14. New Primary Pressure Standard

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Objective: Develop a primary gas-pressure standard with smaller uncertainty than the prevailing NIST standard.

Problem: The prevailing NIST gas-pressure piston gage standard spanning 105 kPa to 1.4 MPa has a relative expanded uncertainty of approximately 19 ppm. This uncertainty is larger than that claimed by many National Metrology Institutes, and is in part, due to the inclusion of accumulated uncertainties resulting from calibration relative to a primary standard. This, in essence, is a transfer standard and we wish to develop a primary standard in this range in order to achieve smaller uncertainties. Furthermore, as this standard underpins the calibration of other NIST gas piston gages spanning successively higher pressures, a reduction in its uncertainty would propagate this reduced uncertainty throughout our higher pressure ranges.

Approach: Piston gauge uncertainties are described by the uncertainty in their effective area, which arises from the fact that the effective diameter lies somewhere in the annular gap between the piston and its encompassing cylinder. Recent technical advances have reduced the manufacturing tolerances between these components to sub-micron dimensions, and allowed the means to accurately dimension these components with nanometer resolution. By using a close-tolerance device, coupled with very precise dimensional values, we have the ability to determine the effective area much more accurately than through conventional means.

Results and Future Plans: Until recently at NIST, piston gauge effective areas near 1 MPa have typically been characterized using one of two techniques:

1. controlled-clearance dead-weight tester in which the geometric area of the piston is known and the cylinder's area is determined through an extrapolated fall-rate analysis, or
2. from calibration via a barometric standard (*e.g.,* mercury manometer) at a lower pressure.

We used both of these approaches but they have drawbacks. Although the first approach is valid over the entire operating pressure range, it relies upon a linearized model and an extrapolation procedure that limits the minimum uncertainty. The second approach is based upon calibration by a primary standard, but this standard only covers the lower third of the piston gauge's pressure range, thus introducing larger uncertainty at higher pressures.

A newly commissioned dimensioning system at the German national metrology institute, *Physikalisch-Technische Bundesanstalt*, has a best-in-the-world measurement capability. We sent our piston and cylinder components there for comprehensive dimensional determinations of roundness and straightness. The data were compiled to form a three-dimensional grid structure and were analyzed several ways. The preliminary results indicate an uncertainty of the gage's area between three to four ppm at 20°C and at zero applied pressure. However, this uncertainty is based on an unloaded gauge operating away from our standard temperature of 23 °C. In actual operation, mechanical deformation from the applied pressure and a 3 °C correction for thermal expansion will increase this uncertainty somewhat. In FY2001, extensive testing is planned to quantify these operational contributions to the uncertainty. We will continue to perform independent comparisons against the Pressure and Vacuum Group's ultrasonic interferometer manometer, which operates up to 360 kPa, as well as against other reference piston gauges. In addition, we shall measure the thermal expansion and pressure coefficients of the gauge to eliminate reliance on nominal values, which may not be suitable for our particular gauge. It is anticipated that expanded uncertainties in generated pressure up to 25°C and pressures up to 1 MPa may increase slightly to about 5 ppm when these tests are completed. This represents approximately a four-fold reduction over today's expanded uncertainty value and a considerable advance for the nation's pressure metrology.