UNIVERSITY OF MICHIGAN

Department of Mechanical Engineering
Cavitation and Multiphase Flow Laboratory

Report No. UMICH 014456-19-I

PRESSURE PROBE CALIBRATION

a. U. of M. Probe

b. U. of M. Waveguide

c. Westinghouse Waveguide

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by

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Approved by: F. G. Hammitt

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Abstract

In order to facilitate our future studies in cavitation phenomena, the charge output of three different pressure transducers was calibrated. Each uncalibrated transducer (The Univ. of Michigan probe, the Univ. of Michigan Waveguide, and the Westinghouse Waveguide) and a previously calibrated probe (the commercially available Kistler K601A and K603A) were placed in a variable pressure field induced by an ultrasonic vibratory horn. The amplitudes of the two resulting probe voltage waveforms were then compared on a dual beam oscilloscope. With the help of the Kistler calibration, a curve relating charge output to pressure input was obtained for each transducer.

Introduction

The four pressure probes used in this study were of two types: 1) the waveguide, in which a pressure pulse is transmitted through a steel rod to a piezoelectric ceramic at its other end and 2) an acoustic probe whose piezo electric ceramic is located just below the elastic diaphragm of the probe. The charge output is transmitted by means of a cable or copper rod which runs through the probe shaft center. (See Figures 1 and 2)

For more detailed information on the Kistler probes, (the latter type) see Reference 1. Information on the Univ. of Michigan probe, (also of the latter type) can be found in Reference 2 and Figure 2.

The Univ. of Michigan Waveguide (See Figure 1) contains a Barium Titanate crystal at its base. Due to a natural property a piezoelectric crystal will develop a voltage when it is deformed whereas a piezoelectric ceramic will only develop this property af- some initial polarizing process.

The Westinghouse Waveguide probe has a PZT-5 disc (lead zirconate-lead titanate) cemented to the base of an 11 13/16 -in. long stainless steel rod. At the tip of the 3/16-in. diameter rod is a 10-32 external thread 5/16-in. in length. This makes it possible to "screw" the probe into a section of pipe. Figure 1 shows the means by which the waveguide rods were fastened to the connector.

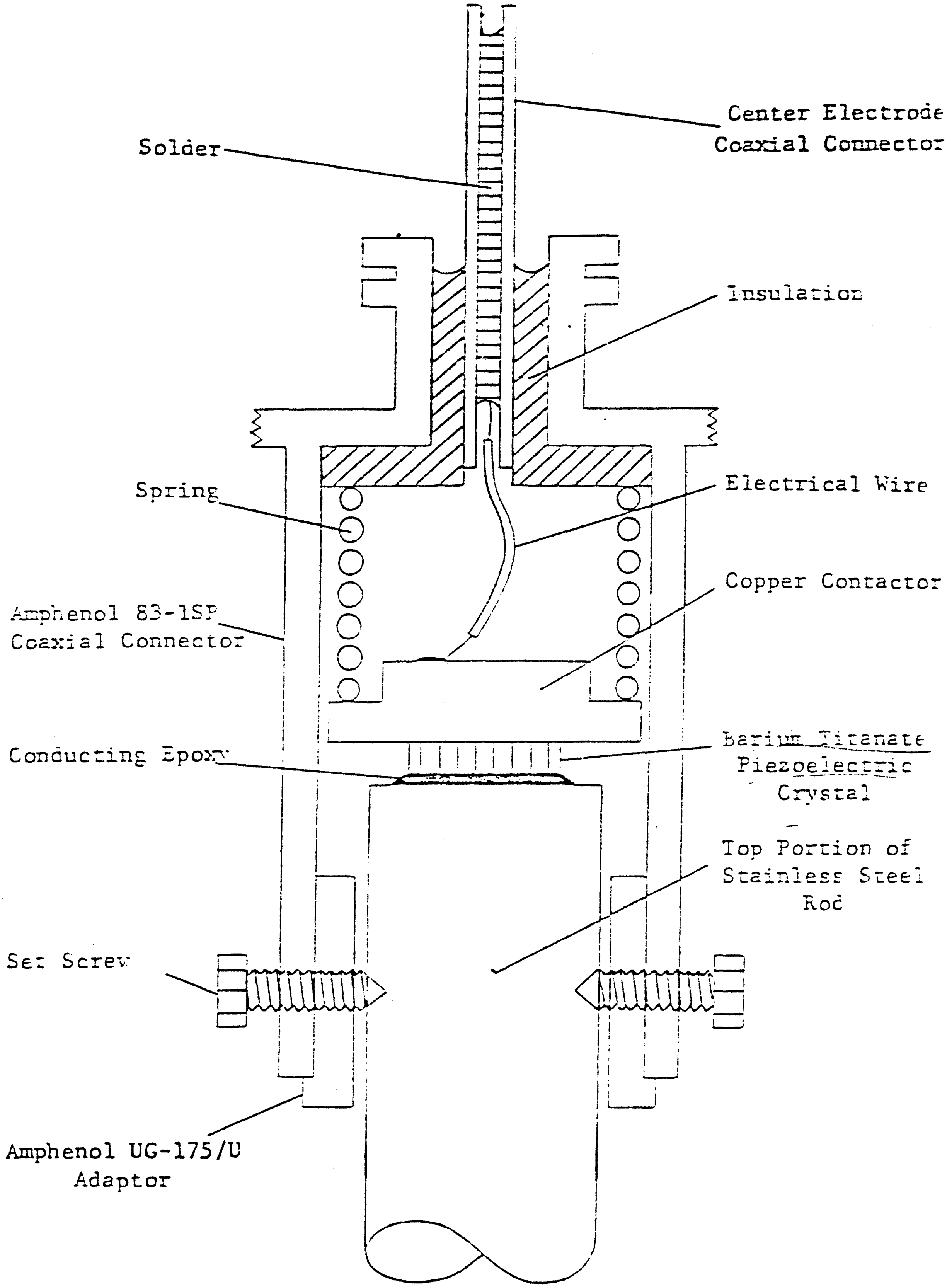


FIG 1 CRYSTAL ASSEMBLY FOR WAVEGUIDE PROBE

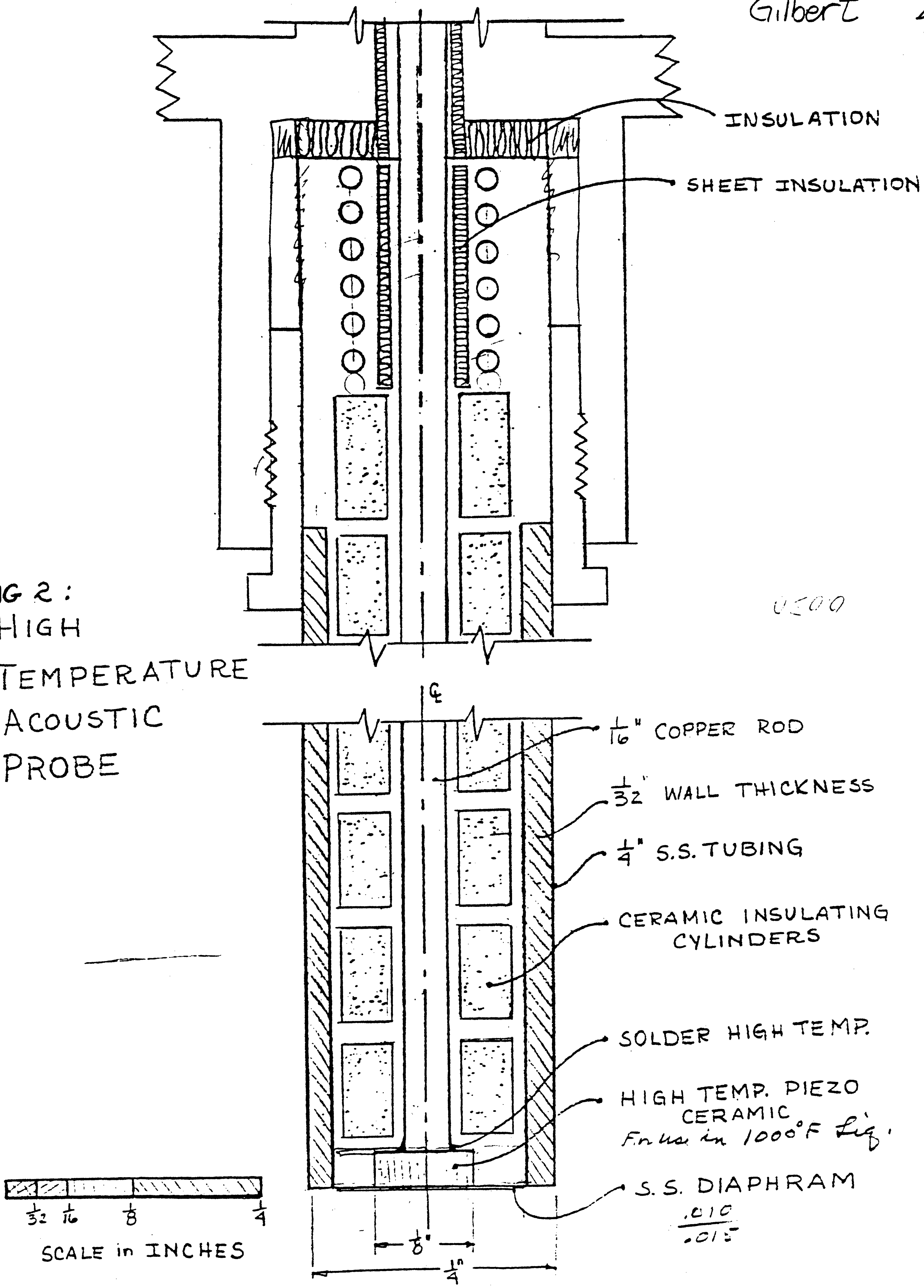


FIG 2: HIGH TEMPERATURE ACOUSTIC PROBE

Instrumentation

The test section used in the transducer calibration was based on the probe calibration arrangement of Nystrom. (See Ref. 1) This device was designed to "sit" on a table and hence, an aluminum bottom plate was bolted to the vessel top plate. This made it possible to safely pressurize the plexiglass vessel. An inlet through the steel housing allowed for direct pressurization of the system.

Two major problems encountered in our application of the Nystrom arrangement were eliminated by removing the water between the plexiglass waveguide tube and the plexiglass cylindrical vessel. (See Figure 3) To satisfy the need for frequent removal of both the vibratory horn and the threaded Kistler probe,(three simultaneous experimental setups in the lab required the Kistler and two required the vibratory horn, hence demanding reasonably quick interchangability) the water was restricted to the waveguide section of the arrangement by waterproofing.

After this improvement the arrangement could be first inverted, the aluminum plate unbolted, plexiglass vessel lifted, and Kistler probe removed. After emptying the small quantity of water from the waveguide by returning the arrangement to its original orientation, the steel housing could be unbolted and the horn unclipped from its position. The use of this method for disassembly and for simple adjustment was found to be far superior to an "entrance from the top" set-up.

Removal of the water from the outer cavity also eliminated the problem of waterproofing the delicate Kistler connector and voltage output cable. Leaks into the connector and cable had plagued earlier

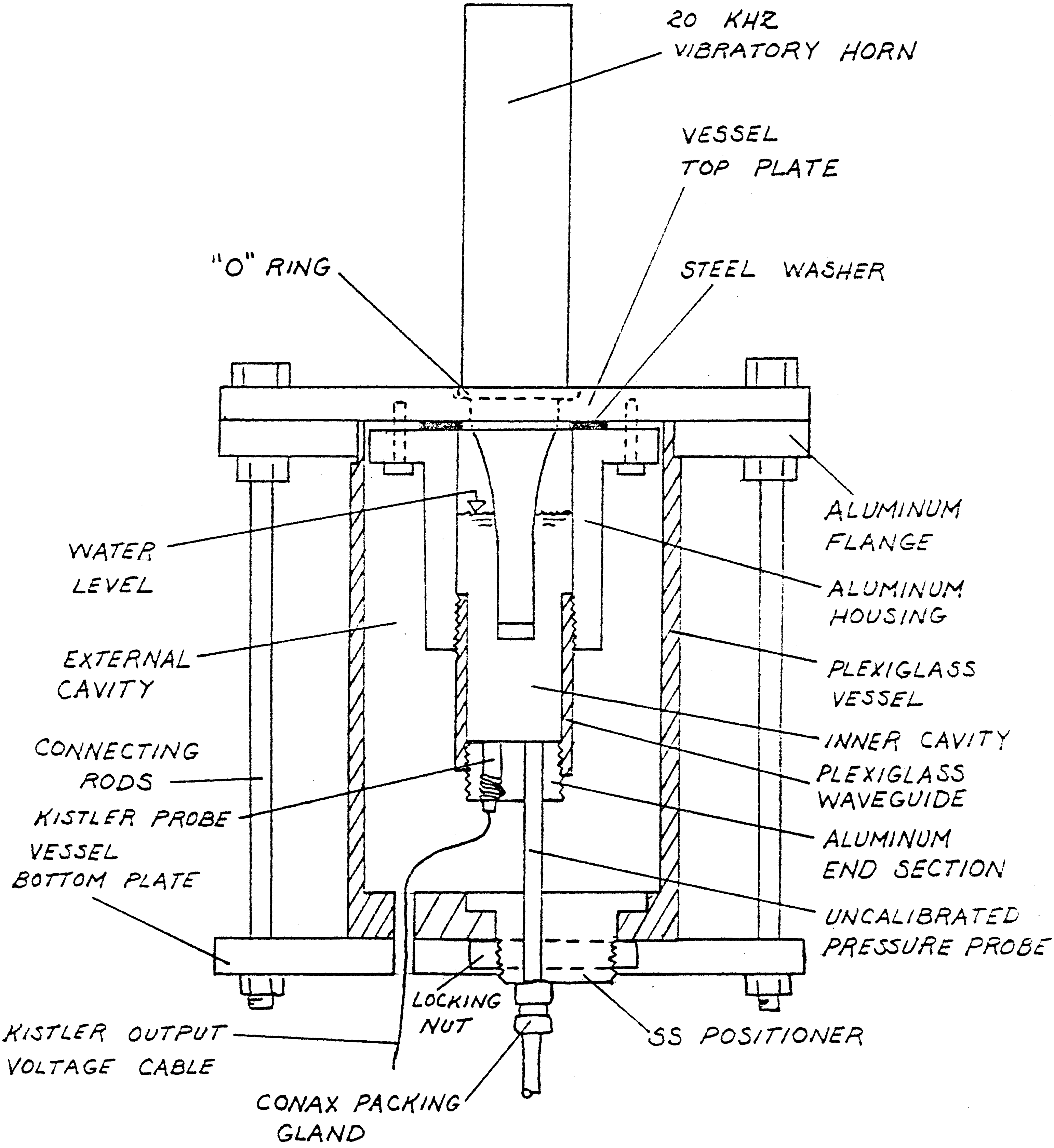


FIG. 3 EXPERIMENTAL ARRANGEMENT FOR PRESSURE PROBE CALIBRATION - (J. KOETAS - 6/6/77)

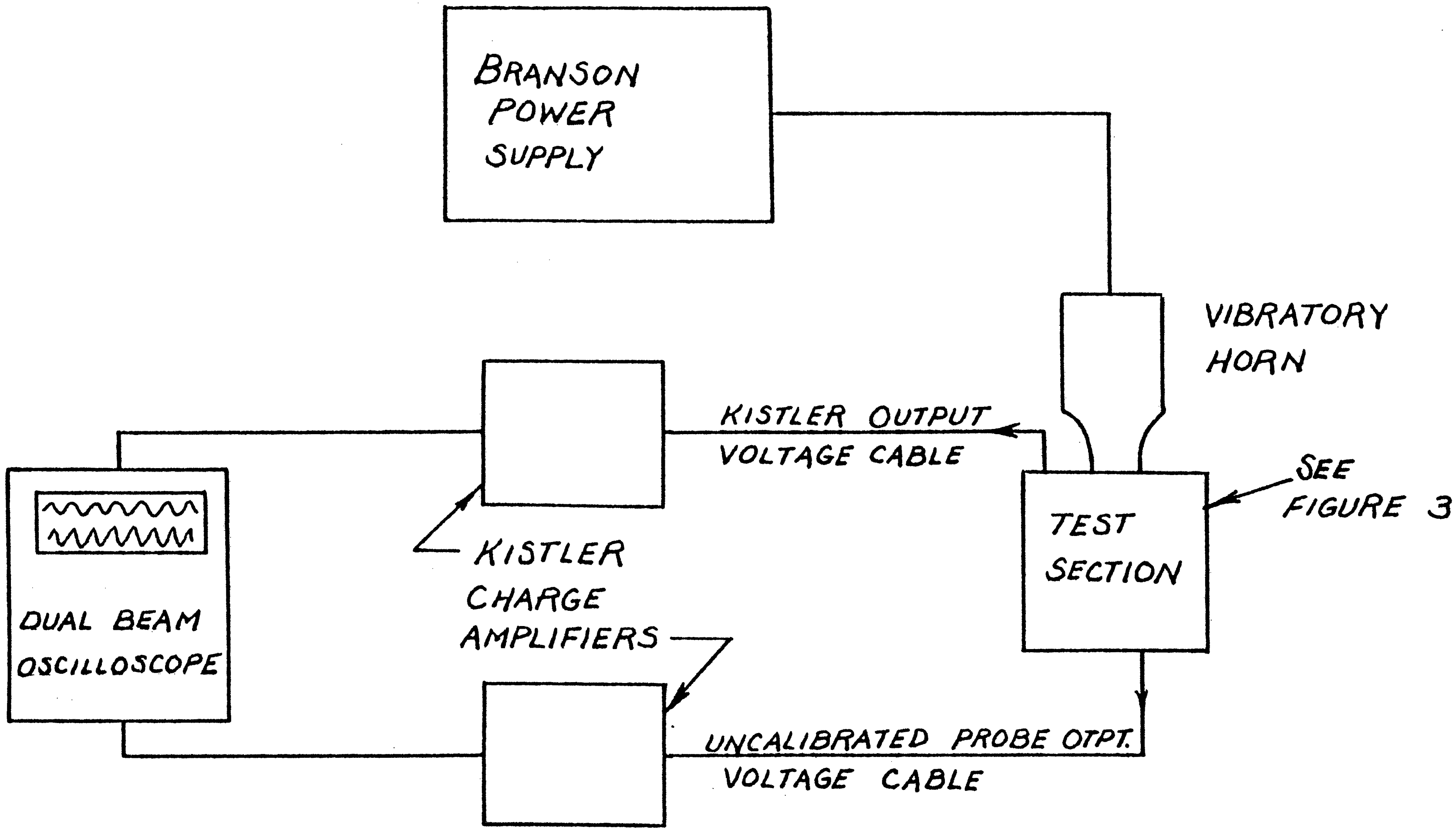


FIG. 4: INSTRUMENT LAY-OUT FOR CALIBRATION OF PRESSURE TRANSDUCER

work on the apparatus.

This improvement was initiated after the completion of the first calibration, and subsequent retesting produced no notable change. A steel washer and a flexible washer were introduce into the arrangement to secure the inner cavity against leaks.

Assembly of the test-section prior to testing consisted first of clipping the horn to the top plate and inverting it, bolting on the housing structure (with the aluminum end section) and then filling the inverted waveguide cavity with water. The Kistler probe, coated with vacuum grease to reduce moisture leakage, was screwed into place. Since the uncalibrated probe was secured in the plexiglass vessel, the vessel was adjusted so that the shaft fit the aluminum end section as the vesselwas lowered onto the assembly. The probe was allowed to just slide into the end section. Probes with smaller diameters were accomodated by cementing a collar into the end section to prevent lateral movement of the probe.

Assembly was completed by bolting on the bottom plate and returning the arrangement to an upright position.

The output lines of the transducers were each connected to Kistler Charge Amplifiers (Model 566) and then to a Tektronix Model 556 Dual Beam oscilloscope.(See Figure 4) Photographs were taken from the screen with a Polaroid camera.

The vibratory horn was connected to a Branson 250 watt 20KHz Power Supply.(See Figure 4)

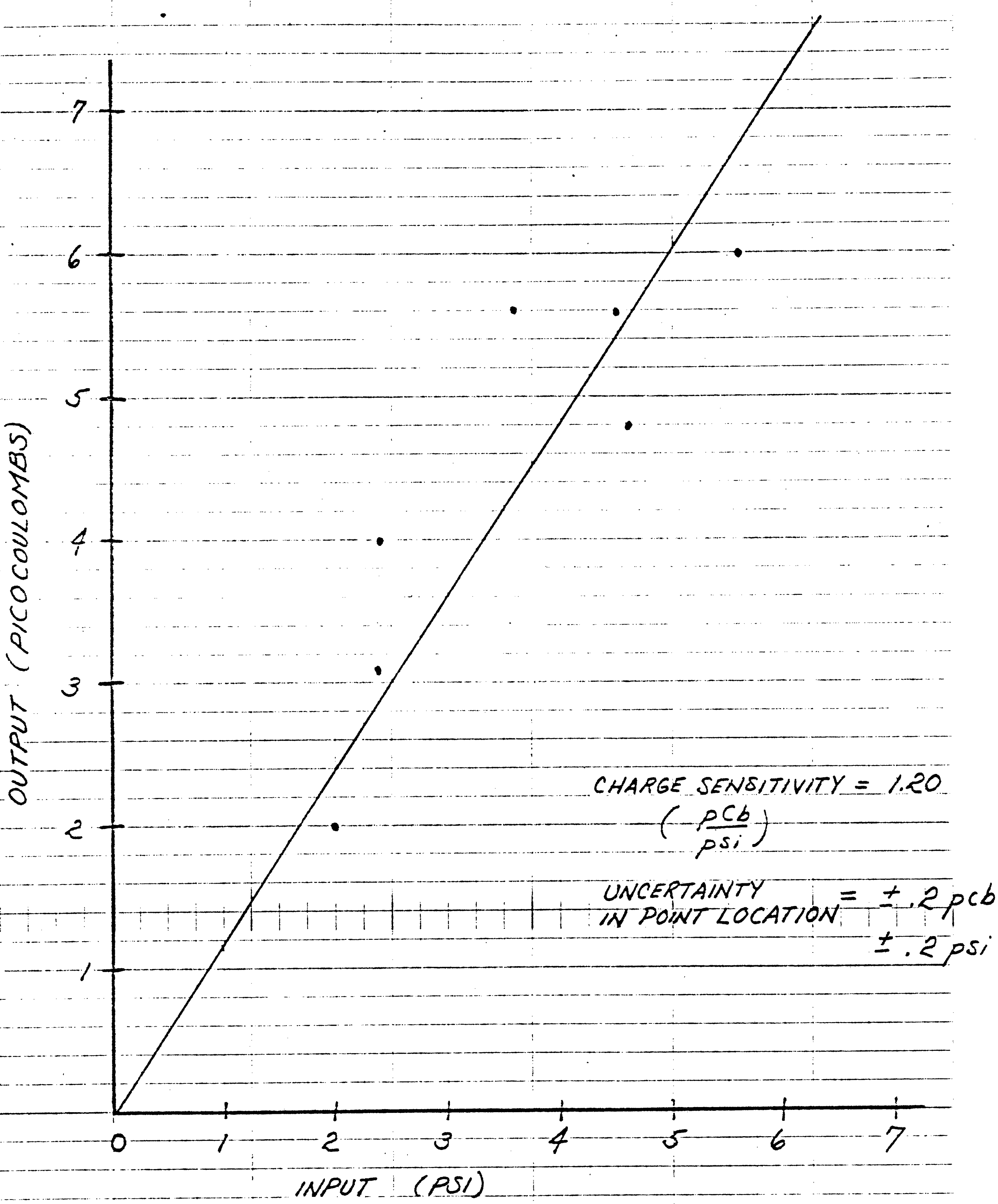
Procedure

Each probe was fixed in the test assembly and about 8-10 data points were taken. Conditions in the waveguide tube were varied by changing the amount of power supplied to the fluid,the radial position of the probe and by interchanging different vibratory horns (hence,different frequencies) during the tests. In addition a Kistler K603A probe was introduced to confirm the results of the more sensitive Kistler K601A. Drive frequency of the vibratory horn was in all cases 20KHz.

The amplified voltage waveforms were photographed from the screen of the dual beam oscilloscope. Maximum amplitddes were later measured from the photographs, and using the manufacturer-supplied Kistler calibration curve (output charge vs. input pressure) a pressure input corresponding to the unknown probe's measured charge output was obtained. A graph of charge output (picocoulombs) versus pressure input (psi) was constructed for each transducer. The error in the final values resulting from a $\pm$ .1 cm uncertainty in the oscilloscope scale was calculated and included in each graph.

Most test points were taken when a minimumof cavitation existed. At these points, the waveforms were most well-defined. It was held acceptable, though, to photograph the waveforms after the onset of cavitation and later to simply compare their maximum amplitudes. These probes are to be used in cavitating fields primarily and hence, calibration for cavitation noise fields is particularly desired.

U OF MICHIGAN PROBE CALIBRATION CURVE



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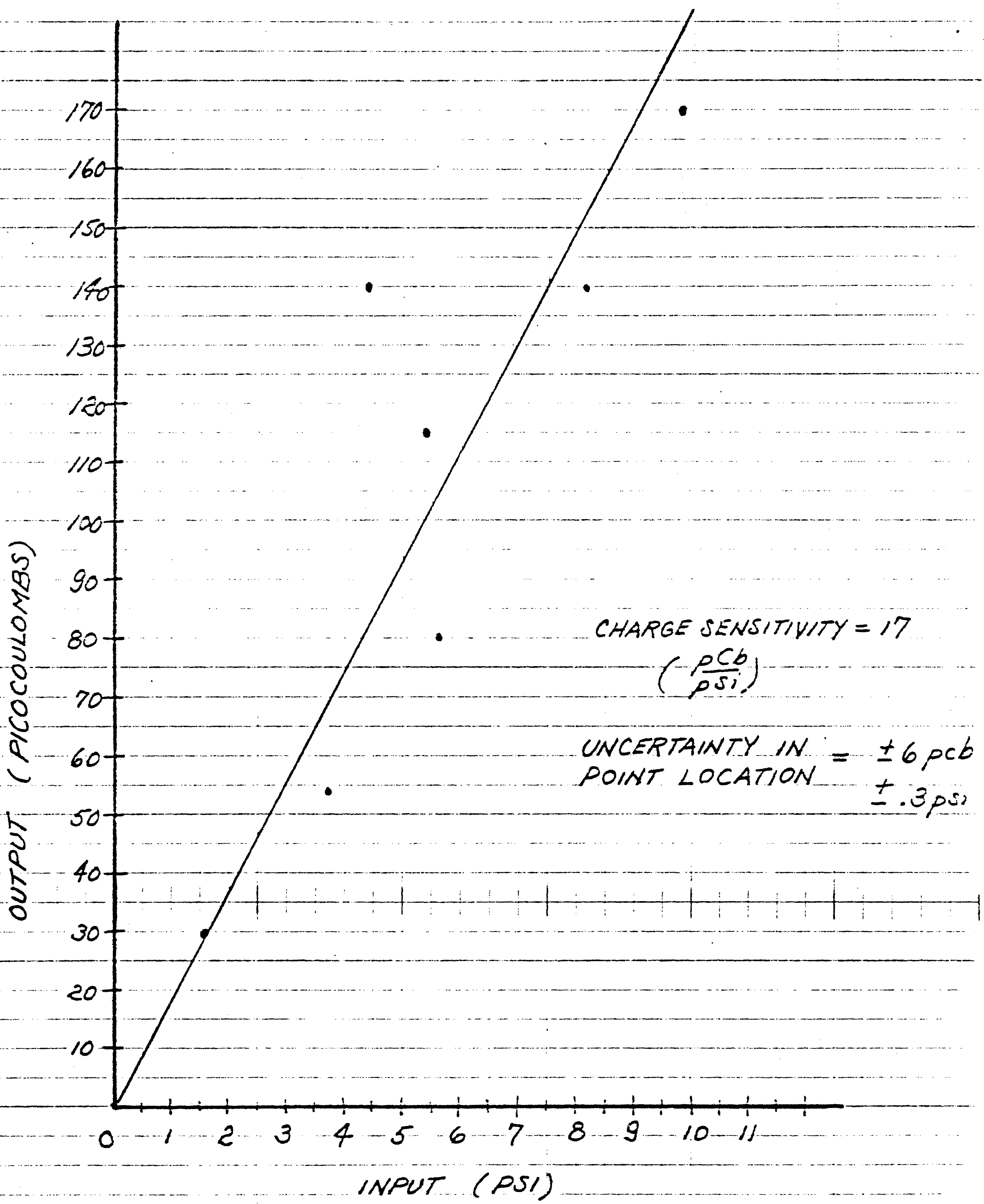
U OF M
WAVEGUIDE (PROBE #1) CALIBRATION CURVE



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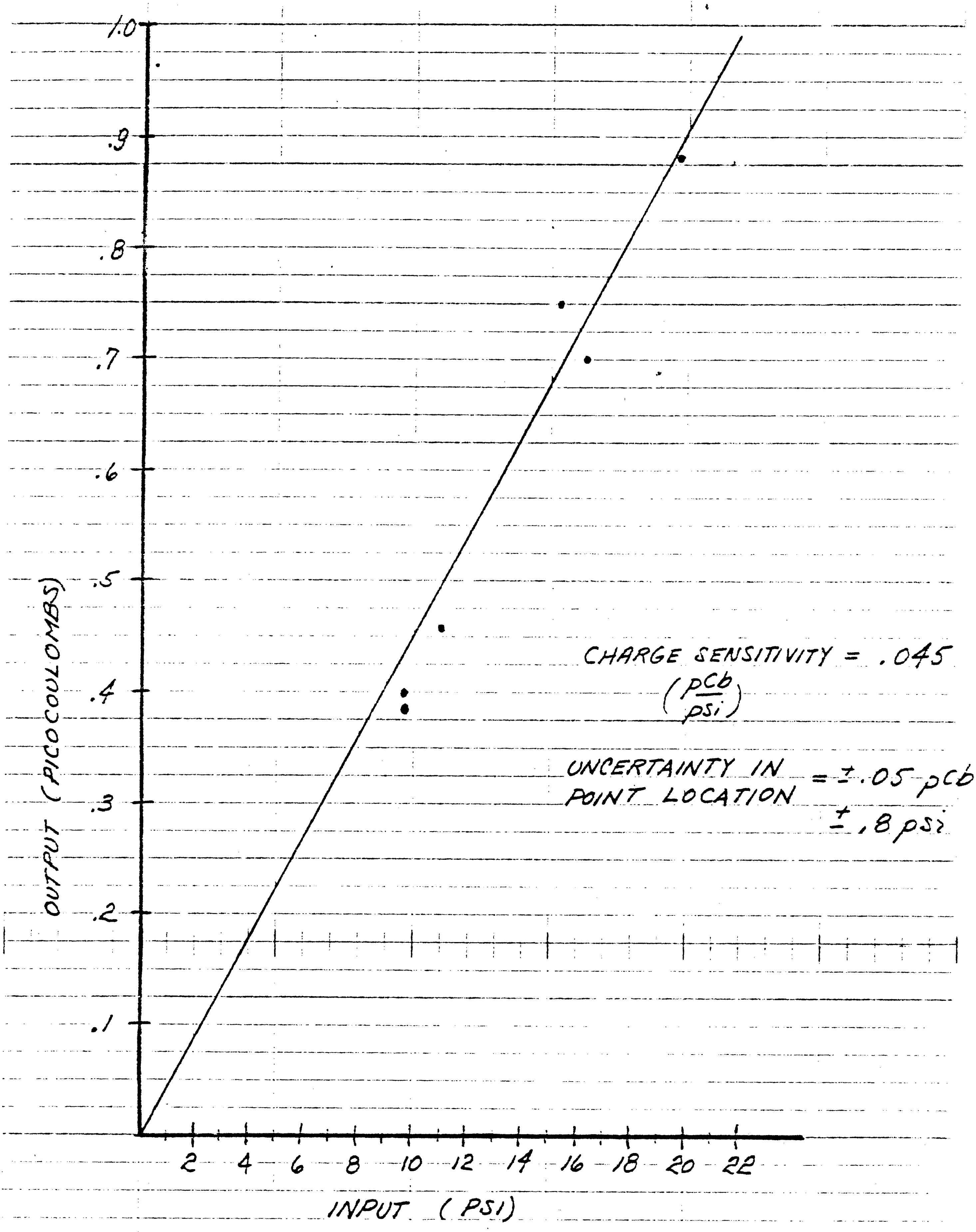
WESTINGHOUSE
WAVEGUIDE (PROBE #2) CALIBRATION CURVE



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Conclusions

The most interesting aspect of the resulting calibrationcurves was the wide range of charge sensitivities obtained. According to the manufacturers calibration,the Kistler 601A pressure probe can achieve a sensitivity of .88 pcb/psi in the 0-100 psi range. The U of M probe exhibited a 1.2 pcb/psi charge sensitivity.

The waveguides, however, vary greatly. The U of M Waveguide, possessing the barium titanate crystal, achieved a 17 pcb/psi sensitivity. The Westinghouse Waveguide, posessing the more sensitive PZT-5 was found to have a charge sensitivity of .05 pcb/psi. This low sensitivity might be due to some loosening of the cement connection between the ceramic and rod. Hence, the ceramic would not be reading the true pressure pulse. Of course, any deficiendy in the two year old probe's connecting assembly could account for such a low signal. It is suggested that a future inspection of the internal assembly of this probe could solve the problem.

References

1. Nystrom,R.E."Ultrasonically Induced Sodium Superheat" Ph.D. Thesis, Dept. of Mechanical Engineering,Cavitation and Multiphase Flow Laboratory,The University of Michigan,May,1969

2. M.K. De and S. Barber,"Pressure Probe Calibration"Dept. of M. E. Cavitation and Multiphase Flow Laboratory Report No. U Mich 014456-1-I;July 1976