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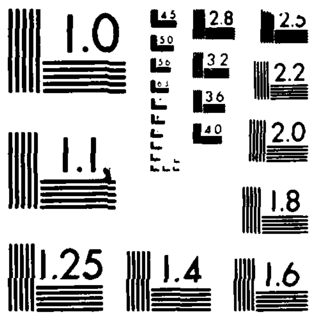

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MICROPHONICS TEST STATION FINAL REPORT

Contractor: Honeywell Electro-Optics Divison

Contract: DAAK 70-82-C-0002

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	P001	**August 1982**
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Reporting Period: DID B003

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Honeywell

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REPORT DOCUMENTATION PAGE

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SUMMARY

OBJECTIVE:

Design, develop and fabricate a test station capable of automatically testing common module detector/dewars for excessive microphonic noise.

TECHNICAL PROBLEMS:

- Frequency Spectrum of Vibration
- Vibration Profile
- Testing Time
- Suitability of Available Equipment
- Random vs Pseudo-Random Noise Generation
- Real Time Control

GENERAL METHODOLOGY:

Conceptual approach followed by paper design, breadboarding, fabrication, testing, and integration of components.

TECHNICAL RESULTS:

Extremely fast testing, analysis, and printout for common module detector/dewars by a compact test station.

IMPORTANT FINDINGS AND CONCLUSIONS:

Automatic testing of common module detector/dewars can be accomplished at volume production rates. The equipment can also be used to provide the detector static noise curves and the vibrational envelopes of mechanical coolers.

IMPLICATIONS OF FURTHER RESEARCH:

Dynamic D* station is possible with shaker reconfiguration and the addition of a modulated IR source. Higher throughputs would be attainable with a reliable and repeatable quick connect/disconnect mechanism.

SIGNIFICANT HARDWARE DEVELOPMENTS:

Very low-noise fifteen-channel amplifier/multiplexer was successfully designed, built, and tested. A three channel pseudo-random digital signal generator was designed, built, and tested.

SPECIAL COMMENTS:

Easily provide individual detector static noise curves, ability to provide cooler vibrational characteristics. Great growth potential through software.

BACKGROUND:

The U.S. Army undertook in 1977 to qualify second sources for the Common Module Detector/Dewar. Successful completion of this action would permit open competition in a cost competitive environment for the planned major procurements of Common Module systems. Santa Barbara Research and Honeywell EOD, formerly Electro-Optics Operations, were competitively selected as the two second source candidates. Both vendors have successfully qualified their detector/dewar designs to the government supplied specification. This specification has been subsequently proven to be no guarantee that the component will be compatible in a given Common Module system. The specification shortcomings have been recognized by NV&EOL and they are endeavoring to correct the deficiencies.

In the production of the M1 Thermal Imaging System (TIS), the problem of microphonics manifested itself. Acceptance of detector/dewars was a subjective judgment of the test technician observing the CRT display in the TIS. No attempt was made to balance the preamplifiers with the detector. This procedure often produced moot results. Rejection rates were unacceptably high even though the units had worked satisfactorily on a Tank Thermal Sight (TTS) and had met the acceptance criteria on the final detector test station. The most significant problem was the question of cooler induced detector noise. There was and still remains no specification on the detector/dewar vibrational environment. This factor is extremely critical to an independent detector/dewar supplier who does not have the luxury of mating cooler performance with that of the detector/dewar while integrated in the final infrared system. As a result of the above conditions, Honeywell vigorously attacked the microphonics problem. A study effort was undertaken to clearly define and characterize the problem. This study was conducted by Dr. Paul Lovecchio for NV&EOL. The results are given in a confidential addendum to the final report for Contract DAAK70-80-C-0072.

NV&EOL recognized the need for a production microphonics test station. They included the requirement for such a station into the Firm Fixed Price No Fee Contract DAAK70-82-C-0002 at Honeywell. This report addresses that contractual requirement and is submitted in response to data item #B003 of CLIN 0069, Data.

DISCUSSION:

The objective of CLIN 0023, Microphonics Test Station, of Contract DAAK70-82-C-0002 was to design, develop, and fabricate a test station that would be capable of production testing Common Module Detector/Dewars for excessive microphonic noise. The Automatic Detector Test Station (ADTS) checks the performance of the detector/dewar under static conditions. The dynamic performance could only be checked in an operating system. For this reason NV&EOL bailed a Tank Thermal Sight (TTS) to each of the detector/dewar suppliers for use in determining M1 detector/dewar dynamic performance. The TTS performance however did not guarantee that similar performance could be obtained in the M1 Thermal Imaging System (TIS). The TTS currently used for production testing is at best a screening tool and not a production tester. The microphonics test station would be required to operate over a broad frequency spectrum, 50Hz to 20 kHz. The vibrational envelope that was being specified was intended to cover the worst case conditions for a broad representation of mechanical coolers. This results in a very stringent requirement being placed upon the detector/dewar. It does however allow great confidence to be placed on a detector/dewar that passed working with any mechanical cooler. Because all aspects of the microphonics issue were not initially understood, NV&EOL originally requested that a "stinger" mode of excitation be employed. Further, they initially desired that the vibration occur simultaneously on all three axes. This type of excitation and control has not been successfully demonstrated. A number of the station development specifications, such as above, had to be resolved before starting the program. The "stinger" requirement was altered to include only the requirement that provisions for future inclusion of a "stinger" be included. The three axes simultaneous vibration was abandoned in favor of the capability to vibrate in all three axes sequentially. A production test station must have adequate throughput and up-time to sustain production rates. Because of the cost aspects of a fixed price contract, it was essential to minimize the technical and schedule risks. Performance flexibility of the station was considered an important factor because of the volatility in the definition of the vibration profile. A number of other technical problems and the availability of appropriate off-the-shelf equipment presented a significant challenge to completing the effort in a timely manner.

TECHNICAL PROBLEMS:

One of the most significant challenges presented itself in the frequency spectrum and vibrational requirements for the proposed testing envelope. A frequency range of 50 Hz to 20 kHz was needed. Normal vibrational equipment is usually designed to operate at less than 10 kHz. Similarly the readily available vibrational exciters operate in the same range. One commercially available controller, the Spectral Dynamics SD1200A, was capable of operating over the desired frequency range. No exciter was commercially available.

Other technical issues involved the short test time, type of noise generation, real time control, and test approach. All of these factors had an influence in the station design.

GENERAL METHODOLOGY:

The methodology of arriving at the final microphonics test station was the classical approach. There was a conceptual design followed by a paper design. New circuitry was breadboarded and tested. These circuits were then fabricated and performance tested. Integration of components was then performed. The build was completed and integration tested. This classical approach was backed up by a number of alternatives should any technical problem create either a schedule or cost risk. For example, a Spectral Dynamics SD1200A was available for use as a controller should the Honeywell design encounter a significant problem. The control software also existed for the SD1200A and this became the fall back position for the software effort. The development of a triaxial exciter was a natural follow-on to the development and use of a single axis piezo-electric exciter undertaken in the M1 microphonics effort. The initial concern that a piezo-electric exciter may not have sufficient response at the low end of the frequency spectrum was proven to be unfounded.

TECHNICAL RESULTS:

A block diagram of the initial design concept is shown in Figure 1. The final design is basically unchanged from that which was envisioned. The design was predicated upon a prudent selection of commercially available equipments and Honeywell designed items. As noted in Figure 1 the three channel Digital Signal Generator, EMI shield, and the Low Noise Amplifier/Multiplexer were to be designed by Honeywell. All of these Honeywell designs proved to be highly successful.

The three channel digital signal amplifier provides the needed signal inputs to the Wilcoxon Power Amplifier. Although the requirement is for single axis vibration the Honeywell design utilizes all three channels or shakers to provide the single axis response. It was determined during the checkout of the fixture that at a given frequency it may be more efficient to drive the fixture from one of the orthogonal axes other than the "Control" axis. The software program determines the most efficient axis for excitation and then commands the response to the power

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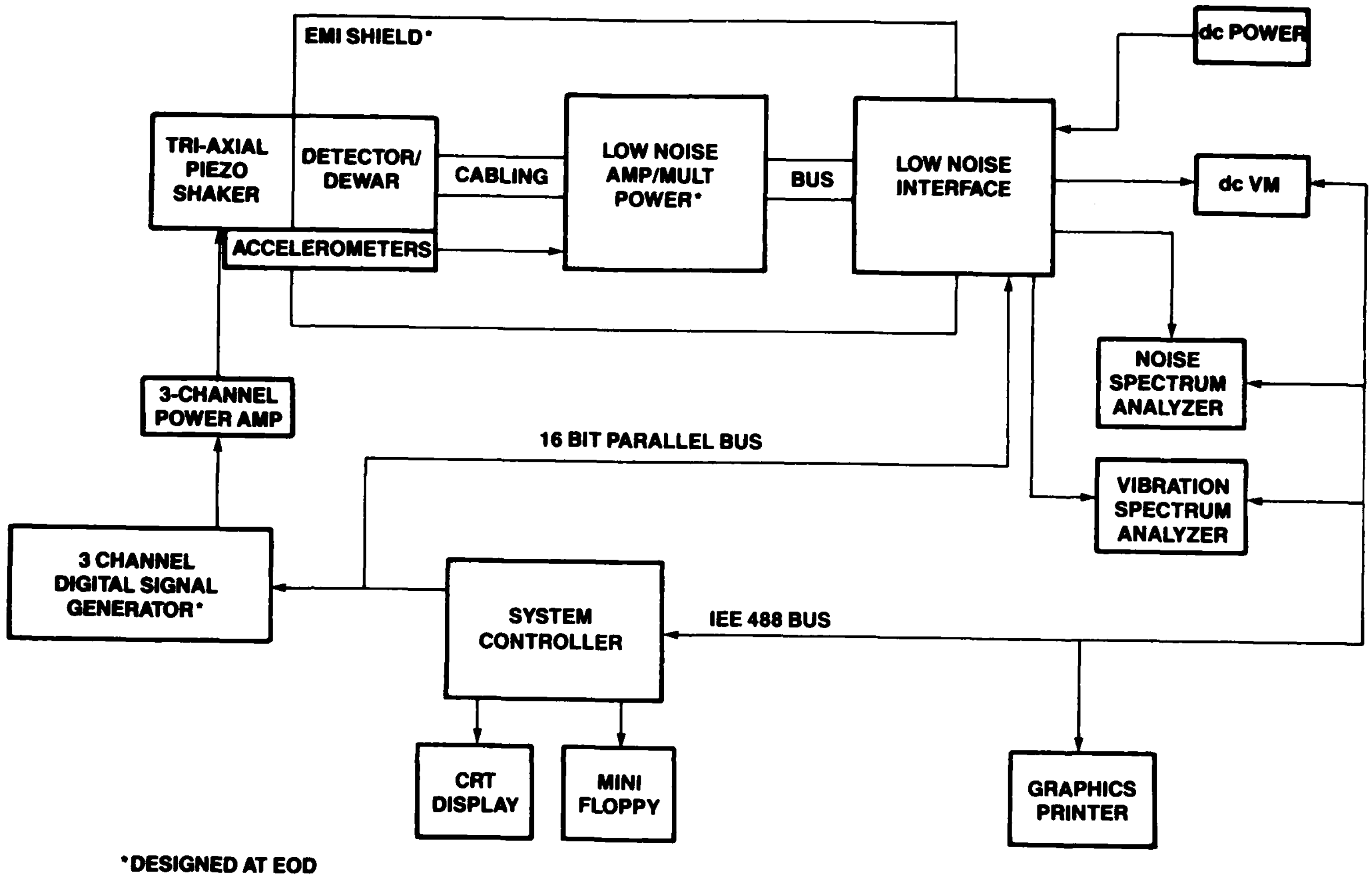

Figure 1 Test Station Block Diagram

amplifier.

The algorithm used to drive all three axes simultaneously in a controlled manner was developed for the first time ever for this program. Since the dynamic range requirements for this program are so severe, an enhancement to the basic single channel algorithm which is used for all previous vibration control systems was developed. This algorithm makes use of the availability of three independent shaker systems to provide the most efficient realization of the desired vibration profile possible without extremely complicated programming and data analysis. The basic algorithm surveys the transfer functions from each of the three shakers to the control accelerometer as a function of frequency and assigns each frequency to that shaker which is most efficient at that frequency. The assignment is rechecked whenever the total adjustment made to the drive spectrum exceeds some limit. The extra computation required for this algorithm is two additional Fourier transforms per iteration, which is well within the capabilities of the HP9836A computer to perform during the 2.5 second per iteration budget.

This algorithm, in addition to providing the intended reduction of the system dynamic range by eliminating those frequencies from the drive signal which require a large drive, also serves to minimize the total drive power and distribute the drive over three shakers rather than one. The result is a significant increase in the capability of the system to drive poorly behaved fixtures over a large frequency range. Although not yet verified, the reduction in total drive power is expected to significantly reduce the magnitude of the off-axis vibration. Although it is a limited application, this is the first use of any algorithm to provide simultaneous control of all axes of a three axis vibration system.

The EMI shield was designed and detailed at Honeywell. The actual fabrication was subcontracted. It was felt that the fabrication by an outside vendor would be cost-effective and be completed in less time. Due to the nature of the signal analysis performed for microphonics, the requirements for the EMI shield were much more stringent than for a normal detector tester. Honeywell's extensive experience in the design and construction of state- of-the-art detector test stations allowed this design to be undertaken with a high degree of confidence, which has since been justified. The assembled system is essentially free of EMI, even with more stringent conditions than are normally encountered in microphonics testing.

The low noise amplifier/multiplexer is a fifteen channel solid state device. The design uses many of the concepts developed on the most recent detector test stations. Solid state switching is faster and more reliable than mechanical relays. Further the digital nature of the hardware permits the interlacing of functions thereby masking any measurement settling times. Fifteen channel preamp-multiplexer boards are required for a 180 element detector while only four are needed for a 60 element device. The boards are all identical, and can be swapped for replacement and service if required. Two additional types of boards are used in the system: a 5 volt detector bias supply board and a sixteen channel accelerometer multiplexer board. The organization of the system is similar to standard computer architecture and readily supports these multiple functions. The extensive experience at Honeywell in the design of detector testers allowed the implementation of this general purpose, flexible system without compromising the extremely high EMI tolerance that is required.

The proper choice of the computer and spectrum analyzers was a critical point to the success of the proposed design. A HP 9836A was selected as the station computer. This computer is very powerful and fast. Programming of the system was done with Pascal, a higher order language. It was desired to have the computer constantly busy during the test and to make the test time the minimum possible. Shorter test times were achieved by writing a portion of the computer code in machine language. The General Radio Spectrum Analyzers are also extremely fast in their operation. One of the analyzers is dedicated to the control loop while the other is dedicated to the data loop. By way of comparison, a test time of one-sixtieth of that required for the interim test station was achieved. Furthermore, there is a hard copy printout of the data taken as well as a summary plot of the data evaluated against a defined criteria. Figure 2 is a plot of the data for the first ten elements of a TOW detector and is representative of the data for the remaining 50 elements. Figure 3 is an example of the summary plot of the data evaluated against the defined input criteria. The accept/reject criteria is shown as 10 dB in this example.

Now that the hardware has been designed and completed, the software becomes the most important factor, other than contractual, related to the continued use of the station. Figure 4 is a photograph of the completed station. The many sophisticated features of the hardware and the likelihood of changing test conditions require a flexible and easily maintained software base. As an example, the preamp-multiplexer cards have multi-state noise detectors which are not currently used. These would allow for a thorough screening for flashing channels due to multi-state (popcorn) noise, should it be required.

Another potential use for the station, requiring software support, is the testing of dewar subassemblies during manufacture for reliability and microphonics problems. Changes in dewar design and manufacturing techniques could be evaluated at a much earlier stage than previously possible.

IMPLICATIONS OF FURTHER RESEARCH:

The station is presently configured with the fixture and dewar mounted vertically above the piezo-electric shaker. This approach is not likely the most optimum. This approach had been driven by the desire of NV&EOL that a "stinger" be employed. This was subsequently changed to require only that the potential of a "stinger" be included in the design. Data has shown that the Honeywell detector/dewar design need not be coupled by a "stinger" . The mechanical design is such that the mounting plate vibrational excitation is directly correlatable to endwell vibration. It is entirely feasible to reorient the shaker and have a much smaller fixture vertically beneath the shaker. If this were accomplished, a modulated blackbody could be added to the system and the detector could be dynamically tested for performance. No such test capability currently exists.

Common Module connectors are not conducive to repeated use. Current connection methods are basically identical to system mounting, i.e. use of jack screws. Additional effort could be expended on developing a reliable, fast interconnection scheme similar to that used on the final test stations.

Further investigations should be made into the microphonics issue to fully understand the importance of defects such as flashing elements and other occurrences that result in a display which is other than perfect. It has been shown that the high performance detector, i.e. one that performs much above the specification, may result in a display which may not appear acceptable to the human eye. The microphonics test station provides the means to quickly provide any necessary detector data.

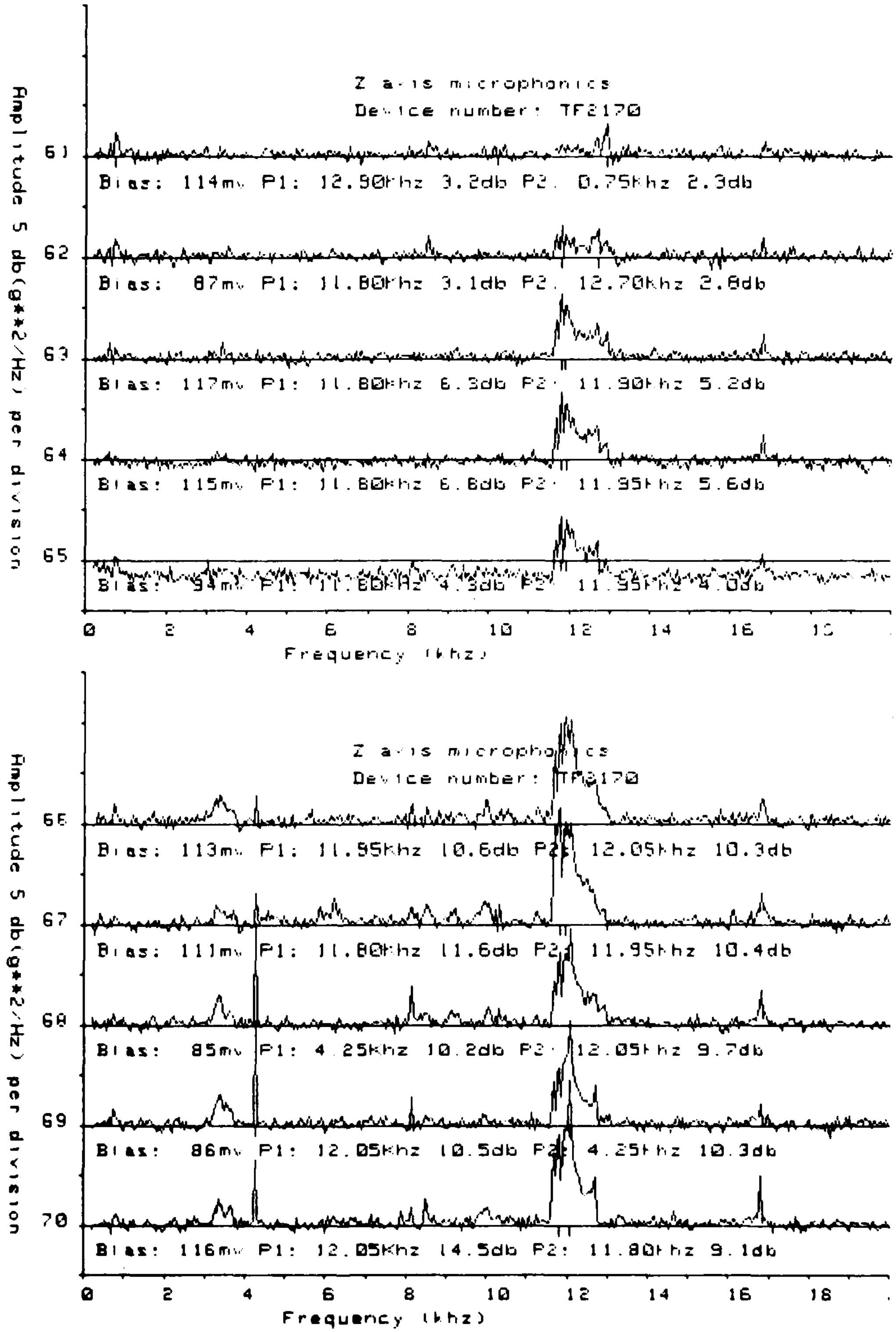

Figure 2 Noise Data Sample, 50 Hz to 20 kHz

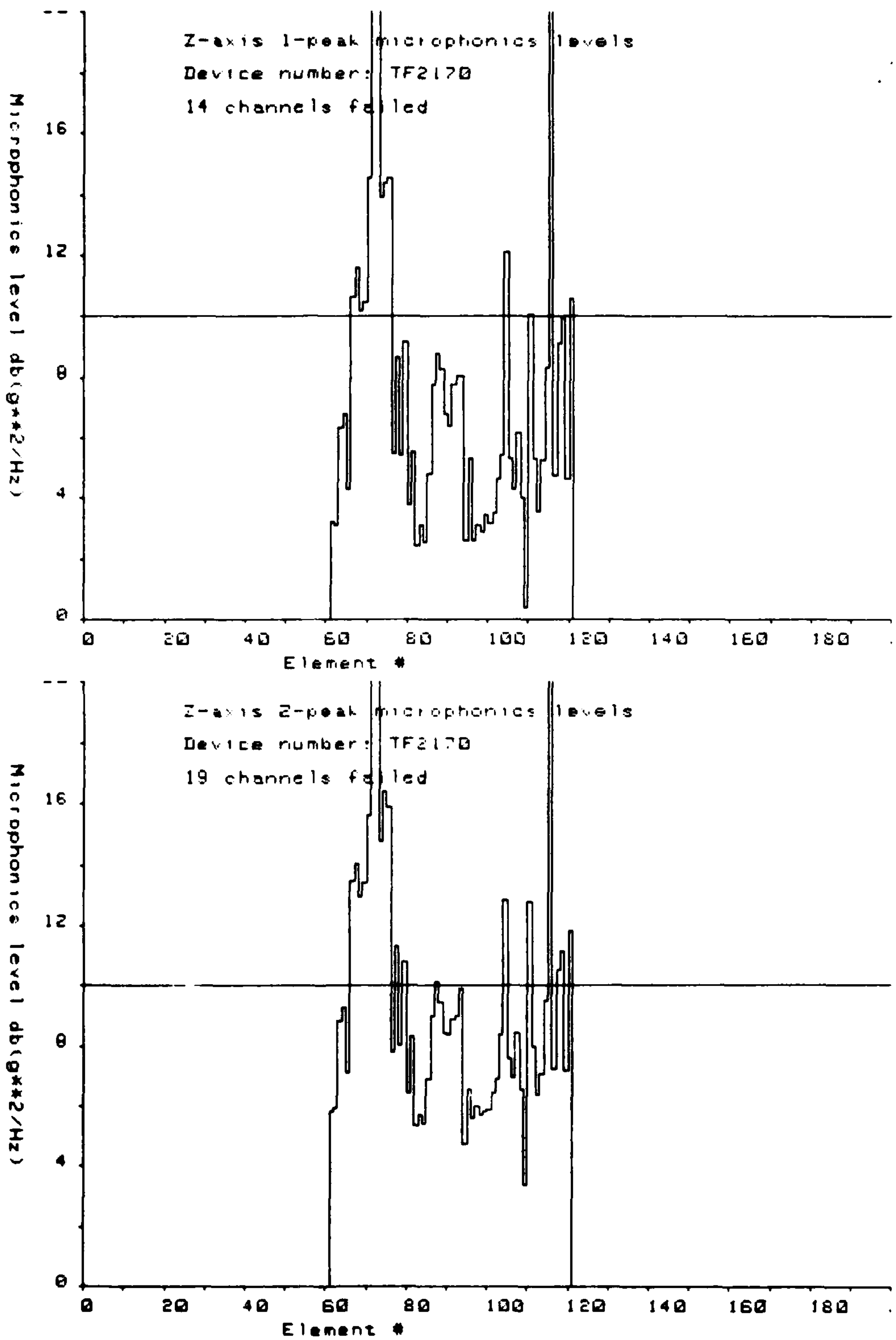

Figure 3 Summary Plot

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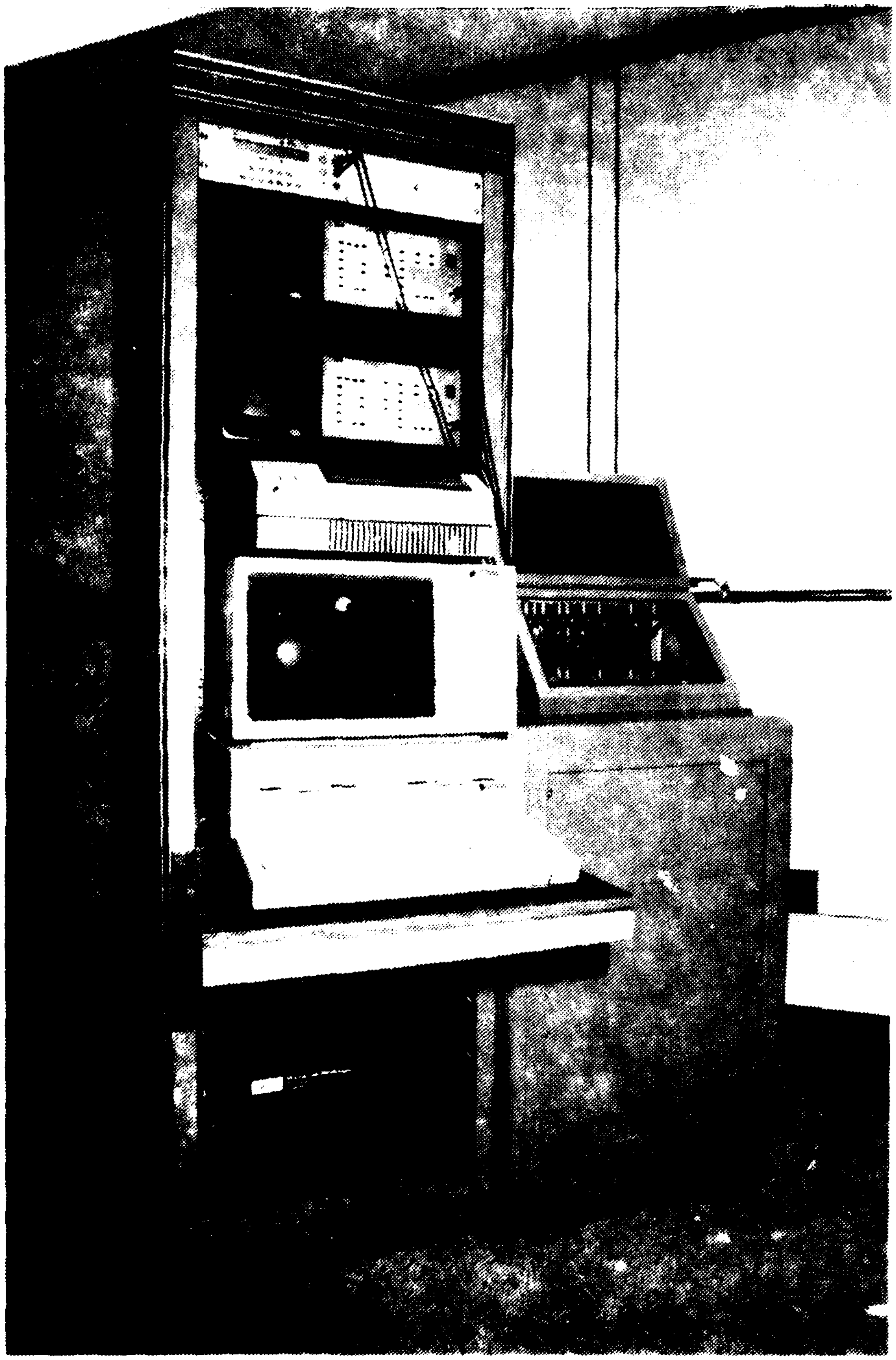

Figure 4 Microphonics Test Station

SIGNIFICANT HARDWARE DEVELOPMENTS:

There were a number of hardware developments that occurred with the development of the microphonics test station. The first item was the piezo-electric shaker system. This system includes three identical orthogonal piezo-electrical crystal stacks that are capable of operating over the range of 50 Hz to 20 kHz. The feasibility of such large crystal stacks had never been attempted. The performance proved to be more than adequate.

The second item was the design and fabrication of a three channel pseudo-random digital signal generator that would provide the necessary control signals to the power amplifiers for the individual piezo-electrical crystals.

The third item was the design and build of a fifteen channel low noise pre-amplifier card that is entirely solid state in operation. Isolation between channels is 100 dB thereby permitting command functions to occur on the same card while data is being taken. This is a significant advance in that the operation involves very low signal levels and extremely high amplifier gains.

It is also significant that the volume of equipment and required floor space have been greatly reduced. This is extremely important when competition for floor space exists.

SPECIAL COMMENTS:

The design of the microphonics test station is such that it is adaptable in many ways. For example, it can immediately be used to characterize the detector noise curves under static conditions. This data provides an immediate visual presentation from which the 1/f value can be determined. Figure 5 is an example of such a printout. The computer also determines the 1/f knee and presents the result graphically on the printout. It is also possible to profile the vibration envelope of a cooler. This vibrational envelope can be filed and be recalled and duplicated by the station. This could prove to be an excellent tool in matching coolers with detector/dewars. Figure 6 is an example of the vibrational envelope for a particular cooler as recorded by the station and the vibrational envelope as returned to the shakers from memory. It is readily apparent that the station can reliably reproduce any envelope within the design operational limits of the station.

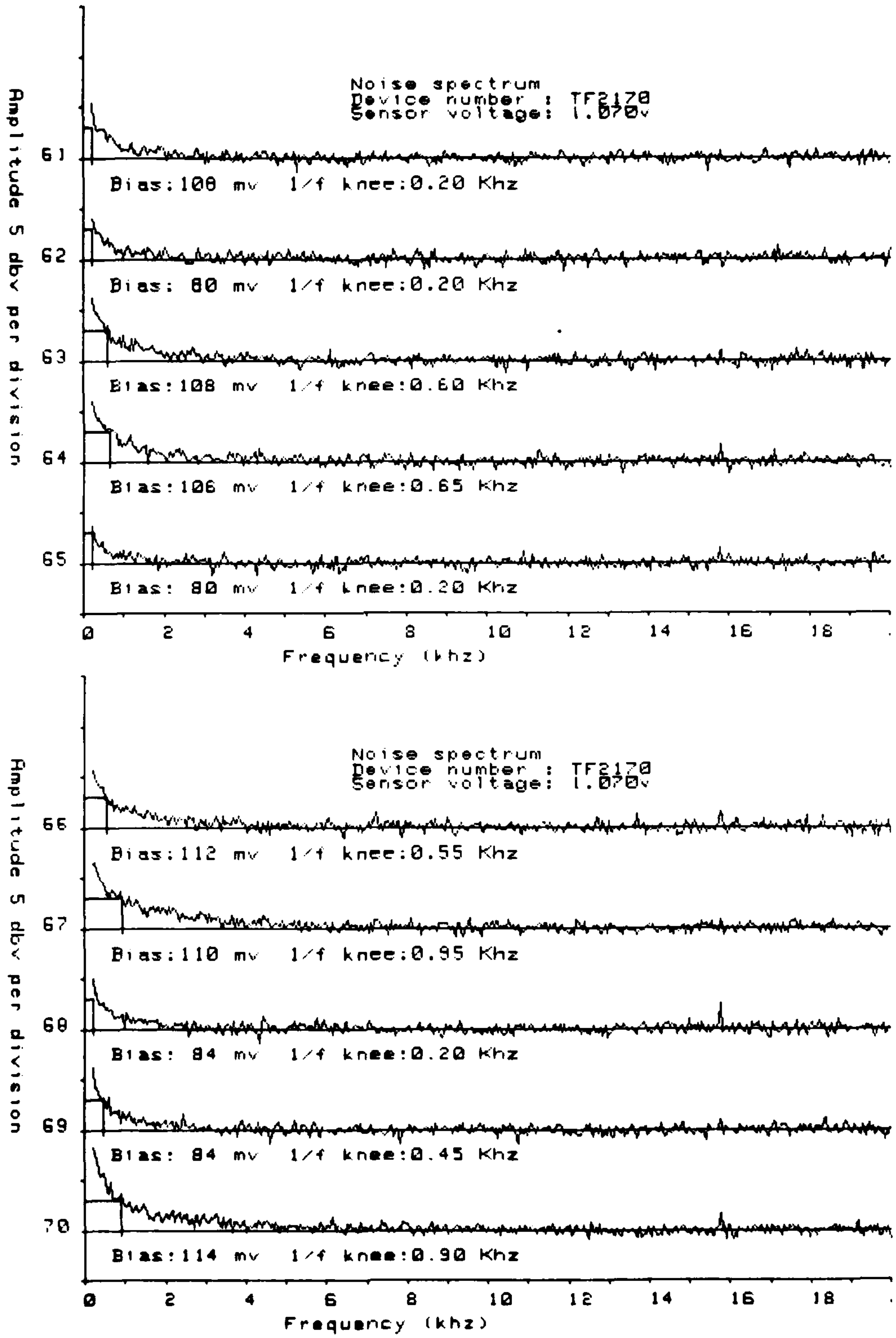

Figure 5 Static Detector Noise Curves

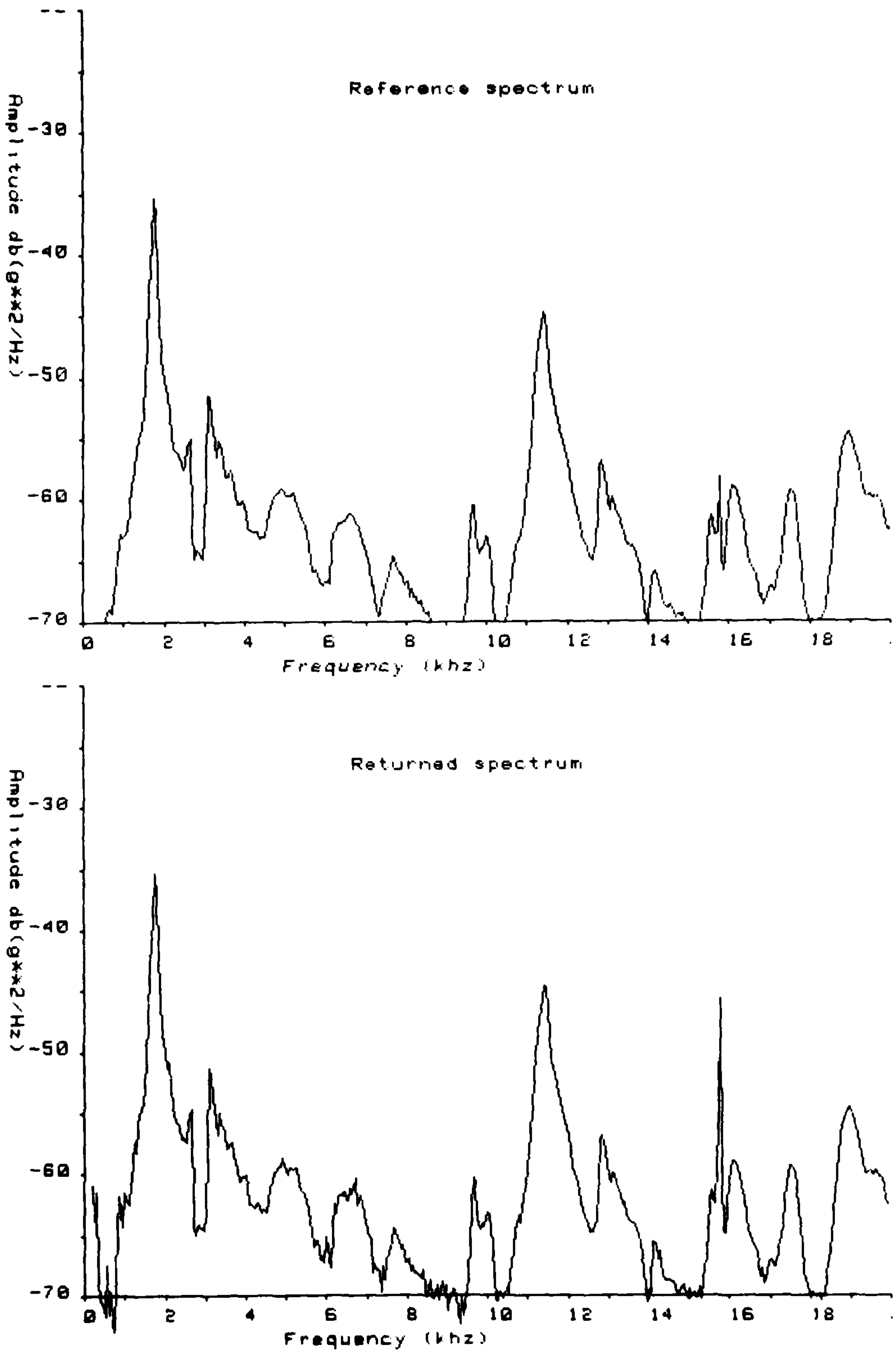

Figure 6 Cooler Vibrational Output

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