# Pavement Test Track Instrumentation System Documentation

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**Planning, Research and Public Transportation Division**
In Cooperation With
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Federal Highway Administration

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16. Abstract

Several pieces of electronic hardware, obtained through previous test efforts have been assembled for laboratory and field use. The equipment consists of two instrument racks. The first contains five Bison inductance type soil strain gage instruments and the associated phase and amplitude controls and solid state switching hardware for switching these controls between sixteen measurement test sections.

The second rack contains switch hardware for switching the actual input leads for the individual inductance coils associated with the sixteen test section. It also contains the necessary data acquisition and analysis hardware.

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# PAVEMENT TEST TRACK INSTRUMENTATION
# SYSTEM DOCUMENTATION

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FINAL REPORT

Research Project Y-2811
Task 15

Washington State Highway Commission
Department of Highways
and In cooperation with
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Federal Highway Administration

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# Pavement Test Track Instrumentation System Documentation

## Abstract

Several pieces of electronic hardware, obtained through previous test efforts at Washington State University's (WSU) pavement test track, have been acquired by Washington State Department of Transportation. An effective effort to tie these items along with a separate data acquisition package into a single monitoring system was undertaken in a previous WSDOT funded project. The current effort is to document this equipment.

The equipment consists of two instrument racks. The first instrument rack houses five Bison inductance type soil strain gage instruments and the associated phase and amplitude controls and solid state switching hardware for switching these controls between sixteen separate measurement test sections. The Bison instruments can also be removed from this rack and used independently.

The second rack contains switching hardware for switching the actual input leads for the individual inductance coils associated with up to sixteen possible test sections. There can also be up to six other independent measurements at each of the sixteen test sections. These could be configured for any type of transducers including, pressure, soil strain gages, DCDT's and etc. Sixteen independent temperature sensors can also be monitored.

This rack also contains a data acquisition and analysis system which can be connected to any of the signals being monitored. It can be used for monitoring the input signals in real time, to store these signals in internal memory or on floppy disks, to analyze these signals and to do final graphics presentation of the results. This unit along with the control of the complete monitoring system can also be interfaced to a separate microcomputer as well as operated manually.

## Introduction

Several pieces of electronic hardware, obtained through previous test efforts at Washington State University's (WSU) pavement test track, have been acquired by Washington State Department of Transportation. An effective effort to tie these items, along with a newly acquired data acquisition system, into a single monitoring system was undertaken in a previous WSDOT funded project (Y2718). However, the necessary time and funds required to complete the documentation of this effort were not available at that time. In this study, the University of Washington, will provide the necessary documentation for the operation and maintenance of this equipment.

The specific objective of the proposed study is to provide a set of working schematics and drawings along with an operations and maintenance manual for the WSU test track monitoring system. As stated above, this system was designed and constructed in an earlier WSDOT project and was designed for the WSU pavement test track in Pullman, Washington.

The documentation of the construction, use and repair of the monitoring equipment will allow for the effective long term use and maintenance of this hardware. It will also enable a higher degree of integration and planning in the ultimate application of this equipment in future research at Pullman and at other possible test sites.

Once the repair and operations manual has been completed the monitoring equipment will be available for installation at Pullman or other possible field or laboratory test sites. Additional hardware may be necessary depending on the exact application for which the monitoring system is to be used. However, in general the package is ready for direct implementation at this time.

This project was conducted in two phases. The first phase consisted of the drafting of the required electrical and mechanical schematics and drawings associated with the monitoring hardware. The second phase produced the final Operations and Maintenance Manual. Phase I ran from July 1, 1984 through September 30, 1984 and Phase II ran through June 30, 1985. The university provided the electrical and mechanical drawings and schematics, along with the final operations and repair manual for the WSU pavement test track monitoring system. Phase I produced the drafting of the following list of figures.

Phase II was also performed by the university and consisted of the writing of a manual that included all of the drawings generated in Phase I and a complete narrative covering the installation, operations, use and repair of the WSU test track monitoring hardware. The operations and maintenance manual along with the individual manufacturers equipment manuals includes all the information required to set up, install and operate an experiment at the WSU test track or at any experimentation site that may require all or any portion of this monitoring equipment.

The instrumentation package developed for the WSU test track is made up of two instrument racks (See Figure 2). The first rack (Bison Instrument Rack) contains five inductance coil type soil strain instruments (Bison Instrument Corporation, Model 4101A). These instruments are packaged with individual switching and balancing hardware for each instrument at each measurement station. This allows them to be switched between sixteen different measuring locations.

The second rack (Read Out and Control Rack) contains the main controls, signal conditioning electronics, read out displays and data acquisition system. The complete instrument system can be switched between sixteen measuring stations. Each station can contain the five Bison soil strain instruments in any desired configuration, plus six independent transducers. The independent transducers can be of any type including foil strain gages, DCDT's and/or pressure sensors. Two card racks are set up for signal conditioning for up to 96 of these input transducers, but no electronics are provided (See Figures 2, 6 and 18 for details of the signal conditioning card option). Also, a separate switching and read out display is included for up to sixteen temperature sensor. Ten inductance coil type, sixteen foot long, extensometers are also included with the system.

The data acquisition system, which is connected to the individual inputs through front panel BNC connectors, consist of a two channel digital oscilloscope with CRT graphics display, internal memory and floppy disk storage. The system is extremely flexible and can operate as a single stand alone piece of equipment or can be used as a front end to any existing mini or microcomputer. It can also be used with off the shelf x-y and/or (HP 7470) digital plotter to further enhance its stand alone or remotely controlled data acquisition capabilities.

A digital panel meter is also located on the front panel to enhance individual read outs of the different outputs. All signals are available at the front panel and can easily be interfaced to any other desired measuring and/or read out equipment. Also, all switching and balancing hardware has been designed to be controlled remotely via a separate control system or computer. This will require minor hardware modifications and a competent electronics technician.

The intended mode of operation would be to manually switch the instruments between the different measuring stations on the test track. Each measuring station could contain up to five inductance coil type strain measurements plus up to an additional six sensors of any desired type. These signals would be measured and displayed on the digital scope and analyzed, stored and plotted. The scope allows for easy horizontal and vertical scale expansion, peak and time spread measurements along with signal averaging, differentiation, integration and even frequency domain analysis. All plots can be displayed, labeled and stored. Also, up to sixteen temperature sensors can be located around the track. These outputs are to be monitored manually. The temperature sensors are a constant current type unit and are manufactured by Analog Devices (P/N AD590).

## Summary

An integrated instrumentation system for collecting data at the pavement test track at Washington State University, Pullman, Washington has been constructed and documented. This system was put together using five Bison soil strain gage instruments and other switching hardware that was used at the test track for an earlier sulfur extended asphalt study. The existing hardware was repackaged and a new data acquisition system and read out equipment were added to it. This system has been completed and documented and is ready for future applications.

## Conclusion

The Bison inductance type soil strain gages have proved to be an excellent transducer for measuring soil strains and for use in other measurements such as the extensometers used in the Pullman, WA sulfer extended asphalt project(See reference 1). They have an excellent long term stability and accuracy and can be adapted to many applications. The ability to switch the bridge balancing controls to an external source proved to be successful.

This operations and maintenance manual along with the individual manufacturers equipment manuals includes all the information required to set up, install and operate an experiment at the WSU test track as well as at another test site or laboratory experimentation that may require all or any portion of this monitoring equipment.

## Recommendations

The development of the existing system was somewhat hampered by time and available manpower constraints. Because of this, several system options were planned for in the design but not included. These include the following:

1. Front panel printer with scanner,and peak and hold circuits. This would allow for a hard copy of the individual read outs.

2. Solid state counters for wheel rotations, etc.

3. Digital plotter and/or x-y plotter.

4. Strip chart recorder.

One problem associated with continuous long term dynamic measurements under conditions where settlement or consolidation are present is that a continual rezeroing or balancing of the instruments is required. Newer electronic modifications could be used to eliminate this problem and should be considered if a similar project, to that of the sulfur extend asphalt study, is undertaken (See reference 1).

Procedure

The procedure used in doing the work in this project was to take previous experience and previously developed equipment and use this as a model to develop the drawings, schematics and documentation required to allow state personnel to use, maintain and service the hardware.

## Test Instrumentation System

### General

The basic overall theory of operation was based on the need to integrate five Bison soil strain gages into a single system that will allow them to be used in a series of independent measurements by switching this group of five instruments between sixteen separate test sections. To do this it was necessary to deactivate the internal adjustments associated with the control of the individual Bison instruments, and supply external adjustments for each which could then be switched with the different inputs form the separate induction coils. Included in these controls are the adjustments for the individual amplitude and phase controls along with the coil separation switches.

To be included in the system was a mechanical means for switching between the separate test sections along with all necessary read out and display equipment to provide a stand alone measurement system.

### Bison Gages

The system consists of a pair of coils and an instrument package that contains the bridge balance controls, as well as the power supply, and amplification and calibration functions. The output can be obtained in the form of either a null balance bridge reading or a voltage. The general principle is that one of the coils is excited with a high frequency voltage signal. A voltage is inducted into the second (or any other) coil by the first. The amplitude of this voltage is proportional to the spacing between the coils.

Calibration of the sensors is accomplished by separating the coils at various known spacings and determining the bridge balance reading of the instrument. The approach is conceptually the same for parallel, coplanar or orthogonal sensor configurations. Because the calibration relationship is nonlinear, more than two points are needed to establish the curve for spacing changes of more than 5%. The most general calibration method employs a fixture with a micrometer to accurately produce and measure small changes in spacing of one coil with respect to the other ( See Figure 15). A more rapid method can be provided for a particular size sensor by using a fixture with slots of known spacing (See Figure 16).

Coil diameters ranging from 1/2 to 14 inches have been tested and found to give about the same strain sensitivity. Normal operating spacing for each size is 1 to 4 times the diameter. Maximum resolution over a period of months is 0.04 percent strain, but dynamic resolution smaller than 0.001 percent strain can be obtained from the voltage or recorder output. The limitations of this resolution are internal noise and external factors influencing the electromagnetic field, such as moving metal object close to the sensor.

The inductance coil is insensitive to such factors as soil composition, moisture content, temperature, and cable length. The major adverse factor is the presence of metal, particularly ferrous, in the zone of influence of the electromagnetic field which couples the pair of sensor coils. The extent of the effect in any particular case can easily be determined. The effect of fixed metal objects on the bridge balance readings will often cancel out in determining strain. The effect of large metal objects which produce significant shifts in readings can be handled by corrected calibration curves. In the past, the main problem with metal has been in dynamic strain determination where moving metal accompanied the moving load that produced the strain. An example is the determination of strains beneath a pavement under traffic loads. This effect is reduced substantially by the height of the vehicle in question and is negligible for larger trucks. This same phenomena is experienced with induction loop type detection system.

## Secondary Amplitude and Phase Adjustment

The Bison instruments have been modified to allow for external balancing control for the amplitude and phase adjustments when the microswitches beside each function is put in the up position. This gives a separate balancing control for each of the sixteen separate master selection switch positions. The screw driver adjustments beside each individual Bison instrument becomes the phase and amplitude adjustments (See Figures 2 and 3). With the microswitches in the down position the Bison instruments function as defined in this manual and manufacturer literature.

## Switching Network

The switching network associated with the control of the instrument package has two basic components. The first is the switching circuitry associated with the individual amplitude, phase, and coil spacing controls on the separate Bison instruments. At present the coil spacing control is deactivated and is accessible for expansion purposes only (See figures 9 and 10 for details). The second portion is the switching circuitry associated with the switching of the input leads from the different induction coils and independent transducer inputs and the control of the monitoring signals or outputs from each of the sensors being used in the overall monitoring system.

The function of the channel selection switch on the Read Out and Control Rack (See Figure 2) is to switch the sensor input leads from the test section in question into the system and to connect the outputs from each of the signals to the appropriate BNC connection on the front panel. This switch also switches the balance control for the individual amplitude and phase adjustments associated with each Bison instrument to the appropriate external adjustment potentiometer if the microswitch for that function on the face of the individual Bison instrument is in the up position.

The individual outputs are manually connected to the oscilloscope, to the digital panel meter and/or to any type of user supplied monitoring unit. This was done to leave the system as flexible as possible. Individual applications may dictate that some of these controls be connected directly to various readout equipment.

## Optional Signal Conditioning

Space and card chassis have been provided for signal conditioning circuitry for the externally switched signals associated with each of the test sections. There is space for six of these signals for each of the sixteen switch settings. This in in conjunction with the Bison instruments. The type of transducer which is wired through this system is only limited by the circuitry which is used. The card chassis excepts a 44 pin 4.5 inch by 7.5 inch circuit board. There is a circuit diagram and printed circuit board layout given in Figures 18 and 19. This circuit can be adapted to accept any voltage (differential or single ended) or resistive type input. Other circuitry can be purchased or designed to function in this piece of hardware. This type of circuitry will have to be defined by the final application and the transducers that are to be used.

## Transducer Inputs

The inductance coils are generally co-axial cables and are wired into the rear of the Read Out and Control Rack (See Figures 4 and 6). They are connected directly to the screw type terminal strips as indicated in Figure 4. These leads are switched, through mercury wetted relays to the individual Bison instruments. The secondary inputs, there are six associate with each of the sixteen test sections, are either wired directly to the channel selection switch or through the signal conditioning chassis, depending on the type and output characteristics of the individual transducer or measurement that is to be made.

Three Dimensional Transducer Array

The three dimensional inductance transducer array that is shown in Figures 1, 4, and 7 is a unique arrangement and was used in the original implementation of this equipment at the WSU pavement test track. This system uses four coils and an extensometer arranged in such a manner as to allow for two vertical strains,two horizontal strains, and three vertical displacements. This is done using only the five Bison instruments. The center coil "A" is excited and the inducted voltages in coils B, C, D and E are monitored using the first four Bison instruments. The fifth Bison instrument is used to monitor the coils used in the extensometer ( See Figures 1, 4, 7, A-1, A-2 and A-3).

Nicolet Oscilloscope

This instrument is an extremely versatile data acquisition system. It can be operated independently to perform most any desired data collection, real time analysis, data storage and post analysis, and data display function. The unit can be interfaced to a separate mini or microcomputer for post type data analysis or it can operate as a front end to a computer system for real time data acquisition and analysis.

The scope is limited to only two channels at present, but can be expanded to a maximum of four channels. This is only a limitation if real time cross spectral or correlation type analysis is needed for more than the two channels, alternate pairs can be analyzed if desired. This should not be a problem in the expected applications for this equipment.

## Applications

The primary application of the equipment documented in this project is at the WSU Test Track. However, the equipment can be used either as a single monitoring system or it can be used in part or as individual components in stand alone applications. Because of this arrangement the ultimate application of this equipment is extremely variable and is up to the imagination of the potential user. See Figure 1,20 and 21 for simple examples.

**FIGURES**

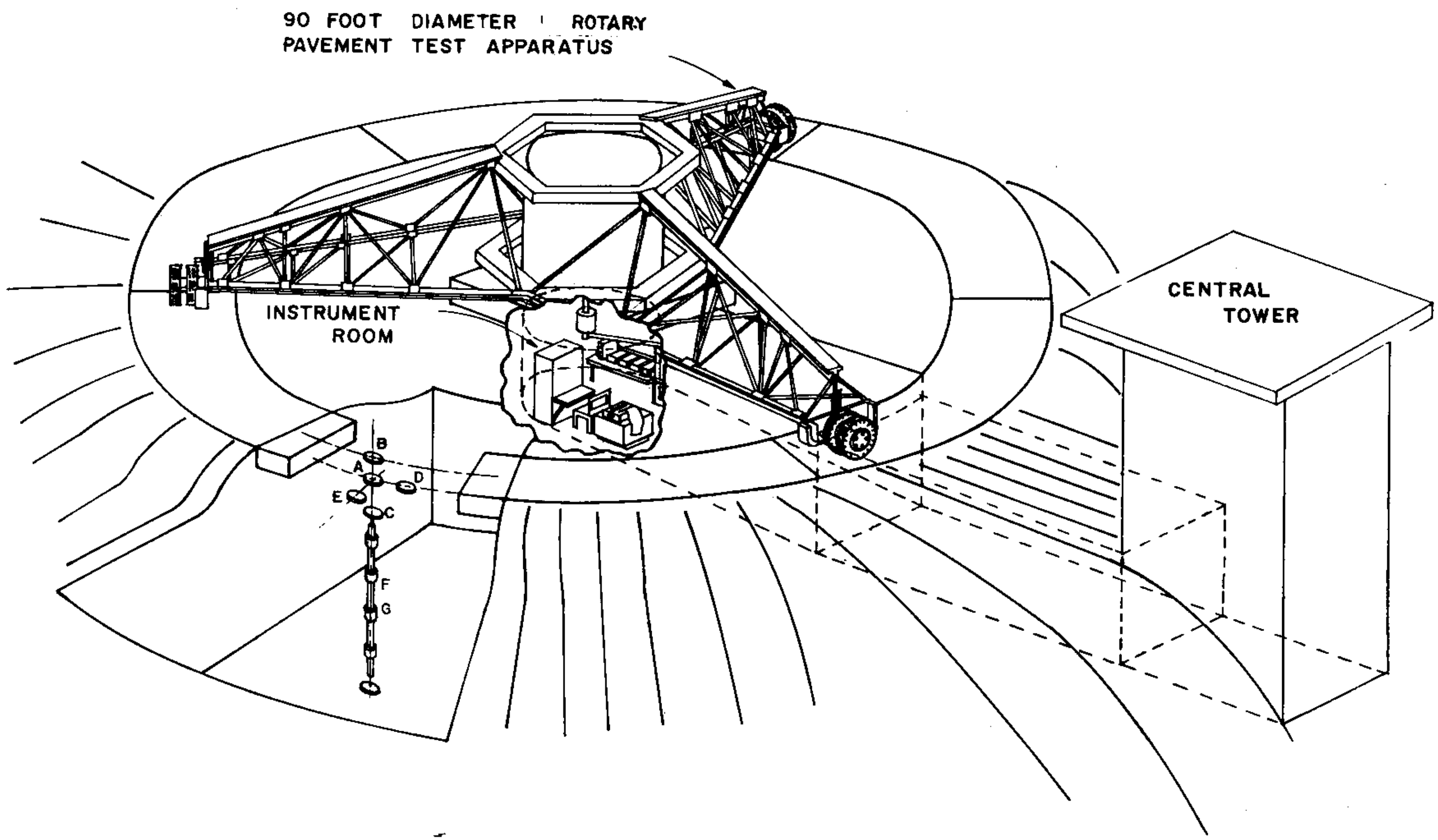



Figure 1 Field Installation - WSU Test Track

INSTRUMENT RACKS

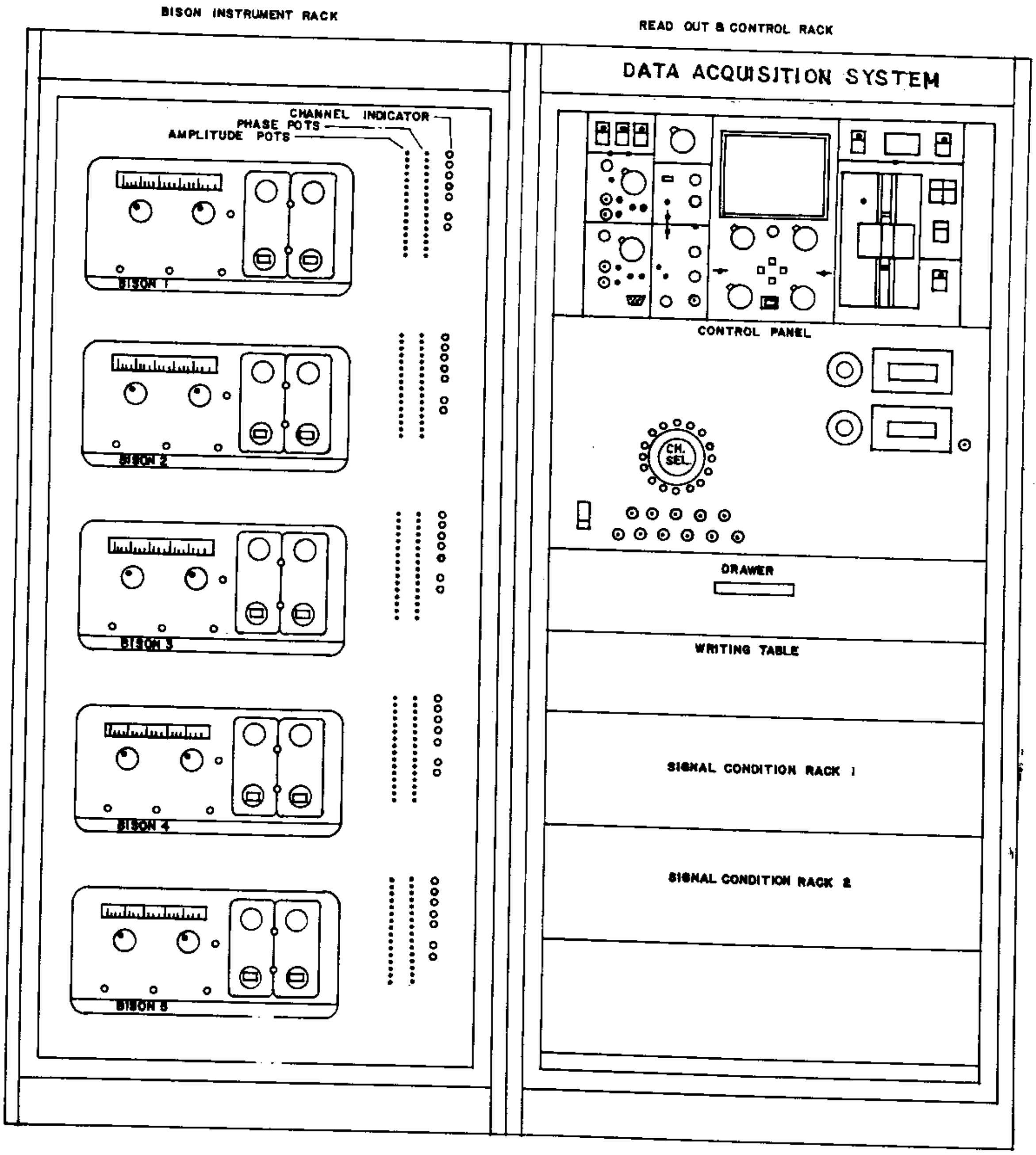
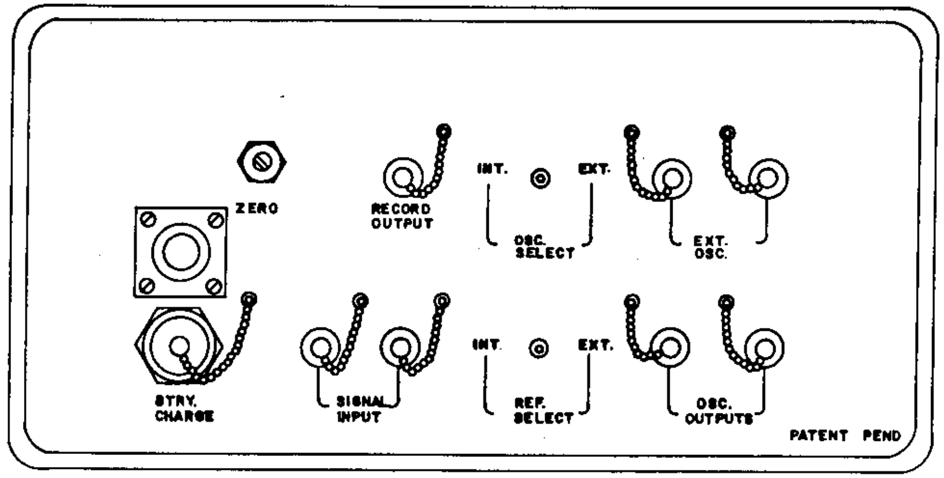
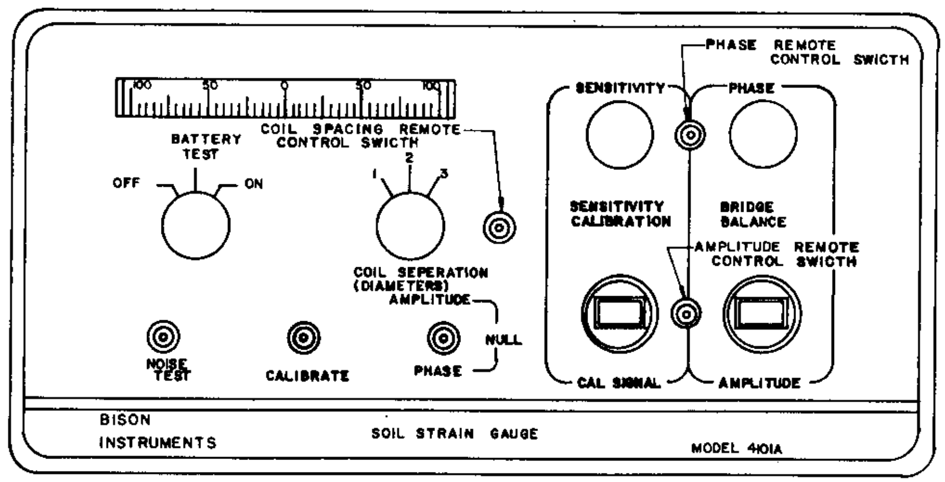



Figure 2 Instrument Racks - Front Panels




REAR BISON GAUGE PANEL




FRONT BISON GAUGE PANEL

Figure 3 Bison Gages - Front and Rear Panels

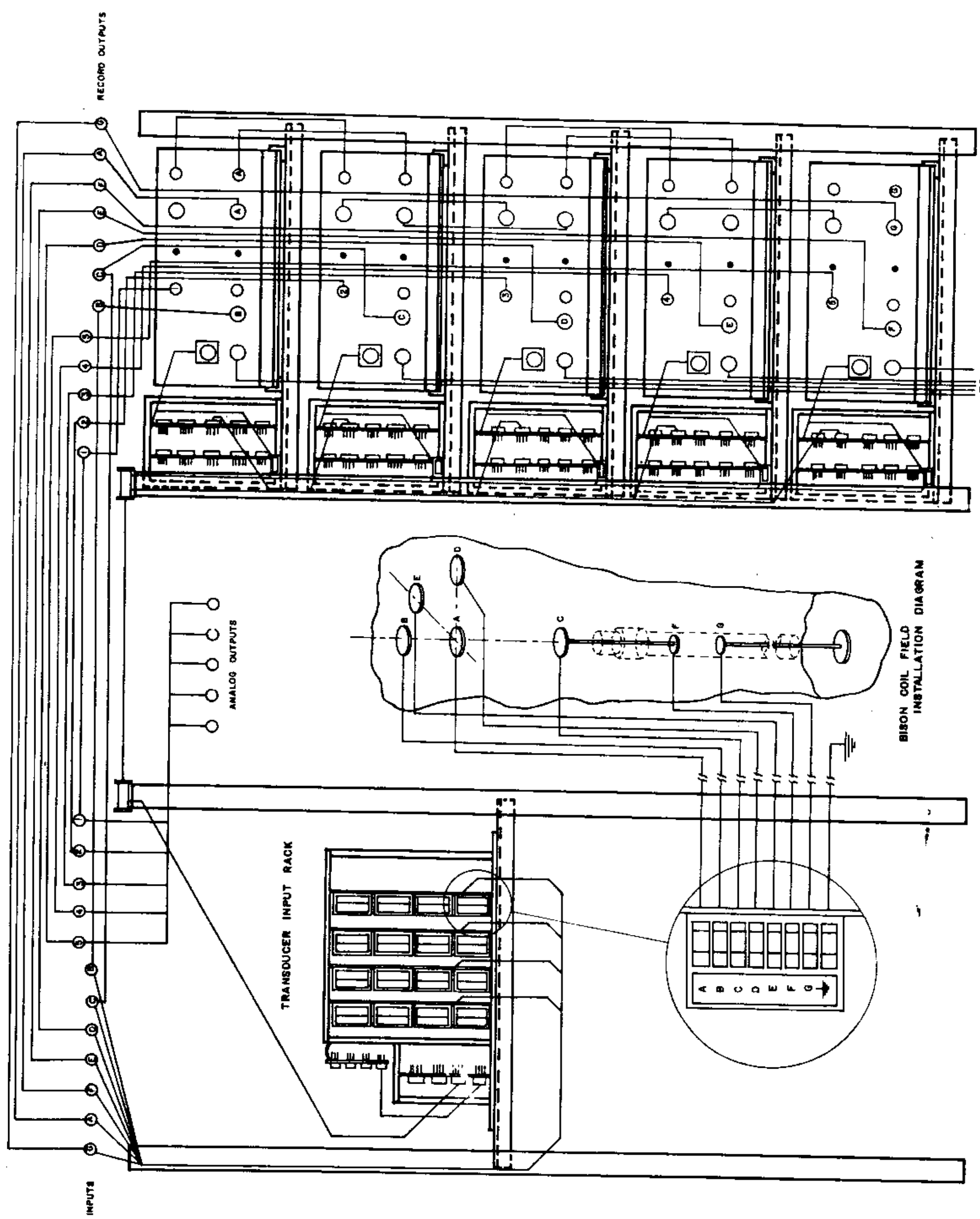



Figure 4 Interconnect Diagram for Instrument Racks

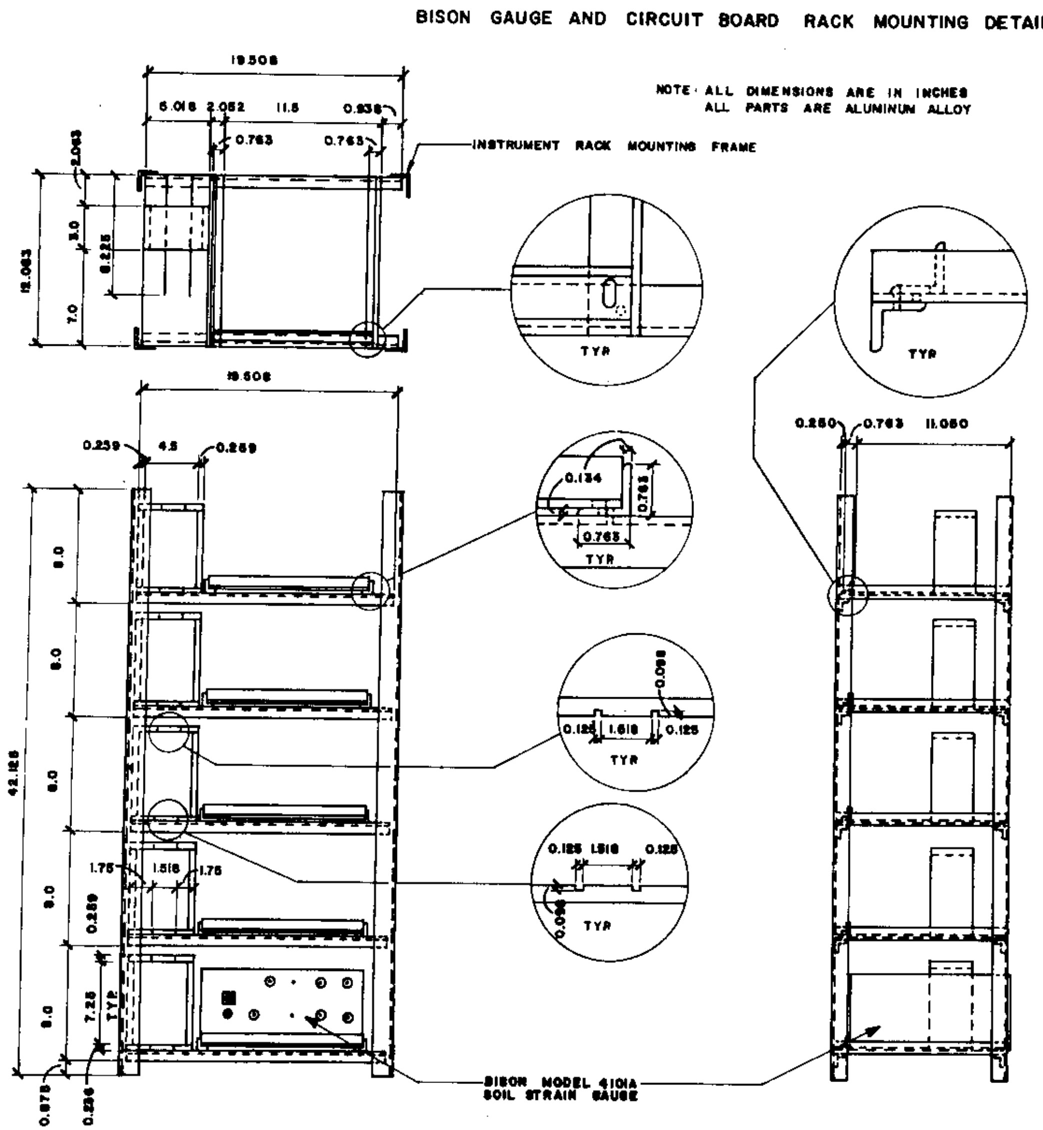



Figure 5 — Bison Instrument Rack - Mounting Detail

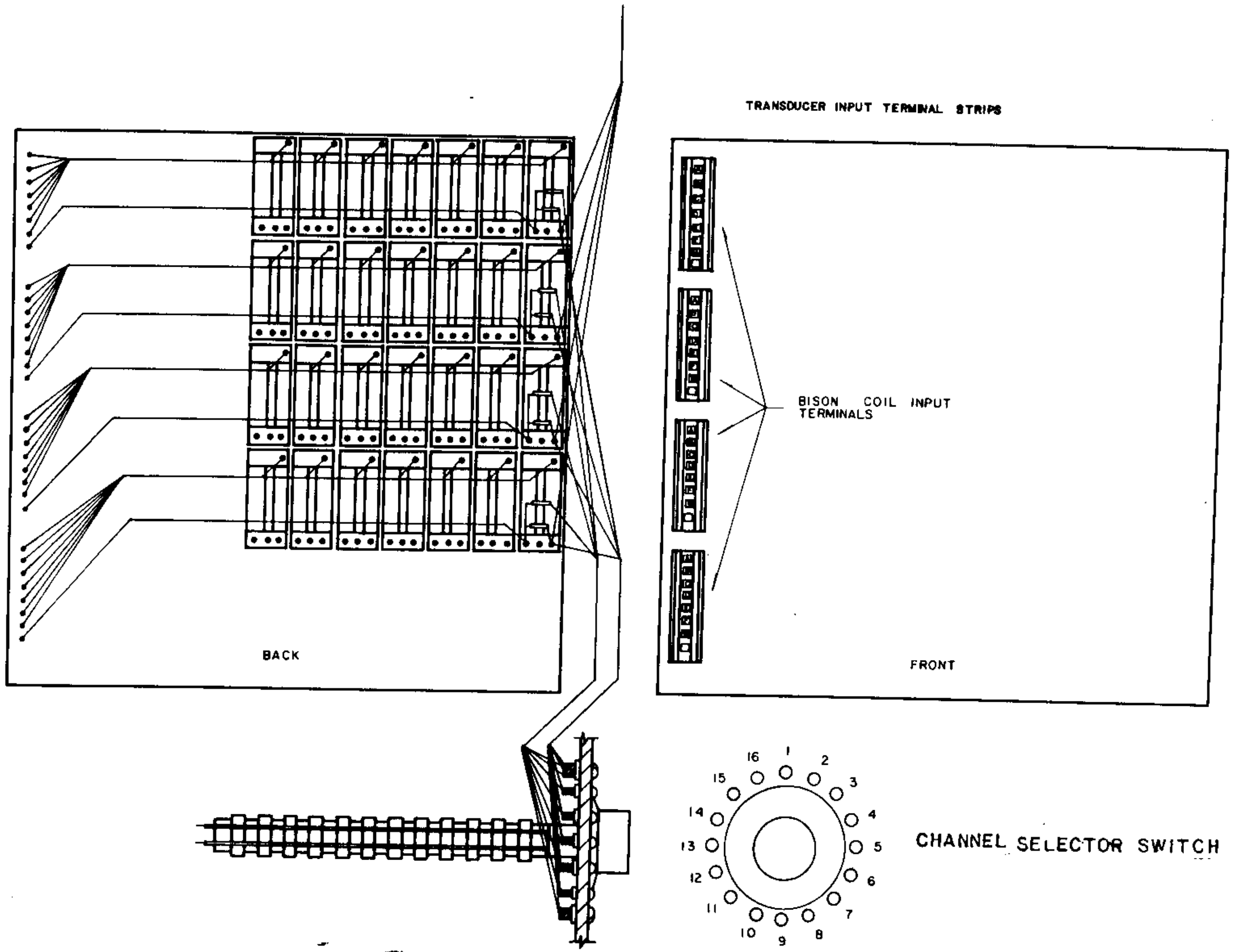



Figure 6 Relay and Coil Input Board Detail

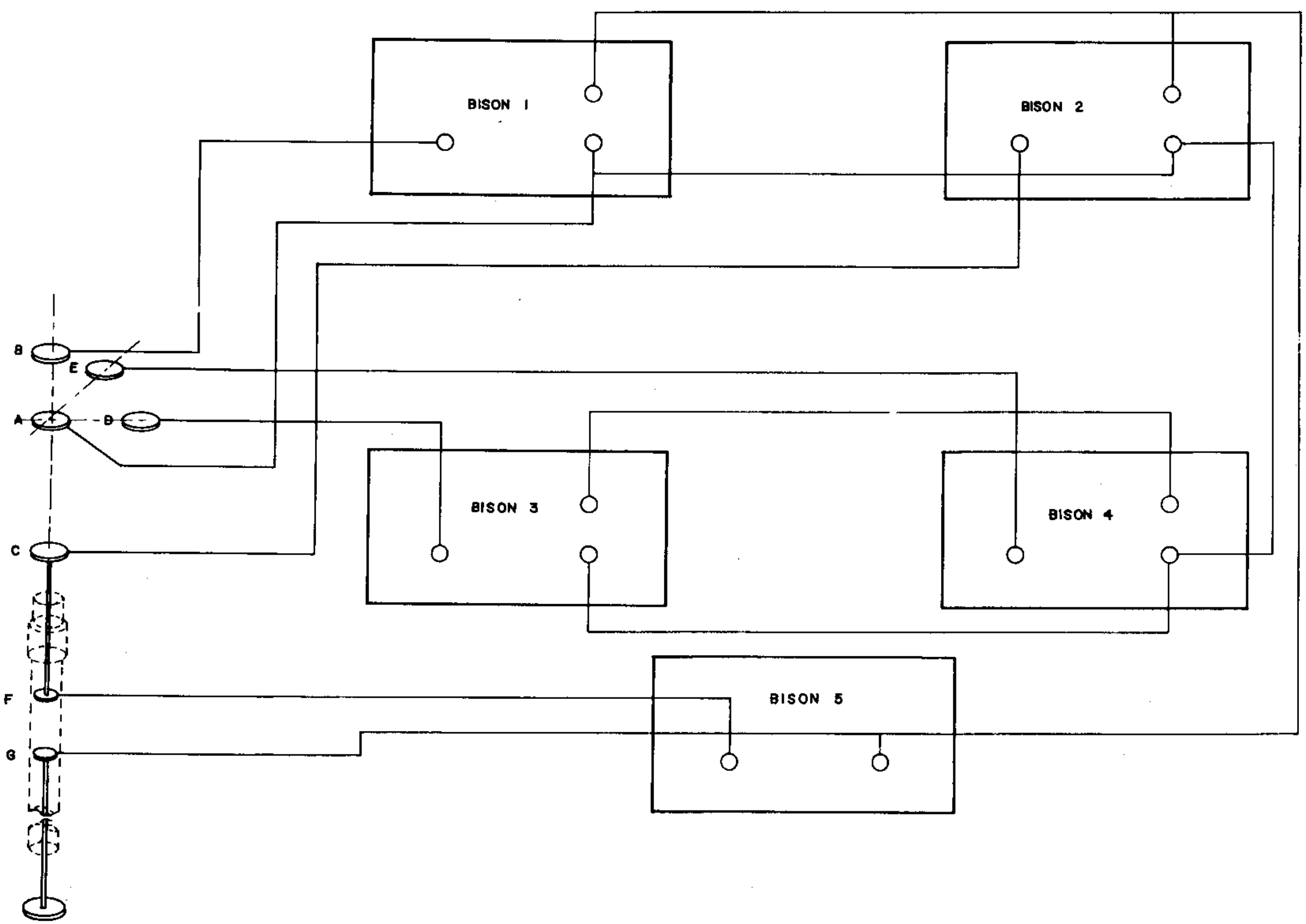
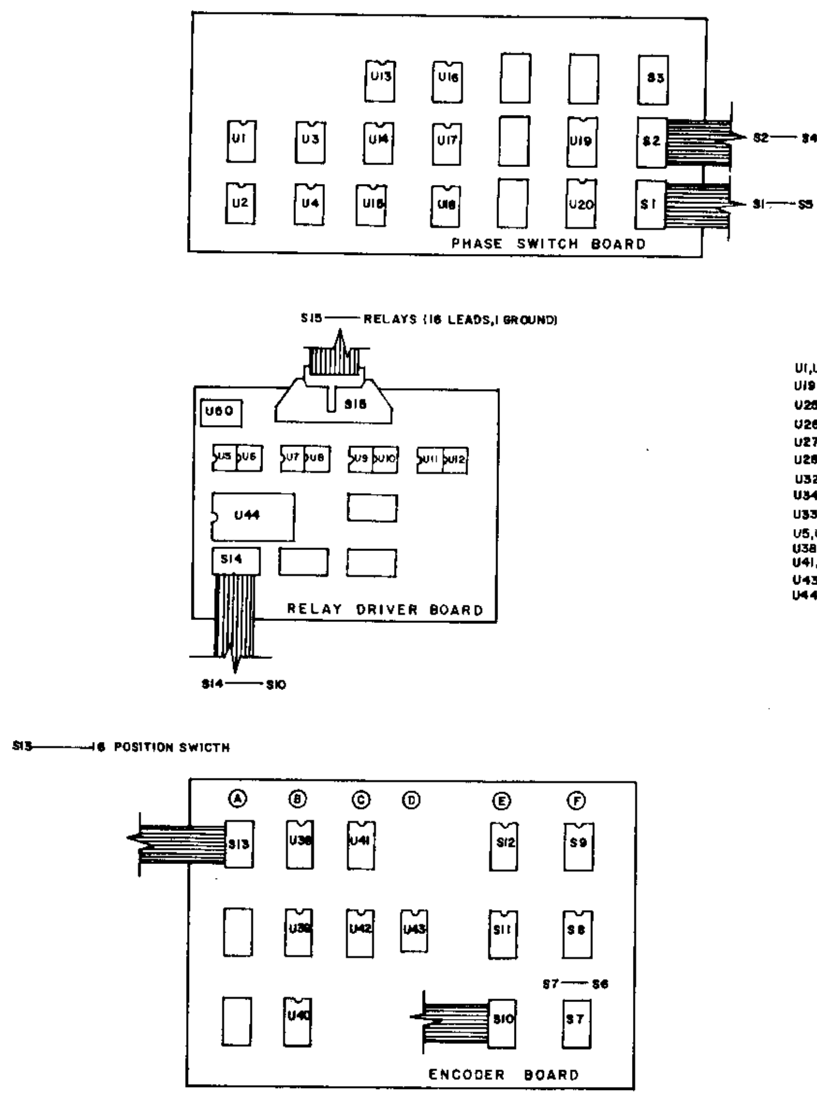



Figure 7 Bison Gage Inner Connect For Three Dim. Coil Arrangement




PARTS LIST

U1,U2,U3,U4,U13,U14,U15,U16,U17,U18 = VQ1000J
U19,U20,U21,U22,U23,U24,U31 = CD4061BE
U25 = MM74C14N
U26 = CD4069 UBE
U27 = HFC 4069UBE
U28,U29,U30 = MM74C00N
U32,U35 = MM74C02N
U34,U37 = DS75491N
U33,U36 = MC14490
U5,U6,U7,U8,U9,U10,U11,U12 = MN74C906N
U38,U39,U40 = F40498PC
U41,U42 = SYL ECG 4532B
U43 = CD 4071 BE
U44 = CD4518 BE

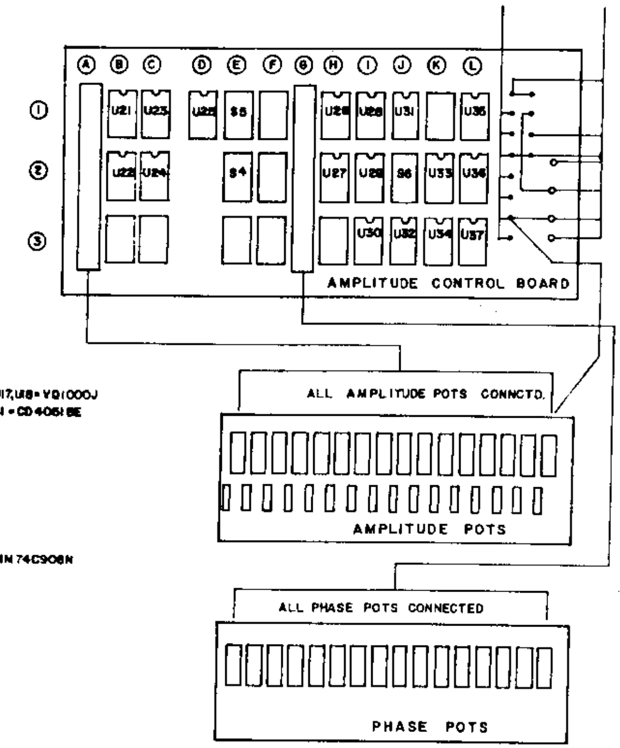



Figure 8 Circuit Board Component Layout and Parts List

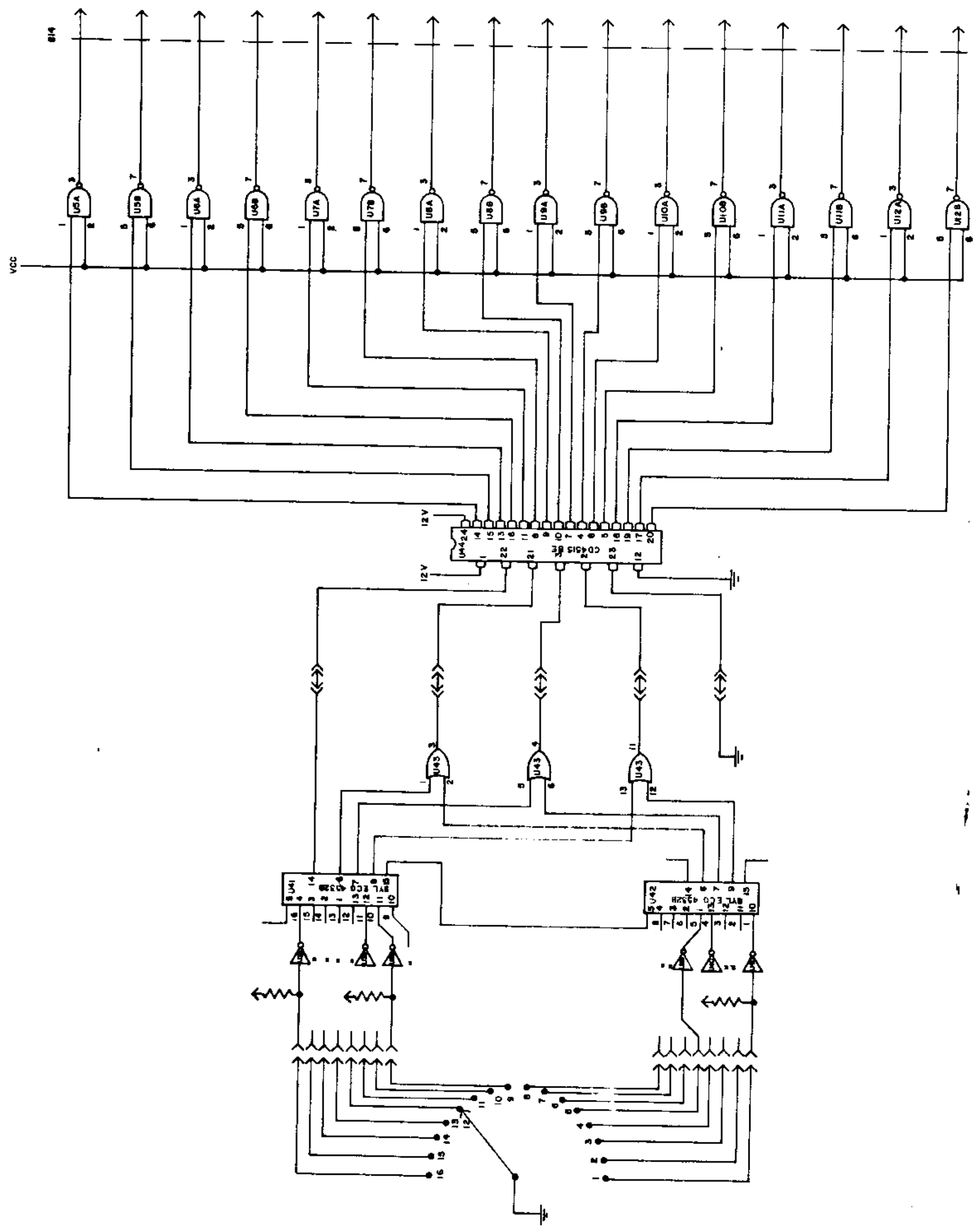



Figure 9 Switching Circuit and Control Diagram

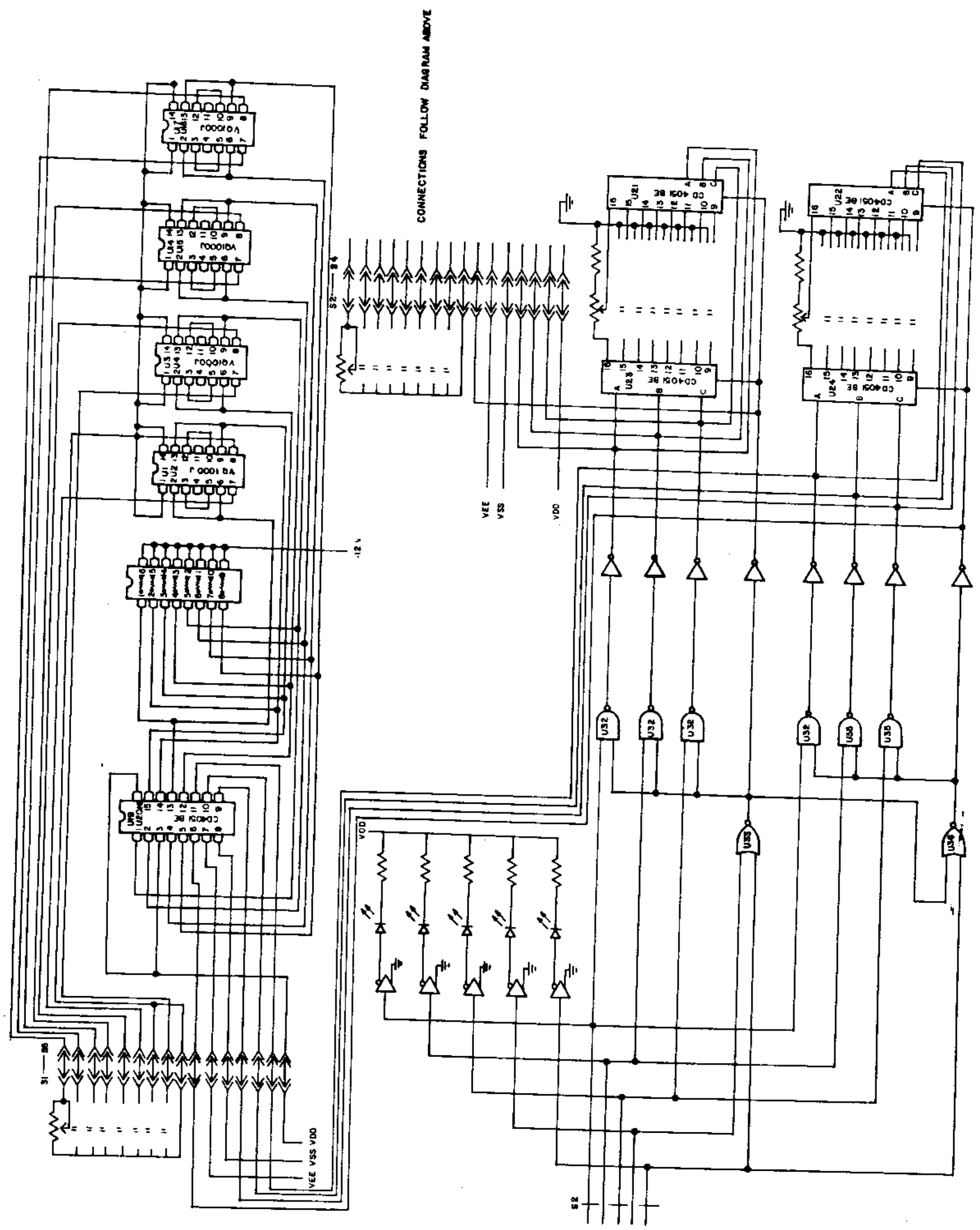



Figure 10 Remote Control Circuit Diagram

# Model 4562 Plug-in

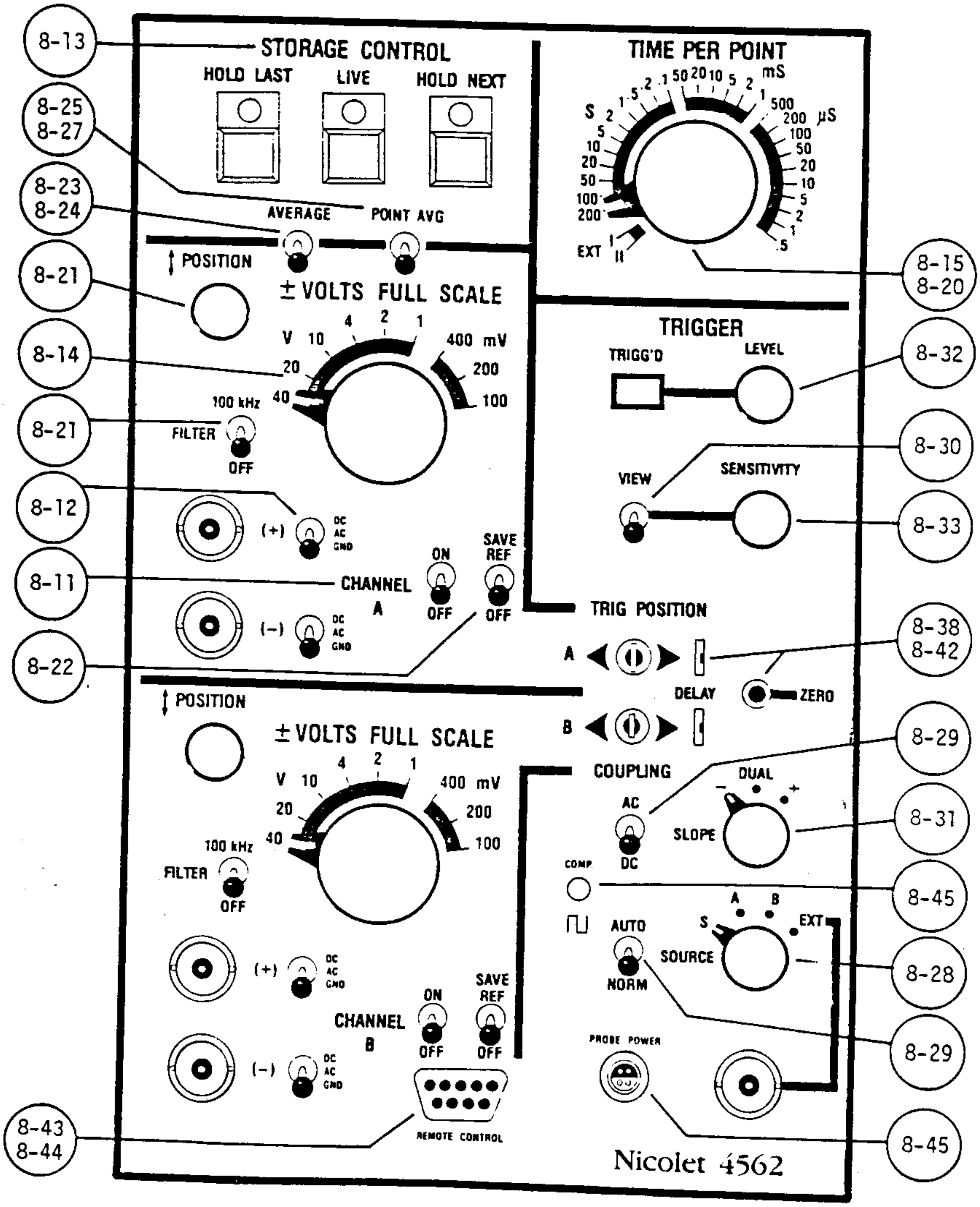



Figure 11 Nicolet Plug-in Amplifier Unit

# Mainframe

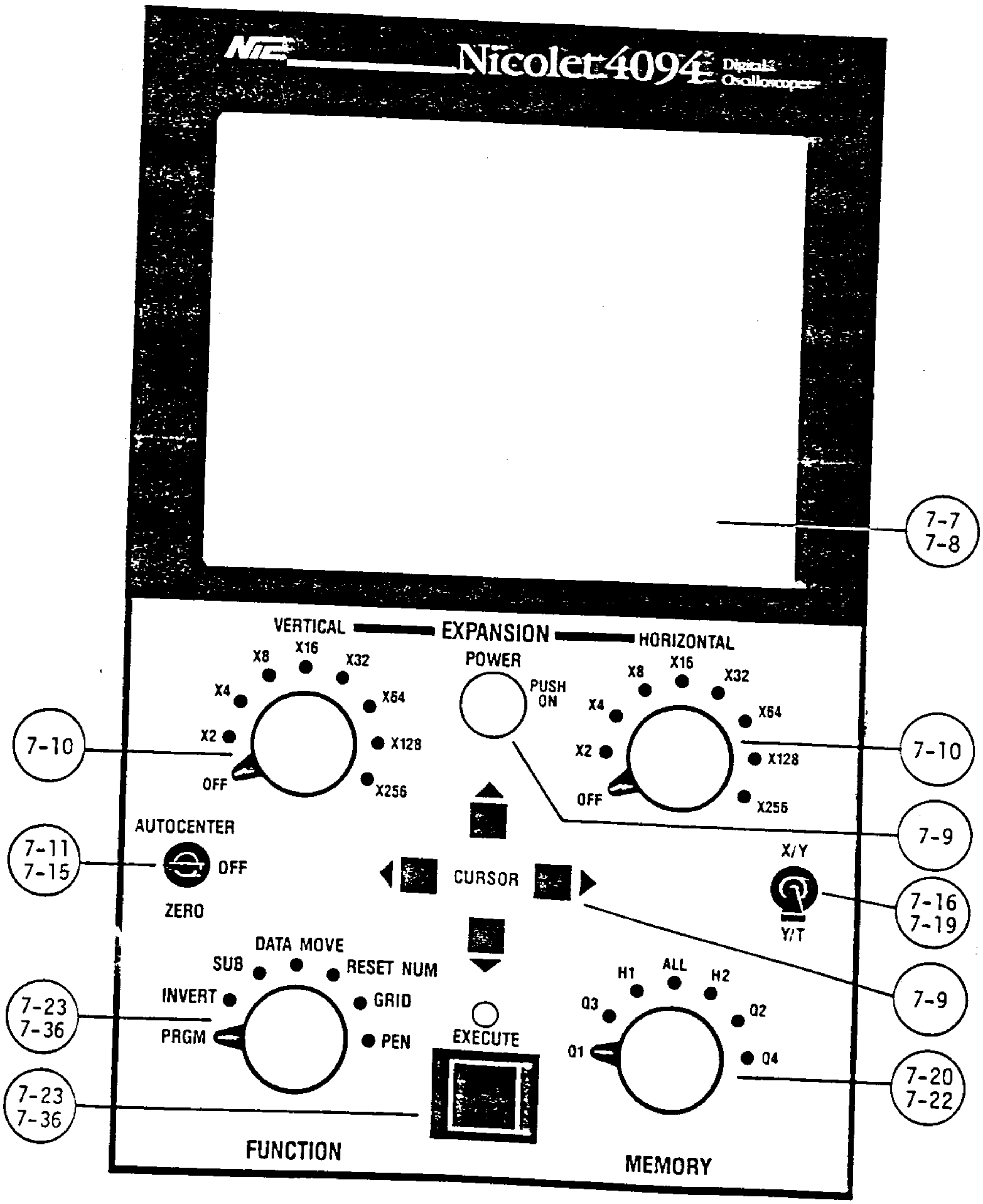



Figure 12 Nicolet Mainframe

# Disk Recorder—F-43

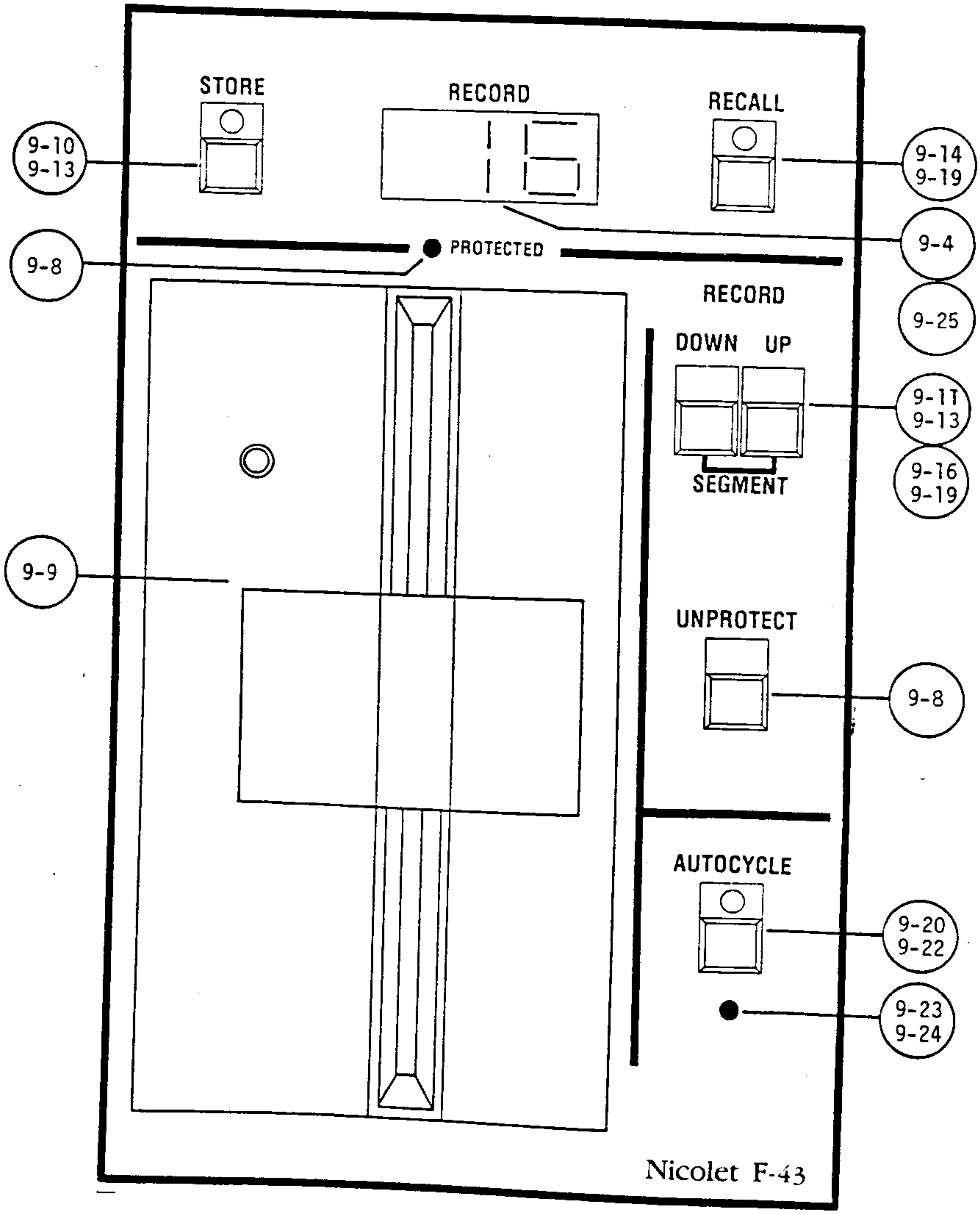



Figure 13 Nicolet Disk Recorder

# Input/Output Panel

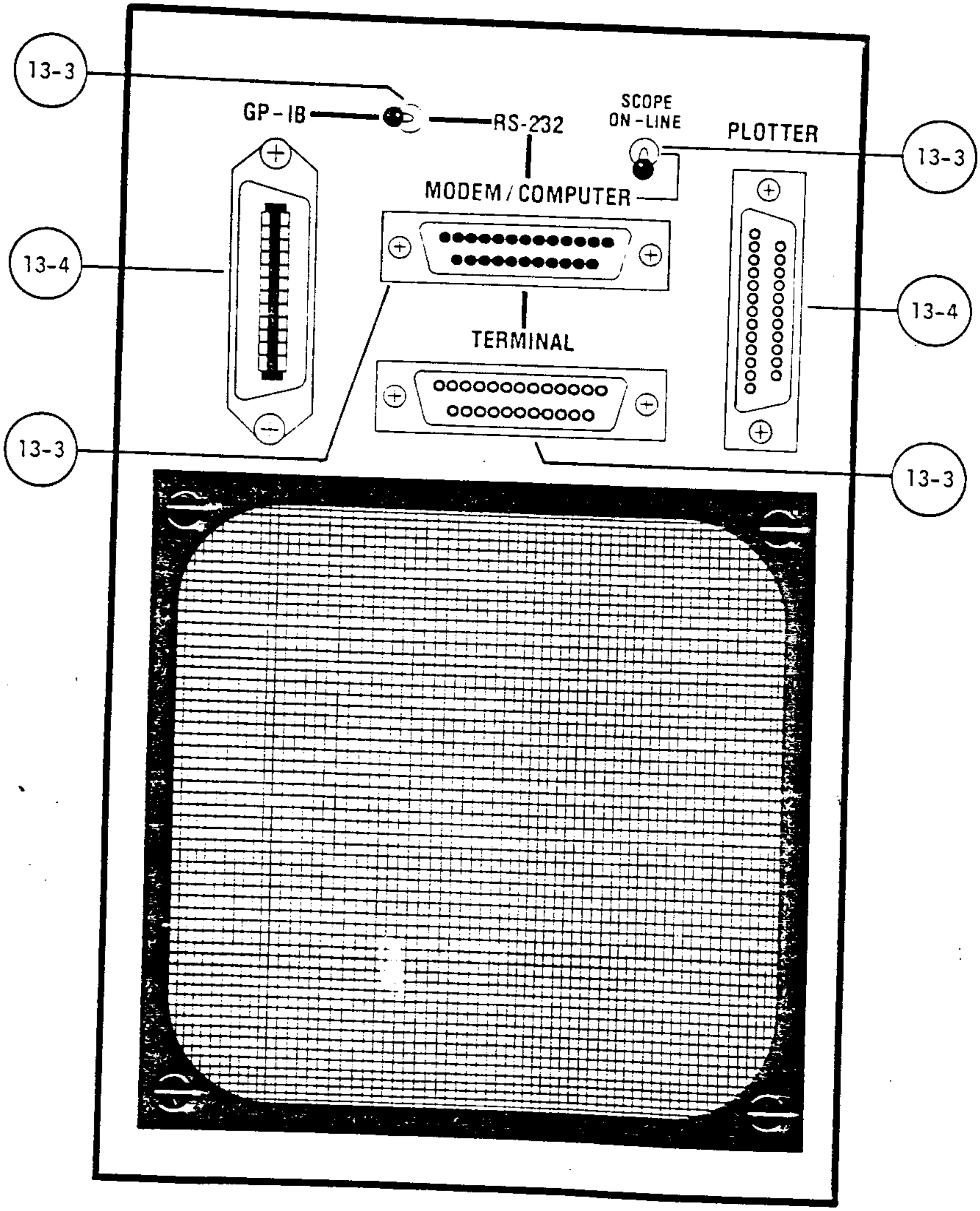



Figure 14 Nicolet Input/Output

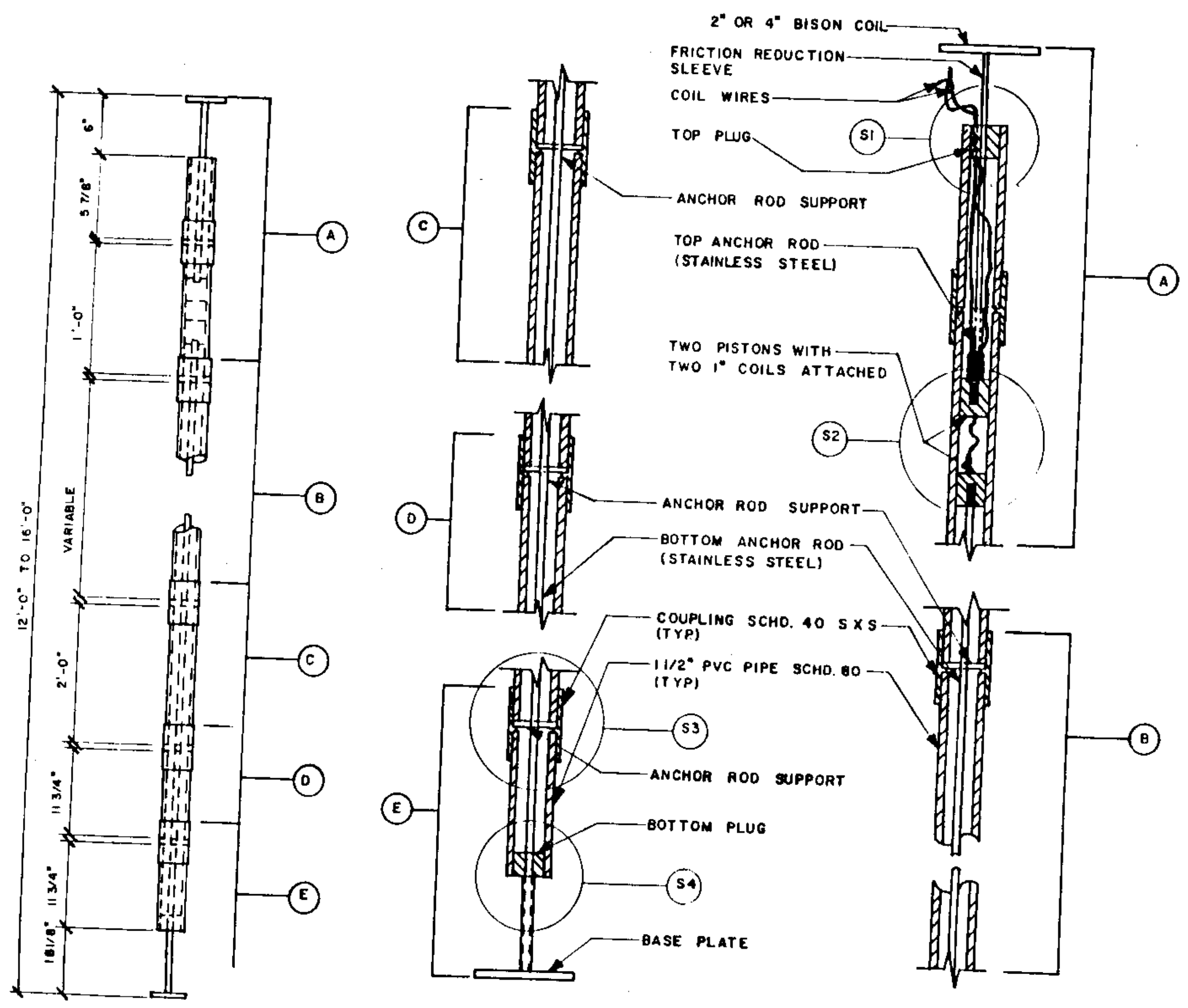



Figure 15 Extensometer - General Detail

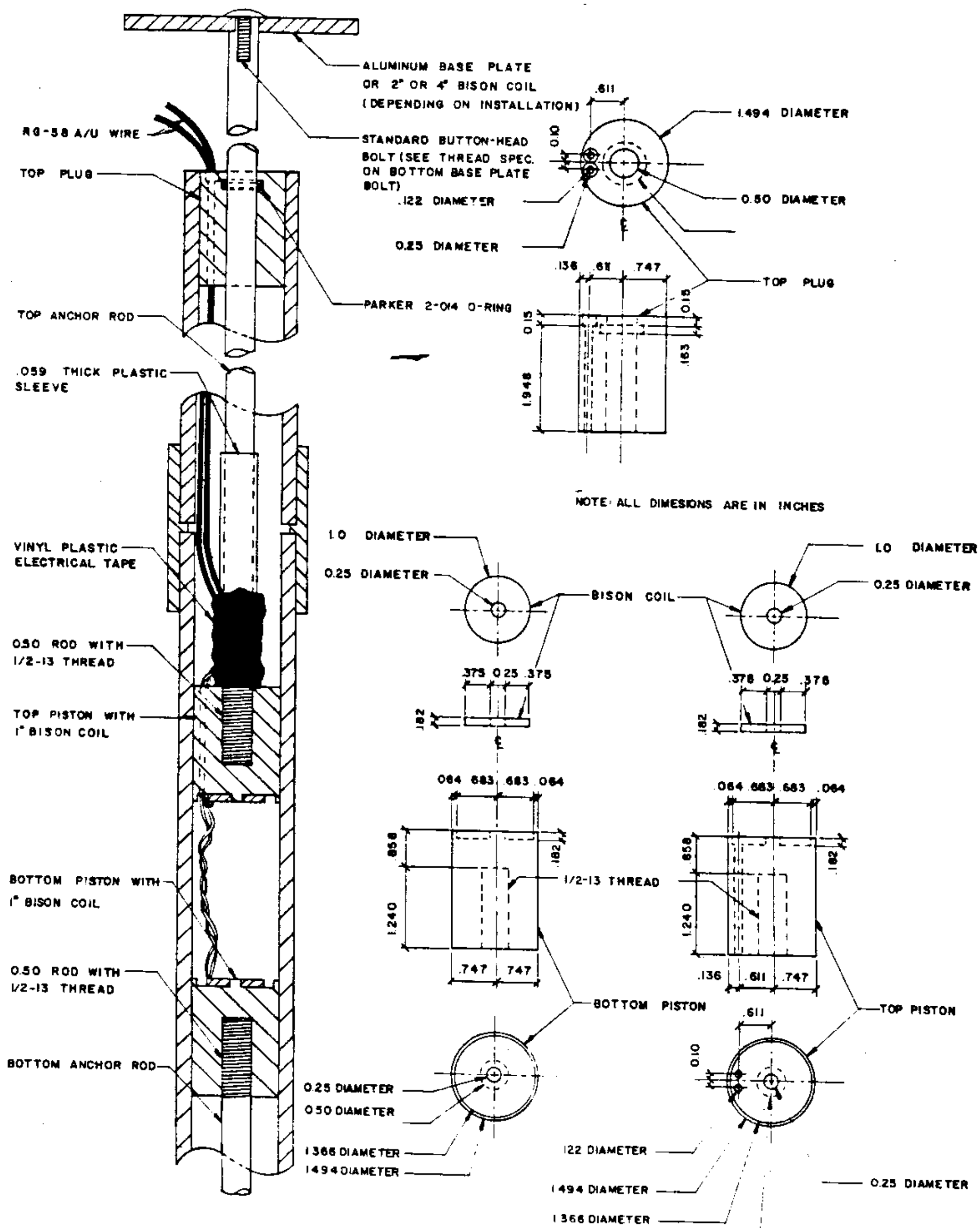



Figure 16 Extensometer - Bison Coil Sensor Detail

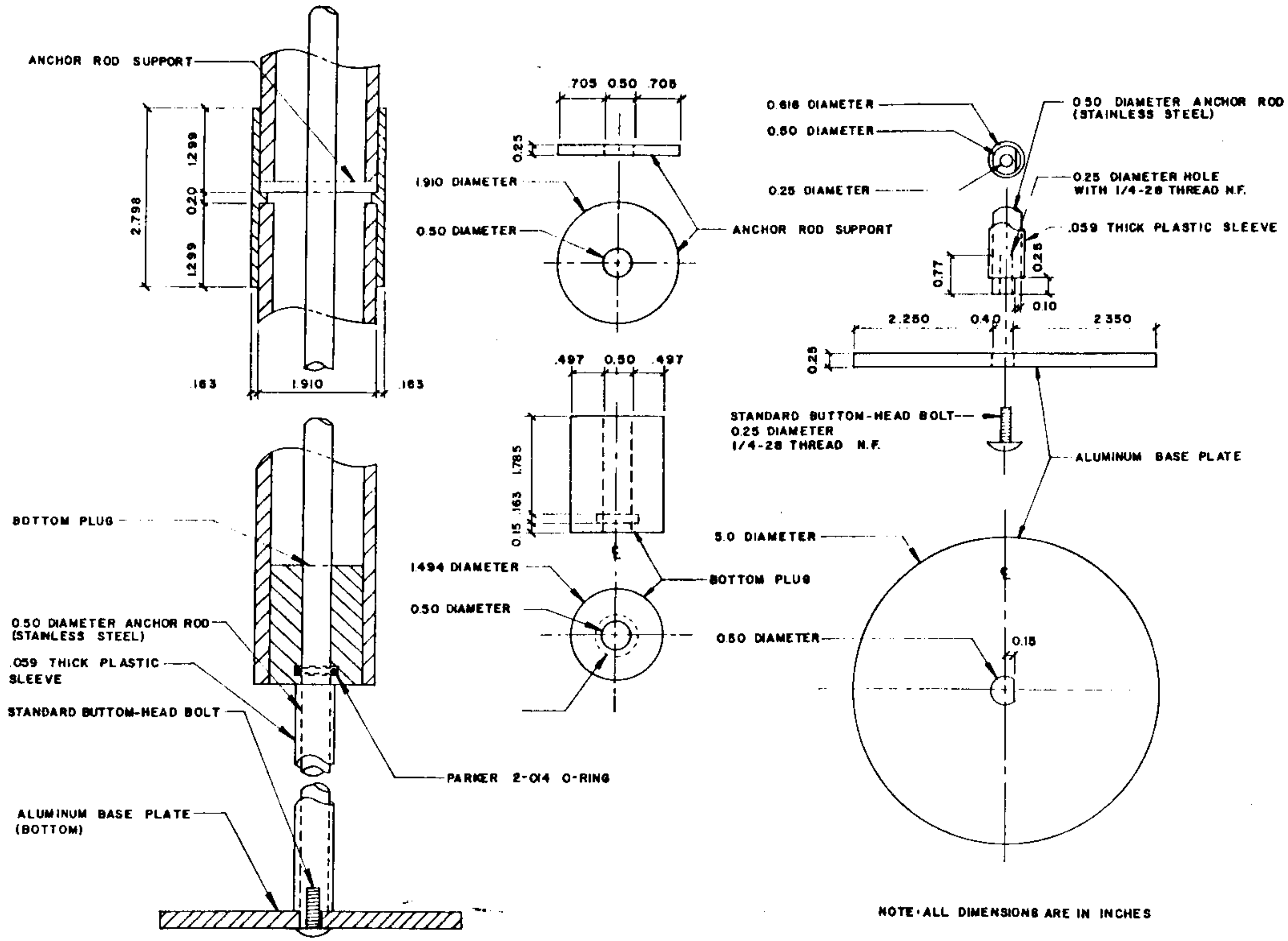



Figure 17 Extensometer - End Plate and Guide Detail

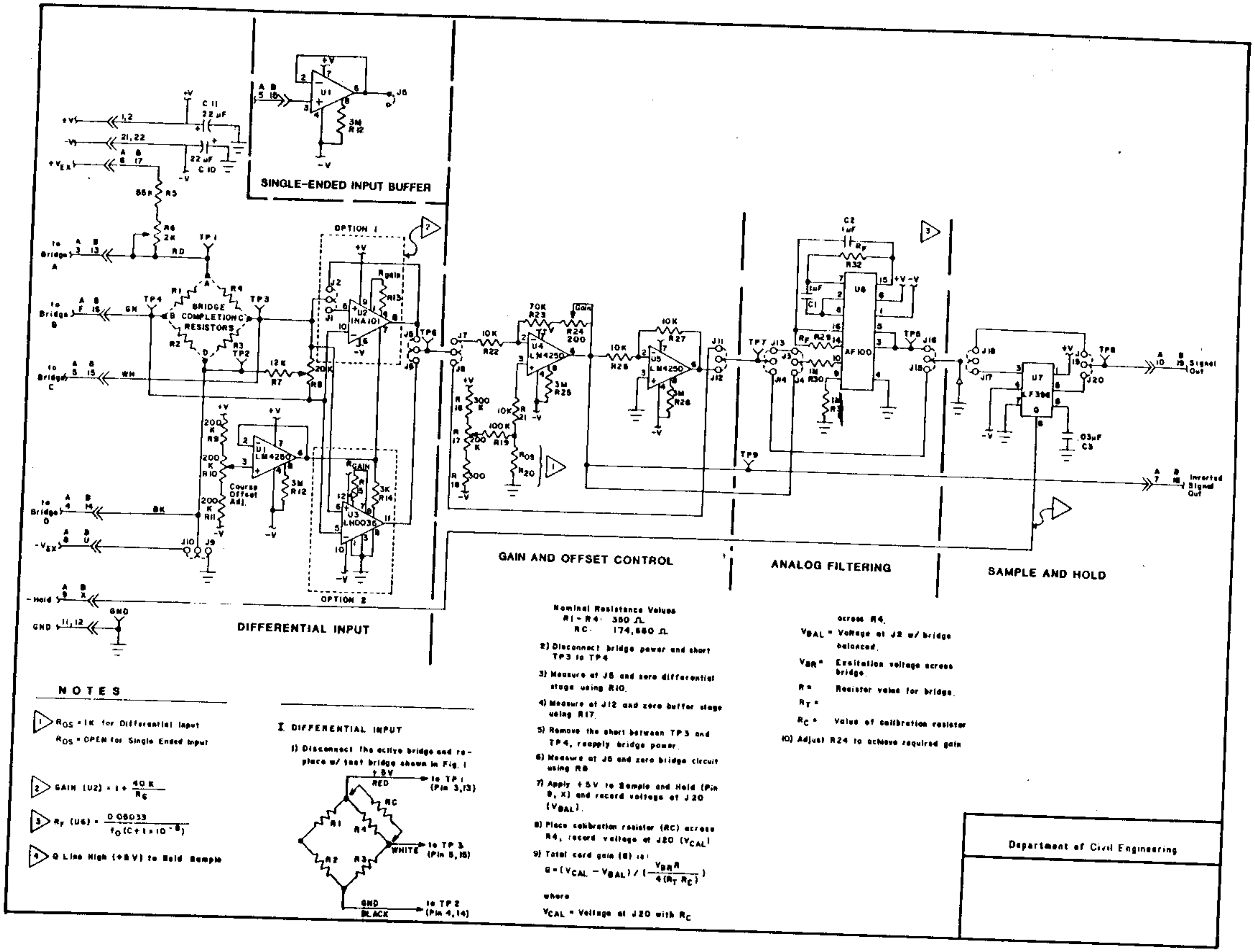
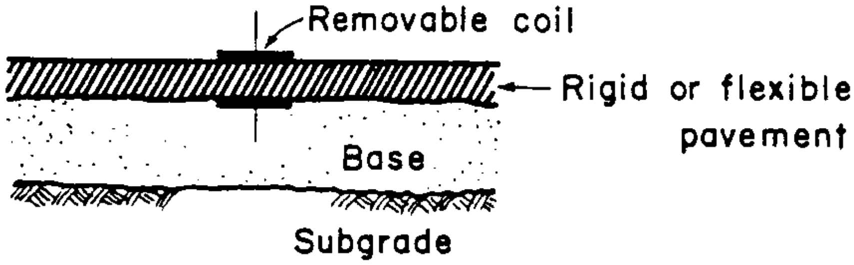
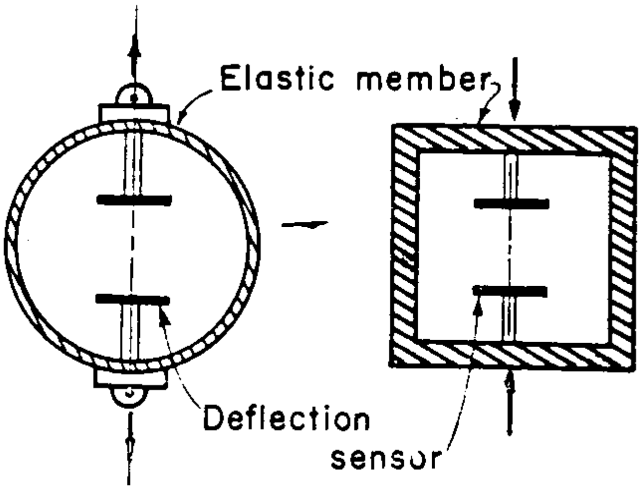


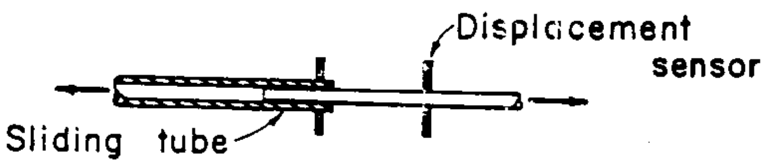

Figure 18 Suggested Signal Conditioning Electronics



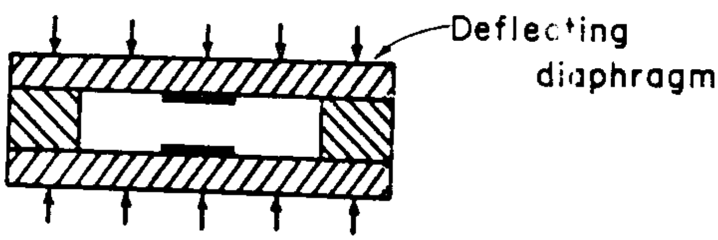

a) Pavement thickness measurement




b) Load cells




c) Extensometer readout




d) Stress or pressure gauge

Figure 19 Applications for Strain Gage Other Than in Soil

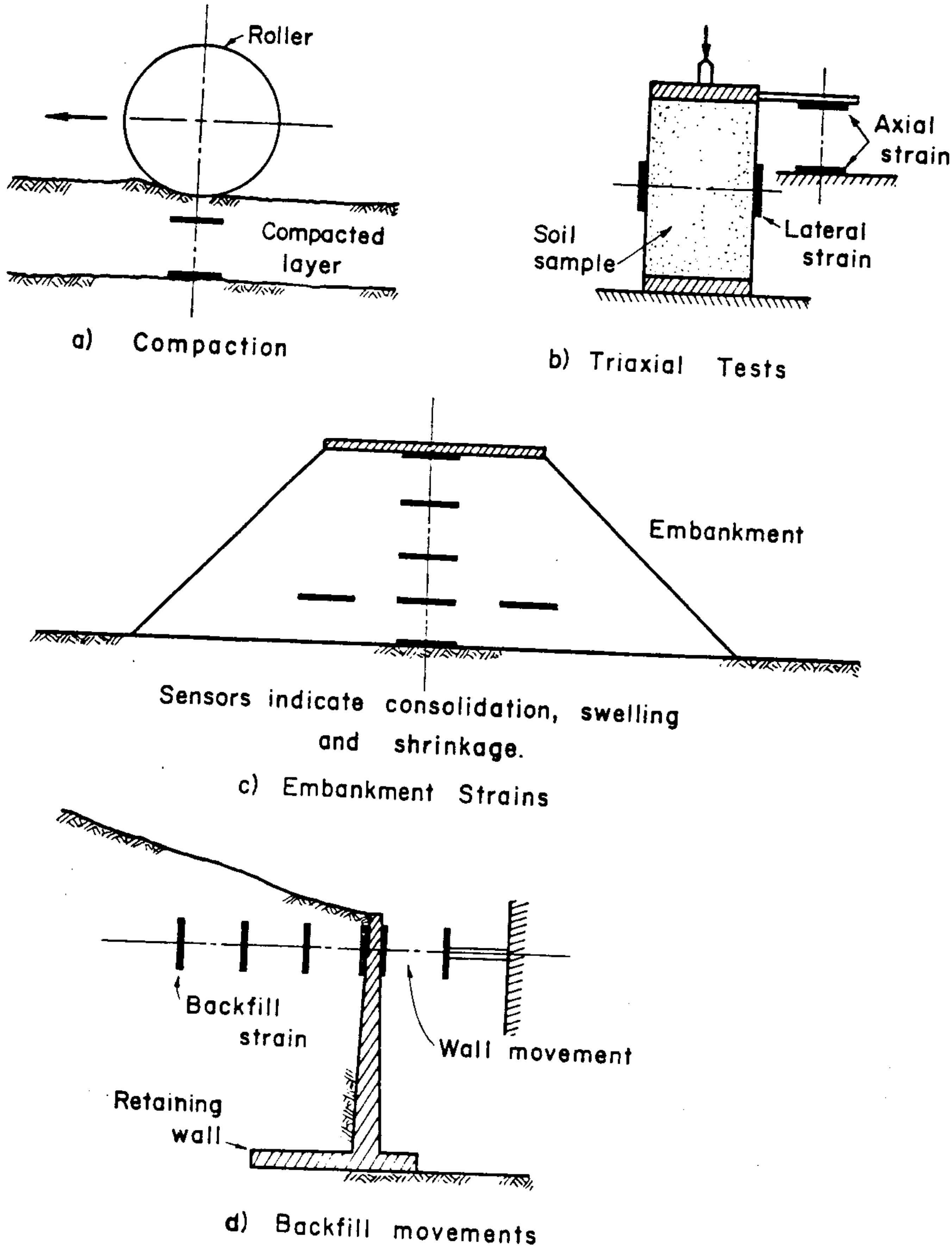



Figure 20 Applications for Strain Gage Embedded in Soil

**APPENDICES**

```
1 REM     13 FEB 1985
2 REM     THIS PROGRAM READS VALUES FROM A NICOLET 4094 DIGITAL
3 REM     OSCILLOSCOPE, CONVERTS THE VALUES TO ACTUAL TIME SERIES
4 REM     VOLTAGES, THEN WRITES THE VALUES IN A RANDOM FILE ON
5 REM     FLOPPY DISK.  THE RANDOM FILE IS A SERIES OF FOUR BYTE
6 REM     RECORDS.  THE FIRST RECORD IS THE START TIME, IN SECONDS;
7 REM     THE SECOND RECORD IS THE TIME INCREMENT IN SECONDS.  ALL
8 REM     FOLLOWING RECORDS ARE VOLTAGES, BEGINNING WITH THE
9 REM     START TIME VOLTAGE AND PROCEEDING SEQUENTIALLY.  A FULL
10 REM    TRACE OF 15872 READINGS WILL REQUIRE A 63496 BYTE FILE.
11 REM
12 REM
13 REM    THE PROGRAM OPERATES OFF A MENU, WHICH APPEARS UPON
14 REM    EXECUTING RUN.  NOTE THAT THE "WAVEFORM" ROUTINE MUST
15 REM    BE CALLED BEFORE ANY DATA CAN BE LOADED.
16 REM
17 REM
18 REM                     PRINT OPTIONS
19 REM
20 DIM NDAT$(32),NSET$(32)
30 OPEN "COM1:4800,N,8,1,LF" AS #1 LEN=4096
35 WRITE#1,">"
40 CLS
50 PRINT:PRINT TAB(21)"MAKE SCOPE BEEP ----------------- B"
55 PRINT:PRINT TAB(21)"LOAD FILE FROM DISK ------------- L"
60 PRINT:PRINT TAB(21)"GET WAVEFORM INFORMATION -------- W"
65 PRINT:PRINT TAB(21)"GET DATA ------------------------ D"
80 PRINT:PRINT TAB(21)"CALL L,W,D IN ORDER ------------- O"
90 PRINT:PRINT TAB(21)"ENTER COMMAND FROM KEYBOARD ----- P"
95 PRINT:PRINT TAB(21)"EXIT ---------------------------- X"
96 PRINT:PRINT
100 REM
101 REM                    SELECT OPTIONS
102 REM
110 S$=INKEY$:IF S$="" THEN 110
150 IF S$="B" THEN WRITE#1,"B":GOTO 110
155 IF S$="L" THEN GOSUB 300:GOTO 40
160 IF S$="W" THEN GOSUB 400:GOTO 40
165 IF S$="D" THEN GOSUB 500:GOTO 40
180 IF S$="O" THEN GOSUB 300:GOSUB 400:GOSUB 500:GOTO 40
190 IF S$="P" THEN GOSUB 200:GOTO 40
195 IF S$="X" THEN CLOSE:END
199 GOTO 110
200 REM
201 REM                    COMMANDS FROM THE KEYBOARD
202 REM
210 INPUT;"ENTER COMMAND:   ",S$:PRINT
215 IF S$="" THEN RETURN
220 WRITE#1,S$
230 WHILE NOT EOF(1):S$=INPUT$(LOC(1),#1):PRINT S$:WEND
299 GOTO 900
```

```
300 REM
301 REM          LOAD ROUTINE
302 REM
310 INPUT;"LOAD FILE.  ENTER FILE NUMBER:  ",S$:PRINT:PRINT
315 IF S$="" THEN RETURN
320 NFILE=VAL(S$):IF NFILE<0 THEN WRITE#1,"B":GOTO 310
330 IF NFILE>20 THEN WRITE#1,"B":GOTO 310
340 S$="R,0,"+S$+",0":WRITE#1,S$
370 PRINT"WAIT UNTIL RECALL LIGHT ON SCOPE IS OUT, THEN PRESS ANY KEY."
399 NWAVS=0:GOTO 920
400 REM
401 REM          WAVEFORM ROUTINE
402 REM
410 CLS
411 IF NFILE=0 THEN PRINT"MUST LOAD FILE FIRST":WRITE#1,"B":GOTO 499
412 WRITE#1,"W"
415 S$=INPUT$(4,#1):IF MID$(S$,3,1)<>CHR$(13) THEN 425
420 A$=LEFT$(S$,2):GOTO 415
425 IF A$<>"00" THEN PRINT"ERROR CODE IN W = "A$:GOTO 499
430 A$=LEFT$(S$,2):NWAVS=VAL(A$)
435 PRINT"FILE "NFILE".    THE NUMBER OF WAVEFORMS = "NWAVS
440 S$=RIGHT$(S$,2)+INPUT$(13,#1)
445 PRINT:PRINT"WAVE NO.    NO. OF DATA PTS      NORM. SET NO."
450 FOR I=1 TO NWAVS
455 IF I<>1 THEN S$=INPUT$(15,#1)
460 NW=VAL(LEFT$(S$,2)):IF NW<>I THEN PRINT"BAD WAVEFORM MATCH":GOTO 499
465 NDAT$(I)=MID$(S$,3,6):NSET$(I)=MID$(S$,9,2)
475 PRINT "  "I,"  "NDAT$(I),"          "NSET$(I):IF I<>15 THEN GOTO 488
480 PRINT:PRINT"PRESS ANY KEY TO CONTINUE"
485 S$=INKEY$:IF S$="" THEN 485
488 NEXT I
499 GOTO 900
500 CLS
501 REM          GET DATA, SET UP FILE
502 REM
510 IF NWAVS=1 THEN S$="1":GOTO 530
520 IF NWAVS=0 THEN PRINT"MUST CALL  W  FIRST":WRITE#1,"B":GOTO 900
525 PRINT"FILE NUMBER "NFILE".";
530 INPUT;"ENTER THE FILE NAME FOR STORAGE:  ",S$:PRINT:PRINT
540 IF S$="" THEN RETURN
550 DNAM$=S$:OPEN DNAM$ AS #2 LEN=4
580 FIELD #2,4 AS RS$
590 PRINT"FILE NAME = "DNAM$:PRINT
```

```
600 REM
601 REM            GET DATA, GET NORMALIZATION SET
602 REM
610 IF NWAVS=1 THEN S$="1":GOTO 625
620 INPUT;"ENTER THE WAVEFORM NO:  ",S$:PRINT:PRINT
622 IF S$="" THEN RETURN
625 NW=VAL(S$):IF NW>NWAVS THEN WRITE#1,"B":GOTO 620
630 IF NW<1 THEN WRITE#1,"B":GOTO 620
635 S$="N,"+NSET$(NW):WRITE#1,S$:WRITE#1,S$
640 S$=INPUT$(4,#1):IF MID$(S$,3,1)<>CHR$(13) THEN 648
645 A$=LEFT$(S$,2):GOTO 640
648 S$=S$+INPUT$(48,#1)
650 IF A$<>"00" THEN PRINT"ERROR CODE IN N = "A$:GOTO 900
660 WVAL=VAL(LEFT$(S$,1)):SWSIZ=VAL(MID$(S$,2,1)):CHNUM=VAL(MID$(S$,3,1))
665 DISCH=VAL(MID$(S$,4,1)):VNORM=VAL(MID$(S$,5,9)):HNORM=VAL(MID$(S$,14,9
670 VZERO=VAL(MID$(S$,23,6)):HZERU=VAL(MID$(S$,29,6))
675 HZERL=VAL(MID$(S$,35,6))
680 PRINT    WVAL,SWSIZ,CHNUM,DISCH,VNORM,HNORM,VZERO,HZERU,HZERL
690 WHILE NOT EOF(1):S$=INPUT$(LOC(1),#1):WEND
700 REM
701 REM            GET DATA, ESTABLISH TRANSFER PARAMETERS
702 REM
710 PRINT:PRINT"FILE NUMBER "NFILE;
712 PRINT".   WAVEFORM NUMBER "NW".   TOTAL POINTS = "NDAT$(NW)
715 MAX%=512:PRINT:PRINT
725 S$=STR$(NW):L$="D,0,"+RIGHT$(S$,LEN(S$)-1)+","
730 INPUT;"ENTER STARTING POINT (A = ALL POINTS):  ",S$:PRINT
735 IF S$="" THEN CLOSE 2:RETURN
740 IF S$<>"A" THEN GOTO 750
745 S$=NDAT$(NW):TOT%=VAL(S$):ST%=0:INC%=1:GOTO 760
750 INPUT;"ENTER THE TOTAL NUMBER OF POINTS:  ",S$:PRINT:TOT%=VAL(S$)
755 INPUT;"ENTER THE INCREMENT:  ",S$:PRINT:INC%=VAL(S$)
760 STEPS%=INT(TOT%/MAX%):RMD%=TOT%-MAX%*STEPS%
```

```
800 REM
801 REM           GET DATA, CONVERT TO VOLTAGE AND TIME
802 REM              D=(VAL(LEFT$(S$,6))-VZERO)*VNORM
803 REM              T=(KNT%-KK*HZERU+HZERL)*HNORM
804 REM
810 STT=(ST%-65536!*HZERU+HZERL)*HNORM:INCC=INC%*HNORM
815 PRINT"START TIME = "STT".     DELTA TIME = "INCC"."
820 LSET RS$=MKS$(STT):PUT #2
822 LSET RS$=MKS$(INCC):PUT #2
825 FOR I=0 TO STEPS%
830 S$=STR$((I)*MAX%*INC%)
835 C$=L$+RIGHT$(S$,LEN(S$)-1)+","
840 IF I<STEPS% THEN S$=STR$(MAX%)
845 IF I=STEPS% THEN S$=STR$(RMD%)
847 IF VAL(S$)=0 THEN GOTO 899
850 C$=C$+RIGHT$(S$,LEN(S$)-1)+","
855 S$=STR$(INC%):C$=C$+RIGHT$(S$,LEN(S$)-1)
865 WRITE#1,C$
866 PRINT"STEP "I,C$
870 S$=INPUT$(4,#1):IF MID$(S$,3,1)<>CHR$(13) THEN 880
875 A$=LEFT$(S$,2):GOTO 870
880 IF A$<>"00" THEN PRINT"ERROR CODE IN D = "A$:GOTO 899
882 S$=S$+INPUT$(2,1)
885 WHILE NOT EOF(1):NPT%=LOC(1):IF NPT%>6 THEN NPT%=6
890 D=(VAL(LEFT$(S$,6))-VZERO)*VNORM:LSET RS$=MKS$(D):PUT #2
891 S$=INPUT$(NPT%,1):WEND
895 NEXT I
899 WRITE#1,"B":CLOSE 2:GOTO 900
900 REM
901 REM           EMPTY BUFFER, RETURN TO MAIN MENU
902 REM
910 PRINT:PRINT"PRESS ANY KEY WHEN FINISHED":PRINT
920 S$=INKEY$:IF S$="" THEN 920
930 IF LOC(1)=0 THEN RETURN
940 S$=INPUT$(LOC(1),#1):GOTO 930
```

References

1 Mahoney, J.P., "Sulfur Extended Asphalt Pavement Evaluation in the State of Washington: Design and Construction Report", WSDOT, 1981