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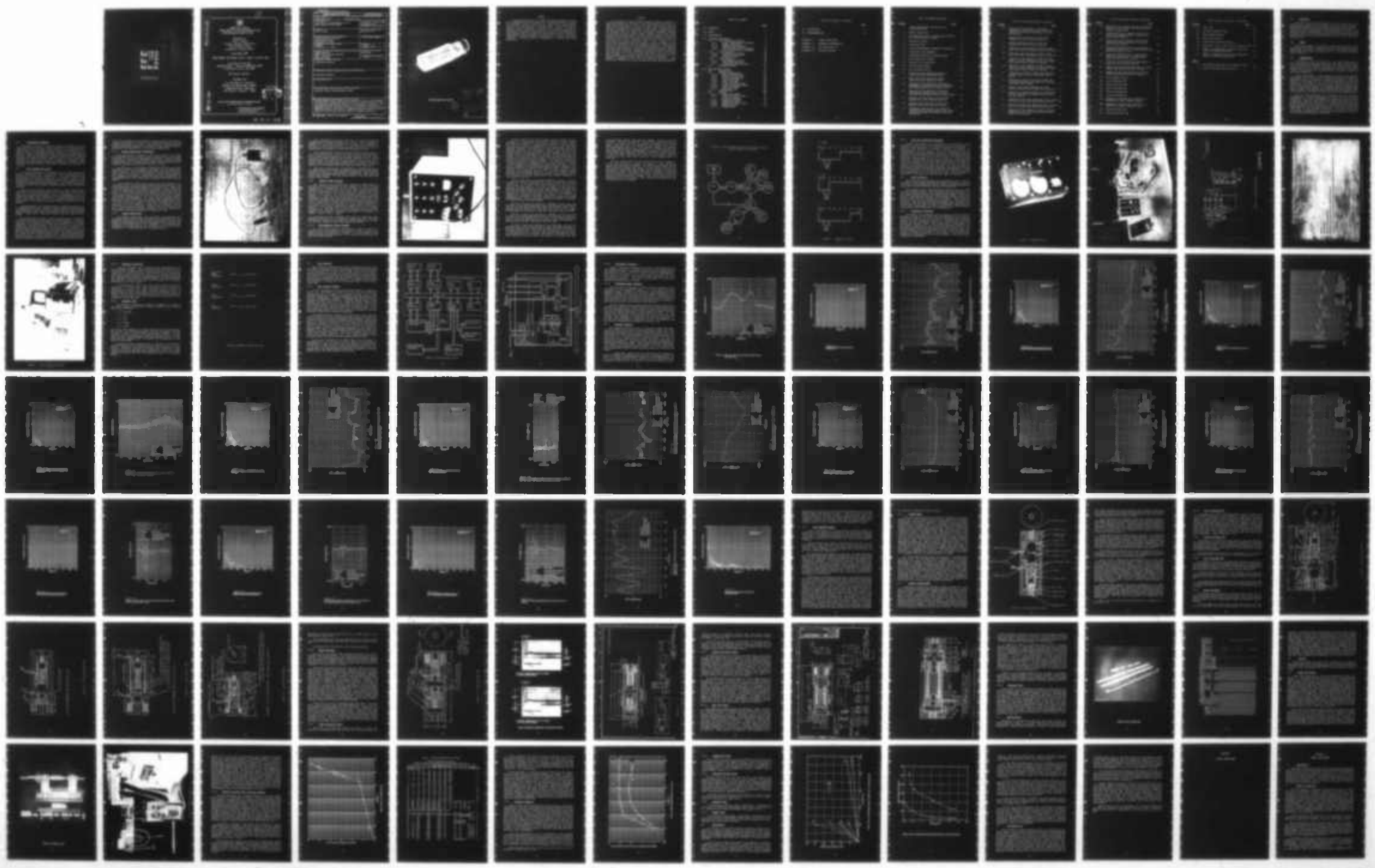

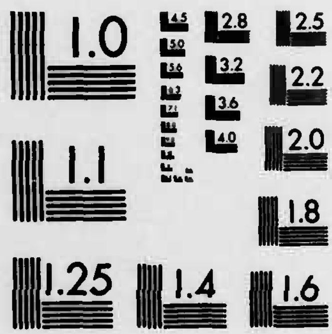

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FINAL REPORT ON THE DEVELOPMENT OF THE STRAIN SENSITIVE SWITCH (SSS)

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A Strain-Sensitive Switch (SSS) has been developed to serve as an inexpensive intrusion sensor in situations where the stress of intrusion results in small but significant displacements (strains) in the structures intruded upon. This Final Report details the various phases of the development, including the gathering of data on typical strain signatures created in structures undergoing simulated intrusion, the design of an advanced development model switch to be sensitive to such strains, and some results of testing the switch.

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STRAIN-SENSITIVE SWITCH

SUMMARY

A Strain-Sensitive Switch (SSS) has been developed to serve as an inexpensive intrusion sensor in situations where the stress of intrusion results in small but significant displacements (strains) in the structures intruded upon. This Final Report details the development, including the analysis of data on typical strain signatures created in structures undergoing simulated intrusion, the design of a switch to be sensitive to such strains, and the results of testing the resulting Advanced Development Model switches for strain sensitivity, frequency response, and environmental performance. Typical switches produce a 1-second alarm in response to a 0.001-inch step deflection.

PREFACE

The concept of using a simple switch to sense intrusion by detecting strain in structures (a Strain-Sensitive Switch, or SSS) was established in 1973, when four "Point-Contact Sensors" were built by Atlantic Research Corporation along informal guidelines suggested by the Army, and delivered to USAMERDC, Fort Belvoir, Virginia for evaluation. Those early sensors embodied two concepts that are central to the present development effort; the concept of using a small ("point") contact area so that small forces could cause relatively high contact pressure to achieve reliable contact operation, and the damping concept by which the contacts are allowed to remain closed to reject false alarms in the presence of slow movements which occur normally in the structural environment but are allowed to open in response to the more rapid movements which accompany intrusion. The present effort is the first step in the formal development of the SSS for military applications. During this program, typical stimuli available from structures undergoing intrusion have been measured and analyzed, several different prototype SSS's have been designed and built, various SSS's response to the stimuli have beem studied, an optimum design has been selected, and 15 Advanced Development Model SSS's have been manufactured. The effects of temperature and other environmental factors, contact electrical ratings, and strain sensitivity have been determined.

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1.0 OBJECTIVE

A militarized Strain-Sensitive Switch (SSS) is under development to serve as an inexpensive yet reliable intrusion sensor when applied tc structures (targets) which generate a displacement (strain) pattern (signature) during the process of intrusion which is mechanically distinguishable from noise. The SSS will directly operate simple alarm indicators, such as lights and buzzers, or will interface with elaborate electronic alarm systems, such as the Military's Facility Intrusion Detection System (FIDS).

2.0 SCOPE

This Final Report, which constitutes Data Item A00B under the subject contract, concludes a 27-month program for the development of a Strain-Sensitive Switch. The effort described herein has culminated in delivery of 15 Advanced Development Model Switches.

3.0 INTRODUCTION

Conceptually, the SSS consists of a simple switch with a pair of normally-closed contacts which open when stimulated by the strain which accompanies intrusion, but which remain closed at all other times. The switch contacts, together with basic damping means to eliminate responses to very slow changes of strain, are enclosed in a sealed plastic container to form a throw-away assembly.

During the program, a Data Acquisition System was assembled, the system was used to record approximately 53 intrusion signatures from 11 intrusion targets on magnetic tape, the recordings were digitized by a microcomputer-based Data Anlysis System, and analysis in the time and frequency domains was performed. In a parallel effort, seven SSS prototype designs were accomplished, twenty two different SSS prototypes were built, a Bench Test System was assembled and SSS response data were measured, and fifteen sets of Advanced Development Model strain-sensitive switches with extension rods were manufactured.

When the SSS responses were compared with the intrusion signatures, it became apparent that much of the intrusion information was below the frequency response of the early SSS prototypes. This was confirmed by a simple field test in which an SSS installed on a stairway failed to alarm when passed over by an intruder moving very slowly. Consequently, a seventh SSS prototype design was accomplished with an order-of-magnitude improvement in low frequency response. Field tests indicated that the new units were very hard to "spoof" with slow intrustions. Refinement of the seventh prototype design resulted in the Advanced Development Model SSS.

4.0 OPTIMIZATION ANALYSIS

The basic task was to produce a Strain Sensitive Switch (SSS) that would provide a high probability of detecting an intrusion and, at the same time, provide a low probability of a false alarm. To provide a basis on which to develop such a device, a number of experiments were conducted to investigate the intrusion strain signatures of targets to which the SSS might be applied. The strains induced in stairs, floors, doors, windows and various other intrusion targets during normal usage were measured in absolute units and recorded on magnetic tape. Excerpts from the magnetic tapes were digitized, analyzed in the time and frequency domains, and used to optimize the design of the SSS.

4.1 Data Acquisition System

Intrusion signatures were gathered using a Data Acquisition System assembled from a combination of off-the-shelf and specially constructed components. The signatures consist essentially of analog recordings on magnetic tape of the displacement of intrusion targets versus time, together with displacement calibration information, voice annotation of the intrustion scenarios as they progressed, and timing information to permit use of an electronic indexing system during signature analysis.

Early in the program, the intrusion target displacement range of interest was estimated to be from a few tenths of an inch down to less than 0.001 inch. Accordingly, the Data Acquisition System was designed to record displacements over the range from 0.0001 inch to 0.500 inch. System noise was to be at least 6 dB below 0.0001 inch, or less than 0.00005 inch (50 microinches). This required a dynamic range of over 86 dB in the system.

Instrumentation tape recorders have a maximum dynamic range of approximately 50 dB. Addition dynamic range was obtained in the system by recording the data on three different tape channels simultaneously, each with 20 dB more gain than the previous channel. This gave an available dynamic range of approximately 90 dB.

The signatures include a constant displacement component (reference deflection) and very low frequencies which require that the Data Acquisition System have dc response. The upper frequency limit was placed at 5 kHz, which proved to be more than adequate. An off-the-shelf linear variable differential transformer (LVDT) was used as the displacement transducer. A special Signal Conditioner had to be built to interface the LVDT with the tape recorder because off-the-shelf signal conditions were found to have excessive noise levels. FM recording was used to record the dc to 5 kHz output of the Signal Conditioner on one-inch magnetic tape in IRIG format. A microcomputer-based Control System was assembled from a combination of an off-the-shelf microcomputer development system (MDS) and special interface modules to control the system during recording and combine the outputs of the 3 data channels during playback. These components, together with special test and calibration equipment, are described in the following subsections.

4.1.1 Linear Displacement Transducer

The intrusion signature range of interect includes displacements of the intrusion target ranging from a few tenths of inches to less than a thousandth of an inch. Linear variable differential transformers (LVDT's) were used to measure these displacements with a sensitivity of better than 0.0001 inch and a frequency response that extended from dc to 5 kHz.

An LVDT is an electrical transformer having a primary excitation winding, two secondary windings, and a moveable non-contactng core. The secondary windings are wired to buck each other. When the core is at the center of travel, this produces a null (zero) at the output. Displacement of the core unbalances the windings and causes an output with amplitude proportional to displacement and with phase which reverses with direction off center.

Two models of LVDT were chosen for the gathering of signatures, both manufacturered by Schaevitz Engineering. The model MHR-100 was selected because of its small size. Being only 1 inch in length and 0.375 inches in diameter, it was installed in a stainless-steel container to simulate an SSS as shown in Figure 1. The linear range for the MHR-100 is ±0.1 inches (± 100 mils) which covers the 0.06 inch range specified for the SSS. The MHR-500 was selected so as to be able to monitor targets with larger displacements. It is 3.3 inchs in length with a diameter of 0.375 inches and will measure ±0.5 inches (±500 mils) with good linearity. Linearity for both transducers is within 0.3% over the rated range. Output of the MHR-500 is 2.4 mV/V/mil and of the MHR-100 is 2.9 mV/V/mil. Maximum excitaton is 10 Vpp at 10 kHz or higher. When excited at 20 kHz, as was done in the Data Acquisition System, both are capable of displacement frequency responses in excess of 5 kHz.

4.1.2 Signal Conditioner

The signal conditioner for the LVDT's was designed and fabricated by Atlantic Research Corporation especially for the signature measurements. The signal conditioner provides the primary ac excitation voltage and the demodulators to convert the outputs of the secondaries to dc. Appendix I is provided with a schematic and description of the operation of the signal conditioner. A brief description is presented here.

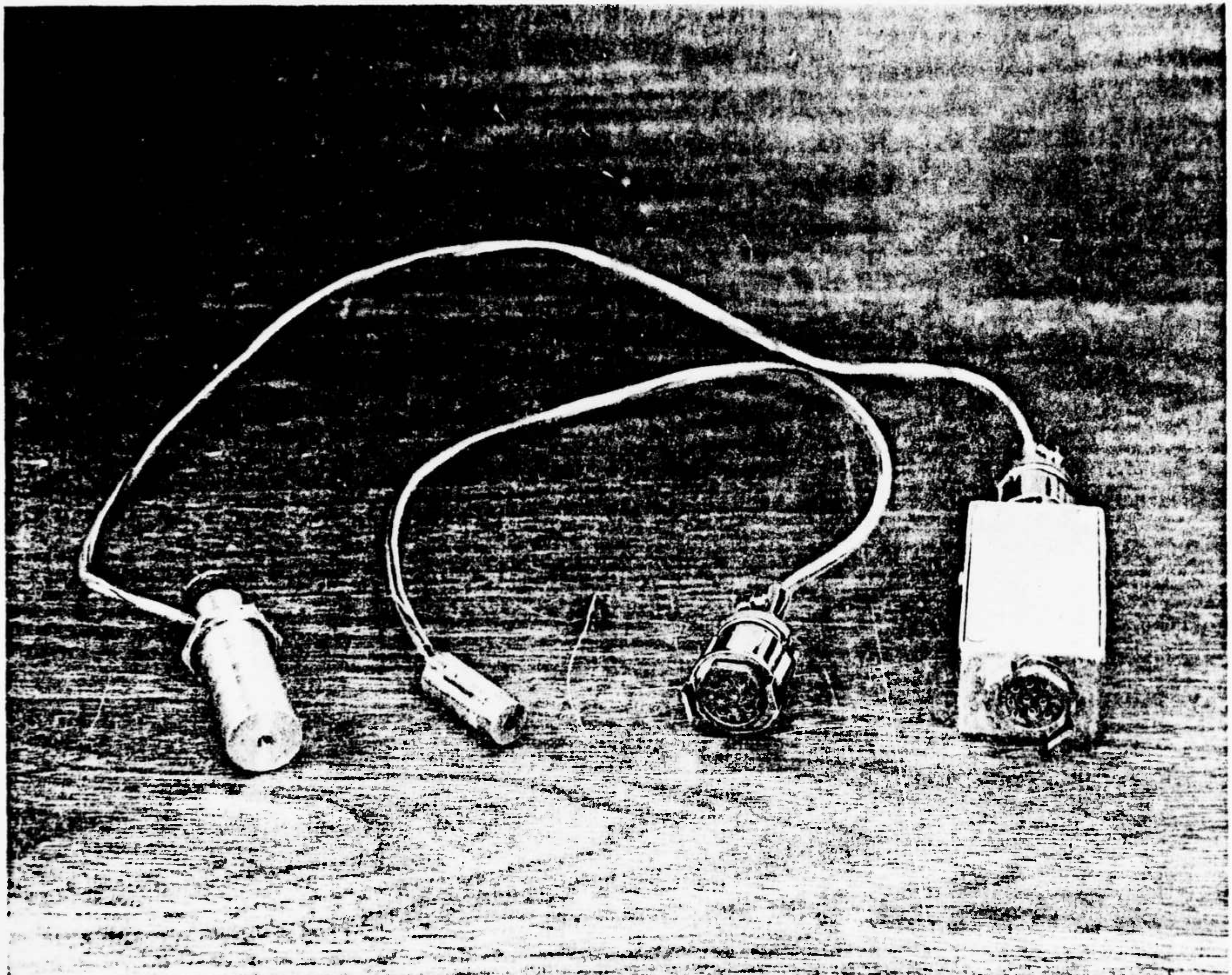


Figure 1 Linear Displacement Transducer and Instrumented SSS

The differential voltage from the two LVDT secondaries represents the core displacement from null. This ac voltage is demodulated to produce a variable dc voltage. The demodulation process is phase synchronized to the excitation voltage to produce a dc voltage with magnitude proportional to core displacement and polarity indicating direction from null.

Three demodulation channels provide sensitivities of 0.001 inch (1 mil) per volt, 10 mils per volt, and 100 mils per volt for recording simultaneously to overcome tape recorder noise. Full-scale output capability of each channel is ±10 volts. System noise levels and stability are such as to allow measurements of 0.0001-inch displacement. Each channel is provided with gain and phase controls for calibration. A common control for all channels provides electrical zero adjustment.

The signal conditioner is packaged in a portable aluminum enclosure with all controls and signal outputs on the front panel as shown in Figure 2. Five outputs are provided. Three are the outputs from the separate sensitivity channels and were connected to the tape recorder. Two are used to monitor the LVDT input and output during setup.

4.1.3 Magnetic Tape Recorder

The magnetic tape recorder was a Honeywell Model 5600C, a portable machine provided as GFE capable of recording and reproducing 7 (expandable to 14) channels of data in IRIG standard format on one-inch wide tape. Seven tape speeds were available progressing from 15/16 inches per second (ips) to 60 ips in binary steps. All signatures were recorded at 15 ips. Channel 1 was set up with 10 kHz bandwidth FM for recording timing data. Channel 2 was set up with 10 kHz bandwidth FM for recording signature data with a sensitivity of 10 mils/volt. The 1 and 100 mils/volt signature data were recorded on channels 4 and 6, respectively, which were set up for 5 kHz bandwidth FM. All signature data were recorded on even numbered channels to avoid the time delay differences between even and odd heads. Channel 3 was set up with 2.5 kHz bandwidth FM for flutter compensation. Channel 7 was used for analog recording of the capstan drive frequency for speed compensation on playback, if needed. Channel 5 was a spare.

A separate voice channel was used to identify each experiment and annotate the signature being collected. The tape recorder was remotely controlled by a microcomputer which served as a central control for the Data Acquisition System.

4.1.4 Microcomputer Control System

An Intel microcomputer (MDS-800) was used to centrally control the Data Acquisition System, place timing and identification information on Channel 1 of the magnetic tape during signature measurements, and to graphically display the data as it was aquired.

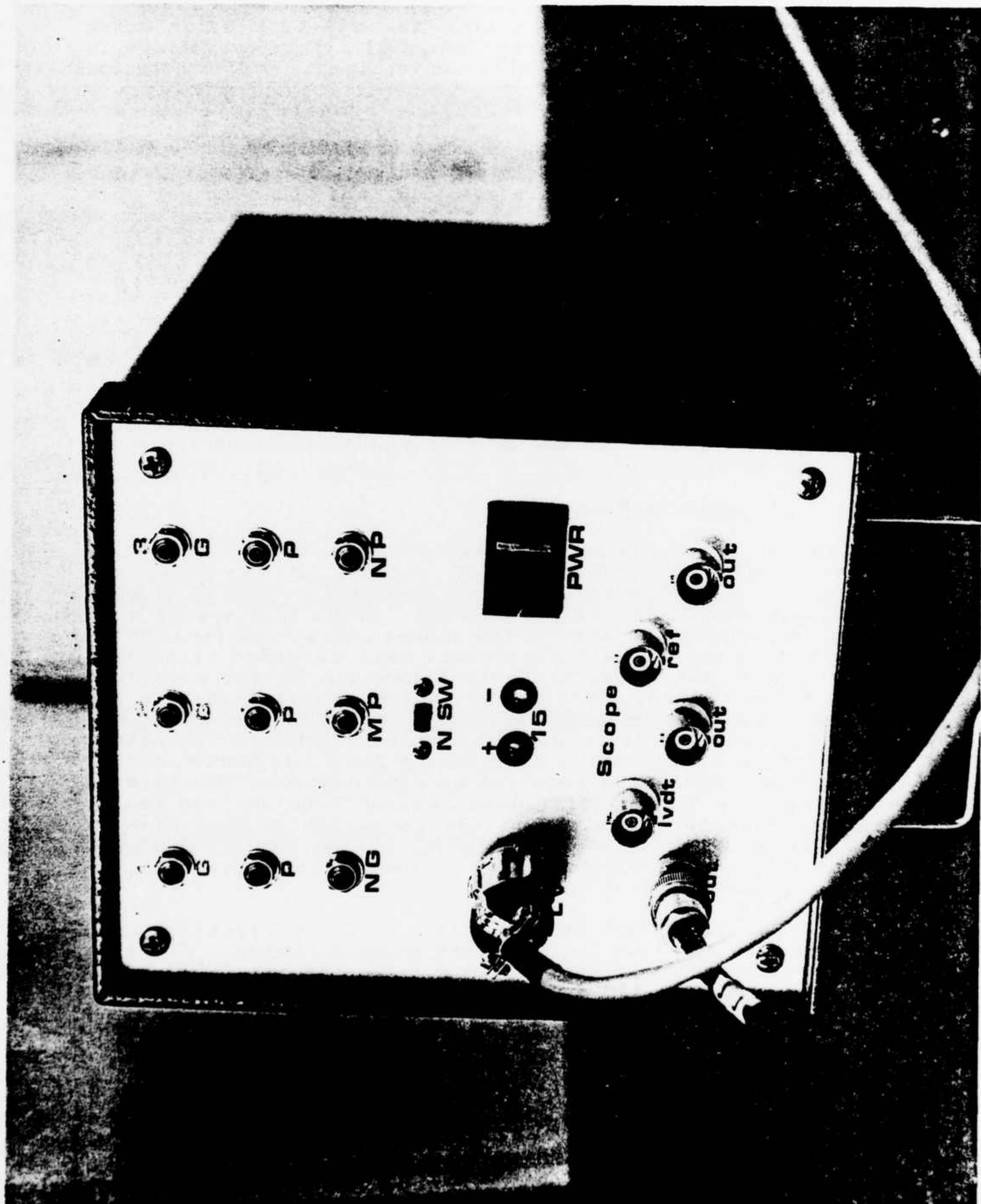


Figure [illegible] Signal Conditioner

A state diagram of the microcomputer control system is shown in Figure 3. The program was written largely in 8080 machine language and burned into a programable read-only memory (PROM) for use in the field. With power turned on, initialization consists of hitting the RETURN key on a cathode-ray tube (CRT) terminal/keyboard. The program will then request DATE, which the operator enters as a four-digit number. The program then requests HOUR, followed by MINUTE and then SECOND, each of which is entered by the operator as two-digit numbers followed by RETURN. When the last number is entered, hitting RETURN uses the numbers to initialize a real-time clock contained in software, outputs the timing signal to Channel 1 of the tape recorder and causes the program to request CHANNEL. The operator then enters a number from 0 to 2, depending on which tape recorder channel is to be monitored and graphically displayed on the CRT. In this context, CHANNEL 0 is the high-sensitivity channel, CHANNEL 1 the medium-sensitivity channel and CHANNEL 2 the low-sensitivity channel, all monitored at the tape recorder outputs using reproduce-while-record operation. With the CHANNEL number entered, hitting RETURN places the system in IDLE ready for the next command; with time, updated once per second, displayed in the corner of the CRT.

Once in IDLE, there are several commands available. Hitting T places the system in the TEST mode which is used for recording signatures. In the TEST mode, the tape recorder starts in the record mode and, when it gets up to speed, a time code is recorded on tape Channel 1, a real-time plot of the digitized amplitude envelope of the monitored data CHANNEL is written onto the CRT once per second and time, updated once per second, is displayed in the corner of the CRT. Thus it is possible to observe the signature envelopes, quantized to 26 levels and displayed as two sets of 80 dots (positive and negative envelope simultaneously), during recording. Hitting E returns the system to IDLE and stops the tape recorder.

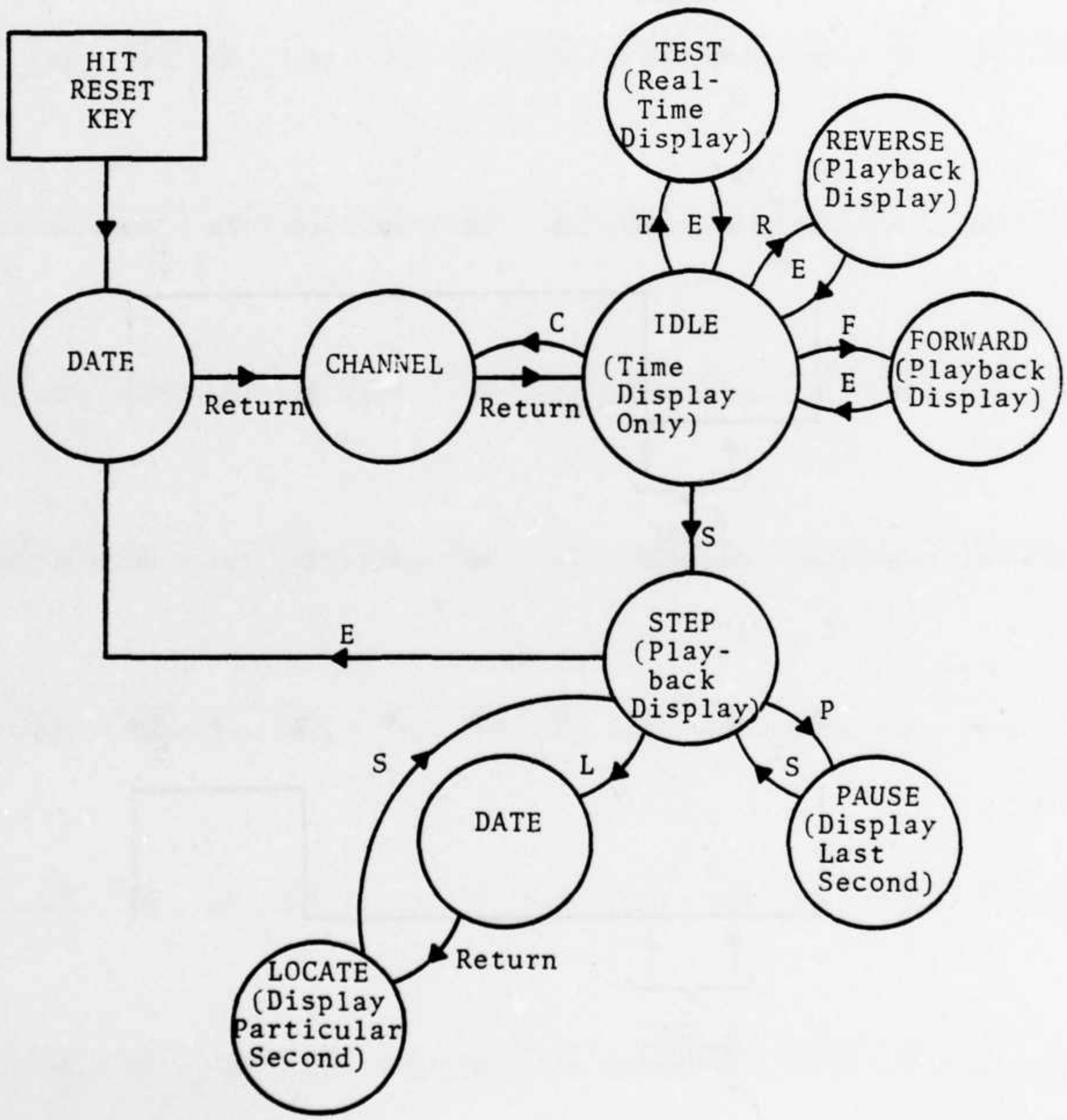
Hitting R places the system in REVERSE, starts the tape recorder in the reverse/playback mode, and displays envelopes on the CRT (backwards) using data played back from tape. Time, updated once per second, from the real-time clock (not from tape) is displayed in the corner of the CRT. Hitting E exits to IDLE.

Hitting F places the system in FORWARD, starts the tape recorder in the forward/playback mode, and displays envelopes on the CRT using data played back from tape. Time, updated once per second, from the real-time clock (not from tape) is displayed in the corner of the CRT. Hitting E exits to IDLE.

Hitting S places the system in the STEP mode, starts the tape recorder in the forward/playback mode, displays envelopes on the CRT, dumps the real-time clock and displays time from tape in the corner of the CRT. This mode can thus be used to locate data if the reference time is known. When interesting data is found, the operator can hit P to place the system in the PAUSE mode. The last envelope will then remain stationary on the CRT with tape time displayed and the tape recorder stopped. Hitting S returns to STEP. If the time code for a particular second of data is known, the operator can hit L to place the system in the LOCATE mode, enter the time, hit RETURN and the system will run in forward/playback until the code is located, display the envelope and time, and stop the tape recorder. If a time earlier than those apearing on tape is programmed, the system will stop one or two seconds after starting. Hitting S returns to STEP. Hitting E exits to DATE, after which a new time must be entered to reinitialize the real-time clock and a new CHANNEL must be selected.

The bit format used for the timing information on Channel 1 of the tape recorder is shown in Figure 4. Time codes are updated on tape once per second. For most of the second, square waves (HOLD waveform, Figure 4a.) are recorded at 1200 Hz. At the beginning of each new second, zeros (Figure 4b.) or ones (Figure 4c.) replace the HOLD waveform for 40 cycles to encode 10 BCD digits of time. The first two digits are seconds, the second two are minutes, the third two are hours, and the last four are days and an identification number. Most significant bits are recorded first in each digit. The time code is handled by the microcomputer as five bytes.

Figure 3 Microcomputer Control System State Diagram for Data Acquisition System



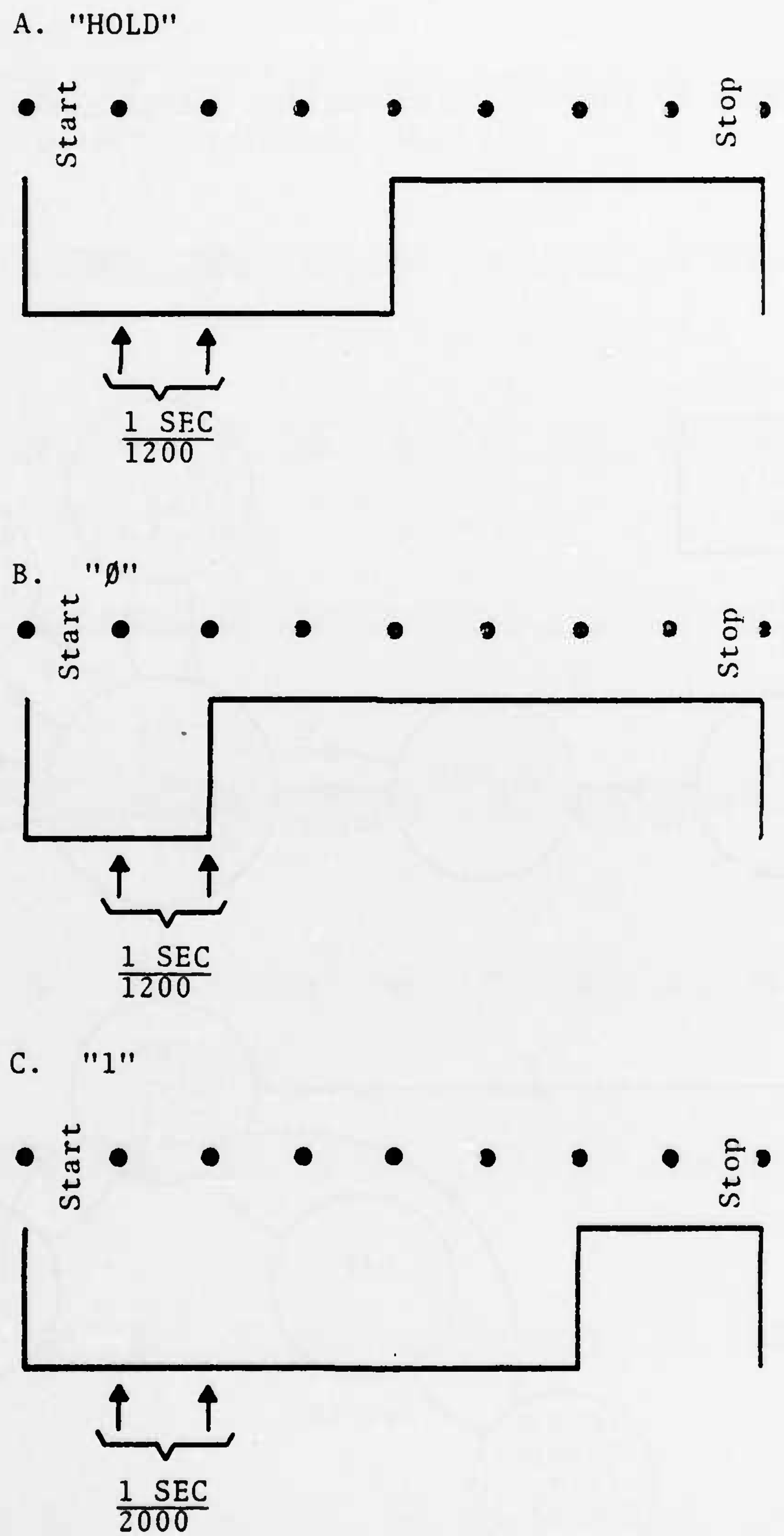


Figure 4 Timing Bit Format

4.1.5 Test and Calibration Equipment

During the acquisition of signatures, calibration of the system was performed at the beginning of each meaurement to maintain the accuracy of the Data Acquisition System. A Calibration Box was built, as shown in Figure 5, to simulate the displacement of the LVDT. The box contains a pair of transformers, a pair of switches, and a set of adjustable voltage dividers as shown schematically in Figure 6. One switch sets the range to 1, 0.1 or 0.01 of full scale, while the other sets the simulated displacement to 1.0, 0.5, 0, -0.5 or -1.0 of the range selected. The Calibration Box was adjusted by connecting the Schaevitz MR-500 LVDT to the Signal Conditioner and applying known displacements measured with a dial caliper, as shown in Figure 7; replacing the LVDT with the box, and setting the adjustments to obtain the same readings. The Schaevitz MR-100 was then matched to the MR-500 by inserting resistance in series with the output of the MR-100 so both could be used interchangeably with the Calibration Box. (The resistor is contained in the small box shown on the right in Figure 1.)

4.2 Data Collection

The Data Acquisition System was assembled onto a cart for transport to the target locations as shown in Figure 8. Once at the target, the equipment was set up, calibrated and measurements made while various intrusion scenarios were enacted.

The procedure was to first determine where to place the LVDT on the intrusion target. Once the position was selected, the LVDT was installed using the extension rods shown in Figure 9. The Signal Conditioner was then electrically zeroed. Next a few tests to check the functioning of the equipment were performed by someone simulating intrusion on the target. This would be monitored by the Data Acquisition System and evaluated for accuracy. When the checkout of the equipment was completed, the Calibration Box was used to record 12 calibration steps plus zero on the tape. The system was then connected back to the LVDT and signatures recorded along with voice annotation.

4.2.1 Calibration Procedure

Calibration was performed at the beginning of each tape to provide a check on the Data Acquition System and to provide calibration steps to be used by the microcomputer Data Analysis System during signature analysis. Calibration involved connecting the Calibration Box to the Signal Conditioner and placing the system in TEST. This started the tape recorder, and the signal conditioner was then exercised by selecting the different ranges and deflections on the Calibration Box. The microcomputer converted the resulting output of the tape into digital information to display on the CRT. The CRT could then verify the proper operation of the system. The calibration procedure was narrated onto the voice channel of the tape as the calibration progressed.

Figure 5 Calibration Box

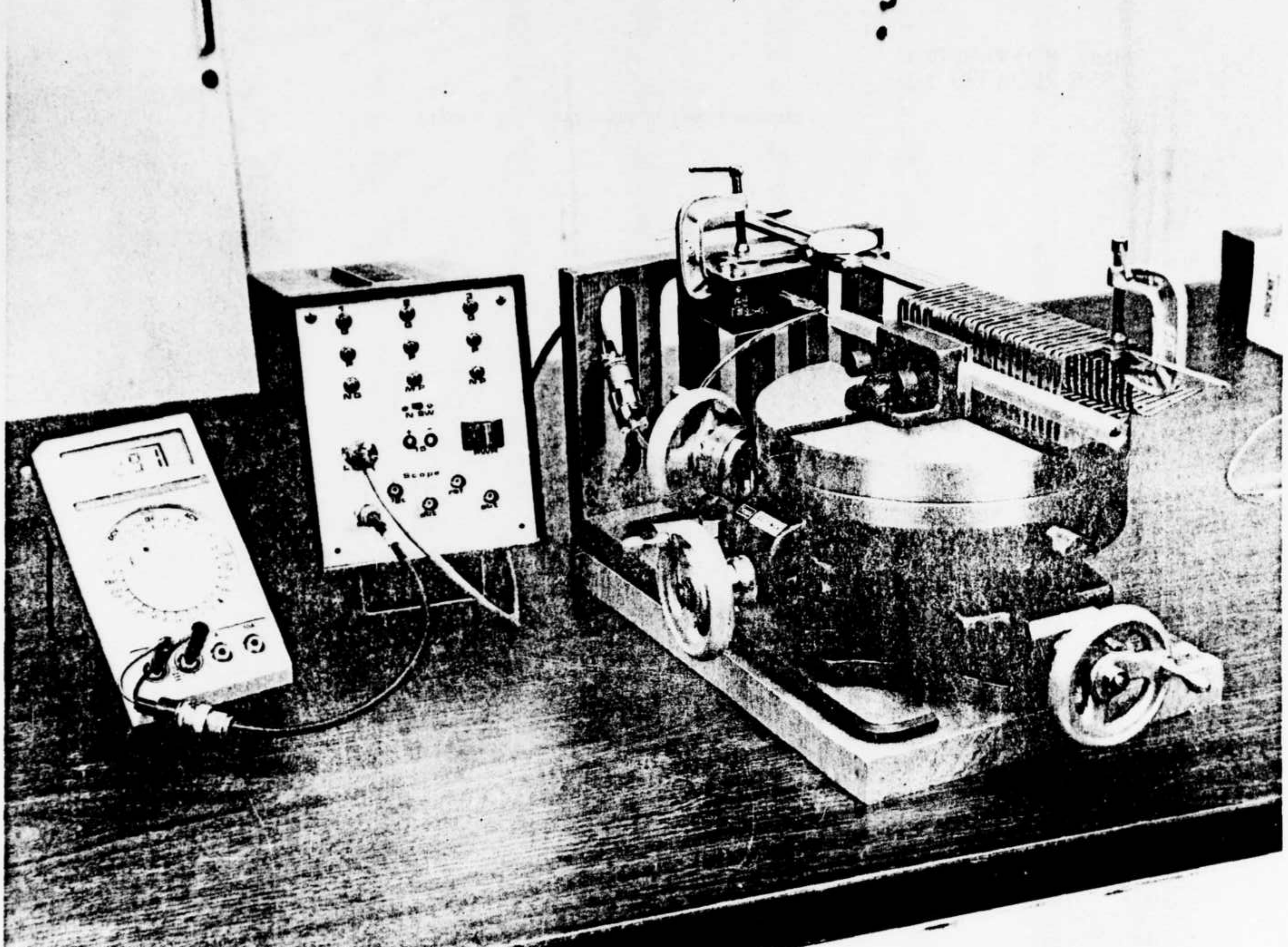
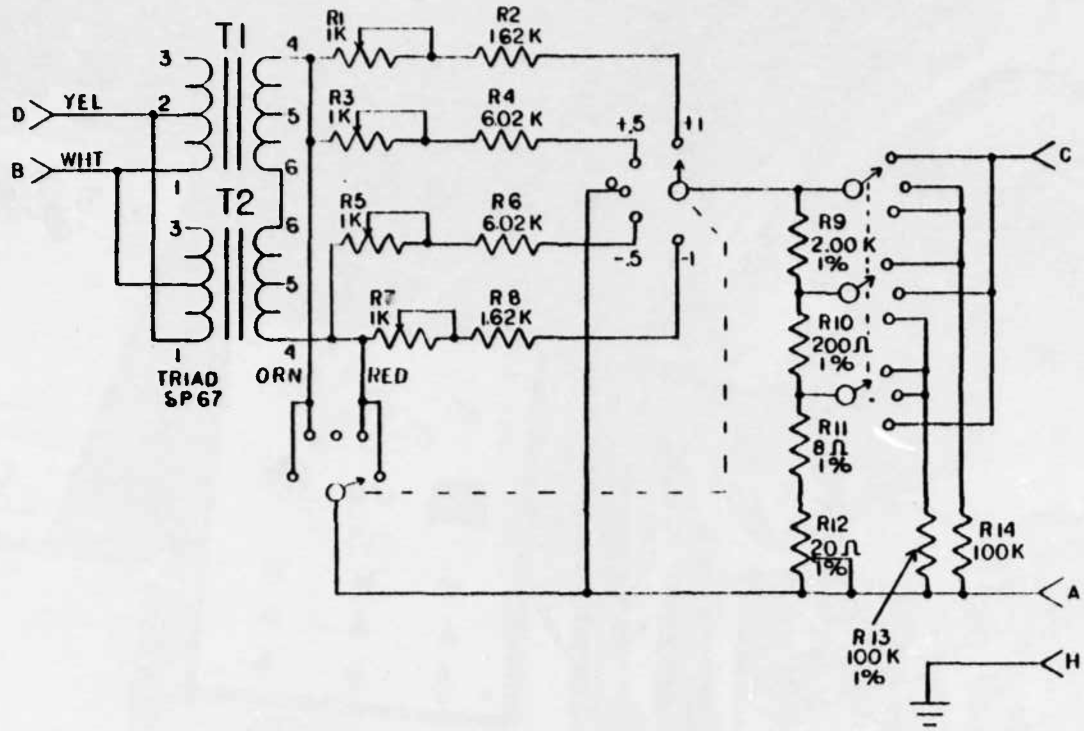


Figure 6 Linear Displacement Transducer Calibration



NOTES:

1. ALL RESISTORS ARE 1% PRECISIONED.

Figure 7. Calibration Box Schematic.

FT. BELVOIR SSS
CALIBRATOR UNIT

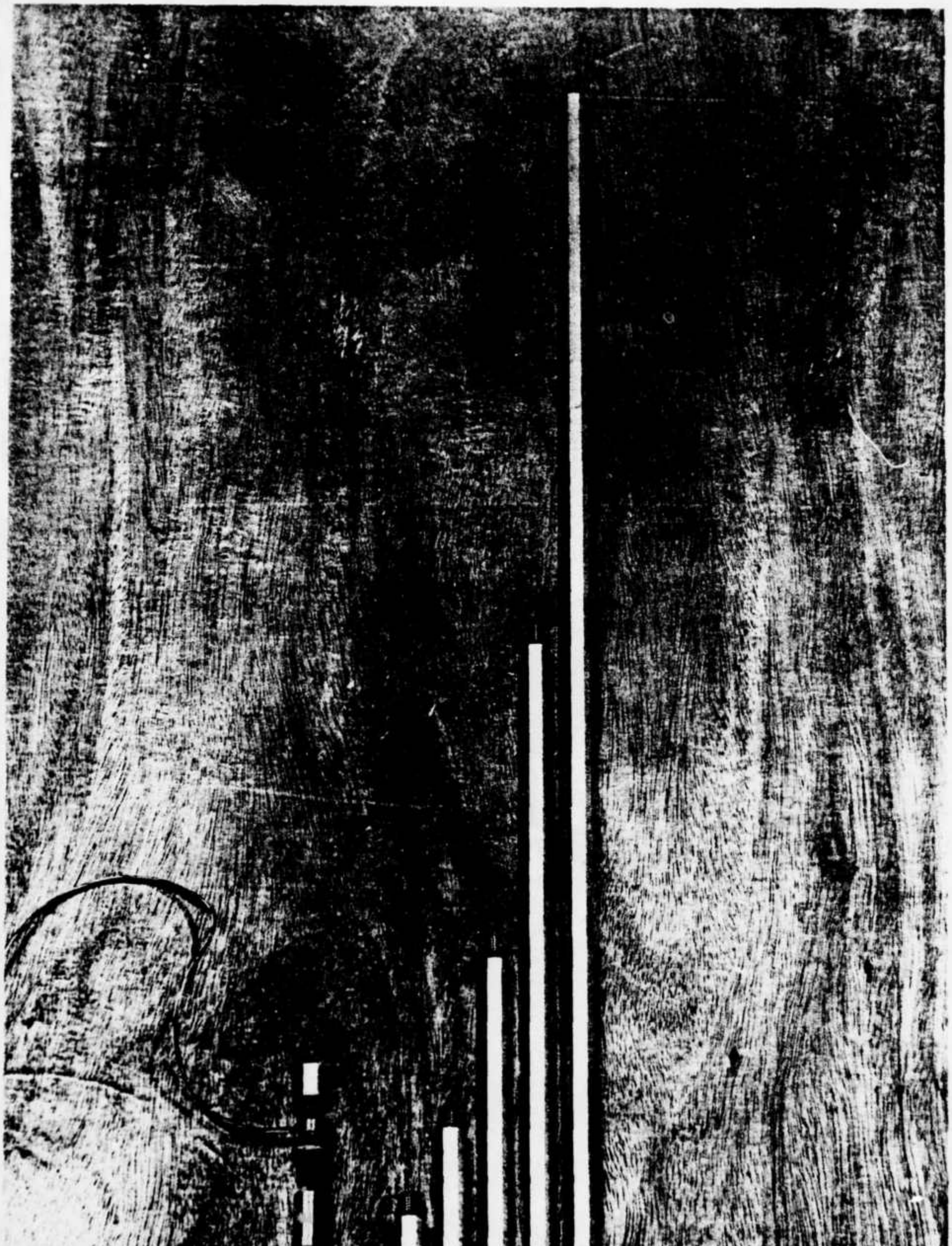


Figure 8 Instrumented SSS With Extension Rods

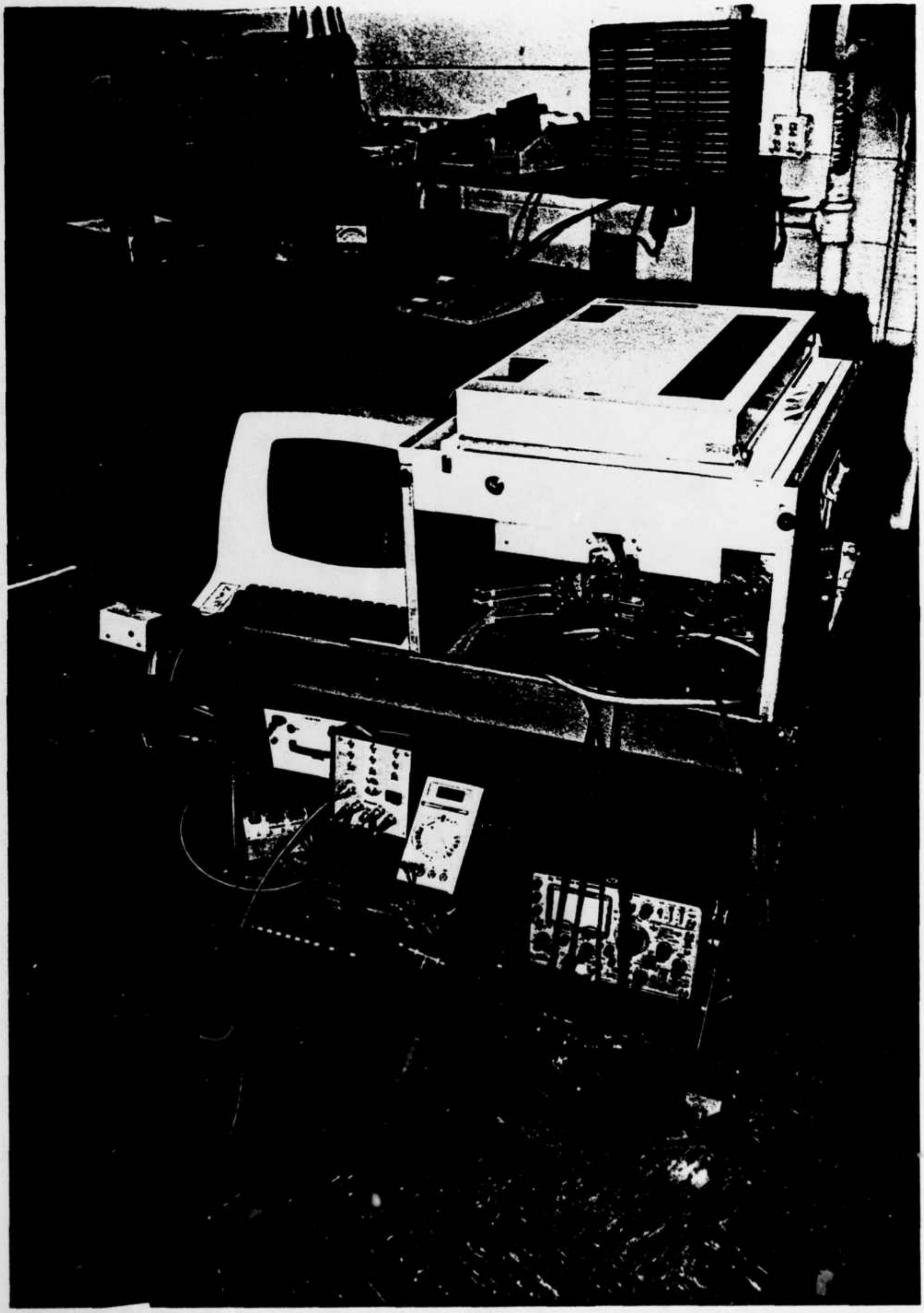


Figure 9 Data Acquisition System

4.2.2 Signature Annotation

The next procedure was to describe the characteristics of the intrusion target. This required explaining details that influenced the signature data including factors that directly affected the displacement of the target during signature collection, such as the type of support, the composition of the wall surrounding the target, and the material of which the target was composed. The narration included factors that influenced the position and location of the LVDT, and the reasons for alternate positioning on a given target.

A standardized test log was kept during signature collection. The log sheet used in the field (Figure 10) was designed to record the tape footage count, signature identification code, date, time of day and signature title. A description of what was going on during recording would be written in the log and also described on the voice annotation channel of the tape. The log was used to locate particular signatures during analysis.

4.2.3 Signature Data

The Intrusion Signature Log appears in Appendix II. Each of the target types is identified in the last number of the 4-digit Date code as follows:

---1 Stairway

---2 Floor

---3 Door

---4 Window

---5 Ladder

The first three numbers in the Date code are the day of the year, 001 to 365. The Time code is hours, 00 to 24: minutes, 00 to 60: seconds, 00 to 60. The time code is recorded on Channel 1 of the tape by the microcomputer with updates every second. The Tape Position Count is the reading of the tape footage counter at the beginning of a signature run. The Tape Serial Numbers were taken from the tape reels.

Signatures were recorded from 11 targets; 6 at Atlantic Research Corporation's Cherokee Avenue facility and 5 at Fort Belvoir, Virginia. Several scenarios were recorded on each target, leading to approximately 53 discrete signatures. Each signature has been digitized and transferred to one or two floppy disks for analysis by the microcomputer-based Data Analysis System.

Tape S/N:
Date: Time:__:__:__ Tape Count:
Signature:

Date: Time:__:__:__ Tape Count:
Signature:

Date: Time:__:__:__ Tape Count:
Signature:

Date: Time:__:__:__ Tape Count:
Signature:

Figure 10 Signature Field Log Form

4.3 Data Analysis

The intrusion signature data were analyzed by playing back the tapes, digitizing discrete signatures located with the help of the voice annotation and timing tracks, storing the discreet signatures digitally on one or two floppy disks, and then using the microcomputer to analyze the stored signatures individually. Once on disk, a signature can be displayed on an oscilloscope, recorded on a strip chart, analyzed in the frequency domain using a fast-Fourier-transform (FFT) routine, or diverted to the Bench Test System to exercise the prototype SSS's with actual signatures.

4.3.1 Data Analysis System

A block diagram of the Data Analysis System is shown in Figure 11. The system is based on the same Intel MDS-800 microcomputer and tape-drive interface used in the Data Acquisition System. The MDS is configured with 64K bytes of RAM and four floppy disks. Primary programming and system control is through a CRT/keyboard terminal. Secondary system control while manipulating data is provided by a separate control panel, which permits moving data in file right and left across the oscilloscope screen, setting cursors for delineating the area of data to be analyzed, and quick movement to either cursor. With the exceptin of the Control Panel, the Tape Controller and the Multi-Function Board, all of the blocks in the figure are off-the-shelf commercially-available equipment.

The Tape Controller contains an input/output (I/O) chip and level-changing circuitry constructed on a wire-wrap board for remotely controlling the GFE Honeywell 5600C magnetic tape drive. The Multi-Function Board is constructed on a second wire-wrap board as detailed in Figure 12. It contains an Arithmetic Processor primarily for use in the FFT routines, digital-to-analog (D/A) converters for driving the X and Y axes of oscilloscopes and X-Y or strip-chart recorders (or the Bench Test System), and a pair of sample-and-hold amplifiers with timers for removing time skew from two (high and low sensitivity) of the three analog data channels. The third (medium sensitivity) analog data channel goes directly to the analog-to-digital (A/D) converter board, which has its own sample-and-hold input.

During tape playback the medium-sensitivity channel is digitized first. If its data is within range, its level code is transferred to file as an 8-bit byte for storage on floppy disc. If its data is above or below range (saturated or zero), the low or high sensitivity channel is digitized and stored instead, as appropriate. The sample-and-hold amplifiers "remember" all three analog levels until the decision can be made.

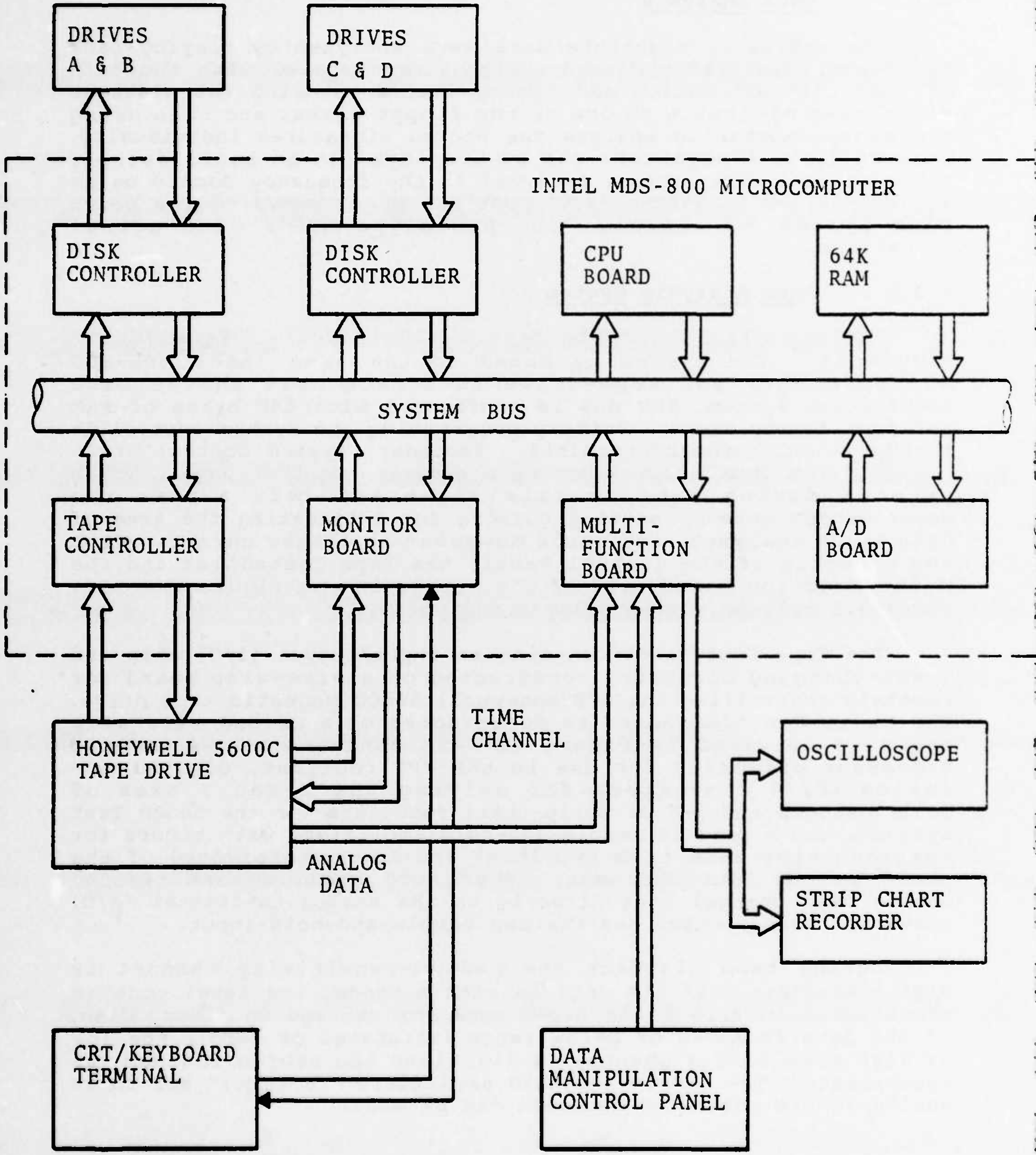


Figure 11 Data Analysis System

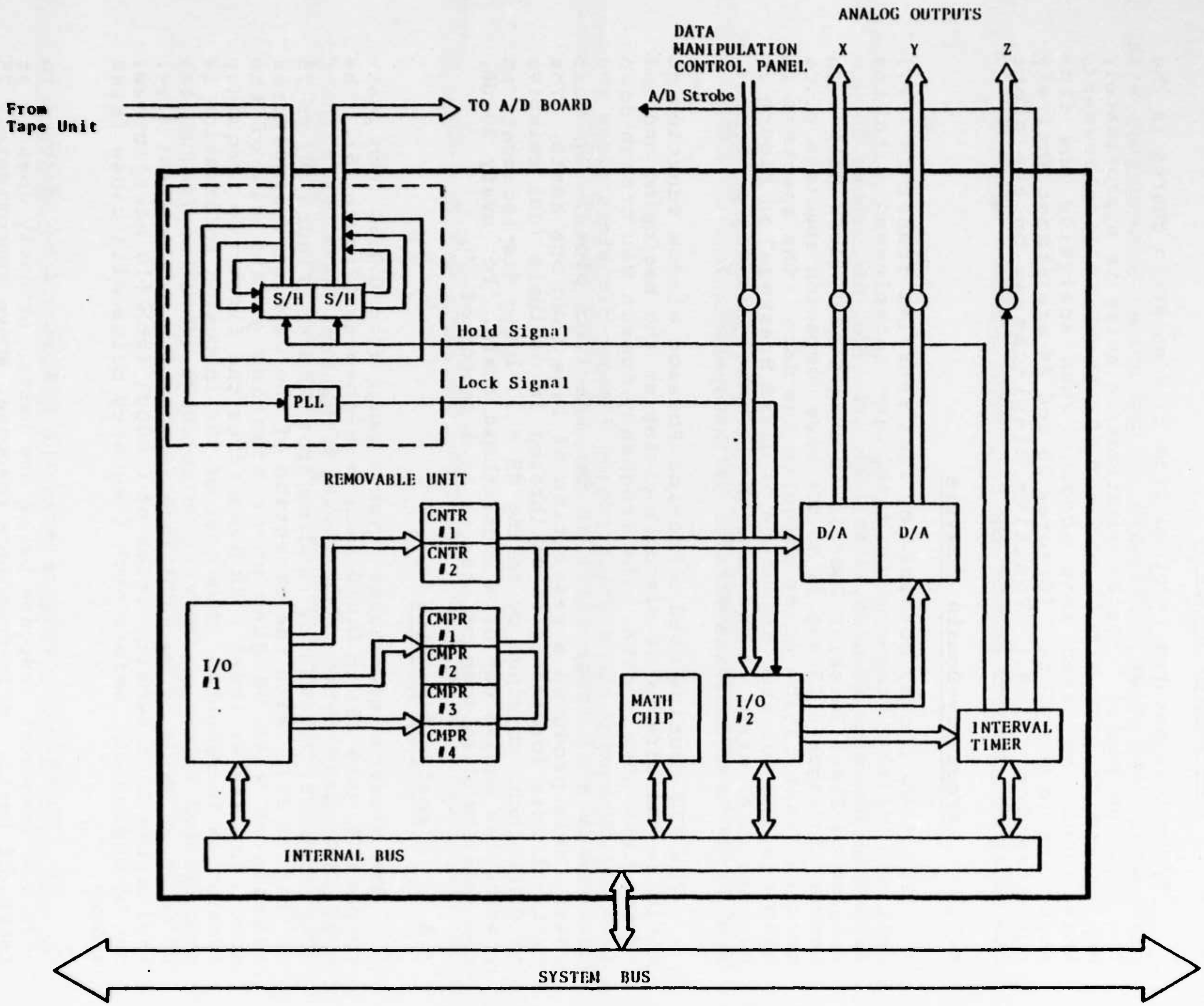


Figure 12. Multi-Function Board.

4.3.2 Time-Domain Analysis

Typical signatures recorded from file on strip charts in the time domain are shown in Figures 13 through 40 (alternating with the spectrum plots). System quantization noise is approximately equivalent to 0.06 mil (1 mil = 0.001 inch) of displacement. This should be taken into account when analyzing the fine structure on the plots. (Figures 25 and 26 are almost entirely quantization noise.) Positive displacement on the plots indicates compression of the SSS.

4.3.3 Frequency-Domain Analysis

Spectrum plots, obtained by Fast Fourrier Transform (FFT) analysis of the time-domain data, are interleaved with the signature plots in Figures 14 through 41. The "Signatures of Man Banging on Steel Interior Door in 12-inch Cinder Block Wall with Hammer" in Figures 25 and 26 do not have companion spectrum plots because quantization noise obscured the data. The spectrum is also missing for the "Signature of Glass Breakage" in Figure 39 because of an error at the time the FFT analysis was performed. (The wrong time code was entered by the operator.)

The FFT routine used a Hanning-Poisson window function to minimize the effects of discontinuities at the beginning and end of the time-domain data. The frequency domain was broken down into 512 frequency steps which occupy 9 major divisions along the horizontal axis (abscissar) of the spectrum plots. In most cases, this produced a resolution of less than one hertz. The vertical axis (ordinant) is calibrated in decibels (dB) relative to 0.001 inch, obtained by taking dB = 20 $\log_{10}$ displacement, to provide the equivalent of a logarithmic scale. For every 20 dB, the relative displacement changes by a factor of 10.

4.4 Analysis Results

The measured signatures cover a range from 0.0004 inch peak-to-peak (Figure 25) to 0.018 inch peak-to-peak (Figure 35). The spectrums associated with these signatures have 6 dB (half displacement) bandwidths ranging from 0.18 Hz (Figure 30) to 75 Hz (Figure 36). With the exception of the impulsive signatures associated with banging on or breaking glass, all of the spectrums are at least 6 dB down after the first two frequency resolution increments. Thus most of the intrusion information is concentrated below one hertz. Noise above intrusion frequencies is at least 39 dB below 0.001 inch (Figure 41) in the worst case, indicating that sensitivities of 0.00001 inch (10 microinches) can be approached before high frequency noise will cause false alarms.

These data indicate that the SSS should be designed to have low-frequency response below one hertz, probably down to at least 0.1 hertz. High-frequency response, above approximately 75 Hz, is unnecessary but will cause little harm because high-frequency noise levels in typical intrusion targets are low.

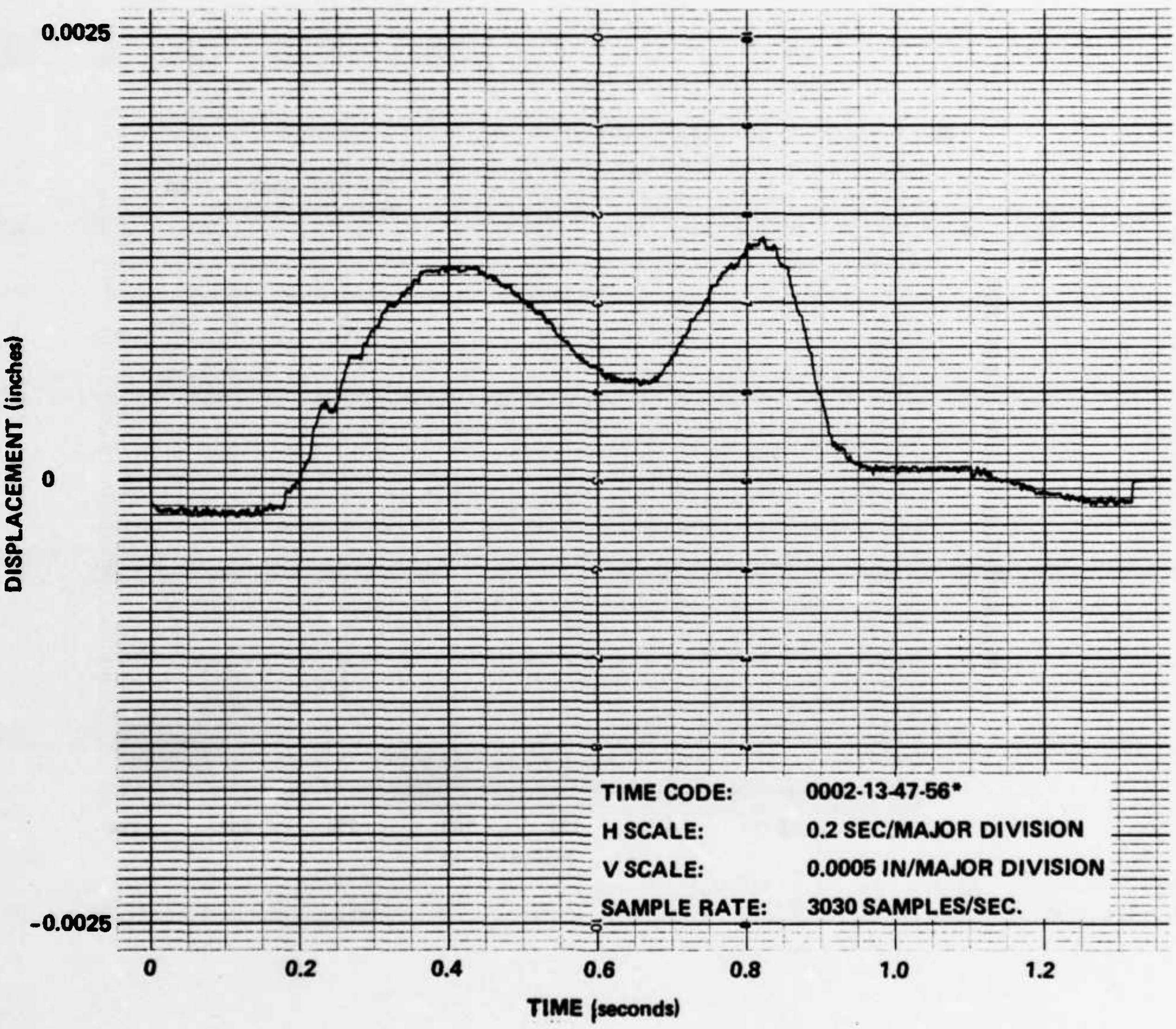


Figure 13. Signature of Man Taking One Step on Steel Staircase (SSS Under Step).

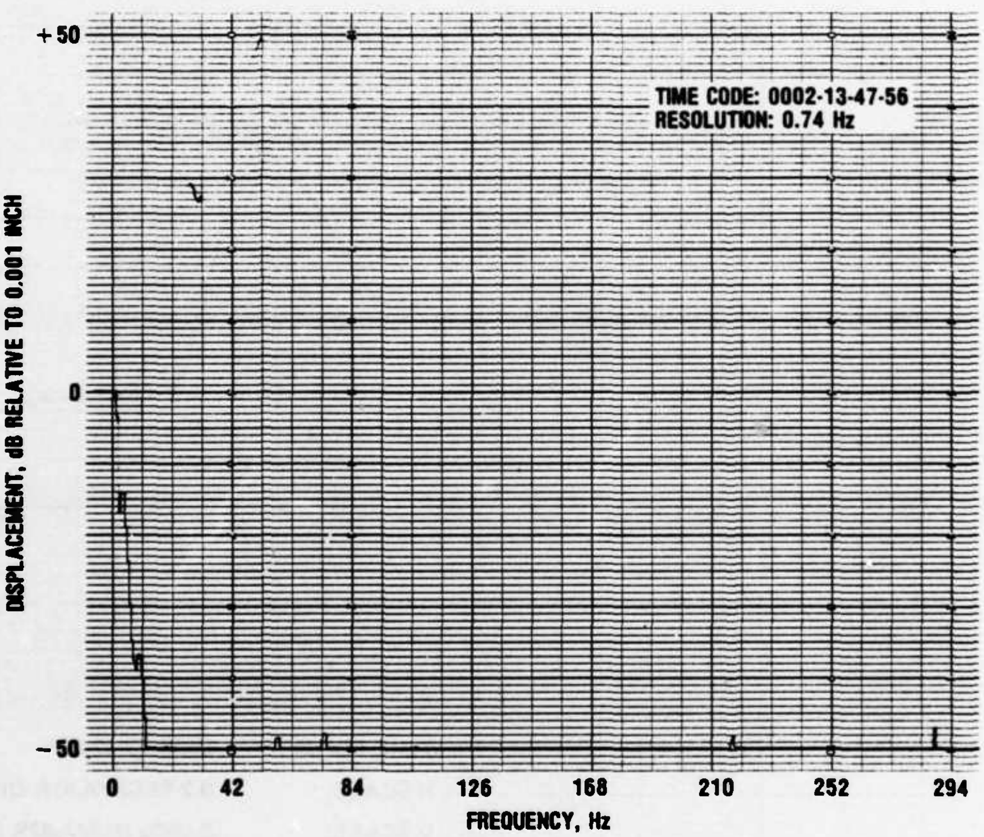


Figure 14.
Spectrum of Man Taking One Step on Steel Staircase (SSS Under Step).

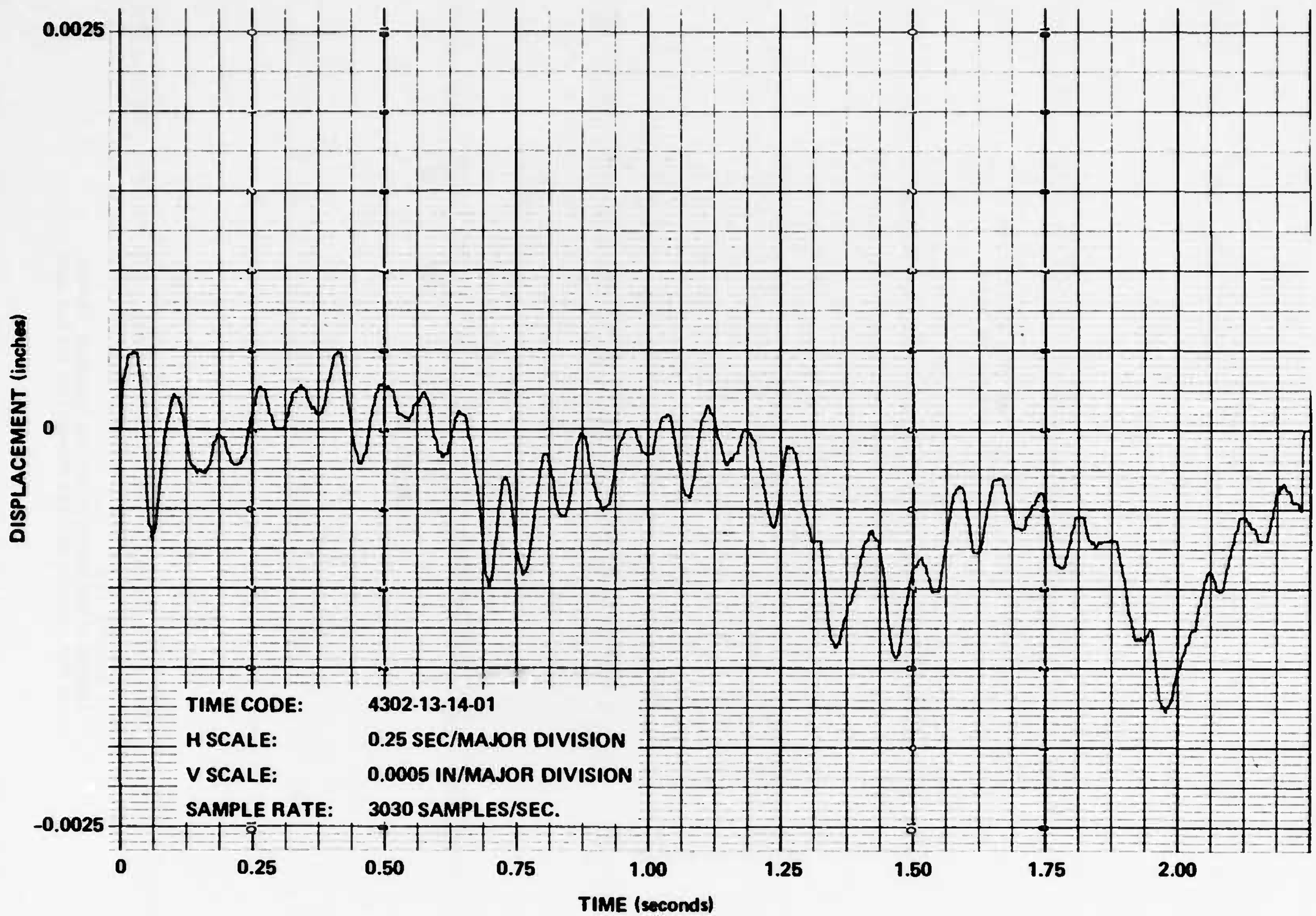


Figure 15.

Signature of Man Walking on Industrial (Suspended) Concrete and Steel Floor Near SSS (SSS Between Floor and Roof Joist).

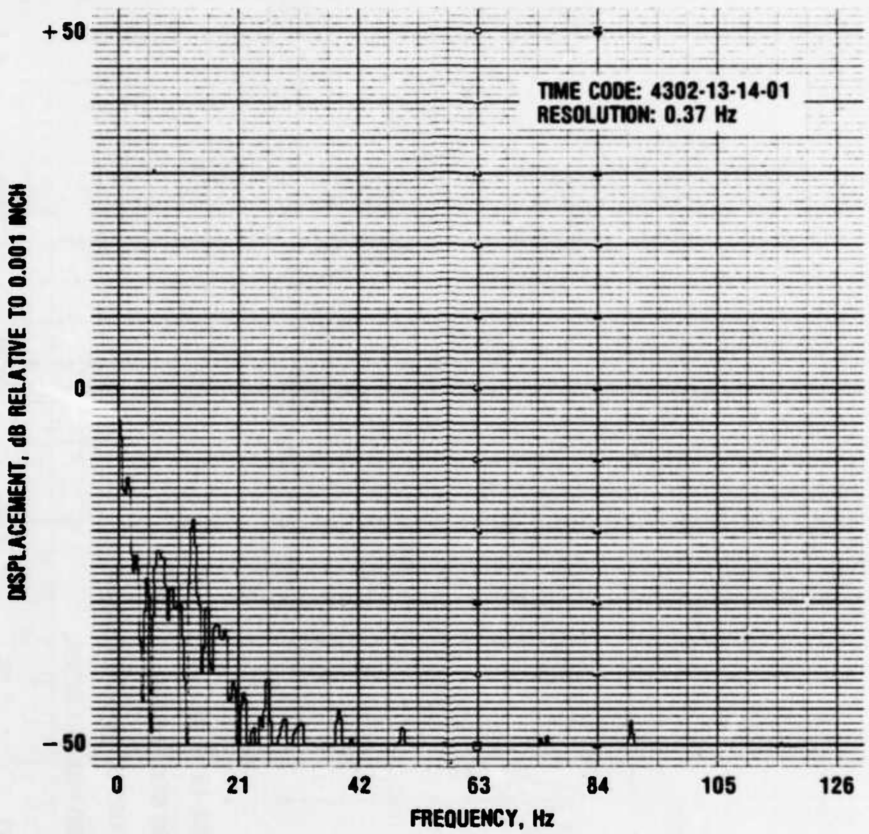


Figure 16.
Spectrum of Man Walking on Industrial (Suspended) Concrete and Steel Floor Near SSS (SSS Between Floor and Roof Joist).

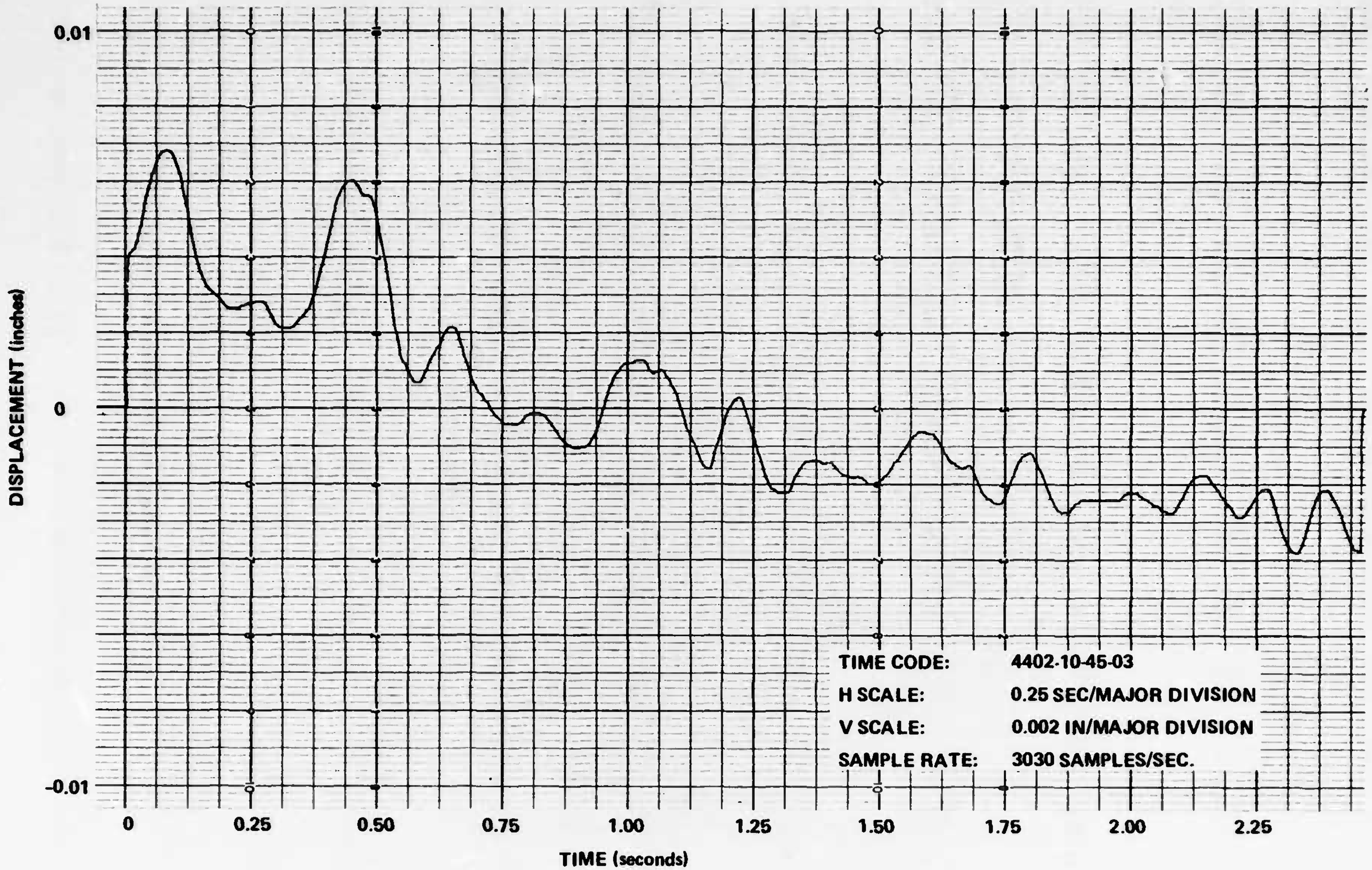


Figure 17,

Figure 15. Signature of Man Walking on Roof (SSS Between Roof Joist and Floor Below).

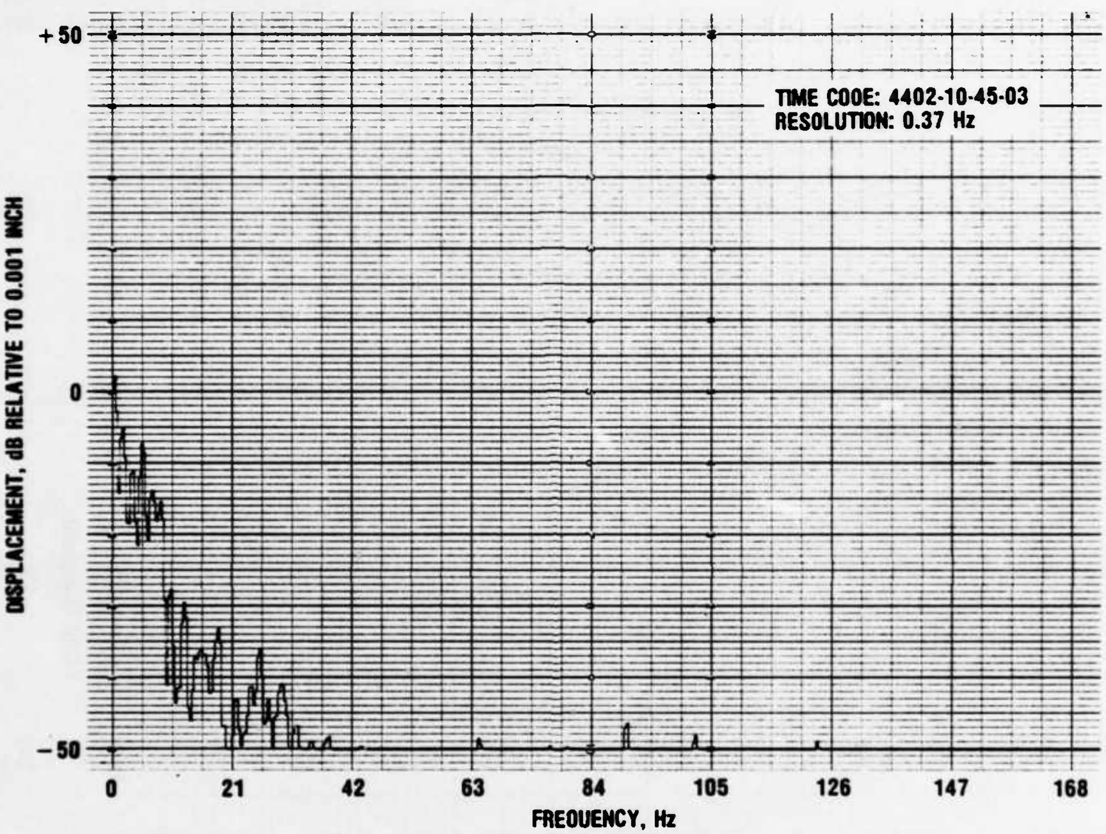


Figure 18.
Spectrum of Man Walking on Roof (SSS Between Roof Joist and Floor Below).

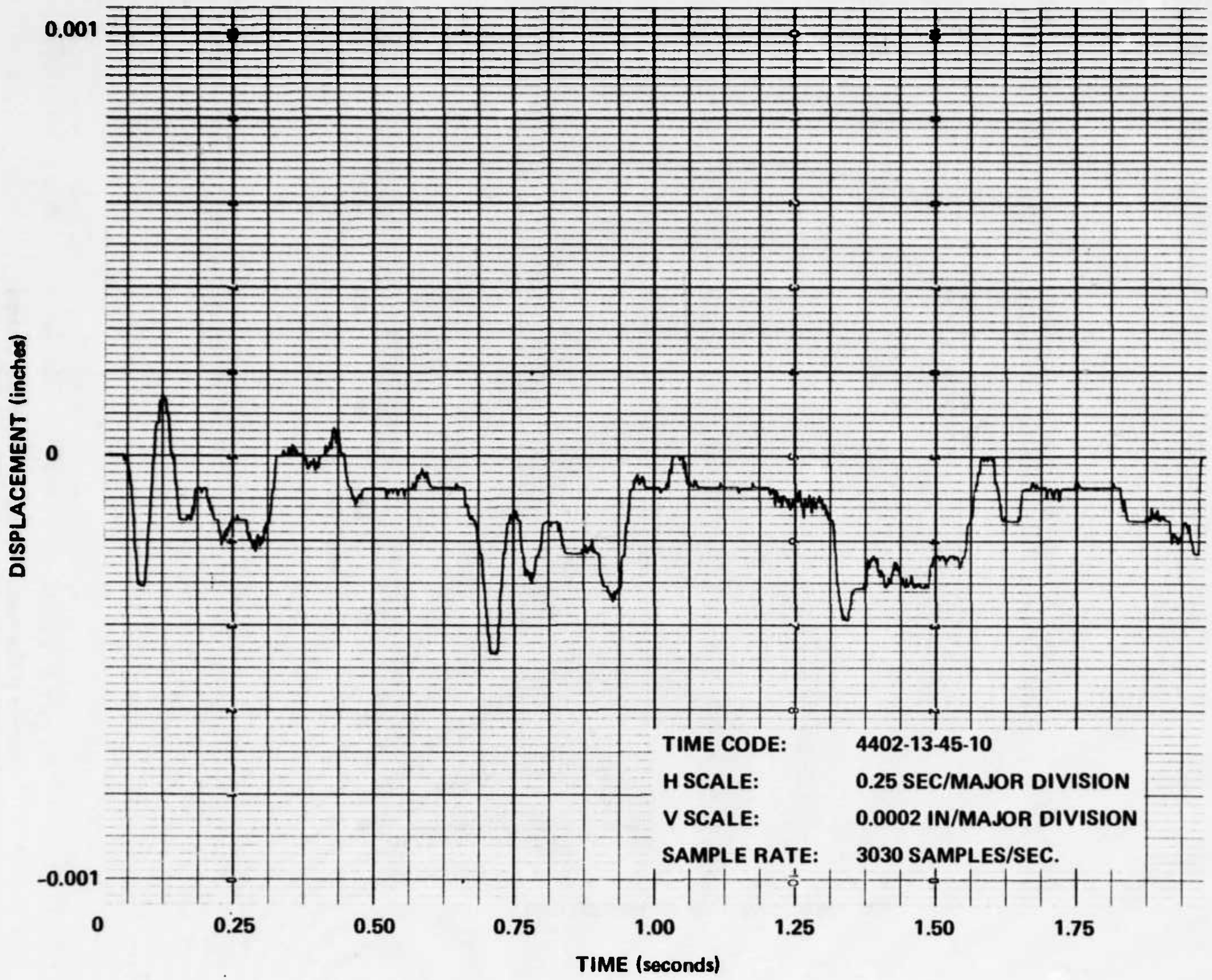


Figure 19.

Signature of Man Walking on Industrial (Suspended) Concrete and Steel Floor Some Distance from SSS (SSS Between Floor and Roof Joist).

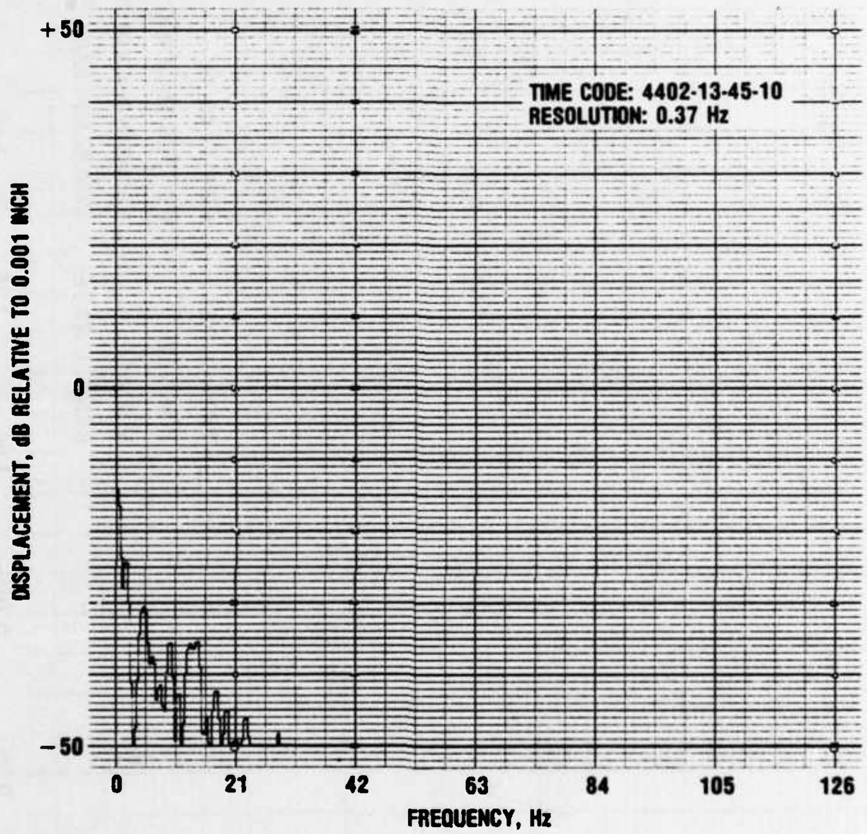


Figure 20.
Spectrum of Man Walking on Industrial (Suspended) Concrete and Steel Floor Some Distance from SSS (SSS Between Floor and Roof Joist).

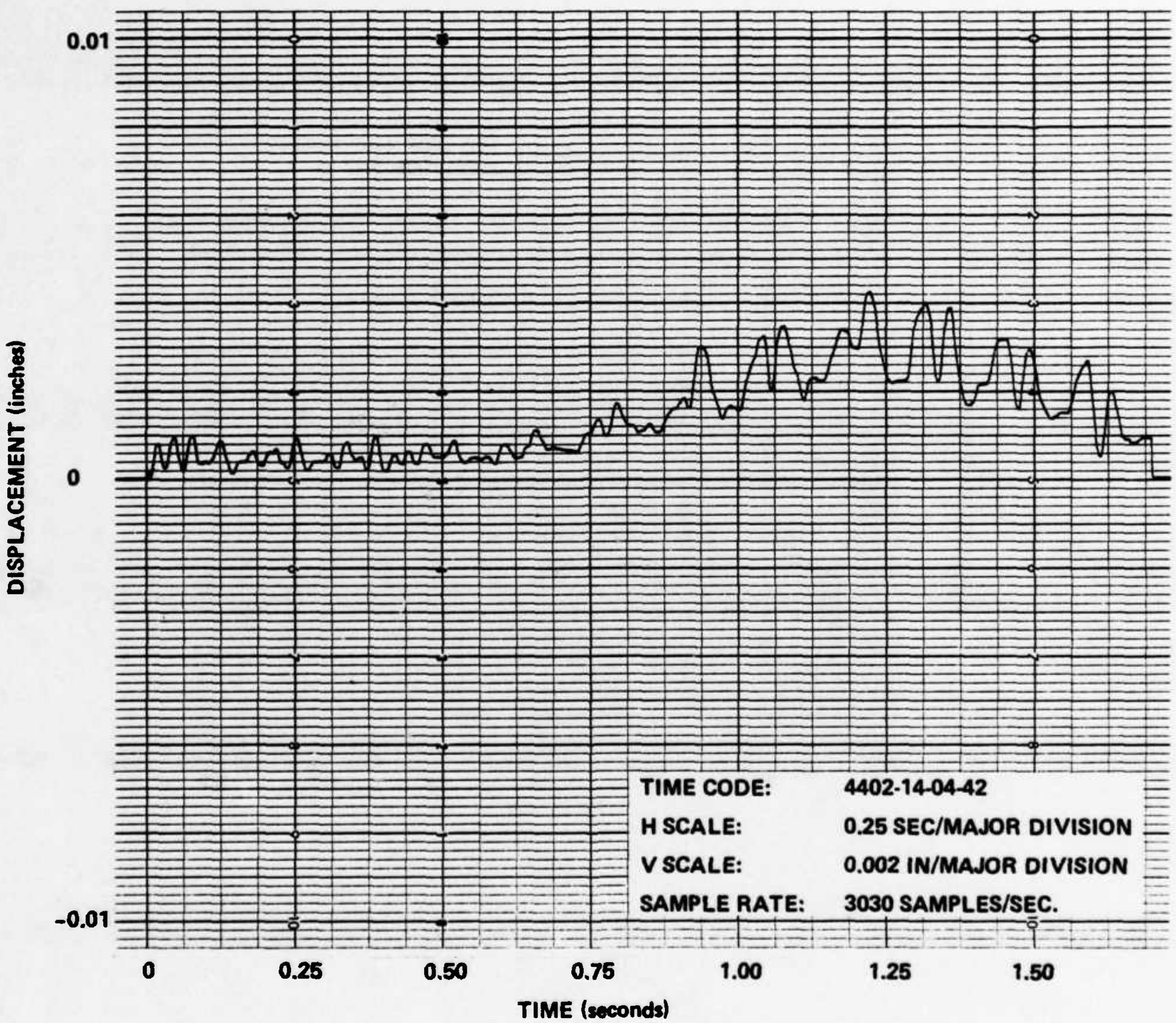


Figure 21.
Signature of Man Walking on Roof (SSS Between Roof Joist and Floor Below).

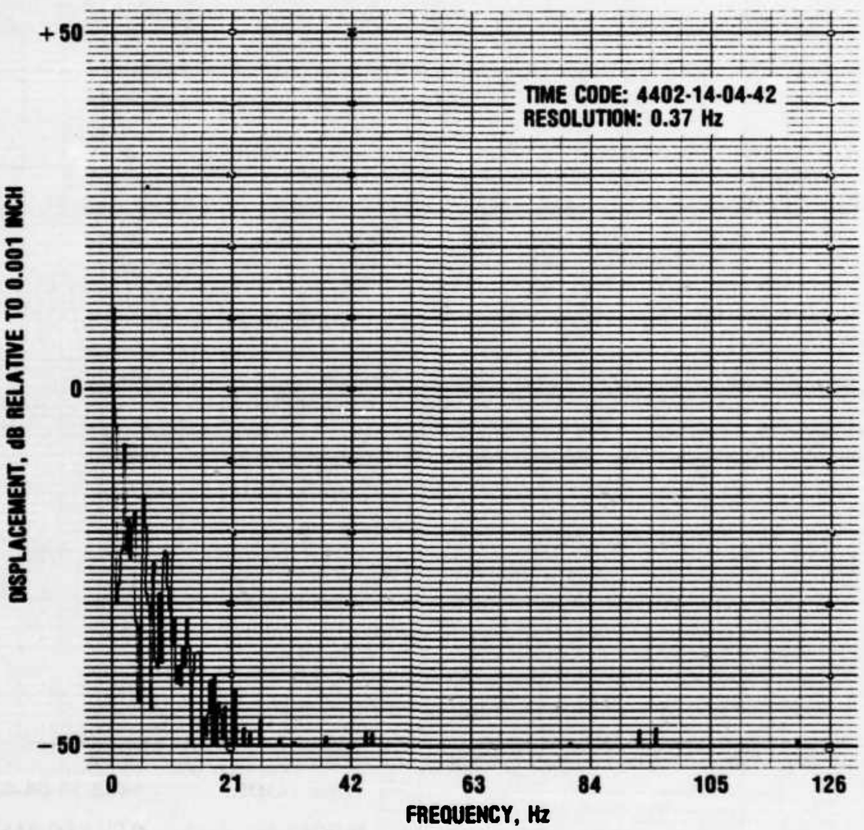


Figure 22.
Spectrum of Man Walking on Roof (SSS Between Roof Joist and Floor Below).

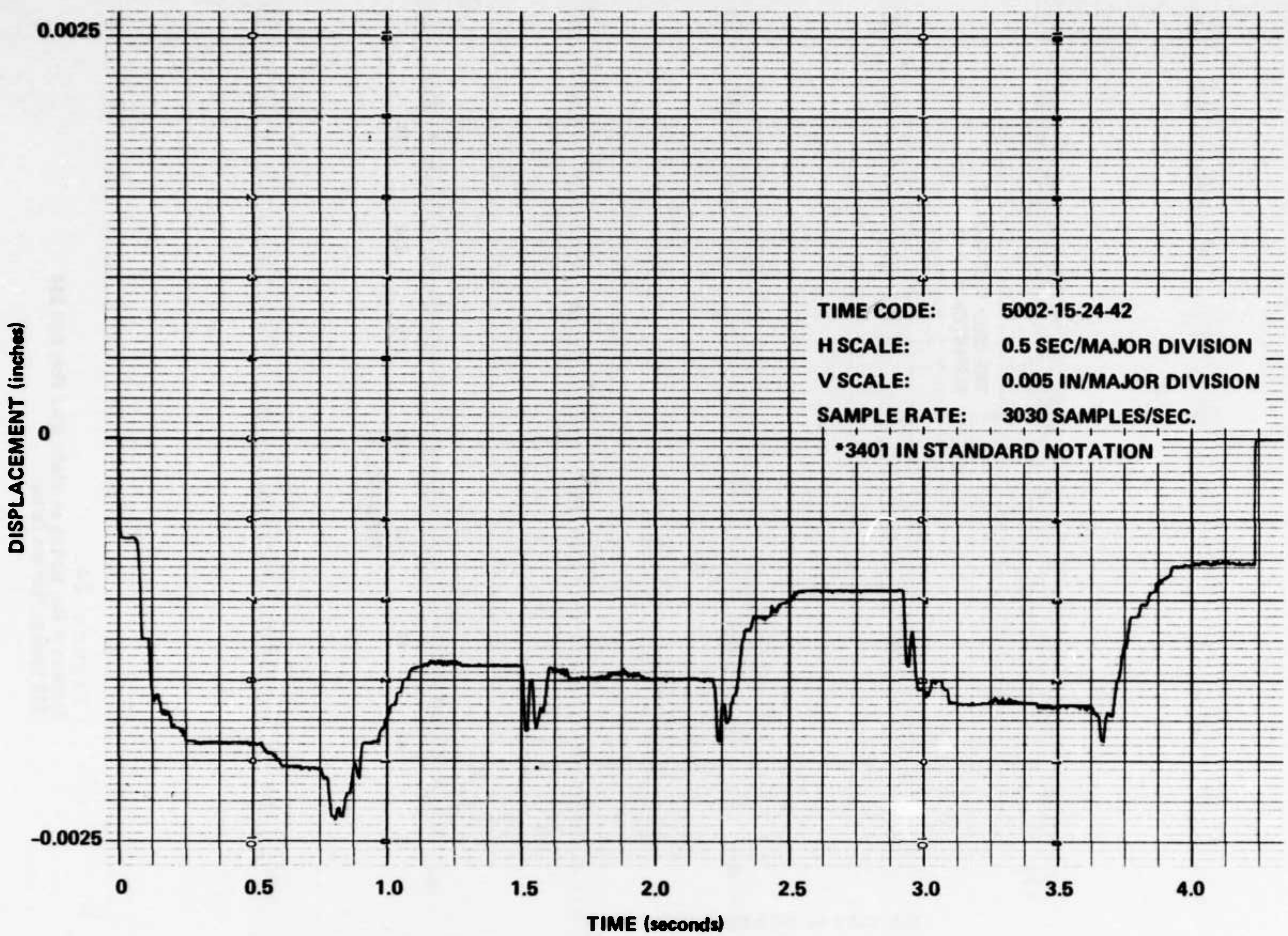


Figure 23.

Signature of Man Walking on Interior Wood Floor Near SSS (SSS Between Floor and Ceiling).

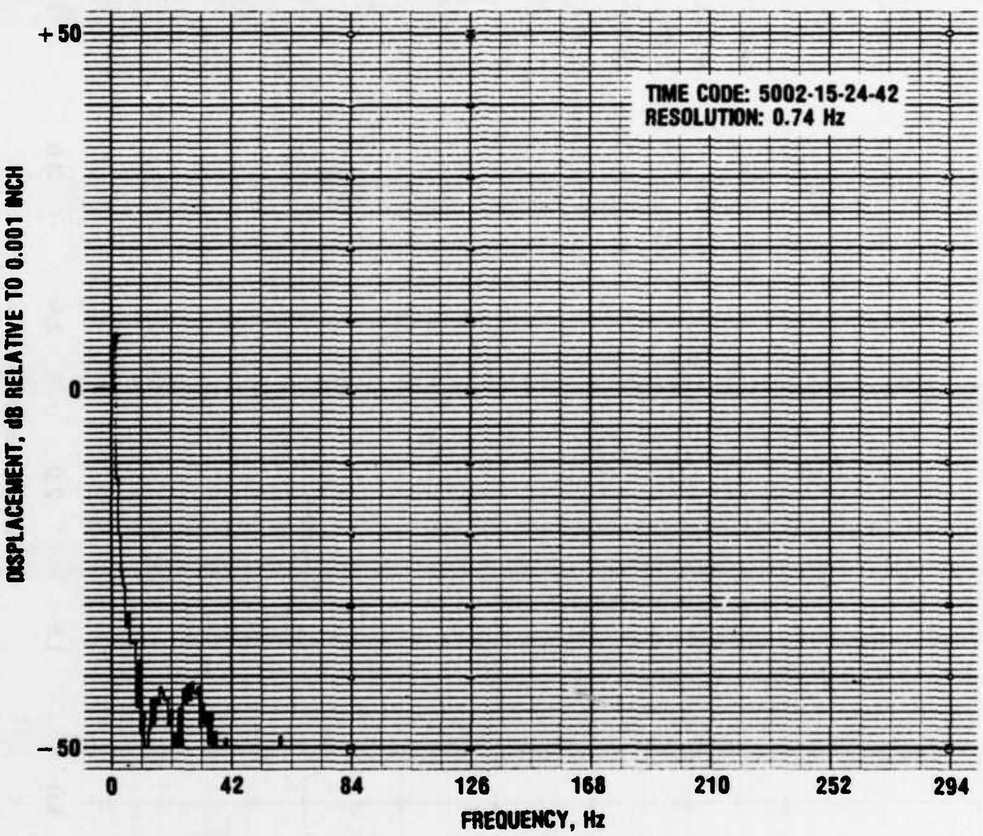


Figure 24.
Spectrum of Man Walking on Interior Wood Floor Near SSS (SSS Between Floor and Ceiling).

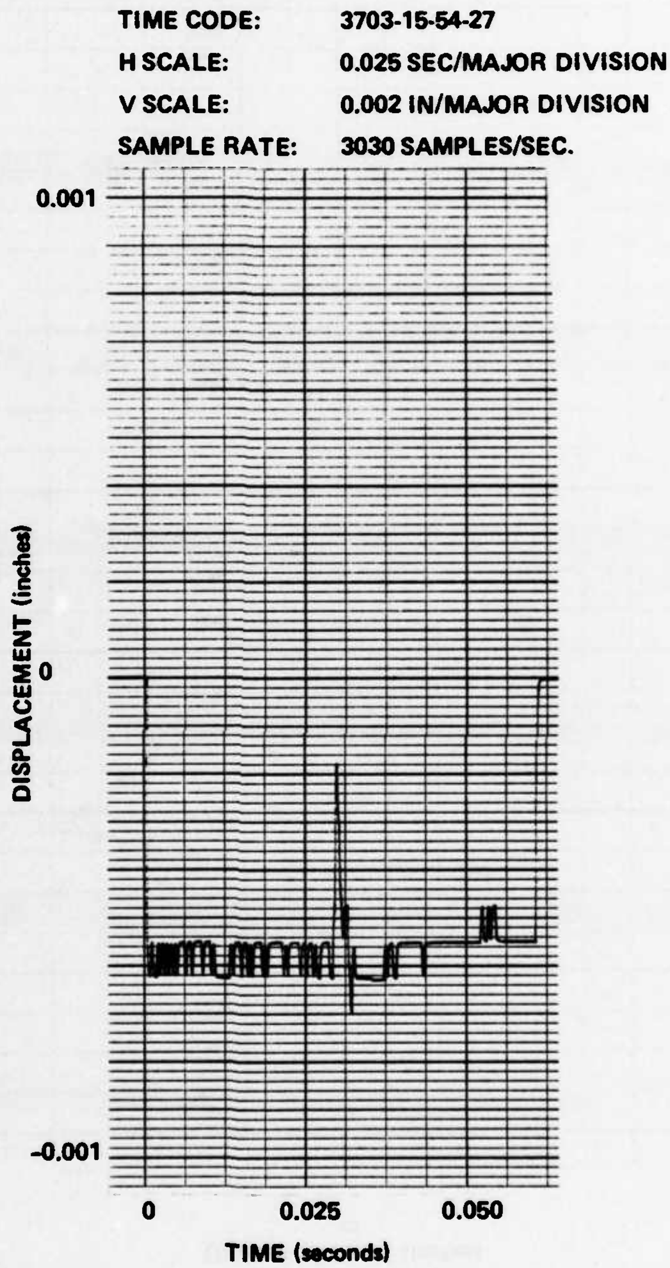


Figure 25.
Signature of Man Banging on Steel Interior Door in 12-inch Cinderblock Wall with Hammer (SSS Behind Center Hinge, No Rubber).

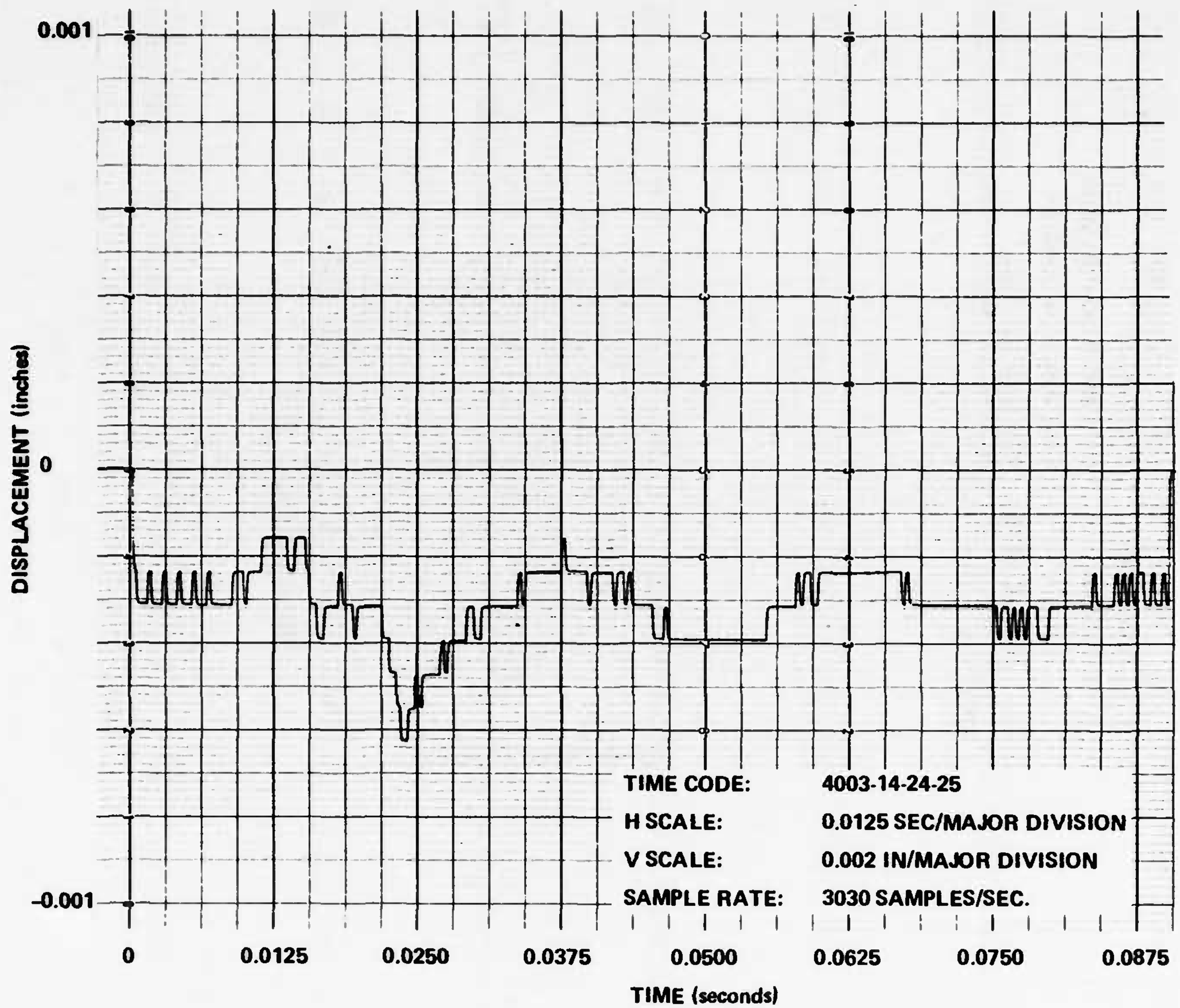


Figure 26.

Signature of Man Banging on Steel Interior Door in 12-inch Cinderblock Wall with Hammer (SSS Behind Bottom Hinge, No Rubber).

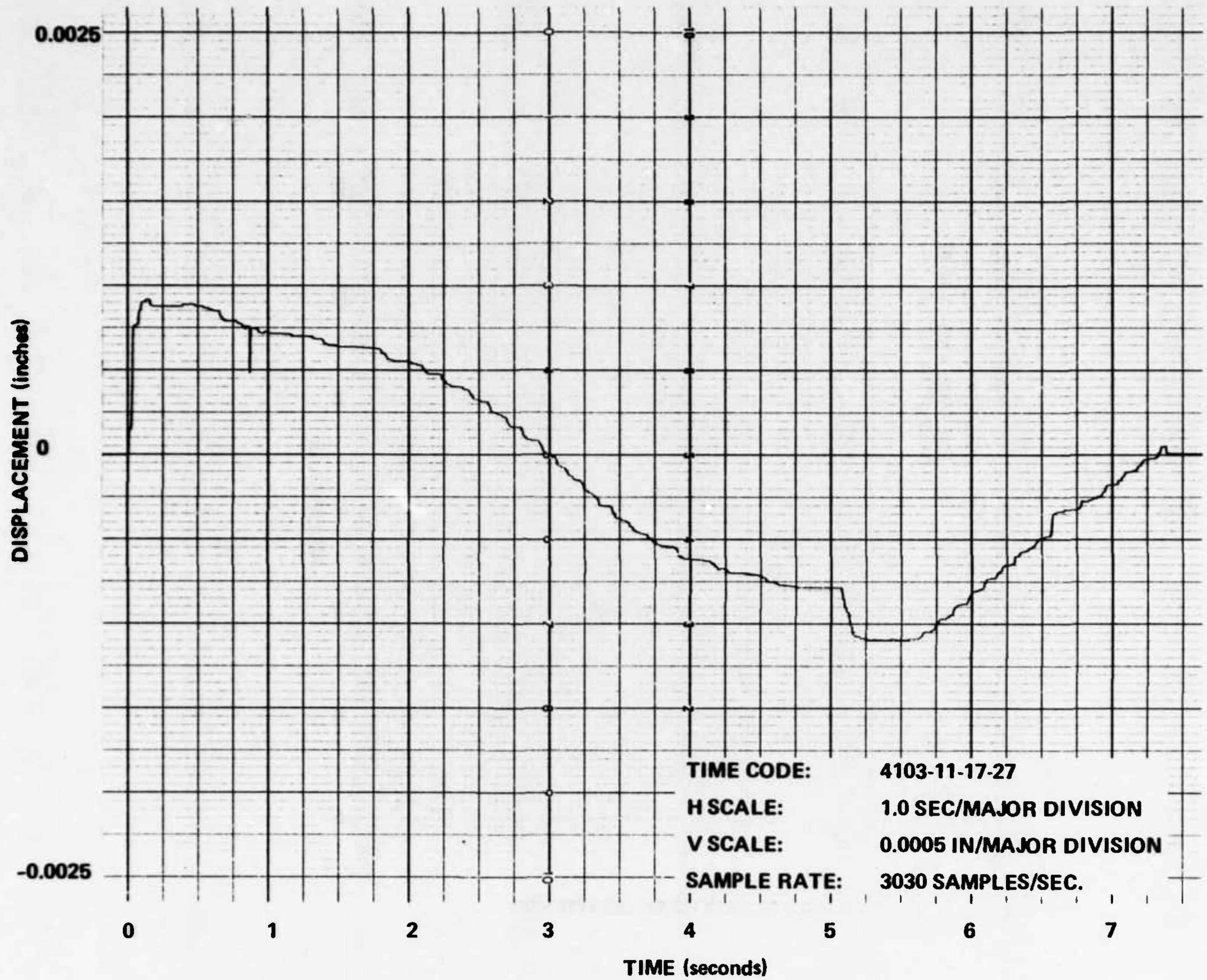


Figure 27.

Signature of Interior Hollow-Core Wood Door in Wood-Frame Partition (SSS under Lower Hinge).

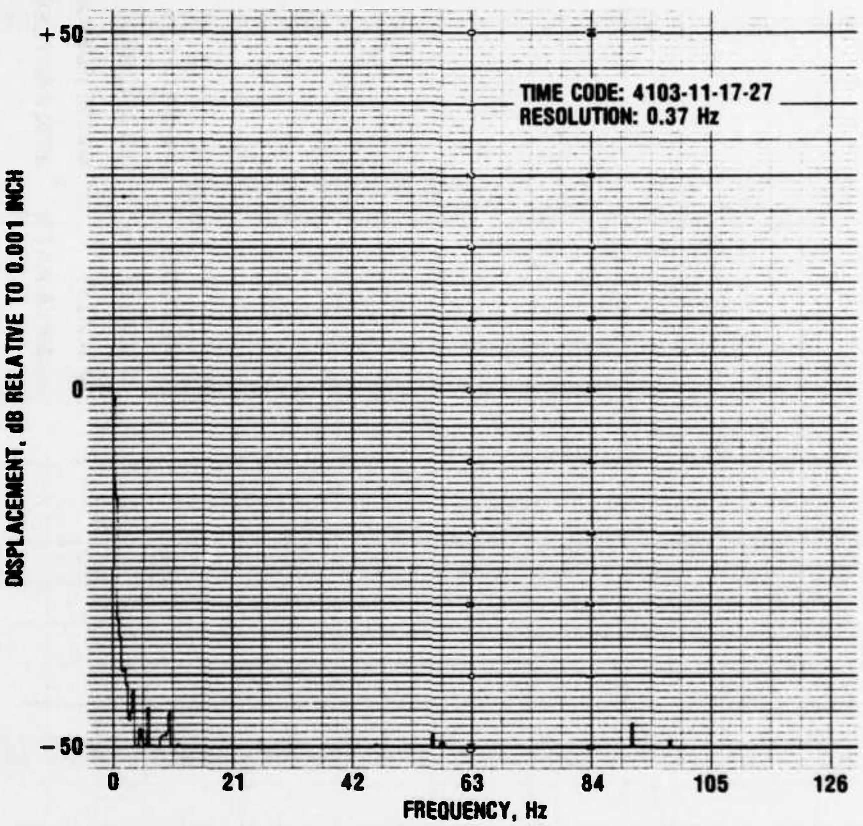


Figure 28.

Spectrum of Interior Hollow-Core Wood Door in Wood-Flame Partition Opening and Closing (SSS Under Lower Hinge).

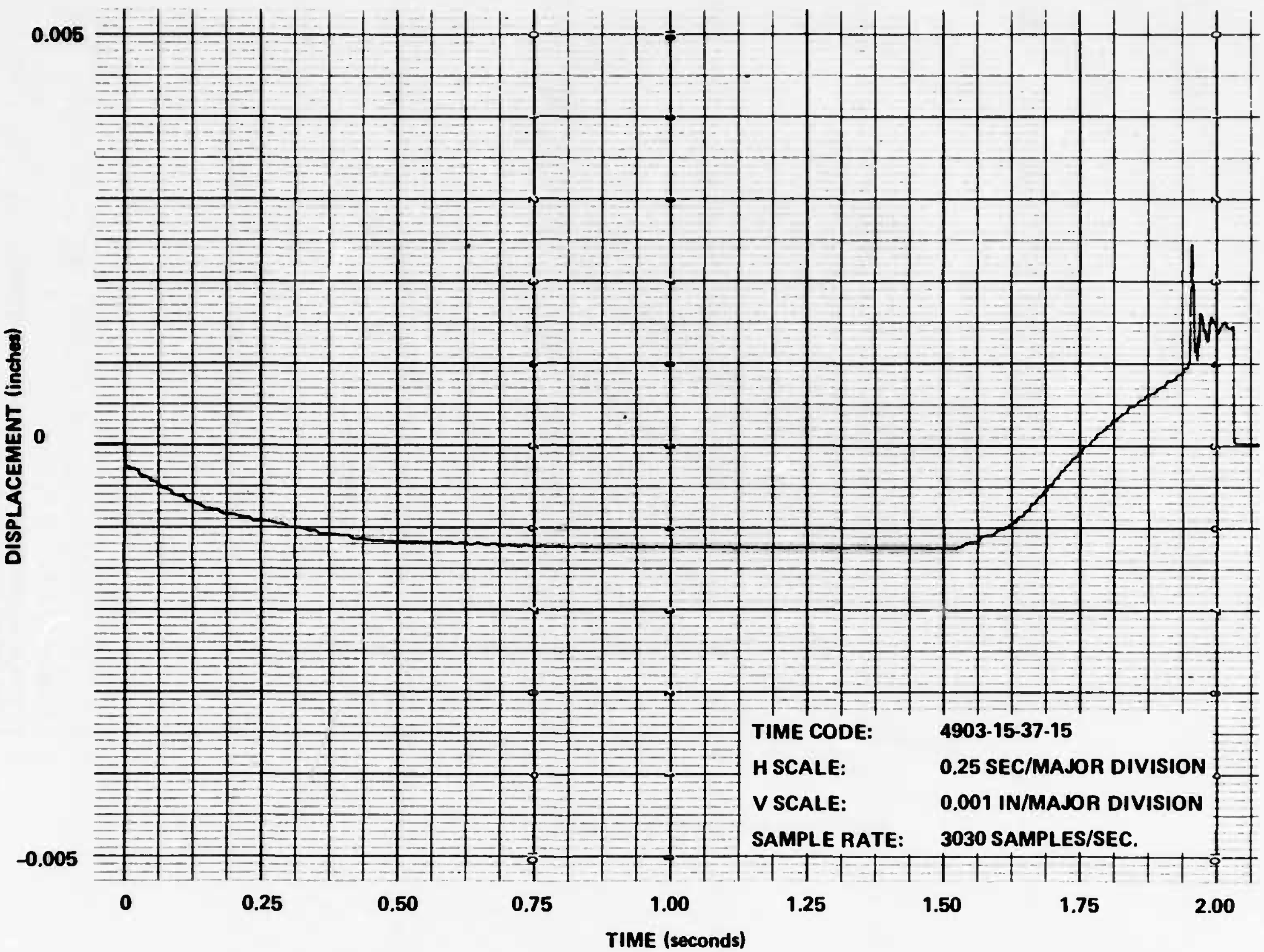


Figure 29.

Signature of Concrete Bunker Door (SSS Vertical Between Top of Hinge Pin and Lintel).

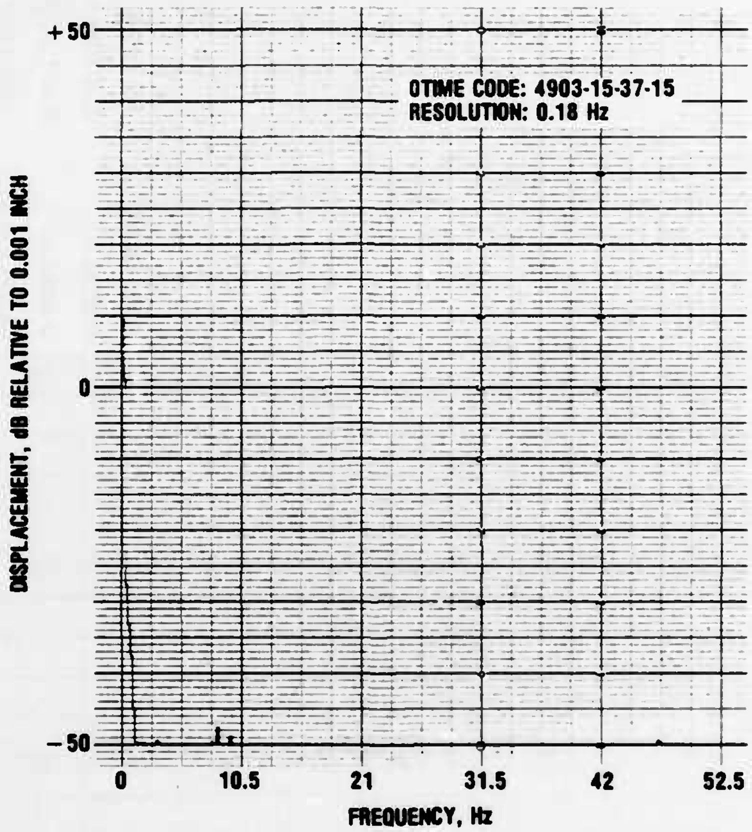


Figure 30.
Spectrum of Concrete Bunker Door Opening and Closing (SSS Vertical Between Top of Hinge Pin and Lintel).

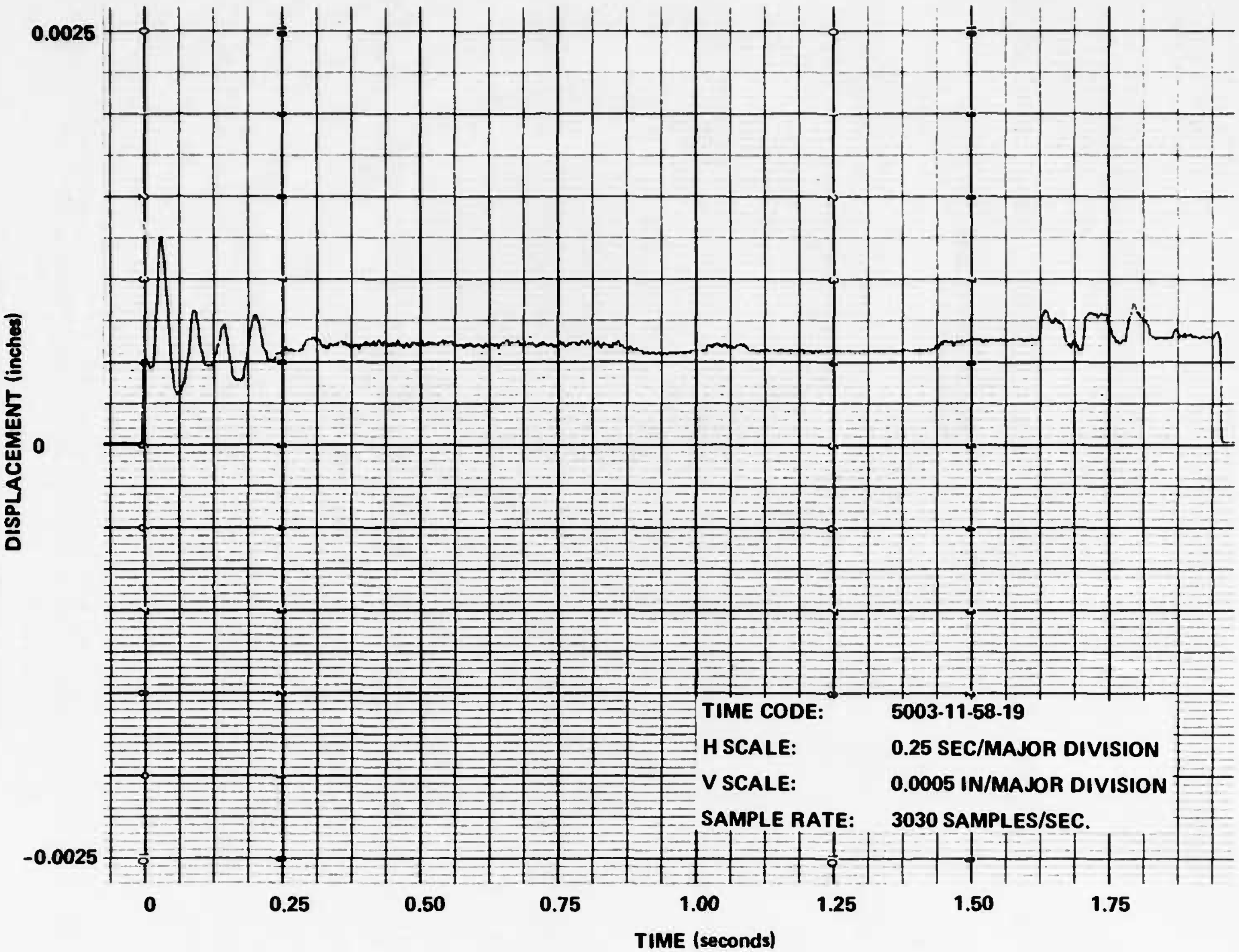


Figure 31.

Signature of Steel-Bar Armslocker Door, Pushing and Pulling Bars (SSS Behind Bottom Hinge).

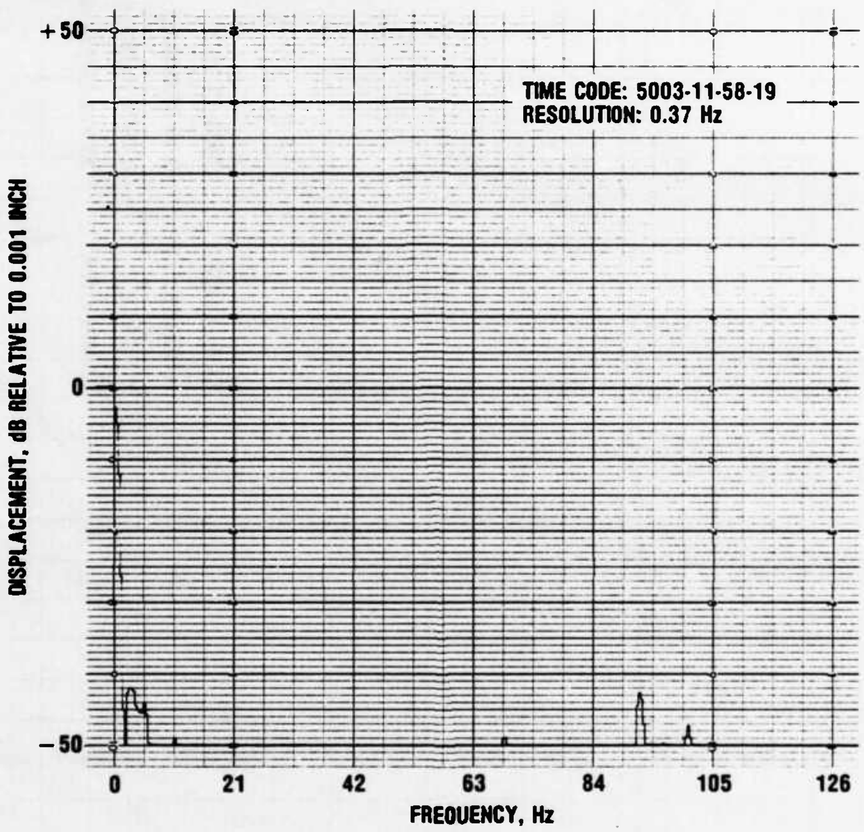


Figure 32.

Spectrum of Steel-Bar Armslocker Door, Pushing and Pulling Bars (SSS Behind Bottom Hinge).

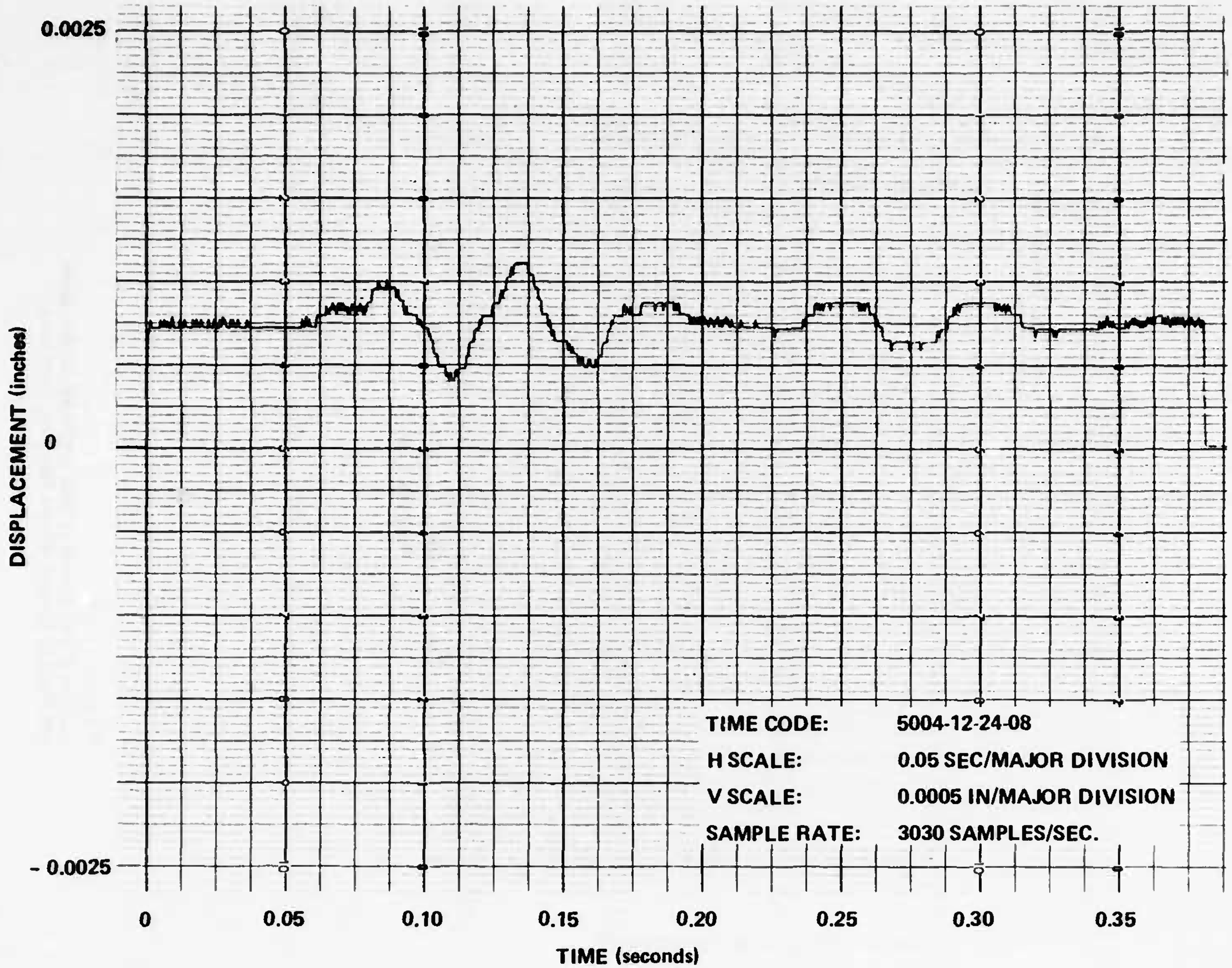


Figure 33.

Signature of Man Banging on Steel Armslocker Window Cover with Fish (SSS Between Window Frame and Large Safe).

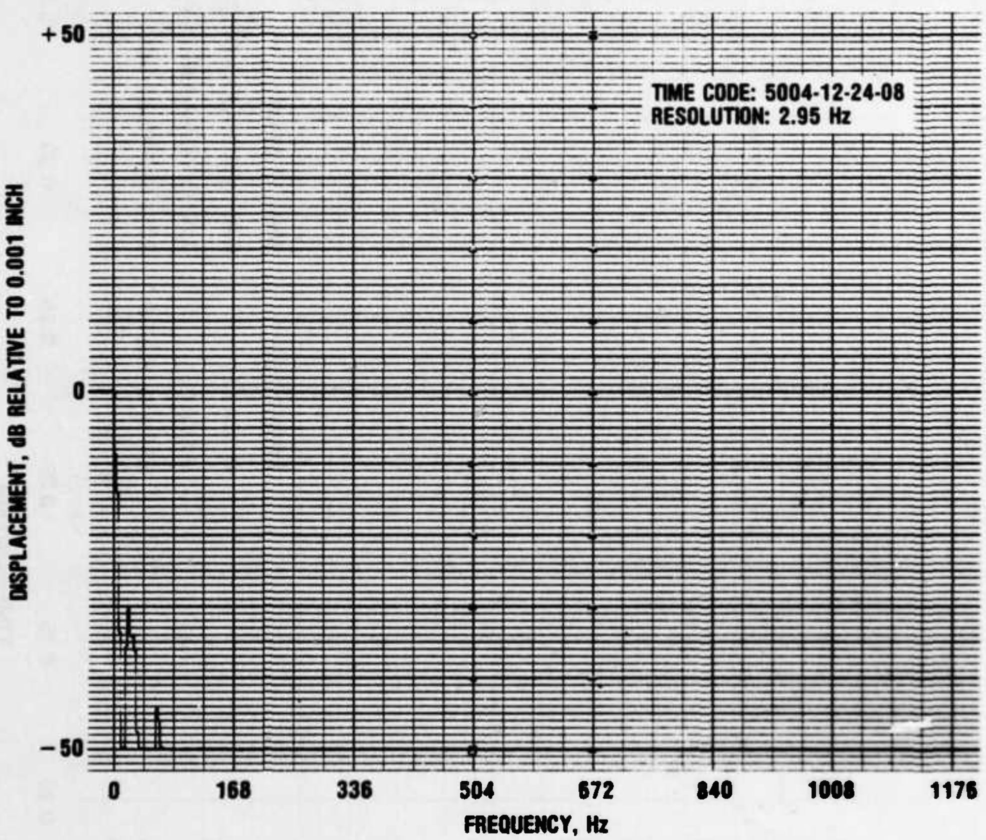


Figure 34.
Spectrum of Man Banging on Steel Armslocker Window Cover with Fist (SSS Between Window Frame and Large Safe).

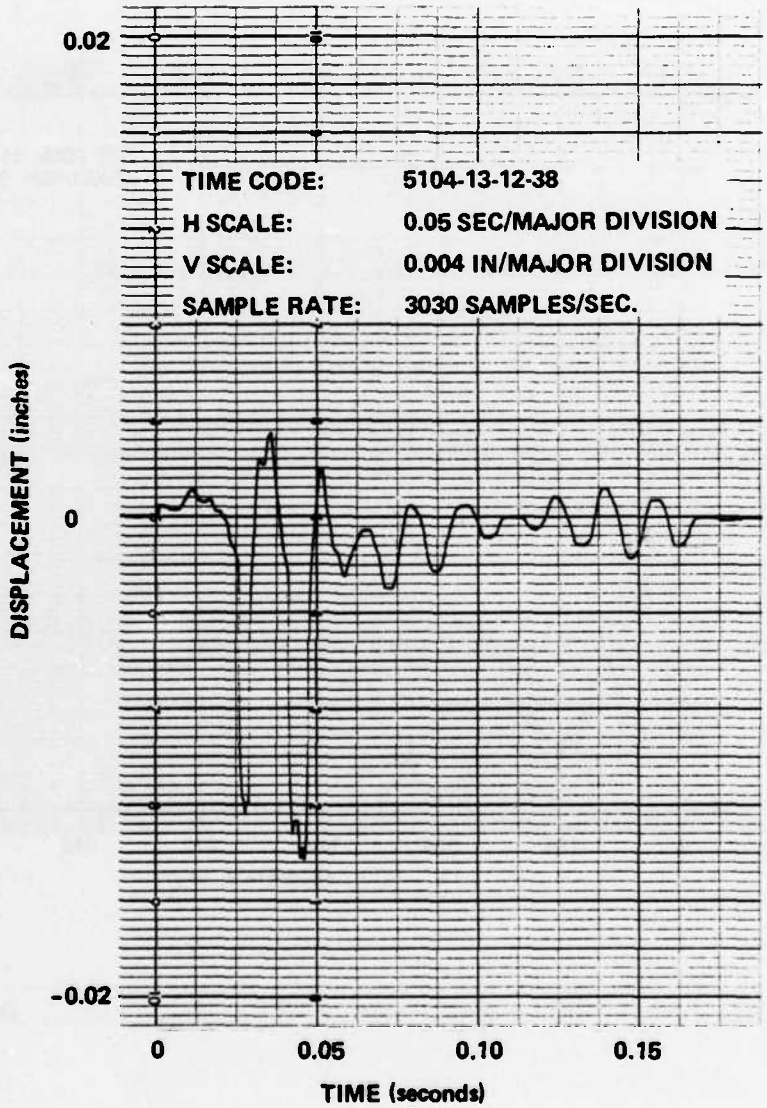


Figure 35.
Signature of Steel Casement Window Being Closed (SSS Between Center of Frame and Wall-to-Wall Fixture).

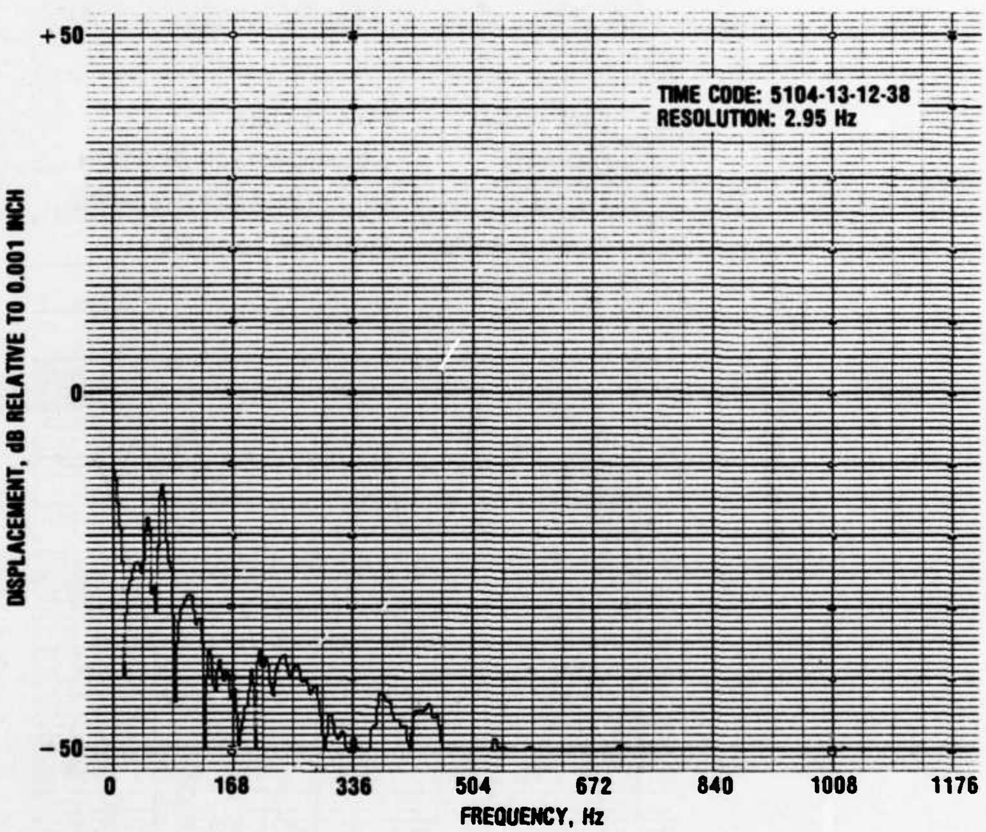


Figure 36.
Spectrum of Steel Casement Window Being Closed (SSS Between Center of Frame and Wall-to-Wall Fixture).

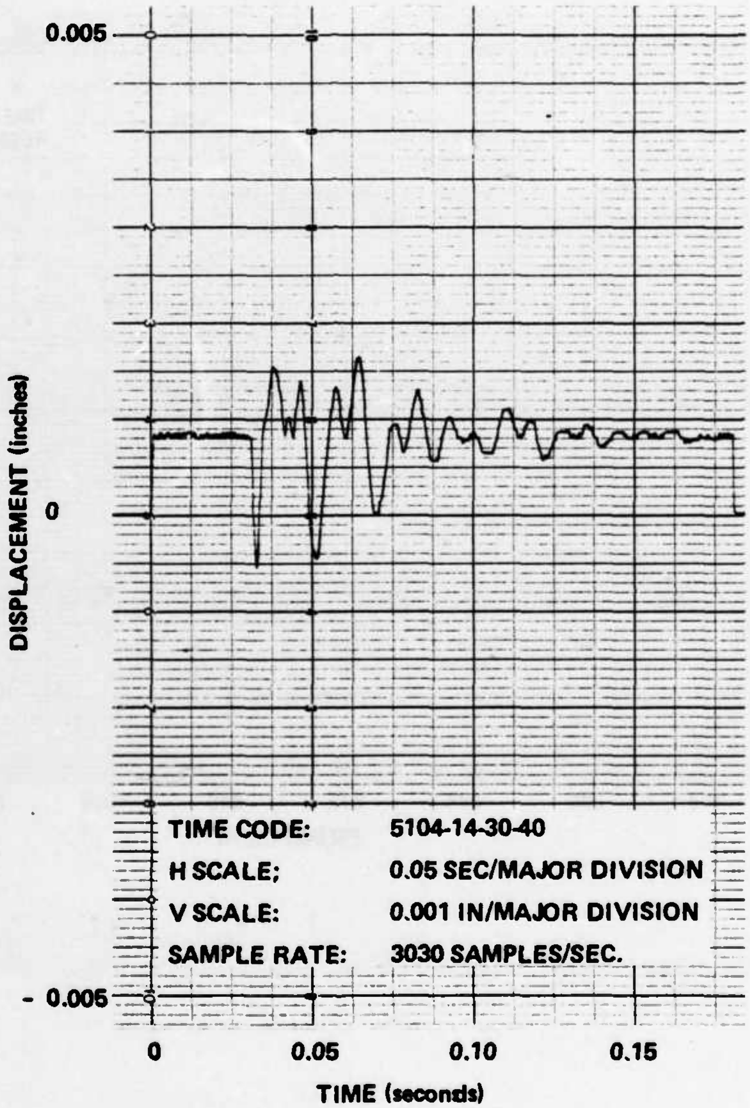


Figure 37.
Signature of Man Banging on Steel Window Frame with One-Foot 2 x 4 (SSS Between Glass and Wall-to-Wall Fixture).

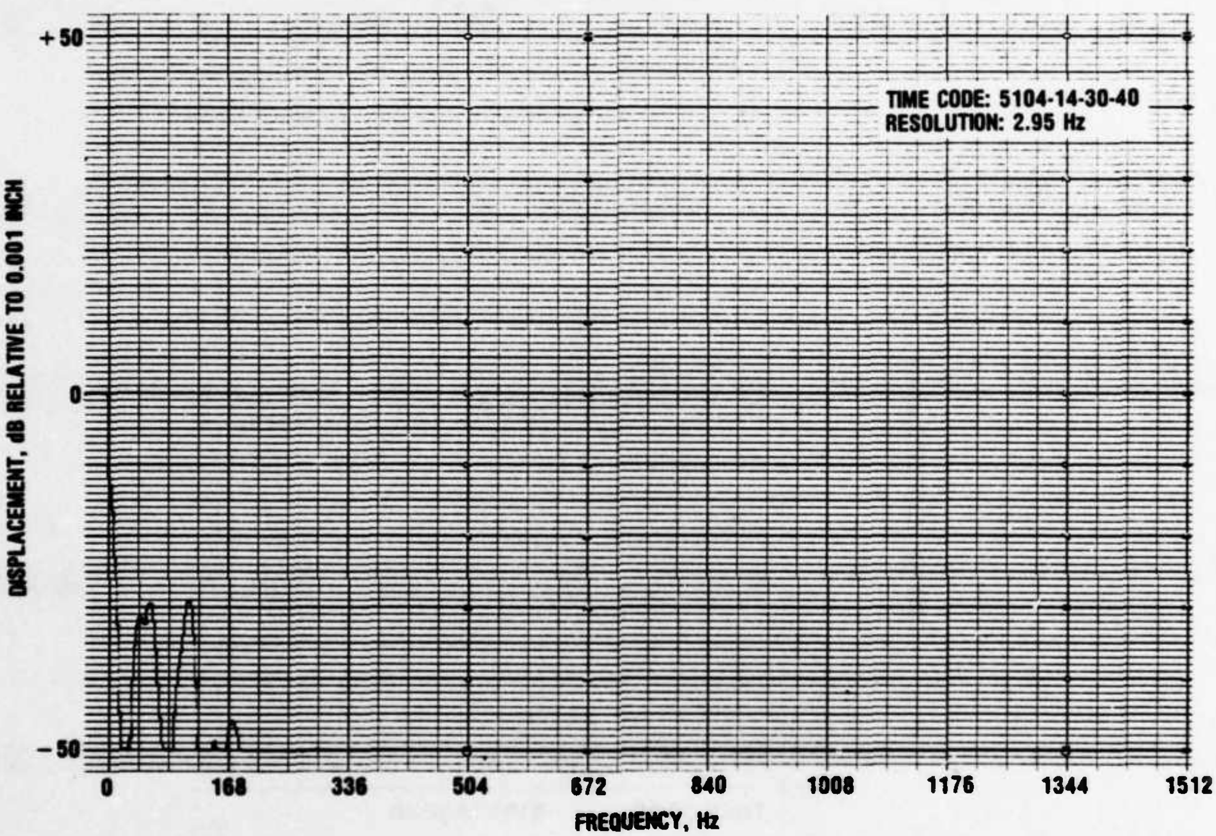


Figure 38.
Spectrum of Man Banging on Steel Window Frame with One-Foot 2x4 (SSS Between Glass and Wall-to-Wall Fixture).

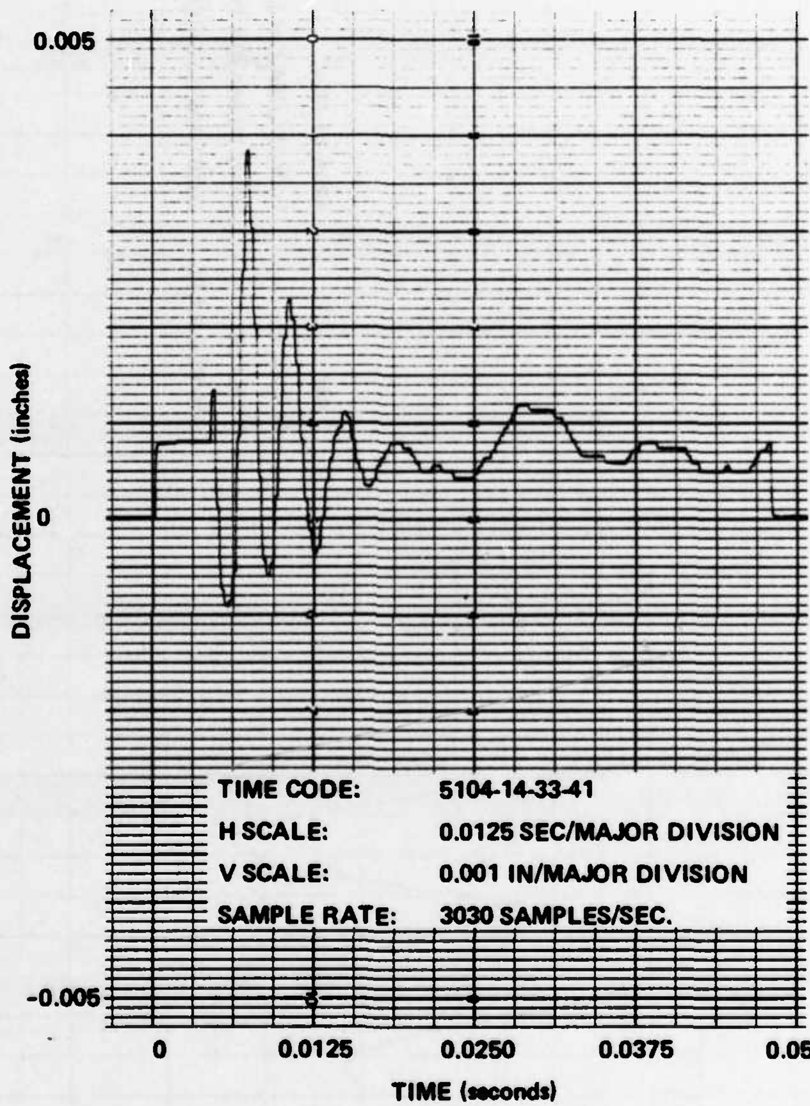


Figure 39.
Signature of Glass Breakage (SSS Between Glass and Wall-to-Wall Fixture).

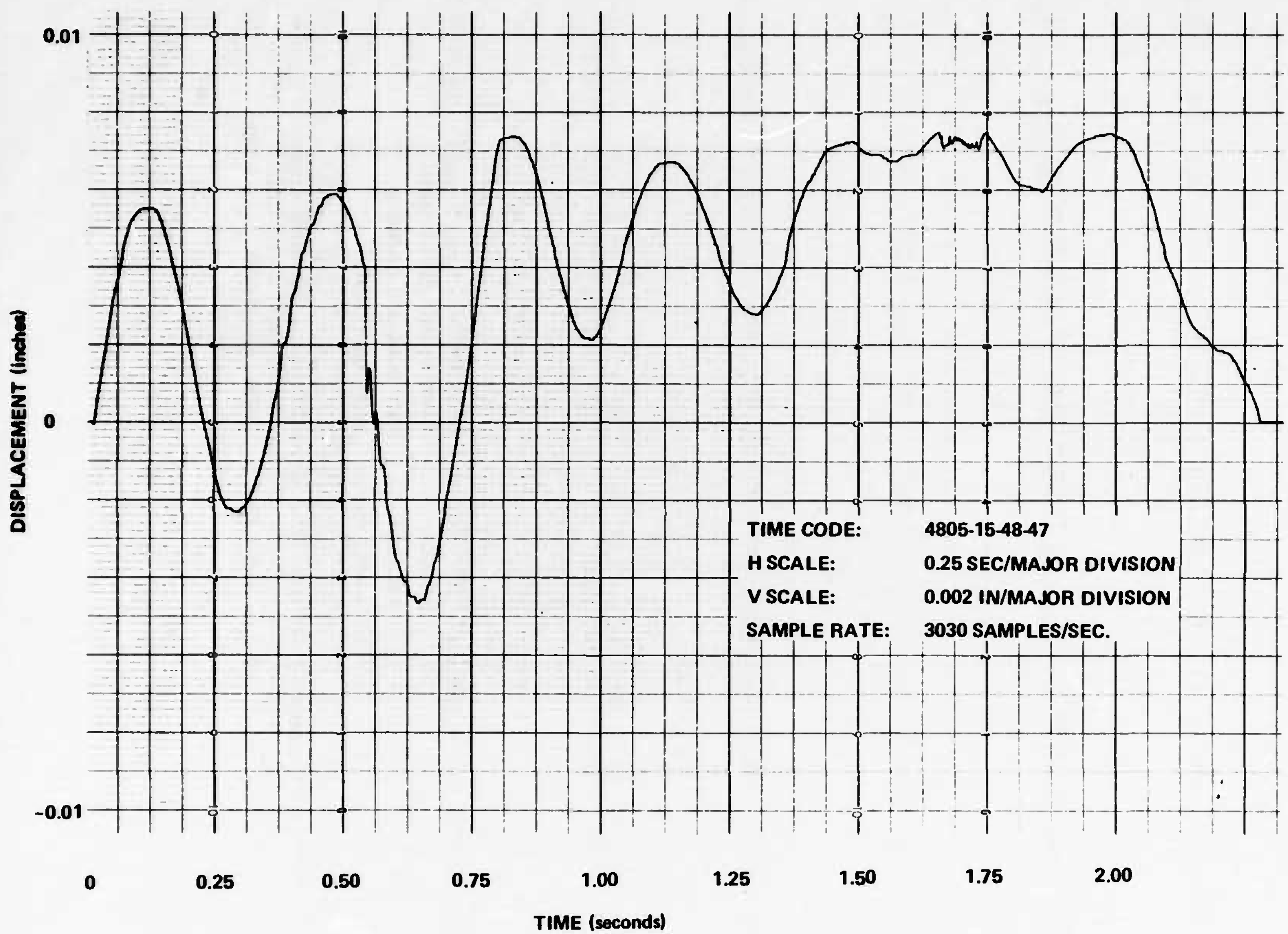


Figure 40.

Signature of Man Taking One Step up a Steel Ladder (SSS Sensing Siderail Flexure).

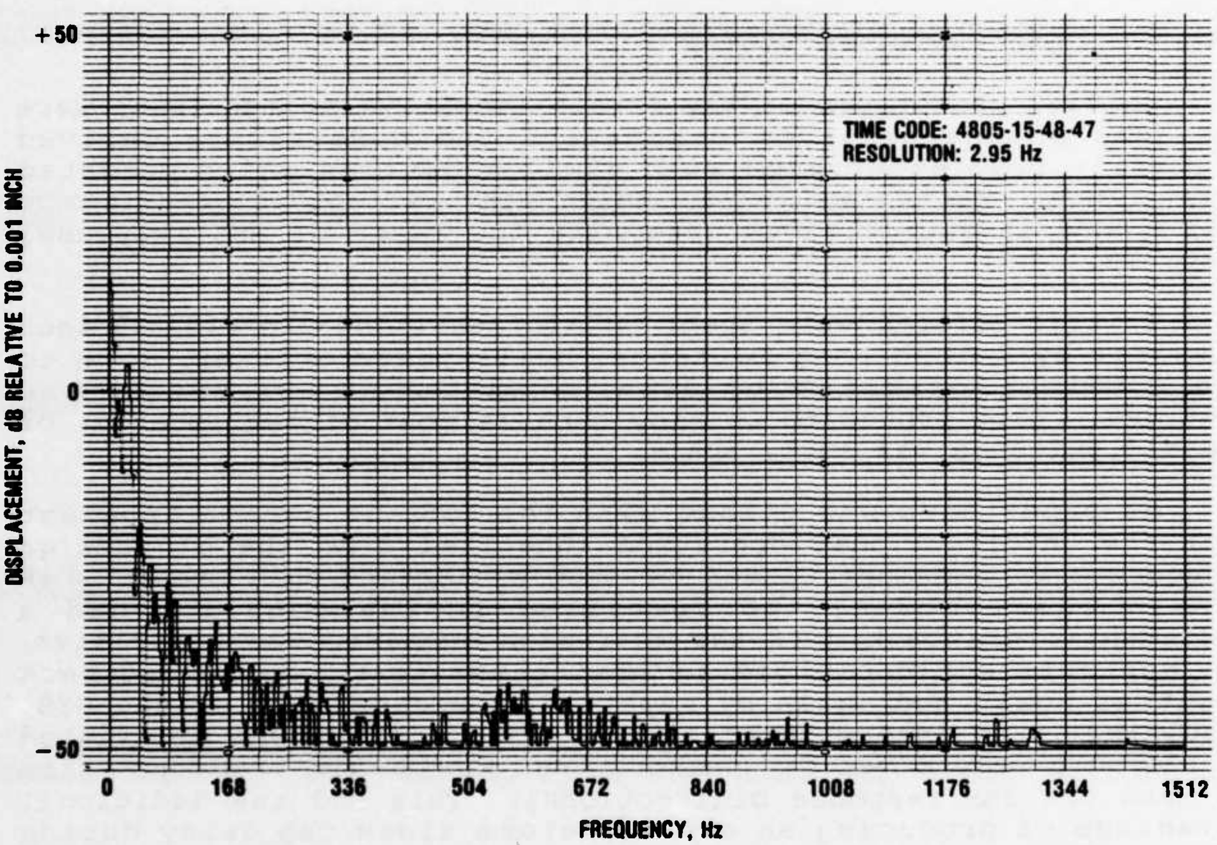


Figure 41.

Spectrum of Man Taking One Step on Steel Ladder (SSS Sensing Siderail Flexure).

Sensitivity to strains as small as 10 microinches can be utilized before high-frequency noise (above 75 Hz) will start to cause false alarms in typical targets. Unfortunately there are insufficient data to make the same generalizations about low-frequency noise, but limited field testing of prototype SSS's appears to indicate that false alarms due to mechanical noise in typical targets is not a problem with any SSS built to date.

5.0 SSS PROTOTYPE DESIGN

Initial prototypes of the Strain-Sensitive Switch (SSS) were designed on the basis of parameters and constraints derived primarily from experience with similar devices which predated this effort. During prototype Design many variations on a common theme were investigated to determine the range of SSS responses possible.

Initial efforts were spent on miniaturizing the old 1.5 inch diameter by 7-inch long switches, built years earlier, down to the 0.5-inch diameter by 1.5-inches long required by the Contract. This proved to be easy because most of the interior of the old switches was empty space.

As experience was gained with the SSS, it became apparent that the unidirectional operation inherited from the old design (the contacts remained closed on compression and only opened when strain was removed) and specified in the contract had a fundamental drawback. If the intrusion scenario was repetitive, the contacts would reclose several times, i.e., be forced back together again and again by repetitive compression of the SSS, resulting in an intermittent alarm. This problem was alleviated by adding a second set of contacts that would open on compression to make the SSS response bidirectional. This had the additional advantage of producing an earlier alarm since the delay during compression was eliminated.

Examination of intrusion signatures in the frequency domain (intrusion spectrums) disclosed that most signature information was well below on hertz and brought up the question as to whether the contact reclosure time of 0.1 second for a 0.001-inch step displacement (0.1 second/mil) as specified in the contract was really long enough. This question was answered rather graphically during a field test in which an SSS having the 0.1 second/mil response provided good alarms when used to monitor a cement and steel staircase as long as traffic was normal, but failed miserably (was "spoofed") when an intruder moved slowly and softly up or down the staircase. At this point, all of the earlier SSS designs were scrapped and a new design was arrived at with a contact reclosure time of over 1 second/mil in a 0.63-inch diameter by 2.0-inch long case (including length adjustment mechanisms). The new SSS proved much more difficult to sneak past in similar field tests and there was no noticeable increase in false alarms because of the increased low-frequency response. The 15 final Advanced Development Model SSS's manufactured under the contract incorporate the new design.

5.1 Design Goals

The major design goal was to design an inexpensive intrusion sensor that would respond without false alarms to the small deflections (strain) of structures (targets) that naturally accompany an intrusion scenario. Original contractual goals required that the sensor shall be a normally-closed mechanical switch that is sensitive to strain as small as 0.0005 inch (desired alarm) while accommodating normal settling of intrusion targets as large as 0.06 inch without opening (false alarm). The contractual guide lines specify that "the contacts shall remain closed as strain is applied, either rapidly or slowly. The contacts shall open when strain is removed rapidly, remaining open for 100 milliseconds (ms) for 0.001 inch of strain removed, and then reclose. The characteristics shall be stable over the temperature range from $-40^{\circ}F$ to $+150^{\circ}F$. Operation shall not be affected by humidity, mold or long periods of quiescence. The contacts shall be capable of operating either dry (low level) or wet (high level) with currents up to 1 ampere (resistive load) at 28 volts dc. The SSS shall not be adversely affected by normal handling or reasonable overloads. The SSS shall be easily installed and adaptable to a wide variety of targets. Size shall be 1.5 inches long by 0.5 inches diameter, or less."

All of the above design goals were subject to modifications as the result of the Optimization Analysis. Accordingly, operation was made bidirectional (contacts open on either application or removal of strain) to reduce intermittent alarms, the length of time the contacts remain open (contact reclosure time) after application or removal of strain was increased from 0.1 to over one second to reduce "spoofing", by slow intrusions, and the size was increased to 0.63 inch diameter by 2.0 inches long to accommodate the increased reclosure time and a length adjusting mechanism. With the qualification that there is considerable variation in contact reclosure time with temperature using even the best damping fluids, all of the remaining goals have been met. It is not anticipated that the temperature variations will adversely affect normal performance.

5.2 Designs Accomplished

A conceptual design for the SSS is shown in Figure 42. The case is typically made of plastic and is approximately 1.5 inches long by 0.5 inch in diameter. Tapped holes in the ends provide mounting means. One end is a cap mounted to the body with a seal, in this case made of rubber. An O-ring seal provides a barrier during vulcanization of the rubber main seal. Within the case are two contacts which come together at a small point to obtain relatively high contact pressure. A spring holds the contacts together and a pair of telescoping tubes keep the spring and contacts in alignment. Damping fluid between the telescoping tubes allows the contacts to follow each other and remain closed for slow movements of the cap relative to the body. The contacts

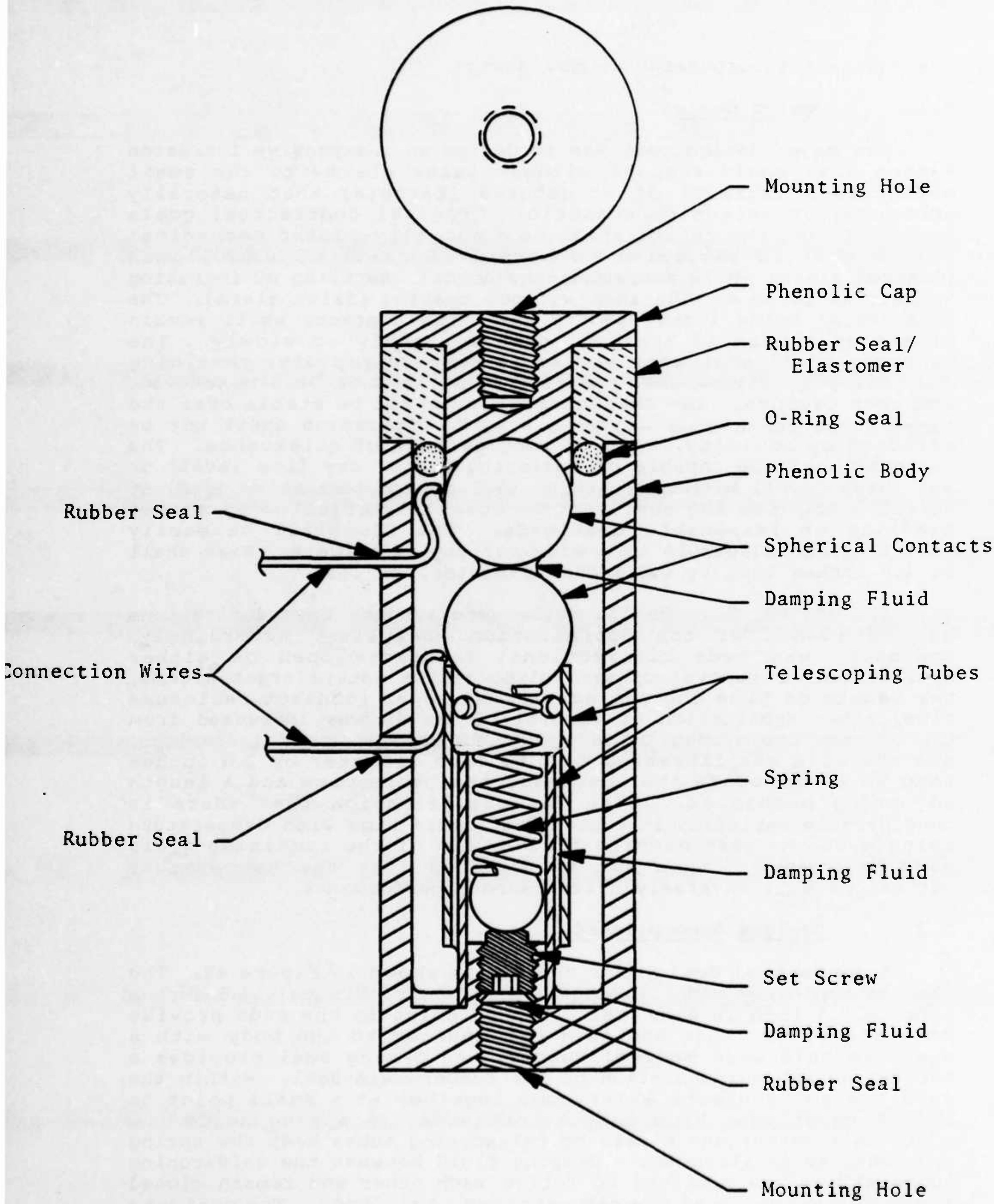


Figure 42. SSS Conceptual Design.

also remain closed for rapid movements that compress the spring, but rapid movements that decompress the spring cannot be followed by the body contact because of the damping fluid and the contacts separate momentarily to create an alarm.

Many variations are possible within the conceptual design. The rubber used for the main seal must be both elastic to provide the return force for the cap, and strong to maintain an effective seal with repeated flexure. High-strength room-temperature-vulcanizing (RTV) silicone rubber is being used for the seal because it is available in a thixotropic form which is easy to use, is compatible with the damping fluid, and has excellent temperature characteristics.

The damping fluid is particularly critical; on it depends the timing of the contact reclosure after opening. Silicone oils are being used because they are available in a wide range of viscosities, have the most constant viscosity with temperature of any liquid found so far and are very stable chemically. The material finally selected is General Electric VISCASIL silicone oil with a viscosity of 600,000 centistokes (cs). VISCASIL is available with viscosities ranging from 5000 to 600,000 cs.

The damping fluid selected must also be compatible with the electrical contacts since the fluid eventually migrates throughout the interior of the case. The VISCASIL silicone oil has given excellent contact performanceto date.

Next to the viscosity of the damping fluid, the most controllable factor in determining the contact reclosure time for a given design is the spring tension. A set screw at the bottom of the mounting hole in the body permited a small range of adjustment for trimming the reclosure time in early prototypes, but the range of adjustments was relatively small and the set screw was eliminated to simplify in the later designs. Minimum spring tension is that necessary to support the weight of the moving parts and hold the contacts closed when the SSS is in a vertical position. Choice of spring tension too close to the minimum results an SSS which is excessively sensitive to orientation and may result in erratic contact closure because of low contact pressure.

Various other factors that were considered in the final design were the equalization of damping areas between the various telescoping cylinders, the weight of the moving parts and its effect on response and response symmetry, the elimination of internal connecting wires because of their inability to withstand flexure without breakage, the internal venting of trapped air and damping fluid, and the ease of assembly and simplicity of construction.

Test data on the following prototypes is presented in Section 5.4.2.

5.2.1 First Prototype SSS

A drawing of the First Prototype SSS is shown in Figure 43. Two versions were built; serial number 1 (S/N 1) with a 0.170-inch OD by 0.800-inch long spring of 0.0089-inch diameter beryllium copper (Small Parts Incorporated type CS-56) and S/N 2 with a similar spring cut to 0.500-inch length. Both used 100,000 cs Dow-Corning 200 silicone oil for damping and both used Dow-Corning 730 RTV fluorosilicone rubber elastomer. The contact wires were 50x4 Litz which has 50 fine enameled wires inside a nylon wrap and is very flexible. The contact spheres were bronze and the telescoping tubes were brass. The set screw was stainless steel. The response of S/N 2 exceeded the design goal of 0.1 second/mil contact reclosure time.

5.2.2 Second Prototype SSS

A drawing of the Second Prototype SSS is shown in Figure 44. The design was the same as the First Prototype SSS except that the contact sphere on the cap was sprung (floating) in a bed of fluorosilicone rubber. This produced some rejection of high frequency responses since the cap must move significantly before the contacts can separate.

Two prototypes were produced to this design; S/N 3 with the same spring as S/N 2, and S/N 4 with the same spring as S/N 1.

5.2.3 Third Prototype SSS

A drawing of the Third Prototype SSS is shown in Figure 45. This was similar to the First Prototype except that the size of the telescoping tubes was increased to maximize the damping area, and the contact spheres were drilled out to reduce weight and provide additional space for the spring and mounting screw.

Two prototypes were built to this design; S/N 5 with the same spring as S/N 1, and S/N 6 with a 0.188-inch diameter by 0.5-inch long spring of 0.018-inch stainless steel (PIC type AV-48).

Two additional prototypes were built to this design modified to include the floating cap contact of the Second Prototype; S/N 7 with the same spring as S/N 1, and S/N 8 with the same spring as S/N 6.

5.2.4 Fourth Prototype

The Fourth Prototype SSS was a miniaturized version of the Third Prototype and is shown in Figure 46. The O-ring was no longer necessary because the space between the cap and the body was too small for the fluorosilicone rubber to penetrate during assembly.

Two prototypes with fixed cap contacts were built; S/N 9 and S/N 10, both with 0.107-inch outside diameter by 0.295-inch long

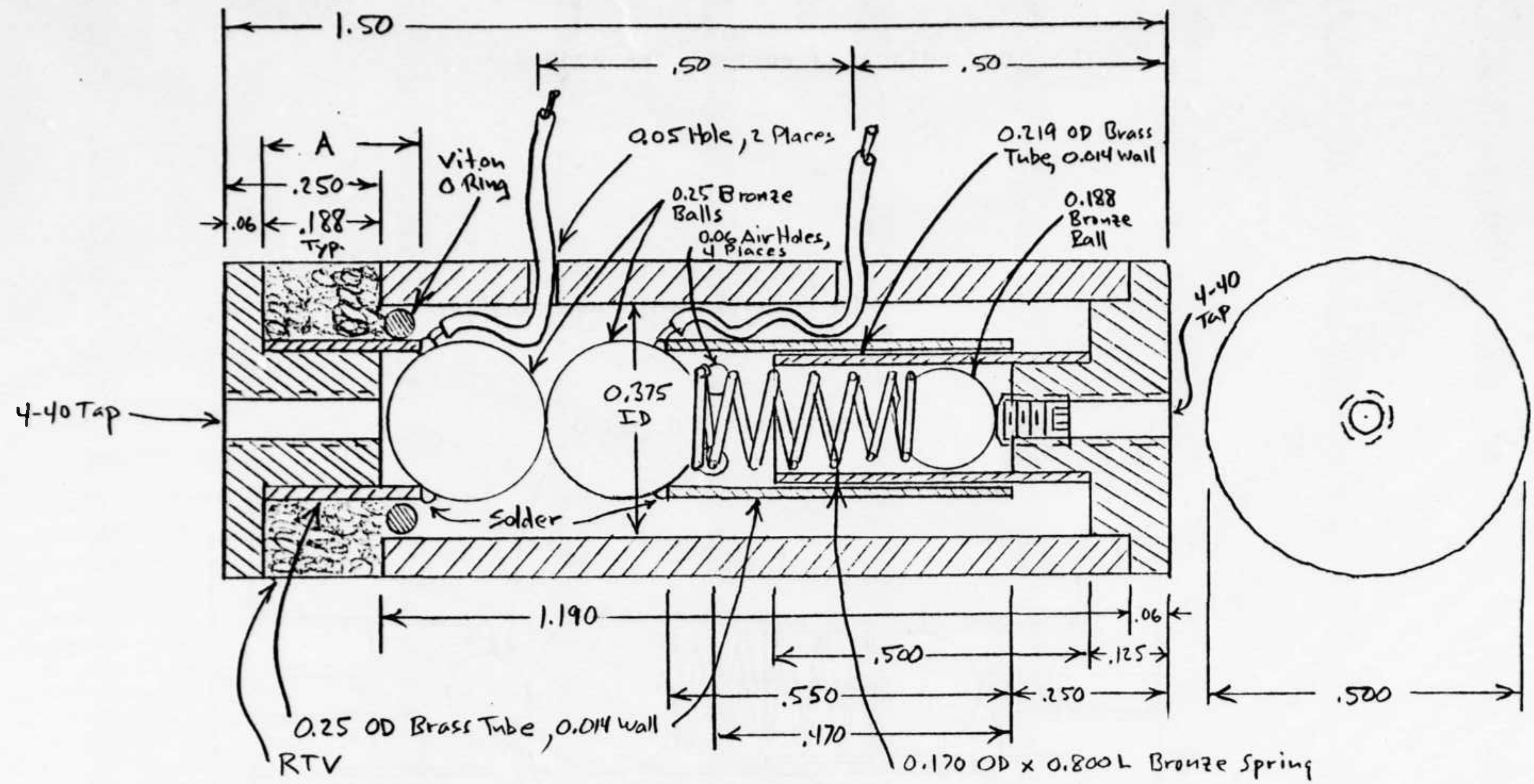
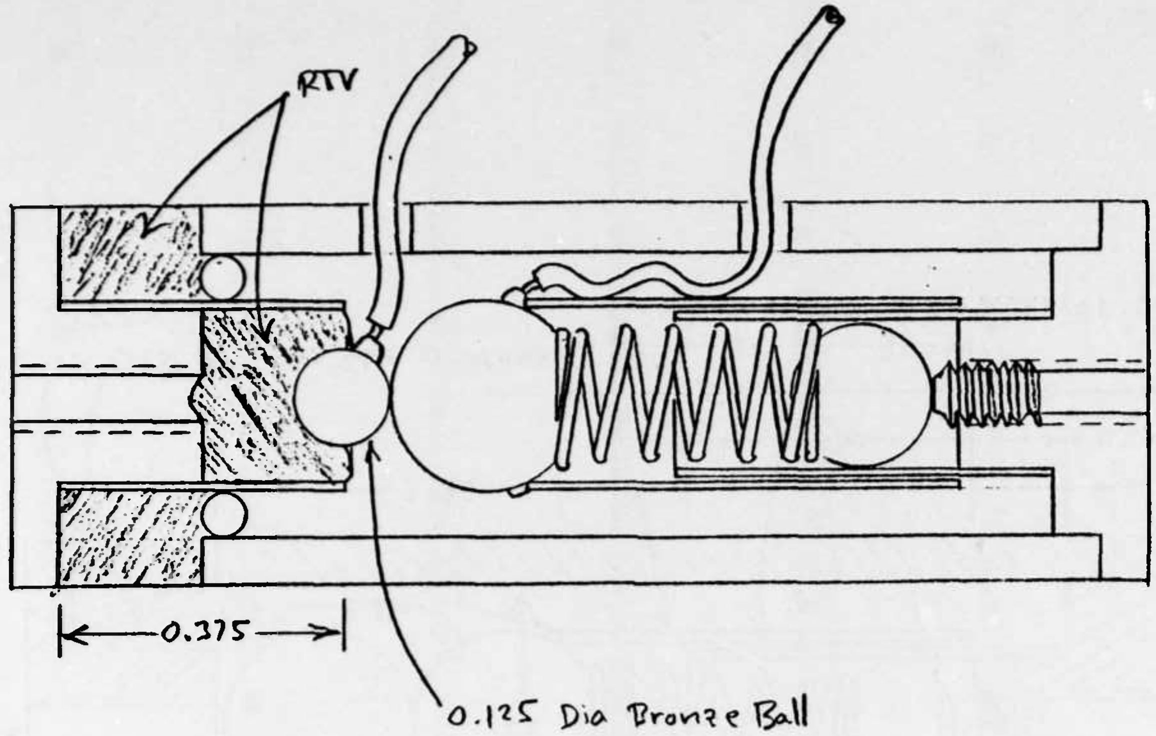
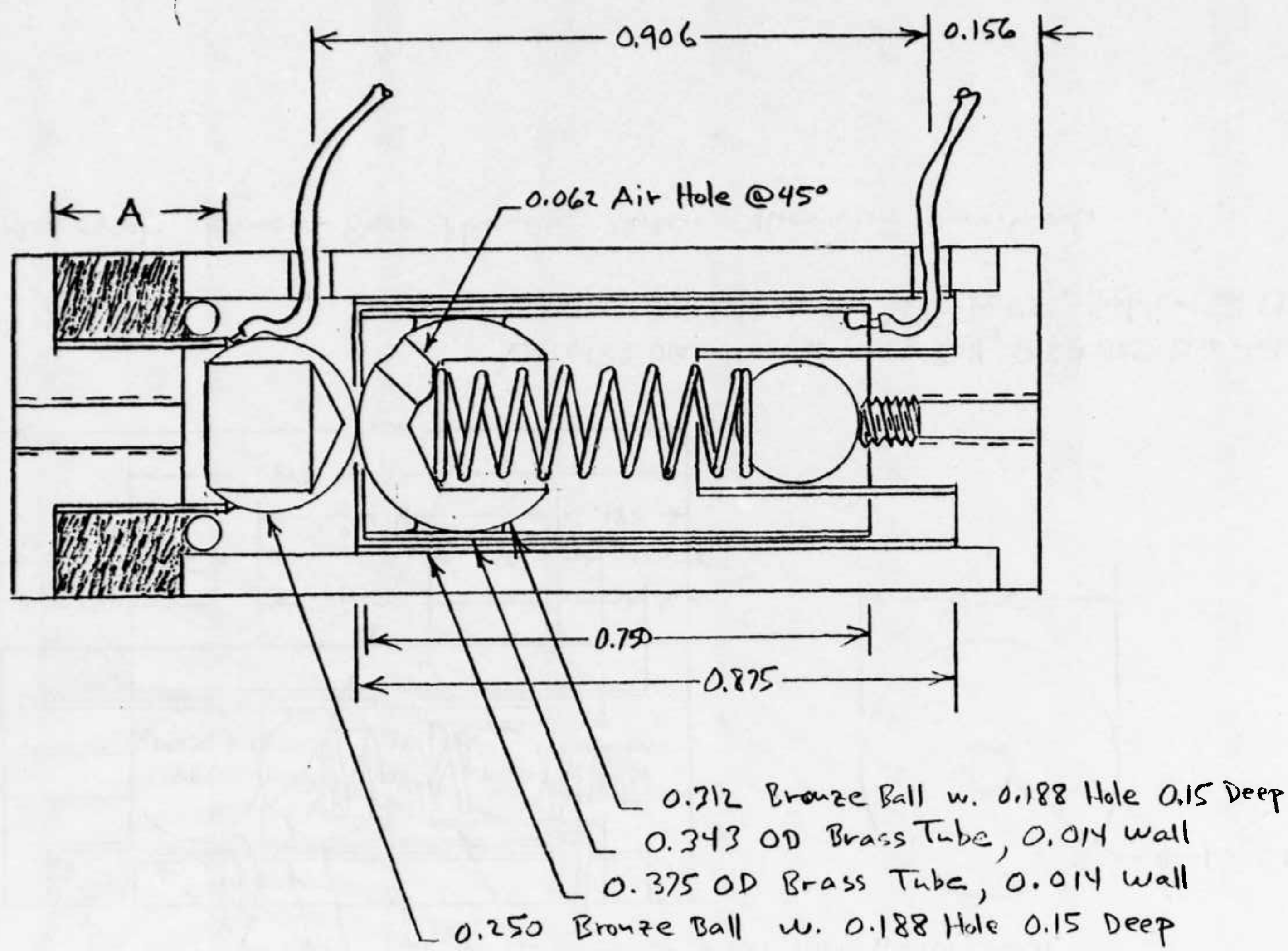


Figure 43. First Prototype SSS.



See First Prototype for dimensions, etc.

Figure 44. Second Prototype SSS.



See First Prototype for dimensions, etc.

Figure 45. Third Prototype SSS.

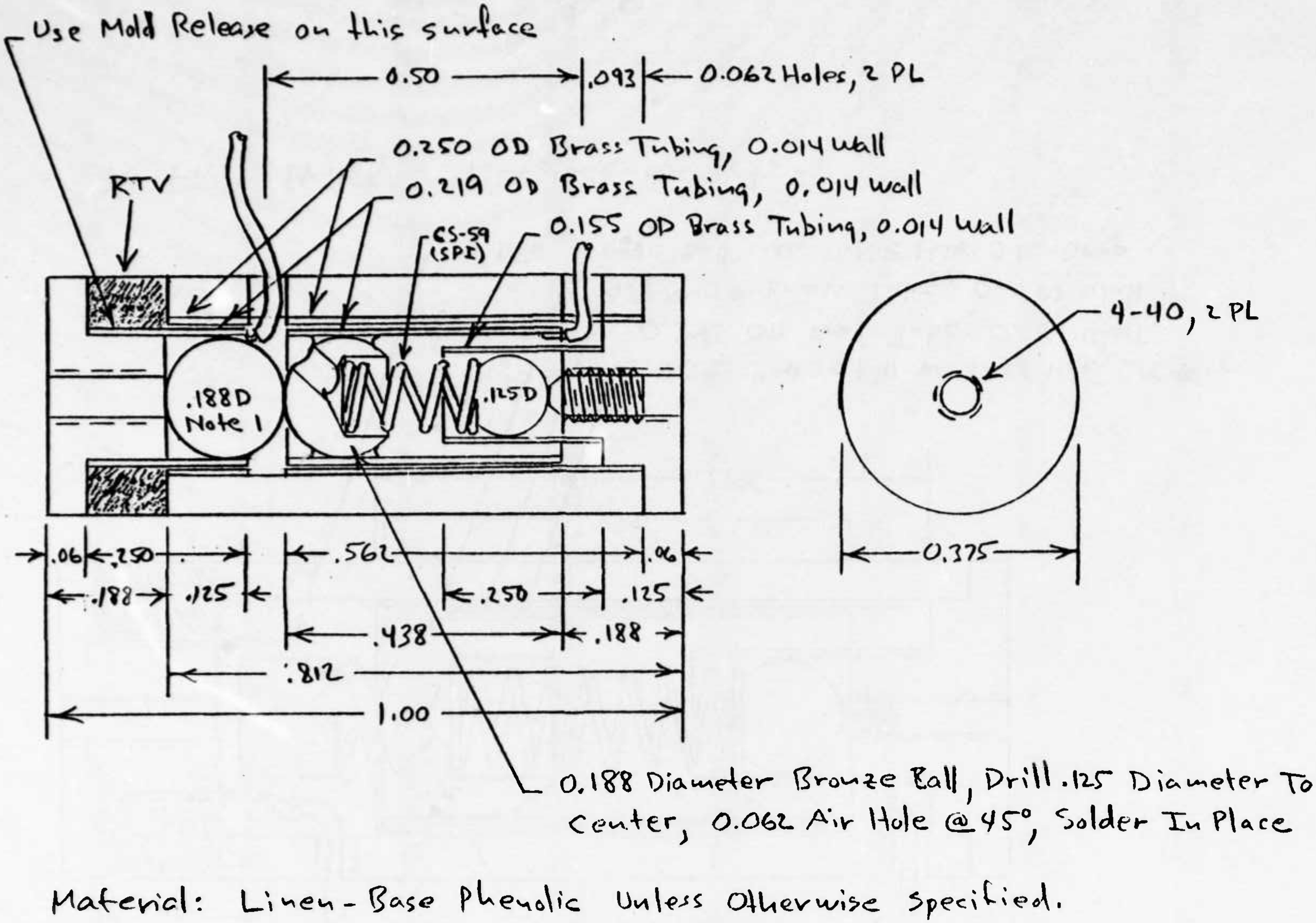


Figure 46. Fourth Prototype SSS.

springs of 0.008-inch diameter beryllium copper (Small Parts Incorporated type CS-59).

Two prototypes with floating cap contacts were built; S/N 11 and S/N 12. The necessary springs were the same as S/N9 and S/N 10.

Performance was equivalent to the larger prototypes.

5.2.5 Fifth Prototype

The Fifth Prototype SSS, shown in Figure 47, was a breakthrough in SSS design. It was essentially two SSS's back-to-back. The design prevented the undesirable alternate opening and closing of the contacts which occured in the earlier designs when the period of repeated stimuli was shorter than the contact reclosure time, and which has in the past required electronic integration of the output to correct.

The design had three contacts in series. The stimulus was applied to the center contact which, since the other two contacts were damped, caused an immediate contact opening no matter whether strain was applied or removed (bidirectional response). The contacts stayed open as long as an oscillatory stimulus existed. This is in marked contrast to the earlier designs where the contacts opened only on the removal of strain, and "chattered" in response to high-frequency stimuli. The effect is illustrated in Figure 48 where the signature of Figure 35 (inverted so that the removal of strain is in the upward direction in the photos) has been reproduced on the Test Stand described in Section 5.4.1 and applied to both a unidirectional SSS (S/N 8) and a bidirectional SSS (S/N 14). Note that where the unidirectional SSS produces only intermittent contact openings (lower trace in Figure 48a), the bidirectional SSS produces a continuous contact opening (lower trace in Figure 48b) for the entire duration of the stimulus. Having the contacts open solidly in response to high-frequency stimuli should greatly improve reliability of alarm in simple systems.

Four units of the 5th Prototype design were built. All used Small Parts Incorporated type CS-59 springs. S/N 13 had the usual phenolic body, plunger and cap while S/N 14 through S/N 16 switched to epoxy-fiberglass (G-10) so as to use a material that would be more resistant to fungus growth. Initially all used Dow-Corning type 200 damping fluid with a viscosity of 100,000 cs. Later, S/N 13 and S/N 16 were switched to General Electric VISCASIL with a viscosity of 600,000 cs to obtain longer contact reclosure times. S/N 15 and S/N 16 incorporated Viton O-rings between the center pin and the body to provide some input filtering (prototype design 5a).

5.2.6 Sixth Prototype Design

The Sixth Prototype SSS design is shown in Figure 49. Operation is basically the same as the Fifth Prototype except the

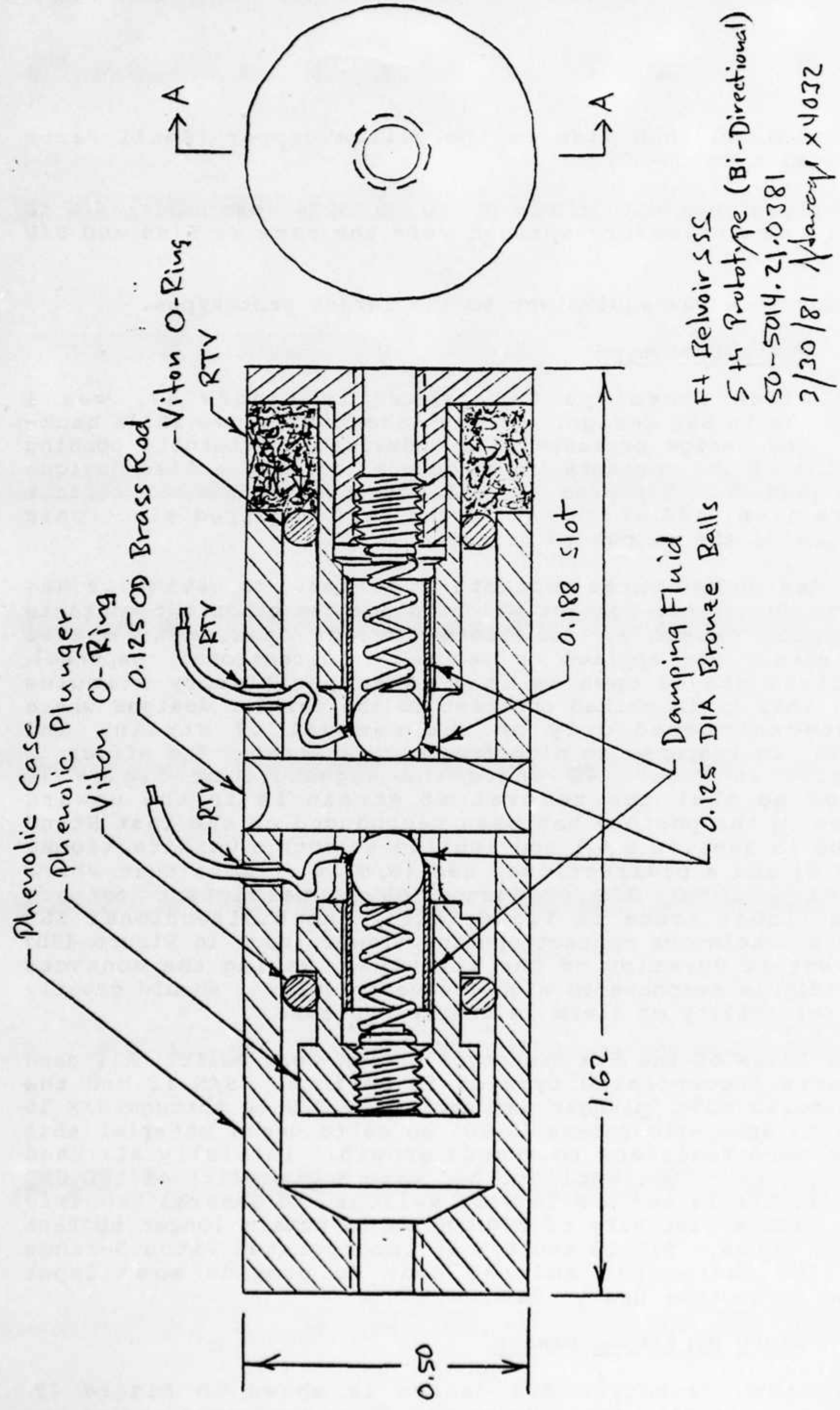
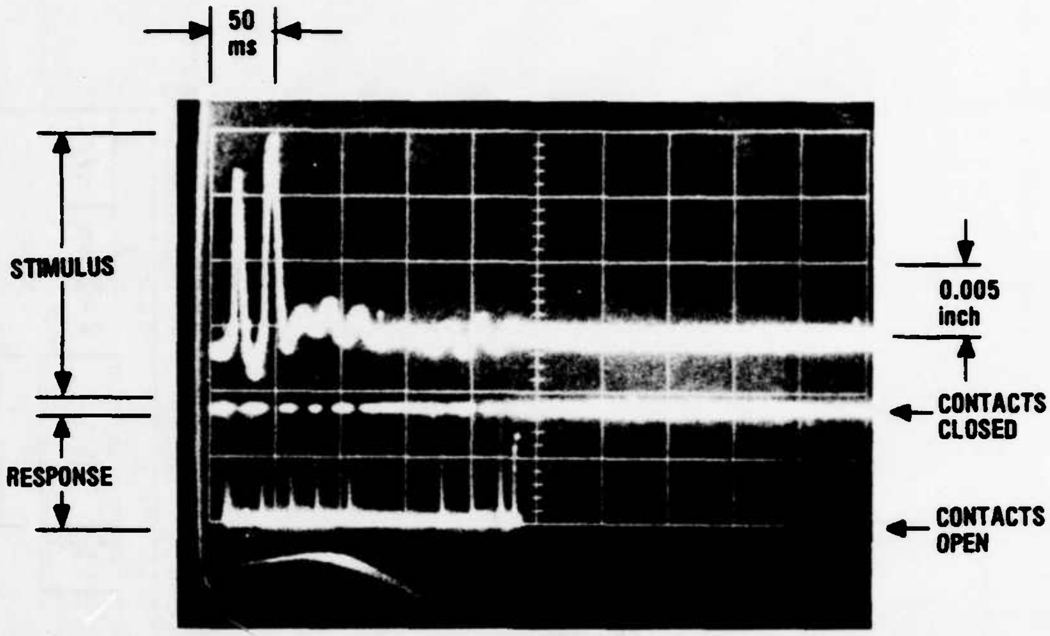
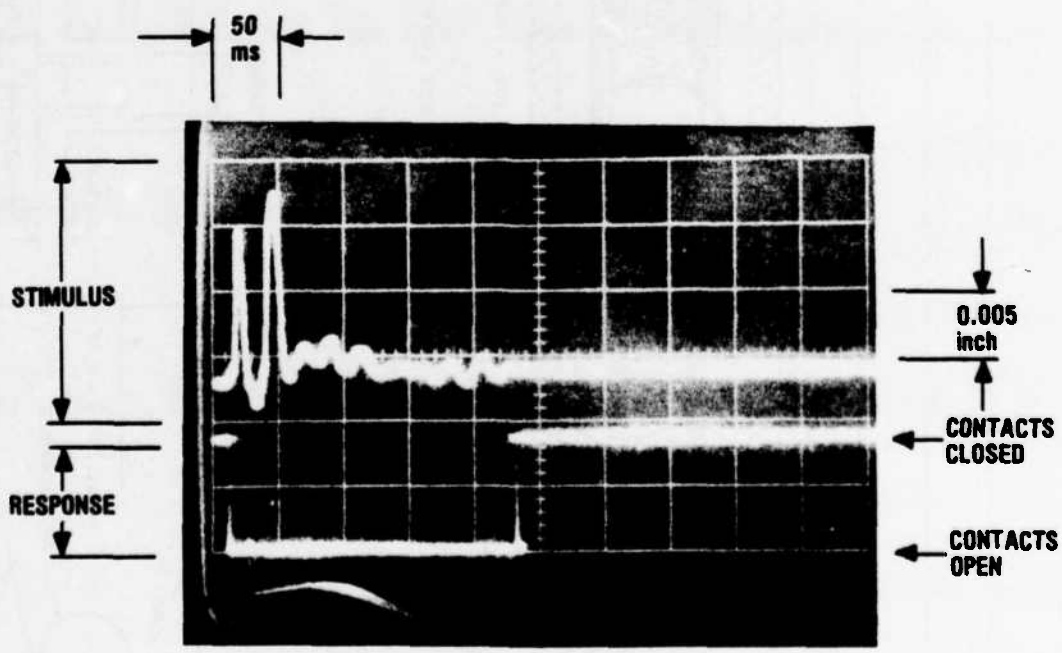


Figure 47. Fifth Prototype SSS.

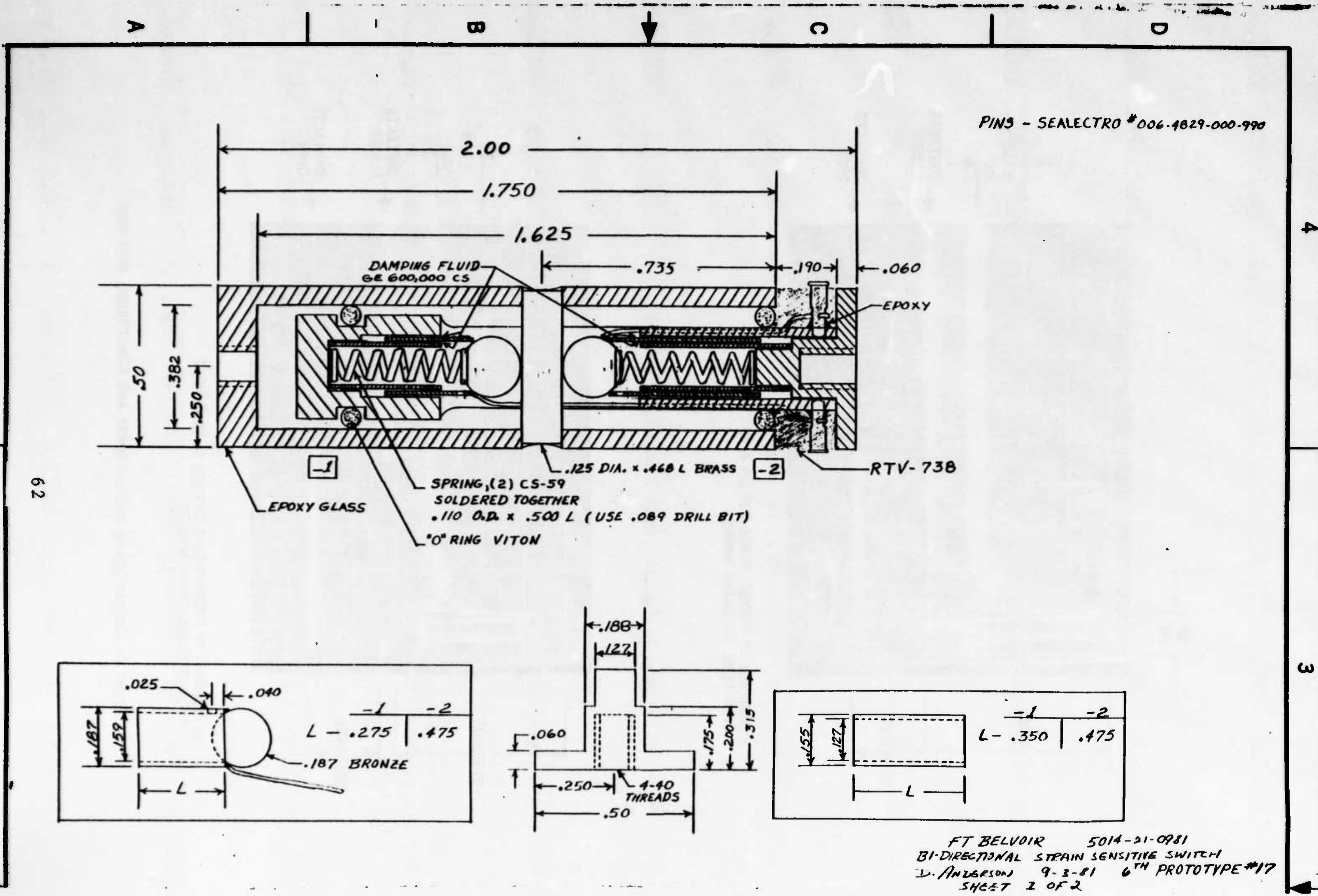


a) RESPONSE OF UNIDIRECTIONAL SSS S/N 8 TO CLOSING OF A STEEL CASEMENT WINDOW.



b) RESPONSE OF BIOIRECTIONAL SSS S/N 14 TO CLOSING OF A STEEL CASEMENT WINDOW.

FIGURE 48. COMPARISON OF UNIDIRECTIONAL AND BIDIRECTIONAL RESPONSE.



A
B
C
D
4
3
PINS - SEALECTRO #006-4829-000-990
2.00
1.750
1.625
.735
.190
.060
DAMPING FLUID
GE 600,000 CS
EPOXY
.50
.382
.250
-1
-2
.125 DIA. x .468 L BRASS
RTV-738
SPRING,(2) CS-59
SOLDERED TOGETHER
.110 O.D. x .500 L (USE .089 DRILL BIT)
EPOXY GLASS
"O" RING VITON
.025
.040
.187
.159
-1
-2
L - .275 | .475
.187 BRONZE
L
.188
.127
.060
.175
.200
.315
.250
4-40
THREADS
.50
.155
.127
-1
-2
L - .350 | .475
L
FT BELVOIR 5014-21-0981
BI-DIRECTIONAL STRAIN SENSITIVE SWITCH
D. ANDERSON 9-3-81 6TH PROTOTYPE #17
SHEET 2 OF 2

Figure 49.

contact damping is applied to both inner and outer plunger surfaces so as to increase the damping area and further lengthen the contact reclosure time.

Only S/N 17 was built to the Sixth Prototype design. Results were somewhat disappointing because it was difficult to obtain a close fit between the contact cylinders (brass) and the plunger walls (epoxy-fiberglass) with the result that contact reclosure times never reached expectations.

5.2.7 Seventh Prototype Design

It became apparent in the Sixth Prototype design that longer damping cylinders would be necessary if the order-of-magnitude increase in contact reclosure times that field testing showed to be desirable were to be attained. The Seventh Prototype design, shown in Figure 50, allowed increasing the length of the damping cylinders without significantly increasing the length of the case by arranging 5 cylinders in a coaxial assembly. At the same time, the flexible internal connecting wires, which were a potential source of reliability problems, were eliminated. Contact reclosure times of several seconds for 0.001-inch displacement were obtained with this design as compared to several tenths of seconds for previous designs.

S/N 18 exhibited non-linear behavior in that operation would be normal for small displacements but once some threshold displacement, still well below the 0.06-inch normal operating range, was exceeded, the contact reclosure time would go to several minutes. Analysis indicated that air, trapped in the spaces at the ends of the contact cylinders, was being driven out at larger displacements leaving only damping fluid in the spaces. Once the air cushion was gone, a step-function increase in contact reclosure time occurred. This effect was alleviated in S/N 19 through S/N 22 by drilling small vent holes into the spaces at the ends of the contact cylinders. The possibility of exploiting the air-free fluid displacement phenomena to obtain very long contact reclosure time (minutes or possibly hours) exists but has not been investigated under this contract.

5.2.8 Final SSS Design

The Seventh Prototype design was refined to create the Final Prototype SSS (Advanced Development Model) design shown in Figure 51. Overall length is adjustable from 2.0 to 3.0 inches. Overall diameter is 0.63 inch. Threaded inserts at each end accept 4-40 screws for mounting. Small connection sockets flush with the surfaces permit insertion of number 24 solid bare copper wire to make electrical connection. Redundant sockets are provided on two sides of the SSS. Lengths of the damping cylinders have been trimmed to provide equal damping areas for the two directions of actuation. Spring tension has been increased somewhat over that used in the seventh prototype design in order to increase contact pressure and reduce sensitivity to orientation. This results in somewhat less sensitivity and

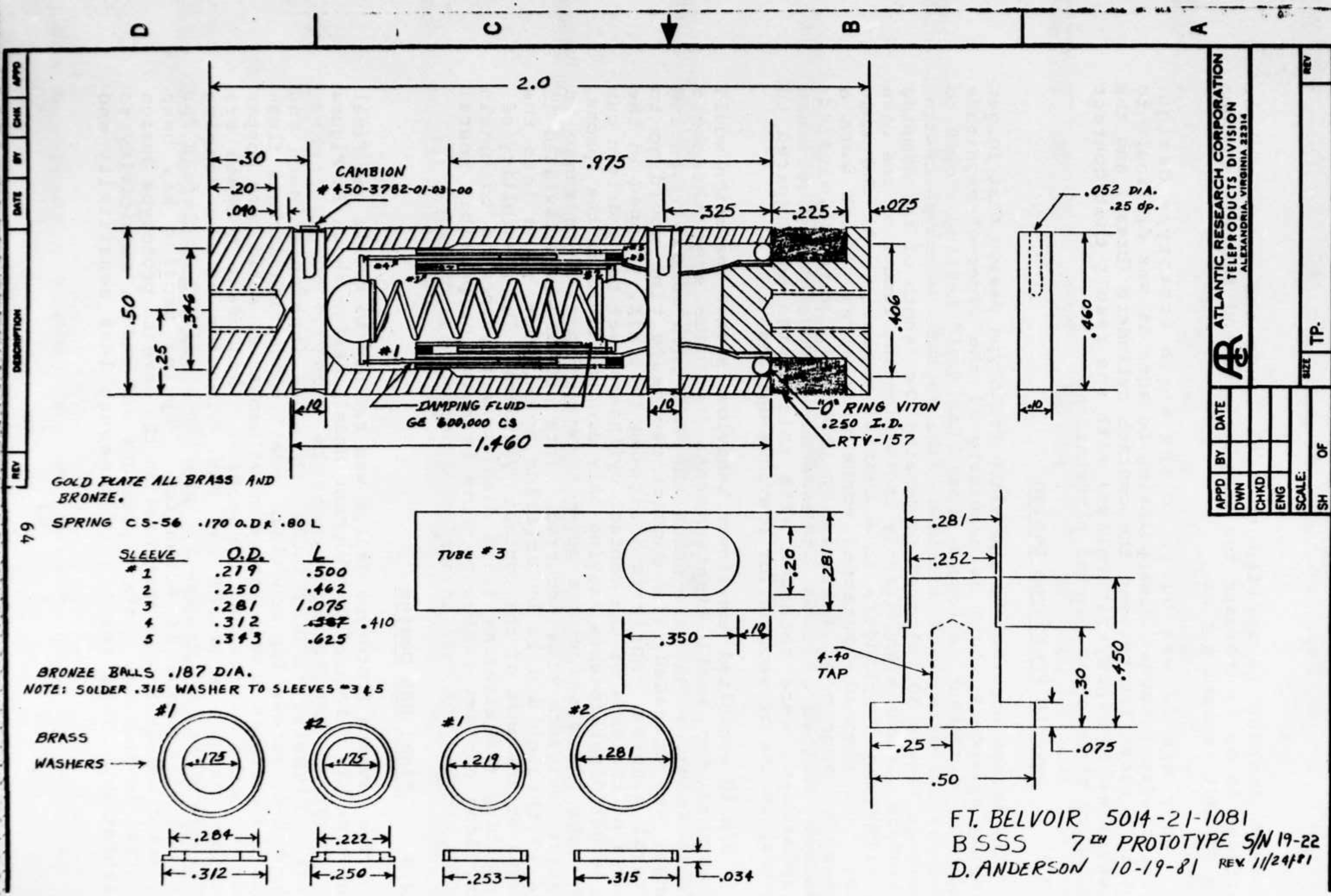

ATLANTIC RESEARCH CORPORATION
TELEPRODUCTS DIVISION
ALEXANDRIA, VIRGINIA 22314
APPD
DWN
CHKD
ENG
SCALE:
SH
OF
BY
DATE
SIZE
TP.
REV
DESCRIPTION
DATE
BY
CHK
APPD
2.0
.30
.20
.040
.975
.325
.225
.075
CAMBION
450-3782-01-03-00
.50
.346
.25
.406
.10
.10
1.460
DAMPING FLUID
GE 600,000 CS
#1
"O" RING VITON
.250 I.D.
RTV-157
.052 DIA.
.25 dp.
.460
.10
GOLD PLATE ALL BRASS AND BRONZE.
SPRING CS-56 .170 O.D. x .80 L
SLEEVE O.D. L
#1 .219 .500
2 .250 .462
3 .281 1.075
4 .312 .587 .410
5 .343 .625
TUBE #3
.20
.281
.350
.10
.281
.252
4-40
TAP
.30
.450
.25
.50
.075
BRONZE BALLS .187 DIA.
NOTE: SOLDER .315 WASHER TO SLEEVES #3 & 5
BRASS
WASHERS
#1
.175
.284
.312
#2
.175
.222
.250
#1
.219
.253
#2
.281
.315
.034
FT. BELVOIR 5014-21-1081
BSSS 7TH PROTOTYPE S/N 19-22
D. ANDERSON 10-19-81 REV. 11/24/81

Figure 50.

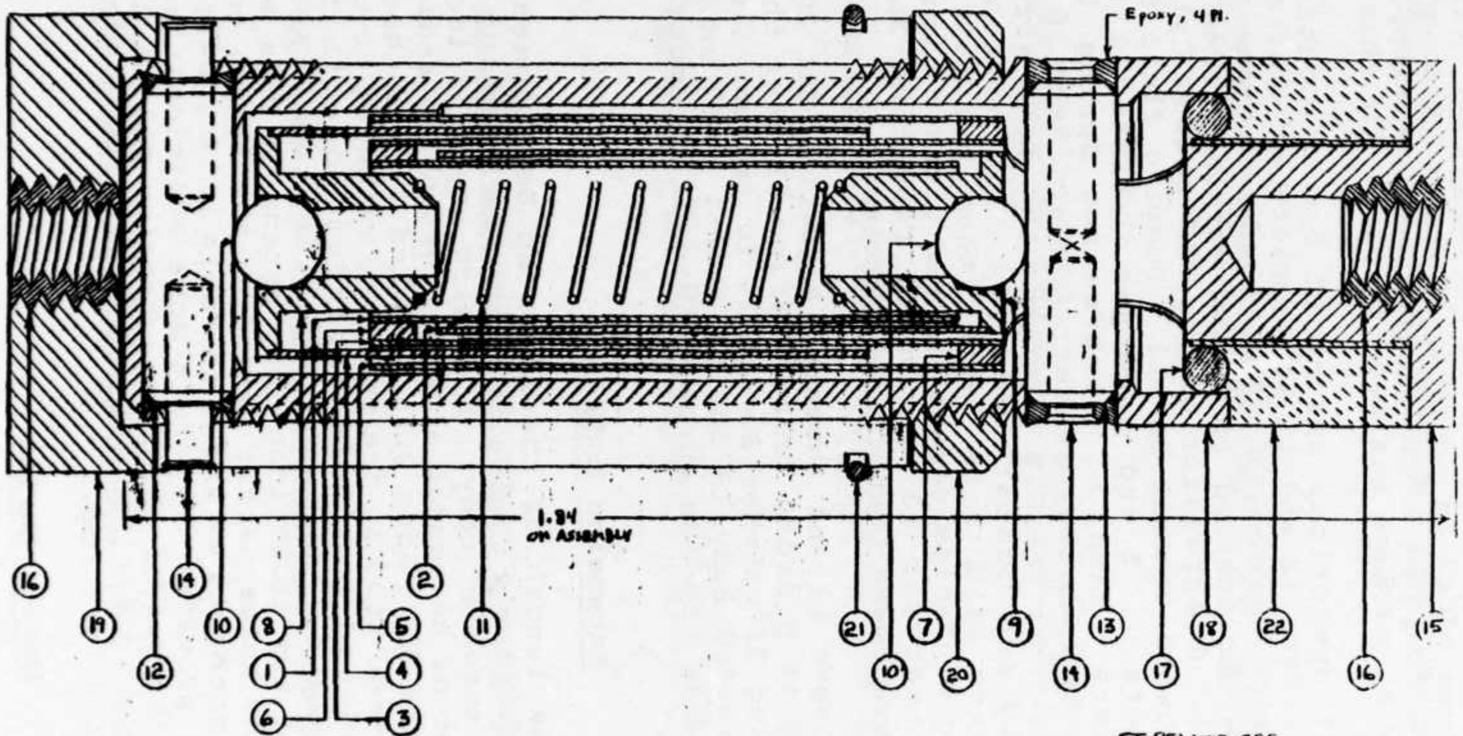

Epoxy, 4 PL.
1.84
ON ASSEMBLY
NOTE: Fill spaces between tubes with GE Viscasil 600,000 silicone fluid.
Gold plate all metal parts.
Joints between parts 1 through 10 and 13 through 19 to be soldered.
Joint between parts 3 and 15 to be epoxy.
Prime surfaces to be joined with RTV rubber using GE SS4044 Silicone Primer.
FT. BELVOIR SSS
FINAL BSSS
SD-5014.43
1/11/82 x4032

Figure 51.

contact reclosure time than was attained by the Seventh Prototype units but should increase reliability. Vent holes (not shown) have been added in parts 6, 7, 8, and 9 to permit flow of air and damping fluid at large deflections. A complete MIL-STD-100 level 1 drawing package has been prepared for this design.

In operation, Spring 11 forces Contact Balls 10 against Contact Bars 12 and 13 to complete an electrical circuit between Connection Sockets 14. The circuit remains closed as long as the SSS is undisturbed (constant strain between the surfaces of 15 and 19). Compression of the SSS causes Cylinders 1, 3 and 5 to move toward Contact Bar 12. Damping fluid (silicon oil) between Cylinders 1, 2 and 3 causes Cylinder 2 to move along with Cylinders 1 and 3., compressing Spring 11 and breaking the electrical contact between Contact Ball 10 and Contact Bar 13. Expansion of the SSS produces the same effect between Contact Ball 10 and Contact Bar 12. Alternating compression and expansion at a rate faster than the relaxation time of the damping mechanism causes an open circuit either at Contact Bar 12 or Contact Bar 13, or both, resulting in a continuous open circuit between Connection Sockets 14.

Sleeve 19 and threaded Adjusting Nut 20 permit lengthening the SSS to preload Rubber Spring 22 when the SSS is installed. Snap Ring 21 catches Socket 14 to prevent Sleeve 19 from sliding off threaded Body 18 during normal handling. Metallic threaded Inserts 16 provide durable threads in epoxy-fibeglass parts 15 and 19.

5.2.9 Extension Rods

The length of the Advanced Development Model SSS can be adjusted from 2 inches to 3 inches by turning a knurled thumb nut on the threaded body. Extension beyond 3 inches is accomplished by a set of hexagonal aluminum extension rods shown with the SSS in Figure 52. Rods 0.75, 1.5 and 2.25 inches long are provided with a 4-40 stud in one end for fastening to the top or bottom of the SSS and a 3/8-16 threaded hole in the other end for attachment of additional extension rods. Additional 2.25, 4.50, 9.00 and two 18.00 inch long extension rods with 3/8-16 threaded studs and holes permit extending the length to 57 inches in 0.75-inch increments as shown in Table 1. A 3/8-16 hex-head cap screw is also provided to permit some additional adjustment range, to fasten the end of the last extension rod to the intrusion target, or simply to fill the hole and provide a smooth surface at the end of the last rod.

5.3 Manufacturing

Assembly of the SSS's is done by hand with the aid of several special fixtures. The metal parts are first cleaned and gold plated for corosion resistance. The tubular parts are then slipped onto shaped aluminum mandrils mounted on interchangeable

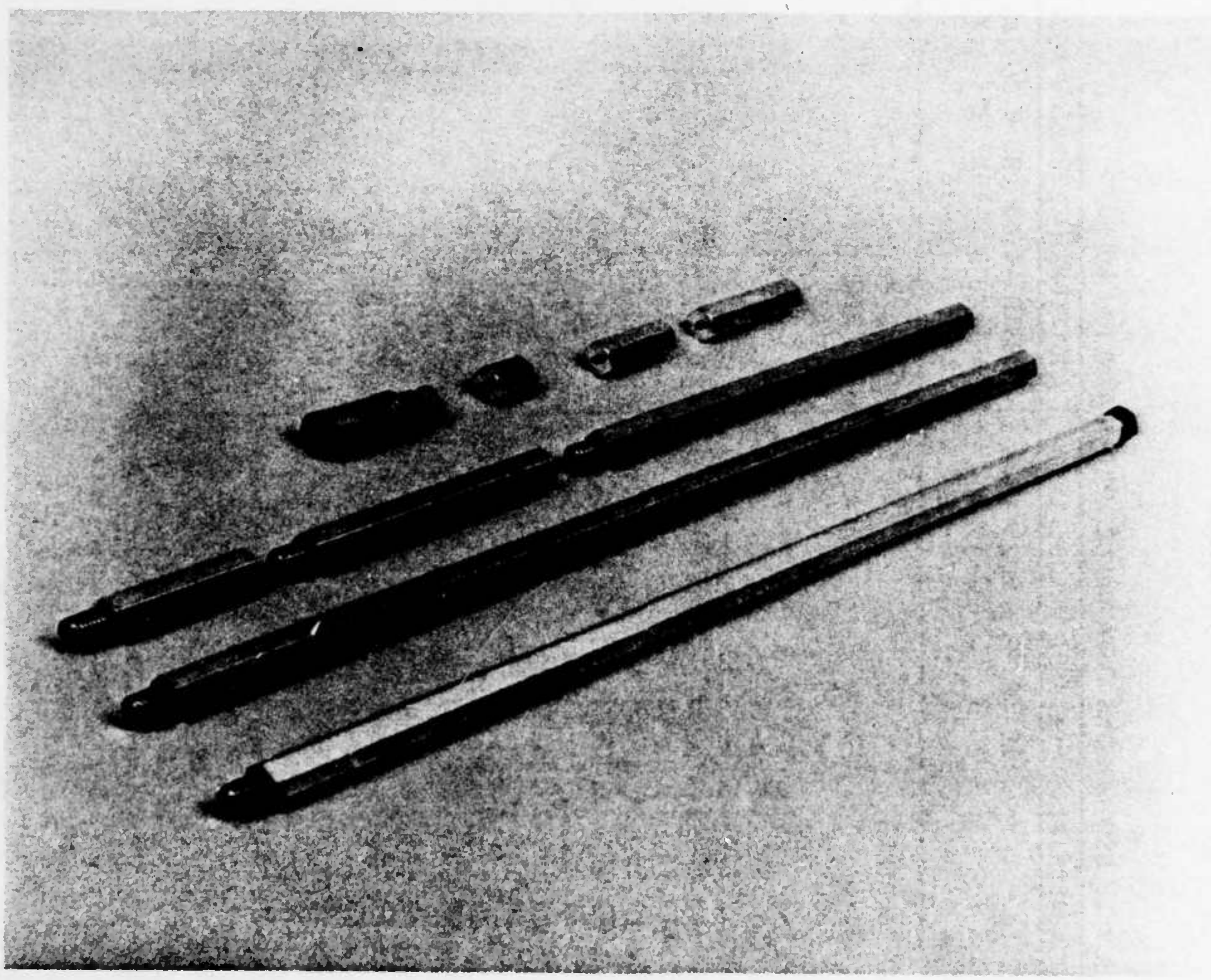


FIGURE 52. SSS WITH EXTENSION RODS.

TABLE 1. SSS LENGTHS OBTAINABLE WITH EXTENSION RODS

SSS LENGTH ADJUSTMENT RANGE, IN.	RANGE WITH FIRST EXTENSION ROD, IN.			ADDITIONAL EXTENSION RODS REQ'D			
	0.75 In. 4-40 X 3/8-16	1.50 IN. 4-40 X 3/8-16	2.25 IN. 4-40 X 3/8-16	2.25 IN. 3/8-16X 3/8-16	4.50 IN. 3/8-16X 3/8-16	9.00 IN. 3/8-16X 3/8-16	18.00 IN 3/8-16X 3/8-16
2.00-3.00	NONE REQUIRED			NONE REQUIRED			
2.75-5.25	2.75-3.75	3.50-4.50	4.25-5.25	NONE REQUIRED			
5.00-7.50	5.00-6.00	5.75-6.75	6.50-7.50	1			
7.25-9.75	7.25-8.25	8.00-9.00	8.75-9.75		1		
9.50-12.00	9.50-10.50	10.25-11.25	11.00-12.00	1	1		
11.75-14.25	11.75-12.75	12.50-13.50	13.25-14.25			1	
14.00-16.50	14.00-15.00	14.75-15.75	15.50-16.50	1		1	
16.25-18.75	16.25-17.25	17.00-18.00	17.75-18.75		1	1	
18.50-21.00	18.50-19.50	19.25-20.25	20.00-21.00	1	1	1	
20.75-23.25	20.75-21.75	21.50-22.50	22.25-23.25				1
23.00-25.50	23.00-24.00	23.75-24.75	24.50-25.50	1			1
25.25-27.75	25.25-26.25	26.00-27.00	26.75-27.75		1		1
27.50-30.00	27.50-28.50	28.25-29.25	29.00-30.00	1	1		1
29.75-32.25	29.75-30.75	30.50-31.50	31.25-32.25			1	1
32.00-34.50	32.00-33.00	32.75-33.75	33.50-34.50	1		1	1
34.25-36.75	34.25-35.25	35.00-36.00	35.75-36.75		1	1	1
36.50-39.00	36.50-37.50	37.25-38.25	38.00-39.00	1	1	1	1
38.75-40.25	38.75-39.75	39.50-40.50	40.25-41.25				2
41.00-43.50	41.00-42.00	41.75-42.75	42.50-43.50	1			2
43.25-45.75	43.25-44.25	44.00-45.00	44.75-45.75		1		2
45.50-48.00	45.50-46.50	46.25-47.25	47.00-48.00	1	1		2
47.75-50.25	47.75-48.75	48.50-49.50	49.25-50.25			1	2
50.00-52.50	50.00-51.00	50.75-51.75	51.50-52.50	1		1	2
52.25-54.75	52.25-53.25	53.00-54.00	53.75-54.75		1	1	2
54.50-57.00	54.50-55.50	55.25-56.25	56.00-57.00	1	1	1	2

tips for a Weller W-TCP-L thermostatically-controlled soldering station. The contact spheres are placed on/in the tubes, heated and soldered in place. The soldered asemblies are then cleaned, gold plated, and assembled to the phenolic parts with Dexter 907 epoxy cement. The parts are again cleaned, the contacts and damping tubes coated with damping fluid, and everything mounted in the Assembly Fixture shown, together with a completed SSS and a set of SSS parts, in Figure 53. The fixture is geared to allow the cap and body subassemblies to be turned in synchronism as the gap between is filled with thixotropic elastomer. The elastomer is allowed to cure, after which the assembled SSS is removed from the fixture. The threads in the fixture are of the same pitch as the mounting threads (40 threads per inch) for the SSS so that the SSS is not stretched or compressed as the arbor is removed.

5.4 Testing

Final prototype testing is the subject of a separate Prototype Test Plan, Data Item A009. Preliminary testing was peformed on the various prototype designs to narrow the field to a single Final Prototype SSS before final prototype testing began.

5.4.1 Bench Test System

A Bench Test System for the SSS was assembled as shown in Figure 54. The central feature of this system is the Bench Test Stand. At the bottom of the stand is a 50-pound-force electrodynamic shake table for applying stress or strain to the SSS. An SSS under test is shown mounted between two 0.375-inch diameter vertical rods which connect the shake-table armature to a 100-pound-force load cell at the top of the stand for measuring stress. The rods enter and exit the plexiglass environmental enclosure through neoprene rubber diaphragms which do not significantly load the rods. Environmentally controlled air from a bench-top test chamber was circulated through the environmental enclosure via 4" hoses which enter the rear of the enclosure. A temperature probe was mounted in the enclosure face plate to monitor actual enclosure temperature. A displacement transducer (linear variable differential transformer) for monitoring strain over the range of ± 0.5 inch is just visible on the rear of the enclosure at the bottom, center. The displacement transducer connects directly to the shake-table armature.

In a typical test setup using the Bench Test Stand, as shown in Figure 54, leads from the SSS under test, which are almost invisible in the picture, connect via clip leads to a power supply (behind the oscilloscope) for excitation and an oscilloscope for monitoring contact performance. Channel 2 of the oscilloscope is used to monitor either stress (force) or strain (displacement) for correlation with the contact waveforms. From left to right, starting with the Tektronix 454 oscilloscope, are an Alinco 518 amplifier which outputs 1.0 volt per pound of

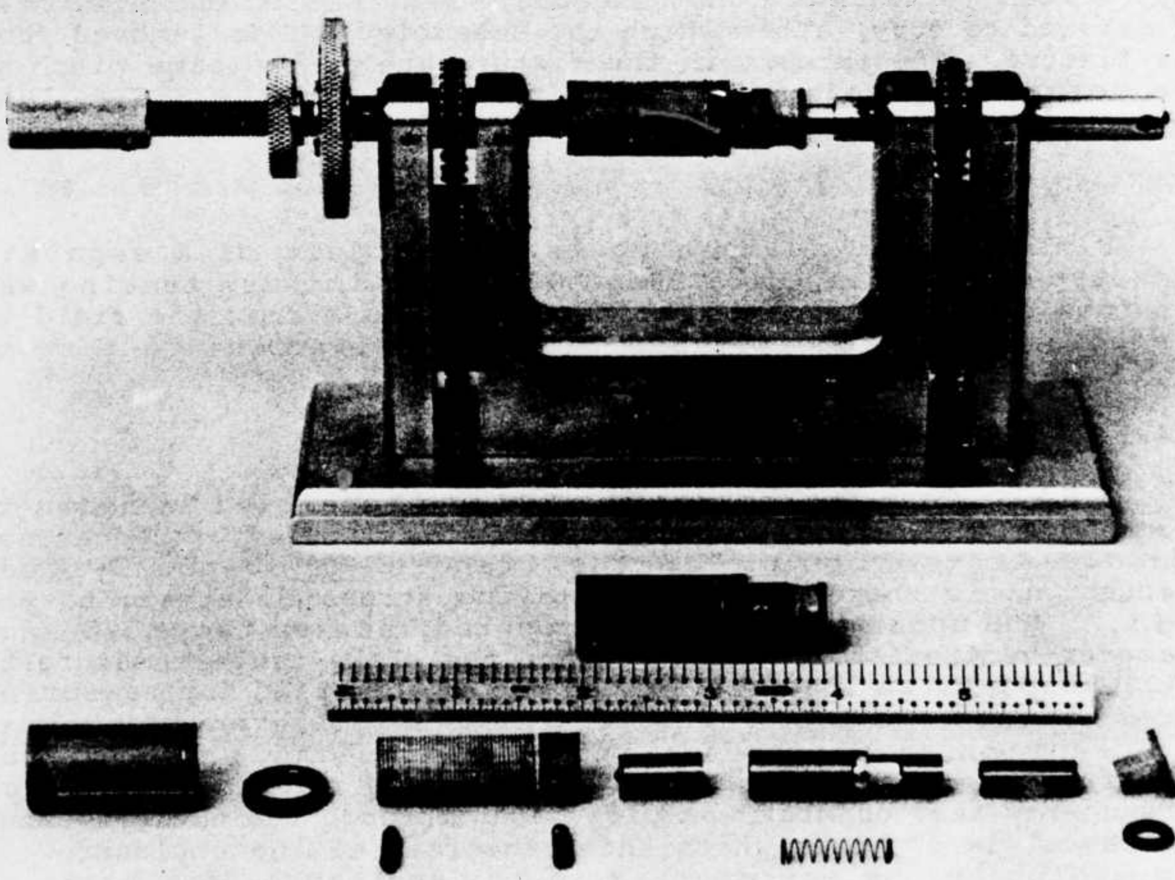


FIGURE 53. SSS ASSEMBLY FIXTURE.

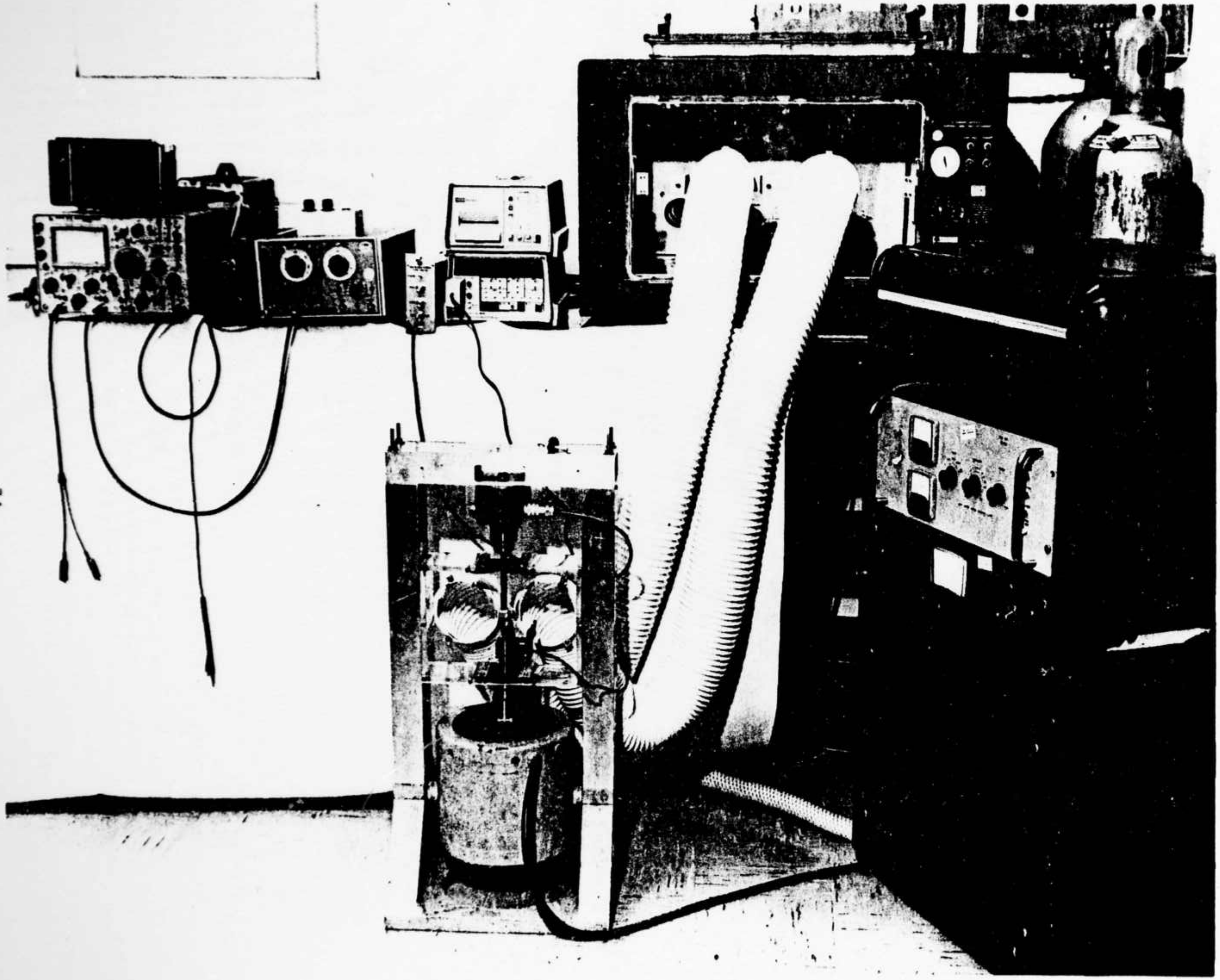


Figure 54. Bench Test System.

force on the load cell, a Krohn-Hite 3202 high-pass/low-pass filter for a quick determination of frequency content, a Schaevitz CAS signal conditioner which outputs 10 volts for 0.1 inch of displacement of the displacement transducer, a Fluke 80T-150 temperature probe with digital voltmeter and strip printer, a Delta Designs Standard-Series test chamber and, on the far right, an ADI N-100 power sine-wave oscillator and dc power supply for driving the shake table. Bottles of CO_2 for low-temperature tests appear to the right of the test chamber. A dc amplifier (not shown) using positional feedback from the Schaevitz CAS permitted driving the test stand with low-level signals from a function generator (sine, square, sawtooth or triangular waves down to 10^{-6} Hz) or a toggle switch (slow step). The test stand frequency response with positional feedback, in terms of a Shake Table Correction Factor to be used to obtain the drive voltage needed for a given deflection at frequencies other than 10 Hz, is shown in Figure 55. This test setup, with some variations for specific tests, was used for all of the bench and most environmental tests, both developmental and final.

5.4.2 Contact Reclosure Time VS Strain Testing

The time required for the SSS contacts to reclose after application of a step change in strain (contact reclosure time) is a useful and comparatively easily obtained measure of SSS performance. Sensitivity can be defined as the smallest step size that will cause an opening of the contacts long enough to be recognized as an alarm condition. (For the Facility Intrusion Detection System or FIDS, a contact opening of at least 250 ms is required.) Low-frequency response can be inferred from the contact reclosure time for a known step size. (For a strain that is applied at a rate slower than the step size divided by the contact reclosure time the contacts will never open.) Finally, various quality control problems such as erratic contact closure, assymetry of contact reclosure times between application and removal of strain and binding of the sliding parts can be easily observed during a contact reclosure time versus strain test.

A contact reclosure time test was run on all SSS's immediately after assembly. The results are tabulated by serial number (essentially chronologically) in Table 2. In its simplest form, the test is performed by simply squeezing the SSS until it bottoms and quickly releasing it while observing the length of time (approximately 2 minutes for the final (F) Advanced Development Model) the contacts remain open as indicated by an ohmmeter or lamp. This results in the entries under Step Deflection, Max in the table.

More elaborate testing was done on the Bench Test Stand using calibrated steps generated with either a de-bounced toggle switch or a function generator. The smallest step deflection at which any SSS has given reliable contact opening is 0.1 mil (0.0001 inch). The data generally run from this threshold deflection up to 60 mils (0.06 inch), which is the maximum rated strain.

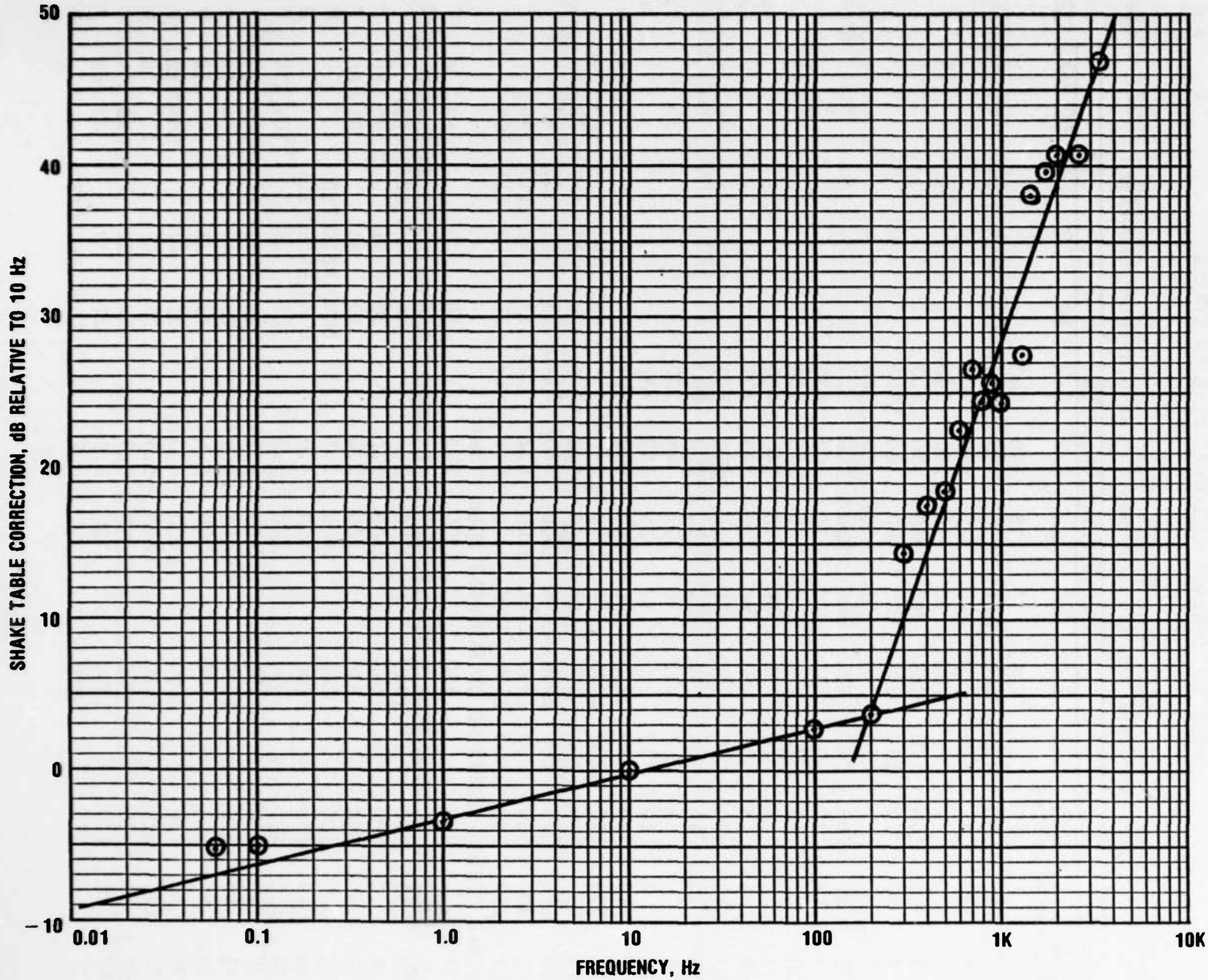


FIGURE 55. SHAKE TABLE CORRECTION FACTOR.

TABLE 2. CONTACT RECLOSURE TIME VS STRAIN

INITIAL DEFLECTION 0.002 INCH
VALUES IN TABLE ARE MILLISECONDS UNLESS OTHERWISE INDICATED

SSS	STEP DEFLECTION, MILS													
S/N	0.1	0.2	0.4	0.6	0.8	1.0	2.0	5.0	10	20	40	60	MAX.	TYPE
PROTOTYPE SSS's:														
1	7	13	25	35	50	75	130	340						1
2	40	60	100	150	180	230	430	1100						1
3	20	42	110	200	240	320	680	1700						2
4				20	35	70	160	500						2
5	60	100	170	260	300	350	650	1500						3
6	40	70	130	230	300	400	760	1900						3
7			20	60	120	170	320	560						3
8	50	100	250	450	620	850	1700							3
9	13	25	52	75	100	130	300	620						4
10	25	45	75	110	140	180	370	800						4
11		3	16	35	50	70	140	420						4a
12	5	15	35	60	80	110	190	520						4a
13	10	20	60	85	120	160	320	870						5
14	10	25	55	80	110	160	300	800						5
15		4	8	11	16	22	46	120						5a
16	2	10	23	45	62	85	160	450						5a
17	40	80	180	250	350	500	1000	2700						6
18	500	750	1200	1600	2100	2700	SECONDS							6
19	120	230	550	800	1200	1500	3.0	7.3	14	27	49	72		7
20	180	370	800	1450	1800	2300	5.0	14	28	56	360			7
21	300	550	1000	1800	2400	3200	6.2	10	23	48	110	540		7
22	250	700	1400	2400	3300	4300	8.3	19	37	70	117	204		7
FINAL DESIGN (ADVANCED DEVELOPMENT MODEL) SSS's:														
23		80		700		1200	2.5		16	32		62	90	F
24	REJECTED (COMPRESSION CONTACTS SHORTED BECAUSE CAP ROTATED ON ASSEMBLY)													F
25	50	100		1400		2100	5.0		36	LONG (REJECTED)				F
26		100		700		1400	2.7		20	36		90	100	F
27	50	100		620		1100	2.4		19	43		81	100	F
28		100		800		1600	2.7		LONG (REJECTED)					F
29	40	150		1000		1500	4.0		LONG (REJECTED)					F
30	30	130		900		1600	3.5		17	37		106	130	F
31	40	200		1000		1800	3.5		22	37		109	112	F
32	40	300		1100		1900	4.0		22	45		94	123	F
33	40	200		900		1700	3.5		18	38		95	112	F
34	50	250		1400		2000	4.0		22	47		LONG (REJ.)		F
35	100	370		1600		2800	6.5		28	48		117	138	F
36	60	220		800		1400	3.0		17	32		80	104	F
37	80	250		1000		1700	4.0		22	39		67	89	F
38		250		1000		1700	3.7		LONG (REJECTED)					F

Early results (low serial numbers) reflect the initial design assumption carried over from past work that a 100 millisecond contact reclosure time for 1 mil deflection was desirable. Starting with S/N 17, efforts were made to increase the contact reclosure time to the maximum attainable within the case size limitations so as to increase the sensitivity to slow intrusions. From S/N 18 on, contact reclosure times are over one second for 1 mil displacement.

Some problems at large deflection show up in the table. serial numbers 20 and 21 show excessive increases in contact reclosure time above some threshold deflection. This is usually due to trapped damping fluid at the ends of the cylinders as explained in Section 5.2.7. While internal vent holes have been added to alleviate the problem, it still shows up in some SSS's, particularly on the first few large deflections after assembly. Serial numbers 25, 28, 29, 34 and 38 all stuck open temporarily at large deflections because of inadequate internal clearances (a fail-safe condition) and were rejected. Serial number 24 was rejected because it was found to have unidirectional response (contacts opened only on release of strain), which indicated that the upper contact pair was short circuited. The problem was traced to improper rotational alignment of the cap and armature with the body during assembly, which allowed the armature to rub against the upper contact bar.

5.4.3 Frequency Response

Application of progressively increasing sinusoidal deflections to the SSS first produce occasional momentary contact openings near the zero crossings of the sine wave where the slope (velocity) is greatest. Increasing the amplitude causes the contact openings to spread out from the zero crossings toward the peaks of the sine wave until they meet and the contacts remain open continuously. These effects are shown in Figure 56, where one curve has been plotted through the deflections at which the first contact openings occurred, and a second curve through the deflections at which contact opening first becomes continuous. The first contact openings typically start to show up at a peak-to-peak sine wave deflection -20 dB (one tenth) below 0.001 inch (1 mil), or at 0.0001 inch. By the time deflection has increased another 10 dB (by approximately 3 times), the contacts will typically open continuously.

Using the response at 10 Hz as reference, first opening response is down by 3 dB (the input strain power must be doubled) at 1.0 Hz and 6 dB (the input strain deflection must be doubled) at 0.7 Hz. Continuous opening response is down 3 dB at 3 Hz and 6 dB at 1.5 Hz. In many of the signature spectrums of Section 4.3.3, signature deflection is down more than 6 dB at 0.37 Hz. This indicates that even more low-frequency response is desirable.

High-frequency data is limited by the test stand, which is difficult to drive above 1 kHz.

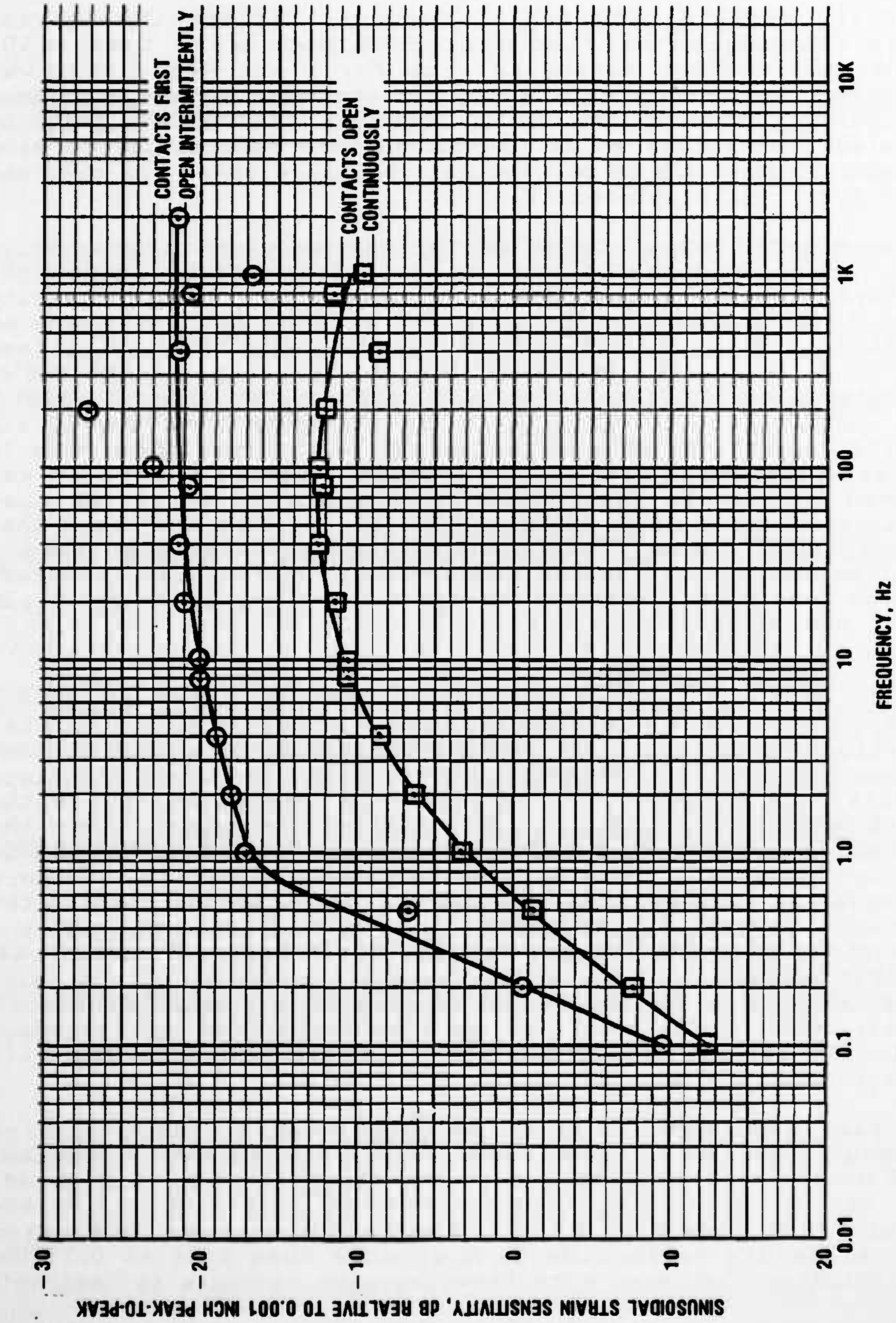


FIGURE 56. SINUSOIDAL STRAIN SENSITIVITY FOR SSS S/N 029.

5.4.4 Temperature Tests

The contact reclosure time was measured as a function of temperature on SSS serial numbers 8 and 14. The data are plotted in Figures 57 and 58. The contact reclosure time is shortened by less than a factor of two for a given deflection as temperature is increased from 24° (room temperature) to 66°. Dropping from room temperature to -40° increases the contact reclosure time by approximately a factor of 6.

5.4.5 Operating Current Tests

Normal SSS testing was done with a one-megohm load (oscilloscope) and 5 to 8 volts on the contacts. No contact problems traceable to the current levels used were encountered under these conditions. Similar results were obtained operating for 8 hours with 24 volts on the contacts and a number 1820 pilot lamp, which draws nominally 0.1 ampere, as load. Increasing the voltage to 40 volts and the current to 0.6 ampere with a 66 ohm resistive load pitted the contacts and caused erratic operation after a few minutes of repeated actuation.

Operation of the SSS should be limited to "signal level" service with a nominal contact rating of 24 volts at 0.1 ampere drawn by a resistive (or lamp) load.

5.4.6 Humidity Tests

A MIL-STD-810C humidity test, method 507.1. Procedure IV was run on two advanced development model SSSs, S/N 26 and S/N 27. Operation was normal both during and after the test.

5.4.7 Fungus Tests

A MIL-STD-810C fungus test, method 508.1, Procedure I, was run on two advanced development model SSSs, S/N 23 and S/N 30. No growth on the outside surfaces of the test samples occurred. Operation was normal after the test.

6.0 Conclusions

In the area of intrusion targets to which the SSS can be applied, of data analyzed to date indicates that there are a great many targets in which the strain signatures due to intrusion are mechanically distinguishable from noise. Even targets which from outward appearances are extremely solid can exhibit significant strains which make them candidates for application of the SSS.

In the area of designing an SSS to be sensitive to strain signatures resulting from intrusion, sensitivities to one-time steps as small as 0.1 mil can be achieved with the SSS alone. Both higher and lower sensitivities can be attained using external levers to obtain mechanical advantage. High-frequency response can extend to at least 2000 Hz. Low-frequency response

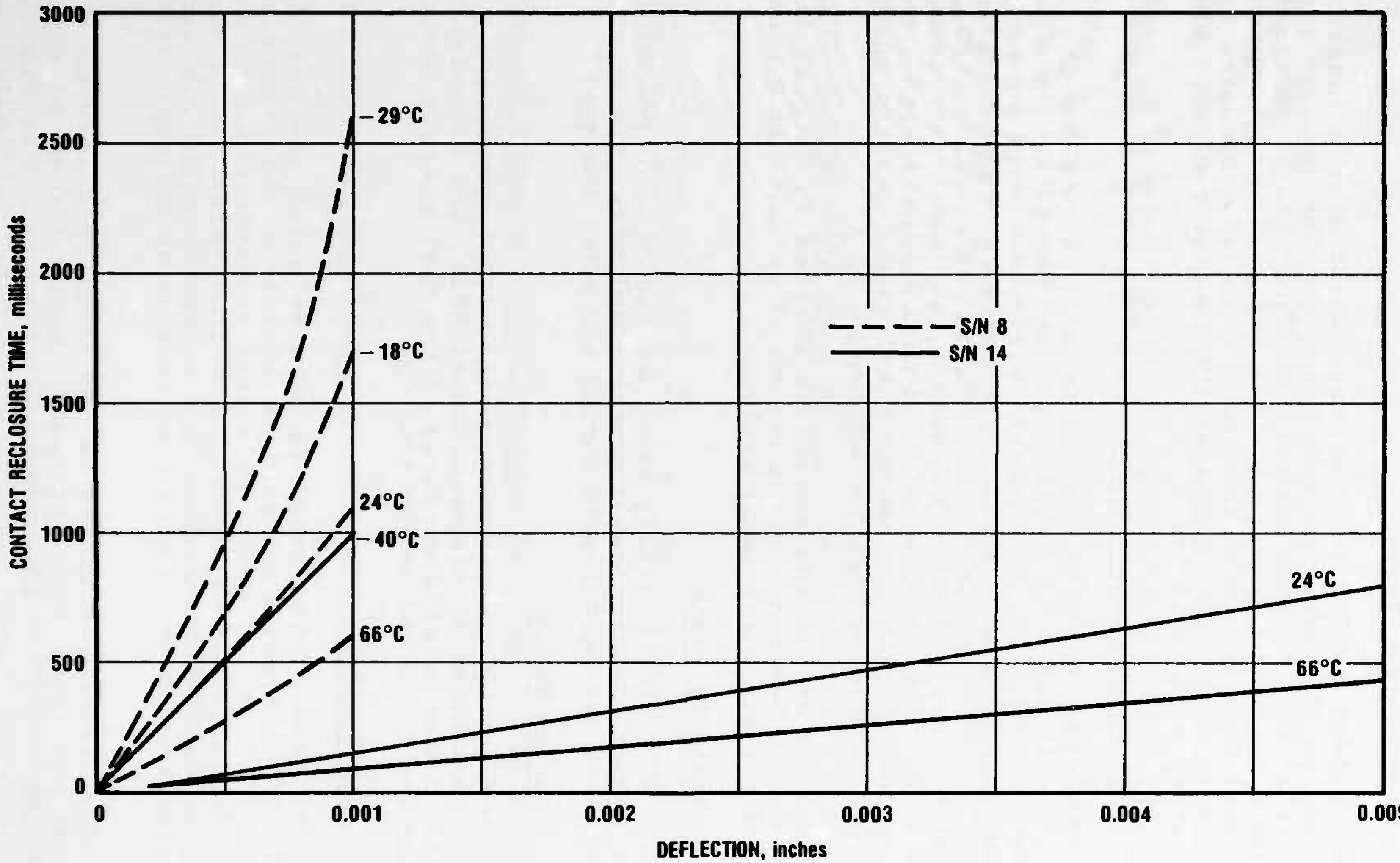


FIGURE 57. EFFECT OF TEMPERATURE ON CONTACT RECLOSURE TIME AT VARIOUS DEFLECTIONS.

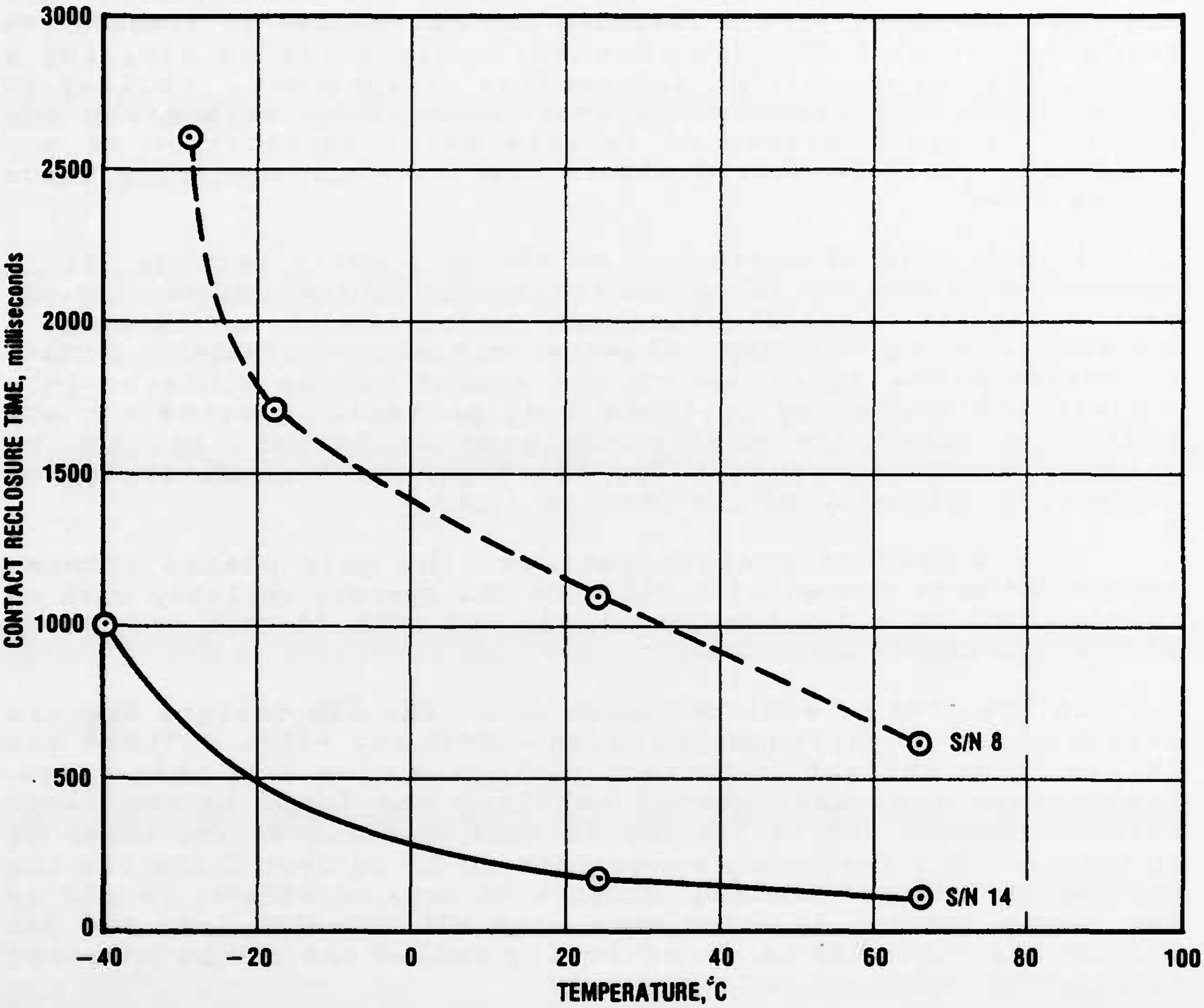


FIGURE 58. EFFECT OF TEMPERATURE ON CONTACT RECLOSURE TIME AT 0.001-INCH DEFLECTION.

down to 1 Hz (first intermittent contact openings) has been achieved with the present design but signature analysis indicates that response down to 0.1 Hz or lower may be useful.

In the area of designing an SSS to be insensitive to false alarms, the "floating-cap-contact" design has demonstrated that the high frequency strain response can be limited to frequencies below 400 Hz at 1-mil displacement while still maintaining a sensitivity of 0.5 mil at frequencies of interest. Ability to reject very low frequency strain stimuli is assured by the ability of the contacts to reclose after application of any relatively constant strain within the 0.06-inch operating range of the SSS.

In the area of designing an SSS in a small package, it is apparent that contact reclosure times meeting the 100 ms original design goal at 1-mil displacement can be readily achieved in a 1.0-inch long by 0.35-inch diameter miniature package. Contact reclosure times in excess of one second can be achieved in a 0.62-inch diameter by 2-inches long package. Shorter contact reclosure times are easily achieved in either package by increasing spring tension (at the expense of sensitivity) or decreasing viscosity of the damping fluid.

In the area of contact ratings, the gold-plated bronze-sphere contacts coated with silicone oil operate reliably with 5-volt excitation and a 1-megohm load, and with 24-volt excitation with a 0.1-ampere lamp load.

In the area of environmental data, the SSS designs operate reliably at temperatures between -40°C and +66°C. There are fairly large changes in contact reclosure time over this range. The designs can stand normal handling and drops to the floor without damage. Shake testing at accelerations on the order of 10 g's over the frequency range from 20 Hz to over 2 kHz (in the process of response testing) appears to have no effect. Humidity and fungus testing in accordance with MIL-STD-810C left the SSS unaffected. The SSS is hermetically sealed and can be operated immersed in water at low pressures.

7.0 RECOMMENDATIONS

The existing intrusion signature library is deficient in two major areas. First, none of the scenarios are for knowledgable, slowly moving intruders that intend to circumvent (spoof) the SSS by taking advantage of its ability to reject slow changes in strain that accompany normal structual settling and environmental shifting. Thus, there is no firm basis on which to establish a minimum acceptable low-frequency intrusion response for the SSS. Second, background noise signatures are not available; both because structual noise levels were often below the sensitivity of the instrumentation and because background measurements were not a formal part of the scenarios and the incidental data is hard to retrieve. Thus, there is also no firm basis on which to establish a minimum rejection of structual noise. Between the increased sensitivity to intrusion that can be obtained by more low-frequency response and the increased rejection of false alarms that accompanies less low-frequency response, there is at present a gap that appears to allow further increases in low-frequeny response (longer contact reclosure times) to improve slow intrusion sensitivity. A program of signature measurements should be implemented to close, or at least define, this gap.

The final Advanced Development Model SSS is difficult to build, as evidenced by the large number of rejections in Table 2. Hand lapping is necessary to prevent binding between the five concentric tubes with 0.001-inch clearances which make up the unit. Production design, tooling and assembly methods should be devised to build the SSS economically.

Longer contact reclosure times than can be achieved using the present damping mechanism within the present case size limitations, appear to be useful for detecting slow intrusions. Very long contact reclosure times have occurred by accident in the near-final design when venting of the pockets of damping fluid at the ends of the cylinders was inadequate. This phenomena can be utilized, by using pistons and fluid flow to replace sliding surfaces and fluid shear, to obtain longer contact reclosure times. It is recommended that designs be investigated that are capable of contact reclosure times of 10, 100, and perhaps even 1000 seconds for 0.001-inch step displacement.

Remote self-test is a requirement for intrusion sensors to be used with some military systems such as FIDS. A program should be initiated to incorporate a self-test feature into the SSS.

APPENDIX I

SIGNAL CONDITIONER

APPENDIX I

SIGNAL CONDITIONER

I.1 Description

The Signal Conditioner used for exciting and demodulating the differential-transformer-type linear displacement transducers used for intrusion signature collection was designed and fabricated by Atlantic Research Corporation. It is a multi-channel instrument designed for simultaneous operation at three decade-related senstivitie. The Signal Condtioner provides ac excitation voltage for the transducer input and synchronous demodulation to linearly convert ac output magnitude and phase to dc output magnitude and polarity.

I.2 Theory of Operation

A block diagram of the Signal Conditioner is shown in Figure I-1 and the schematic diagram is shown in Figure I-2. The primary ac excitation voltage is derived from a 20 kHz square-wave oscillator which is used to chop a reference voltage. The harmonics of the resulting chopped-reference square wave are removed by a low-pass filter leaving the fundamental; a 20 kHz sinusoidal signal. This signal is maintained at a predetermined level by controlling the reference for the square-wave chopper with feedback. A portion of the ac output is rectified and filtered to provide a control voltage which, when compared with a fixed dc reference voltage, produces a difference voltage which is used as the chopped reference voltage. Controlling the amplitude of the chopped-reference square wave controls the amplitude of the sine wave.

A power amplifier stage follows the filter system to provide sufficient excitation current for the transducer primary, demodulator phase shift networks, and electronic null circuits.

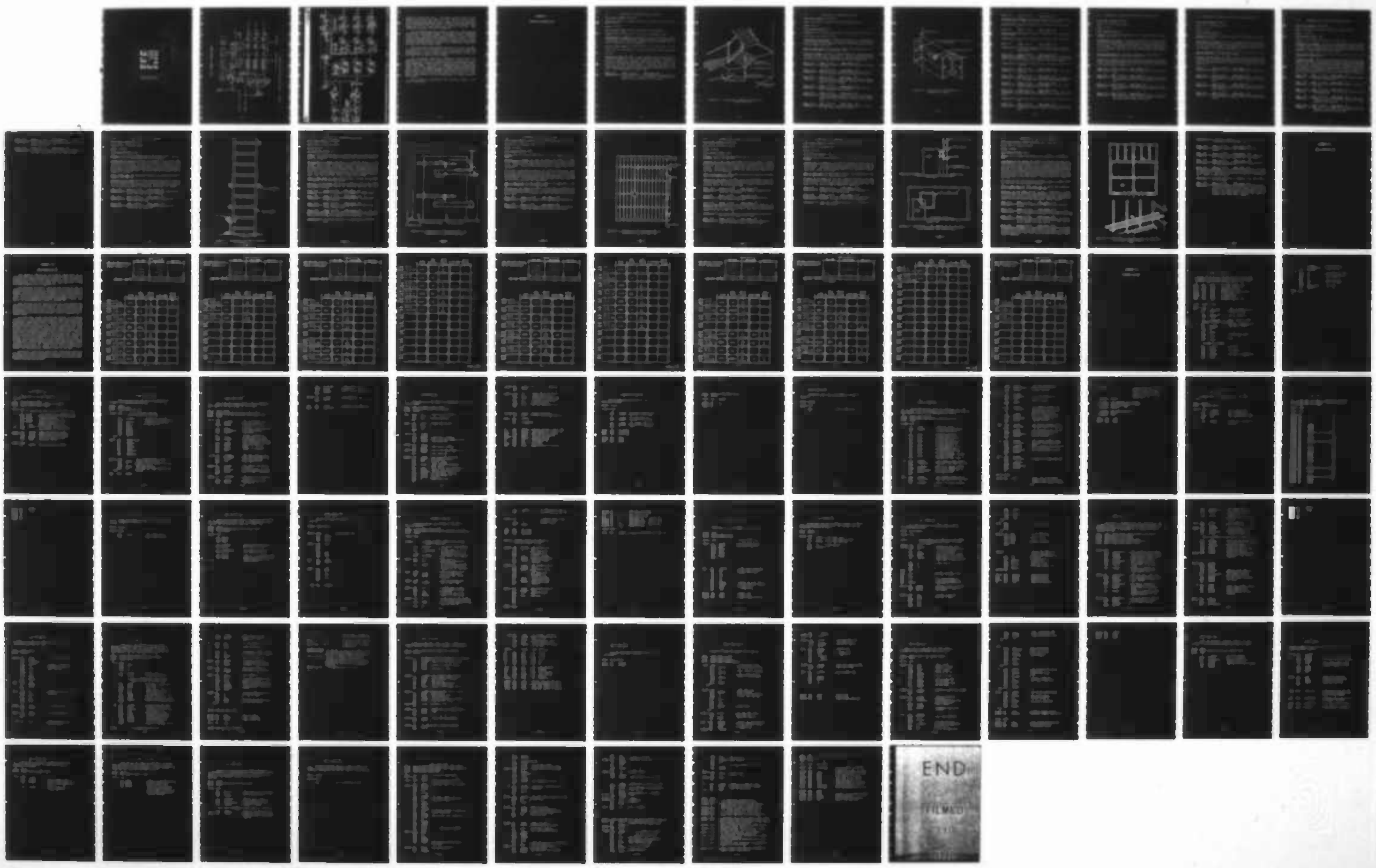
The differential output voltage from a pair of bucking differential transformer secondaries represents the transducer core displacement from null. Demodulation of this ac voltage produces a variable dc voltage correspnding linearly to core displacement. The demodulation process is phase syncronized to the excitation voltage (synchronous detection) to produce superior dc linearity and a dc polarity which indicates the direction of core displacement from null.

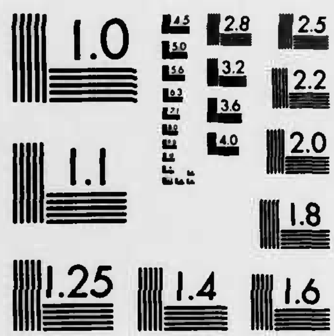
The Signal Conditioner contains three demodulator channels connected to the one transducer output, each with a different sensitivity. Each demodulator channel contains a variable-gain ac amplifier, a full-wave synchronous detector, a phase shifter and a 6-pole 5 kHz active low-pass filter.

The demodulation of the transducer output begins with the ac amplifiers. The first (low-sensitivity) channel has an

AD-A132 343 DEVELOPMENT OF THE STRAIN SENSITIVE SWITCH (SSS)(U) ATLANTIC RESEARCH CORP ALEXANDRIA VA J W SAVAGE 22 DEC 82 DAAK70-80-C-0182 2/2

UNCLASSIFIED F/G 14/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

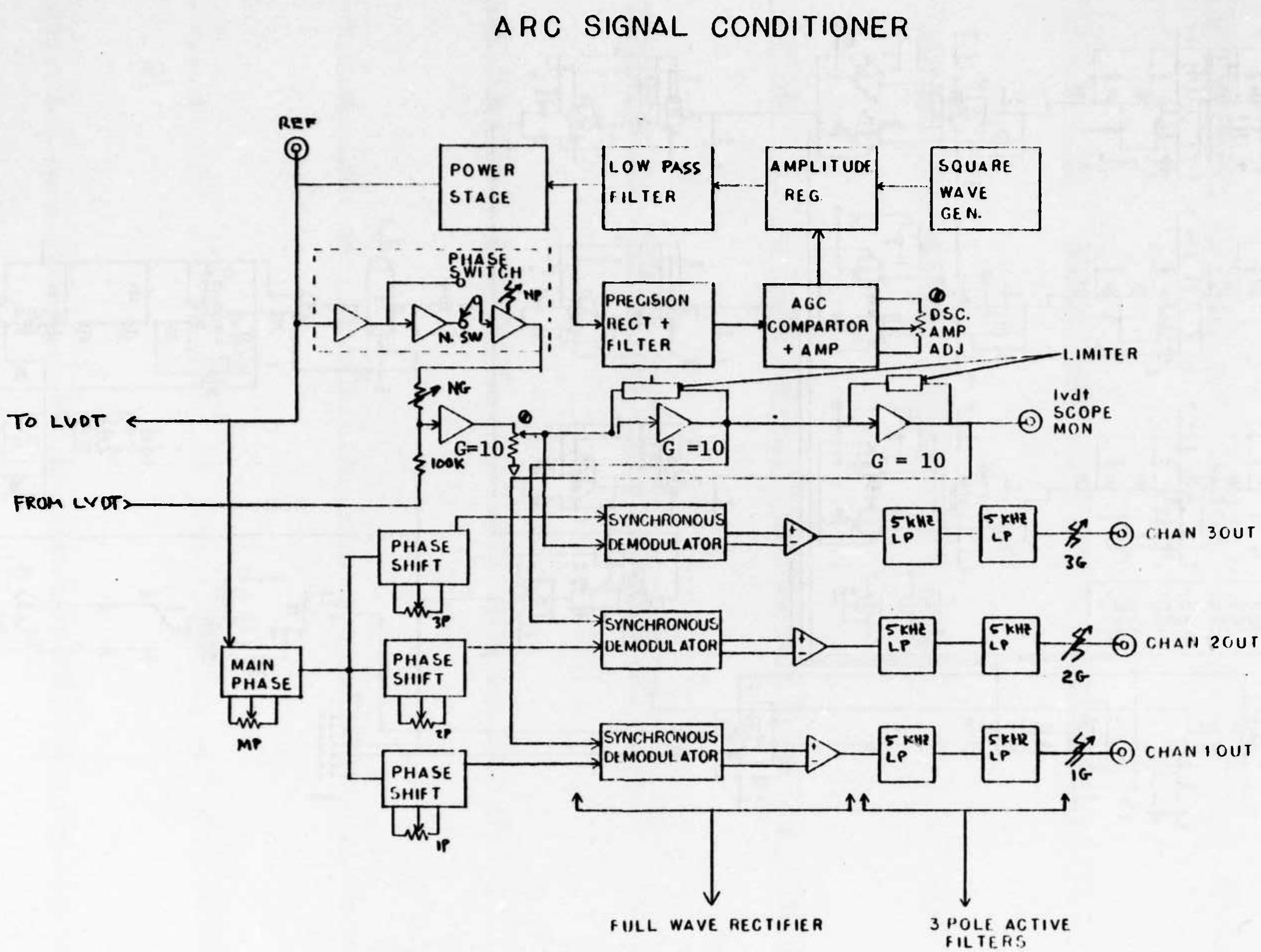
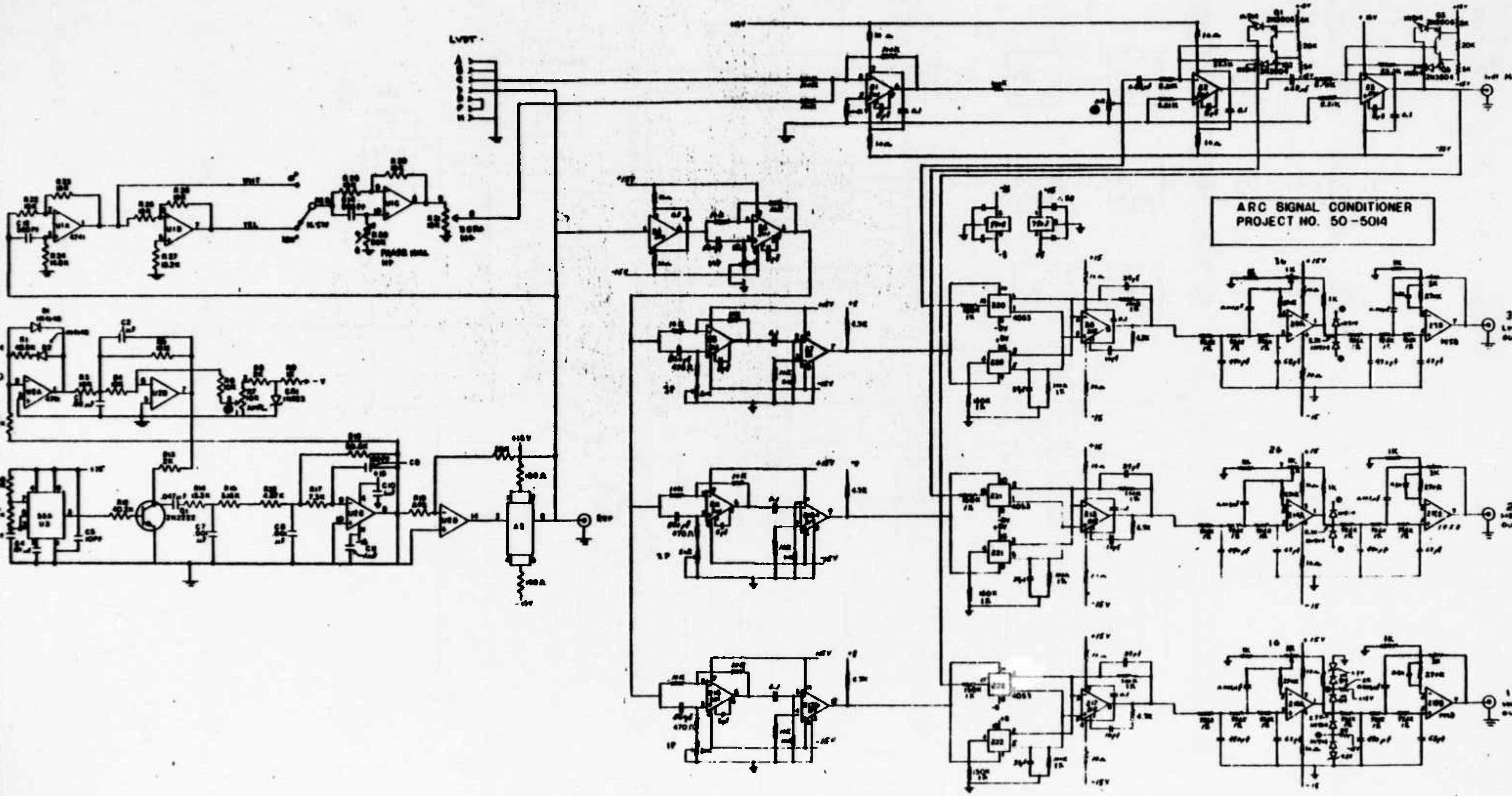


Figure I-1 Signal Conditioner Block Diagram


ARC SIGNAL CONDITIONER
PROJECT NO. 50-5014
LVDT
3 LOW SENS. OUTPUT
2 MED. SENS. OUTPUT
1 HIGH SENS. OUTPUT

amplifier with unity gain. The second (medium-sensitivity) channel amplifier has a gain of ten, and the third (high-sensitivity) channel amplifier has a gain of ten. The two gain-of-ten amplifier stages are output limited to prevent saturation delay and demodulator distortion. A tap off each amplifier stage feeds one of the three synchronous detector circuits. Each synchronous detector circuit is identical.

The synchronous detector circuit is based on a complimentary metal-oxide semicondutor (CMOS) analog-demultiplexer integrated circuit (IC). The demultiplexer is arranged as two single-pole double-throw switches having separate control inputs. Switch control is synchronized to the phase of the excitation voltage. The demultiplexer switches the amplified transducer output signal between the differential inputs of an operational amplifier creating full-wave rectification.

The rectified signal passes through two 3-pole low-pass active filters with a cutoff of 5 kHz. The filters smooth the rectified ac to a dc voltage which corresponds to the core displacement. Each filter network has a gain control to calibrate the dc output of each channel.

For situations where the transducer output cannot be physically nulled, electronic nulling is provided. The electronic null circuit is composed of three unity-gain phase-shift amplifiers, a phase control, a phase reversal switch and an amplitude control. The first two amplifiers have a fixed phase shift. The output amplifier has a variable phase adjustment and level control. The phase adjustment permits setting the proper phase angle to null the transducer output while the level control permits setting the exact amplitude to create the null. The phase switch permits nulling displacements in either direction from center.

Each control is accessible from the front panel of the Signal Conditioner.

APPENDIX II

INTRUSION SIGNATURE LOG

II.1 SIGNATURES OF INTERIOR STEEL STAIRCASE

Tape serial number: 8952071001

Date:0001 (3401, 3 February 1981) (Date Codes on this tape are not standard)

Time: 13:47:52

Tape Position Count: Counter Inoperative (Belt Broken)

Target: The following test will be of a staircase at ARC.

Composition of target:The composition of the staircase is steel mounted upon a concrete base. The stairwell is surrounded by a cinder block wall. This wall provides additional support for the three stories the stairwell connects.

Type of LVDT used: The LVDT used for the first part of this experiment is the MHR-500. The second part was done with the MHR-100.

Position of LVDT: The LVDT is positioned between the underside a step and the concrete floor at the bottom of the stairwell as shown in Figure II-1 (milling table not shown). A block is provided for holding the LVDT. This block was fastened to the center of the step by model cement. The LVDT is clamped in the block and the core is positioned in the milling table vise. The extending rods are used so the milling table may be placed on the floor. The staircase is 42 inches wide.

Date: 0001 Time: 13:42:52 Tape count: N/A

Signature:The first signature is of a person walking from the first floor to the basement. (Subsequent signatures are annotated only on tape.)

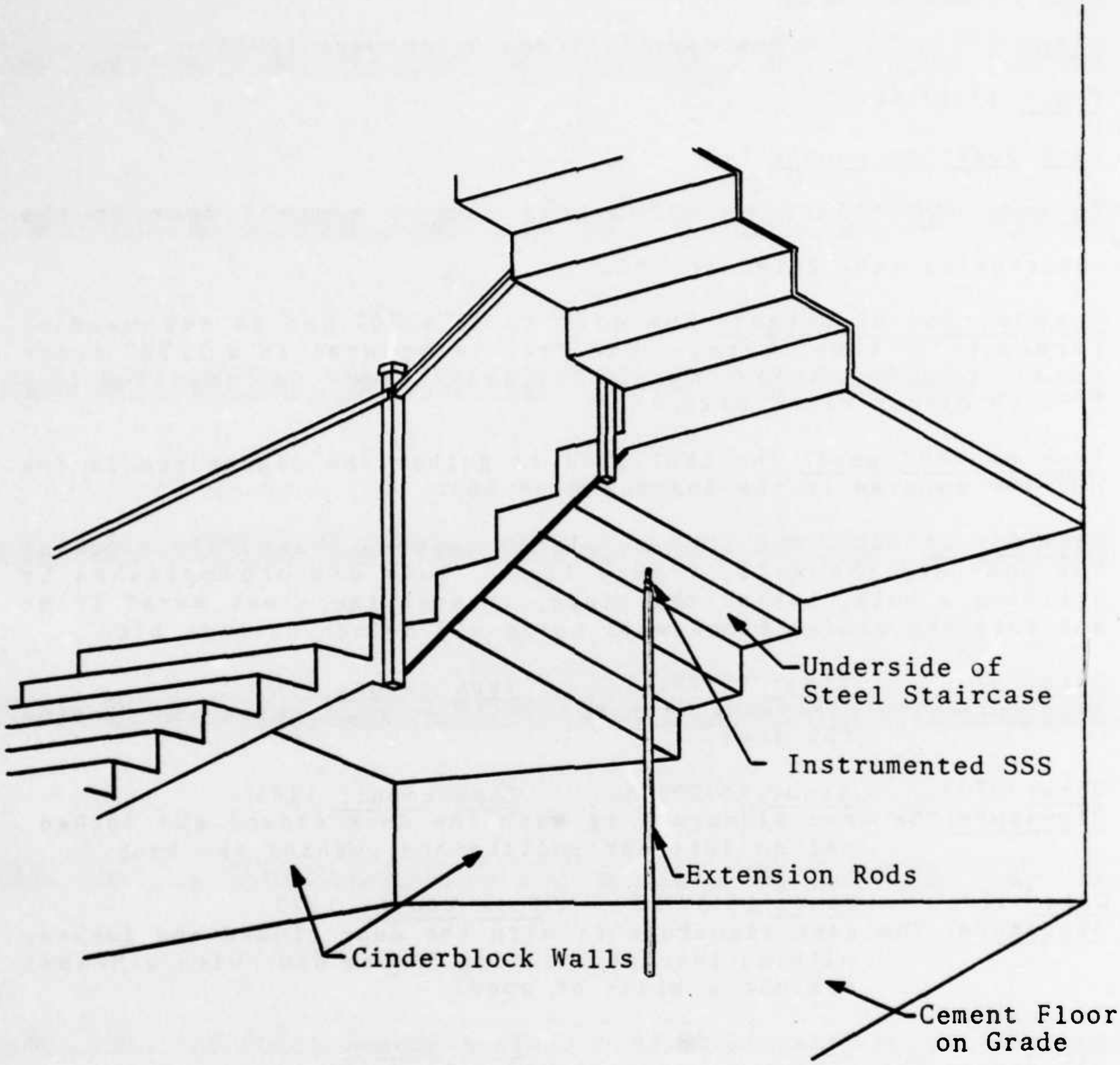


Figure II-1 Positioning of LVDT For Signature of Steel Staircase

II.2 SIGNATURES OF INTERIOR STEEL DOOR

Tape Serial number: 8952012023

Date: 3703,4003 (6 February 1981 and 9 February 1981)

Time: 15:17:31

Tape position count: 940

Target: The following signatures are of a steel door in the electronics lab. 281-C at ARC.

Composition of target: The door is 36"x 80" and is composed of formed 1/32" sheet metal. The door is mounted in a 1/32" sheet metal frame by three hinges. The metal frame is installed in a 12-inch cinder block wall.

Type of LVDT used: The LVDT used to gather the signatures is the MHR-100 mounted in the Instrumented SSS.

Position of LVDT: The LVDT is placed between the middle hinge of the door and the wall, Figure II-2. This was accomplished by drilling a hole, behind the hinge, through the sheet metal frame and into the cinder block wall using a 5/8-inch carbide bit.

Date: 3703 Time: 15:29:18 Tape count: 1103
Signature: The following signature will be of opening and closing the door.

Date: 3703 Time: 15:29:45 Tape count: 1185
Signature: The next signature is with the door closed and locked and an intruder pulling and pushing the knob.

Date: 3703 Time: 15:30:53 Tape count: 1229
Signature: The next signature is with the door closed and locked with an intruder banging on the door with a hammer against a block of wood.

Date: 3703 Time: 15:53:18 Tape count: 1270
Signature: The LVDT was repositioned behind the hinge and the above experiment was repeated.

Date: 3703 Time: 15:54:21 Tape count: 1342
Signature: The following signature is with the door closed and locked and again banging on the door with a hammer and block of wood, but this time from the opposite side.

Date: 3703 Time: 15:57:58 Tape count: 1387
Signature: The next signature is with the door closed and locked the the hinge pins being removed.

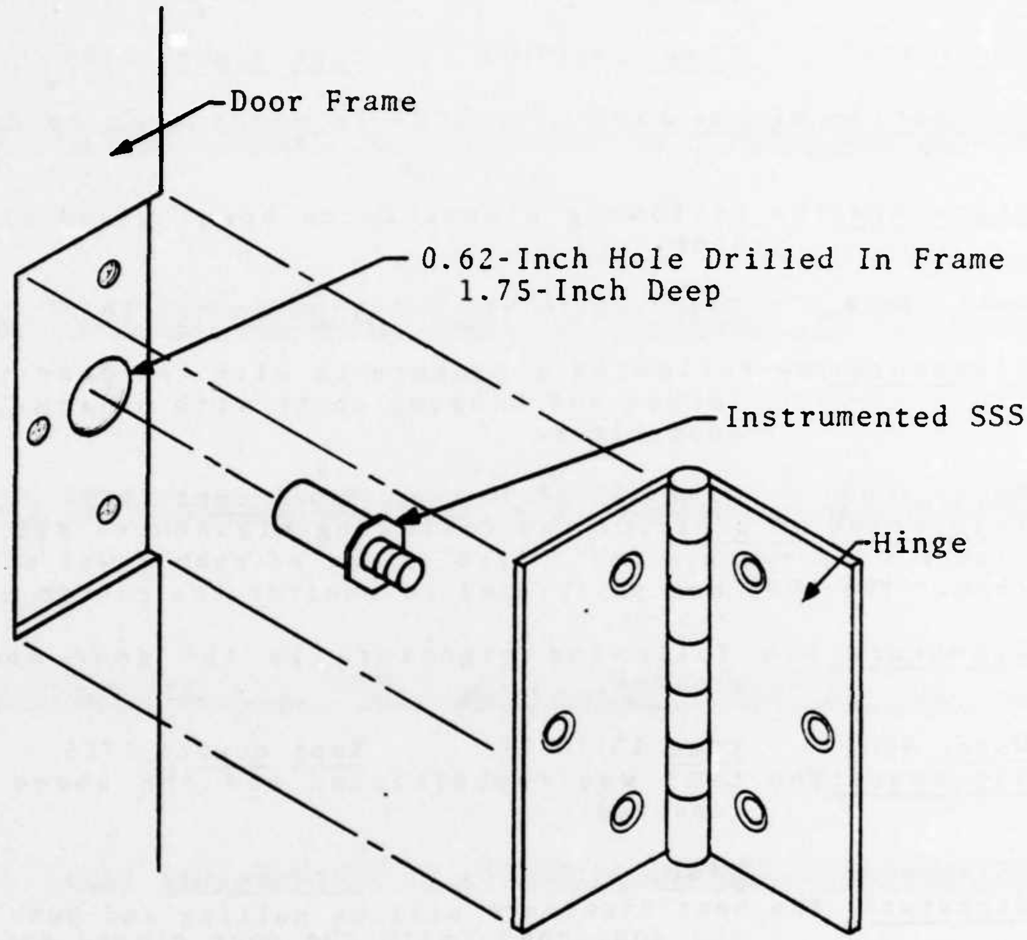


Figure II-2 Installation of Instrumented SSS Behind a Door Hinge

Date: 3703 Time: 16:24:25 Tape count: 1524

Relocation of the LVDT: The LVDT is removed from the middle hinge and positioned to monitor the bottom hinge of the door.

Signature: The following signature is opening and closing the door.

Date: 4003 Time: 14:19:00 Tape count: 1586

Relocation of the LVDT: The LVDT is readjusted to monitor the bottom hinge.

Signature: The following signature is opening and closing the door.

Date: 4003 Time: 14:24:03 Tape count: 1630

Signature: The following signature is with the door closed and locked and banging on it with a hammer against a wood block.

Date: 4003 Time: 15:08:00 Tape count: 1694

Relocation of LVDT: For the following signatures all three door hinges were removed and a 1/16" piece of rubber was placed behind them. The LVDT was positioned to monitor the center hinge.

Signature: The following signature is the door opening and closing.

Date: 4003 Time 15:20:40 Tape count: 1765

Signature: The LVDT was repositioned and the above test was repeated.

Date: 4003 Time: 15:30:19 Tape count: 1832

Signature: The next signature will be pulling and pushing against the door knob, with the door closed and locked.

Date: 4003 Time: 15:32:31 Tape count: 1889

Signature: The following signature is banging on the door with a hammer against a block of wood.

Date: 4003 Time: 16:12:42 Tape count: 1950

Relocation of the LVDT: This signature is with the LVDT positioned to monitor the bottom hinge with the rubber still in place.

Signature: The following signature is opening and closing the door.

Date: 4003 Time: 16:15:14 Tape count: 2017

Signature: The next signature will be with the door closed and locked and someone pulling and pushing on the knob.

II-3 SIGNATURES OF INTERIOR WOOD DOOR IN FRAME PARTITION

Tape serial number: 583856118

Date: 4103 (10 February 1981)

Time: 11:17:23

Tape Position Count: 244

Target: The following signature is of a wooden door in a wood frame wall at ARC.

Composition of target: The door is composed of two 32 x 80 x 1/16" wood venear panels covering each side of a wooden frame. The door is hung by 2 metal hinges spaced 1 foot from each end of the 80" side. The hinges are attached to a wooden frame that is the trimming on a partition wall. The wooden wall is composed of 2 x 4 in. wooden studs covered with 0.5-inch sheet rock panels both sides.

Type of LVDT used: The LVDT used to monitor the signatures is the MHR 100 mounted in the Instrumented SSS.

Position of LVDT: The LVDT is positioned to monitor the bottom hinge. This was accomplished by removing the hinge and drilling a hole into the door frame. The LVDT was placed in the hole and the hinge installed, Figure II-2.

Date: 4103 Time: 11:17:23 Tape Count: 278
Signature: The first signature will be opening and closing the door.

Date: 4103 Time: 11:35:16 Tape count: 370
Signature: The next signature is with the door closed and locked and someone pulling and pushing against the door knob.

Date: 4103 Time: 11:40:33 Tape count: 450
Signature: The next signature is with the door closed and locked and banging on it with a hammer against a wood block.

Date: 4103 Time: 12:52:23 Tape count: 520
Signature: The next signature is with the door closed and locked and the hinge pins being removed. This is performed with a hammer and chisel.

II.4 SIGNATURES OF INTERIOR WOOD DOOR IN CINDER BLOCK WALL

Tape serial number: 583856118

Date: 4103 (10 February 1981)

Time: 14:15:00

Tape position count: 732

Target: The following signatures are of a wooden door in a cinder block wall at ARC.

Composition of target: The door is composed of two 32" x 80" x 1/16" wood venear panels covering each side of a wooden frame. The door is hung by 2 metal hinges spaced 1 foot from each end of the 80" side. The hinges are attached to a wooden frame that is the trimming on a 12-inch cinder block wall.

Type of LVDT used: The LVDT used to monitor the signatures is the MHR-100 mounted in the Instrumented SSS.

Position of the LVDT: The LVDT is positioned to monitor the bottom hinge. This was accomplished by removing the hinge and drilling a hole in the door frame and into the block wall. The LVDT was positioned in the hole and the hinge installed, Figure II-2.

Date:4103 Time: 14:15:00 Tape count: 732
Signature:The following signature is opening and closing the door.

Date: 4103 Time: 15:03:55 Tape count: 838
Signature:The next signature is with the door closed and locked and someone pulling and pushing against the door knob.

Date: 4103 Time: 15:13:41 Tape count: 907
Signature: The next signature is with the door closed and locked and banging on the door with a hammer against a block of wood.

Date: 4103 Time: 15:15:35 Tape count: 987
Signature: The next signature is with the door closed and locked and the hinge pins being removed with a hammer and chisel.

II.5 SIGNATURES OF AN INTERIOR INDUSTRIAL FLOOR

Tape serial number: 8952012007

Date: 4302,4402 (12 February 1981 and 13 February 1981)

Time: 13:00:00

Tape Position Count: 0000

Target: Floor, Electronics Lab., Rm. 281-C, ARC

Composition of target: The floor is composed of concrete slabs 3" thick. The slabs are supported by cinder block walls spaced 30 feet apart. These walls run the entire length of the building. The two adjacent walls, which make up the room, are composed of woodframe and are 30 feet apart.

Type of VDT used: The LVDT used for the first part of this experiment is the MHR-500.

Position of LVDT: The LVDT is supported from the ceiling by a 0.5-inch aluminum hex rod clamped to a bar joist in the ceiling, Figure II-3. This configuration was choosen because the ceiling of this room is the roof of the building. The body of the LVDT is placed in a wooden block which is then clamped to the steel rod. The core of the LVDT is mounted on a 1-72 all-thread rod and attached to the extension rod. The steel rod is clamped in a milling vise and placed on the floor near the center of the span.

Date: 4302 Time: 13:14:00 Tape count: 285
Signature: The following signature is one person walking through the lab, near the LVDT.

Date: 4302 Time: 13:14:58 Tape count: 333
Signature: The following signature is three people working in the lab.

Date: 4402 Time: 09:43:49 Tape count: 431
Signature: The following signature is six people working in the electronics lab.

Date: 4402 Time: 10:44:32 Tape count: 464
Signature: This signature was to check the LVDT response when someone walked on the flat slag roof which formed the lab ceiling.

Date: 4402 Time: 13:45:00 Tape count: 584
Signature: For this signature the MHR 500 was replaced with the MHR-100. The following signature is of one person walking through the room.

Date: 4402 Time: 13:46:00 Tape count: 662

Signature: The following signature is with no activity in the room. This is to gather a signature of the background noise.

Date: 4402 Time: 14:04:38 Tape Count: 758

Signature: This is another signature of someone walking on the roof but, this time using the MHR 100 LVDT.

II.6 SIGNATURES OF A STEEL LADDER

Tape serial number: 8952072021

Date: 4805 (17 February 1981)

Time: 15:48:25

Tape Position Count: 0000

Target: The following signatures are of a steel ladder used for access to the roof of building 399 at Ft. Belvoir.

Composition of target: The ladder is composed of 3/4" steel rungs supported between 1/2" x 2 1/2" steel posts. Figure II-4. The steel posts are bolted to the floor of the top landing of the stairwell. The ladder has four (1/2" x 2 1/2") wall brackets. The brackets are welded to the ladder and bolted to the cinder block wall of the stairwell. The wall brackets are positioned as shown in the figure.

Type of LVDT used: The LVDT used to monitor the signatures of the ladder is the MHR 500.

Position of the LVDT: The LVDT is clamped to the side of one of the steel posts, Figure II-4. The core is positioned in the LVDT and is attached to the extension rods. These rods are clamped in a vise which is placed on the floor at the base of the ladder.

Date: 4805 Time: 15:48:25 Tape count: 240
Signature: The following signature is one person climbing the ladder from the stairwell landing.

Date: 4805 Time: 16:03:41 Tape count: 294
Signature: The next signature is a person climbing onto the ladder from the roof.

Date: 4805 Time: 16:08:11 Tape count: 375
Signature: The final signature is two people walking on the top landing of the stairwell.

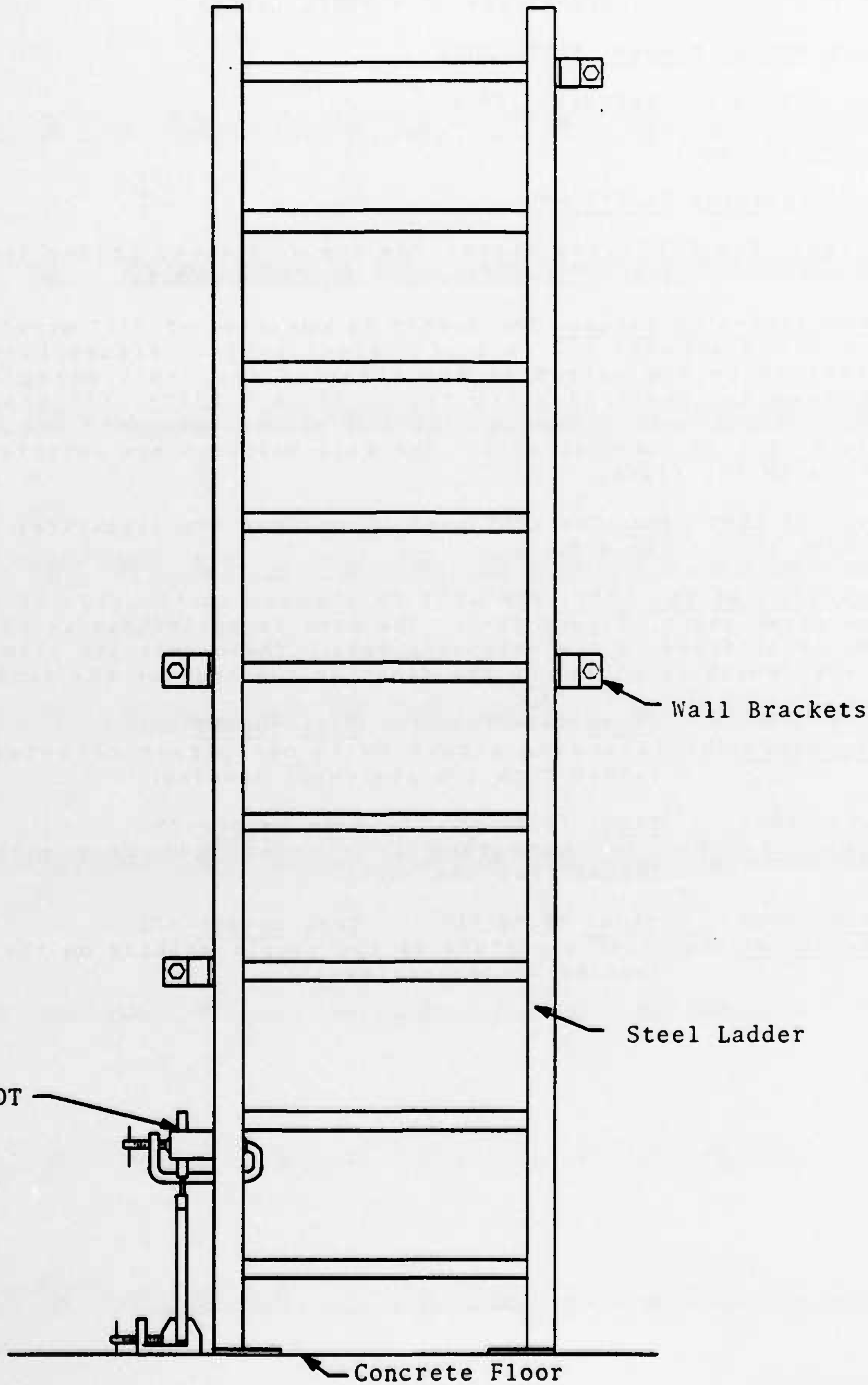


Figure II-4 Positioning of LVDT For Signature of a Ladder

II.7 SIGNATURES OF A CONCRETE BUNKER DOOR

Tape serial number: 6549582010

Date: 4903 (18 February 1981)

Time: 15:09:24

Tape Position Count: 170

Target: The following is of a concrete door on an ammunition bunker. The bunker is made of concrete and surrounded on three sides with dirt.

Composition of target: The door is 6' high by 4'wide. It is composed of 4" of steel-reenforced concrete and mounted by two hinges, Figure II-5. The hinges extend 3' across the door and are mounted to the door with four 1" bolts. The hinge portion is mounted in the concrete of the bunker and is composed of an iron stud for the door hinge to pivot on. The door is recessed 6" into the concrete bunker which creates a wall surrounding the door. This wall provided a means to position the LVDT.

Type of LVDT used: The LVDT used to monitor the door is the MHR-100 mounted in the Instrumented SSS.

Position of the LVDT: The first signature is with the LVDT positioned horizontally between the top hinge base and the wall surrounding the door.

Date: 4903 Time: 15:18:55 Tape count: 267
Signature: The following signature is opening the bunker door.

Date: 4903 Time: 15:21:22 Tape count: 347
Signature: The following signature is banging on the door with a wooden object.

Date: 4903 Time: 15:23:54 Tape count: 429
Signature: The next signature is banging on the door with a larger wooden object.

Date: 4903 Time: 15:36:54 Tape count: 603
Relocation the LVDT: For the following signature the LVDT has been repositioned. The placement of the LVDT is vertically between the top hinge stud and the surrounding wall.

Signature: The following signature is opening and closing the door.

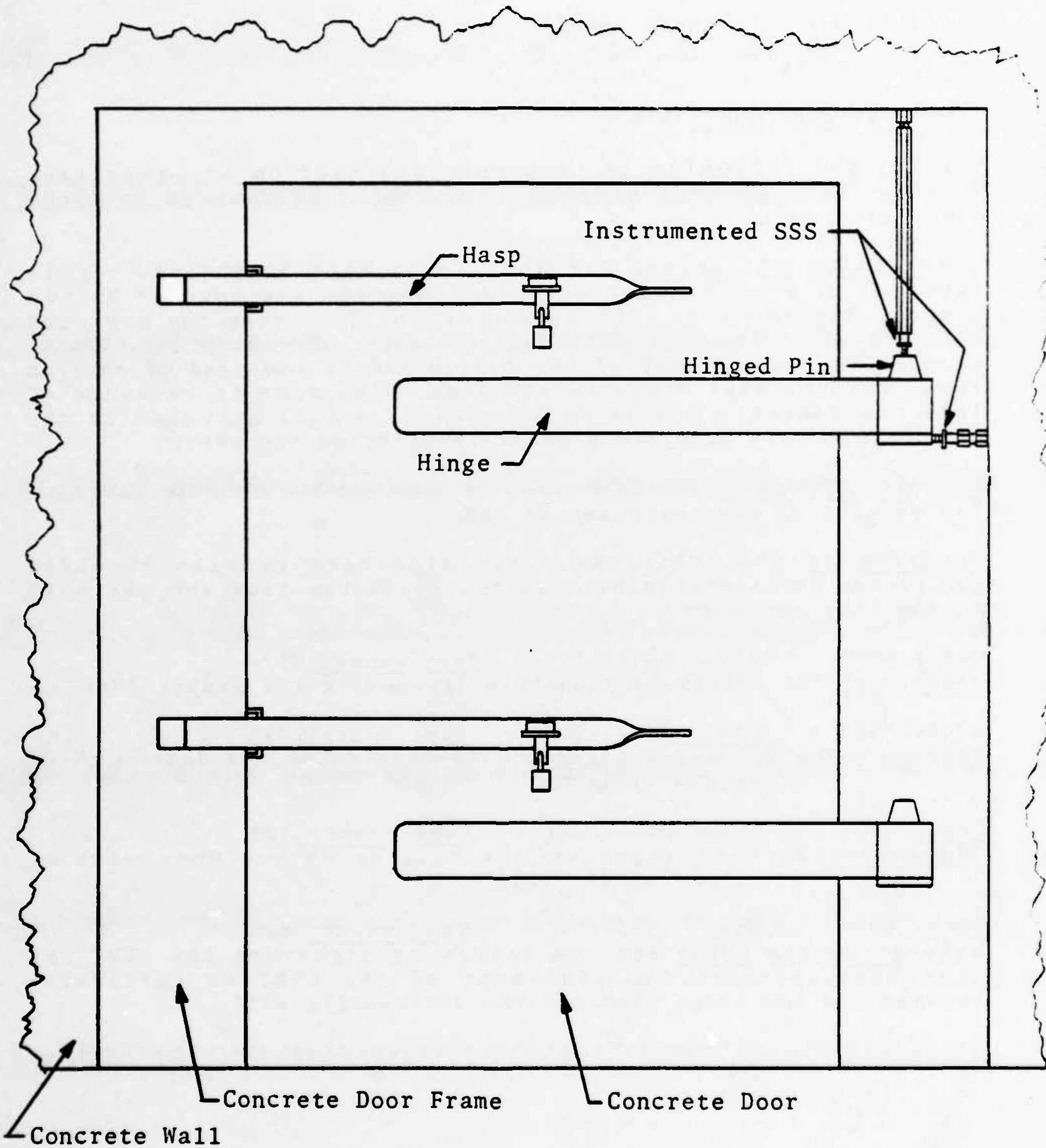


Figure II-5 Installation of Instrumented SSS's for Signatures of a Concrete Bunker Door

II.8 SIGNATURES OF AN ARMSLOCKER DOOR

Tape serial number: 6549582010 (tape continued. from Bunker Door)

Date: 5003 (19 February 1981)

Time: 11:45:00

Tape Position Count: 1000

Target: The following signature is of a door composed of steel bars.

Composition of target: The steel bar door is 36" wide x 72" high. It is composed of 3/4" steel bars positioned 4-1/2" apart, Figure II-6. These bars are supported by 2" x 1/4" steel braces spaced 1 foot apart. These braces are attached to a frame that forms the door.

The frame of the door is made of 2" x 1/4" steel braces. The braces are supported on one side by four 2" x 5" steel hinges. The hinges are attached to the steel bar cage which forms an L shaped barrier inside the entrance to the arms locker. This cage is fastened to a reenforced cinder block wall and concrete ceiling which surrounds the arms locker.

Type of LVDT used: The LVDT used to monitor the signatures is the MHR-100 mounted in the Instrumented SSS.

Position of the LVDT: The LVDT is positioned to monitor the bottom hinge as in Figure II-6. It is placed between the steel brace supporting the hinge and the brace attached to the cinder block wall.

Date: 5003 Time: 11:45:00 Tape count: 1200
Signature: The following signature is opening and closing the door.

Date: 5003 Time: 11:58:12 Tape count: 1403
Signature: The following signature is with the door closed and locked and pushing and pulling on the bars.

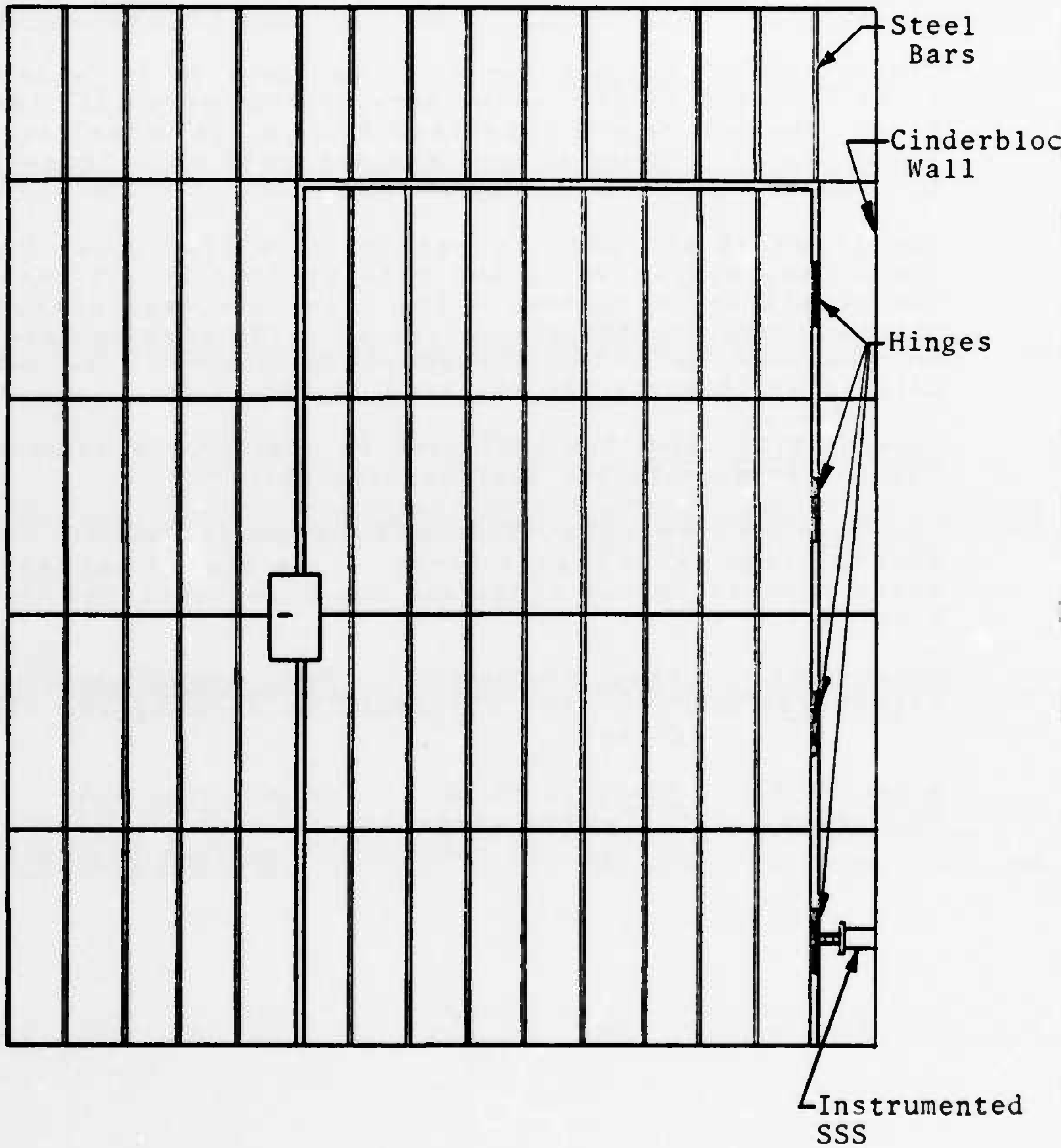


Figure II-6 Installation of Instrumented SSS for Signatures of an Armslocker Door

II.9 SIGNATURE OF AN INTERIOR WOODEN FLOOR

Tape serial number: 8930891006

Date: 5002 (19 February 1981)

Time: 14:00:00

Tape Position Count: 0000

Target: The following signatures are of the wooden floor in building 1825 at Ft. Belvoir.

Composition of the target: Building 1825 (walk test) is a wood-frame building 36' x 85'constructed on concrete pilons. Wooden beams are placed on top of the pilons to support 2" x 8" wooded joists. The joists are spaced 24" apart and covered with plywood. The plywood is covered with linolium tile and make up the floor of the building.

Type of LVDT used: The LVDT used to monitor the floor is the MHR-100 in the Instrumented SSS.

Position of the LVDT: The LVDT is positioned between the floor and the ceiling by a 0.5-inch hexagonal aluminum rod clamped to a ceiling brace. The sensor is placed 4' from the long side of the building and 20' from the short side..

Date: 5002 Time: 15:20:00 Tape count: 200
Signature: The following signature is one person walking around the area of the LVDT.

Date:5002 Time: 15:28:45 Tape count: 317
Signature: The next signature is one person walking from one end of the room to the other.

Date: 5002 Time: 15:49:57 Tape count: 400
Repositioned the LVDT: The LVDT is positioned to monitor the center of the room. A brace is fastened to the ceiling and the aluminum rod is clamped to a brace. The LVDT is positioned between the rod and the floor.

Signature: The following signature is of one person walking from one end of the room to the other.

Date: 5002 Time: 15:52:14 Tape count: 510
Signature: The following signature is one person walking the width of the room about 5' from the LVDT.

II.10 SIGNATURES OF AN ARMSLOCKER STEEL WINDOW PLATE

Tape serial mumber: 6549582010 (tape cont. from Bunker door)

Date: 5004 (19 February 1981)

Time: 12:16:12

Tape Position Count: 1466

Target: The following signatures are of a steel-plate-covered window.

Composition of target: The window is located in a wall of the arms locker. It is 2'8" x 3'2" and is covered on both sides by steel plates. The steel plates are welded to the metal frame of the window. This frame is surrounded by the reenforced cinder-block wall of the arms locker.

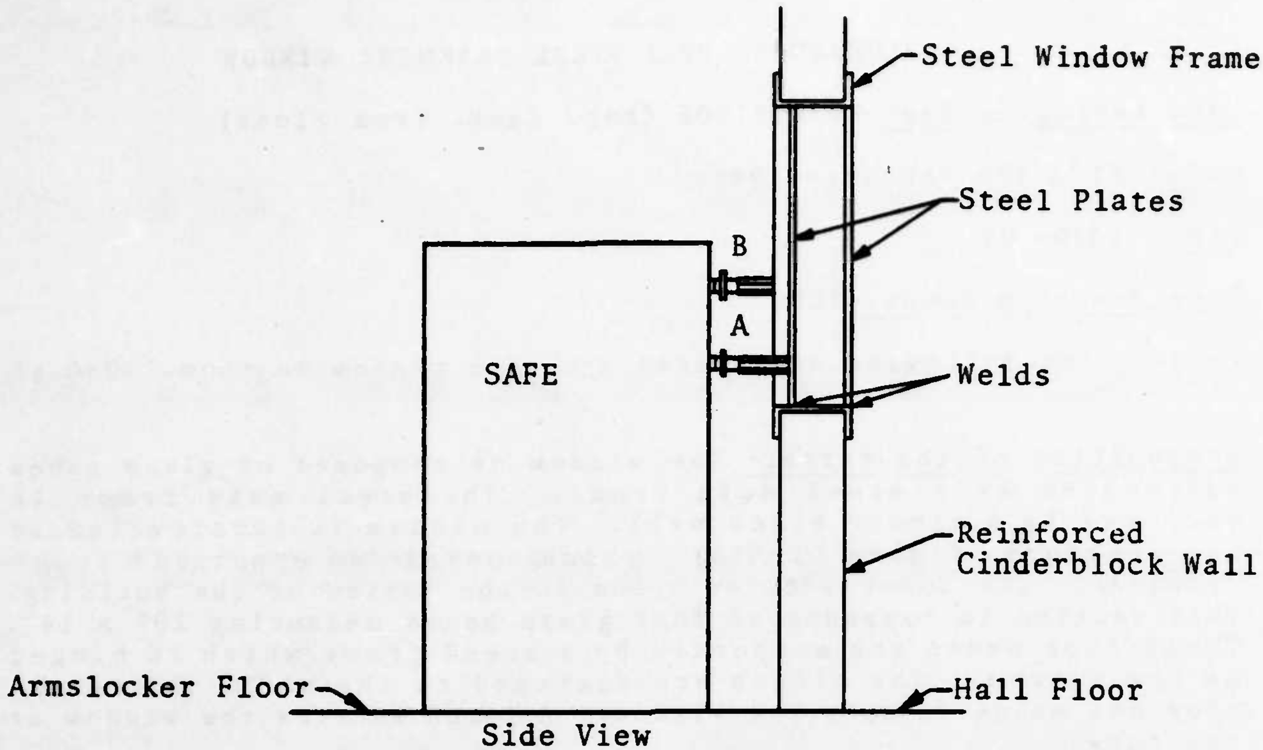
Type of LVDT used: The LVDT used to collect the signatures is the MHR-100 mounted in the Instrumented SSS.

Position of the LVDT: For the first signature collected the LVDT is positioned to monitor the steel plate on the inside of the arms locker. It was positioned between a large safe and the bottom of the plate, as shown in Figure II-7, Position A.

Date: 5004 Time: 12:16:12 Tape count: 1466
Signature: The following signature is someone banging on the outside of the window plate.

Date: 5004 Time: 12:24:00 Tape count: 1582
Relocation of the LVDT: The following signature is with the LVDT repositioned to monitor the frame of the window, Position B.

Signature: The signature is someone banging on the outside window with their hand.



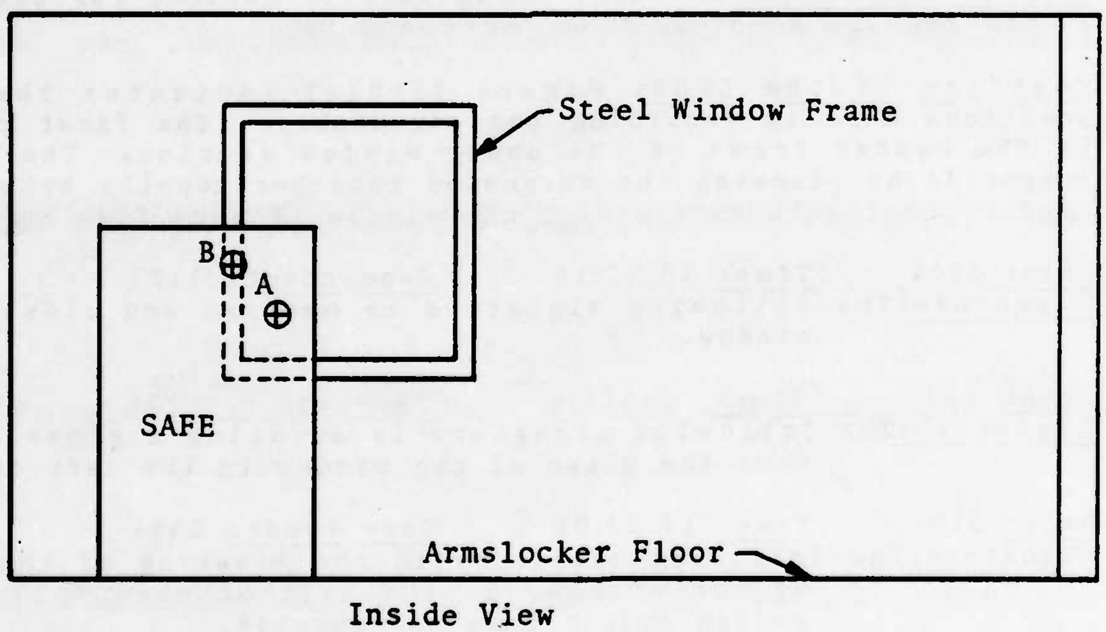


Figure II-7 Installation of Instrumented SSS For Signatures of an Armslocker Steel Window Plate

II.11 SIGNATURES OF A STEEL CASEMENT WINDOW

Tape serial number: 8930891006 (tape cont. from floor)

Date: 5104 (20 February 1981)

Time: 13:09:01

Tape Position Count: 1000

Target: The following signatures are of a window in room 280-C at ARC.

Composition of the target: The window is composed of glass panes surrounded by a steel main frame. The steel main frame is enclosed by a cinder block wall. The window is constructed in two sections, Figure II-8(a) , which contain an upper and lower section. The lower section opens to the inside of the building. This section is composed of four glass panes measuring 20" x 14". These four panes are supported by a steel frame which is hinged at the bottom. The hinges are fastened to the main frame and provides means to open the window. A latch secures the window at the top.

The upper section is perminently mounted to the steel main frame and contains six glass panes measuring 7" x 15".

Type of LVDT used: The LVDT being used to collect the signatures is the MHR-100 mounted in the instrumented SSS.

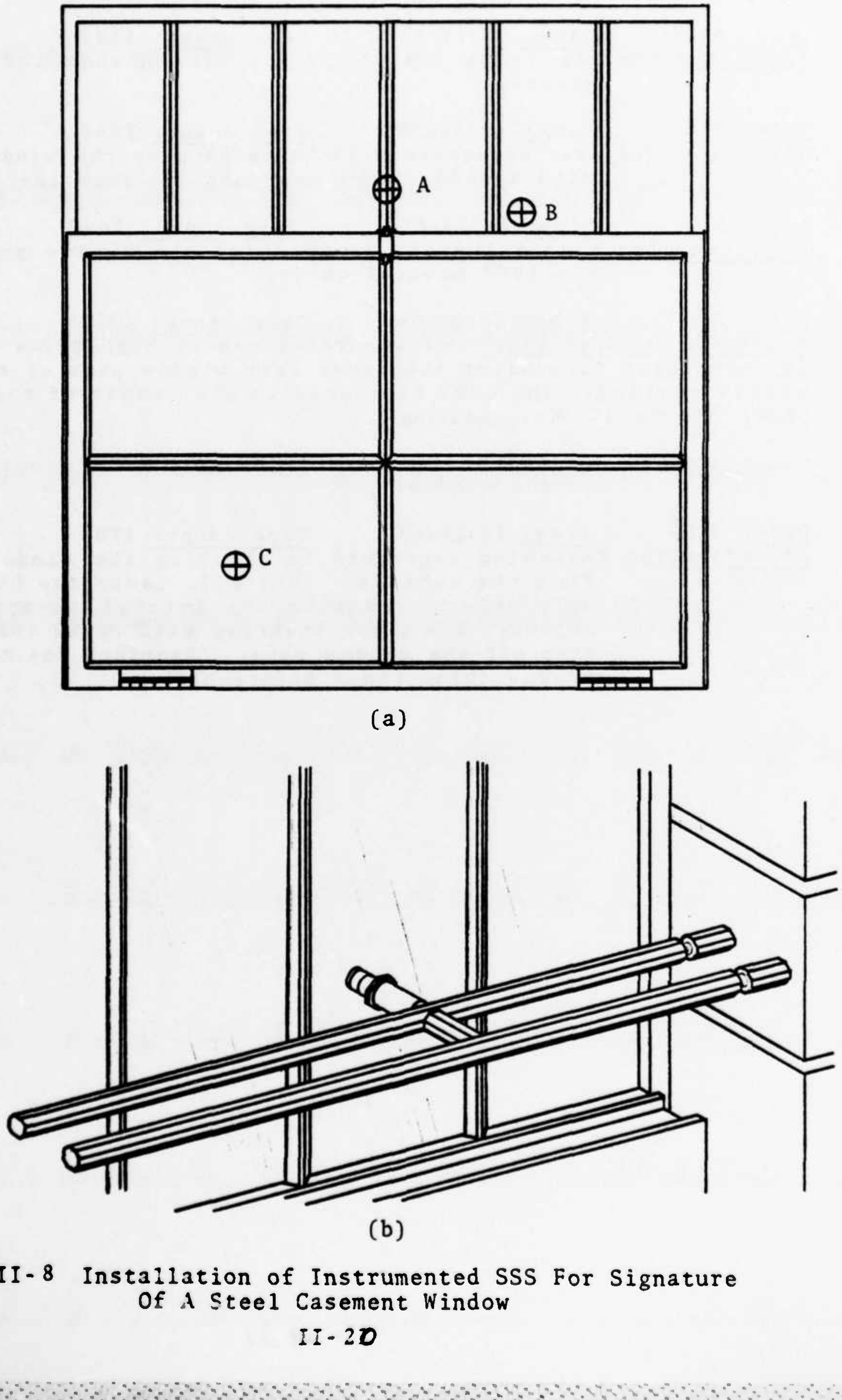
Position of the LVDT: Figure II-8(a) indicates the three positions used in recording the signatures. The first position is the center frame of the upper window section. The LVDT is supported by placeing the extension rods horizonally between the cinder block wall surrounding the window, Figure II-8(b).

Date: 5104 Time: 13:12:16 Tape count: 1123
Signature: The following signature is opening and closing the window.

Date: 5104 Time: 13:47:36 Tape count: 1251
Signature: The following signature is scraping a glass cutter over the glass of the window to the left of the LVDT.

Date: 5104 Time: 13:58:01 Tape count: 1344
Signature: The following signature is the breaking of the glass of the window, on the left of the LVDT, with a wooden object from the outside.

Date: 5104 Time: 14:21:38 Tape count: 1400
Relocation of the LVDT: For the second set of signatures the LVDT is positioned to monitor the glass pane of a window. The window selected is second from the right in the upper section. The LVDT is positioned in the lower left corner of the window pane, Figure II-8(a), position B.



(a)

(b)

Figure II-8 Installation of Instrumented SSS For Signature Of A Steel Casement Window

Signature: The following signature will be a glass cutter scrapping across the window pane.

Date: 5104 Time: 14:28:30 Tape count: 1483
Signature: The following signature is opening and closing the window.

Date: 5104 Time: 14:30:28 Tape count: 1549
Signature: The next signature will be banging on the window frame with a wood object one-foot 2x4 from inside.

Date: 5104 Time: 14:33:21 Tape count: 1649
Signature: The next signature is breaking the window pane with the LVDT mounted on it.

Date: 5104 Time: 15:03:56 Tape count: 1712
Relocation of the LVDT: For the third set of signatures the LVDT is positioned to monitor the lower left window pane of the lower window section. The LVDT is placed in the center of the window pane, Figure II-8(a), position C.

Signature: The following signature is banging on the main frame of the window.

Date: 5104 Time: 15:21:43 Tape count: 1790
Signature: The following signature is breaking the window pane from the outside. This will cause the LVDT to be only able to monitor the initial impact of the object. The glass breaking will cause the LVDT to drop off the window pane. (One-foot 2x4 thrown at window three times before broken.)

APPENDIX III

DATA REDUCTION LOG

APPENDIX III

DATA REDUCTION LOG

This Appendix contains the log of the 8" floppy disks out of which the data were transferred from magnetic tape after analog-to-digital conversion during data reduction. Each log sheet is marked with a tape serial number (S/N) and data time codes corresponding to the codes used for identification in the Intrusion Signatures Log of Appendix II.

The Sensitivity block contains the levels of the 12 calibration steps recorded at the beginning of each signature scenario as seen on a scale of nominally ±1 by the Data Analysis System. The calibration steps correspond to full scale and half scale for the two directions of sensor deflection recorded in each of the three decade-related-sensitivity tape channels. Full scale in the low-sensitivity channel corresponds to ±0.100 inch and in the high-sensitivity channel to ±0.010 inch.

The Scaling Factors were derived fro each channel by averaging the positive and negative full scale calibration step levels and taking half of the result. The Scaling Factor was thus an indication of the relative gain of each channel independent of DC offset and was used to equalize the gains so that the data from all three channels could be combined into a common record.

The Tape Count Column indicates the reading of the footage counter on the tape recorder for roughtly locating the beginning of the data. Raw data was transferred to floppy disks which were nnumbered sequentially from 1 through 61. Each disk holds approximately 25 records of data. Several signatures were long enough to require two disks. As many as three disks (four disk drives, one of which was reserved for system control, were available to the system) could have been loaded without manual intervention (exchanging empty disks for full ones). Once on disk, the data were reviewed on the cathode-ray tube (CRT) display and the actual beginning of meaningful data logged in terms of Disk Drive Number (1, 2 or 3), Disk Track Number (o through 76) and bytes offset from the beginning of the track (0 through 3327). Certain specific events were then located within a signature record for the time domain and frequency domain (FFT) analysis of Section 4.3. These events were transferred to separate disks which are logged in the FFT Data Disk Number Column, with starting point notation as for the raw data.

Because of a shortage of disks, some disks were reused for FFT Data Disks after the specific event of interest had been transferred, or after a "bad data" determination had been made. Such disks could be regenerated by making a new tape-to-disk transfer from the analog tapes.

TAPE S/N: 583356119
DATE: 4103

SENSITIVITY

	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.9916	0.99[illegible]4	[illegible]
	0.4976	0.5029	0.4[illegible]
	-0.4975	-0.5005	-0.4[illegible]12
	-0.9912	-0.9995	[illegible]
SCALING FACTORS:	0.4932	0.4[illegible]5	[illegible]

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 4103 TIME: 11:17:23 FFT TIME: 11:17:27	244	1	1 37 240	61	1 14 124[illegible]
DATE: 4103 TIME: 11:35:16	370	2	1 57 904		
DATE: 4103 TIME: 11:40:33	450	3	1 50 1056		
DATE: 4103 TIME: 12:52:23	520	7≠8			
DATE: 4103 TIME: 14:15:00	732	4	1 47 1030		
DATE: 4103 TIME: 15:03:55	838	5	1 39 1682		
DATE: 4103 TIME: 15:13:41	907	6	1 59 1266		
DATE: 4103 TIME: 15:15:35	927	12			

	SENSITIVITY		
	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.3746	0.[illegible]	[illegible]
	0.4702	0.5[illegible]	[illegible]
	-0.4731	-0.5[illegible]	-0.4[illegible]
	-0.4714	-0.[illegible]	-0.[illegible]
SCALING FACTORS:	0.47[illegible]	0.4[illegible]	0.4[illegible]

TAPE S/N: [illegible]

DATE: 4805

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:	
DATE: 4805 TIME: 15:48:25 FFT TIME: 15:48:47	240	9	1 52 122	1	1 5 450	
DATE: 4805 TIME: 16:03:41	294	10	1 60 1114			CAL DATA
DATE: 4805 TIME: 16:08:11	375	11	1 69 3164			CAL DATA
DATE: TIME:						
DATE: TIME:						
DATE: TIME:						
DATE: TIME:						
DATE: TIME:						

SENSITIVITY

TAPE S/N: 8930891006

DATE: 5002 - 5104

	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.9810	0.9916	[illegible]
	0.4960	0.5020	[illegible]
	-0.4910	-0.4990	[illegible]
	-0.9820	-0.9910	[illegible]
SCALING FACTORS:	0.4902	[illegible]	0.4910

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 5002 TIME: 15:24:21 FFT TIME: 15:24:42	160	13	1 71 600	9	1 9 2413
DATE: 5002 TIME: 15:28:45	317	14	1 70 1290		
DATE: 5002 TIME: 15:49:57	400	38	1 75 960		
DATE: 5002 TIME: 15:52:14	510	17	1 34 2544		
DATE: TIME:					
DATE: 5104 TIME: 13:12:16 FFT TIME: 13:12:38	1000	18	1 52 1222	11	1 1 1203
DATE: 5104 TIME: 13:47:36	1252	19	2 1 440		
DATE: 5104 TIME: 13:58:01	1344	20	1 20 2110		

BAD DATA

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 5104 TIME: 14:21:32	1400	21	1 54 1354		
DATE: 5104 TIME: 14:22:36	1423	22	1 2[illegible] 1694		
DATE: 5104 TIME: 14:30:22 FFT TIME: 14:30:40	1549	15	1 75 1472	10	1 1 1076
DATE: 5104 TIME: 14:33:21 FT TIME: 14:33:41	1649	25	1 51 1074	1[illegible]	1 1 2[illegible]
DATE: 5104 TIME: 15:03:56	1712	26	1 46 2427		
DATE: 5104 TIME: 15:21:43	1790	27	2 69 214		
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					

TAPE S/N: 3952012023

DATE: 3703 - 4003

SENSITIVITY	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.9254	0.9925	0.[illegible]
	0.4950	0.4978	0.4[illegible]
	-0.4927	-0.4937	-0.4[illegible]
	-0.9920	-0.[illegible]	-0.[illegible]
SCALING FACTORS:	0.4919	0.4911	0.4[illegible]5

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 3703 TIME: 15:29:18	1103	28	1 19 2758		
DATE: 3703 TIME: 15:29:45	1185				
DATE: 3703 TIME: 15:30:53	1220	29	1 29 1277		
DATE: 3703 TIME: 15:53:18	1270	30	1 41 204		
DATE: 3703 TIME: 15:54:21 FFT TIME: 15:54:27	1342	34	1 25 244	32	1 1 33[illegible]
DATE: 3703 TIME: 15:57:58	1387	32 & 33	2 69 1936		
DATE: 3703 TIME: 16:24:25	1524	35	1 32 2448		
DATE: TIME:					

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 4003 TIME: 14:19:00	1586	36	1 23 2150		
DATE: 4003 TIME: 14:24:03 FFT TIME: 14:24:25	1630	37	1 51 374	35	1 1 534
DATE: 4003 TIME: 15:02:00	1694	16	1 22 1376		
DATE: 4003 TIME: 15:20:40	1765	23	1 24 2754		
DATE: 4003 TIME: 15:30:19	1832	24	1 26 1574		
DATE: 4003 TIME: 15:32:31	1889	39	1 46 726		
DATE: 4003 TIME: 16:12:42	1950	40	1 24 3074		
DATE: 4003 TIME: 16:15:14	2017	41	1 19 1828		
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					

TAPE S/N: [illegible]2[illegible]12[illegible]7

DATE: 4302 - 4402

SENSITIVITY

	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.[illegible]	0.[illegible]3	[illegible]
	0.4[illegible]	0.5[illegible]2[illegible]	0.4[illegible]3
	-0.4[illegible]1	-0.4[illegible]	-0.4[illegible]2[illegible]
	-0.9[illegible]	-0.[illegible]	-0.[illegible]24
SCALING FACTORS:	0.4[illegible]2[illegible]	0.4[illegible]2[illegible]	[illegible]

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 4302 TIME: 13:14:00 FFT TIME: 13:14:01	285	42	1 25 2028	33	1 5 26[illegible]
DATE: 4302 TIME: 13:14:58	333	43 & 45	2 24 1264		
DATE: 4302 TIME: 13:20:00	429	46	1 10 3064		
DATE: TIME:					
DATE: 4402 TIME: 10:44:39 FFT TIME: 10:45:03	464	50	1 71 2032	24	1 5 1612
DATE: 4402 TIME: 13:45:00 FFT TIME: 13:45:10	584	47	1 57 3102	26	1 4 1962
DATE: 4402 TIME: 13:46:00	662	51	1 75 848		
DATE: 4402 TIME: 14:04:38 FFT TIME: 14:04:42	758	52 & 53	2 42 3326	27	1 13 1310

TAPE S/N: 65415920[illegible]
DATE: 4903-5003-5004

	SENSITIVITY		
	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
		0.[illegible]	0.[illegible]
		0.5153	0.4[illegible]
		-0.5[illegible]	-0.4[illegible]
	-1.0000	-0.[illegible]	-0.[illegible]
SCALING FACTORS:	0.4927	0.4[illegible]	0.4[illegible]7

↑ = $\frac{HI+LO}{2}$

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 4903 TIME: 15:17:55	267	54	1 7 3027		
DATE: 4903 TIME: 15:21:22	347	47	1 73 1212		
DATE: 4903 TIME: 15:23:54	429	55	1 57 2192		
DATE: 4903 TIME: 15:36:54 FFT TIME: 15:37:15	603	58	1 28 870	36	1 15 2734
DATE: TIME:					
DATE: 5003 TIME: 11:55:03	1256	59	1 16 730		
DATE: 5003 TIME: 11:58:12 FFT TIME: 11:58:19	1403	60	1 10 3277	21	1 4 1914
DATE: TIME:					

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 5004 TIME: 12:16:12	1466	62	1 74 [illegible]		
DATE: 5004 TIME: 12:24:00 FFT TIME: 12:24:08	15[illegible]2	56	1 65 31[illegible]	23	1 1 2[illegible]
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					

SENSITIVITY

TAPE S/N: 3[illegible]52[illegible]71[illegible]1

DATE: 0002

	X(0.1) MID	X(0.01) HIGH	X(1.0) LOW
	0.9775	0.9941	[illegible]
	0.4943	0.5039	[illegible]82
	-0.4955	-0.5035	-0.4953
	-0.9929	-0.9902	[illegible]
SCALING FACTORS:	0.4936	[illegible]	[illegible]

	TAPE COUNT	RAW DATA DISK #	DRIVE: TRACK: OFFSET:	FFT DATA DISK #	DRIVE: TRACK: OFFSET:
DATE: 0002 TIME: 13:47:52 FFT TIME: 13:47:56		61	1 26 441	57	1 3 1346
DATE: 0002 TIME: 13:55:47					
DATE: 0002 TIME: 13:59:37					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					
DATE: TIME:					

APPENDIX IV

SOFTWARE LISTING

```
;                 PROG: B:SSBOOT.ASM


; B:SSBOOT.ASM IS THE BOOT ROUTINE FOR THE SSS FIELD TEST
; SOFTWARE IT INITIALISES THE MDS AND MOVES THE PROGRAM
; IN ROM TO LOCATION 4000 RAM AND JUMPS TO 4000
;
CRTC    EQU     0F7H    ; CRT USART CONTROL PORT
TTYC    EQU     0F5H    ; TTY USART CONTROL PORT
CRTM    EQU     0CEH    ; MODE FOR CRT USART
TTYM    EQU     0CEH    ; MODE FOR TTY USART
UCMD    EQU     027H    ; COMMAND WORD FOR BOTH USARTS
PSIZE   EQU    1100H    ; SIZE OF PROMS
REVERT  EQU     0FDH    ; PIC REVERT PORT
MASK    EQU     0FCH    ; PIC MASK PORT
ICON    EQU     0F3H    ; INTERRUPT CONTROL PORT


EXTRN   MAIN01,TTYINT

BASE  : CSEG
        JMP     INIT-BASE          ; JUMP TO INITIALISATION
        DB      081H               ; I/O STATUS BYTE

        ORG     BASE+018H          ; LOC OF INTVECT 3
        JMP     TTYINT             ;

        ORG     BASE+040H          ; BOOT ROUTINE IS HERE
        ;PROGRAM INTERRUPT CONTROLLER
INIT  : DI                         ; DISABLE INTERRUPT SYSTEM
        MVI     A,012H             ; INITIALISE COMMAND
        OUT     REVERT
        XRA     A
        XRA     A
        OUT     MASK
        CMA                        ; INITIAL MASK =0FFH
        OUT     MASK
        CMA                        ; A=0
        OUT     ICON

        ; PROGRAM I/O DEVICES

        MVI     A,CRTM             ; CRT MODE
        OUT     CRTC
        MVI     A,TTYM             ; TTY MODE
        OUT     TTYC
        MVI     A,UCMD             ; CRT AND TTY COMMAND WORD
        OUT     CRTC
        OUT     TTYC
```

```
MOVE   :
        LXI     H,MAIN01          ; DESTINATION POINTER
        LXI     D,START-BASE      ; SOURCE POINTER
        LXI     B,PSIZE
MOVE1  :
        LDAX    D                 ; GET BYTE FROM SOURCE
        MOV     M,A               ; PUT IN DESTINATION
        INX     H                 ; INC POINTERS
        INX     D
        DCX     B                 ; DCR BYTE COUNT
        MOV     A,C               ; TEST FOR DONE
        ORA     B
        JNZ     MOVE1-BASE        ; NOT DONE
        JMP     MAIN01

START   EQU     $
```

```
;                   PROG: MAIN01.ASM

;       MAIN01.ASM IS THE MAIN PROGRAM IN THE DATA AQUISITION
;SYSTEM.

PUBLIC  CALCMD,UPDATE,MAIN01
EXTRN   INITAL,TIMEIN,VECTCD,COCMMD,CRTTIM,ENDSEC
EXTRN   CTINIT,SINTR2,CONVRT,CLSCRN

MAIN01: CSEG
        LXI  SP,STACK0+099H; POINT SP AT TOP OF STACK SPACE

        CALL CTINIT     ; INIT 8255 FOR TAPE RECORDER CONTROL
        CALL INITAL     ; INITIALISES VALUES WHERE NECESSARY
        CALL CLSCRN     ; CLEAR THE SCREEN
        CALL TIMEIN     ; FIND OUT WHAT TIME IT IS
        CALL SINTR2     ; INITIALISE THE CONVERTER
        EI              ; ENABLE INTERRUPTS
        OUT     0F4H    ; WRITE 1 CHR TO TTY PORT
MAIN  : LHLD    VECTCD  ; PUT COMMAND LOCATION IN HL
        PCHL            ; PASS CONTROL TO THAT LOCATION

CALCMD: CALL    COCMMD  ; CHECK FOR CONSOLE COMMAND
UPDATE: CALL    CRTTIM  ; UPDATE TIME FOR CRT DISPLAY
        CALL    CONVRT  ; CONVRT TIME FOR TAPE STORAGE
        CALL    ENDSEC  ; WAIT UNTIL END OF SECOND
        JMP     MAIN    ; LOOP BACK TO MAIN

STACK0: DSEG
        DS      0100H   ; SAVE 256 BYTES FOR STACK
```

```
;                        PROGRAM: TIMEIN.ASM

;       TIMEIN.ASM GETS THE TIME FROM THE OPERATOR AND
;STORES IT IN SECOND/MINUTE/HOUR/DAY

PUBLIC  TIMEIN
EXTRN   WRDOUT,HEXIN
EXTRN   SECOND,MINUTE,HOUR,DAY

TIMEIN: CSEG    ; THIS ROUTINE GETS THE TIME
                ; IT IS THE FRONT END ROUTINE

        LXI     H,INTRO         ; GET ADDR OF 1RST MSG
        XCHG                    ; CANCEL 1RST XCHG IN GETTIM
        CALL    GETTIM          ; WRITE MSG AND GET DAY
        SHLD    DAY             ; STORE IN DAY
        CALL    GETTIM
        STA     HOUR
        CALL    GETTIM
        STA     MINUTE
        CALL    GETTIM
        STA     SECOND
    RET

INTRO : DB      'ENTER TIME'
        DW       CRLF
        DB      'DATE:$'
        DW       CRLF
        DB      'HOUR:$'
        DW       CRLF
        DB      'MINUTE:$'
        DW       CRLF
        DB      'SECOND:$'

GETTIM: XCHG            ; LOC OF 1RST LETTER IS IN DE
        CALL    WRDOUT  ; WRITE MESSAGE TO TRM
        INX     H       ; POINT H TO 1RST LETTER OF NXT MSG
        XCHG            ; STORE HL IN DE
        CALL    HEXIN   ; GET TIME FROM CRT
        MOV     A,L     ; FOR ONE BYTE TIMES STORE INA ALSO
     RET                ; RETURN

CRLF    EQU     OAODH
```

```
;                   PROG: INITAL.ASM

;         INITAL.ASM INITIALISES CERTAIN SYSTEM PARAMETERS, WHICH
;ARE STORED IN THE DATA SEGMENT OF THE SYSTEM.

PUBLIC   INITAL,GRINIT
EXTRN    IDLE01,VECTCD,STATCD,HLDOUT,LSTCHR,TTINIT
EXTRN    HLDOUT,TTYINT,VEC1IN,VECTOR,LSTCHR,WINDUP,COUNT
EXTRN    CONFAC

INITAL:  CSEG
         LXI     H,IDLE01          ; GET LOCATION OF IDLE01
         SHLD    VECTCD            ; PUT IT IN VECTCD
         CALL    INTVAL            ; INITIALISES VALUES IN
                                   ; TTYINT
         CALL    GRINIT            ; INITIALES VALUES FOR GRAPH
         MVI     A,11000001B       ; PUT IDLE01 STATUS
         STA     STATCD            ; IN STATCD

         DI                        ; DISABLE INTERRUPTS
         CALL    TTINIT            ; INITIALISES TTY USART
         CALL    FILLUP            ; FILLS PORTION OF MEMORY
                                   ; FOR TAPEOUT WITH HOLD CHRS
         CALL    IN3VEC            ; SET UP INTERRUPT 3 VECTOR
         MVI     A,0F7H            ; WRITE THE INTERRUPT
         OUT     0FCH              ; MASK
         MVI     A,0FFH            ; RESET TTY INTERRUPT
         OUT     0F3H              ;
         RET

FILLUP:  LXI     H,HLDOUT          ; PUT 1RST LOCATION IN H
         LXI     D,LSTCHR-1        ; LAST LOCATION GOES IN DE
         MVI     C,HOLD            ; DATA IN C REGISTER
         CALL    FILL              ; FILL MEMORY WITH C
         RET

IN3VEC:  MVI     A,0C3H            ; PUT JUPM IN INT3 VECTOR
         STA     018H              ; LOCATION
         LXI     H,TTYINT          ; HL GETS ADDRESS OF TTYINT
         SHLD    0019H             ; PUTS IN NEXT 2 LOCATIONS
         RET

INTVAL:  LXI     H,WINDUP          ; GET LOCATION OF WINDUP IN
                                   ; TTYINT
         SHLD    VECTOR            ; VECTOR ALSO IN TTYINT
         SHLD    VEC1IN            ; AND VEC1IN
```

```
        LXI     H,LSTCHR-1      ; POINT COUNT TO LAST
        SHLD    COUNT           ; CHARACTER
        MVI     A,0FFH          ; PUT FF IN LAST CHARACTER
        STA     LSTCHR          ;
        RET

GRINIT: MVI     A,020H          ; SET CONFAC TO 020H
        STA     CONFAC          ;
        RET

FILL    EQU     0F9E1H          ; MON ROUT FILLS MEM W CONST
HOLD    EQU     00111000B       ;
```

```
;                PROG:SINTRC.ASM


;       CONTAINS UTILITY ROUTINES FOR CALIBRATING SINTRAC A/D D/A
; ST-732 BOARD.

PUBLIC  BASE,MUX,ADDATA,SINTR1,SINTR2
EXTRN   UPDATE,STATCD,IDLE01,VECTCD,WRDOUT
EXTRN   CLSCRN

ECHO  : CALL    CI       ; GETS CHAR AND ECHOES IT
        MOV     C,A      ;
        CALL    CO       ; OUTPUT CHARACTER
        RET

PCRLF : MVI     C,CR     ; WRITES CRLF TO CRT
        CALL    CO       ;
        MVI     C,LF     ;
        CALL    CO       ;
        RET              ;

SINTR1: CALL    CLSCRN
        LXI     H,MSG1
        CALL    WRDOUT   ; WRITE MSG1 TO TRMNAL
        CALL    NEWCHN   ; USED TO GET NEW CHANNEL IN IDLE
        JMP     UPDATE   ; TYPE CONDITION

SINTR2: CALL    CLSCRN
        LXI     H,MSG1   ; WRITE MSG1 TO TRMNAL
        CALL    WRDOUT
SINTR3  CALL    NEWCHN   ; USED TO GET NEW CHANNEL IN CALL
        JZ      SINTR3   ;
        RET              ; TYPE CONDITION

NEWCHN: CALL    SINBEG   ; INITIALISE THE A/D BOARD
        IN      CONST    ; READ CONSOLE STATUS
        ANI     RBR      ; NO INPUT THEN
        RZ               ; JUMP TO UPDATE
        CALL    DIGIN    ; CARRY INDICATES ERRONEOUS
        RC               ; INPUT VALUE
        ANI     01FH     ; TOP 2 BITS 0 INDICATES GAIN OF 1
        STA     BASE+1   ; STORE IN GAIN MUX LOCATION
        LXI     H,IDLE01; ADDR OF IDLE01 GOES IN
        SHLD    VECTCD   ; HL AND THENCE TO VECTCD
        MVI     A,0C1H   ; PUT IDLE STATUS IN
        STA     STATCD   ; STATCD
        ANA     A        ; RESET ZERO FLAG
        RET              ;
```

```
SINBEG: MVI     A,001H   ; THIS IS CONTROL WORD FOR 732 BOARD
        STA     BASE
        RET

DIGIN : CALL    CI       ; READS ONE OR TWO DIGITS
        MOV     C,A      ; STORES VALUE IN D
        CALL    NIB1     ; CNVRTS ASCII TO HEX IN A
        RC               ; OR CARRY IF INVALID CHAR
        MOV     D,A      ; STORE HEX VALUE IN D
        CALL    CO       ; ECHO CHARACTER
        MOV     A,D      ; PUT HEX VALUE BACK IN A
        RET


INITAD: MVI     A,001H   ; ENABLE CONVERSION
        STA     BASE     ; PUT 01H IN COMMAND REGISTER

MSG1  : DW      03D1BH
        DB      '  '
        DB      'CHANNEL?$'


CO      EQU     0FD3CH   ; MONITOR ROUTINE TO WRITE CHAR
CI      EQU     0FCA3H   ; MONITOR ROUTINE TO READ CHAR
BASE    EQU     0F700H   ; BASE ADDRESS OF SINETRAC
MUX     EQU     BASE+1   ; GAIN AND MUX REGISTER
ADDATA  EQU     BASE+4   ; A/D DATA REGISTER
NIB1    EQU     0FEC7H   ; MONITOR ROUTINE
CR      EQU     0DH      ; CARRIAGE RETURN
LF      EQU     0AH      ; LINE FEED
CONST   EQU     0F7H     ; CRT STATUS
RBR     EQU     002H     ; RECEIVE READY BIT ON USART
```

```
;                    PROGRAM B:TTINIT.ASM

;     THIS PROGRAM INITIALISES THE TTY USART ON THE
;MDS MONITOR BOARD.

PUBLIC  TTINIT

TTINIT: CSEG

        MVI     A,RESET ; PUT RESET COMMAND IN A
        OUT     CNTROL  ; WRITE IT TO TTY USART

        MVI     A,MODE  ; PUT MODE WORD IN A
        OUT     CNTROL  ; WRITE IT TO TTY USART

        MVI     A,CMMD  ; PUT COMMAND WORD IN A
        OUT     CNTROL  ; WRITE IT TO TTY USART
        RET

RESET   EQU     01000000B
MODE    EQU     01000110B
CMMD    EQU     00110101B

STATUS  EQU     0F5H
CNTROL  EQU     0F5H
DATA    EQU     0F4H
```

```
PUBLIC  UPDATE,STATCD,IDLE01,VECTCD
EXTRN   NEWCHN

UPDATE  JMP     NEWCHN  ;

IDLE01  DS      2       ;
VECTCD  DS      2       ;
STATCD  DS      1       ;
```

```
;       PROG: FDRCRD.ASM.

;       FDRCRD.ASM TELLS THE TAPE RECORDER TO RECORD IN
;FORWARD.

PUBLIC  FDRCRD

FDRCRD: CSEG

        RET                         ; JUST A DUMMY RIGHT NOW
```

```
;                   PROG:   COCMMD.ASM


;       COCMMD.ASM CHECKS TO SEE IF ANY CHARACTERS HAVE COME IN
;ON THE CRT.  IF SO IT INTERPRETS THEM AS COMMANDS AND STORES THE
;NEW COMMAND LOCATION IN THE COMMAND VECTOR, CMDVEC.

PUBLIC  COCMMD,VECTCD,STATCD
EXTRN   TEST01,END01,STEP,REVOID,TESTOA,MAIN01,TESTOR
EXTRN   SINTR1

COCMMD: CSEG

        IN      CRTS                ; READ CRT STATUS
        ANI     RCVBFR              ; IS RECEIVE BUFFER READY
        RZ                          ; IF NOT THEN RETURN

        IN      CRTI                ; READ THE CHARACTER
        CPI     'T'                 ; T SAYS START TEST
        JZ      TTST                ; DO TEST INIT ROUTINE
        CPI     'E'                 ; E SAYS END TEST
        JZ      ETST                ; DO TEST END ROUTINE
        CPI     'S'                 ; S SAYS STEP ROUTINE
        JZ      STST                ; DO STEP ROUTINE
        CPI     'R'                 ; R SAYS REVERSE ROUTINE
        JZ      RTST                ; DO REVERSE ROUTINE
        CPI     'F'                 ; F SAYS TESTOA ROUTINE
        JZ      FTST                ; DO FTST ROUTINE
        CPI     'C'                 ; C SAYS DO CHANNEL ROUTINE
        JZ      CTST                ; DO CTST ROUTINE
        RET                         ; IGNORE ALL OTHER CHARS

FTST  : LDA     STATCD              ; GET CURRENT COMMAND STATUS
        CPI     11000001B           ; CAN ONLY START TEST FROM IDLE
        RNZ
        LXI     H,TESTOA            ; GET LOC OF TESTOA ROUTINE
        SHLD    VECTCD              ; PUT IT IN COMMAND VECTOR
        MVI     A,11110001B         ; PUT TEST01 STATUS IN
        STA     STATCD              ; STATUS LOCATION
        RET

TTST  : LDA     STATCD              ; GET CURRENT COMMAND STATUS
        CPI     11000001B           ; CAN ONLY START TEST FROM IDLE
        RNZ
        LXI     H,TEST01            ; GET LOC OF TEST01 ROUTINE
```

```
        SHLD    VECTCD          ; PUT IT IN COMMAND VECTOR
        MVI     A,11110001B     ; PUT TEST01 STATUS IN
        STA     STATCD          ; STATUS LOCATION
        RET

ETST  : LDA     STATCD
        CPI     11000001B       ; E IN IDLE MEANS START OVER
        JNZ     ETST1           ;
        DI                      ; JUMP TO MAIN01
        JMP     MAIN01          ;
        RET

ETST1 : LDA     STATCD          ; GET CURRENT COMMAND STATUS
        CPI     11110000B       ; ONLY TEST STATUS=>11110000
        RC                      ; ELSE RETURN CANT END A TEST
                                ; THAT HAS NOT STARTED
        LXI     H,END01         ; GET LOC OF END01 ROUTINE
        SHLD    VECTCD          ; PUT IT IN COMMAND VECTOR
        MVI     A,1110001B      ; PUT END01 STATUS IN
        STA     STATCD          ; STATUS LOCATION
        RET

STST  : LDA     STATCD          ; GET CURRENT COMMAND STATUS
        CPI     11000001B       ; CAN ONLY START STEP FROM IDLE
        RNZ
        LXI     H,STEP          ; GET LOCATION OF STEP ROUTINE
        SHLD    VECTCD          ; PUT IT IN COMMAND VECTOR
        MVI     A,10000001B     ; PUT STEP STATUS IN
        STA     STATCD          ; STATUS LOCATION
        RET

RTST  : LDA     STATCD          ; GET CURRENT COMMAND STATUS
        CPI     11000001B       ; CAN ONLY START TESTOR FROM
        RNZ                     ; IDLE
        LXI     H,TESTOR        ; GET LOCATION OF TESTOR ROUTINE
        SHLD    VECTCD          ; PUT IT IN VECTCD
        MVI     A,11110001B     ; PUT TESTOR STATUS IN STATCD
        STA     STATCD          ;
        RET                     ;

CTST  : LDA     STATCD
        CPI     11000001B       ; CAN ONLY DO CHANNEL FROM IDLE
        RNZ
        LXI     H,SINTR1
        SHLD    VECTCD          ;
        MVI     A,11000010B
        STA     STATCD
        RET


VECT01: DSEG

VECTCD: DS      02H             ; VECCMD TELLS THE PROGRAM
                                ; WHERE TO JUMP SO IT WILL BE
                                ; EXECUTING THE CURRENT COMMAND
```

```
STATCD: DS      01H              ; STATCD TELLS WHAT THE CURRENT
                                 ; COMMAN IS PLUS ITS STATUS
                                 ; BITS 7-4 GIVE THE COMMAND
                                 ; BITS 3-0 GIVE THE STATUS
                                 ; HEREWITH IS A LIST OF COMMANDS
                                 ; AND STATUS
; 11000001:  IDLING

; 11110001:  JUST RECEIVED TEST COMMAND
; 11110010:  WAITING FOR PHASELOCK SIGNAL
; 11110011:  FIRST TEST FRAME
; 11110100:  TESTING

; 11100000:  END COMMAND RECEIVED
; 10000000:  BACKUP
; 10000001:  STEP

CRTS     EQU    0F7H
RCVBFR   EQU    002H
CRTI     EQU    0F6H
```

```
;                  PROG: B:BEGTIM.ASM

;       B:BEGTIM GETS THE CURRENT TIME IN THE START TIME FOR
;A TEST.

PUBLIC  BEGTIM
EXTRN   SECOND,DAY,BEGSEC

BEGTIM: CSEG
        LXI     B,BEGSEC        ; BC IS DESTINATION
        LXI     D,(DAY+1)       ; DE IS SOURCE END
        LXI     H,SECOND        ; HL IS SOURCE START POINT
        CALL    MVO             ; CALL MONITOR MOVE ROUTINE
        RET

MVO     EQU     0FA85H          ; LOCATION OF MONITOR MOVE
                                ; ROUTINE
```

```
;                  PROG: TABLE.ASM

;       TABLE.ASM IS A TABLE OF CONVERSION VALUES FROM
;THE DIGITAL INPUT OF AN ANALOG TO DIGITAL CONVERTER
;TO LOCATIONS ON A CRT SCREEN.

PUBLIC  TABLE

TABLE : CSEG

T00000: DB      '               '          ;1
T00010: DB      '               '          ;1
T00020: DB      '          '               ;1
T00028: DB      '     '                    ;1
T00033: DB      '!!!!!'                    ;2
T00038: DB      '"""""'                    ;3
T00043: DB      '#####'                    ;4
T00048: DB      '$$$$$'                    ;5
T00053: DB      '%%%%%'                    ;6
T00058: DB      '&&&&&'                    ;7
T00063: DB      027H,027H,027H,027H,027H;8
T00068: DB      '((((('                    ;9
T00073: DB      ')))))'                    ;10
T00078: DB      '*****'                    ;11
T00083: DB      '+++++'                    ;12
T00088: DB      02CH,02CH,02CH,02CH,02CH;13
T00093: DB      '-----'                    ;14
T00098: DB      '.....'                    ;15
T00103: DB      '/////'                    ;16
T00108: DB      '00000'                    ;17
T00113: DB      '11111'                    ;18
T00118: DB      '22222'                    ;19
T00123: DB      '33333'                    ;20
T00128: DB      '33333'                    ;20
T00133: DB      '22222'                    ;19
T00138: DB      '11111'                    ;18
T00143: DB      '00000'                    ;17
T00148: DB      '/////'                    ;16
T00153: DB      '.....'                    ;15
T00158: DB      '-----'                    ;14
T00163: DB      02CH,02CH,02CH,02CH,02CH;13
T00168: DB      '+++++'                    ;12
T00173: DB      '*****'                    ;11
T00178: DB      ')))))'                    ;10
T00183: DB      '((((('                    ;9
T00188: DB      027H,027H,027H,027H,027H;8
T00193: DB      '&&&&&'                    ;7
T00198: DB      '%%%%%'                    ;6
T00203: DB      '$$$$$'                    ;5
```

```
T00208  DB       '#####'            ;4
T00213  DB       '"""""'            ;3
T00218  DB       '!!!!!'            ;2
T00223  DB       '     '            ;1
T00228  DB       '        '         ;1
T00235  DB       '          '       ;1
T00245  DB       '          '       ;1
```

```
;                   PROG: PHLOCK.ASM

;       PHLOCK.ASM RETURNS 0 IS THE TAPE RECORDER IS UP TO
;SPEED.  OTHERWISE IT RETURNS 1.

PUBLIC  PHLOCK

PHLOCK: CSEG

        MVI     A,00H               ;  SET A EQUAL TO 0
        RET                         ; JUST A DUMMY ROUTINE NOW
```

```
;                    PROG: TEST03.ASM

;       TEST03.ASM IS IMPLEMENTED THE SECOND AFTER TEST02.ASM
;IS IMPLEMENTED FOR THE LAST TIME.  IT DETERMINES THE START
;TIME OF THE TEST AND PRINTS START AND CURRENT TIME.

PUBLIC  TEST03
EXTRN   BEGTIM,BEGOUT,CUROUT,TEST04,STATCD,VECTCD
EXTRN   UPDATE,OKUPDT

TEST03: CSEG

        CALL BEGTIM
        CALL BEGOUT
        CALL CUROUT

        LXI  H,TEST04               ; ADDR OF TEST04 GOES IN HL
        SHLD VECTCD                 ; AND THENCE TO VECTCD

        MVI  A,11110100B            ; PUT TEST04 STATUS IN A
        STA  STATCD                 ; AND THENCE TO STATCD

        CALL OKUPDT                 ; LOOP TILL OK TO UPDATE TIME
        JMP  UPDATE                 ; UPDATE IS LOCATION IN WHICH
                                    ; MAIN PROGRAM CALLS TIME
                                    ; UPDATE ROUTINE
```

```
;                  PROG: HEXOUT.ASM
;                  PROG: LBYTE

;        HEXOUT.ASM PRINTS THE CONTENTS OF HL IN HEX ON
; THE CRT


PUBLIC  HEXOUT,LBYTE



HEXOUT  CSEG                 ; STOLEN DIRECT FROM MONITOR FE7A
        MOV     A,H
        CALL    LBYTE
        MOV     A,L
        JMP     LBYTE

LBYTE : PUSH    PSW
        RRC
        RRC
        RRC
        RRC
        CALL    HXD
        POP     PSW
        JMP     HXD

HXD   : CALL    CONV
        CALL    CRTOUT
        RET


CONV  : ANI     0FH
        ADI     90H
        DAA
        ACI     40H
        DAA
        MOV     C,A
        RET


CRTOUT  EQU     0FD3CH
```

```
;                         PROGRAM: TIME.ASM

;        TIME.ASM HANDLES TIME ROUTINES FOR THE MAIN
;SSS DGP PROGRAM.

PUBLIC  CRTTIM,DUMVAR,THRU,CONVRT
PUBLIC  SECOND,MINUTE,HOUR,DAY,BEGSEC,BEGMIN,BEGHOR,BEGDAY
EXTRN   SECOUT

TIME00: CSEG

CONVRT:            ; CONVERT SECONDS STORED AS BYTE VALUES
                   ; TO ONE BIT PER BYTE

        LXI     H,SECOUT          ; PUT SECOUT START ADDRESS
                                  ; IN HL
        MVI     C,10000000B       ; C KEEPS TRACK OF BIT TO
                                  ; BE CONVERTED INIT AT 1
        XCHG                      ; KEEP SECOUT ADDR IN DE
        LXI     H,SECOND          ; PUT SECINT START ADDRESS
                                  ; IN
CONV1 : MOV     A,C               ; PUT C IN A
        ANA     M                 ; MASK OFF CURRENT BIT TO
                                  ; BE CONVERTED
        JZ      CZERO             ; IF IT IS A ZERO CONVERT
                                  ; IT TO A ZERO BYTE ELSE
                                  ; CONVERT IT TO A ONE BYTE

CONE  : XCHG                      ; GET BYTE ADDRESS BACK
        MVI     M,ONE             ; PUT IN A ONE CHAR
        JMP     AGAIN             ; GO TO LOOPEND CLEANUP
                                  ; ROUTINE

CZERO : XCHG                      ; GET BYTE ADDRESS BACK
        MVI     M,ZERO            ; PUT IN ZERO CHAR

AGAIN : MOV     A,C               ; C KEEPS TRACK OF BITS
        RRC                       ; IS LO ORDER BIT BEING
        MOV     C,A               ; ADDRESSED
        CPI     080H              ; IF SO THEN SET UP FOR
        JNZ     CONTIN            ; NEW BYTE TO BE OUTPUT

NEWBYT: INX     D                 ; D NOW CONTAINS THE ADDRESS
                                  ; OF NEW BYTE TO BE CONVERTED
        LDA     THRU              ; PUT LO ORDER ADDRESS OF THRU
                                  ; IN A CMP WITH E
        CMP     E                 ;
```

```
         JNZ      CONTIN             ; IF SAME THAN WE ARE DON
         RET                         ; SO GO HOME ELSE KEEP GOING


CONTIN:  INX      H                  ; H CONTAINS ADDR OF NEXT
                                     ; CONVERTED BYTE
         XCHG                        ; SWITCH H AND D
         JMP      CONV1              ;


ZERO     EQU      00111110B
HOLD     EQU      00111000B
ONE      EQU      00100000B


CRTTIM:  ; UPDATES TIME FOR CRT DISPLAY IN
         ; DAY HOURS MINUTES SECONDS


ADJSEC:  LDA      SECOND   ; GET SECOND VALUE
         INR      A        ; ADD 1
         STC               ; SET CARRY FLAG
         CMC               ; NOW RESET IT
         DAA               ; CONVERT TO BCD
         CPI      060H     ; IF SIXTY SECONDS
         JZ       ADJMIN   ; THEN ADJUST MINUTES
         STA      SECOND   ; ELSE JUST ADJUST
         RET               ; SECONDS

ADJMIN:  MVI      A,00H    ; SET SECONDS BACK TO
         STA      SECOND   ; ZERO
         LDA      MINUTE   ; GET MINUTE VALUE
         INR      A        ; ADD 1
         STC               ; SET CARRY FLAG
         CMC               ; NOW RESET IT
         DAA               ; CONVRT TO BCD
         CPI      060H     ; IF SIXTY MINUTES
         JZ       ADJHR    ; THEN ADJUST HOUR
         STA      MINUTE   ; ELSE JUST ADJUST
         RET               ; MINUTES


ADJHR :  MVI      A,00H    ; SET MINUTES BACK TO
         STA      MINUTE   ; ZERO
         LDA      HOUR     ; GET HOUR VALUE
         INR      A        ; ADD 1
         STA      HOUR     ; ADJ HOUR
         RET               ;
         NOP
         NOP
         NOP

TIME01:  DSEG
```

```
SECOND: DS      1       ; BCD VALUE OF SECONDS
MINUTE: DS      1       ; BCD VALUE OF MINUTE
HOUR  : DS      1       ; BCD VALUE OF HOUR
DAY   : DS      2       ; BCD VALUE OF DAY
BEGSEC: DS      1       ; BEGINNING SEC     BCD OF TEST
BEGMIN: DS      1       ; BEGINNING MIN     BCD OF TEST
BEGHOR: DS      1       ; BEGINNING HOUR    BCD OF TEST
BEGDAY: DS      2       ; BEGINNING DAY     BCD OF TEST
DUMVAR: DW      00H     ; DUMMYVARIABLE

TIME02: CSEG

THRU  : DW      (DAY+2) ; POINTS TO BYTE AFTER ALL TIME INFO
```

```
;                       PROG: TOUT01.ASM


;       TIMOUT.ASM WRITES THE CURRENT TIME TO THE CRT.


PUBLIC  TPOUT
EXTRN   WRDOUT,HEXOUT,LBYTE
EXTRN   RSEC,RMIN,RHOUR,RDAY

TOUT01  CSEG                        ; H MUST POINT TO DAY

TPOUT : LXI     H,LOC1             ; PUT WORD ADDR IN DE
        CALL    WRDOUT             ; AND WRITE THEM OUT
        LHLD    RDAY               ;
        CALL    HEXOUT             ;
        LHLD    RMIN               ;
        CALL    HEXOUT             ;
        LDA     RSEC               ;
        CALL    LBYTE              ;
        RET



LOC1  : DB      CLRCHR              ; CLEAR SCREEN CHARACTER
        DB      00                  ; BLANKS BECAUSE CLEAR
        DB      00                  ; SCREEN TAKES TIME
        DB      00
        DB      00
        DB      00
        DB      00
        DB      00
        DB      ESCAPE              ; SECOND TWO CHARS PREP CRT
        DB      EQUALS              ; FOR XY COORDS OF CURSOR
        DB      036H                ; Y COORD OF 23
        DB      049H                ; X COORD OF 42
        DB      '$'

ESCAPE  EQU     01BH                ; ESCAPE CHAR
EQUALS  EQU     03DH                ; EQUALS CHAR
CLRCHR  EQU     01AH                ; CLEAR SCREEN CHARACTER
```

```
;                    PROG: ENDSEC.ASM

;        ENDSEC.ASM LOOPS UNTIL A SECOND IS OVER.  IT CHECKS
;WITH THE INTERRUPT ROUTINE, UNTIL THE INTERRUPT ROUTINE
;DETERMINES A SECOND IS OVER.

PUBLIC  ENDSEC
EXTRN   DUNYET

ENDSEC: CSEG
        LDA     DUNYET  ; PUT DUNYET IN A
        CPI     01H     ; IF 1 THEN SECOND IS OVER
        JNZ     ENDSEC  ; ELSE LOOP SOME MORE

        XRA     A       ; RESET DUNYET
        STA     DUNYET  ;
        RET             ;
```

```
;               PROG: TRMNAL.ASM
;
;
;       THIS PROG CONTAINS THE ROUTINES WHICH DIRECTLY
;INTERFACE WITH THE CRT.

PUBLIC  HEXIN,WRDOUT

TRMNAL: CSEG


HEXIN :                 ; HEXIN READS A 4 OR FEWER DIGIT HEX NUMBER
                        ; FROM THE KEYBOARD AND STORES IT IN THE
                        ; HL REGISTER
HEXIN1: LXI     H,0
HEXIN2: CALL    CRTIN1          ; READS CHAR FROM  CRT
        CPI     CR              ; IS CHAR A CARRIAGE RETURN
        RZ                      ; IF SO THEN RETURN
        CPI     07FH            ; IS IT A RUB CHAR
        JZ      BACKUP          ; IF SO THEN BACKUP A CHAR
        CALL    NIB1            ; MON ROUTINE WHICH CNVRTS
        JC      HEXIN2          ; ASCII CHAR TO HEX NIBBLE OR
                                ; SETS CARRY IF INVALID CHAR

        DAD     H               ;  MULT H BY 16
        DAD     H               ;
        DAD     H               ;
        DAD     H               ;
PUSH    PSW                     ;
PUSH    H                       ;
CALL    HXD1                    ; WRITES CHAR BACK TO CRT
POP     H                       ;
POP     PSW                     ;
ORA     L                       ; PUT BOTTOM NIBBLE OF
MOV     L,A                     ; A IN BOTTOM NIBBLE OF L
JMP     HEXIN2                  ; GRAB ANOTHER CHARACTER

BACKUP: CALL   ROTHLR           ; ROTATE HL RIGHT LOSE FIRST
        CALL   BACKSP           ; CHAR BACK UP A CHAR ON
        JMP    HEXIN2           ; ON SCREEN


ROTHLR: MOV     A,L             ; ROTATES HL REG ONE
        ANI     0F0H            ; HEX DIG TO RIGHT
        CALL    ROT4
        MOV     L,A
        MOV     A,H
        CALL    ROT4
        MOV     H,A
```

```
        ANI     0F0H
        ORA     L
        MOV     L,A
        MOV     A,H
        ANI     0FH
        MOV     H,A
    RET

ROT4   : RRC                          ; ROTATES A RIGHT 4 TIMES
        RRC
        RRC
        RRC
    RET

BACKSP: MVI C,08H                     ; WRITE A BACKSPACE
        CALL CRTOUT
        MVI C,020H                    ; WRITE A SPACE
        CALL CRTOUT
        MVI C,08H                     ; WRITE A BACKSPACE
        CALL CRTOUT
        RET


WRDOUT:                               ; WRITES CHR STRNG TO CRT
                                      ; STOPS AT DOLLAR SIGN
                                      ; STRTNG ADDR PASSED IN HL
        MOV     A,M                   ; GET CHAR
        CPI     '$'                   ; A=DOLLAR SIGN
        JZ      WRDDON                ; WE ARE DONE
        MOV     C,A                   ; ELSE MOV A TO C
        CALL    CRTOUT                ; AND OUT C GOES
        INX     H                     ; GET ADDR OF NEXT CHAR
        JMP     WRDOUT                ;
WRDDON: RET


CRTIN1  EQU     0FC9CH                ; MONITOR ROUTINE
NIB1    EQU     0FEC7H                ; MONITOR ROUTINE
HXD1    EQU     0FE74H                ; MONITOR ROUTINE
CRTOUT  EQU     0FD3CH                ; MONITOR ROUTINE
CR      EQU     0DH                   ; CRRGE RTN CHARACTER
```

```
;                 PROG: TEST01.ASM


;       TEST01.ASM IS IMPLEMENTED THE FIRST SECOND AFTER A TEST
;COMMAND IS GIVEN.  IT PUTS THE TAPE RECORDER IN RECORDER MODE,
;AND PUTS THE LOCATION OF TEST02.ASM IN VECTCD SO THE NEXT
;SECOND TEST02.ASM IS IMPLEMENTED IN THE COMMAND SECTION OF
;THE MAIN ROUTINE

PUBLIC  TEST01,TEST02,TEST03,TEST04,REVOID,TESTOA,TESTOR
EXTRN   FDRCRD,VECTCD,STATCD,UPDATE
EXTRN   OKUPDT,GPHCNT,FSTCNT,PHLOCK
EXTRN   BEGTIM,BEGOUT,CUROUT,GRAPH,CALCMD
EXTRN   REVRSE,IDLE01,FIRST,VECTOR,ADRTN,VEC1IN
EXTRN   ADCNT,LSTCNT,FDPLAY,NORMAL,CLSCRN


TEST01: CSEG
        LXI     H,(FSTCNT-1)     ; GET LOCATION OF 1RST VALUE
        SHLD    GPHCNT           ; TO GRAPH AND STORE IN GPHCNT
        CALL    FDRCRD           ; CALL FORWARD RECORD ROUTINE
        LXI     H,TEST02         ; ADDR OF TEST02 GOES IN HL
        SHLD    VECTCD           ; AND THENCE TO VECTCD
        MVI     A,11110010B      ; PUT TEST02 STATUS IN A
        STA     STATCD           ; AND THENCE TO STATCD
        CALL    OKUPDT           ; LOOPS UNTIL OK TO UPDATE
                                 ; TIME
        JMP     UPDATE           ; UPDATE IS LOCATION IN
                                 ; MAIN PROGRAM WHICH CALLS
                                 ; TIME UPDATE ROUTINE

TESTOA: LXI     H,(FSTCNT-1)     ; GET LOCATION OF 1RST VALUE
        SHLD    GPHCNT           ; TO GRAPH AND STORE IN GPHCNT
        CALL    FDPLAY           ; CALL FORWARD PLAY ROUTINE
        LXI     H,TEST02         ; SHLD  VECTCD
        SHLD    VECTCD           ;
        MVI     A,11110010B      ; PUT TEST02 STATUS IN A
        STA     STATCD           ; AND THENCE TO STATCD
        CALL    OKUPDT           ; LOOPS UNTIL OK TO UPDATE
                                 ; TIME
        JMP     UPDATE           ; UPDATE IS LOCATION IN MAIN
                                 ; PROGRAM WHICH CALLS TIME
                                 ; UPDATE ROUTINE

TESTOR: LXI     H,(FSTCNT-1)     ; GET LOCATION OF OF 1RST VAL
        SHLD    GPHCNT           ; TO GRPH STUFF IN GPHCNT
        CALL    REVRSE           ; CALL REVERSE ROUTINE
        LXI     H,TEST02         ;
        SHLD    VECTCD           ;
```

```
        MVI     A,11110010B     ; PUT TEST02 STATUS IN A
        STA     STATCD          ; AND THENCE TO STATCD
        CALL    OKUPDT          ; LOOPS UNTIL OK TO
                                ; UPDATE TIME
        JMP     UPDATE          ; UPDATE IS LOCATION IN MAIN
                                ; PROG TO CALL TIME UPDATE
                                ; ROUTINE

TEST02: CALL    PHLOCK          ; PHLOCK SETS A=0 IF RECORDER
        ANA     A               ; UP TO SPEED ELSE A=1
        JNZ     THRU02          ;
TEMPOR: LXI     H,TEST03        ; ADDR OF TEST 03 GOES IN
        SHLD    VECTCD          ; HL AND THENCE TO VECTCD
        MVI     A,11110011B     ; PUT TEST03 STATUS IN A
        STA     STATCD          ; THENCE TO STATCD

        ; LINE IS RESERVED TO START THE A TO D CONVERSION

        CALL    OKUPDT          ; LOOP TILL OK TO UPDATE TIME
        LXI     H,ADRTN         ; PUT FIRST IN VECTOR THIS IS
        SHLD    VEC1IN          ; FOR DATA READ IN TTYINT PROG
        LXI     H,FSTCNT        ; PUT FSTCNT ADDR IN
        SHLD    ADCNT           ; ADCNT FOR TTYINT ROUTINE
        MVI     A,011H          ; STORE END CHAR IN LSTCNT
        STA     LSTCNT          ; FOR TTYINT ROUTINE
THRU02: JMP     UPDATE          ; UPDATE IS LOCATION IN MAIN
                                ; WHICH CALLS TIME UPDATE
                                ; ROUTINE


TEST03: CALL    CLSCRN
        CALL    BEGTIM
        CALL    CUROUT
        CALL    BEGOUT
        LXI     H,TEST04        ; ADDR OF TEST04 GOES IN HL
        SHLD    VECTCD          ; AND THENCE TO VECTCD
        MVI     A,11110100B     ; PUT TEST04 STATUS IN A
        STA     STATCD          ; AND THENCE TO STATCD
        CALL    NORMAL          ; SET ALL LINES TO RECORDER
        CALL    OKUPDT          ; TO NORMAL
        JMP     UPDATE

TEST04: CALL    CLSCRN
        CALL    GRAPH           ; GRAPH LAST SECOND'S ENVELOPE
        CALL    CUROUT          ; WRITE CURRENT TIME
        CALL    BEGOUT          ; WRITE STARTING TIME
        JMP     CALCMD          ; CHECKS CONSOLE FOR NEW
                                ; COMMANDS


REVOID: CALL    REVRSE          ;
        LXI     H,IDLE01        ;
        SHLD    VECTCD          ;
        MVI     A,11000001B     ;
```

```
STA     STATCD     ;
CALL    OKUPDT     ;
JMP     UPDATE     ;
```

```
;                   PROG: B:CMPARE.ASM

; B:CMPARE.ASM IS USED FOR COMPARING CURRENT TIME OFF TAPE
; WITH USER REQUESTED STOP TIME


PUBLIC  CMPARE,CFLAG
EXTRN   RDAY,DAY

CMPARE: MVI     A,00            ; 0 IN CFLAG IS NORMAL COND
        STA     CFLAG           ;
        LXI     H,(RDAY+1)      ;
        LXI     B,(DAY+1)
        CALL    CMP1            ; COMPARE 2 TIME BYTES AND
        RNZ                     ; DECREMENT POINTERS TO
        CALL    CMP1            ; NEXT 2 BYTES
        RNZ
        CALL    CMP1
        RNZ
        CALL    CMP1
        JZ      CSEC
        JC      ERROR
        RET
CSEC  : CALL    CMP1
        JC      ERROR
        JZ      EXACT
        RET

CMP1  : LDAX    B               ; COMPARE 2 BYTES AND DECRMENT
        CMP     M               ; POINTERS
        PUSH    PSW
        DCX     B
        DCX     H
        POP     PSW
        RET

ERROR:  MVI     A,01            ; 1 IN CFLAG MEANS ERROR
        STA     CFLAG
        RET

EXACT:  MVI     A,02            ; 2 IN CFLAG MEANS EXACT MATCH
        STA     CFLAG
        RET

CFLAG : DS      01H             ; USED TO RETURN STATUS
                                ; OF COMPARISON
```

```
;                   TTYINT.ASM

;        TTYINT.ASM IS THE INTERRUPT PORTION OF THE
;SSS DATA AQUISITION PROGRAM.  IT IS DRIVEN BY THE TTY
;TRANSMIT INTERRUPT LINE.  THE TTY USART IS RUNNING AT
;9600 BAUD; PUTTING OUT 8 BIT CHARACTERS, INCLUDING START
;AND STOP BITS, SO 1200 INTERRUPTS/SEC OCCUR.

PUBLIC  LSTCHR,VECTOR,WINDUP,SECOUT,FIRST,ADCNT
PUBLIC  TTYINT,VEC1IN,COUNT,HLDOUT,DUNYET,ADRTN
EXTRN   FSTCNT,LSTCNT

TTYINT: CSEG
        PUSH    PSW             ;
        PUSH    B               ;
        PUSH    D               ;
        PUSH    H               ;

        MVI     A,081H          ; RESET TTY TX INT
        OUT     0F3H            ; P. 5-23 MDS MANUAL

CORE  :                 ; COUNT IS INCREASED BY 1/1200 SEC AND
                        ; 1 CHAR IS OUTPUT TO THE TAPE USART

        MVI     A,00H           ; SEND ANTI TRIGGER SIGNAL
        OUT     080H            ; TO SCOPE
        LHLD    COUNT           ; PUT COUNT IN HL
        INX     H               ; ADD 1 AND GET CHAR TO
        MOV     A,M             ; WHICH COUNT POINTS
        CPI     0FFH            ; IS IT THE 1201ST CHAR?
        JZ      FIRST           ; NO THEN WRITE IT TO TAPE
        SHLD    COUNT           ; PUT HL IN COUNT
        OUT     0F4H            ; DUMP A CHAR TO THE USART
        LHLD    VECTOR          ; VECTOR TO COMMAND LOCATION
        PCHL

FIRST:  MVI     A,0FFH          ; SEND TRIGGER FOR SCOPE
        OUT     080H            ; TO PORT A OF 8255 CHIP
        LXI     H,SECOUT        ; LOCAT H AT FIRST TTY CHR
        MOV     A,M             ; PUT CHAR IN A
        OUT     0F4H            ; WRITE CHAR TO USART
        SHLD    COUNT           ; PUT LOCATION IN COUNT
        MVI     A,01H           ; MESSAGE TO MAIN PROG
        STA     DUNYET          ; SAYS SECOND IS DONE
        LHLD    VEC1IN          ; GET NEW COMMAND LOC
        SHLD    VECTOR          ; PUT IT IN VECTOR
        PCHL                    ; VECTOR TO COMMAND LOCATION


ADRTN:                  ;A TO D CONVERSION STARTS HERE
```

```
        LDA     0F705H              ; GET VALUE FROM 732 BRD
        LHLD    ADCNT               ; ADCNT TELLS WHERE TO
                                    ; PUT IT

POS   : CMP     M                   ; A < POS(ADCNT) SKIP TO NEG
        JC      NEG                 ;
        MOV     M,A                 ; ELSE POS(ADCNT)=A

NEG   : INX     H                   ; NEG(ADCNT) STORED 1 BYTE UP
        CMP     M                   ; A> NEG(ADCNT) SKIP TO DONE1
        JNC     DONE1               ;
        MOV     M,A                 ; ELSE NEG(ADCNT+1)=A

DONE1 : LDA     SMPCNT              ; IF SMPCNT=14 THEN 15
        CPI     0EH                 ; SAMPLES ARE TAKEN SO GO
        JZ      DONE3               ; TO DONE3 TO REINITIALISE

DONE2 : INR     A                   ; ELSE INCR SMPCNT BY 1
        STA     SMPCNT              ; AND WIND UP INT ROUTINE
        JMP     WINDUP              ;

DONE3 : MVI     A,0                 ; SET SMPCNT TO 0
        STA     SMPCNT              ;
        INX     H                   ; H IS NOW 2 LOCATIONS PAST
        SHLD    ADCNT               ; STORE H IN ADCNT
        MOV     A,M                 ; ADCNT, IF <H> HAS LSTVAL
        CPI     LSTVAL              ; IN IT THEN ADCNT MUST BE
        JNZ     WINDUP              ; REINITIALISED, ELSE GO TO
        LXI     H,FSTCNT            ; WINDUP
        SHLD    ADCNT               ;

WINDUP: EI                          ; AFTER THE ROUTINE GETS BACK
        POP     H                   ; IT ENDS UP HERE
        POP     D                   ;
        POP     B                   ;
        OUT     0FDH                ; RESTORE INT PRIORITY LEVEL
        POP     PSW                 ; P. 3-43 MDS MANUAL
     RET                            ;


;MEMORY USED FOR TAPE OUTPUT

SECOUT: DS      40D                 ; NEXT 32 CHARS
HLDOUT: DS      01160D              ; NEXT 1160 CHARS
LSTCHR: DB      0FFH                ; USED TO MARK END

COUNT : DS      02H                 ;

;MEMORY USED FOR A TO D CONVERTER
```

```
LSTVAL  EQU     011H                ; THIS VALUE IS STORED IN
                                    ; LSTCNT MARKS END OF ARRAY

ADCNT : DS      02H                 ; POINTS TO CURRENT LOCATION
                                    ; TO RECEIVE A TO D VALUE.
SMPCNT: DS      01H                 ; COUNTS NUMBER OF SAMPLES
                                    ; TAKEN MOD 15

;MESSAGE CENTER
VECTOR: DS 02H  ; THE CONTENTS OF VEC1IN ARE PASSED TO VECTOR
                ; AT START OF EACH SECOND. VECTOR DIRECTS INT
                ; ROUTINE TO PROPER COMMAND IMPLEMENTATION
VEC1IN: DS 02H  ; VEC1IN IS A MESSAGE FROM THE MAIN
                ; PROGRAM IT CONTAINS AN ADDRESS WHICH
                ; IS READ AND DUMPED INTO VECTOR+1 AT THE
                ; BEGINNING OF EACH SECOND. THIS ADDRESS
                ; DIRECTS THE INT PROG TO THE APPROPRIATE
                ; ROUTINES
DUNYET: DS 01H  ; 1 IF SECOND IS OVER ELSE ZERO
```

```
;                 PROG: CNTROL.ASM

;       CNTROL.ASM CONTAINS A GROUP OF SMALL MODULES WHICH
;CONTROL VARIOUS FUNCTIONS OF THE HONEYWELL TAPE RECORDER.


PUBLIC  CTINIT,FDPLAY,PHLOCK,NORMAL,STOPTR,FDRCRD
PUBLIC  REVRSE


CTINIT:         ; INITIALISES 8255 FOR CONTROL OF TAPE RECORDER
        MVI     A,CTWORD; PUT CONTROL WORD IN A
        OUT     CTPORT  ; AND OUT TO THE CONTROL PORT
        MVI     A,00H   ;
        OUT     PORTA   ; WRITE ALL ZEROES TO PORTA
        MVI     A,01H   ;
        OUT     PORTB   ; STOP BIT TO PORT B
        RET             ;


FDPLAY:                 ; STARTS TAPE RECORDER GOING FORWARD
        MVI     A,FWD   ; PUT FORWARD COMMAND IN A
        OUT     PORTB   ; WRITE COMMAND TO PORTA
        IN      PORTC   ; READ PORTC
        XRI     OFFH    ; NOT THE CONTENTS OF A
        ANI     FWD     ; READ RECORDER STATUS
        JZ      FDPLAY  ; IF NOT 0 THEN REPEAT UNTIL IT
        RET             ; IS 0

PHLOCK:                 ; CHECK WHETHER RECORDER IS UP TO SPEED
        IN      PORTC   ; READ PORTC
        XRI     OFFH    ; NOT CONTENTS OF A
        ANI     PHASE   ; CHECK PHASE BIT
        JZ      NOLOCK  ; IF NOT 1 THEN JUMP TO NOLOCK
        MVI     A,00H   ; ELSE RETURN  0 IN A
        RET
NOLOCK: MVI     A,01H   ; RETURN 1 IN A
        RET             ;

NORMAL: MVI     A,00H   ; NORMAL SETS ALL CONTROL LINES TO
        OUT     PORTA   ; ZERO
        OUT     PORTB   ;
        RET             ;

STOPTR: MVI     A,STOP  ; STOPS THE TAPE RECORDER
        OUT     PORTB   ;
        RET             ;

FDRCRD: MVI     A, (FWD OR REC); RECORD IN FORWARD
        OUT     PORTB   ;
        RET
```

```
REVRSE: MVI     A,REV    ; PUT REVERSE COMMAND IN A
        OUT     PORTB    ; WRITE COMMAND TO PORT B
        IN      PORTC    ; READ  PORT C
        XRI     OFFH     ; NOT THE CONTENTS OF A
        ANI     REV      ; READ RECORDER STATUS
        JZ      REVRSE   ; IF NOT ZERO THEN REPEAD UNTIL
        RET              ; IT IS ZERO

;NAME           VALUE      PORT  FUNCTION

A0      EQU     01H      ; A0    15/16
A1      EQU     02H      ; A1    1 7/8
A3      EQU     04H      ; A2    3 3/4
A4      EQU     08H      ; A3    7 1/2
A5      EQU     010H     ; A4    15
A6      EQU     020H     ; A5    30
A7      EQU     040H     ; A6    60

STOP    EQU     01H      ; B0    STOP RECORDER
FWD     EQU     02H      ; B1    FORWARD
REV     EQU     04H      ; B2    REVERSE
FF      EQU     08H      ; B3    FAST FORWARD
FR      EQU     010H     ; B4    FAST REVERSE
REC     EQU     020H     ; B5    RECORD
PHASE   EQU     040H     ; C6    PHASELOCK

CTWORD  EQU     089H     ; CONTROL WORD FOR 8255 CHIP
PORTA   EQU     080H     ; 8080 PORT ADDRESS OF PORT A
PORTB   EQU     081H     ; 8080 PORT ADDRESS OF PORT B
PORTC   EQU     082H     ; 8080 PORT ADDRESS OF PORT C
CTPORT  EQU     083H     ; 8080 PORT ADDRESS OF CONTROL PORT
```

```
;       PROG: DUMMY.ASM

;       CONTAINS SOME DUMMY VARIABLES SO TPREAD.ASM WILL
;LINK PROPERLY.

PUBLIC  EROUT,FROUT

EROUT:  DW      OFFFFH
FROUT:  DW      OFFFFH
```

```
;                   PROG: TIMOUT.ASM


;       TIMOUT.ASM WRITES THE CURRENT TIME TO THE CRT.


PUBLIC  CUROUT,BEGOUT,CLSCRN
EXTRN   WRDOUT,HEXOUT,LBYTE
EXTRN   SECOND,MINUTE,HOUR,DAY
EXTRN   BEGSEC,BEGMIN,BEGHOR,BEGDAY

TIMOUT  CSEG                            ; H MUST POINT TO DAY
        CALL    PUTTIM                  ; DE TO FRST WRD IN MSSG
        DCX     H
        DCX     H                       ; NOW H POINTS TO MIN&HR
        CALL    PUTTIM
        DCX     H                       ; NOW H POINTS TO SEC
        XCHG                            ; POINT HL TO MSG AGAIN
        CALL    WRDOUT
        XCHG
        MOV     A,M
        CALL    LBYTE
     RET


PUTTIM: XCHG                            ; SAVE TIME IN DE
        CALL    WRDOUT                  ; WRITE MESSAGE
        INX     H                       ; POINT TO NEXT LETTER IN
        XCHG                            ; IN MSG, GET TIME BACK
        PUSH    H
        MOV     C,M
        INX     H
        MOV     H,M
        MOV     L,C
        CALL    HEXOUT                  ; WRITE TIME
        POP     H
      RET

CUROUT: LXI    H,LOC1                  ; PUT WORD ADDR IN DE
        XCHG                           ; TIME ADDR IN HL
        LXI    H,DAY                   ; AND WRITE THEM OUT
        JMP    TIMOUT                  ;

LOC1   : DB     ESCAPE                  ; SECOND TWO CHARS PREF CRT
        DB      EQUALS                  ; FOR XY COORDS OF CURSOR
        DB      036H                    ; Y COORD OF 23
        DB      049H                    ; X COORD OF 42
DAYADR: DB      'CURRENT'
```

```
         DB      '- DAY $'
TIMADR:  DB      '  TIME $'
COLON :  DB      ':$'

BEGOUT:  LXI     H,LOC2          ; PUT WORD ADDR IN DE
         XCHG                    ; TIME ADDR IN HL
         LXI     H,BEGDAY        ; AND WRITE THEM OUT
         JMP     TIMOUT          ;

LOC2  :  DB      ESCAPE          ; SAME AS LOC1
         DB      EQUALS
         DB      036H            ; Y COORD OF 23
         DB      020H            ; X COORD OF 1
         DB      'INITIAL'
         DB      '- DAY $'
         DB      '  TIME $'
         DB      ':$'

CLSCRN:  LXI     H,LOC3          ; POINT H AT CHAR SEQUENCE
         CALL    WRDOUT          ; AND CLEAR SCREEN
         RET

LOC3  :  DB      CLRCHR          ; CLEAR SCREEN CHAR
         DB      '         '
         DB      '         '
         DB      ESCAPE
         DB      EQUALS
         DB      '   '
         DB      '$'



ESCAPE   EQU     01BH            ; ESCAPE CHAR
EQUALS   EQU     03DH            ; EQUALS CHAR
CLRCHR   EQU     01AH            ; CLEAR SCREEN CHARACTER
```

```
;       PROG: GRAPH.ASM

;   GETS A LIST OF CHARACTERS PUTS THEM THROUGH A
;CONVERSION TABLE AND GRAPHS THEM ON THE CRT.

PUBLIC  GRAPH,FSTCNT,LSTCNT,GPHCNT,CONFAC
EXTRN   TABLE

GRAPH : CSEG

GRAPH1: CALL    GETY            ; GET Y COORD
        CALL    OUTY            ; WRITE IT TO CRT
        CALL    OUTX            ; WRITE X TO CRT
        CALL    GETY            ; GET Y COORD
        CALL    OUTY            ; WRITE IT TO CRT
        LDA     COLUMN
        CALL    OUTX1           ; WRITE X TO CRT
        LDA     COLUMN
        CPI     079D            ; 80TH COLUMN THEN
        JZ      THRU80          ; WE ARE DONE
        CPI     0159D           ; 160TH COLUMN THEN
        JZ      THRU16          ; WE ARE DONE
        JMP     GRAPH1

THRU80: MVI     A,0D0H          ;CONVERSION FACTOR FOR COLUMNS
        STA     CONFAC
        RET

THRU16: MVI     A,0FFH          ; CLEAR ACCUMULATOR
        STA     COLUMN          ; COLUMN=0
        LXI     H,FSTCNT-1      ; GET COORDINATES OF 1RST
                                ; GRAPH POINT LESS 1
        SHLD    GPHCNT          ; PUT IN GPHCNT
        MVI     A,020H
        STA     CONFAC          ; CONVERSION FACTOR FOR
        RET                     ; COLUMNS

GETY  : LXI     B,0000H
        LHLD    GPHCNT          ; WHAT VALUE ARE WE ON
        INX     H
        SHLD    GPHCNT
        XCHG                    ; PUT CHR PTR IN DE
        LXI     H,TABLE         ; H POINTS AT TABLE BASE
        LDAX    D               ; PUT GRPH VAL IN A
        MOV     C,A             ; PUT IT IN C
        DAD     B               ; ADD IT TO TABLE BASE
```

```
        MOV     A,M                 ; GET Y VALUE FROM TABLE
        LHLD    GPHCNT              ; WHAT VALUE ARE WE ON
        MVI     B,080H              ; CLEAR A/D VALUE TO 080H
        MOV     M,B                 ;
    RET


OUTY  :
        PUSH    PSW                 ;WRITE ESCAPE AND
        MVI     A,ESCAPE            ;EQUALS TO CRT TO
        MOV     C,A                 ;PUT IT IN XY MODE
        CALL    CRTOUT              ;THEN SEND IT A
        MVI     A,EQUALS            ;AS A Y COORD
        MOV     C,A
        CALL    CRTOUT
        POP     PSW
        MOV     C,A
        CALL    CRTOUT
    RET

OUTX  : LDA     CONFAC              ; GET COLUMN CNVRSN FACTOR
        MOV     B,A                 ; STORE IN B
        LDA     COLUMN              ; GET COLUMN VALUE
        INR     A                   ; ADD 1
        STA     COLUMN              ;
        ADD     B                   ; WRITES X COORD TO
        MOV     C,A                 ; CRT THEN A CHARACTER
        CALL    CRTOUT
        MVI     A,'X'
        MOV     C,A
        CALL    CRTOUT
   RET

OUTX1 : LDA     CONFAC              ; GET COLUMN CNVRSN FACTOR
        MOV     B,A
        LDA     COLUMN              ; GET COLUMN VALUE
        ADD     B                   ; WRITES X COORD TO
        MOV     C,A
        CALL    CRTOUT              ; CRT THEN A CHARACTER
        MVI     A,'O'
        MOV     C,A
        CALL    CRTOUT
   RET

COLUMN  DB      OFFH                ; CONTAINS CURRENT COLUMN
GPHCNT  DW      FSTCNT-1            ; POINTS TO CURRENT DATA POINT


GRA001  DSEG

CONFAC  DS      01H                 ; HOLDS COLUMN CNVRSN FACTOR
FSTCNT  DS      0320D               ; HOLDS VALUES FOR CRT
LSTCNT  DS      0001D               ; 1 AFTER LAST VALUE
```

```
CRTOUT   EQU      0FD3CH
ESCAPE   EQU      01BH
EQUALS   EQU      03DH
OFSET    EQU      020H          ;
```

```
;       PROG: END01.ASM

;       END01.ASM RESPONDS TO AND END COMMAND AT THE END OF
;A TEST.  IT PUTS THE TAPE RECORDER BACK INTO IDLE MODE.

PUBLIC  END01
EXTRN   IDLE01,VECTCD,STATCD,OKUPDT,UPDATE,STOPTR
END01 : CSEG

        LXI     H,IDLE01        ; GET IDLE ADDRESS
        SHLD    VECTCD          ; PUT IT IN VECTCD
        MVI     A,11000001B     ; PUT IDLE STATUS IN A
        STA     STATCD          ; THENCE TO STATCD
        CALL    STOPTR          ; ROUTINE STOPS TAPE RECORDER
        CALL    OKUPDT          ;
        JMP     UPDATE          ;
```

```
;               PROG: ADTEST

; READS 3 CHANNELS OF 732 A/D BOARD IN SCAN MODE THEN LOOPS
; BACK AND DOES IT AGAIN

ADTEST: MVI     A,LCHAN         ;
        STA     BASE+2          ; PUT LAST CHAN WRD IN BASE+2
AD1   : MVI     A,GMUX          ;
        STA     BASE+1          ; PUT GAIN/MUX WRD IN BASE+1
        MVI     A,CMMD          ;
        STA     BASE            ; PUT COMMAND WORD IN BASE
                                ; THEREBY ENABLING CNVRSN
        CALL    CDONE           ;
        CALL    CDONE           ;
        CALL    CDONE           ;
        JMP     AD1             ;

CDONE : LDA     BASE            ; READ STATUS REGISTER
        ANI     080H            ; MASK OFF CONV DONE BIT
        JZ      CDONE           ; IF ZERO TRY AGAIN
        LDA     BASE+5          ; READ MSB'S OF DATA
        RET

CMMND   EQU     00000011B       ; COMMAND WORD FOR CONVRTER
                                ; W/ INTRRPTS DISABLED, SCAN
                                ; MODE, CNVRSN ENABLED

GMUX    EQU     00000000B       ; GAIN/MUX REGISTER W/ GAIN OF
                                ; 1,CHANNEL 0 SELECTER

LCHAN   EQU     00000010B       ; LAST CHAN REGISTER=CHAN 2

BASE    EQU     0F700H          ; BASE ADDRESS OF CONVERTER
```

```
;                 PROG: IDLE01.ASM

;        IDLE01.ASM IS THE DEFAULT COMMAND WHEN NO OTHER
;COMMAND IS BEING EXECUTED.  IT DOES MINIMAL UPKEEP
;TASKS AND IS FINISHED.

PUBLIC  IDLE01
EXTRN   CUROUT,OKUPDT,CALCMD,CLSCRN


IDLE01: CSEG
        CALL    CLSCRN          ;
        CALL    CUROUT          ; WRITE CURRENT TIME OUT
        CALL    OKUPDT          ; OKUPDT RETURNS WHEN OK TO
                                ; CALL CRTTIM (UPDATE THE
                                ; TIME)
        JMP     CALCMD          ; GO TO CALCMD AND
                                ; THEN TO CRTTIM
```

```
;                          PROG: TESTO4.ASM

;       TESTO4.ASM IS THE COMMAND ROUTINE WHICH IS NORMALLY
;EXECUTED DURING TESTING, AFTER TESTO1,TESTO2, AND TESTO3
;TAKE CARE OF ALL THE PRELIMINARIES.  IT WRITES CURRENT TIME,
;STARTING TIME, AND CALLS THE GRAPH ROUTINE.

PUBLIC  TESTO4
EXTRN   GRAPH,BEGOUT,CUROUT,CALCMD

TESTO4: CSEG

        CALL GRAPH              ; GRAPH LAST SECOND'S ENVELOPE
        CALL BEGOUT             ; WRITE STARTING TIME
        CALL CUROUT             ; WRITE CURRENT TIME
        JMP  CALCMD             ; CALCMD IS THE LOCATION
                                ; IN THE MAIN PROG WHICH
                                ; CALLS COCMMD, THE ROUTINE
                                ; WHICH CHECKS THE CONSOLE
                                ; FOR NEW COMMANDS
```

```
;                   PROG: TEST02.ASM


;       TEST02.ASM IS IMPLEMENTED THE SECOND AFTER TEST01.ASM
;IS IMPLEMENTED.  IT CHECKS WHETHER THE TAPE RECORDER IS UP TO
;SPEED, IF SO IT PUTS THE LOCATION OF TEST03.ASM IN VECTCD
;AND TELLS THE INTERRUPT ROUTINE TO START THE A TO D
;ROUTINE.

PUBLIC  TEST02
EXTRN   PHLOCK,VECTCD,STATCD,TEST03,UPDATE
EXTRN   OKUPDT

TEST02: CSEG

        CALL    PHLOCK          ; PHLOCK SETS A=0 IF RECORDER
        ANA     A               ; UP TO SPEED ELSE A=1
        JNZ     THRU02

        LXI     H,TEST03        ; ADDR OF TEST 03 GOES IN
        SHLD    VECTCD          ; HL AND THENCE TO VECTCD
        MVI     A,11110011B     ; PUT TEST03 STATUS IN A
        STA     STATCD          ; THENCE TO STATCD

        ; THIS LINE IS RESERVED TO START THE A TO D CONVERSNS

        CALL    OKUPDT          ; LOOP TILL OK TO UPDATE TIME
THRU02: JMP     UPDATE          ; UPDATE IS LOCATION IN MAIN
                                ; PROG WHICH CALLS TIME UPDATE
                                ; ROUTINE
```

```
;                    PROG: OKUPDT.ASM

;       OKUPDT.ASM RETURNS WHEN IT IS OKAY TO UPDATE THE
;TIME.  IT CHECKS WITH THE INTERRUPT ROUTINE UNTIL THE
;INTERRUPT ROUTINE HAS WRITTEN THE TIME OUT TO THE TTY PORT.

PUBLIC  OKUPDT

OKUPDT: CSEG

        RET                 ; JUST A DUMMY ROUTINE NOW
```

```
;                        PROG: TPRD01.ASM
EXTRN    ADRTN,VEC1IN,GPHCNT,FSTCNT,TEST02,ADCNT,LSTCNT
EXTRN    FDPLAY,PHLOCK,TPOUT,NORMAL,STOPTR,GRAPH,ENDSEC,CLSCRN
EXTRN    CMPARE,CFLAG,TIMEIN,MAIN01
PUBLIC   STEP,RSEC,RMIN,RHOUR,RDAY

STEP   : CALL     SSTART   ; INITIALISES SOME VALUES
STEP00:  MVI      A,01H    ;
         STA      SWTCH1
STEP01:  CALL     LOOK1    ; LOOKS FOR A HOLD CHARACTER
                           ; TO KICK THINGS OFF
         CALL     LOOK2    ; LOOKS FOR FIRST TIMING CHARACTER
STEP02:  CALL     GETCHR   ;
         CALL     ROTTIM   ;
         LDA      SWTCH1   ;
         ANA      A        ;
         JNZ      STEP02   ;
         EI
         CALL     COMMND   ;
         LDA      PFLAG    ; HAS PAUSE COMMAND BEEN USED
         ANA      A        ; IF SO GO TO STEP
         JNZ      STEP     ;
         CALL     CLSCRN   ;
         CALL     TPOUT    ;
         CALL     GRAPH
         LXI      H,0000H  ;
         LDA      LFLAG    ; IF LFLAG=1 WE ARE IN LOCATE MODE
         CPI      01H      ; SO DO LOCATESTUFF
         JNZ      NOTLOC   ;
         CALL     CMPARE   ; SEE IF CURR TIME = SPECIFIED TIME
         LDA      CFLAG
         ANA      A
         JZ       NOTLOC
         CALL     STOPTR
         CALL     COMM03
         MVI      A,00H
         STA      LFLAG             ; REINITIALISE LFLAG
         JMP      STEP
NOTLOC:  SHLD     RDAY
         SHLD     RMIN
         XRA      A
         STA      RSEC
         CALL     ENDSEC
         JMP      STEP00
         JMP      STEP00   ; ELSE LOOK FOR START OF NEXT
                           ; TIME CODE

SSTART:  MVI      A,00H    ; SET PAUSE FLAG TO 0
         STA      PFLAG
         LXI      H,ADRTN
```

```
         SHLD    VEC1IN
         CALL    ENDSEC
         DI
         LXI     H,FSTCNT+(159D)
         LHLD    GPHCNT
         MVI     A,01H   ; INITIALISES VALUES
         CALL    FDPLAY  ; FDPLAY STARTS TAPE PLAYBACK
RUREDY:  CALL    PHLOCK  ; PHLOCK SETS A=0 IF RECORDER
         ANA     A
         JNZ     RUREDY
         LXI     H,FSTCNT;
         SHLD    ADCNT   ;
         MVI     A,011H
         STA     LSTCNT  ;
         CALL    NORMAL  ; SETS CONTROLS TO TP REC TO NULL
         RET

LOOK1 :  CALL    GETCHR  ; LOOP UNTIL D CONTAINS A HOLD
         MVI     A,HOLD  ; CHARACTER
         CMP     D       ;
         JNZ     LOOK1   ;
         RET             ;

LOOK2 :  CALL    GETCHR  ; LOOP UNTIL ROT1 INTERPRETS A CHAR
         CALL    ROT1    ; AS NOT HOLD
         ANA     A       ;
         JZ      LOOK2   ;
         RET             ;

GETCHR:  IN      TTSTAT  ; READ TTY STATUS
         ANI     INFULL  ; IS TTY INPUT BUFFER FULL
         JZ      GETCHR  ; IF NOT LOOP TO GETCHR AGAIN
         IN      TTTX    ; READ TTY INPUT VALUE
         MOV     D,A     ; PUT VALUE IN D
         RET


COMMND:  IN      CRSTAT  ; CHECK CRT BUFFE
         ANI     INFULL  ; NOTHING THERE THEN SWCHK1
         RZ              ;
         IN      CRTX    ; ELSE READ A COMMAND
         CPI     'L'     ; IS IT THE LOCATE COMMAND
         JNZ     COMM04
         CALL    STOPTR
         CALL    NORMAL
         CALL    TIMEIN  ;
         MVI     A,01H
         STA     LFLAG
         POP     H       ; UNSTRUCTURED TRICK FOR STARTINE AT
         JMP     STEP    ; STEP WITH LFLAG=01H
COMM04:  CPI     'P'     ; IS IT THE PAUSE COMMAND
         JNZ     COMM02  ; NO THEN COMM02
         CALL    STOPTR  ; YES THEN STOP TAPE RECORDER
         CALL    NORMAL
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         MVI     A,1
         STA     PFLAG  .; STORE A 1 IN PFLAG
COMMO3:  IN      CRSTAT  ; LOOP UNTIL YOU GET AN S COMMAND
         ANI     INFULL  ;
         JZ      COMMO3
         IN      CRTX    ;
         CPI     'S'
         JNZ     COMMO3
         RET
COMMO2:  CPI     'E'     ; B MEANS BACKUP
         RNZ             ;
         CALL    STOPTR  ;
         JMP     MAINO1  ; JUMP TO STRT OF MAIN ROUTINE



ROT1     LXI     H,RSEC  ; SEARCH FOR FIRST NON HOLD CHAR
         SHLD    CURBYT  ;
         MVI     A,HOLD  ; IF D CONTAINS A HOLD CHARACTER
         CMP     D       ; HOP TO ROT1A
         JZ      ROT1B   ;
         JC      ROTZER  ; ELSE CONVERT D TO 1 OR ZERO
ROTONE:  MVI     C,001H  ; [D]=1
         JMP     ROTOID  ;
ROTZER:  MVI     C,00H   ; [D]=0
ROTOID:  MOV     C,M     ; [CURBYT]=D
         MVI     A,01H   ; [ROTS]=1
         STA     ROTS    ;
         RET             ;
ROT1B :  MVI     A,0     ; SET A TO ZERO
         RET             ;



ROTTIM: ;TAKES CHARACTERS OFF TAPE AND RECONSTRUCTS TIME VALUE
C1ORO :  MVI     A,HOLD  ; PUT CHAR BACK IN A IS IT 1 OR 0
         CMP     D       ; GREATER THAN HOLD MEANS ZERO
         JC      ZERCHR  ;
ONECHR:  MVI     C,001H  ;
         JMP     ROT     ;
ZERCHR:  MVI     C,00H   ;
   ROT:  LHLD    CURBYT  ;       GET CONTENTS OF CURBYT
         MOV     A,M     ;
         RLC             ;       ROTATE TO THE RIGHT
         ANI     OFEH    ; SET LSB TO 0
         ORA     C       ; OR A WITH C TO GET CURRENT BIT
         MOV     M,A     ; PUT A WHERE HL POINTS
         LDA     ROTS    ; ARE 8 ROTATIONS DONE
         INR     A
         CPI     08H     ; IF NOT GO TO ROTDON
         JNZ     ROTDON  ;
         INX     H       ; CURBYT=CURBYT+1
         SHLD    CURBYT  ;
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        XRA     A       ;
        STA     ROT8    ; SET ROT8 TO 0
        LXI     B,RDAY+2; DOES L=RDAY+2
        MOV     A,L     ;
        CMP     C
        RNZ             ; IF CURBYT NOT=RDAY+2 RETURN
        MVI     A,01H   ;
        STA     SWTCH1

NEWSEC: XRA     A       ;
        STA     SWTCH1  ; SWTCH1=0 NOW
        RET             ;
ROTDON: STA     ROT8
        RET

TXY1  : DB      ESCAPE  ; SEQUENCE OF CHARACTERS FOR
        DB      EQUAL   ; LOCATING THE TIME ON PLAYBACK
        DB      0660    ; FROM TPTIME ROUTING
TXY4  : DB      0510    ;


LAB01 : DSEG
LFLAG : DS 1    ; 1 IF SUPPOSED TO LOCATE A VALUE
PFLAG : DS 1    ; 1 IF PAUSE H/BEEN EXECUTED, ELSE 0
XCOORD: DS 1    ; KEEPS TRACK OF COLUMNS FOR GRAPHING BUT
                ; USES ADM CHARS (E.G. 1 IS BLANK CHAR)
STATCD: DS 1    ; KEEPS TRACK OF CURRENT COMMAND STATUS
SWTCH1: DS 1    ; 1 IF GETCHR SHOULD CALL ROTTIM ELSE 0
SWTCH2: DS 1    ; 1 IF GETCHR SHOULD CALL TPTIME ELSE 0
SWTCH3: DS 1    ; 1 IF GETCHR SHOULD CALL CHROUT ELSE 0
TCOUNT: DS 2    ; TELLS WHAT TIME CHAR IS TO BE PRINTED OUT

ENVIN : DS 2    ; A CIRCULAR CUE IS KEPT OF ANALOG VALUES READ
ENVOUT: DS 2    ; ENVIN TELLS WHERE THE NEXT VALUE READ SHOULD
                ; BE PUT ENVOUT TELLS FROM WHERE THE NEXT VALUE
                ; FOR GRAPHING SHOULD BE READ
SMPCNT: DS 2    ; EVERY 15 SAMPLES HIGHEST AND LOWEST VALUES
                ; ARE TAKEN SMPCNT COUNTS TO 15
CURBYT: DS 1    ; CONTAINS CURRENT TIME BYTE WHICH IS BEING
                ; LOADED FROM TAPE 1 BIT AT A TIME
ENLOC : DS 2    ; IN CHROUT ROUTINE TELLS WHICH ADDRESS
                ; TO JUMP TO FOR PROPER SUBROUTINE
HILO  : DS 1    ; TELLS WHETHER TO PUT OUT CHAR FOR HI ENVEL-
                ; OPE OR LOW ENVELOPE
TLOC  : DS 2    ; CONTAINS ADDRESS OF SUBROUTINE FOR TPTIME
                ; TO JUMP TO
TOUT  : DS 2    ; TOUT POINTS NEXT CHARACTER TO BE WRITTEN TO
                ; SCREEN IN TPTIME ROUTINE

ROT8  : DS 1    ; TELLS HOW MANY ROTATIONS HAVE OCCURRED ON
                ; CURBYT, WHEN 8 THEN THROUGH
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RSEC  : DS 1     ; RECONSTRUCTED TIME FROM TAPE IS STORED HERE
RMIN  : DS 1     ;
RHOUR : DS 1     ;
RDAY  : DS 2     ;

HOLD    EQU     00111000B

BAKUP   EQU     11000000B         ; INDICATES BACK UP COMMAND
                                  ; IN STATCD
XFIRST  EQU     ' '               ; SYMBOL FOR COLUMN 1 ON ADM-3
XLAST   EQU     06FH              ; SYMBOL FOR COLUMN 80 ON ADM
TTTX    EQU     0F4H              ; PORT ADDR OF TTY I/O
TTSTAT  EQU     0F5H              ; PORT ADDR OF TTY STATUS
CRSTAT  EQU     0F7H              ; PORT ADDR OF CRT STATUS
CRTX    EQU     0F6H              ; PORT ADDR OF CRT OUTPUT
INFULL  EQU     002H              ; RECEIVER READY BIT IN USART
TXRDY   EQU     001H              ; TRANSMIT READY BIT IN USART
FIND    EQU     11000001B         ; FIND COMMAND FOR STATCD
ESTEP   EQU     11000010B         ; END STEP COMMAND FOR STATCD

ESCAPE  EQU     01BH
EQUAL   EQU     03DH
CLRCHR  EQU     01AH              ; CONTROL Z FOR CLEARING SCREEN
CRTOUT  EQU     0FD3CH            ; MONITOR ROUTINE
AD732   EQU     0F705H            ; ADDR OF ANALOG HIGH BYTE
ENLAST  EQU     00H               ; END OF CUE CHARACTER
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END

FILMED

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