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ULTRASONIC INTERFEROMETER MANOMETER

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INTRODUCTION

Work on the Ultrasonic Manometer during the last quarter of calendar year 1973 was devoted to the problems of solving the difficulties with the closures previously discussed and developing a more reliable technique for determining the length of the mercury columns.

CLOSURES

The closure at the bottom of the mercury columns must not only couple the ultrasonic wave from the single crystal quartz transducer to the mercury, but also provide a mechanically strong and stable and chemically inert seal for the bottom of the manometer tube. For ultrasonic coupling fused quartz is a perfectly acceptable material, its reflection coefficient with mercury being about 2.3%. Unfortunately extensive experience has shown that it is very difficult to mechanically secure these disks in a manner that will assure that they are accurately aligned with the rest of the apparatus without cracking them. In addition the low tensil strength of quartz severely limits the differential pressure that can be placed across the closure. Most other materials either amalgamate, are not available in the needed form, or are a poor accoustic match to the mercury. For instance, we had hoped to use stainless steel but its reflection coefficient of 19% causes unacceptably long rise and fall times and amplitude modulation of the ultrasonic pulse. Further searching revealed two available materials with promise, titanium and beryllium, with reflection coefficients of 2.4% and 0.6% respectively. Both materials are strong and ductile and Be has an exceptionally high modulus of elasticity and thermal conductivity. The chemical compatibility of these materials with mercury is not as well established as in the case of quartz or stainless steel. Modern data indicate a solubility of titanium in mercury of 5×10^{-6}% by weight at room temperature and a solubility of beryllium in mercury of 10^{-6}% by weight at 100°C (solubility will be much lower at room temperature).

Samples of commercially pure titanium and beryllium were obtained. The titanium was fabricated into 1/4" thick disks with the surfaces ground plane and parallel to within ±0.0002". Because of its toxicity the beryllium was used as received, a 1/4" disk with a lathe finish. Neither sample worked at all well at first. After many trials it was found that excellent results can be obtained with the titanium by carefully degreasing and cleaning the entire apparatus with a final cleaning of the titanium disk using an etch of 25-30% HNO_3, 2% HF, balance water, followed by a thorough rinsing with distilled water. Carefully and recently cleaned mercury must then be used. Using similar techniques with the beryllium we were able to obtain only slightly better results than with the as received material. Although beryllium should give better results than titanium we do not intend to further investigate it at this time as titanium works adequately well for present purposes.

LENGTH MEASUREMENT

One of the major drawbacks of the fringe counting ultrasonic interferometer manometer is that the length measurement is a cumulative fringe count and susceptible to error from counts lost or gained if the measurement is interrupted for any reason. This is especially true when mercury is used since a mercury surface is so easily disturbed. This problem is alleviated somewhat by the use of relatively long ultrasonic wavelength and different smoothing techniques in the signal processing. This problem is much more severe for the Infrared Laser Interferometer Manometer also being developed in the Pressure and Vacuum Section because of the 10 micrometer wavelength used in that instrument. For this reason we investigated alternate techniques to the fringe counting method to obtain the length information. It now appears that a solution may be the classical excess fractions, exact fractions, or multiple color technique, and that it may be easily applied to the ultrasonic manometer.

In the excess fractions technique one starts from the basic equation $2L = (N_i+F_i)\ \lambda_i$ where L is length being measured and N_i and F_i are the integral and fractional fringes when a wavelength λ_i is used. The λ_i are of course known and the F_i are measured but the N_i are not known. However, if F_i is measured for a number of different λ_i there will, within limits, be a unique set of N_i and hence a unique L that will simultaneously satisfy the basic equation for all of the measured wavelengths We have worked on two techniques to obtain L from the measured F_i. One approach is to simply search for the appropriate length using a computer program that generates successive values of L and tests them against the F_i until it finds one that fits. The second technique algebraically solves for increasingly better approximations to the N_i until the error is less than 1. These equations are not complex and probably could be programmed on a microcomputer. Although we have not developed complete

criteria for picking the optimum λ_i and we are not yet certain what the distance is over which we obtain a unique solution in the case of the computer search routine both approaches appear promising. With three wavelengths and a ±2.5% error in measuring $\sin\theta$ and $\cos\theta$ ($F = \mathrm{Tan}^{-1} \frac{\sin\theta}{\cos\theta}$) we can uniquely determine L to within 3000 fringes (about 23 cm) using the algebraic technique and to within at least 6000 fringes(about 46 cm) with the computer search. Since any number of relatively crude devices could be used to determine the length with an uncertainty less than this repeat distance (the distance within which we have a unique solution) this technique can be used over almost arbitrarily long distances. Furthermore, the ultrasonic interferometer is ideally suited for use with this technique since it can be set up to make a fringe measurement at a number of wavelengths almost simultaneously. We can therefore use it to make an almost instantaneous measurement of the length of the mercury column that is independent of its previous history of the mercury column.

FUTURE

We will try its further quantify the choice of optimum wavelengths for use in the exact fractions technique and the limitations of the technique. We will then modify the interferometer to make measurements at the appropriate wavelengths and use the new interferometer with the 1 meter range manometer that is presently being fabricated.