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Westinghouse Astronuclear Laboratory

EVALUATION TESTING
OF THE CEC TYPE 4-125 AND 4-126 VELOCITY TRANSDUCERS

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EVALUATION TESTING

OF THE CEC TYPE 4-125 AND 4-126 VELOCITY TRANSDUCERS.

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ABSTRACT

Consolidated Electrodynamics Corporation Type 4-125 and 4-126 velocity transducers were evaluated for possible use as diagnostic instruments on NERVA reactor tests.

Non-nuclear and nuclear tests were conducted on both types. Nuclear testing was accomplished by mounting the units on one of the nozzle inlet lines of the Phoebus-1A reactor and monitoring their performance during the full power run.

In general, the test results revealed that the velocity transducers operated very satisfactorily. With some redesign, the units should prove to be rugged, reliable, and accurate transducers for monitoring vibrations on the NERVA pressure vessel, nozzle, and associated piping. With additional development, it is felt that these units could be modified so as to operate in the severe environments encountered at locations inside the reactor pressure vessel.

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EVALUATION TESTING OF THE CEC TYPE 4-125 AND 4-126 VELOCITY TRANSDUCERS

1.0 INTRODUCTION

The purpose of this report is to present the results of the non-nuclear and nuclear evaluation testing conducted on Consolidated Electrodynamics Corporation Type 4-125 and 4-126 linear velocity transducers. The purpose of this evaluation was to determine the suitability of these units for use as diagnostic instruments on NERVA reactor tests. The report describes the static and dynamic non-nuclear tests conducted at WANL by the Reactor Component Sensor Development Group, and the nuclear evaluation conducted by LASL on the Phoebus-1A reactor. The efforts of Mr. E. Brown of LASL and Mr. C. Tallman of AGC in arranging for the evaluation of these units on the Phoebus-1A reactor are gratefully acknowledged.

2.0 BACKGROUND HISTORY

During the first part of Contract Year 1965, increased interest was expressed in the possible use of linear velocity transducers for monitoring vibrational data during testing of the NERVA reactors. Velocity transducers appeared particularly well suited for measuring the types of vibrations experienced on earlier KIWI and NRX tests. This is due to the fact that many of the reactor components exhibited relatively low g, low frequency vibrations in combination with high g, high frequency vibrations. Of the three types of transducers which could be used for measuring vibrational data, namely displacement, velocity, and acceleration sensors, the velocity transducer stands out as the clear choice if one desires to cover the range of g levels and frequencies with one instrument.

A literature survey of commercially available velocity transducers revealed that the Consolidated Electrodynamics Corporation had two models which appeared quite promising for use in NERVA reactor environments. These two models, designated Type 4-125 and 4-126, are constructed entirely from inorganic materials and are rated for use at temperatures up to 700°F. They are presently in widespread use by major airlines for monitoring jet engine vibrations and have proven to be very reliable in actual service. The high reliability is undoubtedly largely due to the simple, rugged design of these units as described in the next section of this report. Another item of considerable importance is the fact that these units are self-generating and require no input power or excitation voltage. This greatly simplifies the data handling equipment requirements, and hence contributes to the reliability of the overall instrumentation system.

Despite the apparent advantages of the CEC Type 4-125 and 4-126 velocity transducers, two major questions remained with regard to their use on NERVA reactors. The first concerned itself with how well these units would perform at cryogenic temperatures. The manufacturer's specification rated them for use at temperatures down to -65°F . They had no data on whether the units could function properly at temperatures down to -320°F . The second question dealt with how the units would perform in a nuclear radiation environment. Because of their design and inorganic construction, there was little concern over the possibility of permanent radiation damage. However, radiation-induced heating in the interior components of the transducers appeared to be a possible problem area, even for radiation levels such as one would encounter on the pressure vessel or nozzle.

In order to resolve the above questions, and to gain first-hand operating experience with the velocity transducers, two Type 4-125 units and one Type 4-126 unit were purchased (Ref. Purchase Order 59-NW-47680, dated December 29, 1964). Delivery of the units was completed in March 1965. After the non-nuclear tests were completed at WANL, the three transducers were shipped to LASL on April 8, 1965 for installation on the Phoebus-1A reactor.

3.0 SYSTEM DESCRIPTION

3.1 Description of Velocity Transducers

Two CEC Type 4-125 (serial numbers 3442 and 3444) and one Type 4-126 (serial number 4930) were subjected to the non-nuclear and nuclear evaluation tests described in this report.

3.1.1 Physical Description of the 4-125 Transducer (See Figure 1)

The Type 4-125 vibration transducer consists of a stainless steel case assembly, bobbin assembly, fixed magnet assembly, magnet sleeve, and two compression springs. The case assembly consists of a cylindrical body with a rectangular base. Four No. 6 mounting holes in the base are used to attach the vibration transducer to the equipment under test. A stainless steel plug is welded into the bottom of the case. The bobbin assembly consists of a bobbin, cap, and a two-terminal electrical connector. The bobbin is a stainless steel cylinder attached to the cap with a special nut. The bobbin is wound with two opposing coils. The coils are insulated by glass impregnation and are connected to the terminals of the electrical connector. The magnet sleeve is installed in the center bore of the bobbin. The permanent magnet is installed inside of the magnet sleeve with a compression spring at each end. The sleeve, magnet and springs are retained in the bobbin by a threaded spring retainer. The bobbin is inserted into the case assembly and attached with four socket-head screws and lockwashers. A diffusion seal is used to seal the bobbin assembly to the case assembly.

FIGURE 1
CUTAWAY VIEW OF THE CEC TYPE 4-125 VELOCITY TRANSDUCER

3.1.2 Physical Description of the 4-126 Transducer (See Figure 2)

The Type 4-126 vibration transducer consists of a stainless steel case assembly, bobbin assembly, fixed magnet, and two coil-type springs. The case assembly consists of cylindrical case brazed to a rectangular base. Four No. 6 mounting holes in the base are used to attach the vibration transducer to the equipment under test. A cylindrical pole piece is welded to the inside of the case. The bobbin assembly consists of a bobbin, cap, and a two-terminal electrical connector. The bobbin is a stainless steel cylinder press-fitted into the cap. The bobbin is wound with two opposing coils. The coils are insulated by glass impregnation and are connected to the terminals of the electrical connector. The permanent magnet is installed inside of the bobbin with a coil spring at each end. The bobbin is inserted into the pole piece in the case assembly and the bobbin assembly cap is attached to the case assembly with four socket-head screws and lockwashers. A diffusion seal is used to seal the bobbin assembly to the case assembly. The vibration transducer is filled with argon gas and sealed by a stainless steel ball welded in a hole in the bottom of the case assembly.

It is obvious that the 4-126 and 4-125 transducers are very similar in their physical design. The major difference lies in the fact that the 4-125 is more suited for repair and/or overhaul by the user in his own instrument shop.

3.1.3 Technical Characteristics

Type 4-126	Type 4-125
<u>Sensitivity</u> 145 ± 4 mv/in./sec at 75°F into a 10,000-ohm resistive load. (Sensitivity is defined as the output voltage divided by the velocity. It is implied that both voltage and velocity are in the same class of units, i.e. peak, rms, or average. The sensitivity is expressed in a vertical upright position, with a 10,000-ohm resistive load impedance, and driven at 100 cps and 2 in./sec/rms.)	$\dots 105 \pm 3$ mv/in./sec.
<u>Input Power Requirements</u> None (self-generating unit)	$\dots$ Same
<u>Frequency Response</u> $\pm 6\%$ between 45 and 1500 cps throughout the operating temperature range. (Frequency response is defined as the variation of the sensitivity with change of frequency. It is expressed as a percent of the mean of the sensitivities measured over the specified frequency range.)	$\dots$ Same

FIGURE 2
CUTAWAY VIEW OF THE CEC TYPE 4-126 VELOCITY TRANSDUCER

Type 4-126

Type 4-125

Damped Resonant Frequency
13 cps nominal.

...15 cps nominal.

Dynamic Range (See Figure 3 for Vibration Nomograph)

Frequency
45 to 1500 cps

...Same

Amplitude
0.15 inch peak-to-peak (maximum).

...0.1 inch peak-to-peak
(maximum).

Acceleration
1 to 50 g's peak.

...Same

Linearity
+1% of the 20 g output within the

...Same

dynamic range.

Thermal Coefficient of Sensitivity
-0.02% per degree F. (Thermal

...Same

coefficient of sensitivity is defined as the change of sensitivity with change of temperature. This is expressed as a percent of the sensitivity at 75°F.)

Transverse Response

2% maximum (Transverse response is defined as the output signal that is caused by an input which is perpendicular to the sensitive axis. It is expressed as a percent of the transverse drive magnitude.)

...Same

Coil Resistance
490 ohms $\pm$ 15% at 75°F.

...420 ohms $\pm$ 15% at 75°F.

Insulation Resistance
0.1 megohm (minimum) over the temperature range and using 45 V dc.

...Same

FIGURE 3
VIBRATION NOMOGRAPH

Type 4-126	Type 4-125
<u>Maximum Static Acceleration</u> 2.2 g's along the sensitive axis will produce full travel of the moving mass. The unit will withstand 100 g's without damage.	...Same
<u>Operating Temperature Range</u> -65°F to 700°F	...Same
<u>Dimensions</u> 1 in. diameter, 2-1/8 in. high, base 1.23 in. square	...1-1/4 in. diameter, 2-1/8 in. high, base 1-1/4 in. square
<u>Weight</u> 6 ounces (maximum)	...8.0 ounces (maximum)
<u>Mounting</u> Four mounting holes in the base to accommodate No. 6 screws.	...Same

3.1.4 Principle of Operation

Both the 4-125 and the 4-126 are linear velocity transducers of the seismic-mass type. Both utilize a permanent magnet suspended "loosely" in a coil of wire. The magnetic circuit is closed through the air gap between the case and the pole pieces of the magnet assembly. This air gap is interrupted by the coils. The flux field in the air gap is normally aligned with the approximate midpoint of the coils by the centering action of the two magnet springs. As the component under test vibrates, the rigidly-mounted case and coil move with the vibration. When the frequency of vibration is higher than the natural resonance of the magnet assembly, the magnet assembly (due to its inertia) remains stationary and the coil windings cut through the magnetic field in the air gap. Due to this relative motion, a voltage E_o is generated across the terminals of the coil according to the following equation:

$$E_o = \frac{d\Phi}{dt}$$

where Φ is the magnetic flux and $\frac{d\Phi}{dt}$ is the rate of change of flux. The term $\frac{d\Phi}{dt}$ is proportional to the relative velocity of the impressed vibration within the useful frequency range, thus the electrical output is directly proportional to the velocity of vibration being measured. This signal can be integrated or differentiated to obtain displacement or acceleration. The low frequency response is limited by the natural frequency, while the high

frequency limit of 1500 cps is determined by the usually small velocity values at these frequencies, and by secondary resonances in the spring-mass system.

3.2 Description of Measurement Systems

3.2.1 Dynamic Test Set: Figure 4 is a single line drawing of the dynamic test set used in the non-nuclear testing conducted at WANL. Output voltage and temperature were automatically recorded utilizing the data logging system. Ling vibration equipment and auxiliary electronics were utilized to test the units under dynamic conditions. Nine curves per unit were hand plotted and are presented in the following sections of this report.

The accuracy of the dynamic test set is estimated to be 4.3 per cent, worst case.

Shaker Calibration	3.0 per cent
Effect of mounting extension	3.0 per cent
Instrumentation, other	<u>1.0 per cent</u>
Accuracy, worst case	4.3 per cent

3.2.2 Static Test Set: Resistance, inductance and capacitance measurements were made with a John Fluke Universal Impedance Bridge, Model 710B. The accuracy of this instrument is as follows:

Resistance: ± 0.1 per cent plus 1 dial division
Inductance: ± 0.3 per cent plus 1 dial division
Capacitance: ± 0.2 per cent plus 1 dial division

Insulation resistance was measured with a General Radio megohm bridge, Type 544-B using a test voltage of 50 V DC.

4.0 DESCRIPTION OF NON-NUCLEAR EVALUATION TESTS

The static tests consisted of a measurement of coil resistance, inductance, insulation resistance, and coil to case capacitance at -320°F , 75°F , 200°F , 400°F and 600°F .

The dynamic tests were run to determine the following transducer parameters:

Linearity: Linearity tests were performed at constant frequencies of 45, 100, 500, and 1000 cycles per second, for temperatures of -320°F , $+75^{\circ}\text{F}$, and $+600^{\circ}\text{F}$.

Frequency Response: Frequency response was determined from 45 cps to 1000 cps at temperatures of -320°F , $+75^{\circ}\text{F}$ and $+600^{\circ}\text{F}$.

Channel Designation	Signal
00	AC Output
01	Transducer Case Temperature
T	Time

FIGURE 4

SINGLE LINE DRAWING
 VELOCITY TRANSDUCER
 DYNAMIC TEST SET

Thermal Sensitivity Shift for Constant Velocity: Percent sensitivity deviation was determined from -320°F to $+600^{\circ}\text{F}$ for the following frequencies: 45, 100, 500, and 1000 cps.

Thermal Sensitivity Shift for Constant Frequency: Percent sensitivity deviation was determined from -320°F to $+600^{\circ}\text{F}$ for the following velocity values: 18.4, 12.2, 6.1, and 2.4 inches/second.

5.0 STATIC TEST RESULTS

5.1 Coil Resistance: Coil resistance was measured at several temperatures within the range of -320°F to $+600^{\circ}\text{F}$. Graphs 1 and 2 show the resistance relationship with respect to temperature for types 4-125 and 4-126, respectively. The coil resistance change with temperature for both types was linear and is described by the following calculated relationships:

$$\text{Type 4-125, } R = 0.88T - 65 \text{ ohms} \quad (1)$$

$$\text{Type 4-126, } R = 0.63T + 160 \text{ ohms} \quad (2)$$

where R = end-to-end coil resistance in ohms.

T = temperature in $^{\circ}\text{R}$.

The variation in the constants of equations 1 and 2 is attributed to the material composition of the coil wire.

5.2 Coil to Case Capacity: Some difficulty was encountered in measuring the capacitance from the coil leads to the transducer case. The 1000 cps excitation voltage of the impedance bridge introduced vibrations in the moving element due to electromagnetic flux induced in the coil. This effectively reduced the sharpness of the null detector. The table below lists the capacitance in picofarads for the three temperatures.

Transducer	-320°F	$+75^{\circ}\text{F}$	$+600^{\circ}\text{F}$
4-125 (SN 3442)	754	818	1042
4-125 (SN 3444)	1202	1305	1582
4-126 (SN 4930)	1433	1490	1795

The average coil capacitance percent deviation was less than -7 per cent at liquid nitrogen temperature and about +21 per cent at $+600^{\circ}\text{F}$.

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5.3 Coil Inductance: The same difficulty was encountered in obtaining the coil inductance as described for the capacitance measurements. The following table lists the inductances in millihenries for the three temperatures.

Transducer	-320°F	+75°F	+600°F
4-125 (SN 3442)	29.9	29.3	28.9
4-125 (SN 3444)	30.2	29.7	29.5
4-126 (SN 4930)	26.6	25.3	24.4

The average coil inductance percent deviation was less than + 3 per cent at liquid nitrogen temperature and about -2.5 per cent at +600°F.

5.4 Insulation Resistance: The insulation resistance from the coil leads to transducer case decreased with increasing temperatures. For 4-125 units SN 3442 and SN 3444, the insulation resistance was 40 megohms and 47 megohms respectively. The 4-126 unit developed a short at 600°F. However, upon returning to room temperature the insulation resistance returned approximately to its original value.

6.0 DYNAMIC TEST RESULTS

6.1 Linearity: Graphs 3, 4, 5 and 6 are representative linearity plots of type 4-125 and 4-126 transducers measured at 100 cps and 1000 cps. Linearity tests were run at -320°F (LN₂), 75°F and +600°F. Linearity plots at 45 cps and 500 cps were similar to the above plots. As can be seen from the plots, the units are linear to within ± 1 per cent of the full scale output.

6.2 Frequency Response: Graphs 7 and 8 are plots of frequency response for types 4-125 and 4-126, respectively. These tests were conducted at -320°F (LN₂), 75°F (room temperature) and +600°F. The specified upper frequency limit of the velocity transducers is 1500 cps. However, since velocity levels were small at higher frequencies due to shaker table limitations, the tests were run up to 1000 cps. The frequency response of both types were within ± 5 per cent.

6.3 Transverse Response: The velocity transducers were installed on the shaker table and vibrated at 100 cps perpendicular to the sensitive axis while the output of the units was displayed on an oscilloscope.

At a 40 g level of vibration a damped high frequency oscillation was observed. The frequency of this oscillation was in the vicinity of 12 k cps and was independent of g level. At 40 g's, the peak-to-peak voltage of the damped oscillation was about 100 millivolts and decreased with a decrease in the g level.

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An analysis of the transducer construction revealed that this oscillation was probably caused by the magnet-spring assembly vibrating at its measured natural frequency of 67 cps and hitting the sides of the coil bobbin.

6.4 Relative Output vs. Temperature: Graphs 9 and 10 are plots of percent sensitivity versus temperature for types 4-125 and 4-126, respectively. The curves for 45, 100, 500, and 1000 cycles per second were plotted utilizing the output at 100 cps and 75°F as the 100 per cent reference point.

As can be seen from the graphs, the sensitivity of the transducers decreased with increasing temperature. This phenomenon can be explained by analyzing the following transducer parameters that are being affected:

(1) **Coil Winding Resistance:** A rise in coil winding temperature results in an increase in the resistance of the wires with a consequent decrease in sensitivity level.

(2) **Change in Air Gap:** The air gap between the case and the pole pieces of the magnet assembly will increase due to increased temperature. This will decrease the flux field in the air gap with a consequent decrease in the voltage induced in the coil winding.

(3) **Permeability of Material:** The permeability of the transducer material increases with temperature up to the curie point (which is over 700°F). This tends to increase the sensitivity with increasing temperature. However, since the reluctance of the air gap is much greater than the reluctance of the case to the magnetic flux lines in the transducer, the effect of permeability variation with temperature can be ignored.

The above analysis indicates that the output versus temperature performance of the transducer can be improved, first, by utilizing a coil winding material that is less sensitive to temperature, and second, by utilizing a case material with a lower coefficient of expansion such that the air gap dimensions will stay fairly constant.

6.5 Percent Deviation vs. Temperature: Graphs 11 and 12 are plots of percent deviation versus temperature for a family of velocity curves at constant frequency. The curves were plotted utilizing the output at 75°F and the corresponding velocity level as the reference point. The percent deviation from LN₂ to 600°F for the selected velocity levels is within ± 13 per cent and ± 9 per cent for types 4-125 and 4-126, respectively. The slope of the curves are similar to each other indicating that the temperature sensitivity effect is essentially independent of velocity level.

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6.6 Temperature Gradient Test: Graphs 13 and 14 are plots of temperature shock tests from room temperature to LN_2 . The units were vibrated at 10 g's and 100 cycles per second at room temperature. They were then suddenly immersed in liquid nitrogen. The vibration was held constant and the outputs were monitored. During this test a temperature gradient approaching 400°F was generated between the case and the internal components of the transducer. Thus, temperature gradients generated by radiation heating were simulated. The sensitivity of the units increased during the cooling period as was expected. It is significant that no output spikes or excursions occurred during the thermal shock test as compared with the accelerometer shock test results. The superior performance of the velocity transducers during the thermal shock test is attributed to the inherent functional characteristics of the units, i.e. large axial movements at relatively high speed are needed to obtain measurable outputs.

7.0 NUCLEAR EVALUATION

7.1 Installation on the Phoebus-1A Reactor

The three CEC velocity transducers (two type 4-125 and one type 4-126) were shipped to LASL for performance evaluation in a nuclear environment.

The three velocity transducers were installed on a Phoebus-1A reactor spider leg near the nozzle (one of the three LH_2 pipelines connecting the main propellant feedline to the nozzle inlet torus). They were located on the 240° spider leg about midway along its length and mutually perpendicular to each other. Two of the units (4-125 and 4-126) were provided with a special mounting bracket to aid in dissipating radiation induced heating. The third unit (4-125) was mounted without a heat sink bracket to obtain comparative data.

7.2 Test Results

The results of this test are reported in LASL memorandum N-3/N-7 dated July 19, 1965. The following preliminary evaluation analysis of the three velocity transducers is extracted from the above-referenced memorandum:

"The three signals were played back after the test on CEC strip charts for visual inspection. The traces appeared very similar to corresponding signals recorded during the KIWI-B-4D and B-4E tests. The traces showed the large increase in vibration level with the introduction of LH_2 at the start of the test. The signal amplitude appeared to peg as the flow rate was increased and subsequently decreased to a low level at 22468.7, the time when the nozzle flowed full as confirmed by the high speed movies.

"Power spectral density (PSD) plots were made of the three signals (using site 400 equipment) at several run times for indications of resonant frequencies. These plots

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appear to be similar, indicating resonances, to those recorded during previous KIWI tests, but they do differ in detail. The resonances indicated in this test are much sharper, probably due to the smaller filter width used for this analysis, 5 cps vs. 20 cps used for previous test PSD plots. The indicated major resonances were shifted from previous KIWI tests as follows:

P-1A Spider Resonant Frequencies cps	KIWI Spider Resonant Frequencies cps
70	---
150	190
380	460
760	715

No apparent structural reason can be found for the change in resonant frequencies; the nozzle, spider and coolant piping are mechanically similar to those used on the KIWI-B-4D-202 and B-4E-301 tests."

During a meeting between WANL and LASL instrumentation personnel to review the instrumentation performance on Phoebus-1A, it was pointed out by LASL that the above discrepancy may lie in the manner in which the PSD plots were made, and that further analysis of the data is being conducted to resolve this problem. LASL is quite enthusiastic over the performance of the CEC velocity transducers and will probably use them on future Phoebus tests.

8.0 CONCLUSIONS

Based upon the results obtained during the non-nuclear and nuclear evaluation testing of the CEC Type 4-125 and 4-126 velocity transducers, the following conclusions have been reached:

1. Both types performed in accordance with the vendor's specifications, with the exception of transverse response. The transducers were found to be somewhat sensitive to vibrations perpendicular to the sensitive axis. It is felt that this difficulty can be corrected by a redesign of the spring-magnet assembly.
2. Both types exhibited less temperature-induced sensitivity variation than any other type of vibration transducer tested to date. The worst case variation was approximately ± 15 per cent of the room temperature value over the temperature range of -320°F to $+600^{\circ}\text{F}$.
3. Both types exhibited excellent performance under thermal shock conditions. This is a vast improvement over the performance observed with piezoelectric, unbonded strain gage, and variable reluctance accelerometers.

4. Neither type exhibited any binding of the magnet assembly at cryogenic temperatures. "Stiction," or static friction was virtually non-existent.

5. Results obtained from both types during the Phoebus-1A test revealed no transducer malfunction or gross deterioration when exposed to radiation levels such as encountered at the spider leg location. Of special note is the fact that these units do not require any special heat-sinking or cooling to operate properly in such locations.

6. In general, it is concluded that the CEC Type 4-125 and 4-126 velocity transducers are potentially well suited for the measurement of vibration over the range of values to be encountered in NRX and XE applications. The features of self-excitation, rugged design, relatively high output, high temperature capability, inorganic construction, and simple conversion of the output signal for displacement or acceleration readings are unusually attractive for NRX and XE applications. With some redesign to minimize the transverse sensitivity, the units should prove to be accurate and reliable transducers for monitoring vibrations on the NERVA pressure vessel, nozzle, and associated piping. With additional development aimed at improving the internal heat transfer, it is felt that these units could be modified so as to operate in the severe environments encountered at locations inside the reactor pressure vessel.

9.0 RECOMMENDATIONS

In light of the very attractive features of the velocity transducers discussed above, it is recommended that serious consideration be given to their use on future NRX and XE tests. Specific courses of action which should be taken include:

1. Additional transverse response testing should be accomplished to better define the nature and magnitude of the problem. Steps should then be taken with CEC to correct this deficiency. Since the Type 4-125 and 4-126 performed essentially equally well during the non-nuclear and nuclear evaluation tests, it is recommended that further effort be concentrated on the Type 4-126 only, since it is smaller and weighs less. The repair and/or overhaul advantages of the 4-125 are not particularly appropriate for NERVA applications.

2. Since both types have a rated lower frequency limitation of 45 cps, it is recommended that effort be initiated with CEC to modify the spring-magnet assembly so as to lower this value to approximately 15 cps. This would make the transducer more valuable as a diagnostic tool. It is felt that this modification could be accomplished in conjunction with the work needed to reduce the transverse response.

3. In order to obtain comparative data with Statham unbonded strain gage accelerometers presently being used on the NRX pressure vessels, it is recommended that at least two of the 4-126 velocity transducers be mounted side by side with the Statham accelerometers specified for NRX-A5.

4. In order to provide an accurate and reliable vibration transducer for use inside the reactor pressure vessel (such as on the core support plate and the control drums), it is recommended that a development effort be undertaken with CEC to improve the internal heat transfer of the velocity transducer. The Wiancko AX-44 variable reluctance accelerometers presently specified for these measurements on NRX-A5 will be operating at or somewhat above their maximum rated temperature with an estimated accuracy of ± 30 per cent. Further improvement of the variable reluctance principle does not appear feasible. Based on the testing of vibration transducers accomplished to date, it appears that the best hope for an improved unit lies with the principle utilized in the CEC Type 4-125 and 4-126 velocity transducers.