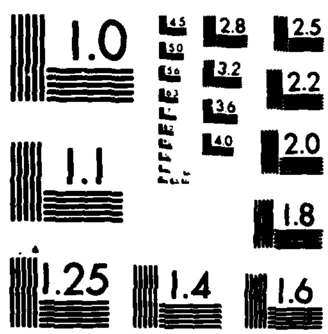
AD-A158 906 ACOUSTIC EMISSION TRANSDUCERS: CALIBRATION ACTIVITIES AND TRANSDUCER DEVELOPMENT(U) NATIONAL BUREAU OF STANDARDS GAITHERSBURG MD F R BRECKENRIDGE ET AL 1/1

UNCLASSIFIED 30 AUG 85 N00014-85-F-0017 F/G 20/1 NL

END
FILMED
DTIC



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

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 85-SUM-ONR	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Acoustic Emission Transducers: Calibration Activities and Transducer Development	5. TYPE OF REPORT & PERIOD COVERED: Summary Report: Fiscal '85
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): F.R. Breckenridge, T.M. Proctor, M. Greenspan, and D.G. Eitzen	8. CONTRACT OR GRANT NUMBER(s): N00014-85-F-0017
9. PERFORMING ORGANIZATION NAME AND ADDRESS: National Bureau of Standards, Gaithersburg, MD 20899	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61153N, RR011-08-01, NR384-303
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of Naval Research, Physics Division, Code 412, 800 N. Quincy St., Arlington, VA 22217	12. REPORT DATE: August 30, 1985
	13. NUMBER OF PAGES: 4
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited. Reproduction in whole or in part is permitted for any purpose of the U.S. Government.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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

The current status of AE transducer calibration and development activities at NBS is summarized.

85 09 06 090

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ACOUSTIC EMISSION TRANSDUCERS: CALIBRATION ACTIVITIES AND TRANSDUCER DEVELOPMENT

F.R. Breckenridge, T.M. Proctor, M. Greenspan, and D.G. Eitzen

Mechanical Production Metrology Division

Center for Manufacturing Engineering

INTRODUCTION

Based on recommendations by ASTM, ASME, and the AE Working Group, a facility for the calibration of AE sensors was developed. This development was partially supported by the Electric Power Research Institute and the Office of Naval Research. The calibration subjects the device under test to a known dynamic displacement in order to determine its sensitivity as a function of frequency. The first method implemented makes use of the surface-pulse configuration[1] in which the mechanical input (a capillary-glass-break source which produces point-force step function) and the device under test are located on the same surface of a large transfer block which approximates a half-space. More recently, a through-pulse method has also been implemented; in this configuration the mechanical input and the device under test are centered on the transfer block on opposite surfaces.

Transducers which measure dynamic surface displacement with high sensitivity and fidelity are being developed, modeled and evaluated by means of the calibration facility. Such transducers are needed as transfer standards for the secondary calibration of acoustic emission sensors, as a tool in developing signal processing techniques to characterize acoustic emission sources, and as transducers for field applications. Both the normal and tangential components of motion must be measured to describe the dynamic displacement at a point on a surface. We previously have developed the NBS conical transducer which measures the normal component of displacement with a sensitivity of approximatley 10^{-13} meter. This transducer is flat in frequency response from a few kilohertz to a few megahertz within a few dB. Transducers based on this development are now available from at least four sources including the NBS Office of Standard Reference Materials.

CALIBRATION AND RELATED ACTIVITIES

Since the beginning of the calibration service for acoustic emission transducers in January 1980, we have performed 633 calibrations, of which, 82 were performed in the past year. Many of these were on experimental transducers constructed at NBS. For example, a number of calibrations have been done as part of the development of transducers described below. Calibration of these transducers has been done using the vertical or horizontal component of motion resulting from the glass-break source and referenced to measured or calculated horizontal displacement. Results from through-pulse calibration and surface-pulse calibration are combined to evaluate the performance of transducers.

A batch of 20 NBS conical transducers is in the final stages of production. They will be used by AE sensor manufacturers, research laboratories, DoD, and testing services as a transfer standards for the secondary calibration of AE sensors or as calibrated displacement sensors for experimental work. The transducers are being equipped with buffer amplifiers to make them more immune to loading and stray capacitance effects, thus increasing the accuracy of the calibration transfer. Other features of the amplifier system include partial shielding of the hot electrode of the transducer, gold contacts for reliability, and an equalizer network to improve the flatness of the frequency response of the transfer standards. Presently, the amplifiers have been constructed, but the transducers need to be recalibrated with the buffer amplifiers in place on the transducers.

Methods for the secondary calibration of AE sensors are being developed. An outline of a possible secondary calibration system has been made. The system would use a steel plate, 91 cm by 86 cm and 3.3 cm thick. The source would be an NBS conical transducer driven by a tone-burst generator, and the calibration would be accomplished by comparing the unknown transducer against a calibrated, NBS conical transducer, both transducers being placed on the same side of the plate as the source transducer and equally distant from it.

A draft ASTM Standard Method on the Primary Calibration of AE Sensors has been written. The ASTM document is currently being balloted at the subcommittee level, having successfully passed an ASTM section ballot. A standard on the secondary calibration of AE sensors is also being developed. This document is envisioned as covering two or three alternative techniques. A technical outline of one technique has been drafted and distributed. A second technique may closely parallel the primary method.

TRANSDUCER DEVELOPMENT

Beginning in 1979 development was begun on piezoceramic transducers for measurement of dynamic displacement. Some of these transducers, which we call NBS conical transducers, have been described in the literature.[2,3] In the past year, work has continued in an effort to develop transducers of motion normal to the surface which can be constructed more easily and to develop transducers of tangential motion. Work has also continued in an effort to analyze the operation of the normal motion transducer.

A new backing design was developed which is much simpler to construct than the polyhedral backing associated with the best model of the transducer. The new backing consists of a rectangular parallelepiped in which a machined cavity is filled with tin. This composite construction provides the backing asymmetry needed to reduce back refelections and the tin improves damping. Transducers produced with this backing are equal to the best transducers using the complex, more difficult to machine polyhedral backing used previously.

A version of the NBS conical transducer having a scaled down active element and conical backing was constructed. An amplifier with a small amount of electrical equalization is used with this transducer to produce a somewhat improved frequency response. Figure 1 shows the time waveform of this transducer. This waveform is very close to the actual normal displacement. Figure 2 shows its amplitude sensitivity versus frequency showing it to have very good fidelity to above 2 MHz.

ANALYSIS

An analysis of the operation of the NBS conical transducer is nearly complete[4]. The analysis is aimed at a better understanding of the device so that it can be optimized or at least tailored for specific applications.

The analysis computes the response of a transducer from the geometry and material properties of the active element and the mechanical impedances looking into the mounting surface and into the backing block. The main problems are

(a) construction of an equivalent circuit for a conical transducer,
(b) derivation of an expression for the terminating impedances,
(c) solution of the Pochhammer-Chree problem for a cone (of finite length), and
(d) calculation of the finite-aperture effect.

The analysis resolves these problems; some approximations being necessary. The analysis is compared with response curves for conical transducers calibrated on the NBS AE calibration facility. One such comparison is shown in Figure 3. The analysis predicts the general features of the measured response well. It also quantifies the importance of the smaller and larger diameters and mechanical impedances of the test surface and backing material. The results also show a modification of the Pochhammer-Chree theory would improve agreement. The roll-off at higher frequencies is, as yet, unexplained.

TANGENTIAL DISPLACEMENT

The development of a high fidelity, sensitive transducer for measuring dynamic tangential displacement continues. This problem is more difficult than the development of normal displacement sensors. In the case of normal displacement sensors, the poled direction is the same as the direction of motion and stress and, since the electrodes of the piezoelectric element are at the ends of this common axis, the element can be poled before or after machining. Preserving this symmetry in a completed transducer is relatively easy.

For tangential transducers, poling electrodes are placed so that the element can be poled parallel to the tangential motion. These electrodes are subsequently removed and measuring electrodes are placed perpendicular to the poling electrodes. Then, when shaping the element, it is more difficult to maintain appropriate symmetries and it is not possible to pole subsequent to machining the element. These difficulties sometimes result in tangential transducers with unwanted sensitivity to normal displacement.

Newly developed fabrication techniques have minimized this problem of cross sensitivity. The response of the newest tangential transducer to normal displacement is more than 20 dB below its tangential response over most of its 1 MHz bandwidth. This newest transducer has quite good fidelity. Its time domain response to a point-force step-function input to the large calibration block is shown in Figure 4A and compares well with the theoretically predicted waveform of tangential displacement shown in Figure 4B. Figure 5 is the amplitude response versus frequency obtained by comparing the FFT of the measured output with that of the theoretical waveform.

SUMMARY

The AE sensor calibration facility continues to be useful for primary calibration and as a basic tool in transducer development.

A new, easier to manufacture backing has been developed for the normal displacement measuring NBS conical transducer. A thorough analysis of the transducer shows good agreement with measured response and provides the tools for optimizing transducer geometry for specific applications. The most recent model of tangential transducer shows good fidelity, measuring waveforms that compare well with theory.

REFERENCES

1. F.R. Breckenridge, "Acoustic Emission Transducer Calibration by Means of the Seismic Surface Pulse," J. Acoust. Emission 1, No. 2, 87-94; (April 1982).

2. T.M. Proctor, Jr., "An Improved Piezoelectric Acoustic Emission Transducer," J. Acoust. Soc. Am. 71(5), 1163-1168 (May 1982).

3. T.M. Proctor, Jr., "Some Details on the NBS Conical Transducer," J. Acoust. Emission, 1(3), 173-178 (July 1982).

4. M. Greenspan, "The NBS Conical Transducer: Analysis," to be submitted to J. Acoust. Soc. Am.

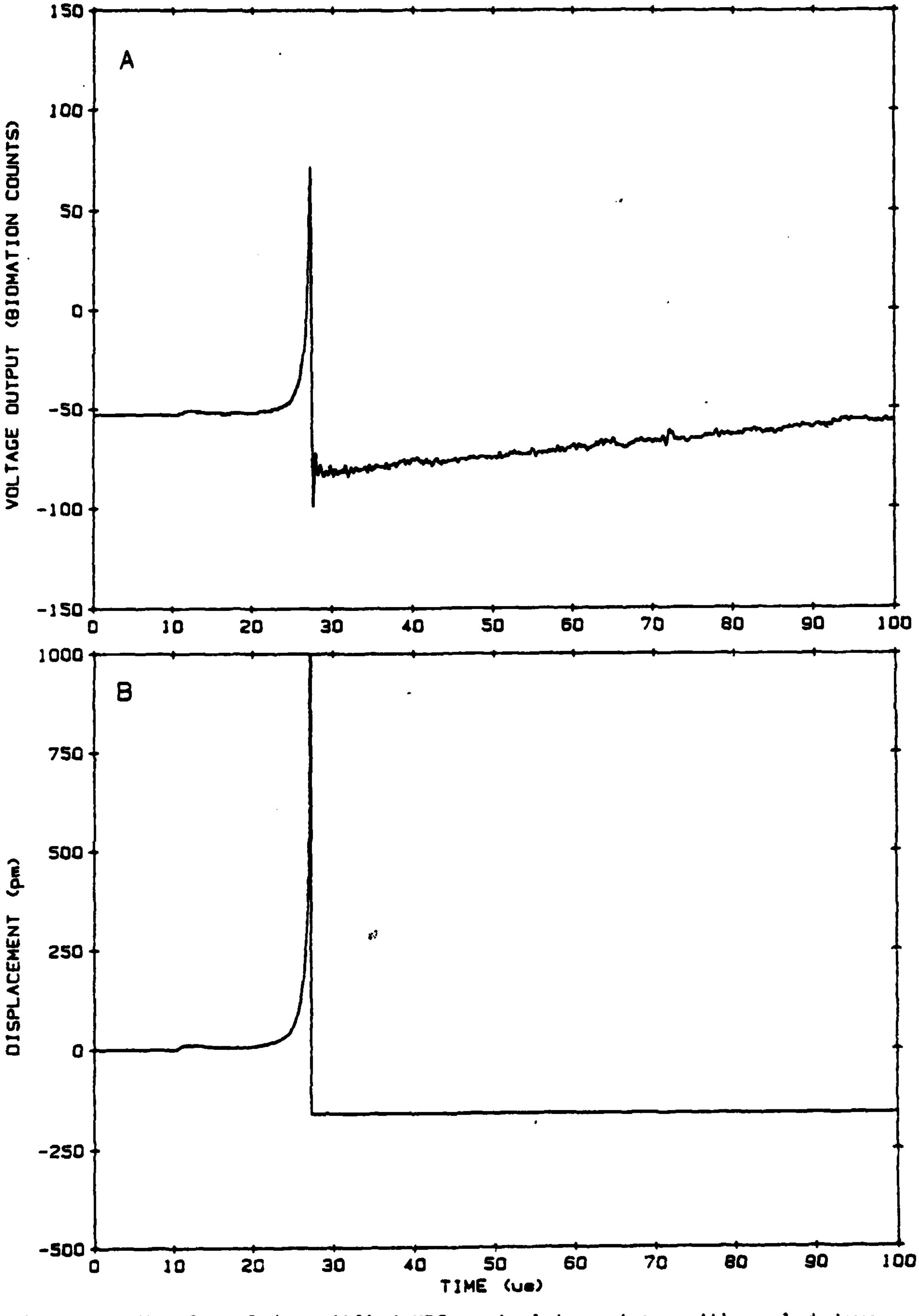


Figure 1. Waveform from modified NBS conical transducer with scaled down active element and electrical equalization: A is the voltage output from the transducer resulting from a glass break 10 cm away. B is the calculated displacement in the normal direction resulting from a step-function source 10 cm away.

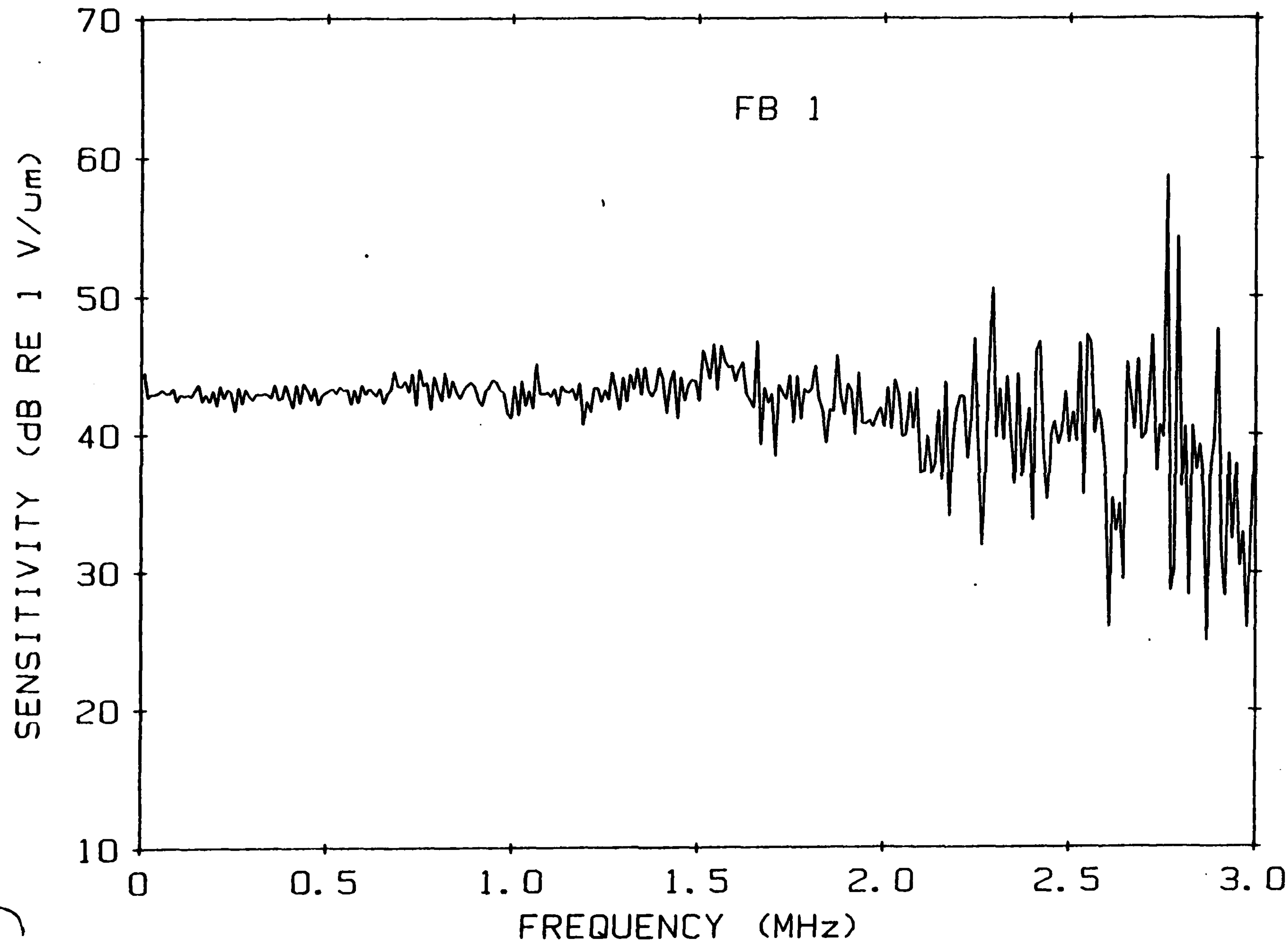


Figure 2. Amplitude response versus frequency for the modified NBS conical transducer.

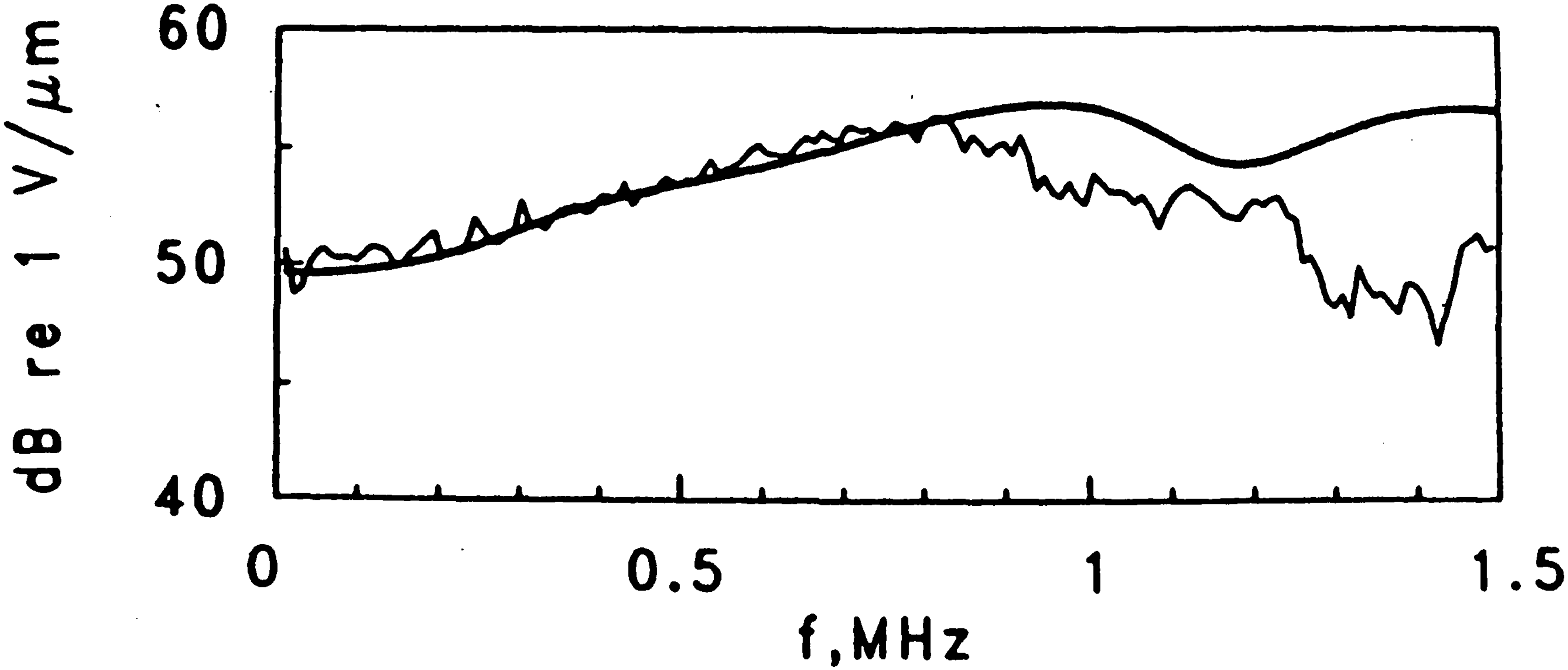


Figure 3. Amplitude versus frequency for a conical transducer with a smaller diameter of 0.62 mm, a larger diameter of 1.74 mm and a length of 1.24 mm. The thick line is from the analysis; the thin line is measured response.

7

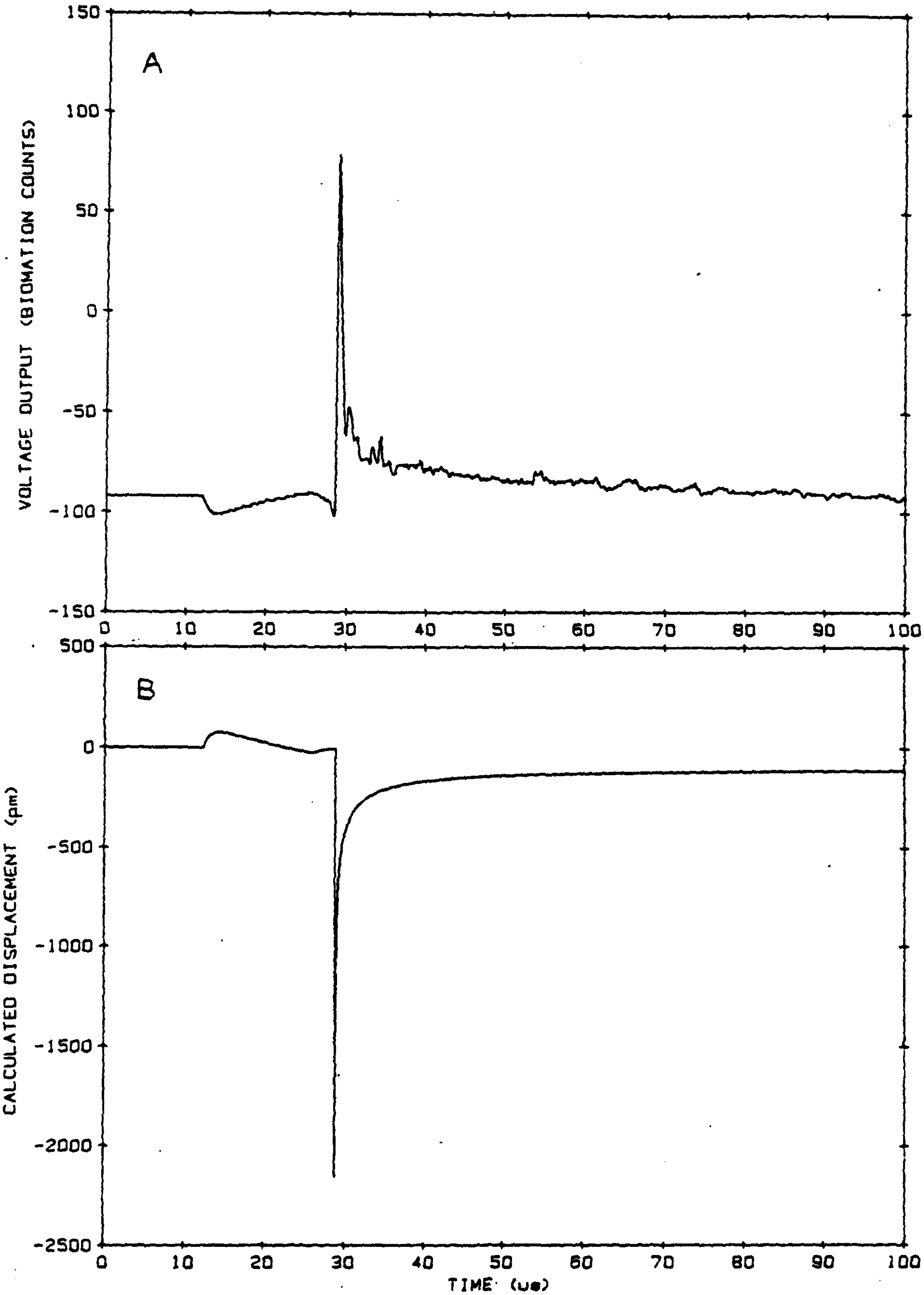


Figure 4. Waveform from the tangential sensor compared with theory: A is the voltage output from the tangential sensor resulting from a glass-break source 10 cm away. B is the calculated displacement in the tangential direction resulting from a step-function source 10 cm away.

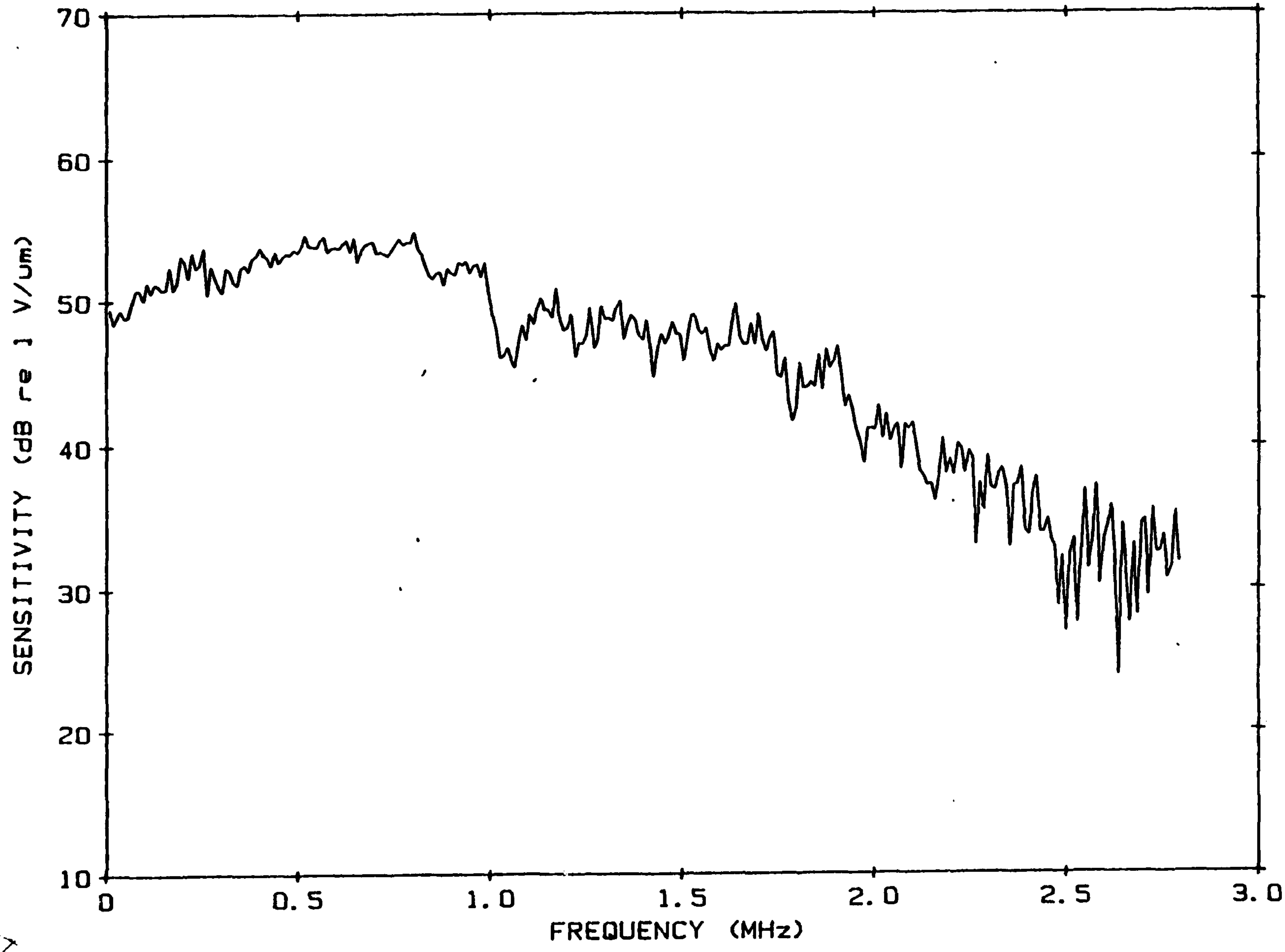


Figure 5. Amplitude of response versus frequency for the NBS tangential transducer.

END

FILMED

10-85

DTIC