AFWL-TR-84-142

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84-142

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AD-A160 914

A DIGITAL MICROBAROGRAPH SYSTEM

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May 1985

Final Report

Approved for public release; distribution unlimited.

AIR FORCE WEAPONS LABORATORY
Air Force Systems Command
Kirtland Air Force Base, NM 87117-6008

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This final report was prepared by the Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, under Job Order 88091385. Dr. Robert E. Reinke (NTES) was the Laboratory Project Officer-in-Charge.

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AD-A16[illegible] 714

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): AFWL-TR-84-142	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Air Force Weapons Laboratory; 6b. OFFICE SYMBOL (If applicable): NTES	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code): Kirtland Air Force Base, NM 87117-6008	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
62601F	8809	13	85

11. TITLE (Include Security Classification): A DIGITAL MICROBAROGRAPH SYSTEM

12. PERSONAL AUTHOR(S): Reinke, Robert E.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 83 Jul TO 84 Oct	1985, May	58

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB. GR.
19	04	

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Digital Recording, Microbarograph, Far-Field Airblast, Pressure Transducers, High-Explosive Testing

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Off-site low pressure airblast measurements are required on almost every high-explosive simulation test. Existing analog equipment which has been used for many years to make these measurements possesses several drawbacks in terms of excessive weight and power requirements and relatively narrow dynamic range of the paper and ink strip chart recording method. By making minor modifications to off-the-shelf recorders and pressure transducers, a digital microbarograph system has been developed which exhibits significant advantages over existing analog equipment in terms of weight, power requirements and dynamic range. Field and laboratory testing of the digital system over the past year has proven it to be a reliable and versatile alternative to existing systems.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL: Dr. Robert E. Reinke	22b. TELEPHONE NUMBER (Include Area Code): (505) 844-0484; 22c. OFFICE SYMBOL: NTES

DD FORM 1473, 83 APR — EDITION OF 1 JAN 73 IS OBSOLETE.

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ACKNOWLEDGEMENTS

The original idea for this project grew out of discussions with Capt Brian Stump, formerly assigned to AFWL/NTES and Capt Al Ronn formerly assigned to AFWL/WE. Mr. Joe Repichowski designed the field stand and protective enclosure for the transducer. Mr. Al Leverette performed much of the laboratory testing and data reduction and much of the field testing. Lt Steve Wert and Capt Don Douglas assisted in field testing. Figures 3, 4 and 13 and the Appendices are reprinted from a catalog supplied by the Validyne Company of Northridge, California.

INTRODUCTION

High-explosive simulation tests are the primary method by which hardened shelters for military systems are tested. The Air Force Weapons Laboratory (AFWL) Civil Engineering Research Division (NTE), conducts or participates in a number of these tests during the course of a year. Off-site low pressure airblast measurements are required on almost every high-explosive simulation test. These microbarograph measurements are made to protect the Government from invalid damage claims and to add to the general data base for airblast generation and propagation effects. For a number of years, these measurements have been made using the Sandia National Laboratories (SNL) SE151 portable self-contained microbarograph system. For the past few years, AFWL/NTE has leased three of the SE151 systems so that measurements could be made in-house on some of the smaller test events, requiring only minimal microbarograph coverage. On large-scale tests, SNL is generally contracted to provide additional microbarograph measurements using additional SE151 systems and/or telemetered pressure measurements recorded in a central van as well as expert airblast prediction and analysis. The purpose of this project was to develop a digital microbarograph system for use in-house on smaller test events which, while essentially duplicating the capabilities of the SE151 system, would be more convenient to use.

SE151 SYSTEM

The SE151 system consists of a sensor, an amplifier and a recorder. The pressure sensor is of the Bourdon tube type in which a twisted tube rotates an iron vane in response to ambient pressure changes. The rotational displacement of the vane is sensed by a set of coils connected in a bridge circuit across which is applied a 1000-Hz carrier frequency. The phase of the amplified 1000-Hz carrier frequency (proportional to bridge unbalance) is detected and, subsequently, fed to the two-channel strip chart recorder to make recordings at two different sensitivity levels. The amplifier system is capable of range switching to record blast waves of 0.1 Pa to 4.8 kPa overpressure.

The two-channel strip chart recorder is of the pressurized ink type adjusted for a factor of 4 difference in sensitivity between channels. An event marking pen on the strip chart can be used to record a WWVB standard time signal or some other time reference (Refs. 1 and 2). Reference 2 states that the system gives about a 95 percent amplitude response to a square wave pressure input in about 30 ms, implying that the system response rolls off in the neighborhood of 30 Hz. The low end corner of the frequency response can be adjusted from approximately 0.008 to 0.003 Hz.

While the SE151 instruments are, in general, reliable and versatile instruments, having been field-proven over the past decade or so, they do have several shortcomings. These are primarily: high power requirements--they require a 110-V supply capable of supplying several hundred watts, meaning that a portable 110-V generator or lead acid battery system and inverter must be used when commercial power is not available, size and bulk, and strip chart recording--the pen and ink method of recording frequently fails under adverse weather conditions (Ref. 2).

THE TERRA TECHNOLOGY DIGITAL RECORDERS

Since 1980, the Site Characterization and Seismology Section (NTESC) of NTE has used portable three-channel digital recording systems built by Terra Technology, Inc.*, to record a variety of ground motion inputs. It was felt that these systems, with some minor modifications, would provide an ideal means of making low pressure airblast measurements when coupled with suitable low pressure transducers.

The Terra Technology DCS302 system is a digital cassette recorder which in standard configuration records three channels of data directly in digital format on magnetic tape cassettes. Although designed primarily to record seismic events as detected by seismometers, geophones or accelerometers, the recorder is well suited to recording the output from virtually any sensor with a DC voltage output which does not exceed the $\pm$ 5-V range. The DCS302 amplifies, filters and converts the sensor outputs to 12-bit digital format.

The DCS302 instruments are available in a variety of configurations and options. The NTESC currently possesses 13 of the recorders. The AFWL standard configuration records 3 channels at switch selectable sample rates of 50, 100, and 200 samples/second/channel. Amplifier voltage gains of 1, 5, 25, 100, 500, 2500 or 10000 are available. The amplifier and 5-pole Butterworth antialias filter are contained on a single printed circuit card. Gains of 1, 5, 25 and 100 are available on the low gain card together with an antialias filter at 70 Hz. The high gain card contains the gains of 100, 500, 2500 and 10000 together with an antialias filter set at 30 Hz. Response of the amplifiers is flat from the antialias filter frequency down to DC. The recorders contain an auto gain feature, which, if desired, automatically downshifts to the next lower gain when amplifier output exceeds 75 percent of full-scale.

In addition to the standard three-channel recording configuration, three of the AFWL recorders may be converted to one-channel operation at a sample rate of 600 Hz. In this mode the antialias filter is set at 200 Hz.

The DCS302 contains a high accuracy internal clock which keeps track of days, hours, minutes and seconds. The complete time from the internal clock is written on to the data tape each second. The recorders also have a

*Reference to specific brand names is made for identification only and does not imply endorsement by the Air Force Weapons Laboratory.

provision for writing an externally supplied time mark upon the tape as well for comparison with the internal clock. Typically, all recorder clocks are synchronized with the National Bureau of Standards WWV time signal before the start of work each day. If a particular application demands a high degree of time synchronization, a common external time pulse is supplied to each recorder by means of a cable or, if the separation between recorders is large, WWVB radio receivers may be connected to each recorder.

Recording time on a standard length digital cassette in the three-channel configuration is 14 min at the 100 Hz per channel sample rate, 7 min for the 200 Hz per channel sampling rate. Recording can be initiated either manually by means of a front panel mounted switch, remotely by means of a 5-V DC pulse applied to the master slave input of the recorder, or automatically when a signal is received using the auto trigger capability. The auto trigger feature can be set to initiate recording when either the short term average exceeds a specified percentage of full-scale amplifier output, or when the ratio of the short term average to the long term average exceeds a specified value. The recording process continues for approximately 17 s after the manual or remote record signal is turned off or after the auto trigger criteria are no longer satisfied. In the standard configuration, 576 data samples are continuously saved in a preevent memory allowing a short length of data recorded prior to the receipt of a turn-on command to be saved on tape.

The DCS302 is quite a compact unit. Its dimensions are 14 by 8 by 10 in. The weight without batteries installed is about 12 lbs. With the gel cell storage batteries installed, the total weight is in the neighborhood of 25 lbs. Figure 1 shows a front panel view of the instrument. Figure 2 shows the recorder in the field sitting upon the top of its protective case which is used for shipping as well as in the field for protection from weather extremes and inquisitive cattle, if the recorder is to be left unattended for any length of time.

The recorder requires a +/- 12-V power supply. Current draw in the standby mode is approximately 30 mA, while the recording mode requires a current of approximately 160 mA. The internal gel cell batteries (if fresh and fully charged) are generally good for 2 to 3 days continuous operation. An optional 110-V charger/power supply is available for recharging the batteries as well as providing power for the unit if a 110-V supply is available.

If the recorder is to be operated at a remote location for an extended period of time, two 12-V auto batteries will power the unit for several weeks before recharging is necessary.

Playback of the digital cassettes is accomplished by means of a Terra Technology SMR 104 playback unit. The unit contains a single channel strip chart plotter, digital to analog converter and may be ordered with an RS232 serial interface which allows data to be passed to a computer for further plotting and analysis. The unit is portable and includes self-contained rechargeable gel cell batteries. Its dimensions are slightly larger than those of the DCS302 recorder. The SMR 104 allows strip chart records to be obtained in the field from data tapes. The AFWL SMR 104 is interfaced with a Hewlett-Packard 9845 minicomputer; however, the unit will interface with any computer possessing an RS232 port capable of accepting 8-bit data words at 9600 BAUD. The data are passed to the computer in somewhat scrambled fashion so that some bit shifting and binary and/or operations are required to reassemble the data points and header information (Ref. 3).

The DCS302 or its predecessor models have been manufactured by Terra Technology, Inc., since about 1974. Several other companies now have similar units on the market. From time to time, stories are heard concerning reliability problems with digital event recorders, such as the DCS302 or similar units. The AFWL set of recorders has, however, proven to be extremely reliable under adverse field conditions ranging from near 0°F operation in winter to ambient temperatures near 120°F in southwestern Arizona in the summer. The original three AFWL recorders obtained in 1980 have been in almost weekly use since then without experiencing major problems after an initial debugging period. Immediately after receipt of the recorders, they are tested on the bench and in the field under actual operating conditions. Typically, one out of three recorders will develop a problem during this debugging period which requires return to the factory for warranty repair. To date, it has not been necessary to return one of the recorders for an out-of-warranty repair.

LOW PRESSURE TRANSDUCERS

The selection of suitable low pressure transducers for use with the digital recorders presented something of a problem. Discussions with several knowledgeable individuals and a literature search revealed that there are no commercially manufactured low pressure airblast sensors specifically designed for measurement of pressure waves from fairly large blasts. Reference 4, a US Bureau of Mines Report, presents a thorough summary of available low pressure transducers for potential use in surface mine blasting. Although numerous types of sound pressure measurement systems and transducers are manufactured, almost all are lacking in frequency response below 2 to 5 Hz. The NTESC procured three types of transducers for testing as to suitability for low pressure airblast measurements. These were Validyne differential pressure transducers, a Brüel and Kjaer (B and K) sonic boom microphone and carrier system (both of which were discussed in Ref. 4), and Kulite 2 lb/in^2 pressure transducers.

The Kulite 2 lb/in^2 pressure transducers were the first units tested for suitability for measurements in the 10 Pa to 1000 Pa pressure ranges. These transducers employ piezoresistive sensing elements.. They require a 15-V DC excitation voltage and have a full scale (2 lb/in^2) output voltage of 50 mV. This yields a very low output voltage range for the pressure range of interest requiring that either a preamp be used, or that the higher DCS302 gain ranges be used for a satisfactory recording. The Kulites were tested on one field test event at the McCormick Ranch test site. Three Kulites were fed into the three channels of a DCS302 recorder; an SNL SE151 microbarograph was fielded alongside the Kulite gages. The SE151 amplifier output was fed into another DCS302 recorder so that a direct digital comparison of the two signals could be made. The SE151 system recorded a clear signal, a few tens of Pascals in amplitude from the shot, while no signal at all was apparent on the Kulite channels. Whether the Kulite gages simply do not respond at these low pressure levels, or whether some other factor was responsible for the lack of a signal on the Kulite channels is not known. Whatever the cause, the decision was made to perform no further testing on the Kulite transducers.

The B and K sonic boom microphone is a wide band instrument having a frequency response extending from 0.01 to 18 kHz. This unit appears to be a well made precision instrument and has a suitably high sensitivity in the pressure range of interest. Its principal shortcoming for the desired application is the 110-V AC required to power its associated electronics package consisting of a carrier demodulator and amplifier. Since the B and K unit arrived after the Validyne transducers had already undergone preliminary testing with satisfactory results, little has been done with the B and K unit other than performing a few bench tests. Further information regarding the B and K unit may be found in Ref. 4 and in brochures and a catalog available from the Bruel and Kjaer Company.

Figure 3 contains a picture of the P305D Validyne transducer as well as some of its specifications. This transducer is a differential pressure instrument originally designed to measure differential line pressures of fluids and gases. The P305D is quite compact in size (dimensions are shown in Fig. 4). Both the transducer and carrier demodulator are included in the same package. The transducer is of the diaphragm type. The principles of operation of the P305D are quite similar to that of the SNL SE151 system, except that the displacement of a diaphragm is sensed instead of the rotation of a vane. Appendix A gives a more thorough explanation of the theory and operation of variable-reluctance transducers.

Power requirements as well as signal output levels of the P305D are well suited for use with the DCS302 recording system in remote locations. The excitation power required by the transducer is 10.8 to 32 V DC unregulated at a nominal current level of 3.7 mA. Twelve-volt DC power, tapped from the internal power supply, is available on the sensor input connector of the DCS302. This auxiliary power supply easily meets the 3.7 mA current requirement which represents only a slight additional current drain relative to the power consumed by the recorder. Full-scale output of the P305D is $\pm$ 5 V which corresponds to the maximum allowable input to the DCS302 amplifiers. Frequency response of the P305D is specified by the manufacturer as flat within $\pm$ 1 dB from 0 to 200 Hz.

DEVELOPMENT AND TESTING OF THE VALIDYNE-
TERRA TECHNOLOGY RECORDING SYSTEM

Since the Validyne transducers were originally intended for measurement of differential line pressures of fluids and gases, some modifications are required to make them suitable for airblast use. To measure ambient overpressures, the chamber on the negative side of the diaphragm must be partially sealed off. The low frequency response limit is determined by the rate of leakage from the negative chamber. If the cavity were completely sealed off, the low frequency limit would be DC. This is not practical, however, since temperature variations and changes in ambient pressure would cause severe drift problems and might possibly damage the diaphragm. The low frequency response limit (-3 dB) is given by the following equation: $F = 1/(2 \pi\tau)$; F_ℓ is the lower limiting frequency, τ = the time required for any given pressure P_0 to drop to $(1/e)\ P_0$ where $e = 2.71828$ ... (Ref. 4).

To precisely adjust the leakage rate from the negative transducer chamber, a precision needle valve was added as suggested by Ref. 4. The valve used was the model 21RS4 built by the Whitey Company of Highland Heights, Ohio. A photograph of the valve installed on the transducer is shown in Fig. 5. This particular model is not entirely satisfactory in that a spring is used in the adjustment mechanism to protect the needle and seat from being damaged by overtightening. This spring coupled mechanism, however, makes for somewhat erratic behavior when very fine adjustments are attempted. A similar valve with a more direct coupling between the adjustment micrometer and needle might provide easier adjustment of the leakage rate.

A cut and try approach was used for adjustment of the needle valves on each of the Validyne transducers to obtain a uniform low frequency cutoff similar to that of the SNL SE151 systems. The change of height technique was used to provide the pressure input for determination and adjustment of the leakage rates for the individual transducers. The change of static pressure induced by a change of height is given by the following relationship:

$$P_C = \frac{4.548\ P_0}{(T + 273)} \cdot h$$

where

h = change in height in meters

P_C = change in pressure in pascals

T = temperature in Celsius

P_O = atmospheric pressure in millimeters of mercury (this is the absolute ambient pressure, uncorrected to sea level).

The Validyne transducers were moved through an altitude change of 1.98 m. The time constants were then determined by measuring the time required for a pressure indication of P_O to drop to the value P_O/e. This process was repeated a number of times while the needle valves on each transducer were adjusted to obtain a uniform low frequency response level which was 0.1 Hz or less. The final adjustments resulted in computed low frequency limits of approximately 0.062 Hz, 0.067 Hz and 0.074 Hz for the three Validyne transducers. Further adjustments could likely lower these values to levels more nearly approximating the low frequency limits of the SE151 system, especially if needle valves without the spring loaded adjustment mechanism were installed.

The Validyne transducers were ordered with a full-scale pressure input level of $\pm$ 862 Pa corresponding to an output level of $\pm$ 5 V yielding a sensitivity of 0.00580 V/Pa. Shortly after the transducers were received, the factory calibration was checked by the Kirtland Air Force Base precision measurement laboratory (PMEL) using a water manometer to determine standard static applied pressures. The PMEL again checked the transducer calibrations in November 1984 using the same technique. The calibration sheets are shown in Tables 1 and 2. For both calibrations, PMEL determined sensitivities are generally well within 2 percent of the factory calibration as long as the full-scale range is not exceeded. Some nonlinear behavior was observed in the first set of PMEL calibrations when the full-scale input pressure was exceeded. Additional calibration techniques, such as those discussed in Refs. 4 and 5, are currently under investigation.

Absolute amplitude scales may be applied to the strip chart records produced by the SMR 104 playback unit by use of the internal plotter calibrator which places ± 1/8 and ± 1/2 full-scale calibration marks on the strip chart. These calibration marks may be converted to pressure levels by consideration of the amplifier gain and Validyne sensitivity. The plotting program on the HP 9845A computer converts digital counts into pressure levels in a simple arithmetical expression using the amplifier gain and transducer sensitivity.

For field use of the Validyne system, a small aluminum stand was built. A Validyne transducer is shown mounted to the stand in Fig. 5. To provide some amount of protection from the elements for the Validyne and to lessen the effects of thermal drift in the DC output level due to solar heating, a sheet metal box, open on the bottom, was fabricated as a cover for the Validyne. The box is shown installed on the stand in Fig. 6. The white paint on the box aids considerably in reducing solar heating of the transducer.

FIELD EXPERIENCE WITH THE SYSTEM

The Terra Technology Validyne System has been used on a number of field tests with good results. Figure 7 shows the results from the first field test of the Validynes compared with a record obtained from an SE151 system on the same event. For this test and for all other tests discussed here, the low gain card with the 70 Hz antialias filter was used in the DC302 recorders. The SE151 system record was obtained by tapping the output of the SE151 amplifier system before it was fed into the SE151 strip chart recorder. This output was fed into the input of the Terra Technology digital recorder. All four records in Fig. 7 are plotted to the same scale. The sensitivity level for the SE151 system in terms of volts/Pascal was determined by recording the 80 percent calibration step sequence shortly before the shot time. The plots in Fig. 7 were made by an HP9845A desk top minicomputer after data transfer was accomplished by means of the SMR 104 playback unit and RS232 interface.

At the time of this test, the precision needle valves had not been installed on the Validyne transducers. For this test, the negative ports were sealed up. To provide a bleed-off of the pressure from the negative chamber, the small bleed screws on the transducers were opened one turn each. This rather imprecise leakage adjustment was responsible for the differences in the waveforms in Fig. 7. Peak-to-peak amplitudes are in fairly good agreement on all four records.

Several laboratory tests have been performed with the Validynes set up alongside the SE151 systems to determine the uniformity of response for the two systems. Slamming the laboratory door and then opening it quickly produced a pressure input of several Pascals. As an example, one particular test was performed in an attempt to resolve a discrepancy between Validyne and SE151 measurements on a large shock tube test. The outputs of three SE151 systems were fed into one digital recorder; outputs from the three Validyne transducers were fed into a separate digital recorder. The sensitivity levels of the individual SE151 systems were again determined by recording the cal pulses shortly before the test. The records from all six systems are shown in Fig. 8. All three Validynes are in excellent agreement; the Validynes are in almost exact agreement with one SE151 record, one other SE151 record is slightly low, the third SE151 record is greater than a factor of 2 higher than any of the other instruments.*

Figure 9 shows a comparison of three Validyne records versus a single SNL SE151 digital record. These recordings were made at a range of approximately 6 km from a 500-lb bomb test conducted at McCormick Ranch. Again, good agreement is seen between all three Validynes; however, the SE151 system, Serial No. 12-05, is again seen to be indicating a slightly lower pressure than the Validynes.

Figure 10 shows a comparison of a Validyne record and an SE151 record from a range of 4.8 km from the HFC-2 HEST test at the ISST test site near Yuma, Arizona. The SE151 and Validyne records are in excellent agreement both with regard to amplitude and waveform shape.

Figure 11 is an illustration of the value of digital recording versus simple strip chart playback with respect to dynamic range. The records in Fig. 11 were obtained at a range of 14.5 km from the SS1-r test event fired at the ISST test site. The analog record was plotted on the SMR 104 playback strip chart plotter using maximum available plotter gain. The digital record was plotted using the Hewlett Packard 9845A computer system. There is no apparent signal visible on the analog strip chart record, while a clear signal is seen on the expanded digital plot. In this particular situation, the instrument operator was not certain of the predicted overpressure range and set the gain to its lowest possible value to err on the side of safety. Consequently, the actual overpressure was less than 0.8 percent of the full-scale range. In spite of this extreme underrange condition, the large dynamic range enabled a clear plot to be obtained.

Figure 11 also gives an illustration of the header information available on the digital tapes and printed out on each plot by the 9845A system. This information includes time marks and time identification as obtained from the internal recorder clock, recorder serial numbers, gain settings on all three channels and external time marks.

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*Serial Numbers 11-11 and 07-08 had been borrowed from Mr Steve Doerr of SNL for this test, Number 12-05 was one of the AFWL leased units. Mr Doerr later returned Numbers 11-11 and 07-08 to SNL for recalibration.

Digital data lend themselves easily to analysis and processing in the frequency domain. Figure 12 contains a simple illustration of this. The two waveforms in Fig. 12 were obtained at ranges of 632 and 823 m on axis from the 5.8 m muzzle of the SNL Thunderpipe shot on 21 September 1984. The waveforms appear identical except for amplitude. The second positive pressure pulse is interpreted as coming from the distant end of the tube. Also shown in Fig. 12 are Fourier amplitude spectra computed for the two waveforms. As in the time domain waveforms, the spectra are seen to be nearly identical except for amplitude, and most of the energy appears to be concentrated in the 2 to 30 Hz band.

Attempts at using the DCS302 automatic triggering system for airblast recording have not been very successful to date. At relatively distant recording stations where overpressures in the neighborhood of a few tens of Pascals are expected, the auto trigger sensitivity must be set so that wind gusts, as well as the actual event signal, will trigger the recorder. On a windy day, the tape cassette may become filled with wind noise records before the actual event occurs. If the sensitivity is reduced in an effort to reduce wind triggers, then the recorder may not trigger on the test event. For recording stations where the expected overpressures are several hundred Pascals, the trigger sensitivity may be set high enough so that wind noise is not a factor. However, at these locations the period of the signal may be shorter especially for smaller shots than the minimum available time window for the short term average causing its value to be lower than anticipated and again causing problems with recorder turn-on. For test events with significant ground motions, a seismometer or accelerometer may be used to provide a trigger signal to turn on the recorder. Two components of the seismometer may either be connected to the two vacant channels on the same recorder to which the Validyne is connected, or a separate recorder may be used to record all three components of the seismometer. The recorder with the seismometer may then be used to control the Validyne recorder by means of the master slave input feature. This may be a workable arrangement, at least for test configurations producing significant off-site ground motions, since it is often desirable to make measurements of ground motion levels at the same locations where overpressure measurements are made. Ground motion signals from typical high-explosive simulation tests are usually much longer in duration (many more cycles are present) than airblast signals, especially at the larger ranges, allowing the auto trigger option a chance to operate successfully.

DISCUSSION

The Terra Technology-Validyne Microbarograph System has been proven to be a reliable alternative to the SE151 analog system. The Terra Technology-Validyne System duplicates most of the functions of the SE151 system, while possessing significant advantages over the SE151 unit. The digital system is much more portable, and the data are recorded reliably directly in digital format on magnetic tape. The magnetic tape format allows a variety of analysis procedures, such as plotting in expanded scales, spectral analysis, etc., to be applied to the data.

In its present configuration, the digital system does not put out a real time strip chart record as does the SE151. The SMR 104 playback system can be hooked up directly to the DCS302 so that one channel may be plotted in real time on the strip chart. It would not be practical, however, to have one SMR 104 system for each DCS302 recorder. The DCS302 recorder does have a connector from which the analog output of each channel may be tapped. This output could easily be fed into an inexpensive minature battery-powered strip chart recorder to provide real time strip chart records. It is felt that real time strip chart records are not really necessary since the SMR 104 field playback system allows strip chart records to be obtained from the tapes within minutes of the event.

The present Validyne transducers do not allow for quite as large an overall dynamic range as the SE151 system. The practical measurement limits of the present system are from a Pascal or so to 862 Pa, while that of the SE151 system is 0.1 to 4800 Pa. The range of the digital system could easily be extended to much higher levels by either ordering the P305D transducer with a higher full-scale pressure level, or by exchanging the existing diaphragms in the P305Ds to ones with higher pressure levels. Given the relatively low cost of the P305D transducer and accompanying precision needle valve (< $700), it would probably be more practical to purchase several higher pressure P305D units. Change-out of a low pressure transducer to a high pressure transducer for a particular recorder can be accomplished in a minute or two.

For extremely long ranges from fairly large simulation tests, it may be desirable to record overpressures of a few tenths of a Pascal. The P305D does respond in this region and the internal noise levels of the P305D are equivalent to no more than a few hundredths of a Pascal after being passed through the recorder antialias filter. The manufacturer, however, does not guarantee an accuracy greater than ± 0.5 percent full-scale. If highly accurate overpressure measurements are desired in this pressure regime, use of the DP103 transducer (Fig. 13) might prove valuable. The DP103 can be obtained with full-scale pressure levels as low as 55 Pa. The DP103 unit does not include the carrier-demodulator unit--this would have to be purchased separately. For extremely long range work, it would also be desirable to drop the recorder sampling rate to 50 samples/second/channel with the antialias filter set in the neighborhood of 15 to 20 Hz. If the one channel configuration were used, a sampling rate of 150 Hz would apply allowing a higher frequency response. Either arrangement would yield a total recording time per cassette of 30 min.

The current price of the complete AFWL digital microbarograph system is approximately $11,000 per unit. The cost of the one channel playback unit is approximately $6,500. The cost of both the recorders and playback can vary somewhat depending on the particular options desired. It is felt that the versatility and many advantages of the digital microbarograph system, coupled with the relatively low cost per unit, make it a highly desirable system for measurement of low level airblast signals.

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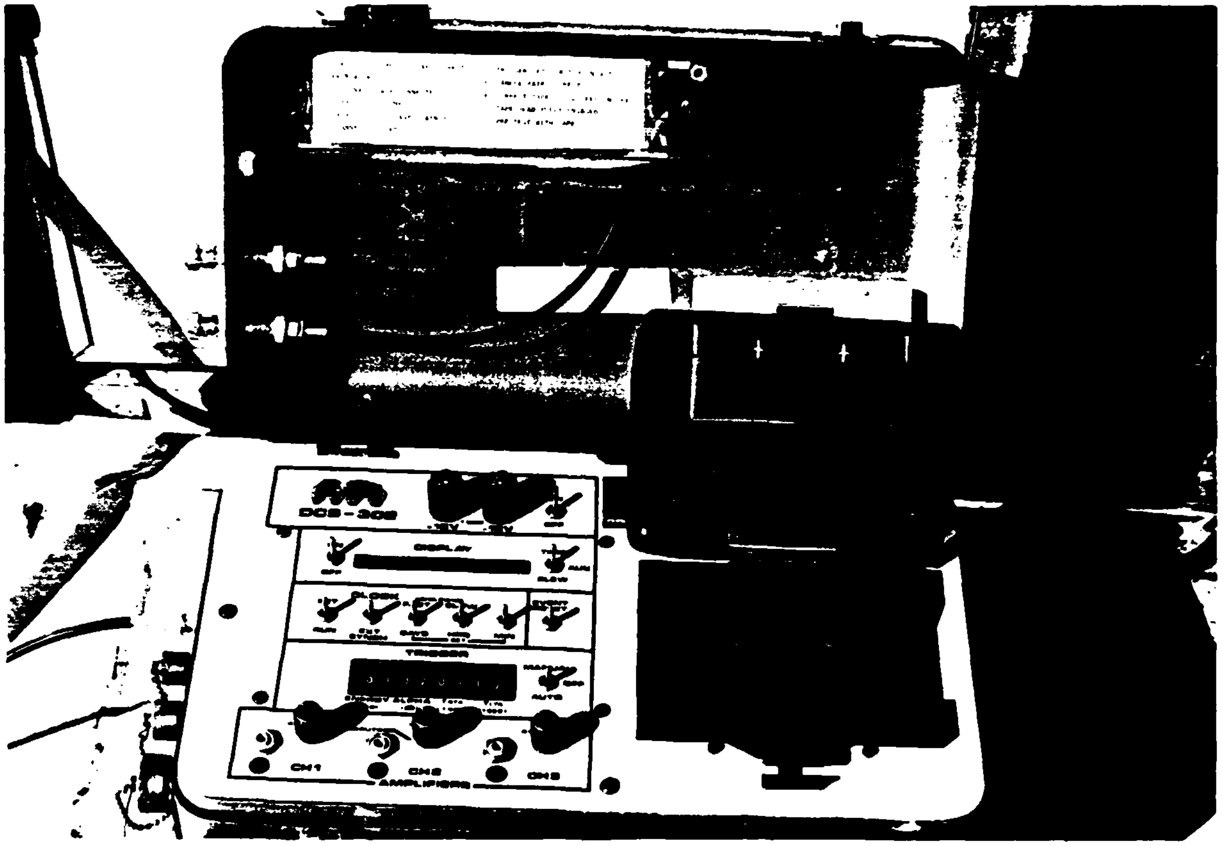


Figure 1. Front panel view of DCS302 digital recorder.

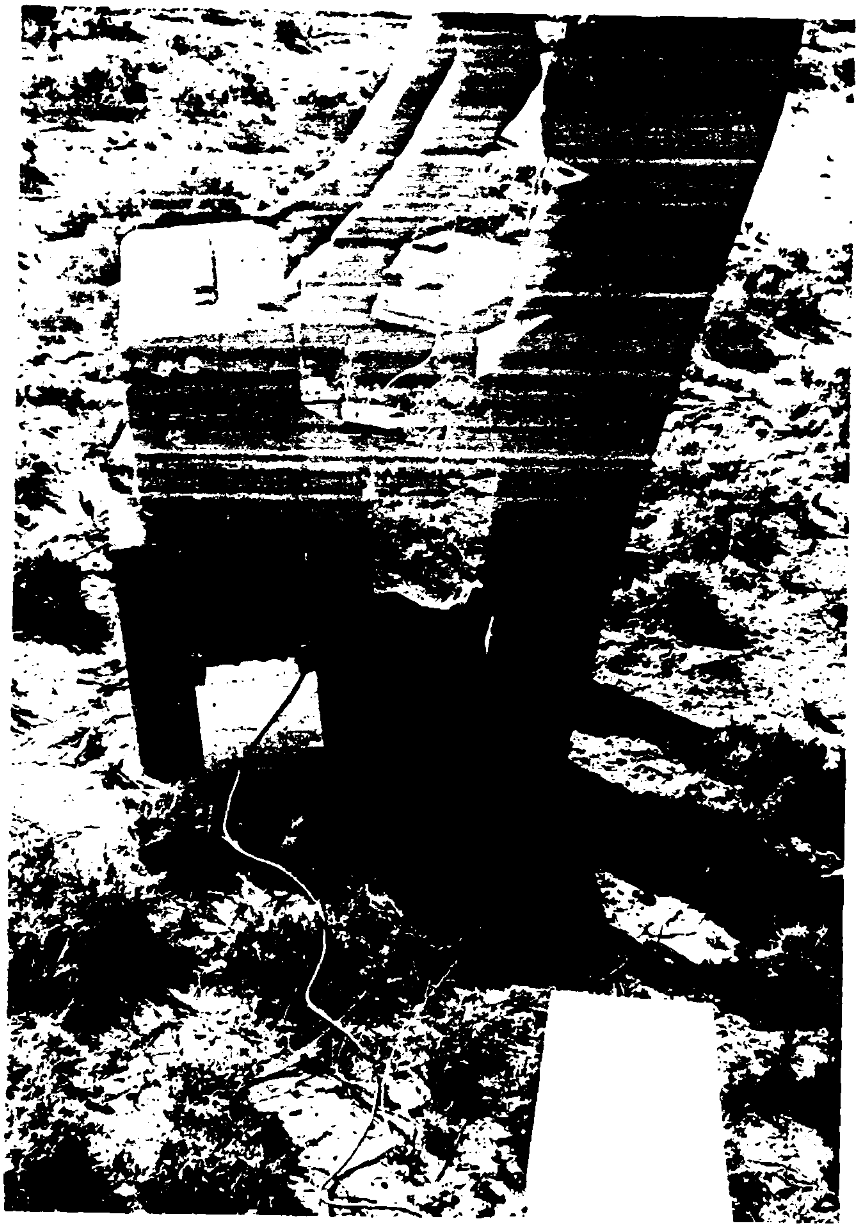
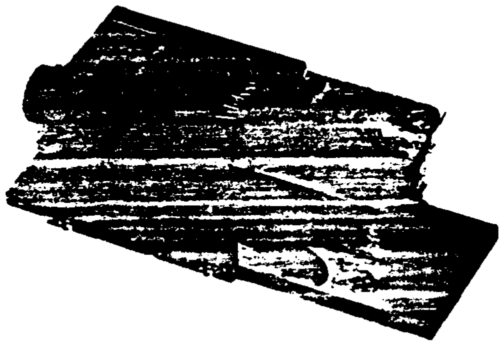


Figure 2. View of DCS302 placed on top of its protective case.



LOW-COST, LOW-RANGE
WET-WET CAPABILITY

Features

- Ranges as low as ±0.08 psi full scale
- Differential or absolute
- 11-32 Vdc input, 5 Vdc output
- Stainless steel pressure cavities

Description

The P305 combines a variable reluctance pressure transducer and carrier demodulator into a single package to provide a 5 Vdc output with operation from unregulated 10.8 to 32 Vdc input power.

The P305D is a differential pressure transducer with symmetrical pressure cavities of stainless steel. Fluid pressures act directly on a central diaphragm in a balanced variable reluctance design which eliminates the need for internal isolation fluids. The transducer diaphragm is replaceable.

The P305A is an absolute pressure transducer with weld sealed stainless steel pressure and reference vacuum cavities. As the P305A is an all welded unit, the diaphragm is not replaceable.

Zero and span adjustments are available under the cover.

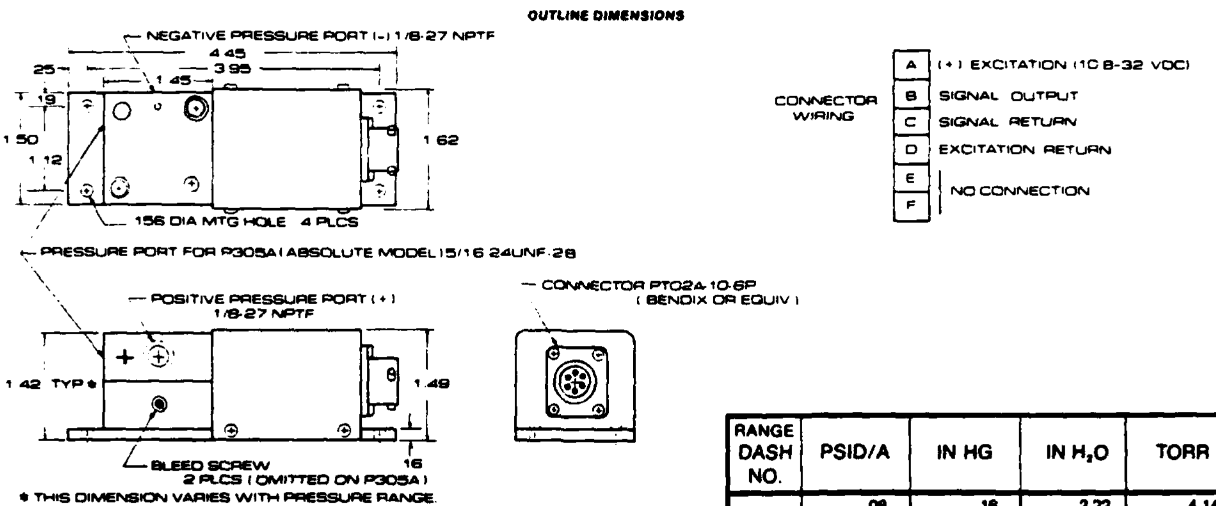
Specifications

Ranges:	P305D: ±0.08 to 3200 psid FS P305A: 0-0.08 to 0-3200 psia FS
Accuracy:	±0.5% FS, including linearity, hysteresis, and repeatability
Overpressure:	P305D: 200% FS up to 4000 psi maximum, with less than 0.5% zero shift P305A: 20 psia, or 200% FS whichever is greater, up to 4000 psi maximum, with less than 0.5% zero shift
Line Pressure: (P305D)	3200 psig maximum, with zero shift less than 1% FS /1000 psi

Specifications (CONTINUED)

Pressure Media:	Fluids compatible with Type 410 stainless steel and Inconel
O-Rings, P305D only:	BUNA-N, other compounds available
Pressure Cavity Volume:	4 X 10⁻³ cubic inch, symmetrical in P305D
Volumetric Displacement:	3 X 10⁻⁴ cubic inch FS
Excitation:	10.8 to 32 Vdc @ 3.7 mA nominal
Signal Output:	P305A: 0-5 Vdc FS @ 0.5 mA P305D: ±5 Vdc FS @ 0.5 mA
Zero Balance:	P305D/A. Less than 0.1 Vdc Adjustable ±1 Vdc
Output Impedance:	100 Ohms in parallel with 2.4 μfd
Frequency Response:	0-200 Hz flat ± 1 db for electronics
Output Noise:	≤5 mV rms
Insulation Resistance:	>10 Megohms, any terminal to case
Input/Output Isolation:	Common input/output return
Operating Temp. Range:	−65° to +250°F
Compensated Temp. Range:	0 to +160°F
Temperature Error:	<2% FS /100°F
Pressure Ports:	P305D: 1/8-27 NPT Female P305A: 5/16-24 UNF-2B
Electrical Connector:	Bendix PT02A-10-6P or equal Mate PT06A-10-6S not furnished
Weight:	16 oz. (0.45 kg.)

Figure 3. Illustration and performance specifications of the Validyne P305D transducer.



Pressure Range Chart

The Pressure Range Chart is tabulated to show the incremental range coverage of each transducer diaphragm used in the P305 from the minimum range (-20 at 0.08 psi) to the maximum (-64 at 3200 psi) available for the model. As suggested by the chart, each diaphragm has a range of full scale values over which it can be calibrated — nominally 65% to 100% of the maximum range shown. For example, a -40 diaphragm installed in the P305 may be calibrated for full scale pressures of from 8.0 psi to 12.5 psi. When calibrated within these limits, the unit will meet all performance and environmental specifications for the model. The chart can be used to select both transducers and, for the P305D, replacement diaphragms. If, for example, the desired measurement range is between two of the ranges listed, select the dash number corresponding to the higher range (e.g., for a 200 Torr measurement, the -36 transducer or diaphragm would be selected, etc.).

RANGE DASH NO.	PSID/A	IN HG	IN H_2O	TORR
	.08	.16	2.22	4.14
20	.125	.25	3.5	6.5
22	.20	.41	5.5	10.3
24	.32	.65	8.9	16.5
26	.50	1.02	14.0	25.8
28	.80	1.6	22.2	41.4
30	1.25	2.5	35.0	65.0
32	2.0	4.1	55.0	103
34	3.2	6.5	90	165
36	5.0	10.2	140	258
38	8.0	16.0	222	414
40	12.5	25.0	350	650
42	20	41.0	550	1030
44	32	65.0	890	1650
46	50	102	1400	2580
48	80	160	2220	4140
50	125	250	3500	6500
52	200	410	5500	10300
54	320	650	8900	16500
56	500	1020	14000	25800
58	800	1600	22200	41400
60	1250	2500	35000	65000
62	2000	4100	55000	103000
64	3200	6500	89000	165000

Figure 4. Line drawing of P305D transducer and chart showing available pressure ranges.

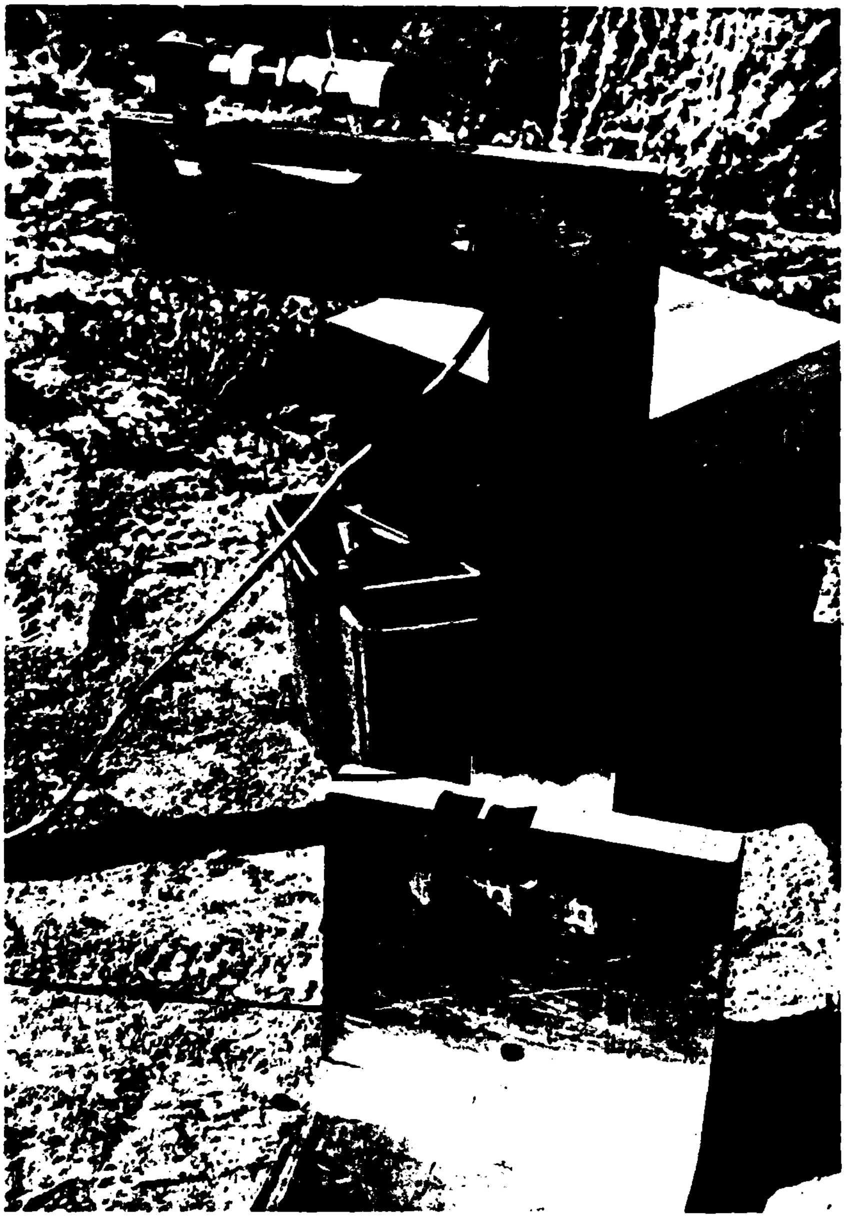


Figure 5. View of Validyne transducer attached to stand for field use.

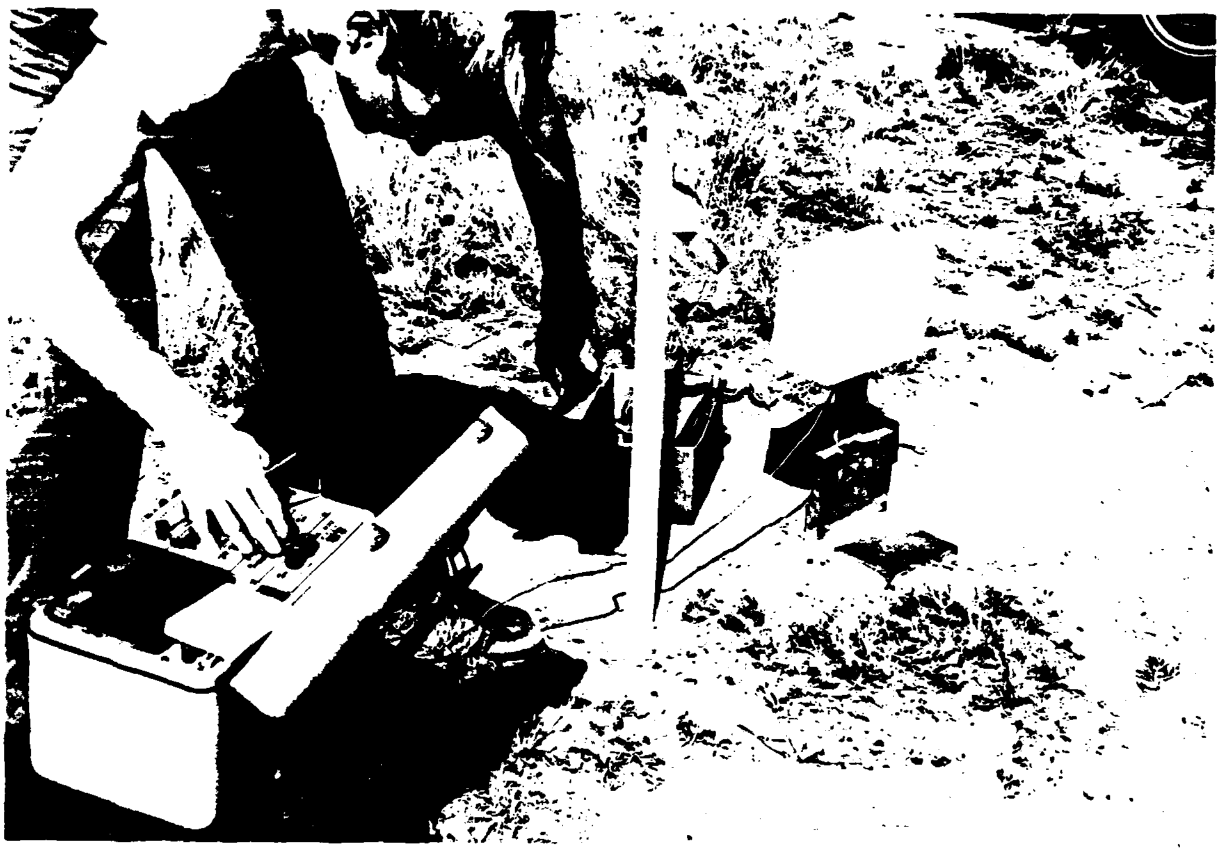


Figure 6. View of Validyne transducer and stand with protective cover attached.

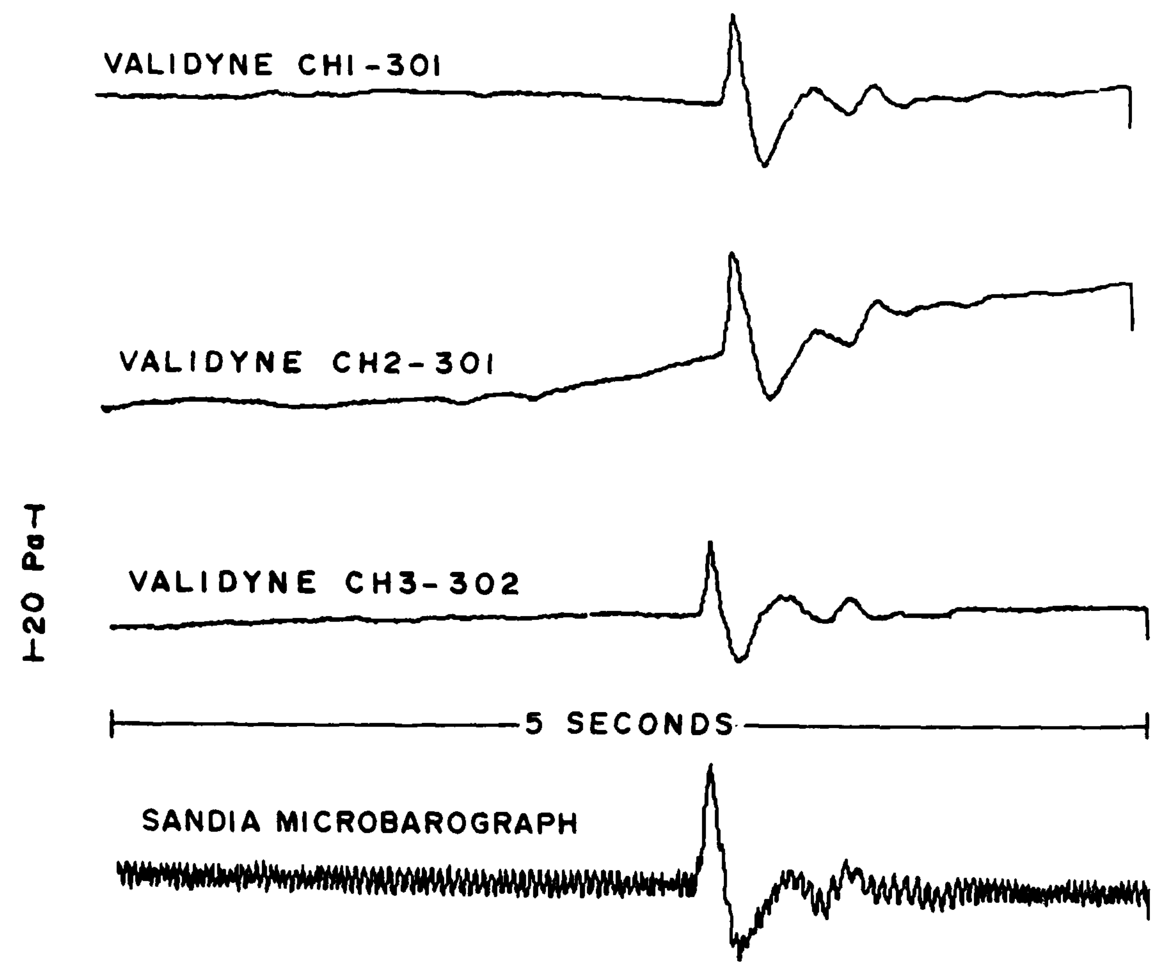


Figure 7. Comparison of Validyne and SE151 records for the CID field tests.

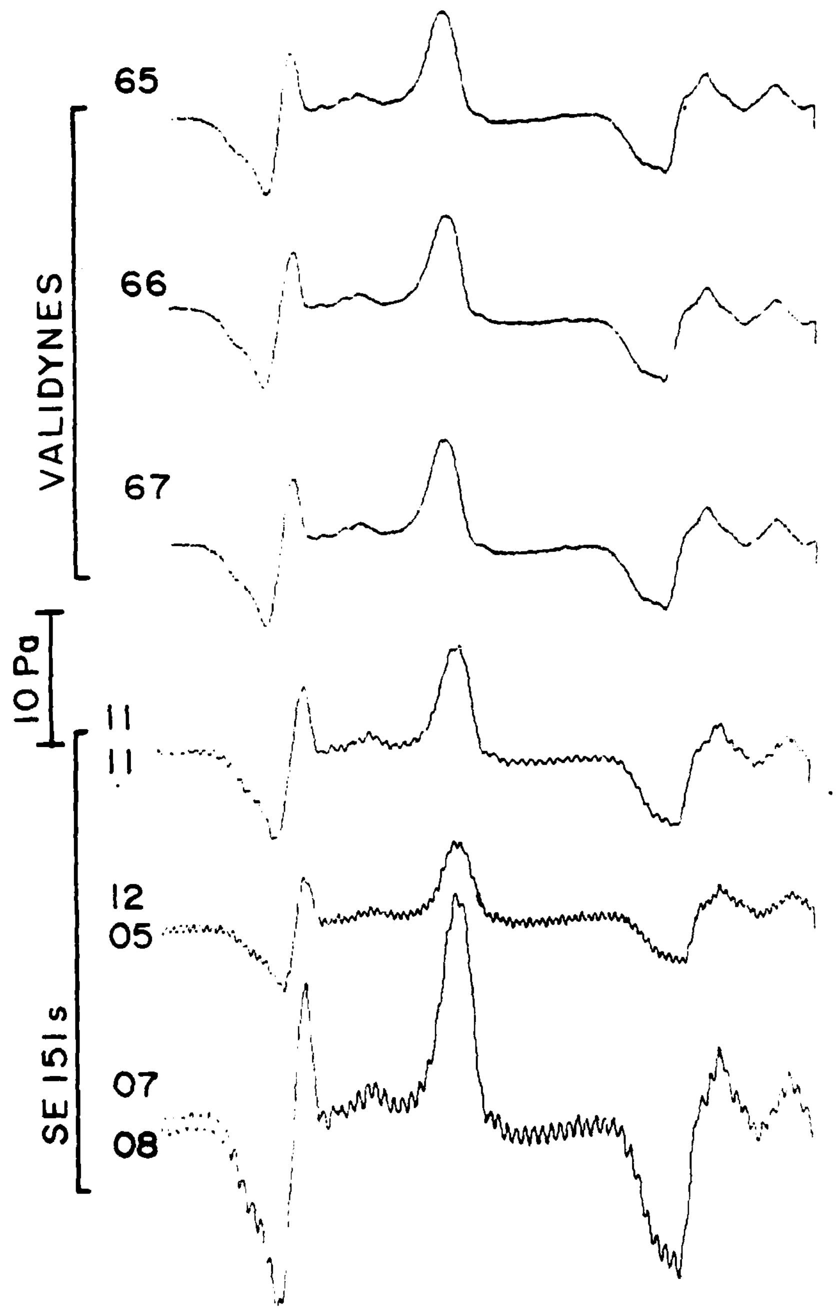


Figure 8. Comparison of 3 Validyne records and 3 SE151 records for the "slamming door" pressure test.

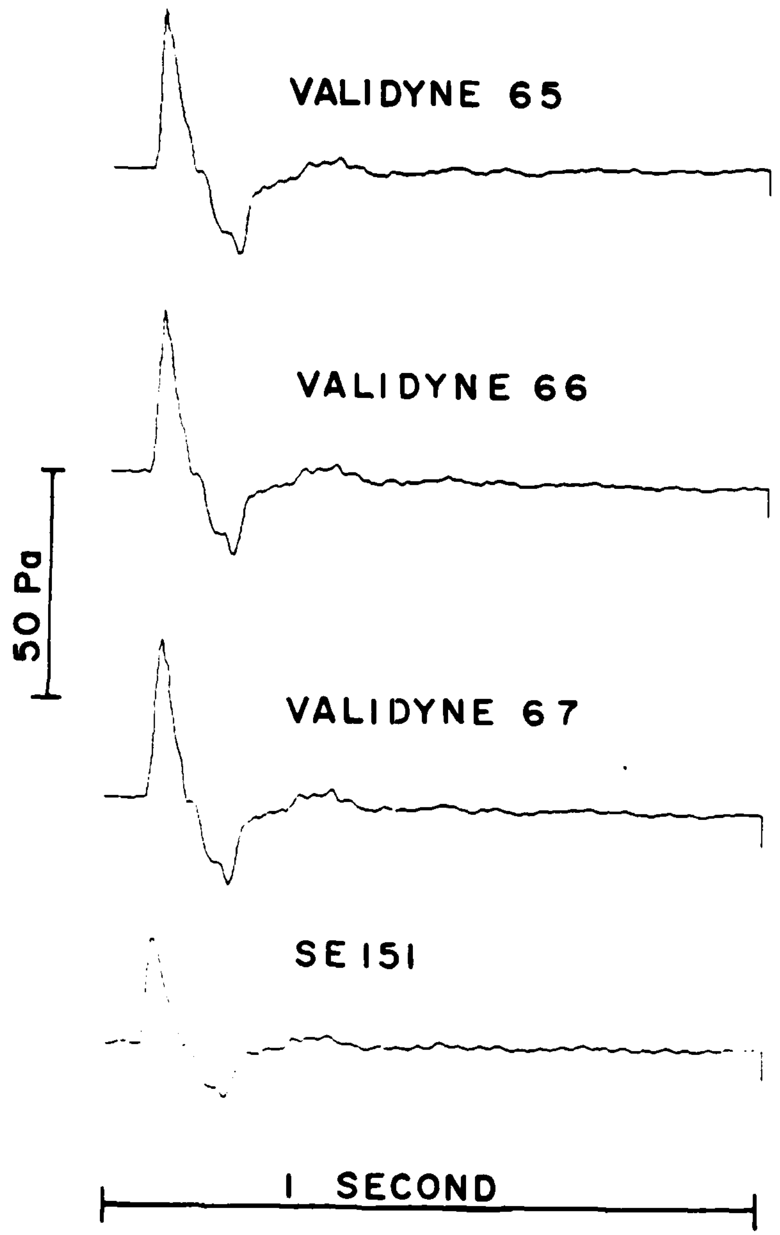


Figure 9. Comparison of 3 Validyne records and an SE151 record at a range of approximately 6 km from the CHEBS 9 bomb test.

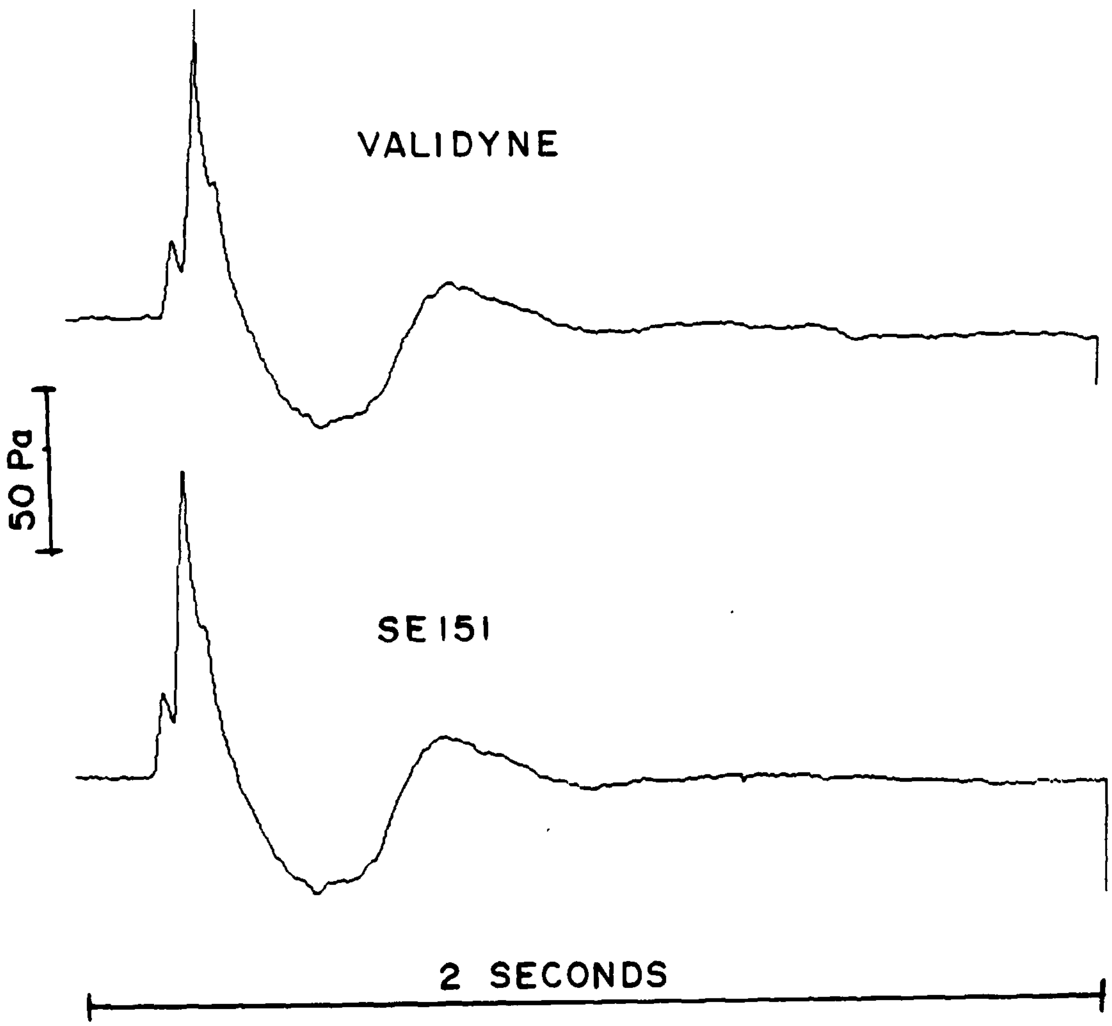


Figure 10. Comparison of Validyne and SE151 records at a range of 4.8 km from the HFC-2 test in the ISST test series.

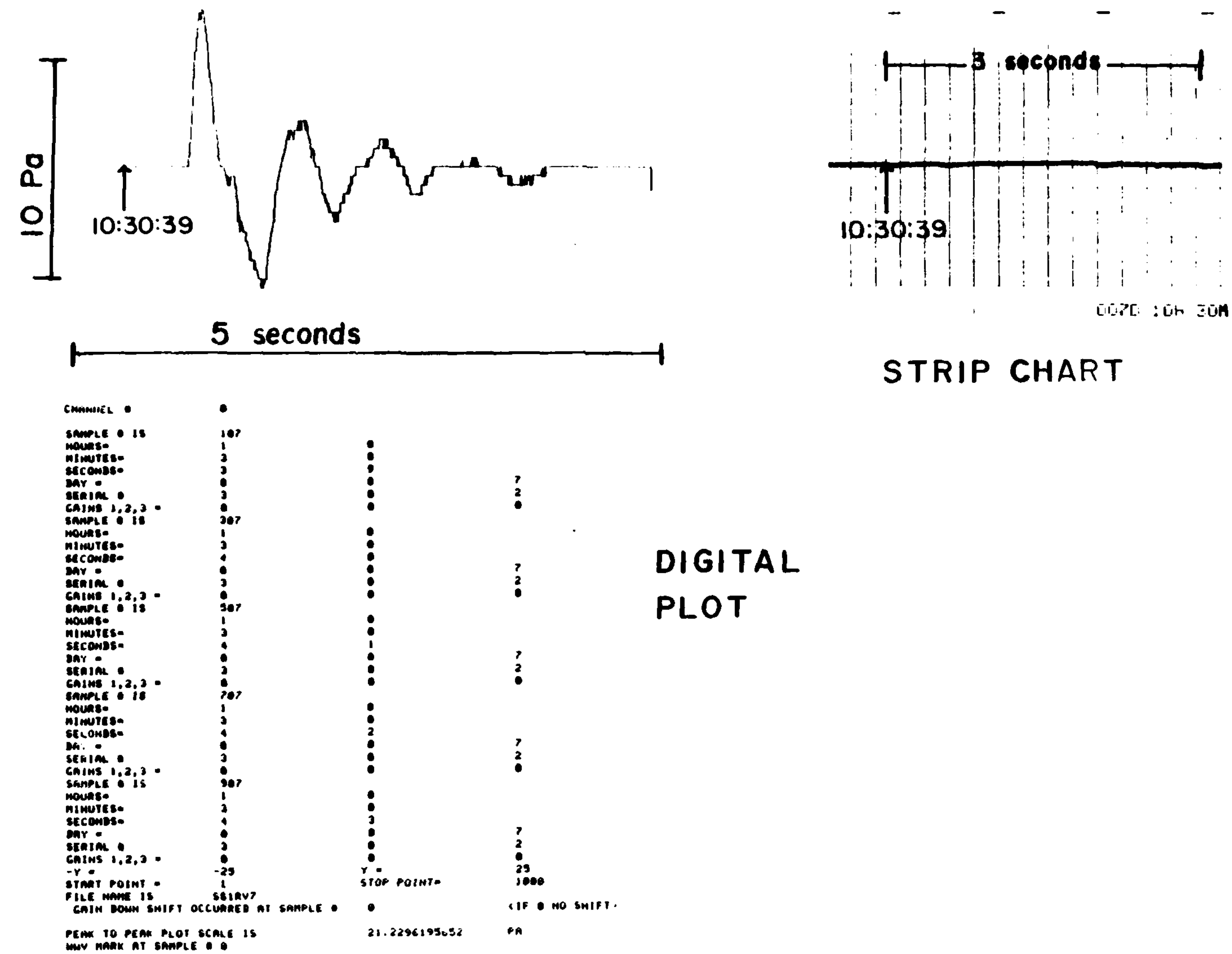


Figure 11. Digital and analog strip chart Validyne records obtained at a range of 14.5 km from the SS1-r test in the ISST test series.

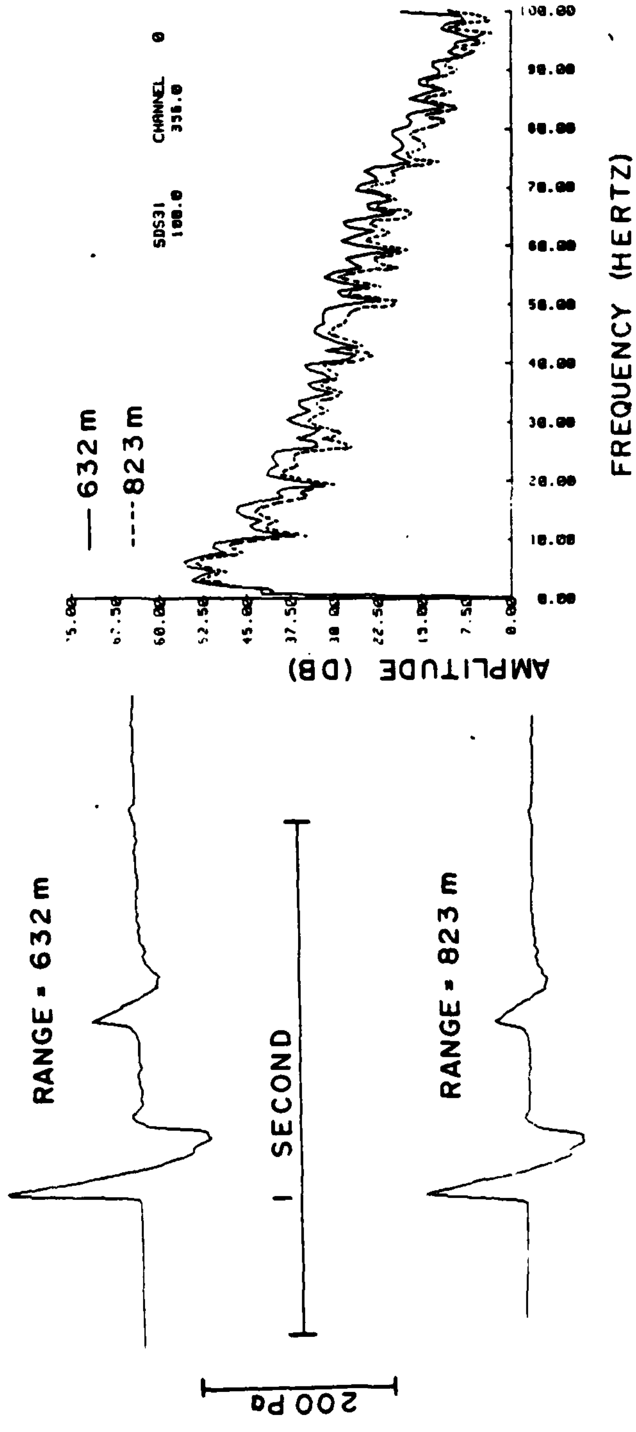
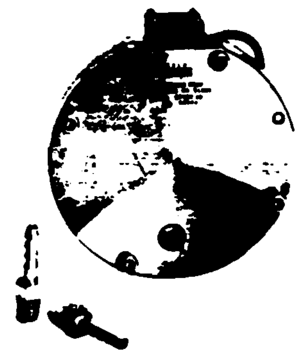


Figure 12. Pressure waveforms and spectra obtained at two ranges from the SNL Thunderpipe shock tube.



Ultra-Low Range

Features

- Full Scale ΔP as Low as ±0.008 PSI
- High Line Pressure Capability
- Wet-Wet Differential
- Equal Pressure Inlet Volumes
- Low Acceleration Sensitivity
- Field Interchangeable Sensing Diaphragms

Description

The DP103 is designed for exceedingly low differential pressure measurement applications where high accuracy is required under rough physical environmental conditions. With full scale ranges down to ±0.008 psid (±0.56 cm H_2O), this instrument is being used in the measurement of very low flow rates of gases where symmetrical pressure cavities are required for dynamic response. Also used in very small leak detection and pressure null detection systems.

Wet-wet applications involving corrosive liquids and corrosive gases are easily handled as all surfaces exposed to the media are corrosion resistant steel. Overpressures as high as 100 psid will not destroy the diaphragm and with recalibration the instrument may continue to be used. Used in conjunction with a Validyne Carrier Demodulator, a ±10 volt DC output may be obtained for a pressure of ±0.008 psid. The transducer may be located 1000 feet or more from the electronics with no problem.

Optional Features

Dash #	Description
DP103-549	Viton o-rings
DP103-1077	Silicon o-rings
DP103-1246	Non-standard cable length (specify length of cable on order)
DP103-1295	With vertical mounting bracket

Ordering Information

Specify: **DP103 - XX - XXXX**

Option Desired

Range Dash Number from Chart on reverse side

Specifications

Standard Ranges:	±0.008 psid FS to ±12.5 psid FS See Diaphragm Selection Chart on reverse side
Accuracy:*	±0.5% FS
Hysteresis:	0.1% pressure excursion
Overpressure:	±200% FS with less than ½% FS Zero Shift
Overpressure Limit:	15 PSI for -26 and below 100 PSI for -28 and above
Line Pressure:	100 psig, less than 1% zero shift
Inductance:	20mH nominal, each coil
Zero Balance:	≤ ±5mV/V at rated excitation
Rated Excitation:	5 volts rms, 5kHz
Excitation Limits:	30Vrms @ 3kHz 1 to 20 kHz with 20 mh coils
Sensitivity:	20mV/V for full scale, nominal
Pressure Media:	Corrosive liquids & gases, compatible with 410ss, inconel, and Buna N O'rings. (Optional O'ring seal compounds available.)
Temperature:	Operating -65° F to 250°F Compensated: 0°F to 160°F
Thermal Zero Shift:	0.01% FS/°F Typical
Thermal Sensitivity Shift:	0.05%/°F Typical
Pressure Cavity Volume:	35×10^{-3} cubic inches (.57 cc)
Volumetric Displacement:	3.5×10^{-3} cubic inches (.057 cc)
Pressure Connection:	⅛-27 NPTF. Adaptor Fittings for 3/16 I.D. hose furnished
Electrical Connection:	Bendix PT06A-10-6S(SR) or equivalent**
Size:	1¼"x4"x4⅜"
Weight:	39 oz. (1.11 Kg)
Replacement Diaphragms:	Order P/N 8 - XX Diaphragm Dash Number from Range Chart on reverse side

*Accuracy includes the effects of linearity, hysteresis and repeatability

**Effective Feb. 1, 1983

Figure 13. Illustration and performance specifications for the DP103 ultra low range pressure transducer.

TABLE 1. PMEL CALIBRATION RESULTS, OCTOBER 1983.

PME CALIBRATION DATA

1. NOMENCLATURE	2. MODEL	3. SERIAL NUMBER
Transducer Press	P305D	62565

4. CALIBRATED BY	5. ENVIRONMENTAL DATA	6. CALIBRATION PROCEDURE	7. DATE
[illegible]		COMM DATA	19 Oct 1983

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING		ERROR
		PSI	D.C. VOLTAGE OUTPUT		
	WATER		POS	NEG	
	MANOMETER		SIDE	SIDE	
		0	-0.002	+0.002	
		0.05	+1.977	-1.954	
		0.10	3.945	-3.928	
		0.15	5.900	-5.831	
		* 0.18	7.655	-6.787	
		0.15	5.918	-5.869	
		0.10	3.956	-3.926	
		0.05	1.991	-1.964	
		0	+0.003	-0.009	
	* UNIT	OVER RANGES	ABOVE	0.18 PSI	

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PME CALIBRATION DATA

1. NOMENCLATURE	2. MODEL	3. SERIAL NUMBER
Transducer Press	P305D	62566

4. CALIBRATED BY	5. ENVIRONMENTAL DATA	6. CALIBRATION PROCEDURE	7. DATE
[illegible]		COMM DATA	19 Oct 83

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING		ERROR
		PSI	VOLTAGE OUTPUT		
	WATER		POS	NEG.	
	MANOMETER		SIDE	SIDE	
			D.C.	VOLTS	
		0	+0.002	-0.002	
		0.05	1.998	-2.015	
		0.10	3.970	-3.971	
		0.15	5.901	-5.872	
		* 0.18	7.112	-6.721	
		0.15	5.937	-5.856	
		0.10	3.991	-3.972	
		0.05	2.005	-1.995	
		0	-0.002	-0.005	
	* UNIT	OVERRANGES	ABOVE	0.18 PSI	

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PME CALIBRATION DATA

1. NOMENCLATURE	2. MODEL	3. SERIAL NUMBER
Transducer Press.	P305D	62567

4. CALIBRATED BY	5. ENVIRONMENTAL DATA	6. CALIBRATION PROCEDURE	7. DATE
[illegible]		COMM DATA	19 Oct [illegible]

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING		ERROR
		PSI	D.C. VOLTAGE OUTPUT		
	WATER		POS.	NEG.	
			SIDE	SIDE	
	MANOMETER				
		0	-0.002	+0.004	
		0.05	+1.985	-1.995	
		0.10	+3.959	-3.947	
		0.15	+5.911	-5.851	
		* 0.2	+7.988	-6.565	
		0.15	+5.936	-5.564	
		0.10	+3.964	-3.900	
		0.05	+2.010	-1.974	
		0	+0.003	-0.009	
	*	OVERRANGES ABOVE	0.2 PSI		

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TABLE 2. PMEL CALIBRATION RESULTS, NOVEMBER 1984.

PME CALIBRATION DATA

1 NOMENCLATURE	2 MODEL	3 SERIAL NUMBER	
TRANSDUCER	P305D	62865	
4 CALIBRATED BY	**5 ENVIRONMENTAL DATA**	**6 CALIBRATION PROCEDURE**	**7 DATE**
C Potts WG-12		33K1-4-3499	1 Nov 84

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING	ERROR
		in H₂O PSI	D.C. OUTPUT	
	WATER	0 0	-0.001	
		0.7 .025	0.997	
	MANOMETER	1.4 .050	1.997	
		2.1 .075	3.000	
		2.8 .100	4.003	
		3.5 .125	4.998	
		3.5 .125	5.003	
		2.8 .100	3.996	
		2.1 .075	2.999	
		1.4 .050	2.000	
		0.7 .025	0.994	
		0 0	-0.003	

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PME CALIBRATION DATA

1 NOMENCLATURE	2 MODEL	3 SERIAL NUMBER	
TRANSDUCER	P305D	62866	
4 CALIBRATED BY	**5 ENVIRONMENTAL DATA**	**6 CALIBRATION PROCEDURE**	**7 DATE**
C Potts WG-12		33K1-4-3499	1 Nov 84

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING	ERROR
		in H₂O PSI		
	WATER			
		0 0	0.001	
	MANOMETER	0.7 .025	1.007	
		1.4 .050	2.010	
		2.1 .075	3.011	
		2.8 .100	4.008	
		3.5 .125	5.008	
		3.5 .125	5.007	
		2.8 .100	4.009	
		2.1 .075	3.007	
		1.4 .050	2.009	
		0.7 .025	1.006	
		0 0	0.001	

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PME CALIBRATION DATA

1 NOMENCLATURE	2 MODEL	3 SERIAL NUMBER	
TRANSDUCER	P305D	62867	
4 CALIBRATED BY	**5 ENVIRONMENTAL DATA**	**6 CALIBRATION PROCEDURE**	**7 DATE**
C Potts WG-12		33K1-4-3499	1 Nov 84

CALIBRATION FUNCTION	STANDARD USED	STANDARD READING	TEST INSTRUMENT READING	ERROR
		in H₂O PSI	DC OUTPUT	
	WATER			
		0 0	.000	
	MANOMETER	0.7 .025	1.0[illegible] 15	
		1.4 .050	2.007	
		2.1 .075	3.004	
		2.8 .100	4.004	
		3.5 .125	5.002	
		3.5 .125	5.000	
		2.8 .100	3.999	
		2.1 .075	3.000	
		1.4 .050	2.001	
		0.7 .025	1.012	
		0 0	0.002	

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APPENDIX A

THEORY AND OPERATION OF VARIABLE-RELUCTANCE TRANSDUCERS*

*Validyne Engineering Corporation, 8626 Wilbur Avenue, Northridge, CA 91324.

THEORY AND OPERATION OF VARIABLE-RELUCTANCE TRANSDUCERS

TRANSDUCERS

Diaphragm-type pressure transducer designs are based on the magnetic-reluctance principle and offer a number of advantages in pressure measurement and control. These include:

1. Excellent dynamic response characteristics with liquid as well as gas systems due to high natural frequency, low volumetric displacement and low internal volume.
2. Ability to accept corrosive liquids and gases on both sides for differential pressure measurement without isolation of a pickoff mechanism.
3. Extreme overload tolerance—operator proof.
4. Ability to withstand severe shock and vibration.
5. High level output.
6. High noise immunity.

In a pressure transducer, shown in simplified form in Figure 1, a diaphragm of magnetically permeable stainless steel is clamped between two blocks, and deflects when the pressure difference is applied through the ports illustrated. An E core and coil assembly is embedded in each block with a small gap between the diaphragm and the E core, in a symmetrical arrangement, resulting in a condition of equal inductance with the diaphragm in an undeflected position. The diaphragm deflection results in an increase in gap in the magnetic flux path of one core and an equal decrease in the other. The magnetic reluctance varies with the gap, determining the inductance value, so that the effect of the diaphragm motion is a change in inductance of the two coils, one increasing and the other decreasing.

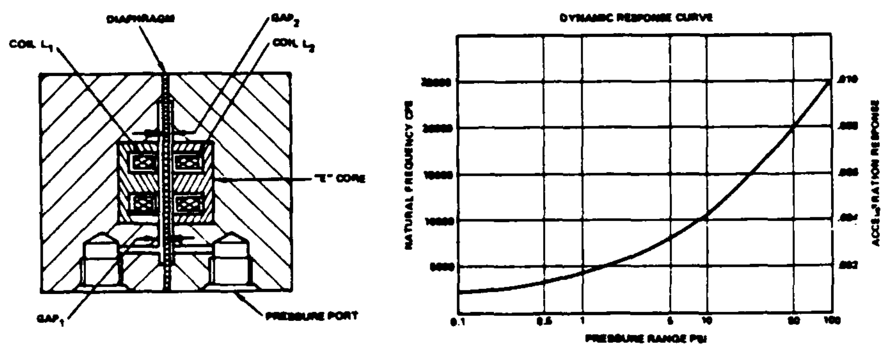

FIGURE 1.0

When the coils are connected in a bridge circuit and are excited by an AC carrier voltage, this output voltage will vary proportionally to the differential pressure applied across the diaphragm. If this output is then applied to the carrier demodulator of Figure 2, the AC output voltage of the transducer may be amplified and rectified (demodulated) to a DC output voltage which is proportional to the pressure applied to the transducer.

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CARRIER DEMODULATOR FUNCTION

The carrier oscillator is a low distortion Wien Bridge-type, with a differential amplifier level sensor. A field effect transistor, used as a voltage-controlled resistor, balances the bridge. Both oscillator frequency and amplitude are regulated by a stable, temperature-compensated zener diode. The oscillator supplies 5.0 V rms at 3 or 5 kHz sine wave to the transducer from the center tapped secondary of a transformer. Grounding the center tap completes the transducer bridge circuit and produces an output which is amplitude proportional to transducer unbalance and sense dependent in the unbalance direction. This AC output is fed to the input of the amplifier/demodulator.

AMPLIFIER/DEMODULATOR

The outputs from the transducer, the *ZERO* control, and the auxiliary balance pin, are summed into the *SPAN* potentiometer. The pot wiper feeds the AC amplifier which drives the demodulator stage. The output stage utilizes an active filter to control the carrier ripple on the carrier demodulator output.

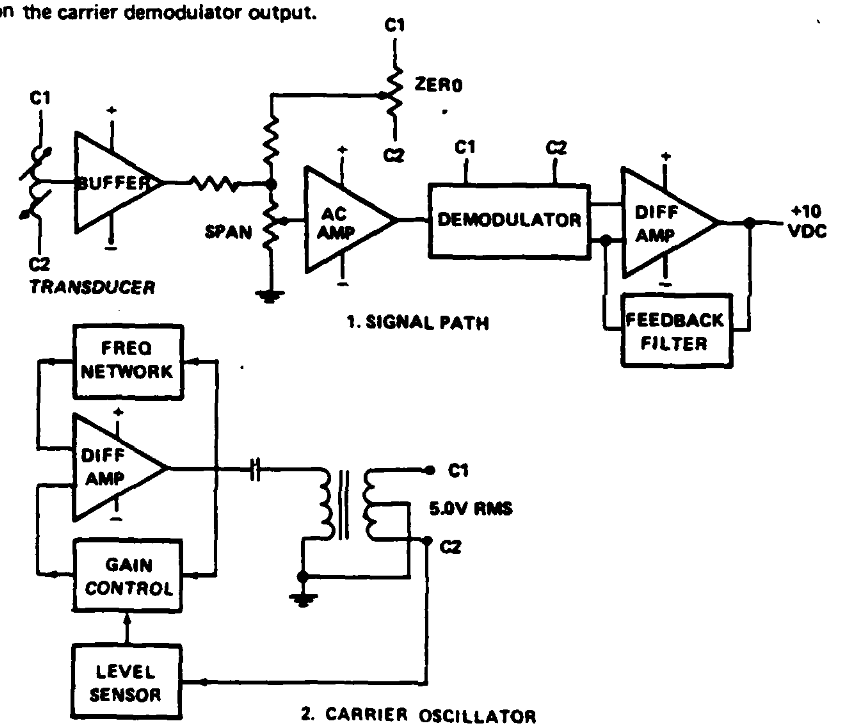

FIGURE 2.0 SIMPLIFIED CARRIER DEMODULATOR

More elaborate systems utilizing full-wave demodulation and carrier amplification are used in many applications to achieve greater output. Carrier demodulators of the CD Series (described in this catalog) are typical. With the solid state circuitry used, these systems are sufficiently small and rugged.

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APPENDIX B

MODEL P305 OPERATING INSTRUCTIONS*

*Validyne Engineering Corporation, 8626 Wilbur Avenue, Northridge, CA 91324.

Validyne Engineering Corporation

Model P305 Operating Instructions

I. INTRODUCTION

The P305A/D Pressure Transducers are a combination of a rugged and reliable variable reluctance pressure sensor combined with a solid state carrier demodulator electronics package to yield a dc-dc transducer capable of operation from an unregulated 10.8 to 32 Vdc power supply and providing a 5 Vdc analog output signal proportional to the applied pressure.

The P305D is used for differential and gage pressure measurements and features symmetrical pressure cavities with only corrosion resistant materials and O-ring cavity seals in contact with the pressure media in both ports. The P305D sensor may be disassembled in the field for cleaning and for diaphragm replacement.

The P305A is used for absolute pressure measurements and features all-welded stainless steel construction.

In both the P305D and P305A, internal adjustments are provided for Zero and output Span.

II. UNPACKING

Transducers are shipped with plastic caps, plugs or adhesive stickers over the pressure ports to prevent dirt from entering the pressure cavities. It is recommended that the covers be left on the ports until ready to make pressure connections. On very low range units the port covers may have a small hole in them— this is intentionally done to eliminate internal pressures caused by installing the cover.

When unpacking, be sure to check the shipping carton thoroughly for any accessory items—pressure fitting adaptors, mating connectors, etc.— that may have been ordered. When replacement diaphragms are ordered for the P305D, a spline wrench used to remove the transducer body bolts will be enclosed. A pressure fitting adaptor with O-ring seal is provided with each P305A.

III. INSTALLATION

Proper installation of a transducer is important but not difficult. This section covers a few guidelines regarding mounting, pressure connections, plumbing, liquid-filling (or "bleeding") and electrical connections which, when observed, will go a long way toward assuring the success of the measurement.

Mounting. The P305A/D offers an integral plate with four holes for mounting on a flat surface. (See Figure 1 for details) The P305D, with two 1/8-27 NPT female pipe ports, can be mounted by rigid pipe connections, the P305A, or the P305D with fitting adaptors for use with tubing systems, should be mounted using the integral plate to prevent strains on the tubing connections. When the integral mounting plate is used, the surface on which it is to be mounted should be flat so as not to induce strain into the transducer body. On low range units such strains can cause small zero shifts which can be accentuated by temperature changes.

Where practicable the transducer should be mounted with the plane of the diaphragm vertical (the plane of the diaphragm is parallel to the mounting surface). This has two advantages: it results in zero gravitational deflection of the diaphragm (this is noticeable in low range units, and particularly so with liquid-filled units), and it allows any dirt particles to fall to the outer edge of the pressure cavity where they will be least likely to interfere with diaphragm motion.

Internal cleanliness will also be enhanced if the transducer is mounted above the point of measurement in order to minimize dirt entrapment or the accumulation of condensate.

Finally, be sure to provide for access to the electrical connector and bleed ports.

Plumbing. The transducer plumbing should allow transducer removal and re-installation without necessitating shutdown of the pressure system. If the transducer is used for gage pressure measurement where one port is left open to the atmosphere, a simple shutoff valve can be installed in the line to the transducer. The open (reference) port should be covered by a porous filter to prevent access of dirt and dust. A plastic cap with a small hole could be used, for example. Use of non-porous plugs is not recommended— the relatively small volume of air trapped in the reference cavity will both act to severely damp transducer response and substantially increase temperature error.

A differential pressure transducer used for measuring the pressure drop across an orifice or filter requires more extensive valving not only to place it into operation but also to remove it without overpressure damage. In this case a valve arrangement as shown in Figure 2 should be used.

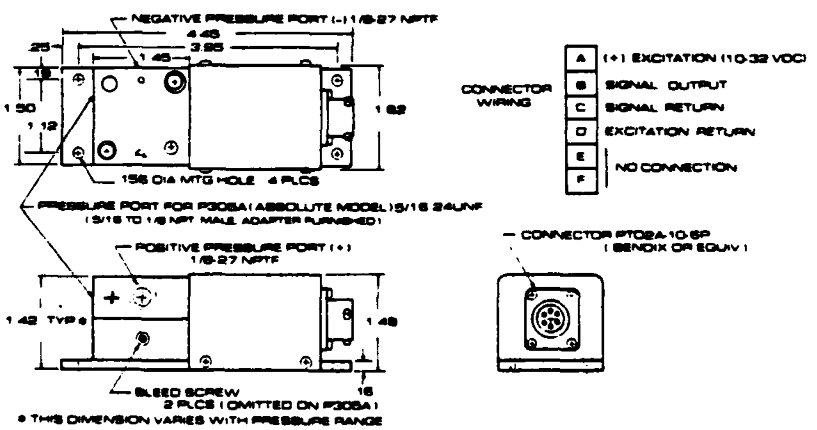

FIGURE 1. Outline/Installation Drawing

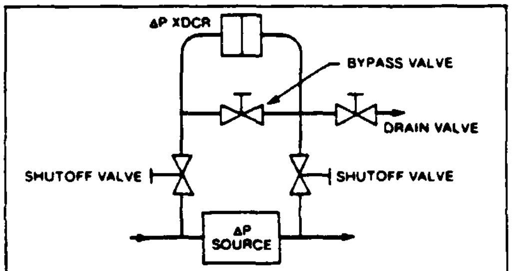

FIGURE 2. Typical Valve Arrangement for ΔP Use

To pressurize the transducer, the drain valve is closed and the bypass valve opened. Then both shutoff valves are opened to apply line pressure equally to both sides of the transducer. Finally, the bypass valve is closed. To remove the transducer, the bypass valve is opened, the shutoff valves closed and the drain valve opened. Valve manifolds for this purpose are commercially available from valve and fitting suppliers.

Pressure Connections. Pressure connections to the P305D are made via 1/8-27 NPT female pipe ports in each cavity. Before making connections to the transducer, be sure the connecting pipe or fitting is free of loose internal scale, and check the threads for cleanliness or damage. If torn or nicked, clean up the thread with a die or chaser. Then wrap the tapered thread with two layers of ½" wide Teflon pipe thread tape (available at most plumbing supply stores), stretching it lightly as it's wrapped so that it conforms to the threads. Wrap in the direction of the thread, as if screwing on a fitting. The Teflon acts as both a thread lubricant and sealant, minimizes thread galling and makes disassembly easier.

When attaching the pipe or fitting, screw it in with a small wrench until it is snug; then, give it another one-half turn. If the threads are not properly prepared and/or excessive torque is applied to the tapered thread, the case material around the pressure port can crack from the high tensile stress created.

The 5/16-24 port in the P305A requires a mating fitting adaptor with an O-ring to make a leak-free connection. The standard P305A is supplied with a 5/16-24 to 1/8-27 NPT male fitting adaptor, with O-ring, for this purpose.

Liquid-Filling ("Bleeding"). The P305D is provided with a bleed port for each pressure cavity to facilitate cleaning or liquid filling of the cavities. The bleed port is sealed with a set screw machined to carry a glass-filled Teflon gasket at its inner end. The gasket provides the sealing action. For static pressure measurements it is generally unnecessary to fill the pressure cavity with the liquid media as any trapped air or gas will transmit the pressure to the sensing diaphragm. However, when good response to dynamic pressure changes or oscillations in liquid-filled systems is important, the pressure cavities and transducer connections should be free of gas. Otherwise the trapped gas acts as a pneumatic damper and can seriously decrease the frequency response of the measuring system.

To remove entrapped gases, loosen the bleed screw one or two turns with a 5/64" hex wrench, with system pressure ON (It is recommended that the bleed screw not be fully removed as the bleed screw gasket could be lost, making an effective seal impossible.) After the trapped gas has been expelled and bubble-free liquid begins to flow out the vent hole, tighten the bleed screw to seal the cavity. Note that the bleed port vent hole for the negative pressure cavity is covered by the base (mounting) plate with the transducer normally mounted. If it is necessary to liquid-fill this cavity, it is suggested that the two screws used to secure the transducer to the base plate be removed to provide sufficient clearance for the expelled media to exit the vent during the bleed operation.

Electrical Connections. The standard P305 uses a PT02A-10-6P (Bendix, or equivalent) 6-pin electrical connector. Input and output connections are as shown on Figure 1. The internal circuitry is electrically isolated from the transducer case. If desired, the cable shield can be connected to the transducer case through the connector shell. However, if the transducer is grounded through its mounting or through the pressure connections, the cable shield should be left floating at the transducer end to eliminate noise from ground currents circulating through the cable shield.

IV. CALIBRATION

As supplied from the factory, the P305A/D transducers have been calibrated for the full scale pressure and output voltage levels specified on the purchase order (full scale output will be 5 Vdc if not otherwise specified). If desired, the P305 can be adjusted for other pressure/voltage relationships, using internal Zero and Span adjustments provided in the electronics module. To determine the range of full scale pressures a given transducer may be calibrated to without diaphragm replacement, see the Pressure Range Chart, Section VI.

EQUIPMENT REQUIRED:

DC Power Supply
Digital Voltmeter, 0 to 10.00 Vdc scale
Calibrated Pressure Source

PROCEDURE:

A. Connect the P305 to a calibrated pressure source commensurate with the transducer range. For the P305A, use a vacuum pump for zero psia input and full scale ranges less than atmospheric pressure.

B. Remove the P305 electronics cover for access to adjustments.

C. Connect the DC power supply to terminals A (+) and D (-) of the P305 connector. Set the supply voltage to the voltage to be used at the installation; this can be any value between 10.8 Vdc and 32 Vdc.

D. Connect the DVM to terminals B (+) and C (-) of the P305 connector.

E. Apply zero pressure to the transducer, and adjust potentiometer Z for a DVM reading of 0± .01 Vdc (For the standard P305, this can be set at any value between ±1 Vdc.) For the P305-1581 (2.5 Vdc output at zero pressure), adjust output to 2.50 ±0.01 Vdc.

F. Apply full scale pressure to the transducer and adjust potentiometer S for a DVM reading of 5.00 ±0.01 Vdc. For the standard P305, this can be set at any voltage between 3 and 5.5 Vdc. For the P305-1581, adjust output to 5.00 ±0.01 Vdc.

G. Repeat steps E and F until interaction between adjustments is eliminated.

NOTE: The potentiometer marked "C", adjacent to the Zero (Z) and Span (S) potentiometers in the electronics modules is used for factory adjustments during temperature compensation operations. Under normal conditions it should not be necessary to readjust this potentiometer in the field. For critical measurements involving widely fluctuating ambient temperatures, it may be necessary to recompensate the unit following disassembly. If so, contact the Application Engineering group at Validyne for detailed instructions based on the span of temperatures to be encountered and pressure range of the transducer.

V. SENSOR DISASSEMBLY & DIAPHRAGM REPLACEMENT (P305D)

The P305D uses a Model DP15 Differential Pressure Transducer as the pressure sensor. This unit may be disassembled for cleaning or diaphragm replacement as described below. The P305A is an all-welded assembly and therefore cannot be disassembled. Figure 3 is an exploded view of the P305D sensor assembly.

Disassembly. To disassemble the transducer first remove the two screws that secure the transducer to the mounting base (#10-32 x ¼" flat Phillips head screws) The leads connecting the transducer and electronics package are approximately 2"-3" long, which should be sufficient to permit disassembly, routine cleaning, diaphragm replacement and reassembly without unsoldering the leads **If it is necessary to unsolder the leads, exercise care in keeping the heat and/or heating time to a minimum—** the terminals to which the leads are attached are tubular feedthru s, inside of which are soldered extremely fine coil termination wires. Excessive heat can result in loss of one or more of these wires and an open coil circuit.

Next, remove the four transducer body bolts (two per side) with a spline wrench (Bristol number S-183, or equivalent). Carefully separate the case halves and remove the diaphragm. Thoroughly clean the case halves, O-rings and diaphragm with a low residue solvent, such as Freon or alcohol, making sure no particles of foreign matter are left inside to interfere with the diaphragm motion (clearance between the diaphragm and the case is only .005" at the center), or in the O-ring grooves.

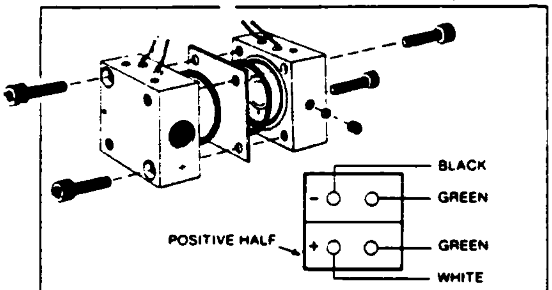

FIGURE 3. P305D Sensor Assembly/Transducer Wiring

Diaphragm Selection. If a damaged diaphragm is to be replaced, or if a different range diaphragm is desired, the Pressure Range Selection Chart, Section VI, describes the available ranges and provides instructions on how to select the appropriate diaphragm for a specific measurement need.

O-Ring Replacement. The cavity seal O-rings supplied in the standard P305D are BUNA-N (Parker Seal compound N674-70, or equal), size 2-024. Replacement BUNA-N O-rings or O-rings of different compounds may be obtained from local suppliers or from Validyne. A listing of available compounds, part numbers and prices are shown in the current Validyne Price List. **NOTE:** Teflon or FEP Thermallon compounds generally should not be used with diaphragms below a 3-32 (2.0 psi) range as their relative hardness may induce stresses in the diaphragm resulting in zero instability.

Reassembly. To reassemble, place the O-rings in the grooves in each half and the diaphragm between the case halves With corrugated diaphragms, the corrugations are usually faced toward the negative case half. Be sure the bolt holes in the diaphragm are carefully aligned with the holes in the case halves. Replace body bolts on one side of the transducer, tightening the bolts until just snug. Inspect the other bolt holes for alignment of the diaphragm holes with the case halves. Replace the last body bolts and tighten all bolts to the torque value given below. If a torque wrench is not available, tighten the bolts as much as possible with a spline wrench. It is very important that the threads on the body bolts do not catch on the holes in the diaphragm, and that the O-rings have been seated in their grooves. Either may cause the transducer zero to shift out of tolerance.

The final bolt torque for the P305D sensor should be 125-130 inch pounds The recommended sequence of bolt tightening is to snug one side and then the other until the O-rings are compressed, then final torque each side in turn

If the leads between the transducer and electronics have been disconnected, it is suggested that, before resoldering the leads to the transducer terminals, temporary connections be made using clip leads to permit a quick functional check of the electronics/transducer combination (see wiring diagram, Figure 3).

Ideally, a check to ensure that the unit can easily be zeroed and adjusted to approximately 5 Vdc output at the required full scale pressure should be made If not practical, at least check ability to zero. If problems are encountered, see the Troubleshooting Guide, Section VII.

Next, resolder leads to transducer, as shown in Figure 3 **Again, be sure to keep solder temperature and time to a minimum, consistent with good soldering practice.** Once reconnected an effective continuity check can be performed by applying power to the unit and adjusting the Z control to verify ability to zero the transducer Finally, reassemble the transducer to the mounting base.

Calibration After Sensor Disassembly. Following disassembly of the pressure sensor, whether for cleaning or diaphragm replacement, recalibration is required Recalibrate as described in Section IV.

VI. PRESSURE RANGE/DIAPHRAGM SELECTION CHART

DIAPH DASH NO.	PSI	IN HG	IN H_2O	KPA	MM HG	CM H_2O
	08	16	2 22	55	4 14	5 60
20	125	25	3 5	86	6 5	8 80
22	20	41	5 5	1 40	10 3	14 0
24	32	65	8 9	2 2	16 5	22 5
26	50	1 02	14 0	3 5	25 8	35 0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	8.0	16 0	222	55 0	414	560
40	12.5	25 0	350	86.0	650	880
42	20	41 0	550	140	1030	1400
44	32	65 0	890	220	1650	2250
46	50	102	1400	350	2580	3500
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
58	800	1600	22200	5500	41400	56000
60	1250	2500	35000	8800	65000	88000
62	2000	4100	55000	14000	103000	140000
64	3200	6500	89000	22000	165000	225000

To order replacement diaphragms, specify

Model Code and Diaphragm Dash No

3 -20 thru -64

HOW TO USE THE PRESSURE RANGE CHART

First, enter the chart by selecting the appropriate engineering units desired (PSI, mmHg, etc.) Move down this column until the desired full scale pressure range is located. Then, select the diaphragm dash number that corresponds to the desired pressure range (number located in far left column). Should the pressure range desired fall between the ranges listed, use the diaphragm dash number for the next higher range Example to obtain a 100 PSI transducer, select a -50 diaphragm This transducer may then be calibrated for any full scale pressure range from 81 through 125 PSI Should the pressure range desired fall on a range listed, then use the diaphragm dash number in the left most column Example to obtain a 650 mmHg transducer, select a -40 diaphragm This transducer, may then be calibrated for any full scale pressure range from 415 to 650 mmHg. When this pressure range chart is so used, the transducer will meet all of the performance specifications for the model

VII. TROUBLESHOOTING

In general, the three most prevalent sources of transducer "problems" are particulate contamination inside one or both of the pressure cavities, over-pressure and improper assembly of the sensor after diaphragm replacement or cleaning operations.

Contamination. To help envision the kinds of problems possible from dirt particles in the pressure cavities, recall that the sensing diaphragm is essentially a flat plate symmetrically placed between two case halves with a nominal clearance, at null, of 0.005" between the diaphragm and each case half. Diaphragm deflection for full scale pressure differential is approximately 0.0013". Depending on particle size, it can be seen that particulate contamination can restrict full diaphragm deflection and/or can prevent the diaphragm from returning to a null position when the differential pressure is removed.

Another contamination phenomenon that can affect very low range units involves the presence of small quantities of liquid trapped between the diaphragm near its center, and one case half. Due to the surface tension of the liquid, the force required to initially deflect the diaphragm is increased over that required for a dry cavity, resulting in an apparent dead-band or severe non-linearity near zero.

Fortunately, contamination problems are easily resolved. Liquid contaminants can often be removed by baking the transducer with the pressure ports open (be sure temperature is well within the 250°F operating temperature rating). For particulate contamination, first try cleaning the cavities by injecting Freon or some other low residue solvent into the cavity. To do this, remove the pressure fittings, if any, and the bleed screw. **DO NOT LOSE THE SMALL TEFLON GASKET ON THE INNER END OF THE BLEED SCREW.**

Flush the cavity by holding the transducer so that the solvent can flow out the pressure port. Repeat until the solvent comes out clean. Then check the transducer calibration before reinstalling. If the contamination consists of hardened material it will be necessary to disassemble the transducer for cleaning (see section V).

Overpressure. In general, the 200% overpressure rating for Validyne Variable Reluctance Pressure Transducers is quite conservative. In many cases, the lower the rated range, the higher the actual overpressure (as a percentage of full scale) required to physically damage the diaphragm.

A first indication of possible overpressure is a fairly large zero shift. A shift of up to 15 to 20 percent of full scale does not necessarily mean that the diaphragm is useless. Rezero the transducer and check the calibration as outlined in Section IV.

A substantial zero shift, e.g. greater than 50% of full scale, may indicate that the diaphragm has been seriously distorted and must be replaced. As a first diagnostic step to determine the usefulness of the diaphragm after a substantial overpressure, the transducer body bolts should be loosened and retorqued to the limits given in Section V. This permits the diaphragm to fully return to an unstressed null position. A calibration test is then performed, looking particularly at zero stability (repeatability), linearity, full scale output and, if necessary, plus to minus full scale symmetry.

In the Trouble Shooting Guide that follows are a listing of several catagories of observed problems, possible causes and solutions. Obviously it is not practical to cover all possible situations. If a problem persists, call Validyne's Application Engineering group for assistance (it's toll-free except in California, Alaska and Hawaii).

TROUBLE SHOOTING GUIDE

PROBLEM	POSSIBLE CAUSE	SOLUTION
ZERO BALANCE OUT OF SPEC	1 Warped or damaged diaphragm	Reverse diaphragm. If still out of spec with opposite sign, replace diaphragm
	2 Contaminated pressure cavity	Clean & reassemble
	3 Body bolts improperly torqued	Loosen & retorque bolts. Follow sequence & torque levels in Section V
OUTPUT NOT IN SPECIFICATION	1 Diaphragm range incorrect	Check diaphragm by dash number. Required range should be between 50 & 100% of tabulated value.
	2 Body bolts improperly torqued	Retorque in sequence to levels specified in Section V
	3 Obstruction in port or pressure cavity	Clean transducer halves & diaphgram clear ports
NON-LINEAR RESPONSE OR EXCESSIVE HYSTERESIS	1 Over-ranging diaphragm	Check diaphragm dash number with chart
	2 Obstruction in pressure cavity	Clean and reassemble
	3 Body bolts not torqued correctly	Retorque in sequence to levels in Section V
	4 Swollen or torn O-rings	Check for compatibility with pressure media, replace as required
EXCESSIVE OR ERRATIC ZERO SHIFT UNDER LINE PRESSURE	1 Leak in system	Recheck all fittings
	2 Loose body bolts	Retorque per level & sequence instructions of Section V
	3 Damaged diaphragm	Replace as necessary
	4 Missing or damaged O-rings	Replace as necessary
	5 Loose bleed screw	Check bleed screws are tight
	6 Improperly bled pressure cavity	Bleed pressure cavities to remove entrapped air
	7 Missing bleed screw gasket(s)	Replace bleed screw gasket(s)

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