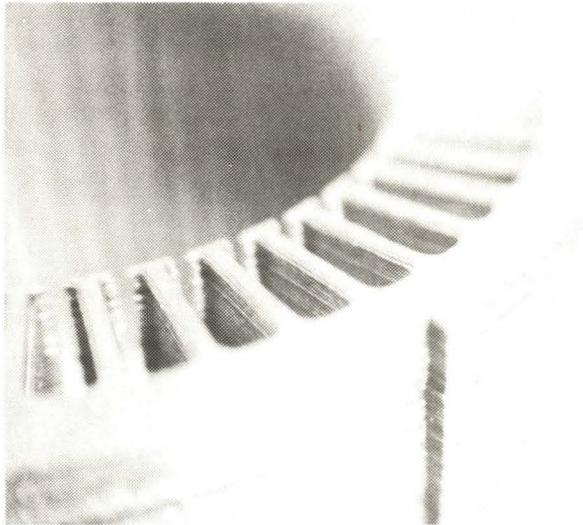
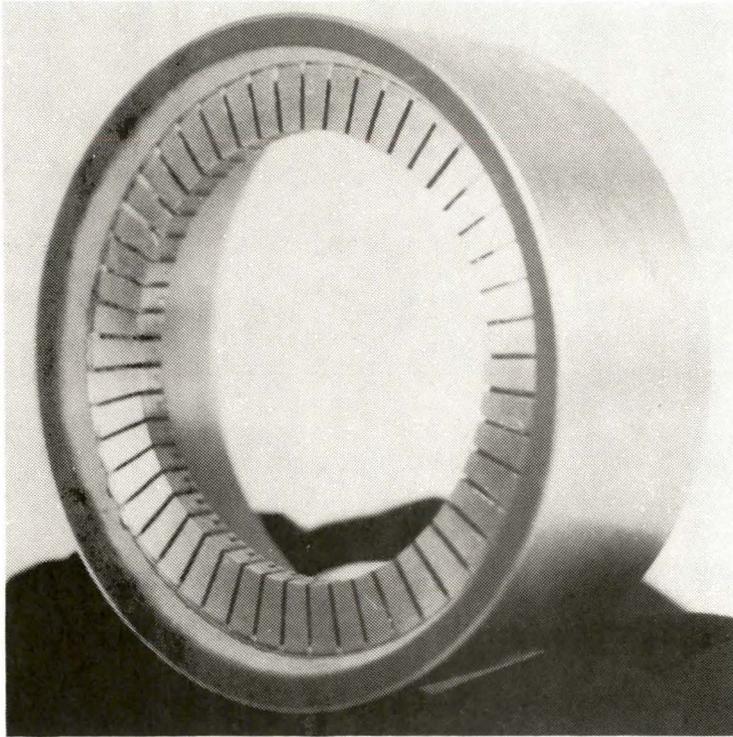
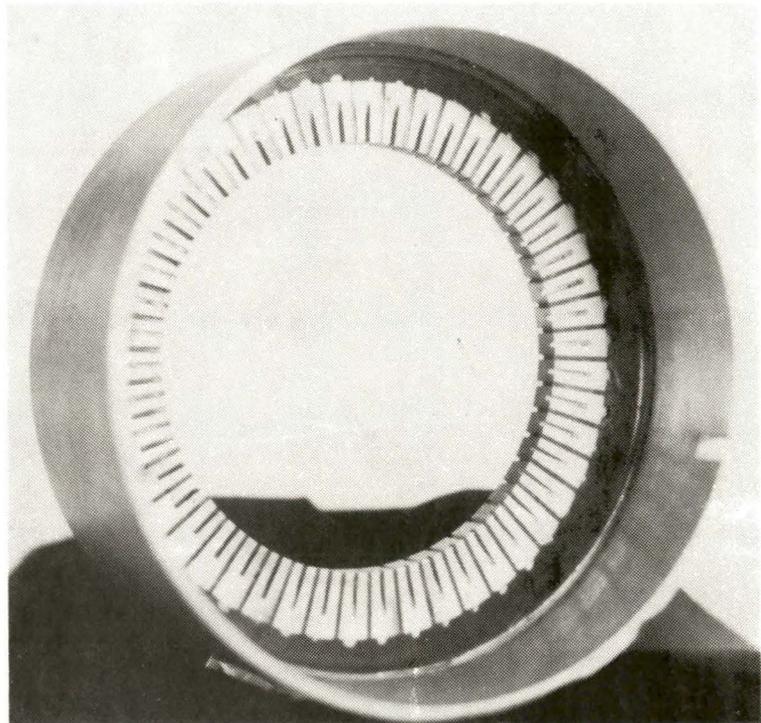


FIGURE 2.4-4
ARMATURE LAMINATION STACK
(Without coils and commutator)

MBA
1089-16651



BRUSH SIDE

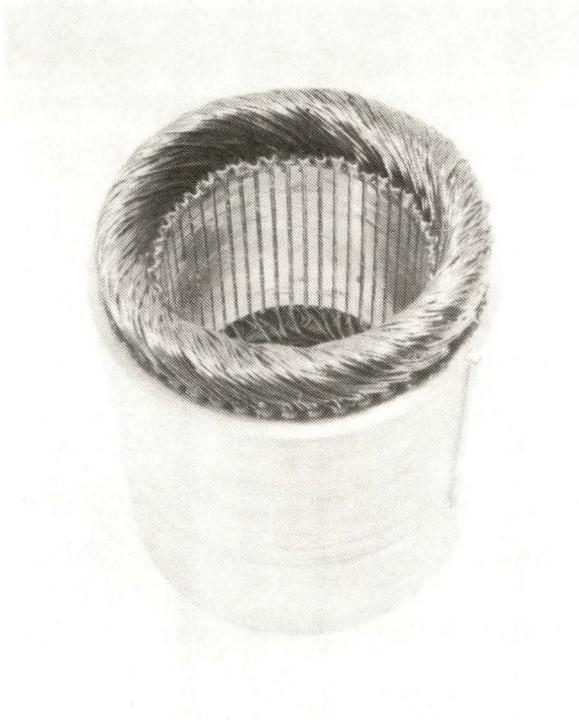


WIRING SIDE

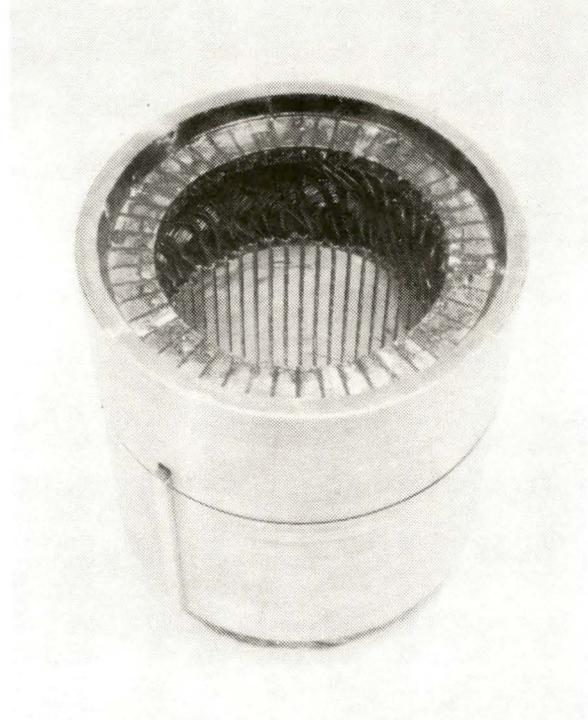
FIGURE 2.4-5
MOLDED COMMUTATOR ASSEMBLY



2089-16744



TOP END



COMMUTATOR END

FIGURE 2.4-6
ARMATURE/COMMUTATOR SUB-ASSEMBLY

This armature passed all magnetic, resistance, and insulation tests, showing it to be of superior construction.

The armature subassembly and the machined aluminum housing were furnished at about the same time and were immediately assembled along with the spanner-tightened ring nut and $\frac{1}{4} \times \frac{1}{4}$ inch key. This assembly sequence involved heating the housing to 400°F and before cooling, pressing the armature assembly completely into the housing and against the internal shoulder. The ring nut was then immediately screwed in and torqued tight before the aluminum could shrink very much. This procedure insured a very solid rotor assembly. (See Appendix for assembly sketches.)

2.4.7.3 Hydraulic Subassembly

This unit consists of a ring-attached (threads on the bottom of the stator) manifold which houses a check valve for the pump discharge circuit, and a solenoid valve for the cylinder discharge circuit (dump valve to lower the pole). This manifold also serves to mount the motor-pump unit and the reservoir, along with the hydraulic circuit tubing and a pressure-relief valve (pump bypass).

After cadmium plating to the same specification as the stator finish, the above parts were lubricated and assembled, and as a subassembly air-tested for leaks.

When no leaks were detected, this hydraulic subassembly was fastened and sealed to the bottom of the stator with the threaded ring. (This ring allows radial adjustment of motor-pump and reservoir position.) The Appendix contains the assembly drawing, showing the stator, rotor, hydraulic subassembly, pole socket, and other details of the basic RCB Assembly. (Also see Figure 2.4-7.)

2.4.7.4 Preliminary Bench Testing at MBA

The torque motor was bench tested and found to operate exactly as required when energized with a peak of 36 volts D.C. The no-load speed was 191 R.P.M. and the peak torque at 27.8 amps was significantly greater than the 36 ft.-lbs. at locked rotor, which the initial design calculations had indicated.

2.4.7.5 SAU Procurement and RCL Fabrication

The servo amplifier could not be ordered (from M. Williams Associates) until the actually-tested performance of the motor was known.

While this unit was being designed and manufactured for MBA to our specifications, we concentrated our efforts on the design and manufacture of an RCL assembly which would be compatible with the torque-motor, valving, and hydraulic pump motor. This unit was fabricated and installed into a small sealed NEMA enclosure in conformance with the RCB System Schematic sketch and mechanical detail sketch contained in the Appendix.

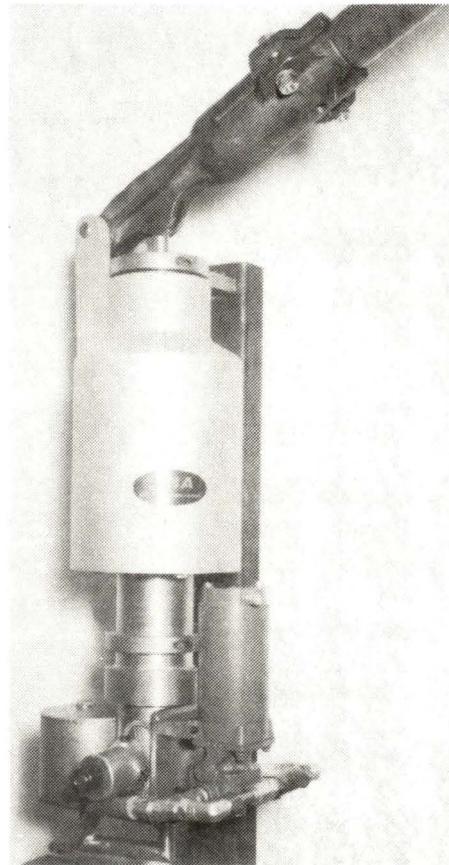
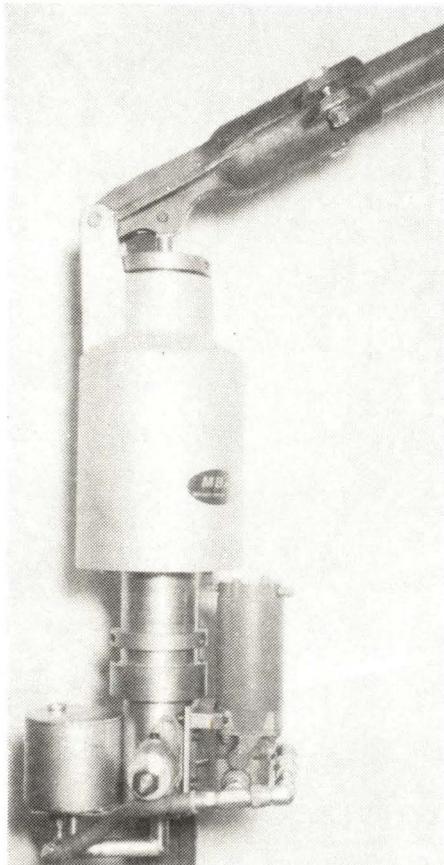


FIGURE 2.4-7
REMOTELY CONTROLLED BASE (RCB)

MBA
2089-16743

2.4.7.6 SAU Subassembly

The specifications for the SAU are contained in the Appendix. When delivered by Williams and subsequently modified by Williams and MBA, this unit finally performed satisfactorily during bench testing. It caused an additional problem (200 to 1000 Hz oscillation) before we started the test series at Bruceton but was repaired, debugged, readjusted and did the required job during Bruceton in-plant tests (even though it would occasionally oscillate for a few hundred milliseconds, there was no circuit damage). This unit should be improved. (See 3.0 Recommendations.)

2.4.7.7 Final Bench Tests at MBA

After the RCB was completely assembled, with the pretested subassemblies, it was mounted on a weldment frame and the frame clamped to our lab bench. The WVA standard type pole socket was added, along with the special ball-link which interfaces to the main-spring assembly and the pole and harp.

The remaining pieces of the RCB System were cabled to the RCB (RCL, SAU, and Battery) and several days of testing conducted.

We found that the RCB System performed better than expected, especially pertaining to the azimuth torquer performance. We consistently obtained an angular velocity of 110° per second while slewing this angle and the shoe and harp could be easily controlled to an accuracy of better than $\frac{1}{2}$ inch.

During the "real situation" tests at Bruceton, the RCL design contributed to difficulties of azimuth and elevation control experienced by people who had never previously operated the system. With improvement in the RCB System design and especially the RCL (human engineering), this Remotely Controlled Base System can be an important factor in improving the safety on coal mine locomotives.

2.4.8 In-Plant Tests at Bruceton

The testing was performed with the RCB System mounted on USBM's locomotive during the week of 24 September 1979. The Test Report has been submitted and details the measurements of performance on the locomotive, both of the existing completely manual trolley pole which came with the vehicle, and the RCB System with heavy and light weight harps.

3.0 RECOMMENDATIONS

MBAssociates recommends that this trolley pole system improvement effort be continued by performance of the following tasks:

3.1 Review and Analyze the Phase IV Test Data

Much was learned by MBA's Program Manager and USBM's TPO during the performance of tests at Bruceton in September 1979. The test data should be reviewed and any necessary analysis performed in order to gain maximum benefit from Phase IV experience in general and tests in particular.

The human-machine interface is of great importance and the difficulties experience during testing will go far in helping to improve the RCB System and any other peripherals. MBA recommends maximum useful application of this data.

3.2 Product Engineer the RCB System

3.2.1 Redesign of RCB for Compactness and Low Cost

We found, during prototype construction, that certain design changes would contribute to reduction of costs of the System when produced in volume. We also found that the initial (Phase IV) prototype was larger, (taller) than ideal, and also heavier. Figure 3.2-1 shows this existing prototype along with an illustration of an improved unit of reduced size and weight. MBA recommends that an improved RCB be designed from the viewpoint of "Product Engineering."

3.2.2 Redesign of the RCL for Compatibility with Motorman

During the Phase IV tests, it was learned that coordination by the motorman of the RCL (Remote Control Lever) with the trolley pole was extremely difficult for someone who had never operated the system, moderately difficult for a person with several hours practice, and would only have a possibility of ease-of-control for a person with many hours of practice.

The reponse of the RCL aximuth torque motor and elevation hydraulic cylinder with its valve were satisfactory, but the human engineering of the lever had not been optimized in the initial prototype RCL.

MBA recommends that the RCL be redesigned, stressing human engineering considerations, for optimum control of the RCB System by the motorman.

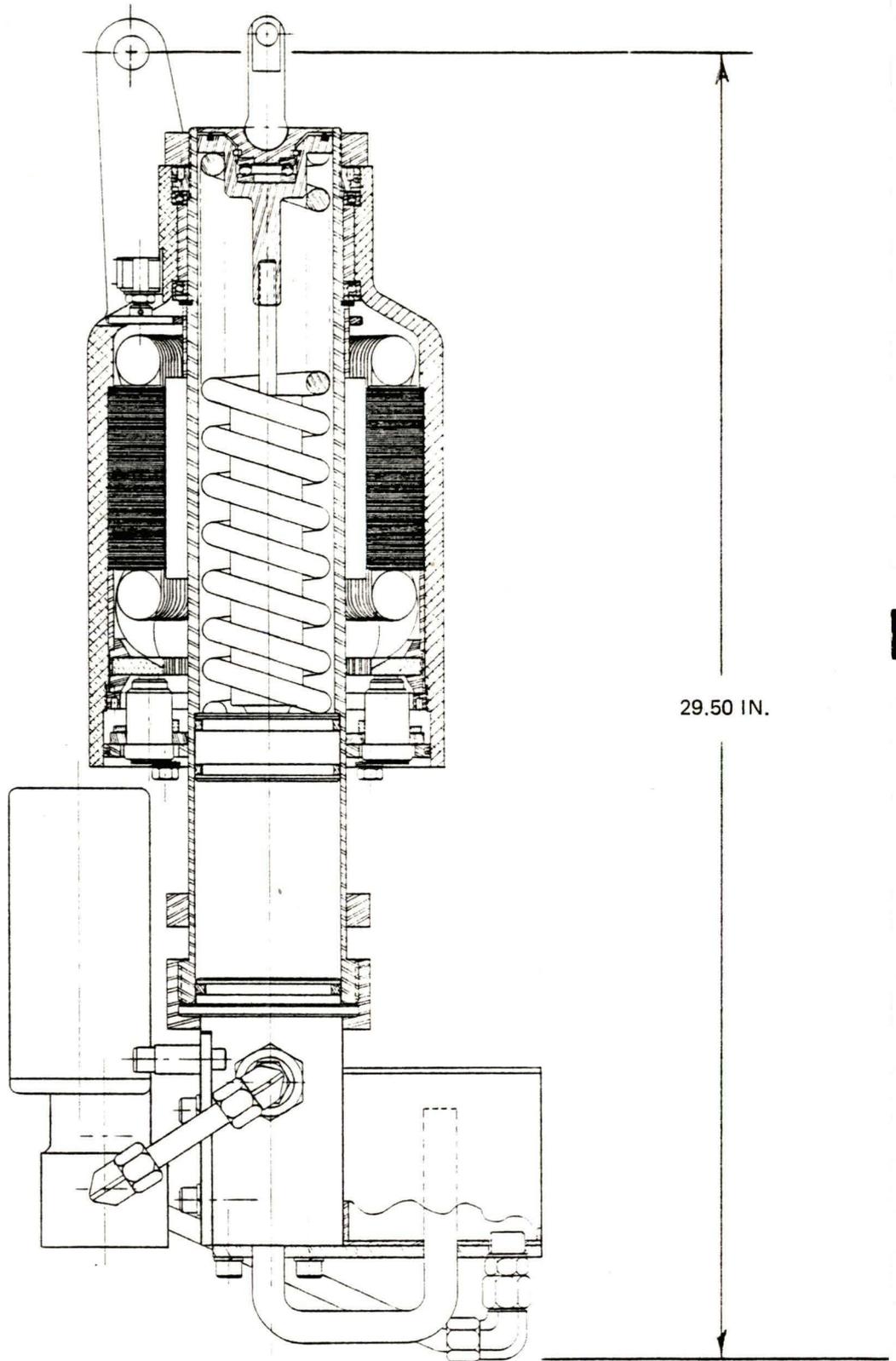


FIGURE 3.2-1A
REMOTELY CONTROLLED BASE

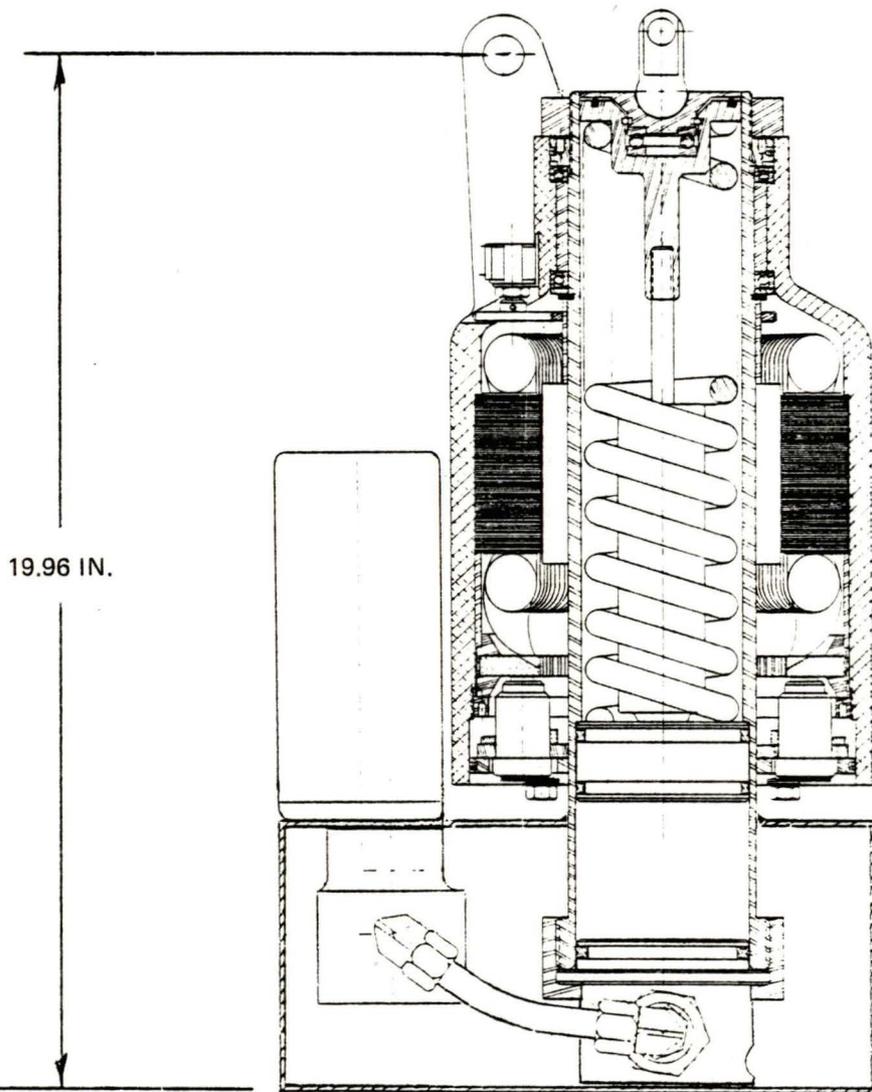


FIGURE 3.2-1B
COMPACT REMOTELY CONTROLLED BASE

3.2.3 Redesign of the SAU for Compactness and Low Cost

The Servo Amplifier Unit which interfaces the aximuth control portion of the RCL to the torque motor can be redesigned to be less than half the size and weight of the initial prototype, and also to be much less costly to produce. MBA recommends that this redesign be done.

3.3 Design Innovation Harp for Improved Tracking on Wire

Two of the concepts generated during Phase I of this Program were for improvement of the Harp and Shoe Assembly at the top of the trolley pole. This was explained in much detail in the Phase I monthly reports and summarized in Section 2.1.1 of this Phase IV Report (see Figure 2.1-1A and B.)

MBA recommends that a prototype (or possibly a prototype of each concept) be designed (and manufactured, and tested at Bruceton) along with the improved RCB System as follows.

3.4 Manufacture One Prototype RCB System and One Prototype Harp(s)

MBA recommends that upon review (oral) and approval of the above design, these items be manufactured for prototype testing.

3.5 Conduct In-Plant Tests of Improved RCB System and Harp(s)

MBA recommends that the innovative RCB and Harp prototype be thoroughly tested using the USBM locomotive and railroad at Bruceton, Pennsylvania.

These tests, if practicable, should be with more than one length of trolley pole. Of even greater importance, the vehicle should be in motion during some of the tests in order to obtain as much data as possible for the feasibility study which follows.

3.6 Conduct Feasibility Study and Generate Concepts for RCB/
Pole Guidance

MBA feels that maximum application of a successful man-operated RCB System will only be attained if the system is also successfully operated with no motorman on the locomotive. We suggest, therefore, that an automatic guidance system would be of great benefit. We suggest that a feasibility and concepts generation study be conducted after the results of the RCB and Harp Tests are completed.

APPENDIX

PHASE I
MSHA DATA

SUMMARY

Disabling Injuries Caused by Trolley Pole or Trolley Wire
Yearly Totals - 1972 through 1977
(Cause 1401)

<u>Year</u>	<u>Injuries</u>	<u>Disability Days</u>
1972	47	440
1973	37	282
1974	32	592
1975	28	341
1976	44	1,047
1977	<u>43</u>	<u>1,819</u>
Total	231	4,521
Average Per Year	39*	754*

* Average total injuries and disability days per year for all U. S. coal mines with trolley powered haulage.

SUMMARY OF ESTIMATES
OF QUANTITY OF POLE BASES IN USE

(Based on Locomotives in Use)

<u>Source</u>	<u>Estimate</u>
<u>Keystone Mine Directory</u>	At least 2,000 large haulage locomotives.
<u>General Electric</u> , Guy Jacobs, Sales Manager, G.E. Locomotives	Approx. 5,000 G.E. Locos (33%) Approx. 5,000 Jef. Locos (33%) Approx. 2,500 Goodman Locos (17%)
(Guy assured me that these are "close" to the actual quantities)	Approx. 1,500 Westinghouse Locos (10%) Approx. <u>1,000</u> Atlas (7%)
	Subtotal Approx. 15,000 of all make locos. Plus Approx. <u>15,000</u> other trol. vehicles
Total Trolley Pole Bases	30,000
<u>Goodman Equip. Corp.</u> , Wayne Gerdes, V.P., Marketing	Approx. 15,000 Locos by all mfgs. Approx. <u>15,000</u> other trol. vehicles
Total Trolley Pole Bases	30,000 now in use
<u>FMC/Mining Equip Div.</u> , Joe Leary, Sales Manager	2,000 FMC bus & util vehs 250 FMC drills, etc. <u>would</u> not guess other mfg veh.
Total Bases on FMC Vehicles	2,500 now in use
<u>Jeffrey Mining Machinery</u> , Don York, Sales Manager (614) 421-3010	Because their first loco was made in 1888, and they don't know the replacement scenerio he couldn't guess % or numbers.

G.E. Haulage Locomotives (33% of underground units)

<u>Ident. No.</u>	<u>Op. Wt.</u>	<u>Total H.P.</u>	<u>Motors</u>	<u>Width</u>	<u>Length</u>
RY24826	50T	640	4	*	*
RY24824	37T	528/460	4		
RY24823	25T	320	2		
RY24822	20T	264	2		
RY24821	20T	264	2		

G.E. doesn't manufacture any standard locos in the 3 to 18 ton range. All small units are specials, and are seldom used underground.

*Above info. from Mr. P. H. Whitney, G.E., S.F., 415/546-4202. The lengths and widths promised, but not received; probably similar to Jeffrey and Goodman.

Jeffrey Haulage Locomotives (33% of underground Units)

<u>Model</u>	<u>Op. Wt.</u>	<u>Total H.P.</u>	<u>Motors</u>	<u>Width</u>	<u>Length</u>
50A	50T	720	4	88 in	37.0 ft
50B	50T	720	4	90 in	37.3 ft
37A	37T	600	4	74 in	34.3 ft
37B	37T	600	4	74 in	34.3 ft
37C	37T	600	4	84 in	34.5 ft
27A	27T	380	4	88 in	36.3 ft
37B	27T	380	4	80 in	31.0 ft
27C	27T	360	2	80 in	22.8 ft
20A	20T	300	2	82 in	22.5 ft
20B	20T	300	2	82 in	23.3 ft
15A	15T	190	2	70 in	20.0 ft
15B	15T	190	2	78 in	24.1 ft
11A	11T	100	2	78 in	18.7 ft
11B	11T	120	2	78 in	18.7 ft
8A	8T	80	2	66 in	17.1 ft
6A	6T	60	2	66 in	14.5 ft
6B	6T	60	2	60 in	14.5 ft

(above info from Don York at factory)

Goodman Haulage Locomotives (17% of underground units)

<u>Type</u>	<u>Op. Wt.</u>	<u>Total H.P.</u>	<u>Motors</u>	<u>Width</u>	<u>Length</u>
202	50T	680/800	4	84 in	36 ft 6 in
201	35T	496	4	73 in	33 ft 6 in
201	27T	400	4	73 in	33 ft 6 in
202	20T	340	2		23 ft 6 in
201	15T	200	2	68½ in	22 ft
136B	14T	150	2	74 in	19 ft 3 in
184	12T	130	2	74 in	19 ft
173B	11T	100	2	65-¾ in	13 ft 11 in
75DB	10T	60	2	69¼ in	18 ft 3 in
132AK	8T	80	2	65-¾ in	12 ft 8½ in
75BB	7T	60	2	69¼ in	17 ft 8½ in
T-Mule	3½T	18.5	1	64 in	13 ft 4 in/ 16 ft 8 in

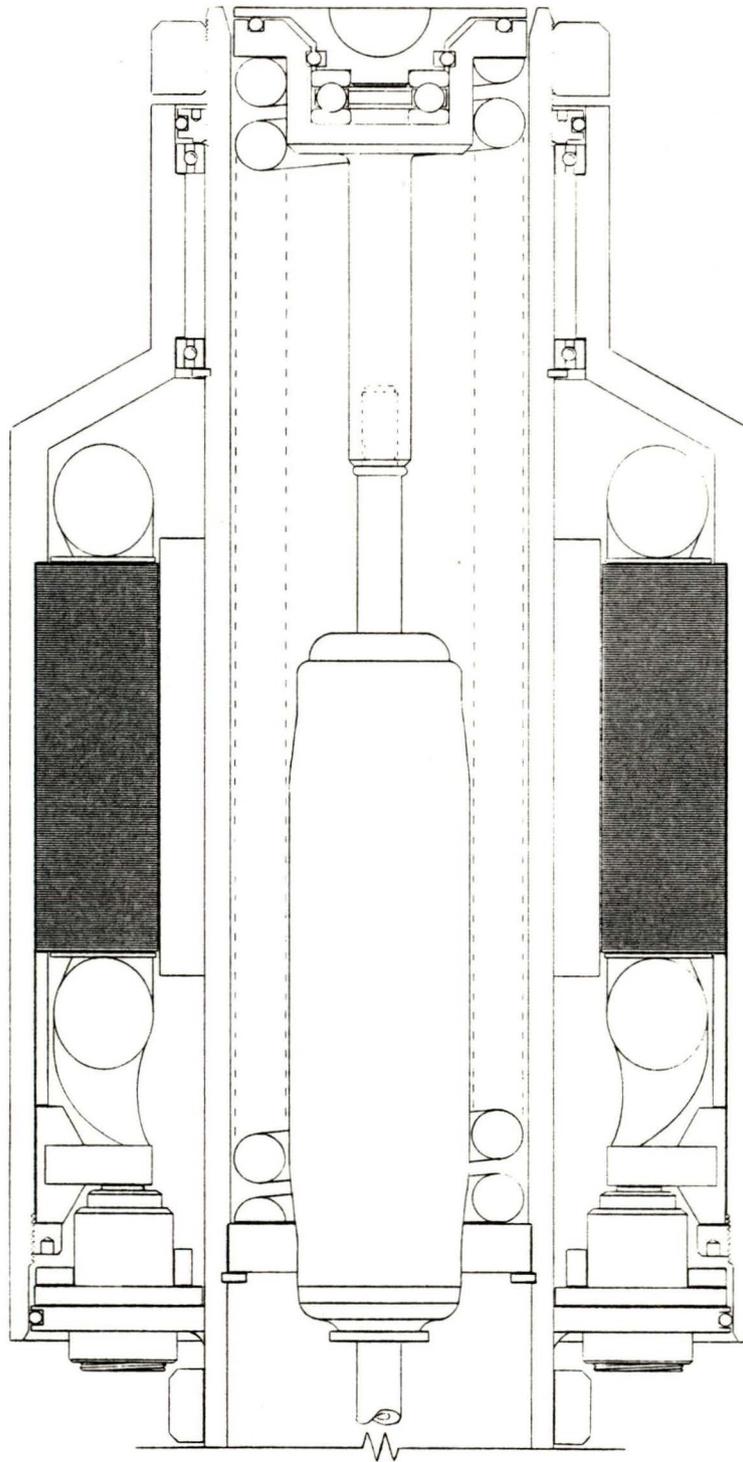
(above info from Catalogs & Wayne Gerdes)

Westinghouse Haulage Locomotives (10% of underground units)

Not manufactured since the 1960s. No info available.

Atlas Haulage Locomotives (7% of underground units).

No info available.



PROTOTYPE "AA"
TORQUER DESIGN SKETCH

SPEED AND TORQUE
49 SLOT MOTOR DESIGN
(wave-wound)

When:

$$\begin{aligned}
 m_a &= 2 \text{ (2 parallel paths through armature)} \\
 V_{\max} &= 36 \text{ (normal battery voltage)} \\
 V_{\min} &= 32 \text{ (battery under heavy current load)} \\
 I_a &= .90 \text{ no load (27.8 with locked rotor)} \\
 R_a &= 1.15 \ \Omega \text{ (49 wave-wound coils, 18T-AWG16, 1.27ft/turn)} \\
 P &= 6 \\
 Z &= 1764 \text{ (2 coil sides per slot x 18T per coil x 49 slots)} \\
 \emptyset &= 207,834 \left(\frac{\psi_m \times L_m \times r_{\text{mean}} \times B_r \times .1128 \times .962}{55^\circ \times 4.5'' \times 2.01'' \times 3850 \times .1128 \times 20 \text{ mil. gap loss}} \right) \\
 L_m &= 4.5 \text{ in.} \\
 l_m &= .48 \text{ in.} \\
 \psi &= 55^\circ
 \end{aligned}$$

Then:

$$\begin{aligned}
 S_{\max} &= 60 \times 10^8 \times m_a \times \frac{V_{\max} - (I_a \times R_a)}{p \times Z \times \emptyset} \\
 &= 60 \times 10^8 \times 2 \times \frac{36 - (.90 \times 1.15)}{6 \times 1764 \times 207,834} \\
 &= 1.2 \times 10^{10} \times \frac{34.965}{2.1997 \times 10^9} \\
 &= \underline{\underline{190.7 \text{ RPM}}} \text{ (3.18 RPS)}
 \end{aligned}$$

And:

$$\begin{aligned}
 T_{\text{peak}} &= .224 \times 10^{-6} \times \frac{p \times \emptyset \times Z \times V_{\min}}{m_a \times R_a \times 192} \\
 &= 2.24 \times 10^{-7} \times \frac{6 \times 207,834 \times 1764 \times 32}{2 \times 1.15 \times 192} \\
 &= 2.24 \times 10^{-7} \times \frac{7.0391 \times 10^{10}}{441.6} \\
 &= \underline{\underline{35.7 \text{ ft-lbs}}} \text{ peak (locked rotor w/27.83 amps)}
 \end{aligned}$$

TORQUER ROTOR INERTIA

6/20/79 A. St. Amant

Armature-Commutator Sub-assembly at .245 ft. = 27.5#

$$\begin{aligned}
 I &= \frac{W}{g} r^2 \\
 &= \frac{27.5}{32.174} \times .245^2 \\
 &= .855 \times .060 \\
 I &= \underline{\underline{.051}} \text{ lb. ft. sec}^2
 \end{aligned}$$

Rotor Housing Sub-assembly at .302 ft = 11.91#

$$\begin{aligned}
 I &= \frac{11.91}{32.174} \times .302^2 \\
 &= .370 \times .091 \\
 I &= \underline{\underline{.034}} \text{ lb. ft. sec}^2
 \end{aligned}$$

Pole Socket Casting at .375 ft = 8.00#

$$\begin{aligned}
 I &= \frac{8.00}{32.174} \times .375^2 \\
 &= .249 \times .141 \\
 I &= \underline{\underline{.035}} \text{ lb. ft. sec}^2
 \end{aligned}$$

Total Rotor Assembly Inertia

$$\begin{aligned}
 I_T &= .051 + .034 + .035 \\
 I_T &= \underline{\underline{.120}} \text{ lb. ft. sec}^2
 \end{aligned}$$

POLE ASS'Y INERTIAS

6/20/79 A. St. Amant

Lightened Harp with Small Shoe at 5.54 ft = 11.3#

$$\begin{aligned}
 I &= \frac{W}{g} r^2 \\
 &= \frac{11.3}{32.174} \times 5.54^2 \\
 &= .351 \times 30.69 \\
 I &= \underline{\underline{10.77}} \text{ lb. ft. sec}^2 \text{ (Plus .120 rotor inertia = } \underline{\underline{10.89}} \text{ total)}
 \end{aligned}$$

Lightened Harp with Large Shoe at 5.54 ft = 13.2#

$$\begin{aligned}
 I &= \frac{13.2}{32.174} \times 5.54^2 \\
 &= .410 \times 30.69 \\
 I &= \underline{\underline{12.59}} \text{ lb. ft. sec}^2 \text{ (Plus .120 rotor inertia = } \underline{\underline{12.71}} \text{ total)}
 \end{aligned}$$

Standard Harp with Small Shoe at 5.54 ft = 12.8#

$$\begin{aligned}
 I &= \frac{12.8}{32.174} \times 30.69 \\
 I &= \underline{\underline{12.21}} \text{ lb. ft. sec}^2 \text{ (Plus .120 rotor inertia = } \underline{\underline{12.33}} \text{ total)}
 \end{aligned}$$

Standard Harp with Large Shoe at 5.54 ft = 14.7#

$$\begin{aligned}
 I &= \frac{14.7}{32.174} \times 30.69 \\
 I &= \underline{\underline{14.02}} \text{ lb. ft. sec}^2 \text{ (Plus .120 rotor inertia = } \underline{\underline{14.14}} \text{ total)}
 \end{aligned}$$

MOTOR ACCELERATION

$$(T_M = 87.87 \text{ ft-lbs})$$

$$A = \frac{T_M}{I_T} \quad \text{and} \quad t = \sqrt{\frac{2\theta}{\alpha}}$$

Loaded with Lightened Harp and Small Shoe

$$I_T = 10.89 \text{ lb. ft. sec}^2$$

$$A = \frac{35.7}{10.89} = \underline{\underline{3.28}} \text{ radians/sec}^2 = \underline{\underline{10^\circ \text{ in } 512 \text{ ms}}}$$

Loaded with Lightened Harp and Large Shoe

$$I_T = 12.71 \text{ lb. ft. sec}^2$$

$$A = \frac{35.7}{12.71} = \underline{\underline{2.81}} \text{ radians/sec}^2 = \underline{\underline{10^\circ \text{ in } 553 \text{ ms}}}$$

Loaded with Standard Harp and Small Shoe

$$I_T = 12.33 \text{ lb. ft. sec}^2$$

$$A = \frac{35.7}{12.33} = \underline{\underline{2.90}} \text{ radians/sec}^2 = \underline{\underline{10^\circ \text{ in } 543 \text{ ms}}}$$

Loaded with Standard Harp and Large Shoe

$$I_T = 14.14 \text{ lb. ft. sec}^2$$

$$A = \frac{35.7}{14.14} = \underline{\underline{2.52}} \text{ radians/sec}^2 = \underline{\underline{10^\circ \text{ in } 583 \text{ ms}}}$$

HARP ASSEMBLY WEIGHTS

O-B Harp Ass'y w/Large Shoe

Std. Shoe	3.50#	
Std Nuts & Bolts, Shoe35#	
Standard Shoe Ass'y	3.85#	
Shunt	2.15#	
Harp Ass'y	<u>6.48#</u>	
Standard Assembly	<u>12.48#</u>	
Std. Shoe Ass'y	3.85#	
Alum. Braid Shunt	1.18#	(M _{Cu} x .33 x 1.65)
Alum. Harp Ass'y	<u>2.29#</u>	(M _{Fe} x .353)
Alum Ass'y w/Std. Shoe	<u>7.32#</u>	
Composite Alum/Iron Shoe Assy	2.61#	(M _{Fe} x .5)+(M _{Fe} x .177)
Alum. Braid Shunt	1.88#	
Alum. Harp Ass'y	<u>2.29#</u>	
Alum Ass'y w/Alum-Iron Shoe.	<u>6.08#</u>	

CRITICAL PURCHASED COMPONENTS

<u>Part Description</u>	<u>Manufacturer</u>	<u>Model/Part Number</u>
Ball Bearing	Kaydon/Keene	KB035ARO
Thrust Bearing	Aetna	1102
Spur Gear, driven	PIC design	P17-4-48
Spur Gear, drive	PIC design	G44-132
Epoxy/Glass, ¼ inch	General Electric	NEMA FR-4
Brushholder, 7/16x7/16x1	Advance Carbon Products	1.00 O.D. (Press Fit)
Felt Seal Strips	Boothfelt	62DA24-125 (3/16x1/8)
Armature Lam. Adhesive	3M Company	2290 (Scotch-Weld)
Commutator Cast. Resin	3M Company	5064
Potentiometer	Bourns	3543S-1-103
Shock Absorber	Koni America	80-2289-SPA (E-OKG, R-100KG)
Motor/Pump, 12 VDC	John S. Barnes	GC-3958-12-A
Cartridge Check Valve	Fluid Controls	3C60-S
Solenoid Valve	FPS Div., Ambac	5-039-4, w/coil 6010030
Relief Valve	Circle Seal	5159S-3MP-200
Hydraulic Fluid, UCON	Union Carbide	Hydraulube CC-746
Relay	Potter-Brumfield	KRP-11-AG-240VDC
Battery, Lead-Acid, 12V	Any BCI Standard	GT9L

MAIN SPRING

Vendor

Scandic Spring Co.
 901 Montague Avenue
 San Leandro, CA. 94577
 (415) 352-3700
 Mr. Eric Eckberg

SPRING FOR CONCEPT AA

O.D. —————	2.900	
I.D. —————	1.900	
Wire Dia ————	.500	$\frac{D}{d} = 4.8$
Mean Dia ————	2.400	
Total Coils ———	21	
Active Coils ———	19	
Free Lgth ————	15.0 (squared and ground)	
Weight —————	8 # 9 oz	

FIND: Spring Rate

$$R = \frac{Gd^4}{8ND^3} = \frac{10.5 \times 10^6 \times .5}{8 \times 19 \times 2.4^3} = \frac{6.563 \times 10^5}{2101.25} = \underline{\underline{312.3 \text{ lbs/in}}}$$

FIND: Load at Solid Height

$$P = (H-h) \times R = (15-10.5) \times 312.314 = \underline{\underline{1405.4 \text{ lbs}}}$$

FIND: Stress at Solid Height

$$S = \frac{GFd}{\pi ND^2} = \frac{10.5 \times 10^6 \times 4.5 \times 15}{3.14 \times 19 \times 2.4^2} = \frac{2.3625 \times 10^7}{3.4382 \times 10^2} = \underline{\underline{68,714.1 \text{ PSI}}}$$

Shock Absorber Type: 80-2239

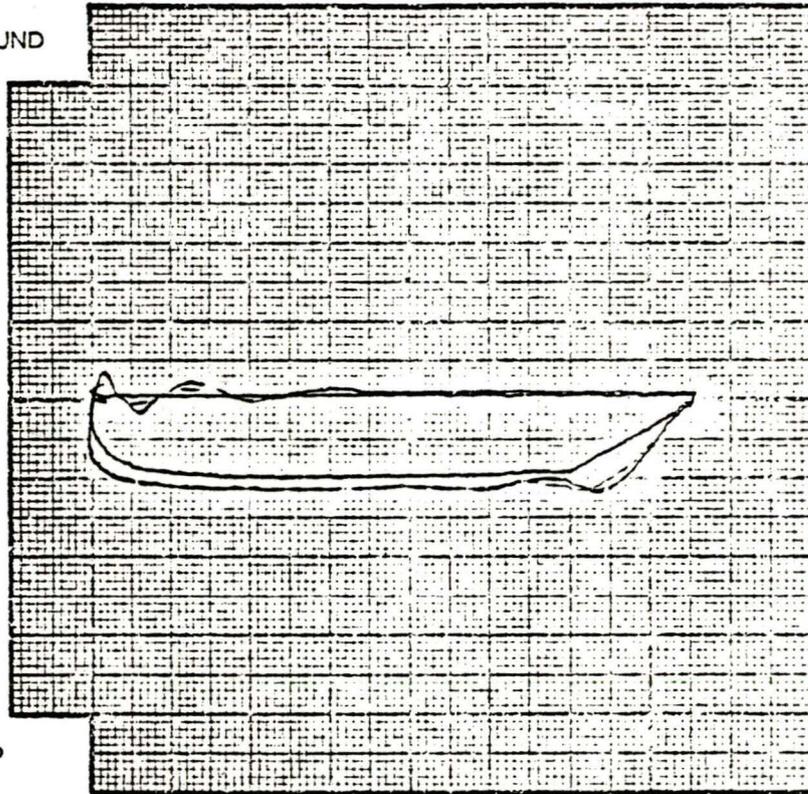
Date: 7-9-79

MB Assoc.

1027 01 00 79

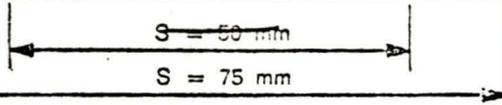
REBOUND

In
N
↑
0
↓
In
N

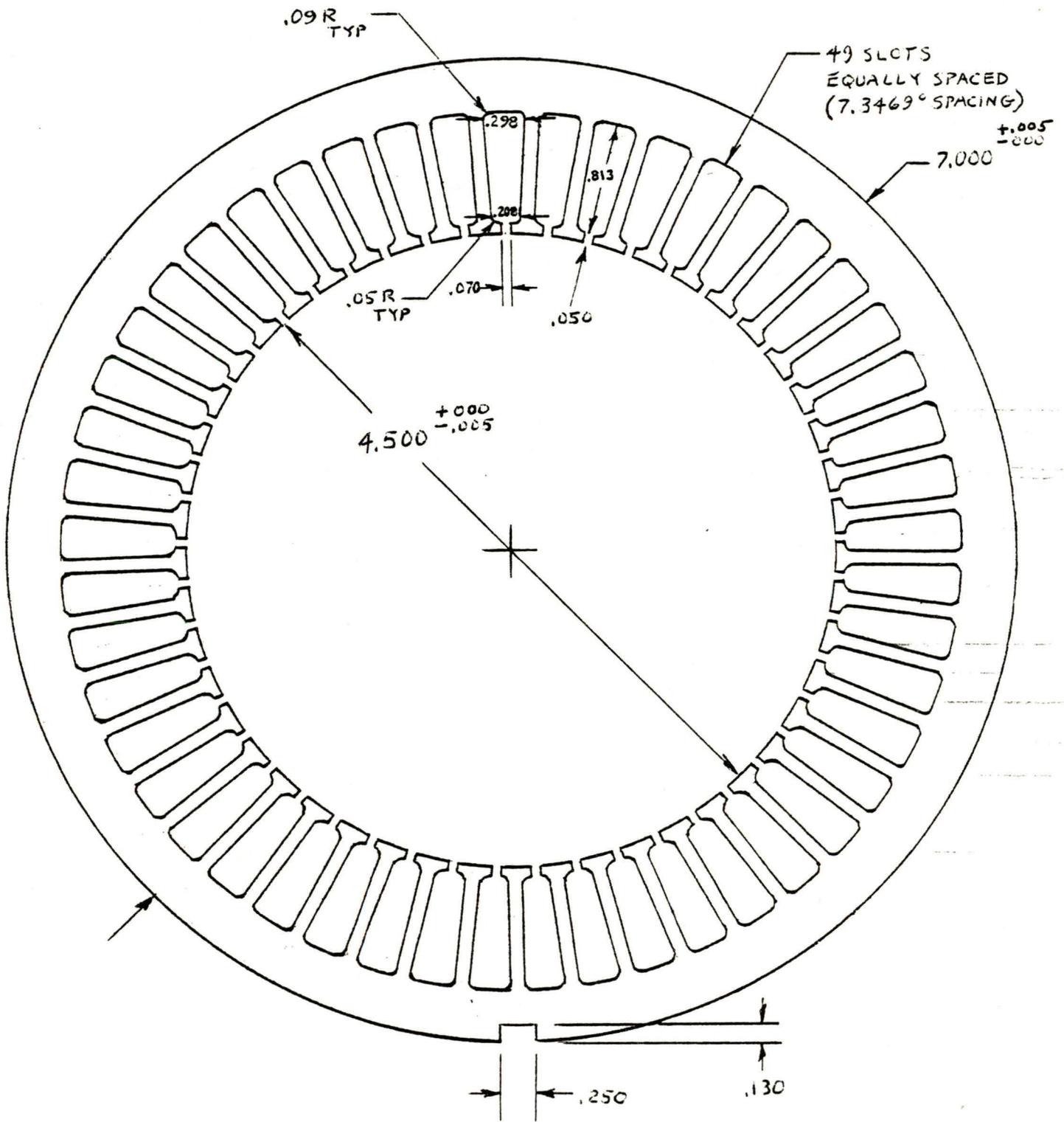


BUMP

n = 84 / 168 r.p.m.
1 mm = 100 N



PISTON ROD: CONSTANT:
BYPASS: 12 x 1.5 / NONE SPRING: NONE VALVE: NONE
UPSTREAM:
BOTTOM VALVE: #7



Armature Lamination, 49 Slot
 Scale - Full
 Tol - $\pm .002$, unless otherwise specified
 Mat - M19 - 24 GA (Nom .024)

ASSEMBLY OF ARMATURE

The armature is external to, and rotates about the 4.480-inch O.D. of the 6-pole ceramic field magnet subassembly. The field to armature lamination gap is .010-inches, therefore, the I.D. of the internally slotted armature is 4.500. The lamination stack O.D. is 7.000 and its length is 4.00-inches. There are 170 laminations of 24 GA (nom. .0235) thickness.

There are 49 slots in the armature; it is wave wound with 49 coils of 18 turns of AWG16 each. There are two coil sides per slot; therefore, 36 wires in each slot. Two wires exit from each slot and there are a total of 49 commutator bars; therefore, there are two wires (each from a different slot) welded to each commutator bar.

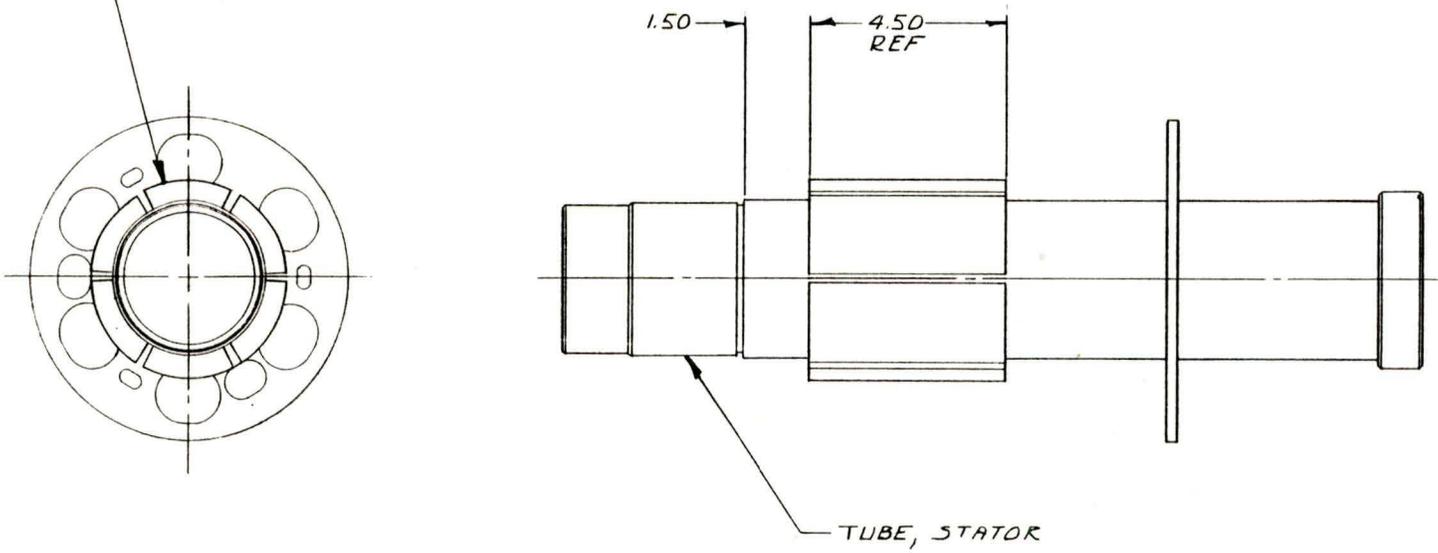
The armature and commutator assembly procedure is as follows:

1. Assembly and heat-bond 4" lamination stack.
2. Machine and mold commutator assembly (see instructions).
3. Wind armature coils per Armature/Commutator Data Card.
4. Assemble coils with sheet plastic insulation into slots.
5. Shape, trim, and strip coil leads for bar interface.
6. Fasten commutator subassembly to armature stack and TIG weld the coil lead pairs to the appropriate commutator bars.
7. Impregnate with varnish using vacuum/pressure method, and bake.

4 3 2 1

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

FIELD MAGNET 6 REQD
 ALLEN-BRADLEY MB
 CERAMIC MAT'L BONDED
 TO STATOR TUBE WITH
 HIGH STRENGTH ADHESIVE
 PER BEST ALLEN-BRADLEY
 PRACTICE

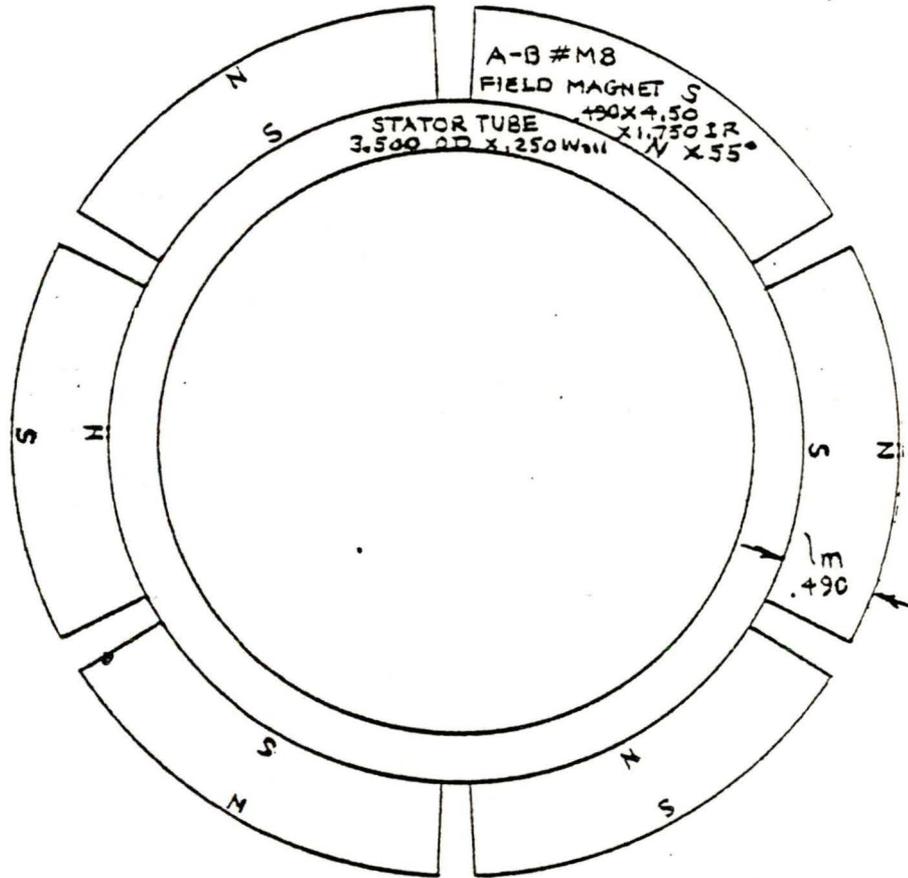


B
57
A

B
115595
A

QTY REQD	SYM	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL	SPECIFICATION	ZONE	FIND NO.
DASH NO.				PARTS LIST				
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES				DATE		MBA Associates <small>SAN RAMON, CALIF.</small> SCIENCE AND ENGINEERING		
TOLERANCES ON				DRAWN HEYNIGER 2-16-77		TITLE		
DECIMAL XX ± .02				CHECK [Signature] 4/14/79		STATOR ASSEMBLY, TROLLEY POLE		
ANGULAR XXX ± 1°				DESIGN				
DO NOT SCALE DRAWING				ENGR				
TREATMENT				QA				
FINISH				DESIGN ACTIVITY APPD				
115595-300				TROLLEY POLE		DWG SIZE C 27934 115595		
PART NO.				NEXT FINAL		SCALE 1/2		
QTY REQD PER ASSY				NEXT ASSY USED ON		RELEASE DATE		
APPLICATION				CONTRACT NO.		SHEET		

4 3 2 1



STATOR TUBE WITH FIELD MAGNETS

SCALE - FULL



PROTOTYPE DATA FOR DESIGN EVALUATION
Ceramic Magnets

Prepared for M.B. Associates Shipment Date 5/15/79
Order No. 68562 A-B Order No. 552181
Reference A-B P.N. 1751N000A

MAGNETIC PERFORMANCE

ALLEN-BRADLEY PROTOTYPE MAGNETS ARE CAREFULLY AND SELECTIVELY FABRICATED TO SIMULATE THE MAGNETIC PERFORMANCE THAT IS EXPECTED FROM MAGNETS PRODUCED IN VOLUME PRODUCTION QUANTITIES.

A PRECISE COMPARISON of the magnetic characteristics of these prototype magnets to production magnets CANNOT BE MADE until the magnet has been manufactured in volume with production tooling and measured with a fixed permeance magnetic test fixture specifically designed to qualify the magnet.

MAGNET SPECIFICATIONS

The magnetic data listed for these prototypes is compared to the expected capability of a production magnet with the following specifications:

Nominal print dimensions: length 4.500 inches, thickness .466 inches,
~~chord height~~/arc 55 ~~inches~~/degrees.

Material: Allen-Bradley M8, nominal flux density 3850 gauss,
minimum coercive force 3000 oersteds.

PROTOTYPE DATA

THE TOTAL FLUX CAPABILITY OF THE 6 PROTOTYPE MAGNETS IN THIS SHIPMENT IS 6.7 % ABOVE THE ESTIMATED MINIMUM CAPABILITY OF MAGNETS WHICH WILL BE PRODUCED IN VOLUME PRODUCTION.

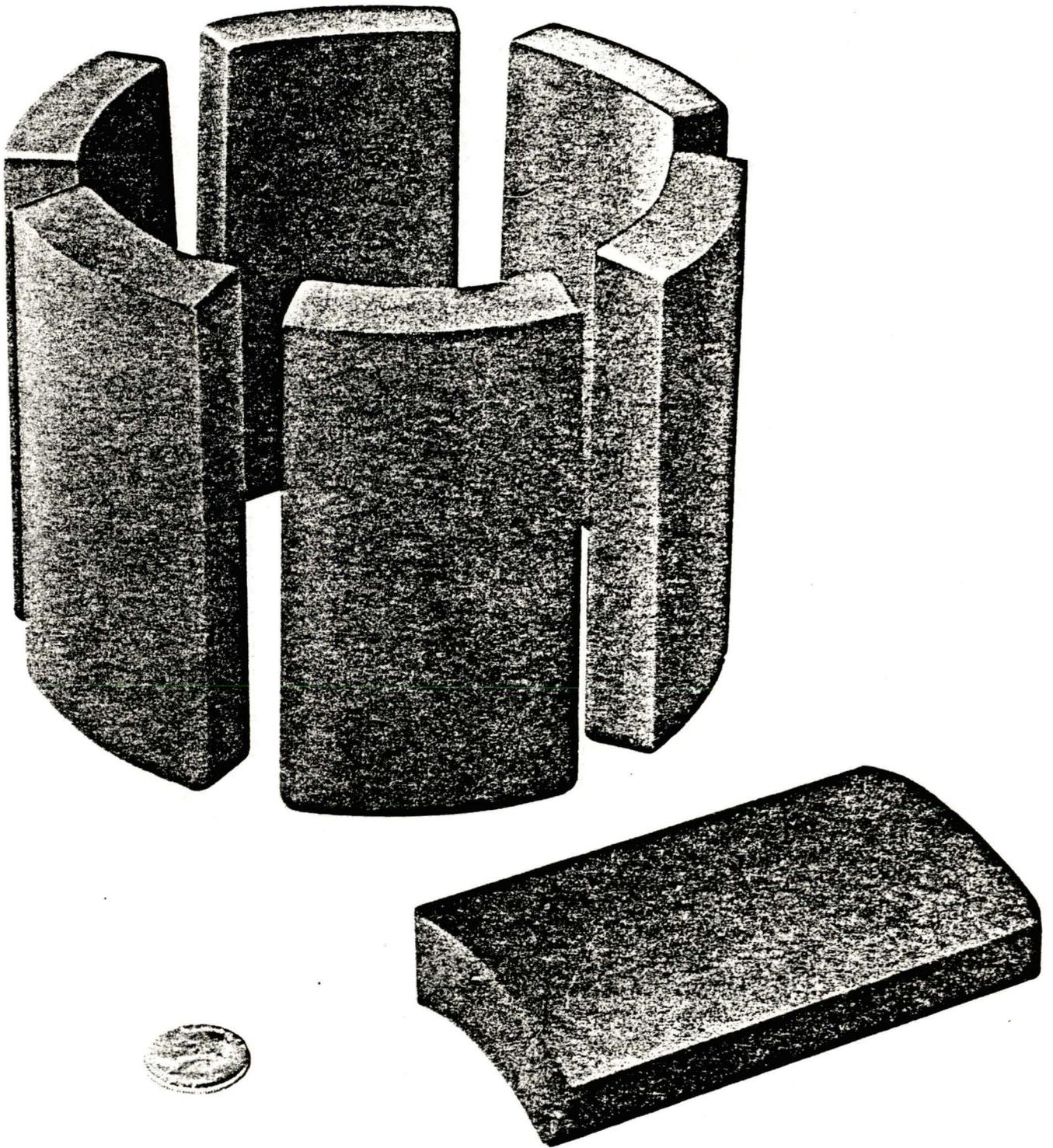
THE INTRINSIC COERCIVE FORCE RANGE OF THESE PROTOTYPE MAGNETS IS 3275-3350 OERSTEDS.

ADDITIONAL INFORMATION

Production Magnet Flux Tolerance: The flux capability of production magnets will be within +7% of the capability of a nominal flux magnet when inspected to a 1.5% AQL.

Nominal Flux Magnet: A magnet that is made to essentially nominal print dimensions and of nominal flux density material.

Production Magnet Data: Magnets of certified flux capability can be furnished by Allen-Bradley for magnetic correlation purposes following manufacture of this magnet in volume production.



M-8 STRONTIUM-FERRITE MOTOR MAGNETS

METAL GRAPHITE BRUSHES (SILVER)

MANUFACTURE

These brushes are made by mixing in suitable proportions purified natural graphite and copper in powder form with the addition of powders of lead and/or tin. The mixed powders are then compressed and fired in an atmosphere and at a temperature chosen to give the degree of solidity and cohesion desired. Equally a part of the metal graphite group are those brushes which are impregnated under pressure with pure molten copper or a mixture of molten copper and lead.

MAIN CHARACTER

Dense or very dense brushes with low friction and very low contact drop; therefore, leading to very low losses.

PRINCIPAL APPLICATIONS

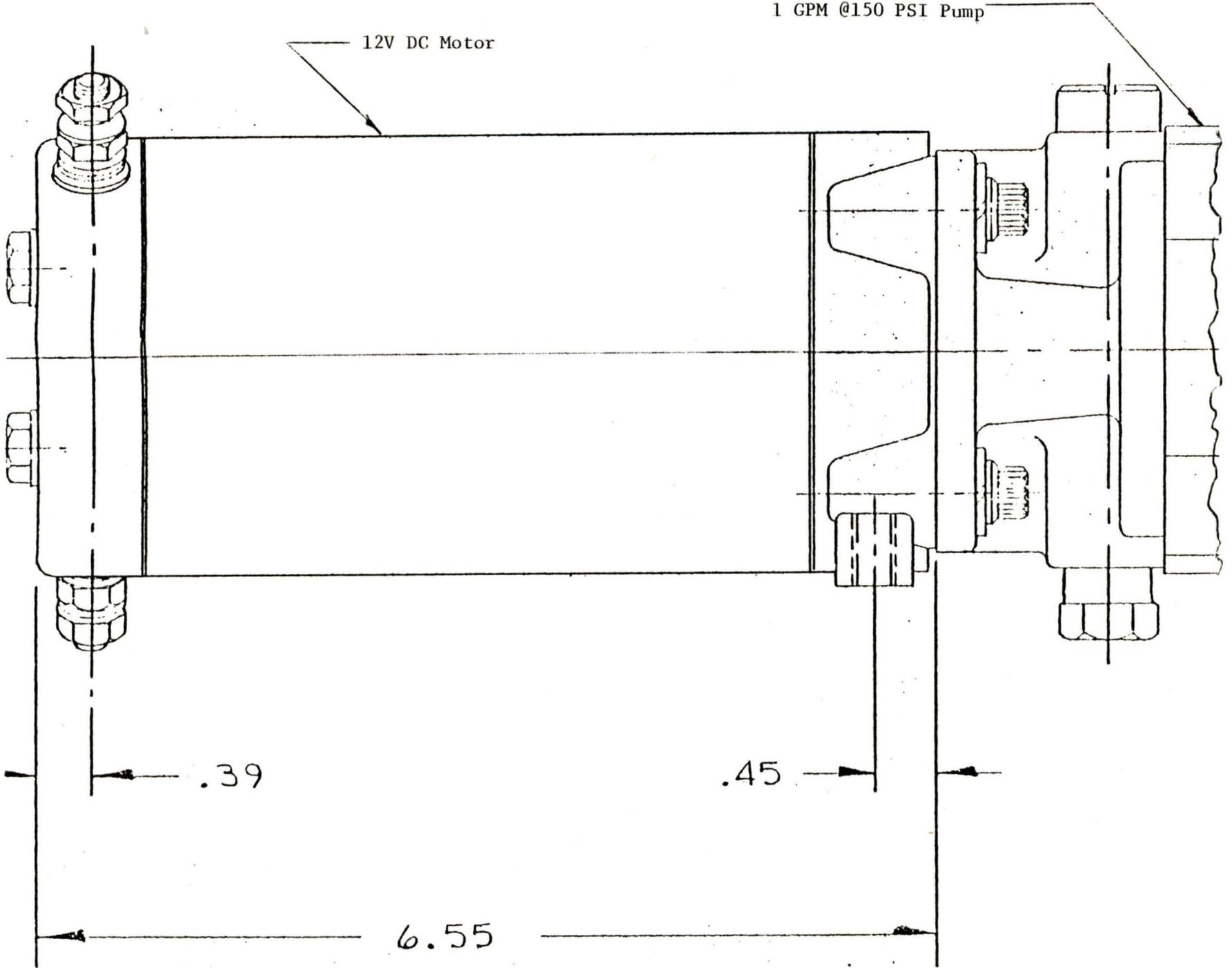
DC machines of low speed and low or very low voltage. Bronze rings of slow speed asynchronous motors, heavily loaded, with or without brush lifting gear. Bronze or steel rings of synchronous motors of low or medium speed.

LIMITS OF APPLICATION

Current Density: continuous: 80 - 200 amps/in²
instantaneous transient peaks: about 660 amps/in²
Peripheral Speed: Up to 7000 fpm

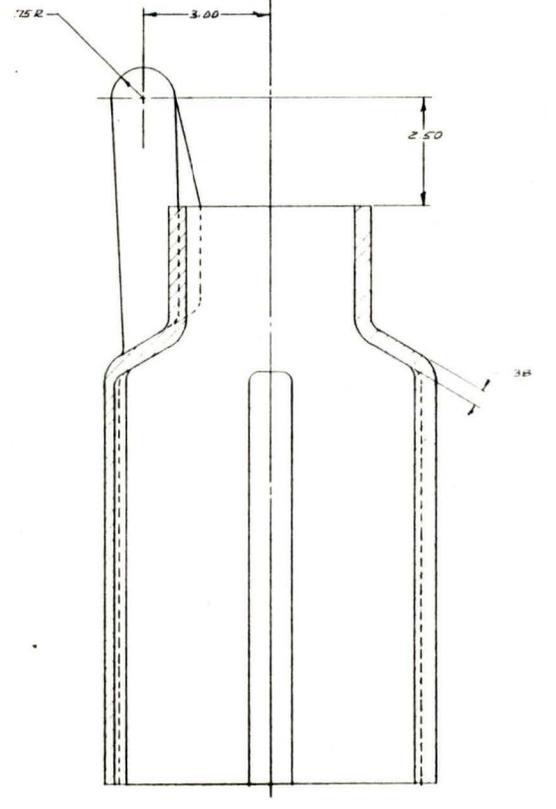
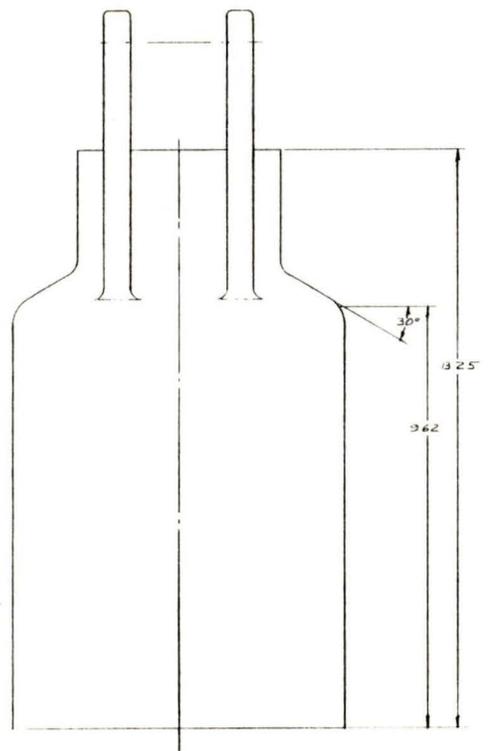
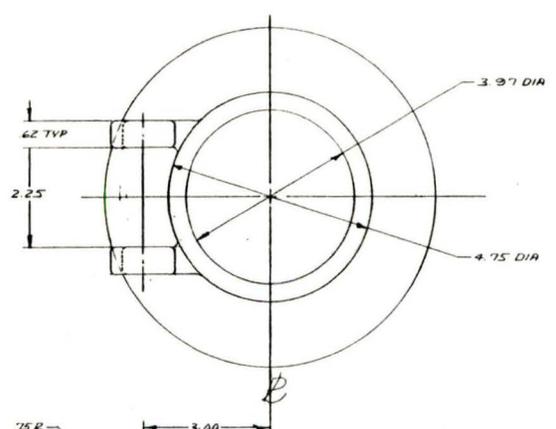
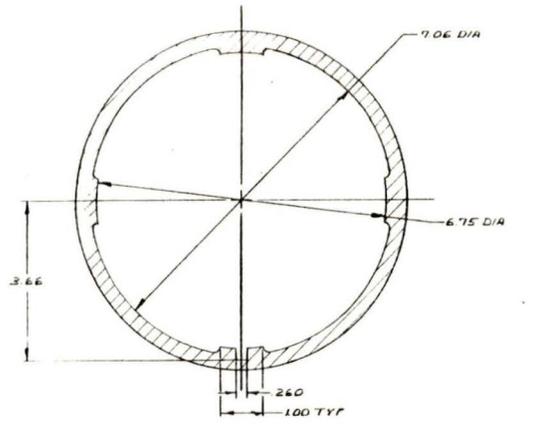
1 GPM @150 PSI Pump

12V DC Motor



MOTOR-PUMP SUBASSEMBLY
SCALE - FULL

79



- NOTES, UNLESS OTHERWISE SPECIFIED:
1. MAT'L: CONSIDER DATED ALUMINUM COMP ALUM. ALLOY 201-2
 2. HEAT TREAT TO 1/8 CONDITION
 3. CORNER AND FILLET RADIUS TO BE .32 MAX
 4. FOR PACKING SEE SHEET 2

REVISES		DATE	APPROVED

QTY REQD	SYM	LINK	PART OR IDENTIFYING NO	MANUFACTURE OR DESCRIPTION	MATERIAL	SPECIFICATION	QTY	LINK NO

DESIGN NO	DATE	DESIGNER	CHECKED	ENGR	QA

UNLESS OTHERWISE SPECIFIED	UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES	UNLESS OTHERWISE SPECIFIED
TOLERANCES UNLESS OTHERWISE SPECIFIED	
DESIGN: AS + 0.2	
ENG: 0.005	
DO NOT SCALE DRAWING	
TREATMENT	

FINISH	FILLET RADIUS	USED ON

CONTRACT NO	APPLICATION

DATE	QTY REQD	QTY NO

SCALE	RELEASE DATE	SHEET NO

PARTS LIST	

MBA ASSOCIATES	

TITLE	

MOTOR HOUSING CASTING	

8 7 6 5 4 3 2 1

H G F E D C B A

MANUFACTURE OF COMMUTATOR ASSEMBLY

1. Purchase tubular 7.0-inch O.D. x 1.8-inch wall (3.4 I.D.) x 12-inch long heat treated centrifugal castings of copper alloy (CDA #182, 1% chrome - 99% copper, Rockwell_B 70) from Ampco-Pittsburgh Corp., (213) 328-4284, Mr. Ray Cline.
2. Machine one 6.800^{+0} O.D. x 3.60 I.D. x $.400^{-0}$ thick blank ring for each commutator assembly.

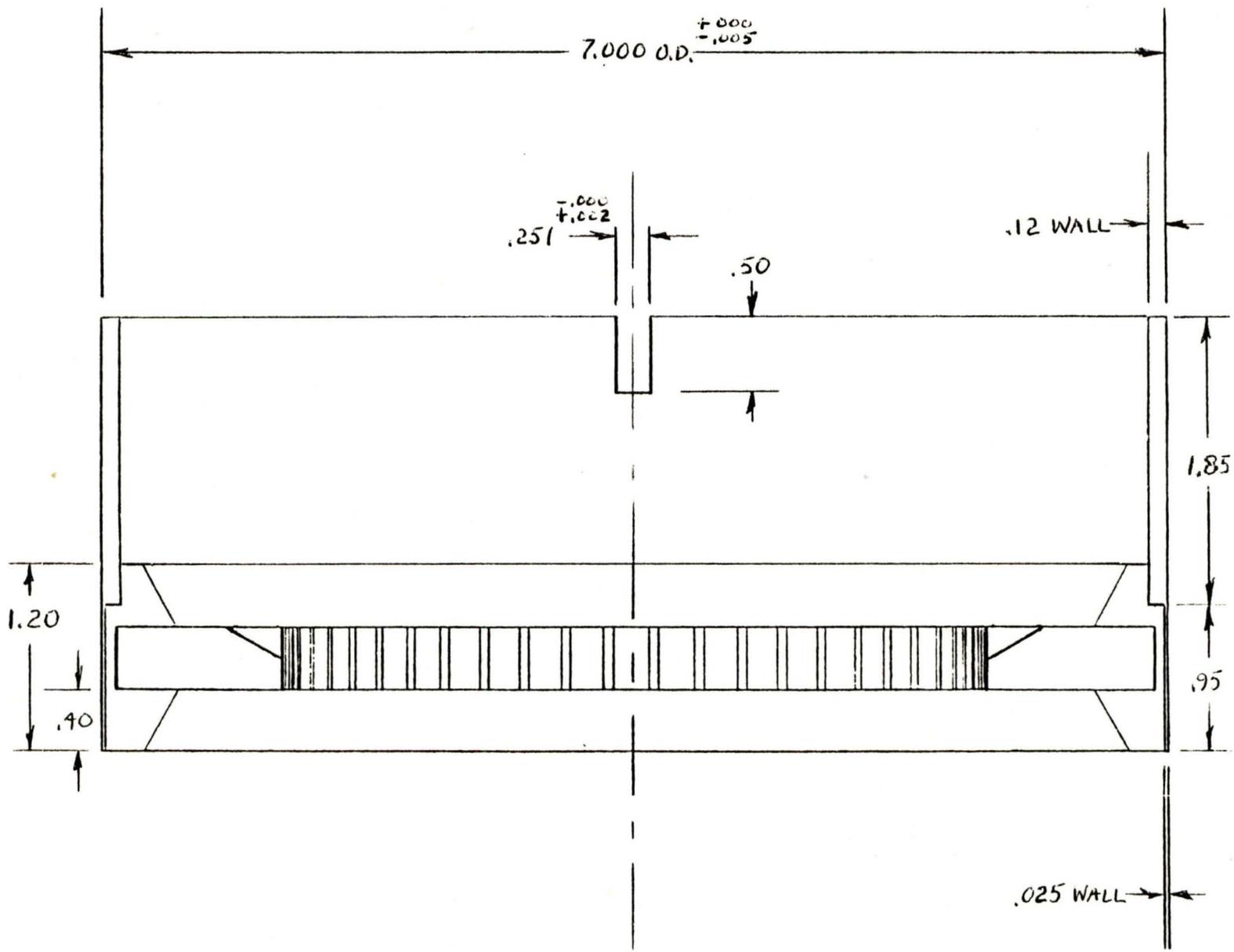
At 90° to the plane and radial to the center of the ring, machine 49 equally spaced (7.3469° spacing) .056-inch wide x 1.3-inch deep slots from the ring O.D. to within .30-inches of the ring I.D. (Alternating with and radially centered between these slots, machine 49 additional .056-inch wide x 45° angled, .80 deep from the inside top edge and along only the top face.*)

Using 3 short sections of thick walled tubing as mold parts (2 inside and 1 outside), mold the outer part of the slotted ring so that it is encapsulated by a block letter "C" shaped section of reinforced epoxy on the O.D. and both faces. For ease of removal, use split sections of tubing and mold-sealing and release compounds.

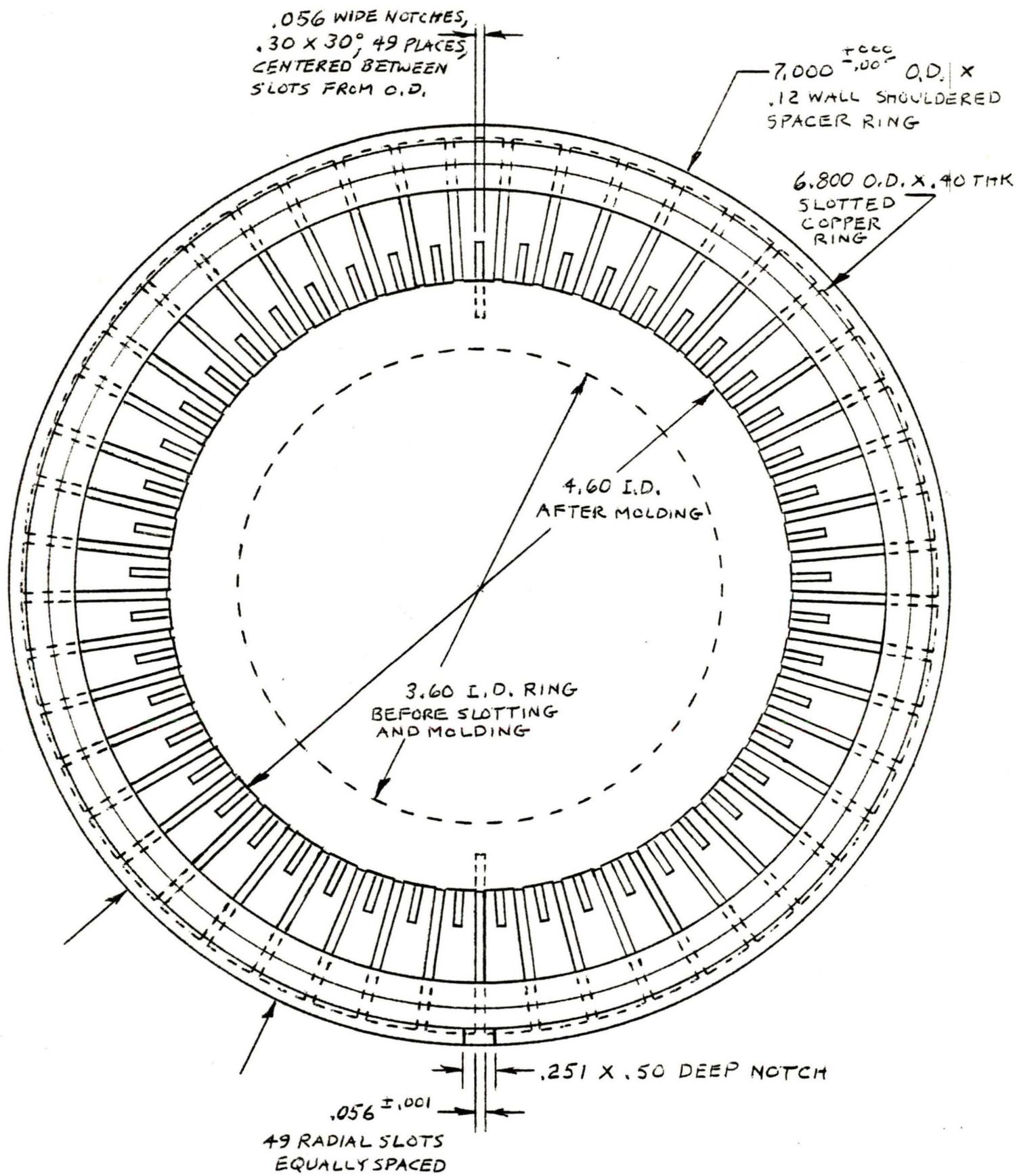
Remove the epoxy/copper ring from the tubes after thorough cure.

Finish machine the copper part of the molded ring at 4.60 I.D. and trim width of epoxy to 1.20-inches. This increase in I.D. removes the excess copper, producing individual commutator bars. (The temporarily fastened and aligned commutator bars allow ease and accuracy of molding.)

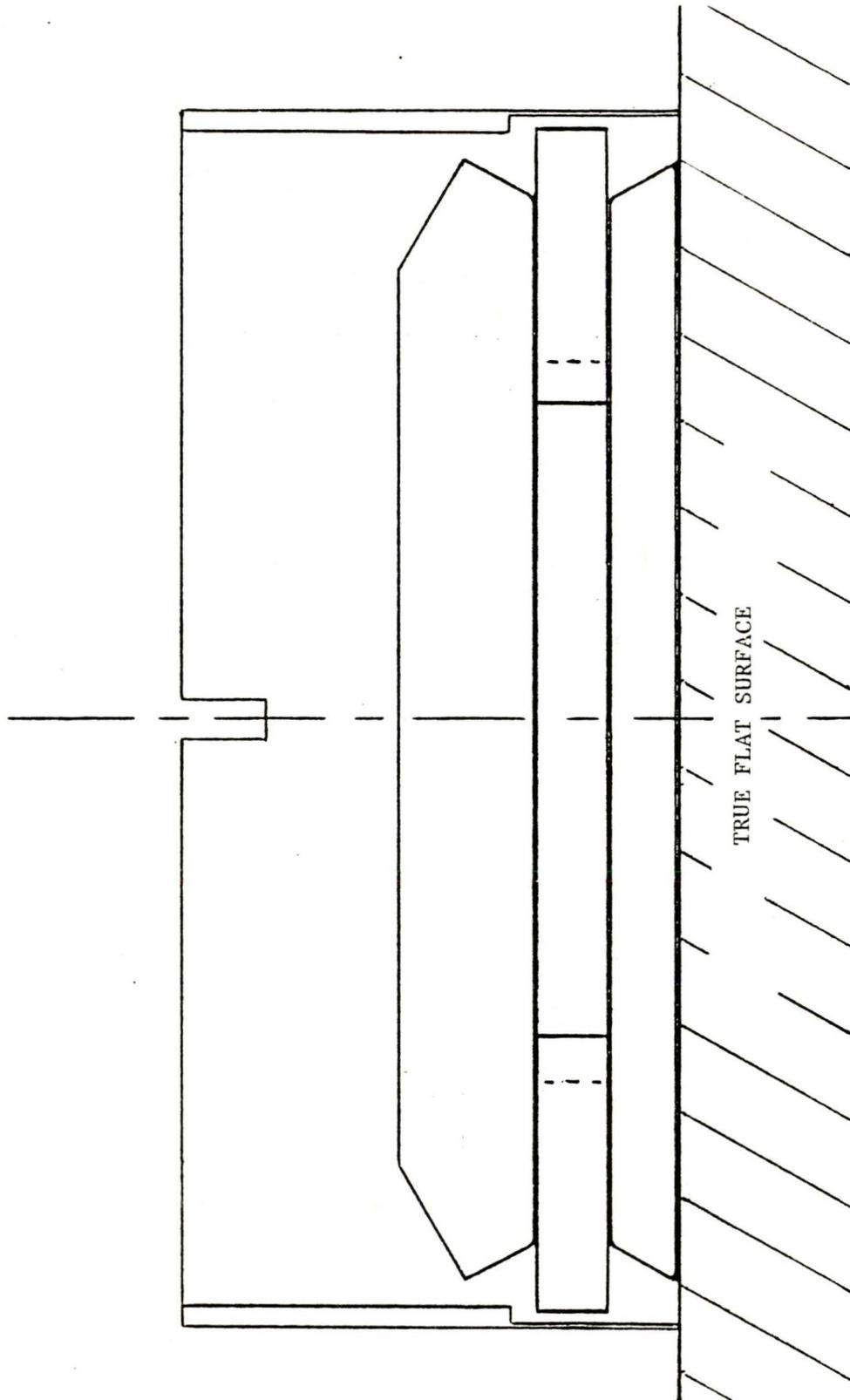
*As an alternate method, it may be easier to machine the angled notches after molding and increase of copper I.D. has been done.



COMMUTATOR ASSEMBLY
 SCALE - FULL
 MAT - ELEC. COP. & EPOXY



COMMUTATOR ASSEMBLY
 SCALE - FULL
 MAT - ELEC. COP. & EPOXY



CASTING MOLD ARRANGEMENT
SCALE - FULL

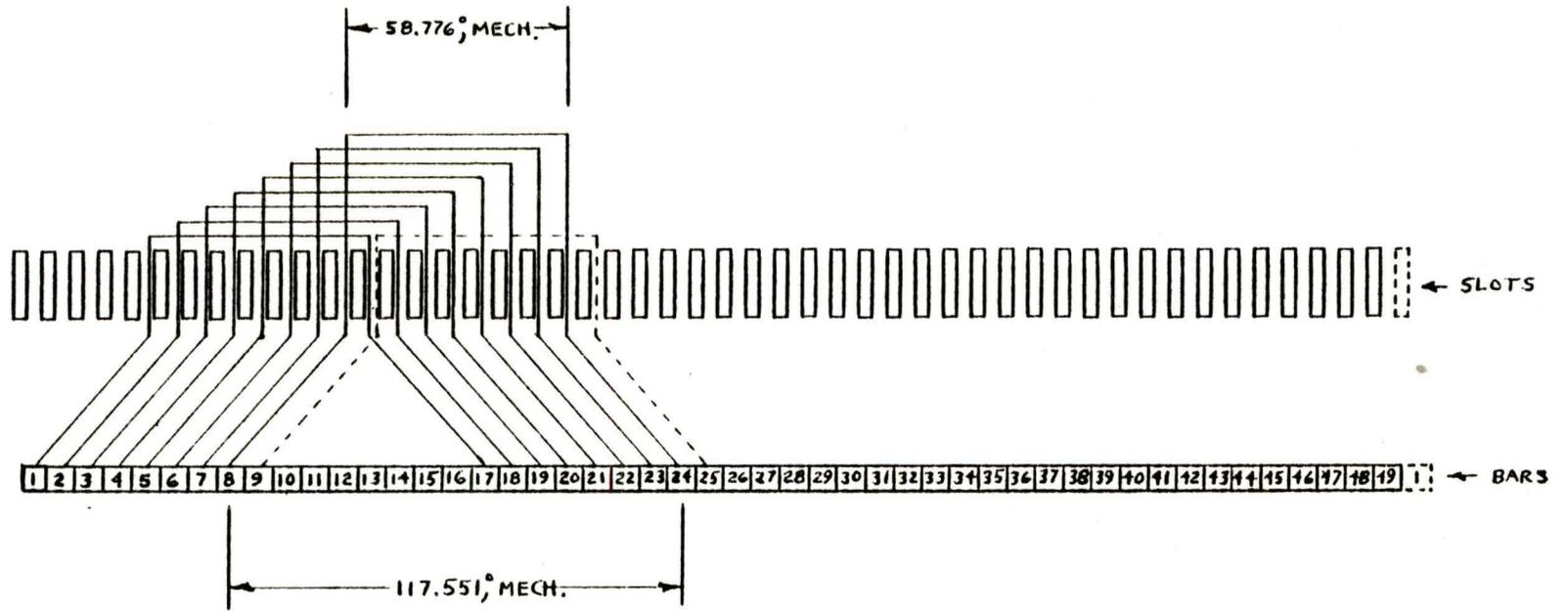
ASSEMBLY OF ARMATURE

The armature is external to, and rotates about the 4.480-inch O.D. of the 6-pole ceramic field magnet subassembly. The field to armature lamination gap is .010-inches, therefore, the I.D. of the internally slotted armature is 4.500. The lamination stack O.D. is 7.000 and its length is 4.00-inches. There are 170 laminations of 24 GA (nom. .0235) thickness.

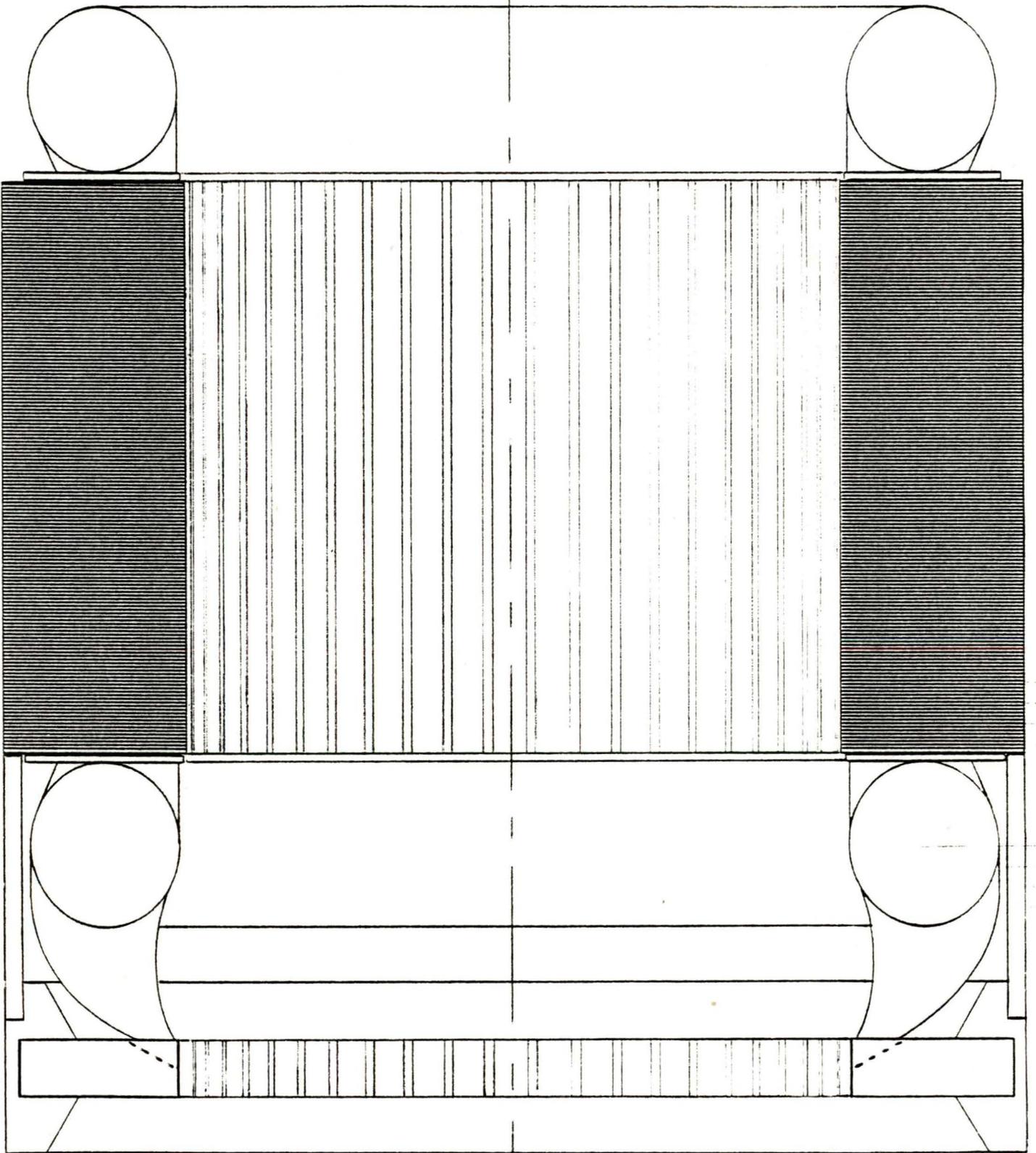
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The armature and commutator assembly procedure is as follows:

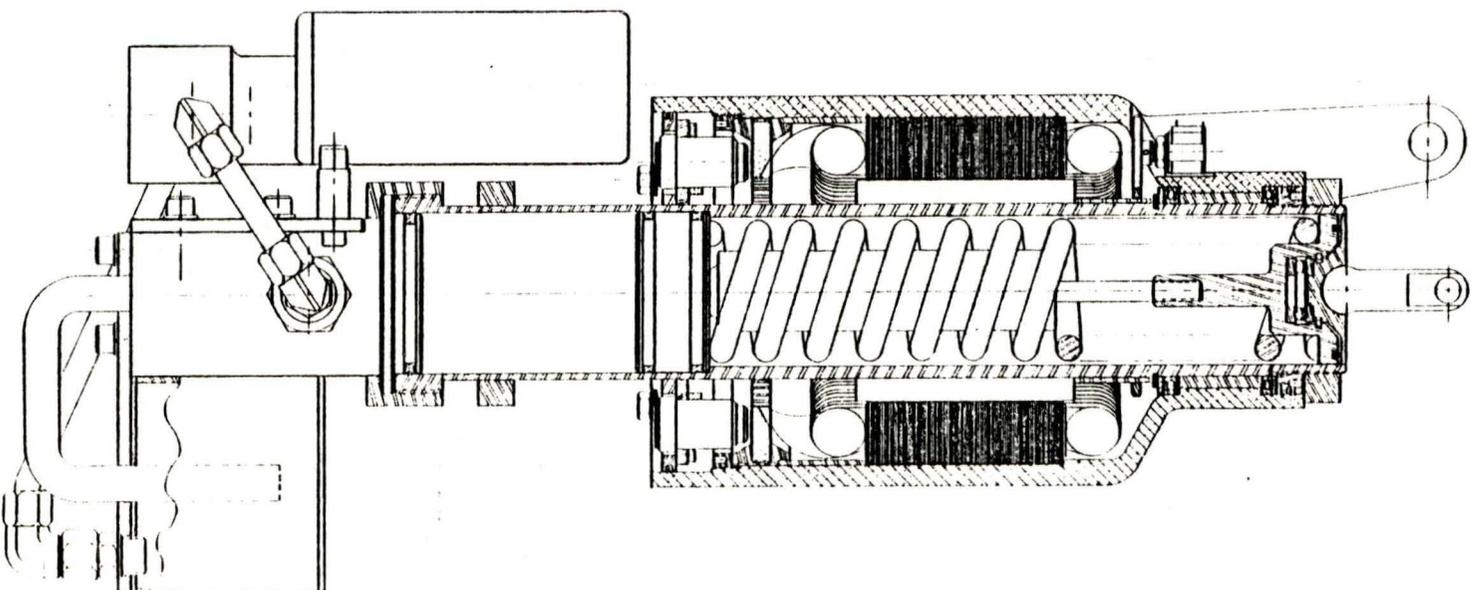
1. Assembly and heat-bond 4" lamination stack.
2. Machine and mold commutator assembly (see instructions).
3. Wind armature coils per Armature/Commutator Data Card.
4. Assemble coils with sheet plastic insulation into slots.
5. Shape, trim, and strip coil leads for bar interface.
6. Fasten commutator subassembly to armature stack and TIG weld the coil lead pairs to the appropriate commutator bars.
7. Impregnate with varnish using vacuum/pressure method, and bake.



COIL PATTERN, ARMATURE
49 BAR/49SLOT, WAVE-WOUND



ARMATURE - COMMUTATOR ASSEMBLY
SCALE - FULL



REMOTELY CONTROLLED BASE (RCB)

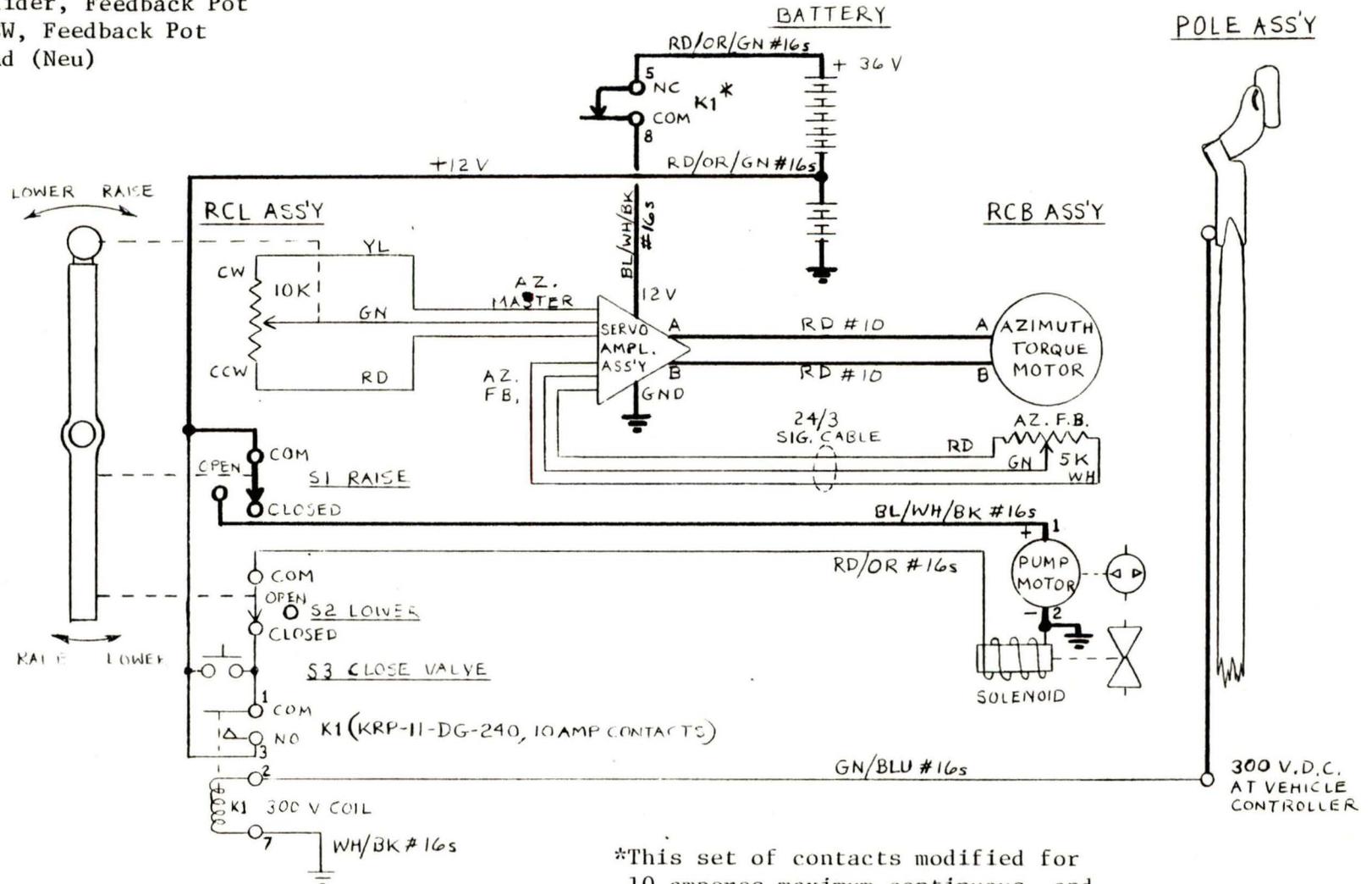
WEIGHTS

Motor Support Barrel (Stator), bare weldment	14.94#
Top Nut, Bearing Adjustment	.55
Bearings (2) @ .23# ea.	.46
Bearing Spacer, Upper	.71
Bearing Spacer, Lower	.05
Truarc ring	.10
Main Spring	8.60
Shock Absorber	2.10
Magnets (6) @ .725# ea.	4.35
Laminations (155) @ 1.357 oz. ea.	13.15
Coils (49) @ 2.808 oz. ea.	8.60
Commutator (Copper-1.08#, epoxy-.5#, steel-1.7#)	3.28
Brush Assembly (6) @ 2.64 oz. ea., plus .39# ring	1.38
Cylinder Nut	1.76
Piston, Aluminum	.72
Bulkhead/Reservoir/Valves	4.10
Seals	.03
Potentiometer and Gears	.30
Motor/Pump (Motor-5.3#, Pump & Couplg'-5.1#)	10.40
Cast Motor Housing	11.91
	<hr/>
Trolley Pole Base Total Weight	87.49#

TERMINAL BOARD CIRCUITS

- 1 +12 VDC
- 2 Terminal 1 (+) of Pump Motor
- 3 Solenoid Valve
- 4 Relay Coil
- 5 CW, Feedback Pot
- 6 Slider, Feedback Pot
- 7 CCW, Feedback Pot
- 8 Gnd (Neu)

SCHEMATIC DIAGRAM
RCB SYSTEM



*This set of contacts modified for 10 amperes maximum continuous, and 30 amperes peak current.

SAU Specifications

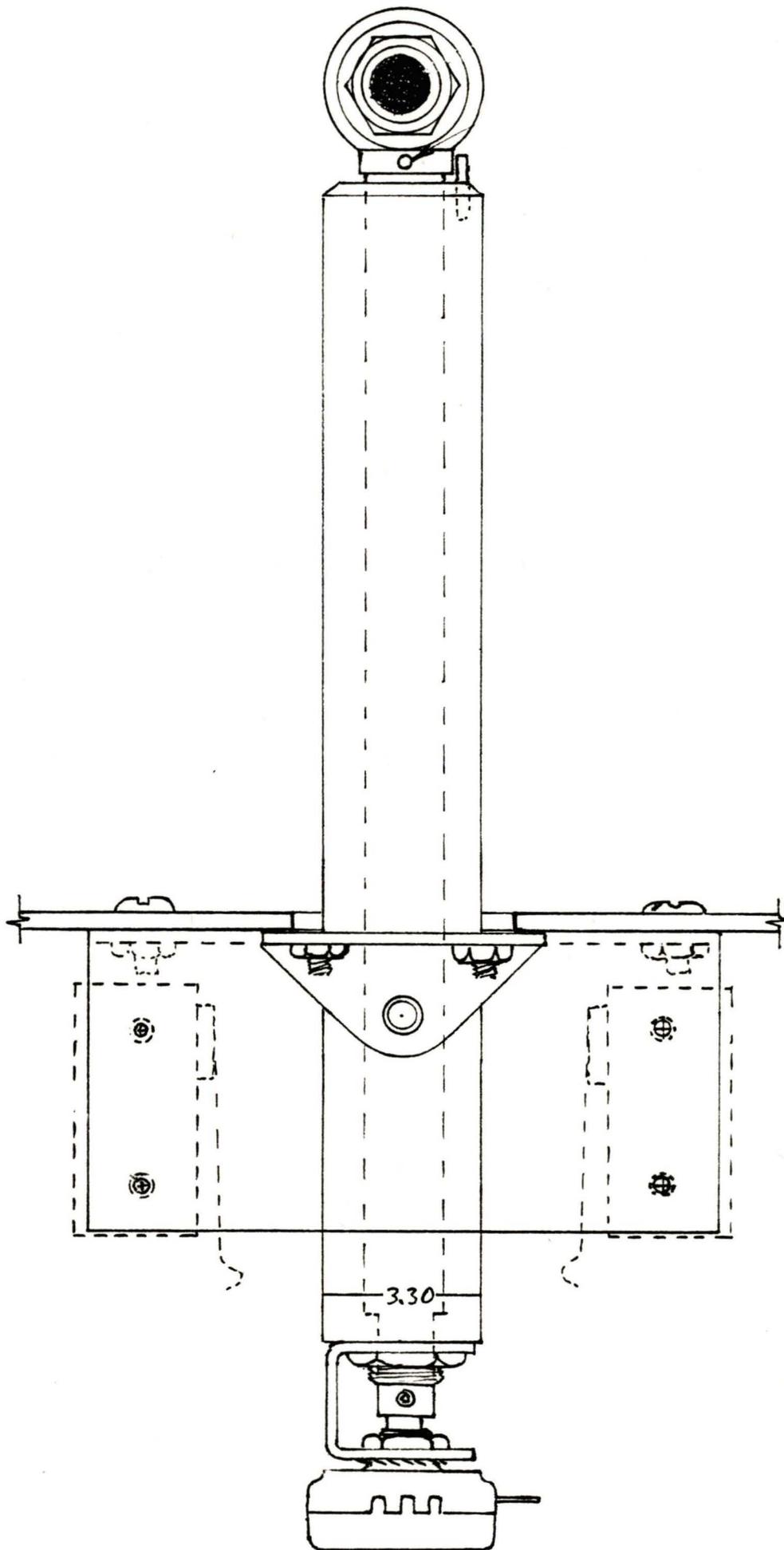
BRIDGE TYPE POWER AMPLIFIER

This unit is for servo position control of a permanent magnet torque-motor circuit which has the following characteristics:

V_{\max}	—————	37.8 (lead acid battery, 41.4v. on charge)
V_{\min}	—————	32.0 (with locked rotor; 4.8v. battery drop)
I_{\max}	—————	27.8 (@ 32v. with locked rotor)
R_{arm}	—————	1.15 (6 pole wave-wound motor with parallel paths of 2.3 ohms)
Feedback Pot	—————	10,000 ohms
Control Pot	—————	10,000 ohms
Reference Volts	—————	20 D.C.

Amplifier has the following characteristics:

Input Power	—————	37.8 v.D.C. (33 v. @ 27.8 amps)
Output Voltage	—————	minus 34.8 v. to plus 34.8 v. (@ 10 amps)
Output Voltage	—————	minus 32.0 v. to plus 32.0 v. (@ 27.8 amps)
Output Current	—————	\pm 75 amps max.
Current Limiting	—————	30 to 75 amps (resistor adjustment)
Gain	—————	Unity to 1000 variable adjustment
Lead and Lag	—————	Variable adjustments
Bandwidth	—————	100 Hz, max.
Input Impedance	—————	100,000 ohms min.
Heatsink Diss.	—————	400 watts



REMOTE CONTROL LEVER (RCL)

SUPPORT BRACKET
"RCB" TEST

