Glossary of

Terms used in air gauging with notes on the technique

Confirmed
January 2010

Co-operating organizations

The Instrument Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

British Clock and Watch Manufacturers' Association
British Electrical and Allied Manufacturers' Association*
British Industrial Measuring and Control Apparatus Manufacturers' Association*
British Nautical Instrument Trade Association
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Individual Manufacturer

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Contents

Foreword

This standard makes reference to the following British Standard:

BS 308, *Engineering drawing practice — Part 3: Geometrical tolerancing using ISO symbols*[1].

This British Standard has been prepared under the authority of the Instrument Industry Standards Committee and is based upon a glossary drawn up by a group of British manufacturers of air gauging systems.

Since its introduction some thirty years ago the use of the air gauging method of dimensional measurement has grown enormously in Great Britain. Not surprisingly, the terminology relating to the method has become confused; terms have been invented without regard to their etymology and often with no thought as to their relationship to similar or corresponding terms in other technologies. This glossary aims at removing this confusion.

During its preparation, the following objectives were kept in mind:

i) to rationalize the terminology by choosing suitable terms which manufacturers would agree to use, and thus eliminate the present confusion arising from the use of different terms by different manufacturers;

ii) to provide users, and potential users, of air gauging equipment with an unambiguous means for communicating their requirements to manufacturers;

iii) to furnish for this particular technology a terminology which finds general acceptance and becomes, in due course, the recognized terminology in the literature and in discussions of the air gauging method.

In the introduction to the glossary the principles of air gauging are briefly described and examples are given of the application of the method to the measurement of dimensions and the inspection of form; some notes are included on the operating pressures used. Section 1 of the glossary defines the general terms relating to the air gauging technique, whilst Section 2 deals specifically with the air gauge unit, that part of the air gauging system which contains the indicating unit and the controls. In Section 3, the measuring heads for dimensional measurement are detailed, and the related terms and their definitions are given, whilst Section 4, in conjunction with Appendix A, provides corresponding information for measuring heads employed in the inspection of form and position. Appendix B covers applications of air gauging not included in Section 3, Section 4 and Appendix A.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 30, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1] In course of preparation.

General introduction

If the tube A which terminates in the jet J (Figure 1) is connected to a source of compressed air held at constant pressure, air will flow through the jet to atmosphere at a constant rate. If now the surface S is moved toward the jet the escape of air will be impeded and the flow will begin to decrease. Continued advancement of the surface will steadily reduce the flow until finally, with the surface in contact with the whole area of the jet, the flow ceases. This simple device is thus a displacement-flow transducer which permits detection of the movement of the surface normal to the jet by observing the change in air flow.

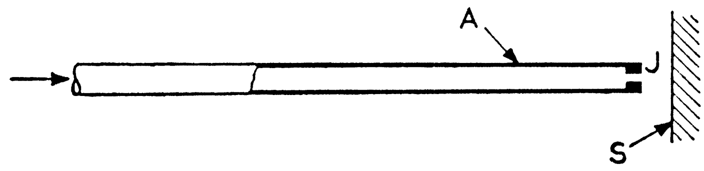


Figure 1 — Displacement-flow transducer

In Figure 2, a regulator R maintains the incoming air supply at a constant pressure and a variable-area flowmeter F measures the flow of air through the jet. The float responds to the changes in flow, rising as the flow increases and falling as it decreases. The flowmeter can be graduated in units of length to give a scale which can be used to measure the displacement of the surface S normal to the jet.

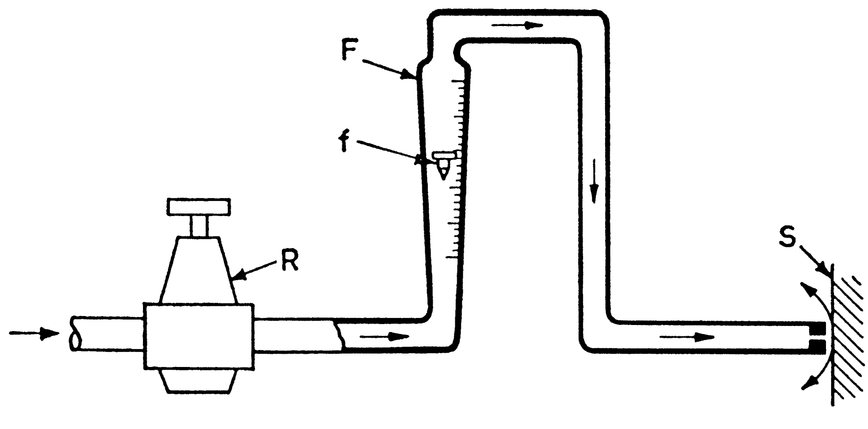


Figure 2 — Displacement flow-transducer with flowmeter

It is not, however, essential to measure directly the changes in air flow: these changes can be converted into changes in air pressure by the method shown in Figure 3. A restriction O, called the control orifice, is introduced between the regulator and the jet, and the air pressure between this restriction and the jet is measured by a suitable pressure indicator G. The indicator (shown in Figure 3 in simple diagrammatic form) will register a lower pressure when the air flow through the jet increases, a higher pressure when it decreases; as before, the scale of the indicator can be graduated in units of length and used for gauging. The arrangement shown in Figure 3 is thus a displacement-pressure transducer.

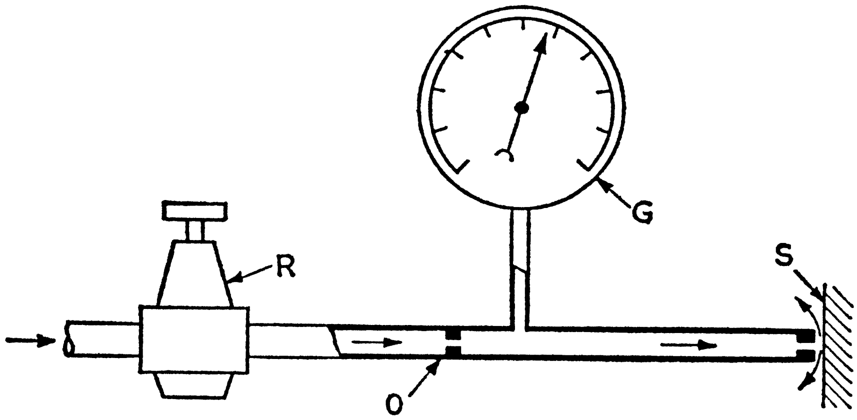


Figure 3 — Displacement-pressure transducer

These then are the basic ideas of air gauging. Their simplicity will be appreciated, but what is important is that they can be used to build robust measuring instruments of extremely high accuracy and stability for use in precision engineering. Their magnification, that is the ratio of the movement of the indicator index, e.g. the float in Figure 2 or the pointer in Figure 3, to the movement of the surface which produces it, can be relatively low, say, 1 000, or very high, say, 100 000. Magnifications of 10 000 and 20 000 are common and permit accurate inspection of closely-toleranced components; the true sizes of the components are obtained and errors of form and position can be investigated. The air gauging system thus offers substantial advantages over inspection by limit gauging and furthermore can, when required, be used for selective assembly of mating components. The actual gauging element, the jet in Figure 2 and Figure 3, can be separated from the indicator (flowmeter or pressure indicator) by suitable hose connexion, so that remote reading can be readily arranged.

The open jet of Figure 2 or Figure 3, which never makes contact with the work being gauged and which may, therefore, be described as a non-contact gauging element, is suitable for many applications of air gauging. For others, e.g. when measuring components which have a relatively rough surface finish or porous surfaces, it is better to use a contact gauging element.

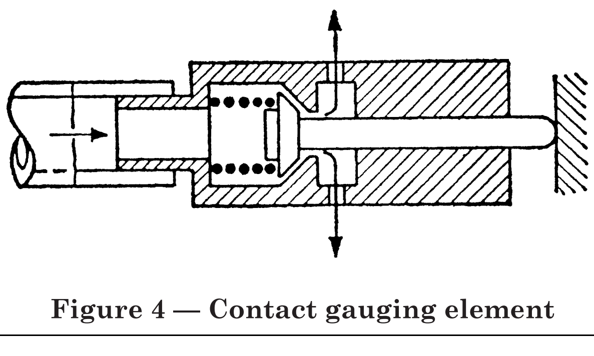


Figure 4 — Contact gauging element

This may take one of several forms, but the principle is shown in Figure 4. The contact gauging element provides a stylus which is in contact with the work being gauged and it will be seen how movement of the stylus changes the flow of air.

An air gauging system comprises essentially an air gauge unit and a measuring head. The air gauge unit contains the means to display the measured sizes, or to generate signals based upon them, and certain other elements depending on its type; in particular, when the variable measured is pressure, it will contain the control orifice. The measuring head may contain a single gauging element, either contact or non-contact, or two or more such elements. The form of the measuring head and the number of gauging elements used will depend upon the type of measurement (length or thickness, internal diameter, external diameter, straightness, squareness, etc.) to be made.

The air supply for the air gauging system will usually be drawn from the factory's compressed air line but, if necessary, a suitable local compressor may be employed. The air gauging system must be operated at a constant pressure; this is readily done by using a pressure regulator, which is usually provided in the air gauge unit. It is essential that the supply pressure is significantly greater than the operating pressure and the manufacturer's directions should be observed. Systems using flow measurement normally operate at 0.7 bar.[2)] The operating pressures in systems using pressure measurement range up to 4.1 bar and it is convenient to classify these systems as low, medium and high by subdivision as follows:

Operating pressure	Classification
Not greater than 0.3 bar	low
Greater than 0.3 bar but less than 1 bar	medium
1 bar and above	high

It is important that the air supplied to the air gauge unit is clean and dry and, in particular, free from oil mist. Filters should be regularly drained and periodically cleaned; attention to this point will ensure trouble-free service for a long time; but neglect will inevitably lead to a breakdown.

The air gauging principle shown in Figure 2 and Figure 3 furnishes a means for comparing the sizes of like objects; in other words an air gauging system is a comparator and, as with all other comparators, requires standardization before it can give true size. Suitable setting standards are therefore required for use with the system and are employed, in conjunction with simple controls, for datum setting and for fixing the magnification. In some cases, it is convenient to fix the magnification by using master setting jets which are substituted for the measuring head.

However precise the instrument used in measuring, it cannot give the correct answer if a poor inspection technique is employed. Change of temperature alters the size of components being measured; difference of form between standard and component, or errors of form in the component, may lead to false results, and so on. The need to use sound techniques is common to all methods of measurement; it is not to be neglected when the air gauging method is employed.

Some of the more direct applications of air gauging are illustrated in the simple line drawings of Figure 5 and Figure 6, in which the gauging element is represented by an arrow head thus .

2) 1 bar = 10^5 N/m^2.

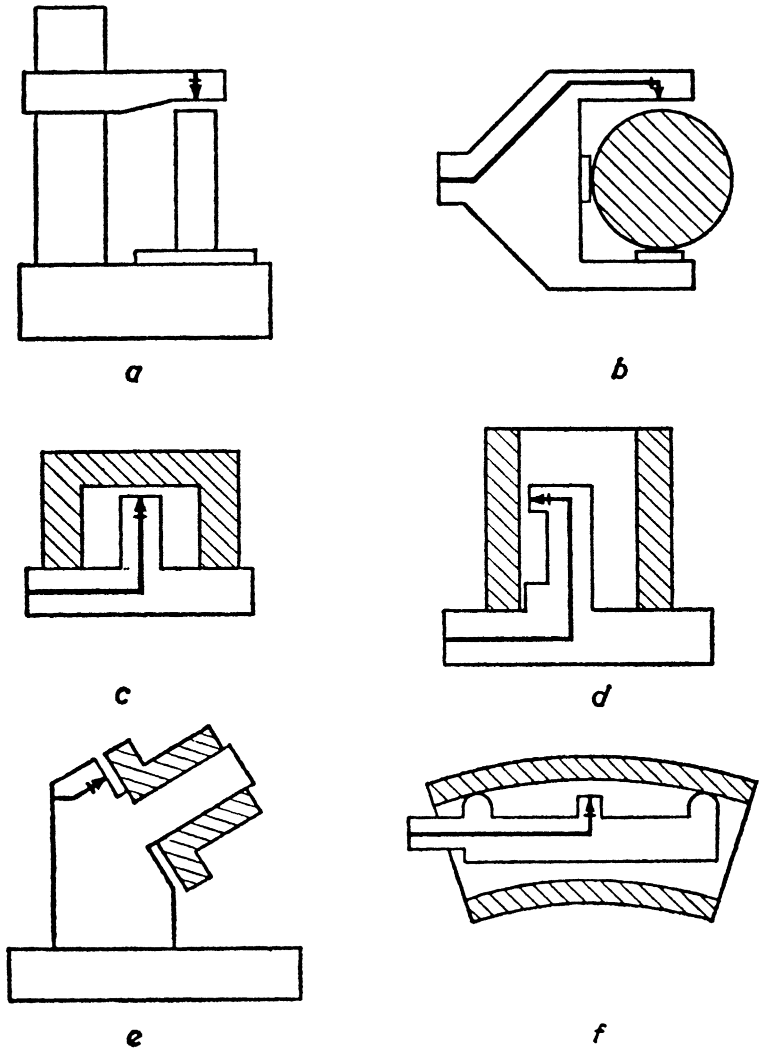


Figure 5 — Examples of air gauging applications

In the examples of Figure 5, a single gauging element is used; the measurement of length or thickness is depicted at *a*, that of diameter at *b* and depth at *c*; checking for squareness is shown at *d* and *e* and for straightness at *f*.

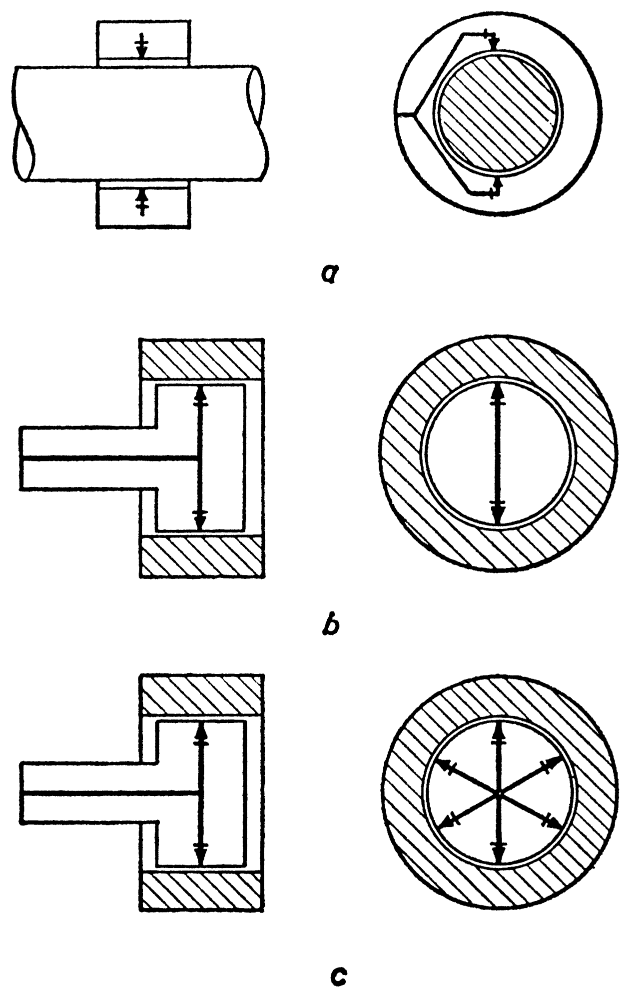


Figure 6 — Measurement of diameter

In the examples in Figure 6, two or more gauging elements are used for measuring diameter, the last example showing how several gauging elements can be disposed so as to measure average diameter.

Since it is the purpose of Figure 5 and Figure 6 to show as clearly as possible how the air gauging method is applied, the illustrations have been confined to simple applications. One of the outstanding features of the method is its extreme flexibility and, in consequence, its very wide field of application. It is particularly valuable for the simultaneous inspection of several dimensions, and can be conveniently employed on the machine tool to give measurement during production. Signal retainers and signal inverters can readily be incorporated in some systems; measurements can be recorded or converted into electrical signals for automatic control. All these techniques are straightforward and in everyday use.

For further information on the theoretical aspects of air gauging reference should be made to "Notes on Applied Science No. 34" — "Principles of Pneumatic Gauging" by J. C. Evans and I. G. Morgan — published by H.M.S.O. (1964).

1 General

No.	Term	Definition
1001	**air gauging** PNEUMATIC GAUGING, *deprecated*	A precise measuring technique, using air drawn from a compressed air supply, which can be employed to measure size, or to check form or position. NOTE The technique can be based on the determination of air flow or alternatively the determination of air pressure. In either case, the measured sizes are displayed on indicators; in the latter they may alternatively or simultaneously be recorded, converted into audible or visual signals, or into signals for automatic operations, e.g. inspection, grading, control of size.
1002	**air gauging system**	Measuring equipment employing air gauging based on the determination of flow or pressure and comprising an air gauge unit and one or more measuring heads as detailed in Section **2** and Sections **3**, **4** and **5** respectively. The air gauging system may be designed for measuring one variable only, or for the simultaneous measurement of two or more independent variables.
1003	**air gauging (flow) system**	An air gauging system based upon the determination of flow.
1004	**air gauging (pressure) system**	An air gauging system based upon the determination of pressure.
1005	**air gauge unit**	That part of the air gauging system which displays the measured sizes or provides visual or audible signals or converts the measurements into signals for automatic operations. For details see Section **2**.
1006	**measuring head**	That part of the air gauging system which contains the gauging element(s) and which is presented to the work, or vice versa. For details see Sections **3** and **4**.
1007	**gauging element**	The element in the measuring head which detects dimensional change and provides the response which enables the air gauging system to measure that change. The gauging element may be an open jet or a contact gauging element, and the measuring head may have one, two or more elements depending on its type. For details see Sections **3** and **4**.
1008	**open jet**	A gauging element in the form of a jet of circular or rectangular section which does not contact the work being measured. The parameters of a jet are its internal and external diameters, when the section is circular; the external and internal length and breadth when the section is rectangular.
1009	**land width**	The terminating wall thickness of an open jet.
1010	**jet recession**	The amount by which an open jet is recessed behind the outer surface of the measuring head. NOTE Recession fulfils two objectives: 1) It protects the jet from mechanical damage, 2) it maintains the essential minimum distance between the jet and the work being measured.
1011	**jet guard**	A protective device to prevent mechanical damage to an open jet when the design of the measuring head does not permit the jet to be recessed.
1012	**contact gauging element**	A gauging element fitted with a stylus which contacts the work being measured. See, for example, Figure 4.
1013	**matched gauging elements**	Gauging elements which have matched pneumatic characteristics so that they may be used in combination in a single measuring circuit.

No.	Term	Definition
1014	**asymmetry error**	The error which may arise when the work being measured is asymmetrically disposed between gauging elements which are combined in one measuring circuit. This error is reduced to negligible proportions by correct design of the measuring head and the stipulation of its measuring range.
1015	**air escape duct**	An air passage, e.g. a groove or hole, which provides an easy final escape to atmosphere of air which has emerged from a gauging element.
1016	**control orifice** **control jet**	The restriction used in air gauging (pressure) systems. In association with the gauging elements, the control orifice determines the magnification of the system.
1017	**supply pressure**	The pressure of the supply from which the air gauging system draws its air.
1018	**air filter**	A device for cleaning the air supply to the air gauging system and which, ideally, removes all liquid and solid particles.
1019	**inlet restrictor**	A fixed inlet orifice used in some air gauging (pressure) systems upstream of the pressure regulator to limit the quantity of air supplied to the system.
1020	**economiser orifice**	The fixed orifice in the measuring head in some air gauging (flow) systems which limits the maximum air flow when the measuring head is disengaged from the work.
1021	**operating pressure**	The constant pressure at which the air gauging system is operated.
1022	**operating pressure indicator**	A pressure measuring instrument which registers the operating pressure and which is usually fitted to the air gauge unit.
1023	**pressure regulator**	A device which keeps the operating pressure constant irrespective of pressure changes in the supply line and of changes of air flow in the air gauging system itself.
1024	**intermediate pressure** BACK PRESSURE, *deprecated*	In air gauging (pressure) systems, the pressure between the control orifice and the measuring head.
1025	**simple pressure measurement**	Measurement of the intermediate pressure in relation to the ambient atmospheric pressure or to the operating pressure as datum. NOTE This term and terms 1026 and 1027 serve to distinguish between the different methods currently used in air gauging (pressure) systems for measuring the intermediate pressure.
1026	**differential pressure measurement**	Measurement of the intermediate pressure in relation to a pre-set fixed pressure obtained from a branch circuit having the same operating pressure as the measuring circuit. This fixed pressure is adjusted to be approximately equal to the intermediate pressure at the mid-point of the measuring range.
1027	**null-balance pressure measurement**	Measurement of the intermediate pressure by a self-balancing system which brings the pressure in a secondary chamber to equality with the pressure being measured by means of a pressure regulating mechanism fitted with an appropriate indicating device.
1028	**datum setting control**	The control which enables the indicator reading to be set to a datum, e.g. zero. NOTE This control will normally be used in association with a setting standard or a master setting jet.

No.	Term	Definition
1029	**magnification**	The ratio of the movement of the indicator index (float, liquid surface, pointer) to the dimensional change which produces it, both being expressed in terms of the same unit of length. Thus, if a dimensional change of 0.001 inch causes the float in a variable-area flowmeter or the liquid surface in a pressure manometer to move 1.000 inch, the magnification is 1000. Magnification is therefore a measure of sensitivity.
1030	**ranging**	The process of adjusting an air gauging system so that the movement of the indicator index (float, liquid surface, pointer) conforms to a pre-established scale at two or more points, i.e. so that the air gauging system has a specified magnification.
1031	**measuring range**	The range of sizes (minimum to maximum) which the air gauging system is designed to measure and over which the indicating device is graduated.
1032	**magnification control**	The control which enables the magnification of the air gauging system to be adjusted to a specified value. NOTE This control will normally be used in association with setting standards or master setting jets.
1033	**setting standard**	A standard of appropriate form and of established size used for setting up the air gauging system so that its reading represents true size. NOTE Two setting standards, one to provide a reading near the lower limit of the measuring range and the other a reading near the upper limit, enable both magnification and datum to be set. A single setting standard allows the datum to be set when ranging has already been done.
1034	**master setting jet**	A calibrated jet, which is substituted for the measuring head and used to set up the air gauging system so that it has the required magnification. NOTE When ranging, two master jets are used, one to provide a reading near the lower limit of the measuring range and the other a reading near the upper limit. A single master setting jet allows the datum to be set when ranging has already been done.
1035	**measuring signal**	In measuring systems, the physical quantity which represents the measurement.
1036	**signal limiter**	A device which may be used in air gauging (pressure) systems to limit the movement of the indicator index when the measuring head is disengaged from the work, i.e. when the measuring signal has been removed.
1037	**signal retainer**	A device which may be used in air gauging (pressure) systems to retain the indicator display when the measuring signal has been removed.
1038	**signal inverter**	A device which may be used in air gauging (pressure) systems for reversing the direction of the indicator movement relative to the measuring signal.
1039	**pressure amplifier**	A device in which an input measuring signal is used to release from a local source an output signal of pressure greater than that of the input signal but bearing a definite relationship to it.
1040	**transducer**	A device which converts a measuring signal expressed in terms of one physical quantity into an equivalent signal expressed in terms of another physical quantity.
1041	**differential air gauging**	A technique whereby two individual measurements are combined so as to display their difference on a single indicator.
1042	**in-process gauging**	Gauging carried out during processing, e.g. measurement of a workpiece whilst it is being machined.
1043	**post-process gauging**	Gauging carried out immediately after processing, e.g. measurement of a workpiece immediately after it has been machined.

No.	Term	Definition
1044	**air gauging machine**	An inspection machine employing air gauging in which all, or the greater part, of the complete process of loading, positioning, measuring, classifying and unloading the work-pieces is carried out automatically. NOTE The machine may measure one or more dimensions of the work-piece and the acceptable work-pieces may be classified by grading into size groups within the tolerance zone. Classification may be effected by marking the work-pieces according to a symbol or colour code or by their physical separation. (See also **B.4**.)
1045	**air gauge size control**	The control of size by a monitored automatic air gauge control system comprising a measuring head to measure the work and an air gauge control unit to generate the control signals which regulate the manufacturing process so that the work is brought to the desired size without the intervention of a human operator. See also (**B.5**.)

2 Air gauge units

Introduction. The air gauge unit contains all those parts of the measuring circuit which are used in conjunction with the measuring head to form the air gauging system. It provides the means to display the measured sizes or to generate signals based upon them for purposes of control or recording. The unit may contain one or more of the following items:

Air filter, pressure regulator, operating pressure indicator, control orifice, magnification and datum setting controls, signal retainers, signal limiters, signal inverters.

Air gauge units may be subdivided into air gauge indicating units and air gauge control units.

21. Air gauge indicating unit

No.	Term	Definition
2101	**air gauge indicating unit**	An air gauge unit which displays the measured sizes. NOTE In air gauging (flow) systems the unit contains a flow-responsive device which is usually a variable-area flowmeter, the measured size being then indicated by the position of the float in the tapered tube. In air gauging (pressure) systems the unit contains a pressure-responsive device, the measured size being displayed on a manometer type column indicator or a scale and pointer indicator. Alternatively, in air gauging (pressure) systems, the results of measurement may be displayed by means of electric signal lights, announced by audible signals, or recorded.
2102	**single display air gauge indicating unit**	An air gauge indicating unit for displaying the measurement of a single variable.
2103	**multiple display air gauge indicating unit**	An air gauge indicating unit for simultaneously displaying the measurements of two or more variables.
2104	**special air gauge indicating units**	Air gauge indicating units generally conforming to the basic definition but particularly designed for specific applications.

22. Air gauge control unit

No.	Term	Definition
2201	**air gauge control unit**	An air gauge unit as described earlier which converts the measurements into signals for automatic control. In addition to this primary function, the unit may also contain means for displaying or recording the measured sizes.
2202	**single input air gauge control unit**	An air gauge control unit which generates signals for the control of a single variable.
2203	**multiple input air gauge control unit**	An air gauge control unit which generates signals for the simultaneous (or programmed) control of two or more variables.
2204	**special air gauge control units**	Air gauge control units generally conforming to the basic definition but particularly designed for specific applications.

3 Measuring heads for dimensional measurement

Introduction. In this section will be found terms and definitions relating to measuring heads used for the measurement of length, internal diameter and external diameter. Terms relating to measuring heads for inspecting form and position are given in Section **4** and Appendix A.

31. Length (including thickness and depth) and diameter

No.	Term	Definition
3101	**air gauge probe**	A measuring head for general use fitted with a single gauging element which may be an open jet or a contact gauging element. When two or more are used in one measuring circuit, the gauging elements must be matched.
3102	**air gauge jet probe**	An air gauge probe in which the gauging element is an open jet.
3103	**air gauge contact probe**	An air gauge probe fitted with a contact gauging element.
3104	**air gauge comparator**	A rigid structure fitted with a work-table and one or two gauging elements for measuring work-pieces by comparison with standard gauges of closely similar size, the standard gauge and the work-piece being placed in turn on the work-table. The gauging elements may be open jets or contact gauging elements. When one gauging element is fitted, its distance from the work-table is adjustable to accommodate work-pieces of different sizes and the work-table provides the measuring datum. When there are two gauging elements, the position of the upper one in relation to the work-table is adjustable but the lower one is fixed rigidly to the work-table which then serves only as a support for the work-piece. The capacity of the comparator is the maximum size of work-piece it will accommodate.
3105	**external air gauge comparator**	An air gauge comparator for measuring external dimensions.
3106	**internal air gauge comparator**	An air gauge comparator for measuring internal dimensions.

32. Length (including height above a datum surface)

No.	Term	Definition
3201	**air gauge test indicator probe**	A probe of small size, and therefore particularly suitable for measurements in positions of restricted access, which is fitted with a single contact gauging element. The probe is designed for clamping to a rigid stand and contact with the work-piece is made by means of a ball-ended stylus lever. This lever may be mounted on a friction pivot so that its angular relationship to the body of the probe can be adjusted.

33. Internal diameter

No.	Term	Definition
3301	**air plug gauge**	A plug gauge which can be inserted into the bore to be measured and which is fitted with one or more pairs of gauging elements. The gauging elements may be open jets or contact gauging elements. The air plug gauge is of fixed size and can be used to measure only diameters lying within its measuring range as specified by the manufacturer. For the measurement of **single diameter** the air plug gauge is fitted with two gauging elements arranged diametrically. By rotation and translation of the plug within the bore the position of the diameter measured can be varied both in azimuth and depth. For the measurement of **average diameter** the air plug gauge is fitted with an even number of gauging elements, four or more, spaced equally around the circumference.

No.	Term	Definition
3302	**through-bore air plug gauge**	An air plug gauge for measuring through bores. Since the gauge can be passed right through the bore the longitudinal position of the gauging elements is not of primary importance.
3303	**blind-bore air plug gauge**	An air plug gauge for measuring blind bores. The gauging elements are placed so as to permit measurements to be made as close as possible to the bottom of the bore.
3304	**shouldered-bore air plug gauge**	An air plug gauge for measuring shouldered holes. The gauging elements are placed so as to permit measurements to be made as close as possible to the shoulder.
3305	**multi-dimension air plug gauge**	An air plug gauge for the simultaneous measurement of two or more spaced diameters which may be of equal or of different size.
3306	**special air plug gauges**	Air plug gauges generally conforming to the basic definition but particularly designed for specific applications.
3307	**adjustable air bore gauge**	A gauge of adjustable size which can be inserted into the bore to be measured and which is fitted with one or more gauging elements. The adjustable air bore gauge is designed for the measurement of single diameter. It can be adjusted to cover a wide range of sizes and for each size will have a specified measuring range. NOTE 1 Adjustable air bore gauges of three types are available, namely: i) gauges which are self-centring and self-aligning; ii) gauges which are self-centring only; iii) gauges which are self-aligning only. NOTE 2 In present designs the gauging elements are of the contact type.

34. External diameter

No.	Term	Definition
3401	**air ring gauge**	A ring gauge through which is passed the cylindrical work to be measured and which is fitted with one or more pairs of gauging elements. The gauging elements may be open jets or contact gauging elements. The air ring gauge is of fixed size and can be used to measure only diameters lying within its measuring range as specified by the manufacturer. For the measurement of ***single diameter*** the air ring gauge is fitted with two gauging elements arranged diametrically. By relative rotation and translation of the shaft within the ring gauge the position of the diameter measured can be varied both in azimuth and along the axis. For the measurement of ***average diameter*** the air ring gauge is fitted with an even number of gauging elements, four or more, spaced equally around the circumference.
3402	**through-shaft air ring gauge**	An air ring gauge for measuring plain cylindrical work. Since the work can be passed right through the ring gauge the longitudinal position of the gauging elements is not of primary importance.
3403	**close-to-shoulder air ring gauge**	An air ring gauge for measuring shouldered shafts. The gauging elements are placed so as to permit measurements to be made as close as possible to the shoulder.
3404	**multi-dimension air ring gauge**	An air ring gauge for the simultaneous measurement of two or more spaced diameters which may be of equal or different size.
3405	**special air ring gauges**	Air ring gauges generally conforming to the basic definition but particularly designed for specific applications.

No.	Term	Definition
3406	**air calliper gauge**	A calliper gauge for the measurement of cylindrical work. It has one or two gauging elements, which may be open jets or contact gauging elements. The air calliper gauge is designed to measure a single diameter and cannot conveniently be used to measure average diameter. By relative rotation and translation of the gauge and the work, the position of the diameter measured can be varied both in azimuth and along the axis.
3407	**hand air calliper gauge of fixed or adjustable size**	A hand air calliper gauge of fixed or adjustable size which can be applied by hand to the work to be measured. The fixed size calliper gauge can be used to measure only diameters lying within its measuring range as specified by the manufacturer. The adjustable calliper gauge can be adjusted to cover a wide range of sizes, and for each size will have a specified measuring range.
3408	**multi-dimension hand air calliper gauge**	A hand air calliper gauge, normally of fixed size, designed for simultaneous measurement of two or more diameters of equal or different size.
3409	**special hand air calliper gauge**	Air calliper gauges for hand use conforming generally to the basic definition but particularly designed for specific applications.
3410	**fixture mounting air calliper gauge (non-floating) (fixed or adjustable size)**	An air calliper gauge of fixed or adjustable size designed for rigid mounting in a holding fixture, or to form part of a multi-gauging fixture, and which normally provides location for the work being measured. The fixed size gauge can be used to measure only diameters lying within its measuring range as specified by the manufacturer. The adjustable gauge can be adjusted to cover a wide range of sizes, and for each size will have a specified measuring range.
3411	**fixture mounting calliper gauge (floating) (fixed or adjustable size)**	An air calliper gauge of fixed or adjustable size mounted in a holding fixture, or forming part of a multi-gauging fixture, so that it is free to move and is thus self-locating on the work being measured. The fixed size gauge can be used to measure only diameters lying within its measuring range as specified by the manufacturer. The adjustable gauge can be adjusted to cover a wide range of sizes, and for each size will have a specified measuring range.
3412	**machine mounting air calliper gauge (fixed or adjustable size)**	An air calliper gauge of fixed or adjustable size designed for mounting on a machine tool to measure the work-piece during or immediately after machining. The calliper may for example be arranged for mounting on the wheelhead, the machine bed or the headstock, and may be of the floating or non-floating variety. The fixed size gauge can be used to measure only sizes within its measuring range as specified by the manufacturer. The adjustable gauge can be adjusted to cover a wide range of sizes, and for each size will have a specified measuring range.

4 Measuring heads for the inspection of form and position

The work-pieces made by the engineering industry are usually based upon a few fundamental geometrical forms such as the plane, sphere, cylinder and cone. Determinations of the sizes of these work-pieces calls for measurements of length, diameter and angle, but if errors of form are present, i.e. the work-pieces are not true to the geometrical forms they are meant to represent, the measurements may be wrong and so prove misleading when assessing functional qualities. Inspection therefore normally requires assessment of form as well as determination of size, a requirement to which the designer may have drawn attention in advance by specifying certain form tolerances in addition to size tolerances.

It is well to emphasize that the true measurement of form usually presents more difficulty than the true measurement of size, and this because two or more different errors of form may be present simultaneously. Thus, to take a simple example, a nominally circular, straight bore may be both out of round and tapered, and a test for taper which overlooks the out-of-roundness, and so ignores the latter's influence on the readings taken, will give misleading results. When checking form, irrespective of the technique used, it is therefore necessary to consider in advance what types of error may be present and to adopt methods of inspection which will not lead to incorrect conclusions. The inspection of the out-of-round, tapered bore can be satisfactorily made with a through-bore air plug gauge (3302) fitted with two gauging elements arranged diametrically provided i) the diameter variation in each of several sections is first examined by rotation of the gauge without axial traverse and ii) when axial traverse is made to check for taper, the gauge is kept in the same azimuth. By adopting this method, the out-of-roundness measurement is not invalidated by the taper and the taper test is not affected by the out-of-roundness. (In the rare case when the pattern of diameter variation rotates with depth, the taper can still be measured by rotating the gauge during the axial traverse so that it keeps in step with the pattern rotation, though the accuracy is likely to be impaired if the out-of-roundness is marked and the pattern rotates rapidly with depth.)

The first work-pieces from a new production run must be critically examined in order to establish what different types of form error are present and to what degree. Experience of a given manufacturing process, or even with a particular machine tool, will suggest what should be expected; lobing in spherical or cylindrical parts made by centreless grinding, camber in plain holes finished by honing are examples in point. But when the nature of the form errors has been established and the production is under control, a relatively simple method of inspection can usually be devised which will be adequate to maintain control and be economically suitable.

Air gauging can usefully be introduced at this stage, and in Appendix A of this glossary will be found information regarding measuring heads designed for the inspection and measurement of form. The use of these measuring heads offers an economic means of inspection, but it must be appreciated that like all other techniques with similar intention, it does not necessarily give the full information obtainable from a detailed, point-to-point examination. Where it has been considered desirable to do so, the limitations imposed by the presence of compound errors of form when using the measuring heads described in the appendix have been indicated.

Appendix A Examples of air gauging techniques for checking common errors of form and position

A.1 Introduction

The aim of this appendix is to illustrate the application of air gauging techniques to the practical assessment of errors of form and position.

The various types of error of form and position dealt with in this appendix are separately enumerated in Sections **A.2**, **A.3**, etc., below, the definitions given being based upon the initial draft proposals for expressing tolerances of form and position prepared by ISO (International Organization for Standardization) and currently being considered by the ISO Technical Committee ISO/TC 10 — "Drawings (General Principles)"[3]. In each section, immediately following the definition, illustrations are shown of recommended air gauging methods which may be used to make a practical assessment as to whether the component being examined is within the prescribed tolerance zone.

In the illustrations, the component being gauged is shown shaded. The gauging elements in the measuring heads are shown thus  and translation or rotation of the measuring head or of the component is shown thus . Those measuring heads for inspecting for taper which are marked with an asterisk (*) may also be used to determine variation of diameter along the axis. Those marked with a dagger (†) should be used with the necessary caution when inspecting shafts or holes in the rare cases in which the pattern of diameter variation rotates with depth.

These illustrations, though including the majority of the measuring heads normally available, should not be regarded as exhaustive and they do not, of course, show measuring heads particularly designed for special applications. It should be noted that certain errors of form and position can be measured by means of external and internal air gauge comparators (3104), using conventional methods.

A.2 Straightness tolerance — of a line

The tolerance zone in any one plane is limited by two parallel straight lines in that plane a distance *t* apart.

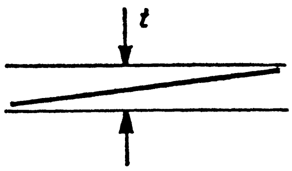
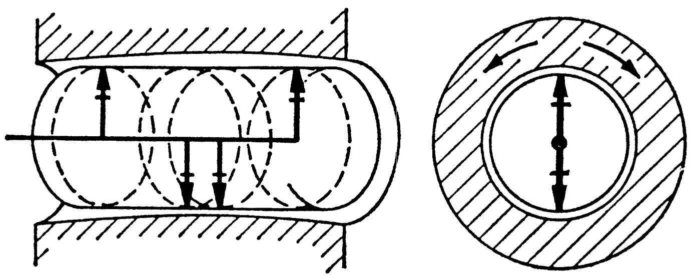
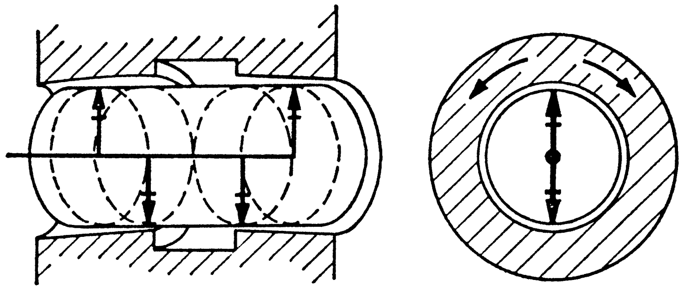
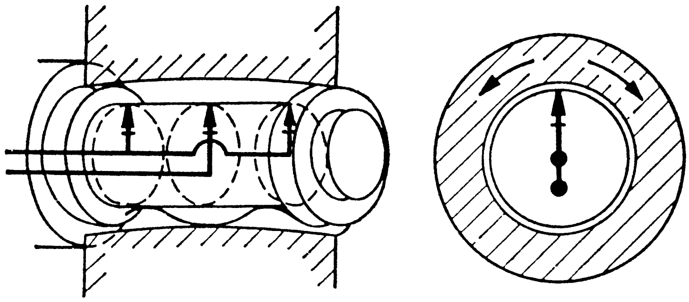
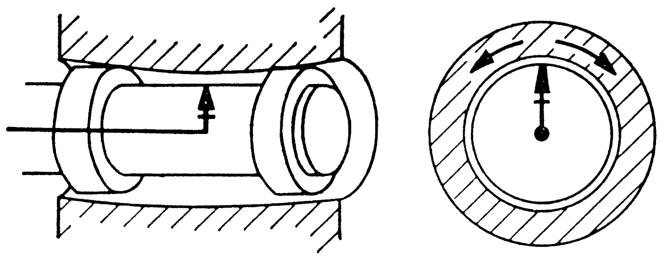
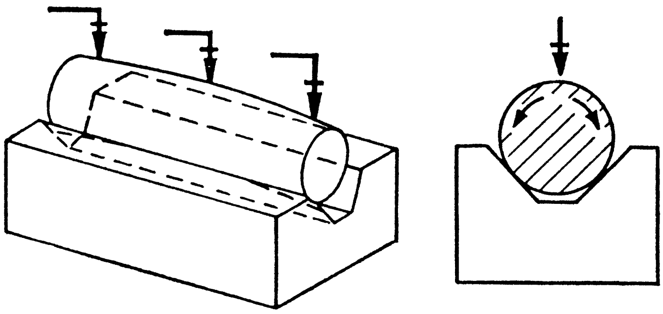


Figure			
7	Straightness		AIR PLUG GAUGE 4 gauging elements in common axial plane

[3] See Draft ISO Recommendation No. 1016. To appear in BS 308, *"Engineering drawing practice"*, Part 3, *"Geometrical tolerancing using ISO symbols"*. (In course of preparation.)

Figure			
8	Straightness		Air Plug Gauge 4 gauging elements in common axial plane, centre pair disposed to suit component conditions
9	Straightness		Air Plug Gauge 3 gauging elements in common axial plane
10	Straightness		Air Plug Gauge 1 gauging element
11	Straightness		Vee Block with Gauging Elements *n* gauging elements

A.3 Parallelism tolerance — of a line with reference to a datum line

The tolerance zone in any one plane is limited by two parallel straight lines in that plane a distance *t* apart and parallel to the datum line.

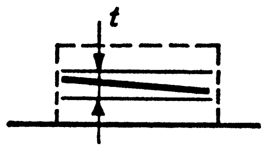
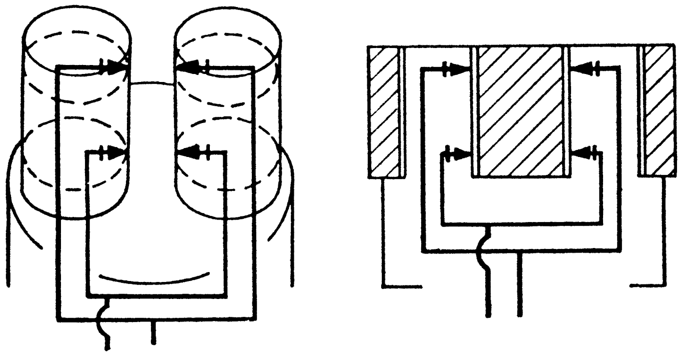
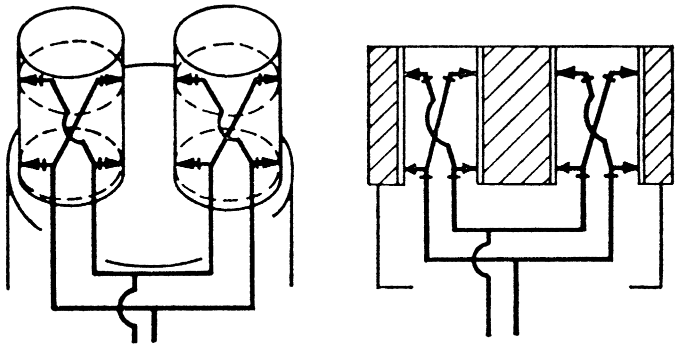


Figure			
12	Parallelism in one plane of 2 holes of uniform diameters		4 gauging elements in 2 pairs measuring thickness of material between holes
13	Parallelism in one plane of 2 holes		8 gauging elements in 2 sets of 4 giving compensation for diameter variation

NOTE These illustrations indicate methods of measuring parallelism of two holes in one plane only. When it is required to measure parallelism in two planes, the measuring arrangements should be duplicated with the second system at right angles to the first.

A.4 Perpendicularity tolerance — of a line with reference to a datum plane

The tolerance zone in any one plane is limited by two parallel straight lines a distance *t* apart and perpendicular to the datum plane.

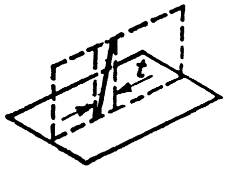
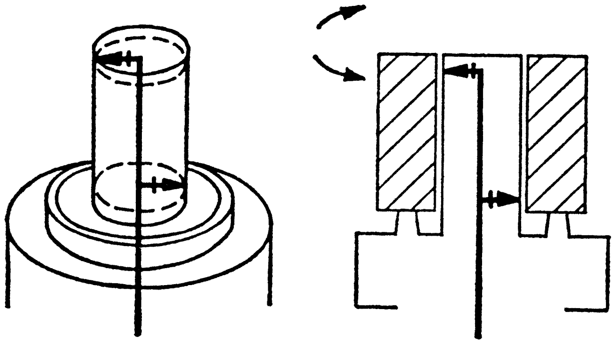
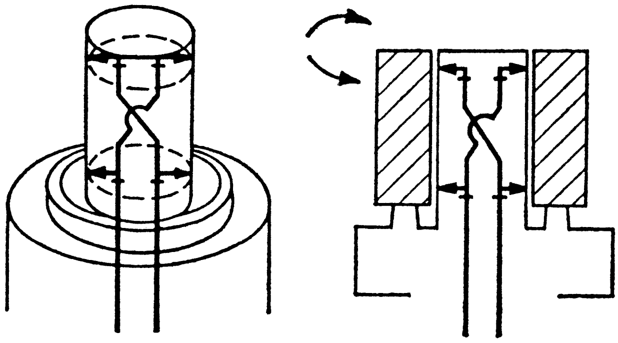


Figure			
14	Squareness bore to face in any plane, diameter being uniform		2 gauging elements
15	Squareness bore to face in any plane		4 gauging elements in 2 pairs giving compensation for diameter variation

A.5 Flatness tolerance

The tolerance zone is limited by two parallel planes a distance *t* apart.

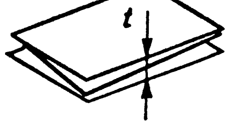
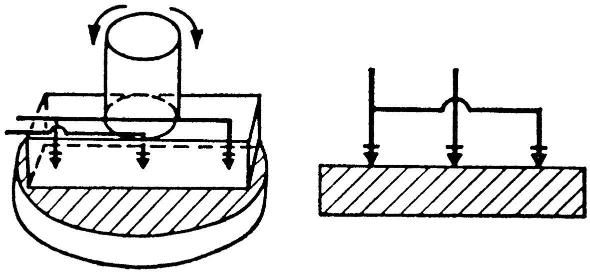
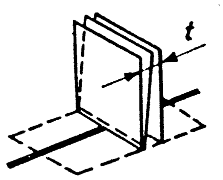


Figure			
16	Flatness		3 gauging elements in common plane

A.6 Perpendicularity tolerance — of a surface with reference to a datum line

The tolerance zone is limited by two parallel planes a distance *t* apart and perpendicular to the datum line.

NOTE This may be regarded as a corollary to **A.4**, q.v.



A.7 Perpendicularity tolerance — of a surface with reference to a datum plane

The tolerance zone is limited by two parallel planes a distance *t* apart and perpendicular to the datum plane.

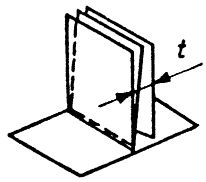
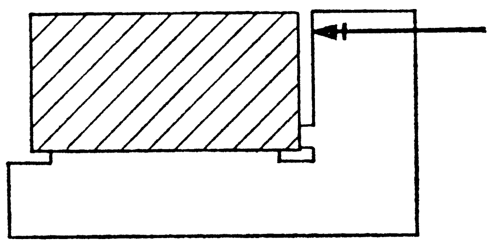


Figure 7	Squareness when surfaces are flat		Reference square with 1 gauging element

8 Angularity tolerance — of a line with reference to a datum line

The tolerance zone is limited by two parallel straight lines distance *t* apart and inclined at the specified angle to the datum line.

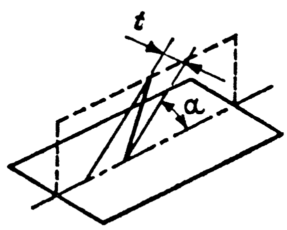


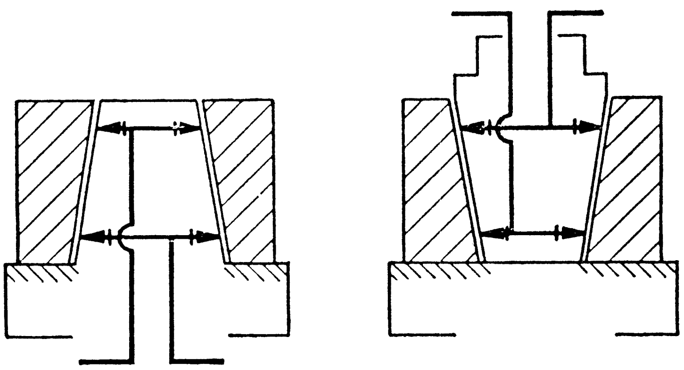
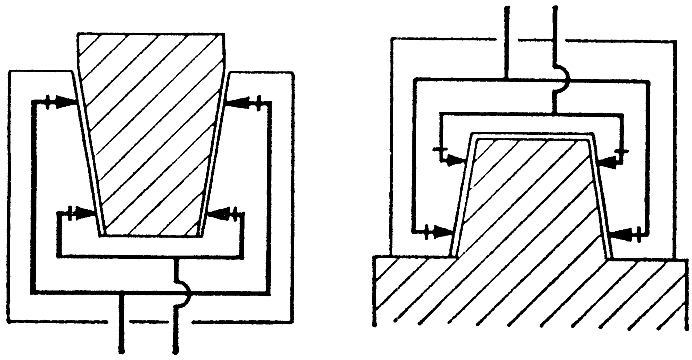
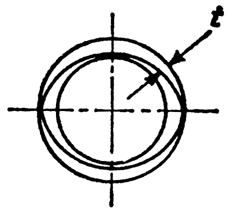
Figure 18	Error in design taper		TAPERED AIR PLUG GAUGE 4 gauging elements in 2 pairs

Figure			
19	Error in design taper		TAPERED AIR RING GAUGE 4 gauging elements in 2 pairs

A.9 Circularity tolerance

The tolerance zone is limited by two co-planar concentric circles a distance *t* apart.



For the purposes of this standard, two types of circularity error are distinguished, viz.:

i) *Ovality*. The ovality of a nominally circular profile is the difference between the major and minor diameters of the profile.

ii) *Lobing*. The error of form when a nominally circular profile is of varying curvature but apparently constant diameter.

With this distinction in mind, the following methods are available, but see Section **4**, paragraph 3.

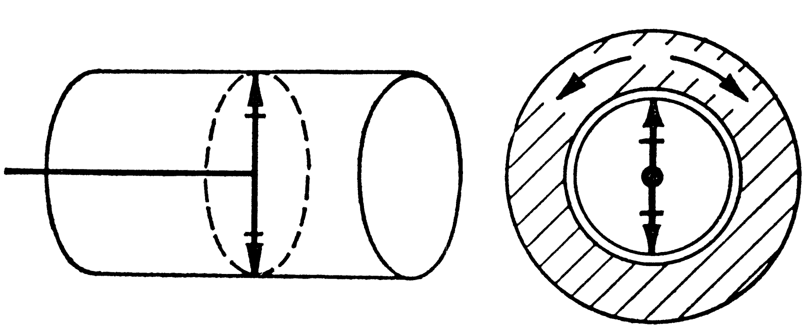
Figure			
20	Ovality		AIR PLUG GAUGE 2 gauging elements

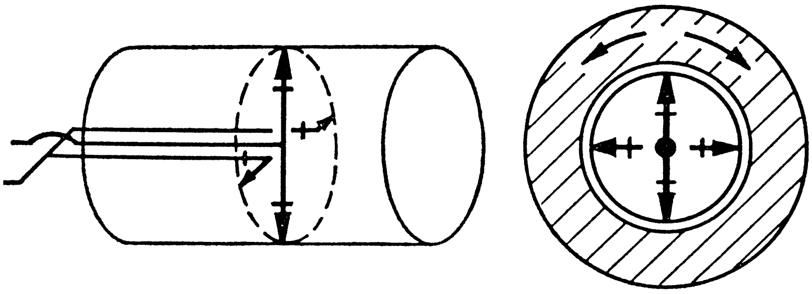
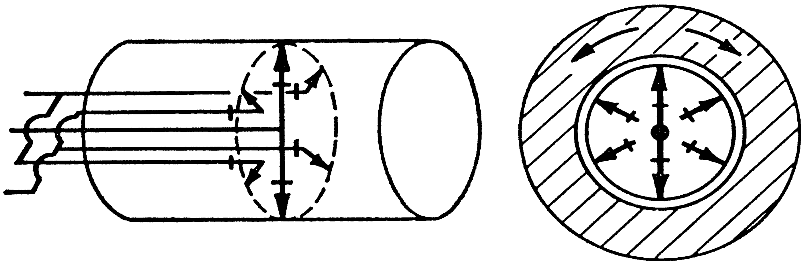
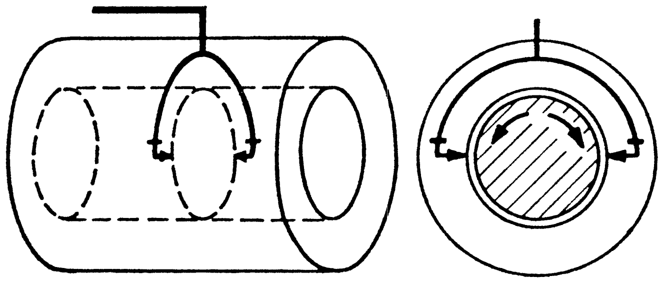
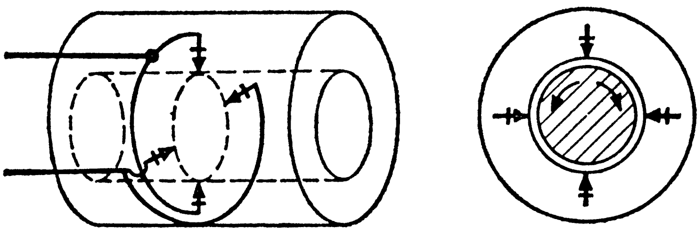
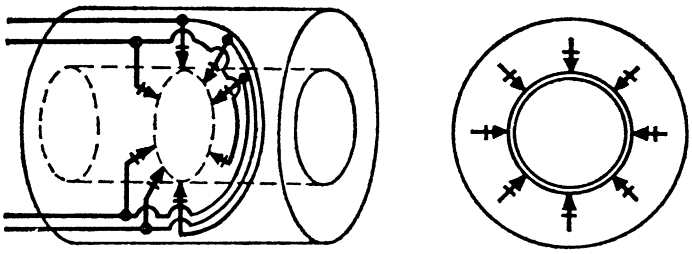
Figure			
21	Ovality		AIR PLUG GAUGE 4 gauging elements in 2 pairs spaced at right angles
22	Ovality		AIR PLUG GAUGE 6 gauging elements in 3 pairs equally spaced in one plane
23	Ovality		AIR RING GAUGE 2 gauging elements
24	Ovality		AIR RING GAUGE 4 gauging elements in 2 pairs spaced at right angles
25	Ovality		AIR RING GAUGE 8 gauging elements in 4 pairs equally spaced in one plane

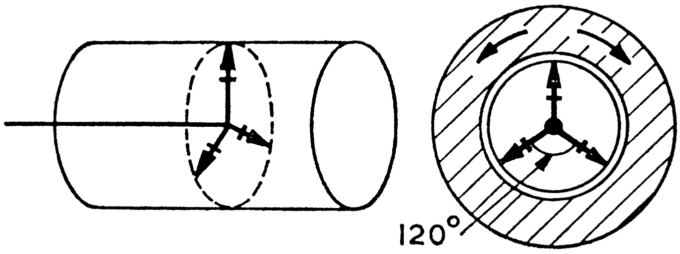
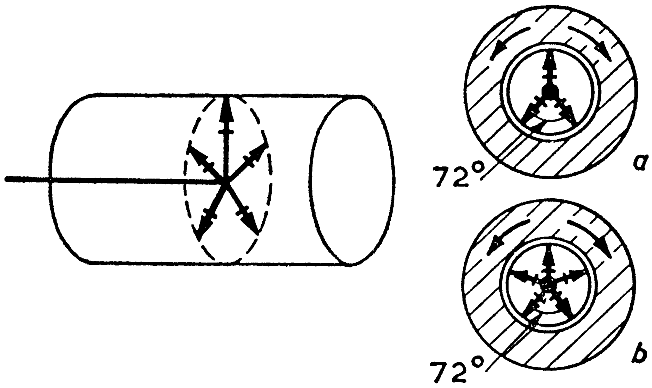
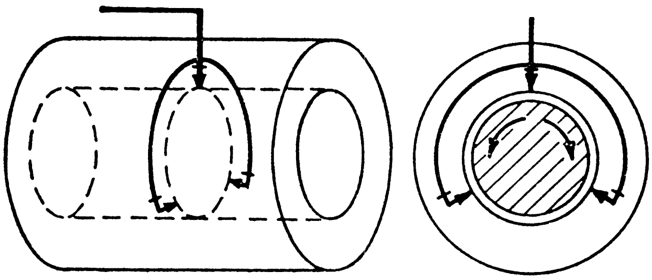
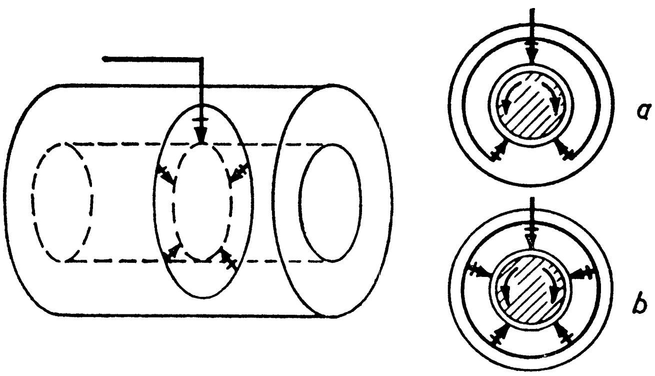
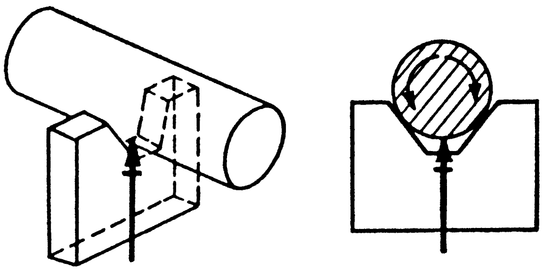
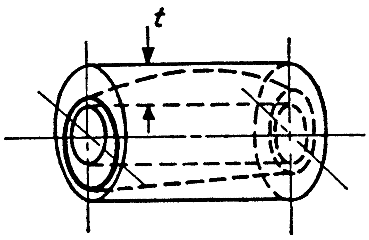
Figure			
26	3-point lobing		Air Plug Gauge 3 gauging elements
27	5-point lobing		Air Ring Gauge (a) 3 gauging elements (b) 5 gauging elements
28	3-point lobing		Air Ring Gauge 3 gauging elements
29	5-point lobing		Air Ring Gauge (a) 3 gauging elements (b) 5 gauging elements

Figure			
30	Ovality or lobing (comparative)		VEE GAUGE 1 gauging element

A.10 Cylindricity tolerance

The tolerance zone is limited by two coaxial cylinders a distance *t* apart.



Errors of cylindricity can arise as the result of one or more of the following errors:

i) errors of straightness — see **A.2**.

ii) errors of circularity — see **A.9**.

iii) variation of diameter along axis.

For the purposes of this standard, inspection of errors of cylindricity is made by separate tests for these three types of error. Suitable methods are indicated in illustrations 7 to 11 for straightness (**A.2**), in illustrations 20 to 30 for circularity (**A.9**), and in the following illustrations 31 to 39 for variation of diameter along the axis.

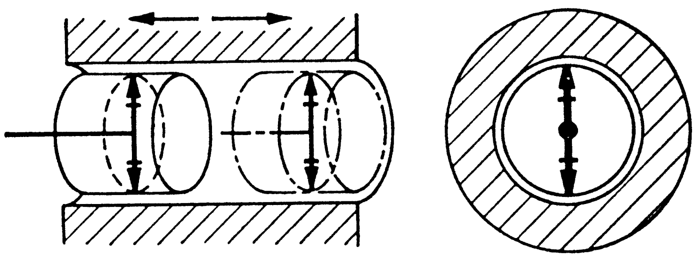
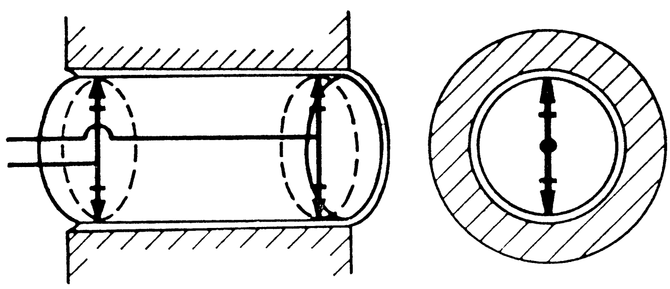
Figure			
31	Taper * †		AIR PLUG GAUGE 2 gauging elements
32	Taper†		AIR PLUG GAUGE 4 gauging elements in 2 pairs suitably spaced along axis

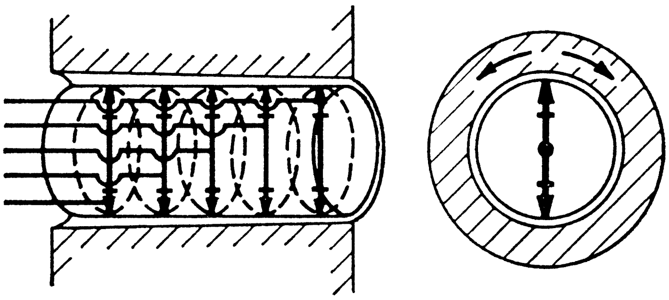
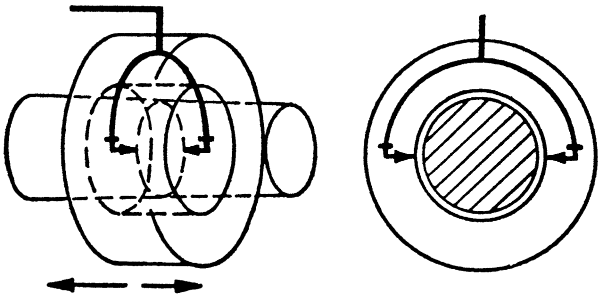
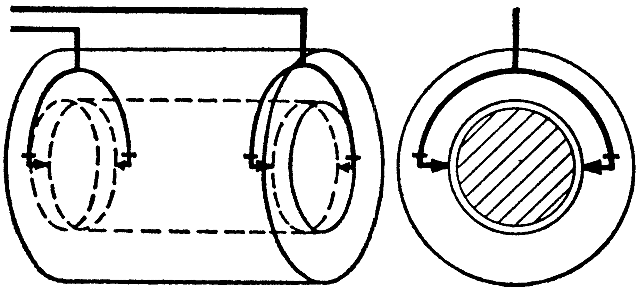
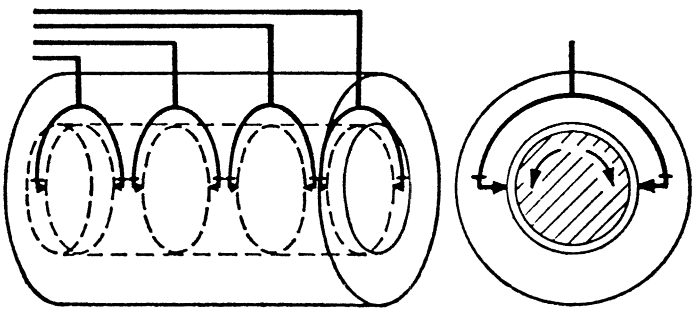
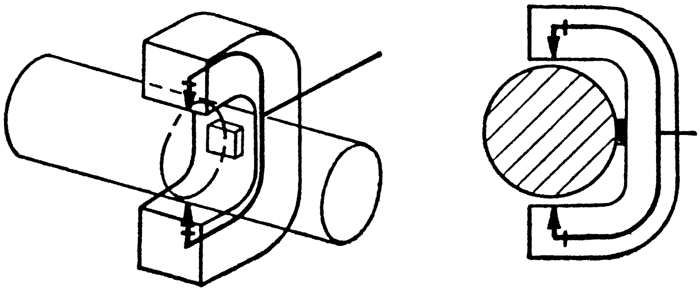
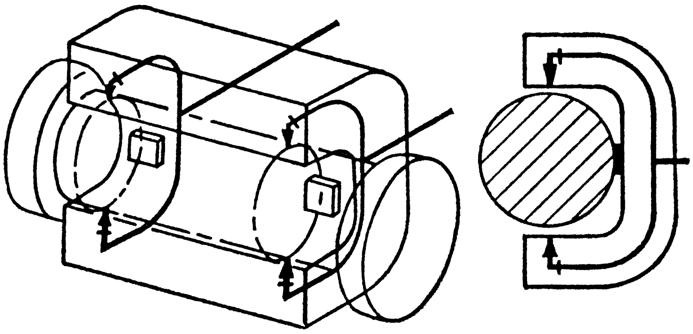
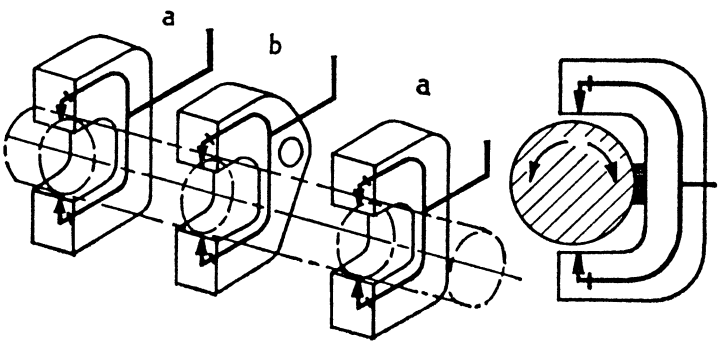
Figure			
33	Variation of diameter along axis		AIR PLUG GAUGE 2*n* gauging elements in *n* pairs suitably spaced along axis
34	Taper * †		AIR RING GAUGE 2 gauging elements
35	Taper †		AIR RING GAUGE 4 gauging elements in 2 pairs suitably spaced along axis
36	Variation of diameter along axis		AIR RING GAUGE 2*n* gauging elements in *n* pairs suitably spaced along axis

Figure			
37	Taper * †		HAND AIR CALLIPER GAUGE 1 or 2 gauging elements
38	Variation of diameter along axis		MULTI-DIMENSION HAND AIR CALLIPER GAUGE 2*n* gauging elements
39	Variation of diameter along axis		FIXTURE MOUNTING AIR CALLIPER GAUGE (a) Non-floating (b) Floating 2 gauging elements

A.11 Concentricity tolerance

The tolerance zone for the concentricity of a circle B with reference to a coplanar datum circle A is the diameter *t* of the circle concentric and coplanar with A within which the centre of B lies.

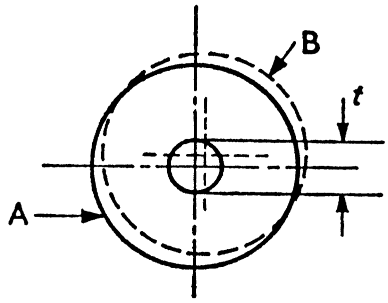
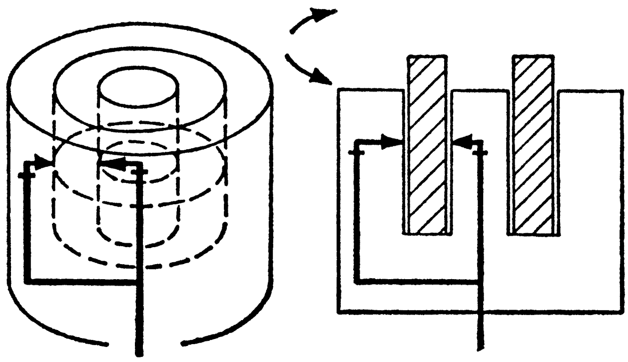


Figure			
40	Concentricity outside to inside diameter where there are no errors of circularity		2 gauging elements measuring material thickness

A.12 Radial and axial run-out tolerance

The run-out tolerance represents the maximum permissible variation *t* of position of the considered feature with respect to a fixed point during one complete revolution about the datum axis (without axial movement in the cases shown in Figure b and Figure c). Except when otherwise stated this variation is measured in the direction indicated by the arrow at the end of the leader line which points to the toleranced feature.

The run-out tolerances specified may include defects of circularity, coaxiality or perpendicularity provided the sum of these defects does not exceed the specified run-out tolerance.

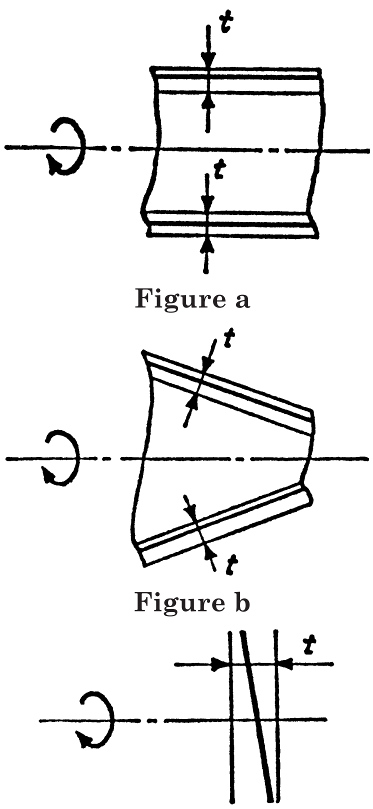


Figure a

Figure b

Figure c

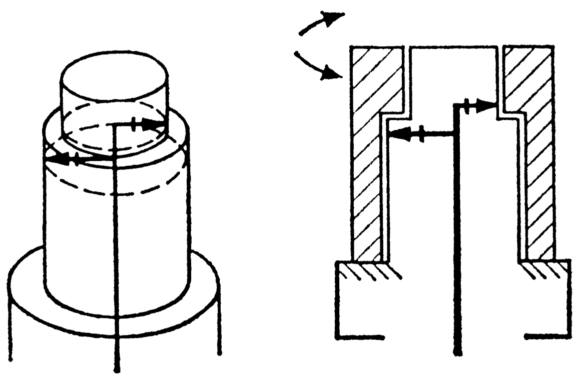
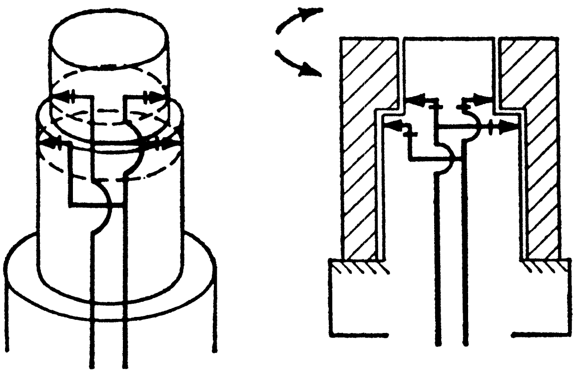
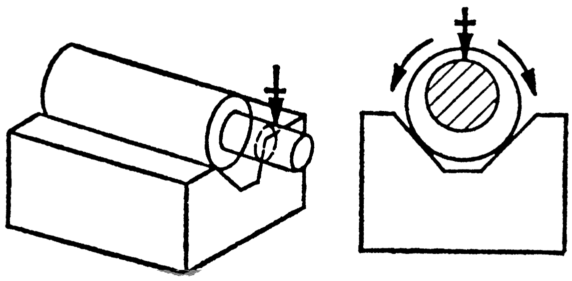
Figure			
41	Radial run-out (concentricity) of 2 inside diameters		2 gauging elements End face of component is datum and must be square to axis

Figure			
42	Radial run-out (concentricity) of 2 inside diameters		4 gauging elements in 2 pairs giving compensation for diameter variation End face of component is datum and must be square to axis
43	Radial run-out (concentricity) of 2 shaft diameters		1 gauging element

A.13 Positional tolerance of a line

The tolerance zone is limited by two parallel straight lines a distance *t* apart and disposed symmetrically with respect to the true specified position of the considered line if the tolerance is only specified in one plane.

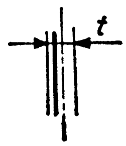


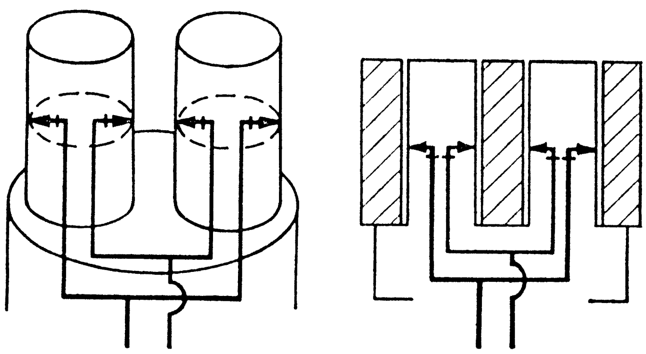
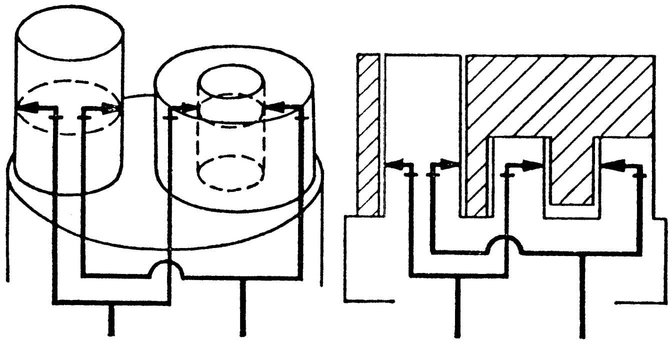
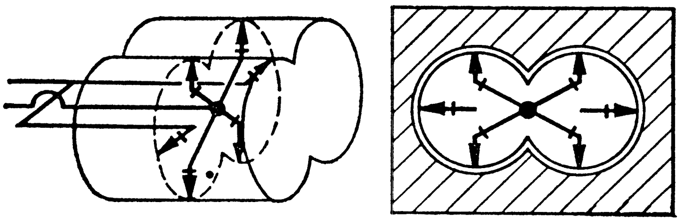
Figure			
44	Centre distance of 2 holes		4 gauging elements in 2 pairs giving compensation for diameter variation

Figure			
45	Centre distance shaft to hole		4 gauging elements in 2 pairs giving compensation for diameter variation
46	Centre distance of intersecting holes		6 gauging elements giving compensation for diameter variation

Appendix B Other applications of air gauging

B.1 Introduction

In this appendix, examples are given of applications of air gauging which have not been considered in the earlier Sections. The examples have been divided into six categories, viz. measurement, recording, automatic inspection, gauging for selective assembly, match machining and control of size. In the first category a few examples are given which, though not making strict use of the air gauging principle, employ related methods of measuring. It should also be noted that in some of the applications in this category the introduction of control, as a further stage, is readily achieved; thus, measurement of the travel of a moving member (see position detection) would be a first step in controlling the movement.

When considering the use of air gauging in the applications mentioned below it will be recalled that the method offers high sensitivity with stability of indication, that the measuring head can be very small and contact with fragile or easily damaged components avoided by the use of open jets, and that remote indication is readily arranged.

The examples given are not exhaustive; they are intended to illustrate the numerous additional ways in which air gauging can be useful in engineering, and they will probably suggest further applications to the reader.

B.2 Measurement

The following are some of the applications of air gauging methods to measurement.

B.2.1 ***Position detection***

B.2.1.1 In machine tool applications, monitoring the position of the work or of slides, quills, clamping devices, the cutting faces of grinding wheels, etc.

B.2.1.2 Measuring the travel of a moving member.

B.2.2 *Fiducial indication.* To show when a given datum condition has been established, the air gauge being used as a sensitive null indicator.

B.2.3 ***Continuous gauging***

B.2.3.1 Measurement during production of the thickness of materials (metals, plastics, paper, etc.) manufactured in strip or sheet form by a continuous process.

B.2.3.2 Measurement of the average diameter or mass per unit length of materials (textiles, plastics, metals, etc.) manufactured in thread or wire form by a continuous process.

B.2.4 *Measurement of fragile products*. Examples are the measurement of the diameter of cigarettes and cigarette filters during production. The use of non-contact measuring heads and low operating pressures are particularly valuable in this application.

B.2.5 ***Contour and shape***

B.2.5.1 Complex shapes, using multiple measuring heads or a single measuring head following a path determined by a master profile.

B.2.5.2 Standard air gauge spherometer for radial measurement of spherical surfaces.

B.2.6 ***Extensometry and dynamometry***

B.2.6.1 Standard designs of extensometers and dynamometers.

B.2.7 ***Distortion***

B.2.7.1 Change of dimension or shape of structures.

B.2.7.2 Movement under load of a nominally rigid member of a machine, e.g. the bed of a machine tool.

B.2.7.3 Dimensional changes or distortion of moving members using non-contact measuring heads, e.g. the increase in diameter of turbine discs running at high rotational speeds.

B.2.8 *Jet calibration*. Calibration of fluid metering jets and determination of flow characteristics. Typical examples are carburetter jets and capillary tubing for refrigerators.

The dependence of flow characteristics on pressure and on the nature of the fluid must not be overlooked in this application of air gauging.

B.2.9 ***Leakage and leakage rate***

B.2.9.1 Inspection, as an aid to production, of fluid control units to establish overall quality of fit by determining leakage rate, e.g. the leakage rate between spool and sleeve in hydraulic spool valves.

B.2.9.2 Fibre fineness tests and porosity tests of paper.

B.2.9.3 Checking porosity of castings and leakages of built-up assemblies, e.g. engine blocks.

B.2.9.4 Checking the clearance around the ball in ball-point pens.

B.2.9.5 Establishing the presence of an essential hole, e.g. in primer caps.

B.3 Recording

Recording of measurements made with an air gauging system based on the determination of pressure can be arranged by using a signal from the air gauge unit. Two schemes are in general use; the signal is fed to a pneumatic recorder, or a transducer is employed to convert the pressure signal into an analogue electrical signal which is then fed to an electrical recorder.

B.4 Automatic inspection

Air gauging machines (1044) for the automatic inspection of machined parts are available. They may be fully automatic, the complete process being carried out without the intervention of a human operator, or they may be semi-automatic, one or more operations, such as leading, positioning, being performed manually.

Although inspection is their primary function, air gauging machines may also be used to exercise some form of control of the production. In general, this control is limited to stopping the machining when one work-piece, or each of several consecutive work-pieces, is outside tolerance. Examples of applications are to those machines, e.g. presses, broaching machines and multi-spindle automatic lathes, which do not admit of any other control action.

B.5 Control of size

Air gauge size control (1045) may be used to provide control systems for manufacturing processes which have the necessary in-built facilities, e.g. certain machine tools and rolling mills.

Both in-process and post-process control are catered for, a typical example of the former being the application to plain cylindrical grinding, and of the latter for through-feed centreless grinding. On-off or multi-step controllers may be employed, control action being normally based on the measurement of one dimension only of the work, though in some applications information in regard to other dimensions is also provided.

Since air gauging can be used for position detection (**B.2.1**) a comprehensive system for machine tools, covering monitoring of the position of the work and of the various moving members, as well as the control of size, can be organized.

Terms used in air gauging

Index

British Standards

The following are available on application:

YEARBOOK

Including subject index and numerical list of British Standards 15*s*.

SECTIONAL LISTS. Gratis

Acoustics (SL 10)
Aerospace materials and components (SL 25)
Automobile (SL 34)
British Standard Handbooks (SL 27)
Building (SL 16)
Chemical engineering (SL 5)
Chemicals, fats, glues, oils, soap, etc. (SL 4)
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Furniture, bedding and furnishings (SL 11)
Gardening, horticulture and landscape work (SL 41)
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Glassware, excluding laboratory apparatus (SL 39)
Heating, ventilating and air conditioning (SL 42)
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Illumination and lighting fittings (SL 14)
Industrial instruments, etc. (SL 17)
Iron and steel (SL 24)
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Leather, plastics, rubber (SL 12)
Local authority purchasing officers' guide (SL 28)
Machine tools (SL 20)
Mechanical engineering (SL 6)
Nomenclature, symbols and abbreviations (SL 29)
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