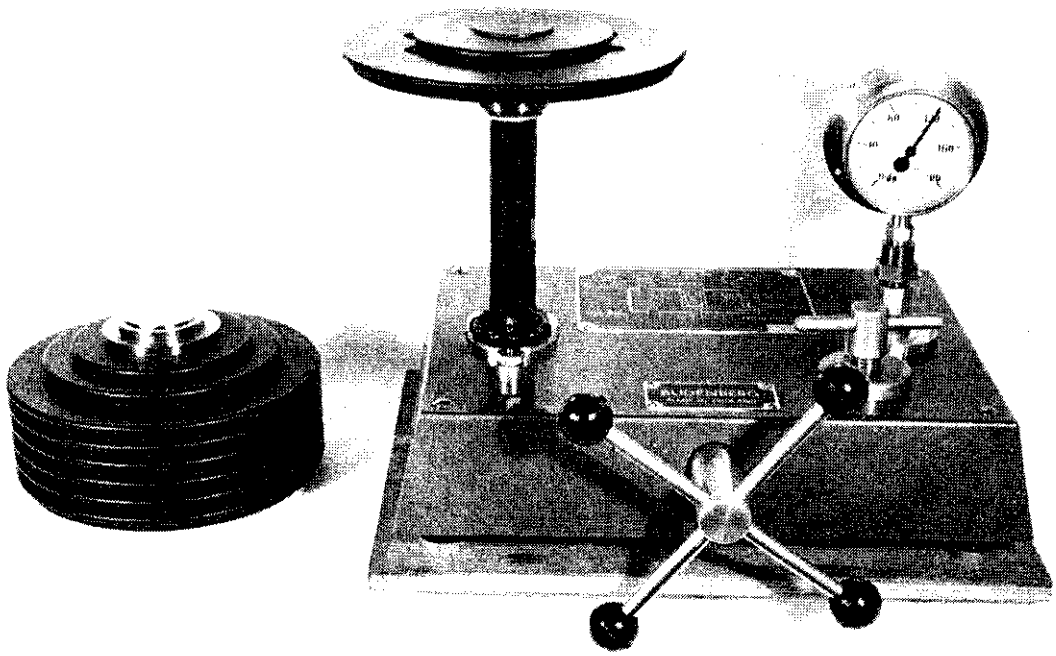

FIG. 1 BUDENBERG RANGER DEADWEIGHT TESTER

TYPE TESTING OF PRESSURE GAUGES

BY

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Introduction

For some time there have been widespread complaints concerning the standard of pressure gauges in service in H.M. ships. Early in 1956 a new Admiralty specification, No. 1001, was in the draft stage and it was decided to use this as a basis for type tests to be carried out at the Admiralty Engineering Laboratory, West Drayton. Test equipment was designed, manufactured and installed at the A.E.L. during 1957. Some twenty-six manufacturers of gauges were approached by the Admiralty ; of these only five were prepared to submit gauges for trials.

Admiralty Specification 1001 was issued officially in April, 1959. From that date all gauges ordered under Admiralty contract or by shipbuilders' sub-contracts should comply with its provisions. At the time of issue, only one firm had completed the type tests successfully, but at least two others showed promising results.

Test Equipment

Calibration Equipment

The accuracy of all pressure gauges was checked by a Budenberg 'Ranger' Deadweight Tester. This instrument, which is shown in FIG. 1, has a range of

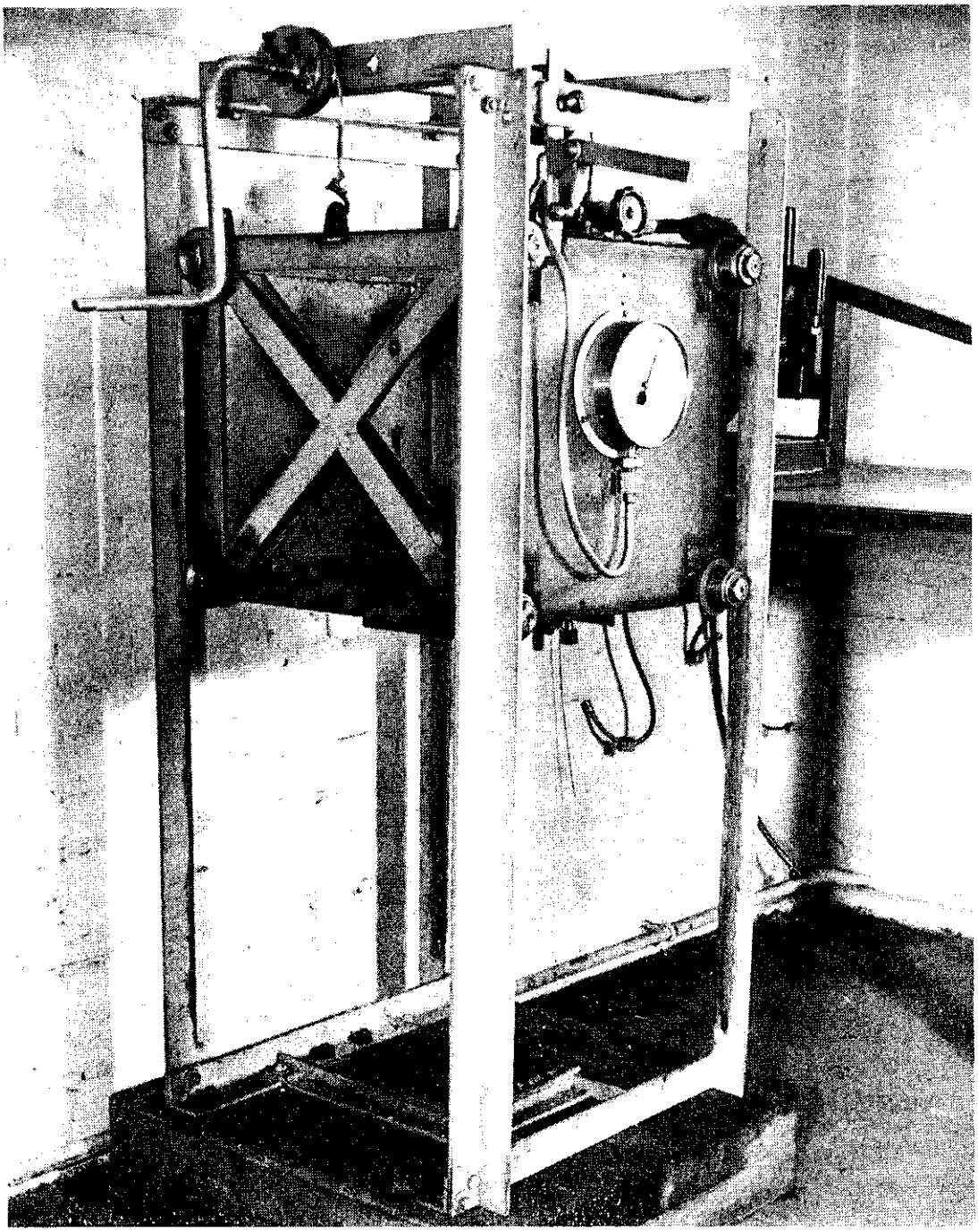

FIG. 2—PRESSURE GAUGE SHOCK TEST MACHINE

10 8,000 lb/sq in. and an accuracy certified as within 0·03 per cent of the measured pressure. It was also used for the overload test.

For vacuum gauge calibration, the gauge was connected to a mercury manometer, and vacuum conditions obtained by means of a small Edwards pump.

Shock Test Equipment

The first shock-test machine used in these trials was a falling table machine designed by the Naval Construction Research Establishment. A cage, approximately 18 in. × 18 in. × 18 in. and weighing approximately 100 lb was allowed to fall freely through a vertical distance of two feet. At the bottom of the fall,

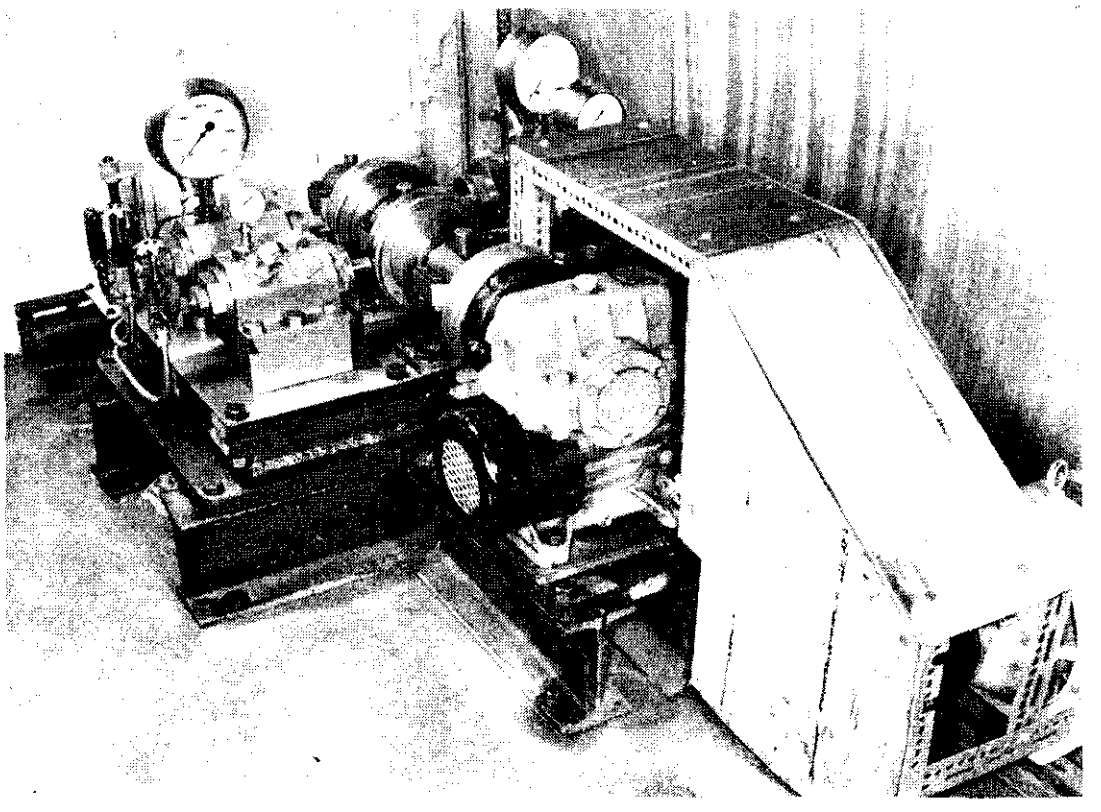

FIG. 3—PRESSURE GAUGE ENDURANCE TEST MACHINE

a mild steel striking pad on the underside of the cage struck a mild steel anvil plate, the blow being slightly cushioned by a sheet of $\frac{1}{16}$ in. rubber insertion.

The specification for this machine was insufficiently detailed ; with the result that very different loadings were imposed by the various machines constructed.

It also became apparent that the shock characteristics of the machine at the A.E.L. were changing, due to flexure and distortion in service. The machine was, therefore, strengthened and stiffened and a detailed drawing issued. As far as possible, the shock characteristic was arranged to satisfy both the Oudenarde Trial conditions and the requirements of the *Shock Manual ;* the mean retardation applied on impact being 75 g. This machine is shown in FIG. 2.

Endurance Test Equipment

The endurance test machine was designed by D.M.E., S.S.M. Section, in collaboration with the A.E.L., and manufactured at Chatham Dockyard. The machine took the form of a pressure pulsation rig (FIG. 3), based on the principle of a plunger working in a pre-loaded hydraulic cylinder. In practice four cylinders and plungers were fitted, mounted in pairs. The plungers were driven by adjustable eccentrics mounted on a driving shaft. Three holes were drilled and tapped in each cylinder, so that a maximum of twelve gauges could be tested simultaneously. To facilitate adjustment of the pressure range in each cylinder, and to prevent excessive changes in pressure due to ambient temperature variations, a small compensating device was fitted.

This took the form of a small cylinder fitted with a piston, piston movement being opposed by a rubber disc of suitable hardness, fitted between the piston crown and a screwed adjusting cap.

TABLE I

J.S.C. No.	*Size*	*Range*	
6685 420553	6 in.	0 —6,000 lb/sq in.	High Pressure Gauges
420634	6 in.	0—6,000 lb/sq in. (oxygen)	
420508	4 in.	0- 3,000 lb/sq in.	
420625	4 in.	0 —200 lb/sq in. (oxygen)	Low Pressure Gauges
420451	2½ in.	0—200 lb/sq in.	
420531	6 in.	0- 15 lb/sq in.	
420471	4 in.	0 — 30 in. vacuum	
420476	4 in.	30 in. vacuum- 60 lb/sq in.	

Test Procedure

The range of eight surface mounted gauges required for test is shown in TABLE I.

Inspection and Calibration

On receipt all gauges were inspected visually to determine whether they were manufactured in accordance with Adspec 1001 and B.S.1780. Details of construction and materials used were noted.

Gauges were then calibrated on a dead weight tester. Readings were taken both up and down the scale, the maximum permissible error at any point between 10 per cent and 90 per cent of the full scale reading being 1 per cent of the range.

Overload Test

Immediately following the initial calibration, all gauges were subjected to overload. In the case of the low pressure gauges the pressure was raised steadily to 125 per cent of the maximum scale reading ; with high pressure gauges the test pressure was 115 per cent of the maximum scale reading. The pressure was then released and the gauge again calibrated, the same accuracy being required as in the initial calibration.

Shock Test

The gauge being tested was secured firmly to the cage of the shock test machine by the gauge mounting holes. Pressure was applied to give approximately half the full scale reading and the gauge was then isolated from the source of pressure.

The cage of the machine was dropped four times :

(i) The gauge being mounted vertically with the connection at 6 o'clock
(ii) ,, ,, ,, ,, ,, ,, ,, ,, 3 o'clock
(iii) ,, ,, ,, ,, ,, ,, ,, ,, 9 o'clock
(iv) ,, ,, ,, ,, horizontally with the dial facing upwards.

The gauge was then calibrated on the deadweight tester.

A gauge was considered to have failed the shock test :

(i) If it was physically damaged so that its operation was seriously impaired
(ii) If it failed to meet the required standard of accuracy on calibration; i.e. an error of less than ¡ 5 per cent of the maximum scale reading at any point between 10 per cent and 90 per cent of the full scale reading.

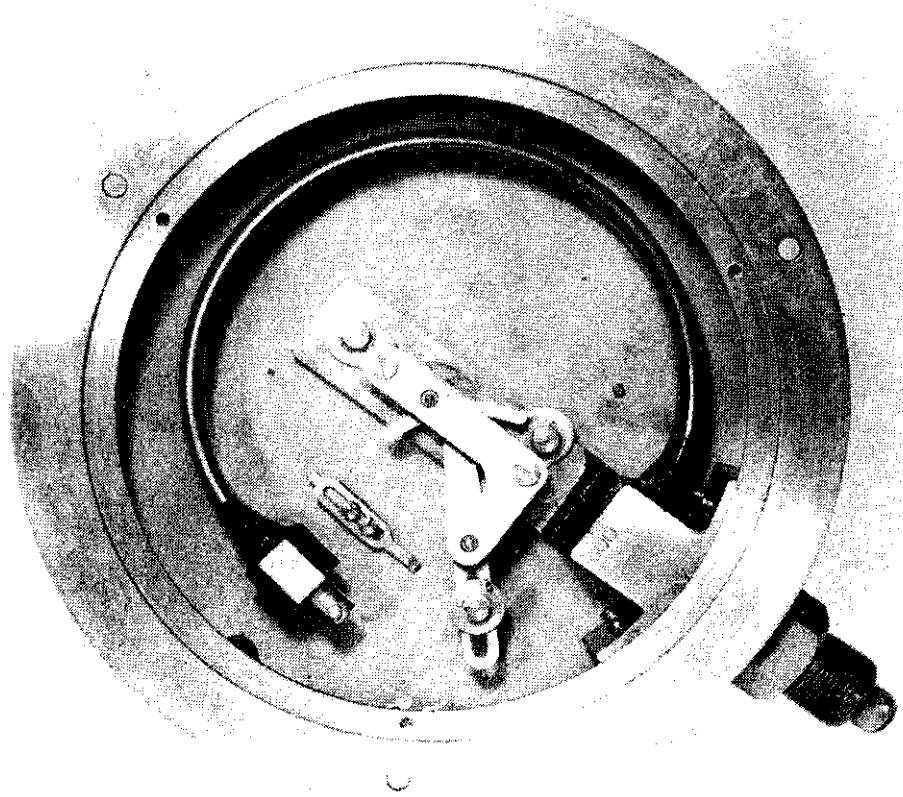

FIG. 4 SHOCK TEST FAILURE—BROKEN LINKAGE

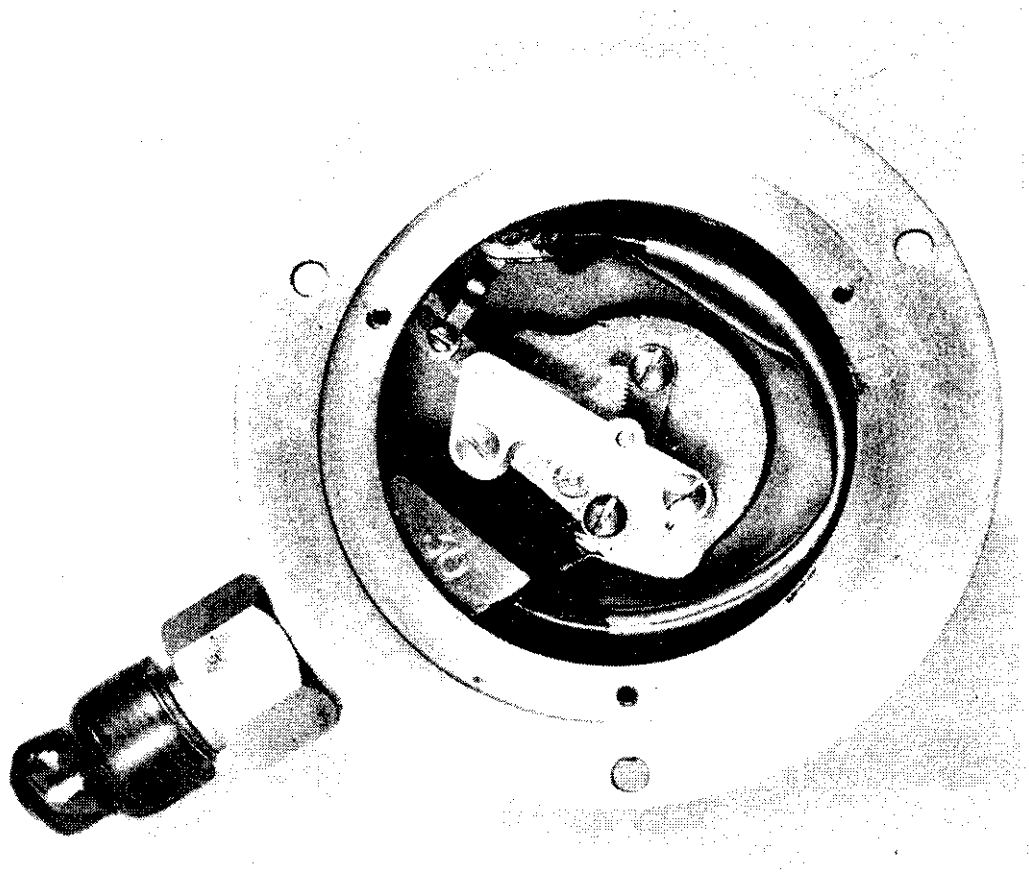

FIG. 5 BOURDON TUBE FAILURE

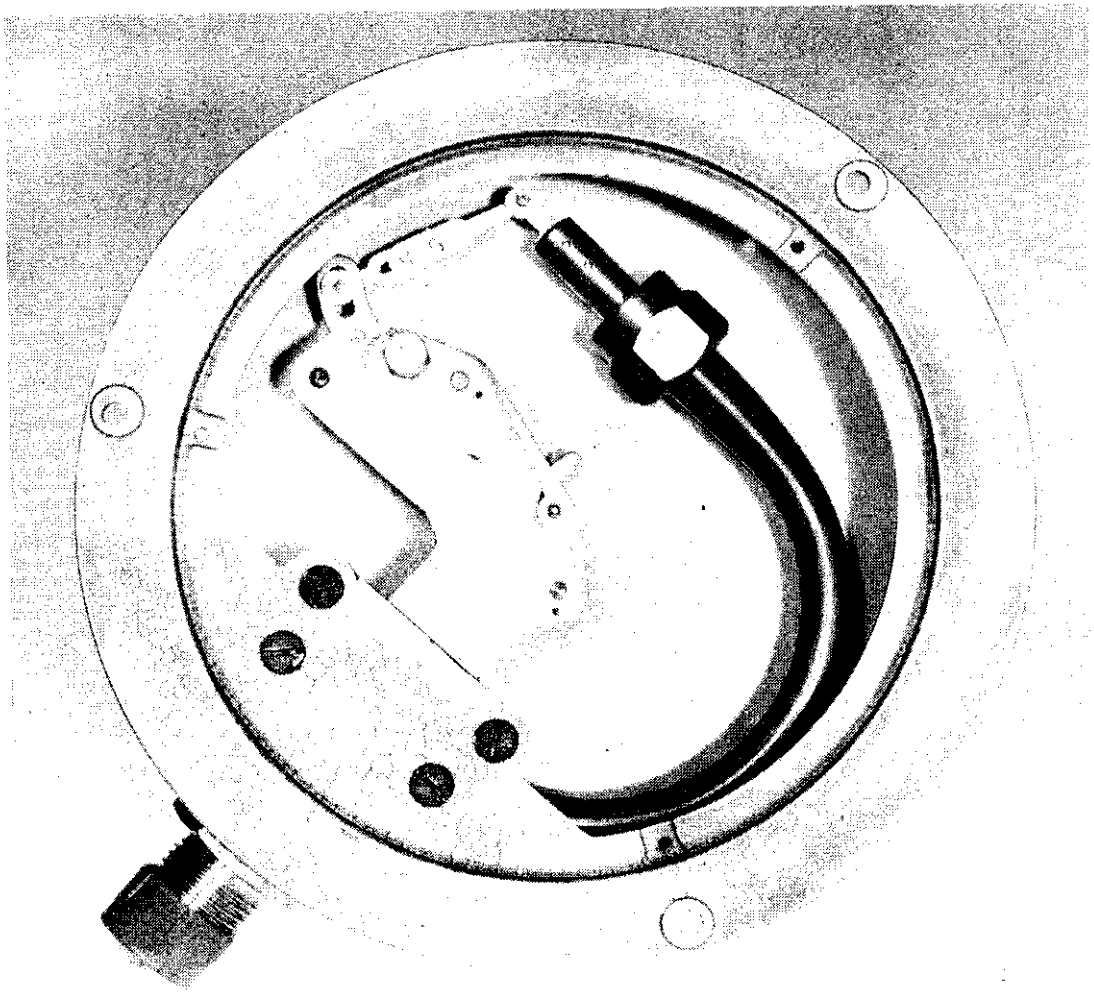

FIG. 6—IMPROVED HIGH-PRESSURE GAUGE

Endurance Test

Gauges completing the overload and shock tests were mounted on the endurance test machine and subjected to cyclic pressure pulsation as follows :

(*a*)	Low Pressure Gauges :	
	Range of pressure fluctuation	approximately 50 per cent of maximum pressure range, adjusted to lie between 25 and 75 per cent of maximum scale reading
	Frequency	60 cycles/minute
	Duration	300 hours
(*b*)	High Pressure Gauges :	
	Range of pressure fluctuation	approximately 30 per cent of maximum pressure range, adjusted to lie between 35 and 65 per cent of maximum scale reading
	Frequency	30 cycles/minute
	Duration	100 hours

The test machine was run continuously for periods of approximately 100 hours, being shut down at weekends.

On completion of the endurance test, gauges were again calibrated on the deadweight tester. A gauge was considered to have failed the endurance test:

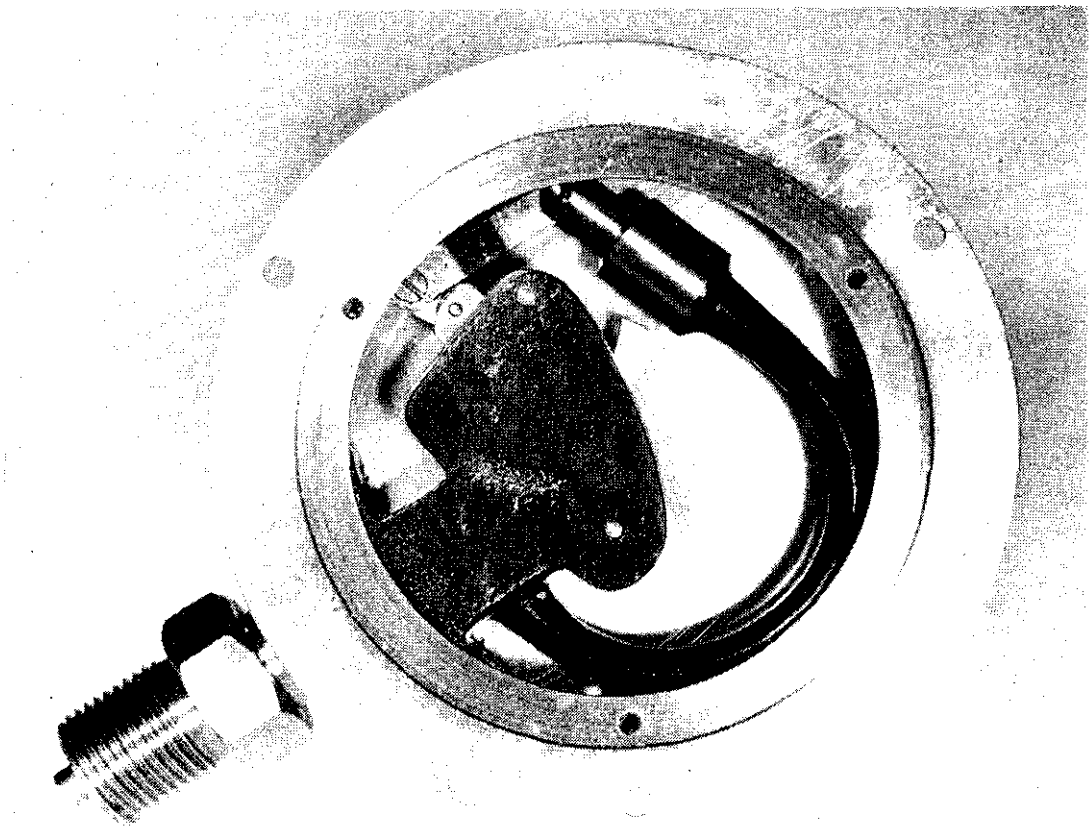

FIG. 7—IMPROVED HIGH-PRESSURE GAUGE

(i) If the Bourdon tube fatigued and failed
(ii) If the gauge failed to meet the required standard of accuracy on calibration. The difference between gauge errors before and after endurance test should not exceed 2 per cent of the maximum scale reading at any point in the range.

Test Results

During 1958, five manufacturers submitted ranges of gauges for type test ; the gauges in each case being of the highest quality normally manufactured for commercial use. It soon became apparent that a higher standard was required.

Of the most successful range submitted, 50 per cent passed the type test completely, 25 per cent failed the shock test and 25 per cent failed the endurance test. In general, results were very much below this standard. The majority of low pressure gauges failed the shock test due to bad design or faults in production. Linkages fractured and Bourdon tubes distorted (see FIGS. 4 and 5). Most of the high pressure gauges which passed earlier tests failed the endurance trial due to fatigue of the Bourdon tubes. One manufacturer's gauges failed the initial calibration and overload trials.

These failures led most manufacturers to completely re-design their gauges. Improved gauges submitted during 1959 were in general very much more robust (see FIGS. 6 and 7), although one manufacturer retained his original design, fitting rubber stops and cushions to provide restraint and support under shock conditions (see FIG. 8). There was also a tendency to use new materials. Bourdon tubes have been supplied in beryllium copper, monel metal, chrome-molybdenum steel and stainless steel in place of phosphor bronze. With

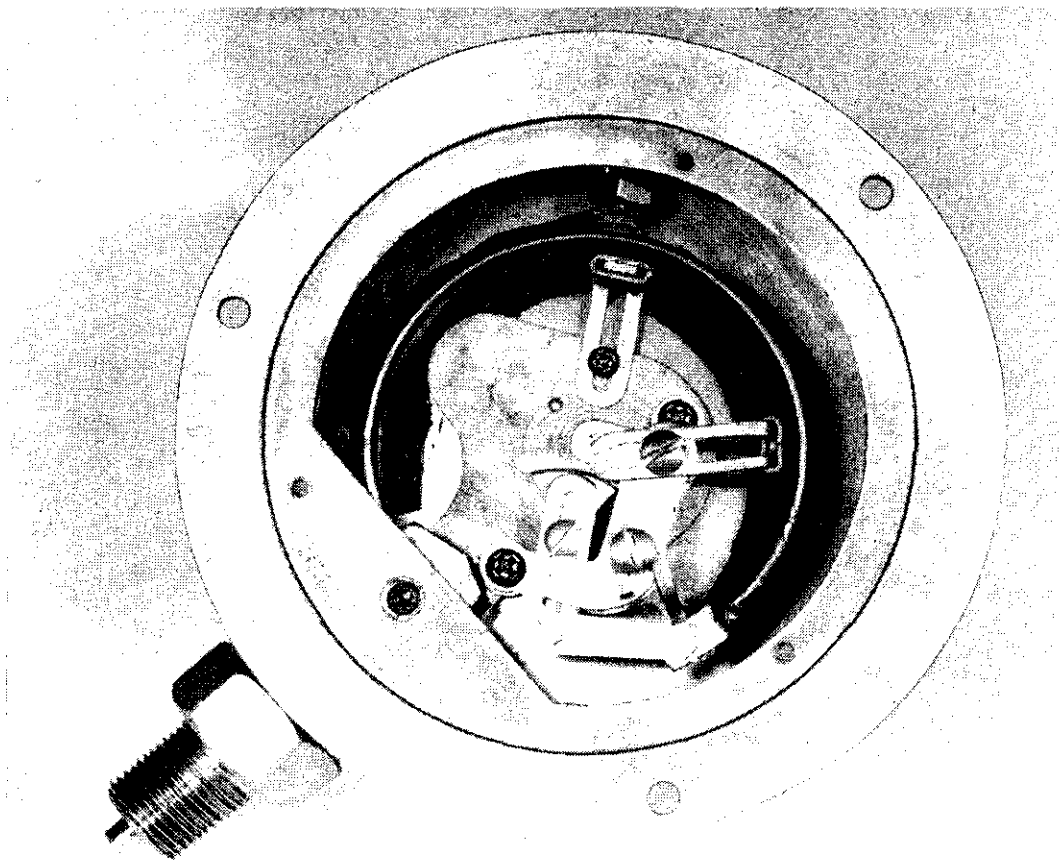

FIG. 8 MODIFIED GAUGE WITH RUBBER STOPS AND CUSHIONS

improved design, manufacture and inspection, there have been relatively few failures in the shock test during recent months. The principal difficulty seems to be the production of high pressure Bourdon tubes capable of withstanding the endurance trial. Failures have occurred due to :

(*a*) *Choice of unsuitable material*
(*b*) Small defects in the tube as manufactured
(*c*) Severe stressing of the tube by the gauge maker
(*d*) Incorrect heat treatment.

Present Position and Future Programme

The new standard, Adspec 1001, has been very beneficial in raising the standard of pressure gauges supplied to the Admiralty. Although only one manufacturer has satisfied the specification to date, it is anticipated that at least two others will shortly reach the required standard. This should result in attempts to reduce the price of the improved gauges.

Since D.M.E. now favours flush-mounted gauges, the test equipment at the A.E.L. will require modification. It is not anticipated, however, that this change in the method of mounting will affect the accuracy or reliability of gauges. In the future the range of gauges to be submitted for type tests will be extended to include a representative number of the flush-mounted type.

It is hoped that the Pressure Gauge Committee of the British Standards Institute will extend their specification for commercial pressure gauges. B.S.1780 lays down calibration and overload tests only ; some reference to shock testing and endurance testing would appear to be necessary.