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The Accurate Measurement of High Pressures and the Precise Calibration of Pressure Balances

By R. S. Dadson, M.A.*

IN CONNEXION with the work of the National Physical Laboratory on the P–V–T relationships of gaseous mixtures, attention has been given to improvement in the accuracy of high-pressure measurements and in particular to the precise calibration of pressure balances.

The paper describes the progress made in this work with special reference to the 'similarity' method developed at the N.P.L. for the measurement of the variation of the effective areas of pressure balances under the influence of elevated pressures.

INTRODUCTION

THE ACCURATE ESTIMATION of the pressure-volume-temperature relations of gases or gaseous mixtures involves the precise measurement of four quantities, namely the pressure, the volume and the temperature of the substance, and in certain cases the measurement of the mass. For a considerable time now measurements of mass, volume and temperature have been on a very precise basis, as will be clear from reference to the standards maintained at centres such as the National Physical Laboratory and other similar standardizing laboratories. The measurement of pressure, however, is in a very different category. It is true that measurements of considerable precision are available in the region of 1 atm. but at higher pressures the precision of pressure measurements falls considerably short of those of the other quantities mentioned.

In most investigations involving the accurate measurement of high pressures, the measuring instrument employed is the pressure balance, or dead-weight gauge, in which the fluid pressure acting on a piston of known area is balanced by a load derived from a set of accurately calibrated weights. For practical use, no other instrument can compare in precision with the pressure balance, and its only serious rival is the mercury manometer, the direct use of which at high pressures would involve serious complications. In practice therefore, the precise determination of a high pressure virtually reduces to the problem of the determination of the effective area of a pressure balance, and the dependence of this quantity on the pressures to which it is subjected. Most past attempts to calibrate pressure balances have relied on the use of high-pressure mercury columns, but the published investigations have given very variable results, to such an extent that when the Laboratory became concerned in this problem some three or four years ago, it was difficult to arrive at any consistent indication of the changes in effective area which pressure balances were likely to exhibit under the influence of elevated pressures. Michels (1923, 1924)† discussed this matter at length in his earlier papers and indicated by calculation the order of magnitude of the probable effect, but did not provide any confirmatory measurements. Beattie and Edel (1931), using a high-pressure mercury column, attempted to measure these variations up to pressures of about 500 atm. but found no measurable effect. Ebert (1935), on the other hand, using a method of a different character developed at the P.T.R.,‡ reported changes of effective area which were considerably in excess of those indicated by elementary theory. Recently, Professor Newitt and his co-workers at Imperial College (Bett and others 1954) have described a very carefully constructed high-pressure mercury column intended to act as a fundamental standard for pressures up to the region of 2,500 atm. but no results of any measurements of the effective areas of pressure balances made with this instrument seem to have appeared as yet.

In these circumstances it was decided to devote effort at the N.P.L. to the development of new methods for establishing the effective areas of pressure balances

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* *Principal Scientific Officer, Physics Division, National Physical Laboratory.*

† *An alphabetical list of references is given in Appendix 1.VI.*
‡ *Physikalisch-Technische Reichsanstalt.*