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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Technical drawings — Geometrical tolerancing — Maximum material principle

Dessins techniques — Tolérancement géométrique — Principe du maximum de matière

Reference number
ISO 2692 : 1988 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 2692 was prepared by Technical Committee ISO/TC 10, *Technical drawings.*

This first edition of ISO 2692 cancels and replaces ISO 1101-2 : 1974 of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Technical drawings — Geometrical tolerancing — Maximum material principle

0 Introduction

0.1 The assembly of parts depends on the relationship between the actual size and actual geometrical deviation of the features being fitted together, such as the bolt holes in two flanges and the bolts securing them.

The minimum assembly clearance occurs when each of the mating features is at its maximum material size (e.g. largest bolt and smallest hole) and when their geometrical deviations (e.g. positional deviation) are also at their maximum.

Assembly clearance increases to a maximum when the actual sizes of the assembled features are furthest from their maximum material sizes (e.g. smallest shaft and largest hole) and when the geometrical deviations (e.g. positional deviations) are zero.

From the above, it follows that if the actual sizes of a mating part do not reach their maximum material size, the indicated geometrical tolerance may be increased without endangering the assembly of the other part.

This is called the "maximum material principle" and is indicated on drawings by the symbol Ⓜ .

The figures in this International Standard are intended only as illustrations to aid the user in understanding the maximum material principle. In some instances, figures show added details for emphasis; in other instances, figures have deliberately been left incomplete. Numerical values of dimensions and tolerances have been given for illustrative purposes only.

For simplicity, the examples are limited to cylinders and planes.

0.2 For uniformity all figures in this International Standard are in first angle projection.

It should be understood that the third angle projection could equally well have been used without prejudice to the principles established.

For the definitive presentation (proportions and dimensions) of symbols for geometrical tolerancing, see ISO 7083.

1 Scope and field of application

This International Standard defines and describes the maximum material principle and specifies its application.

The use of the maximum material principle facilitates manufacture without disturbing the free assembly of parts where there is a mutual dependence of size and geometry.

NOTE — The envelope requirement (see 5.2.2) for a single feature may be indicated by the symbol Ⓔ (see ISO 8015) or by reference to an appropriate national standard invoking this requirement.

2 References

ISO 1101, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Generalities, definitions, symbols, indications on drawings.*

ISO 5458, *Technical drawings — Geometrical tolerancing — Positional tolerancing.*

ISO 5459, *Technical drawings — Geometrical tolerancing — Datums and datum-systems for geometrical tolerances.*

ISO/TR 5460, *Technical drawings — Geometrical tolerancing — Tolerancing of form, orientation, location and run-out — Verification principles and methods — Guidelines.*

ISO 7083, *Technical drawings — Symbols for geometrical tolerancing — Proportions and dimensions.*

ISO 8015, *Technical drawings — Fundamental tolerancing principle.*

3 Definitions

3.1 actual local size: Any individual distance at any cross-section of a feature, i.e. any size measured between any two opposite points [examples: see figures 1, 12 b) and 13 b)].

3.2 Mating size

3.2.1 mating size for an external feature: The dimension of the smallest perfect feature which can be circumscribed about the feature so that it just contacts the surface at the highest points.

NOTE — For example, the size of the smallest cylinder of perfect form or the smallest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface(s) (see figure 1).

3.2.2 mating size for an internal feature: The dimension of the largest perfect feature which can be inscribed within the feature so that it just contacts the surface at the highest points.

NOTE — For example, the size of the largest cylinder of perfect form or the largest distance between two parallel planes of perfect form which just contacts the highest point(s) of the actual surface(s).

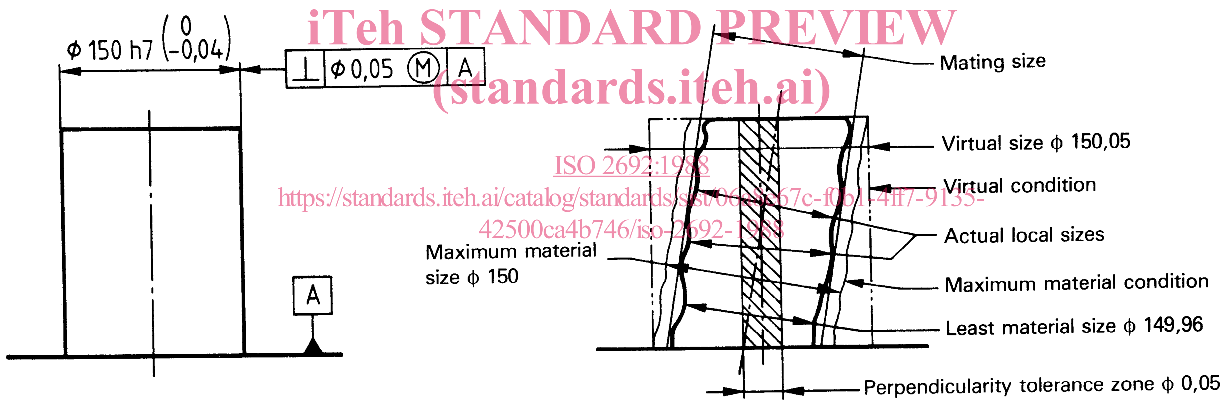
3.3 maximum material condition (MMC): The state of the considered feature in which the feature is everywhere at that limit of size where the material of the feature is at its maximum, e.g. minimum hole diameter and maximum shaft diameter (see figure 1).

NOTE — The axis of the feature need not be straight.

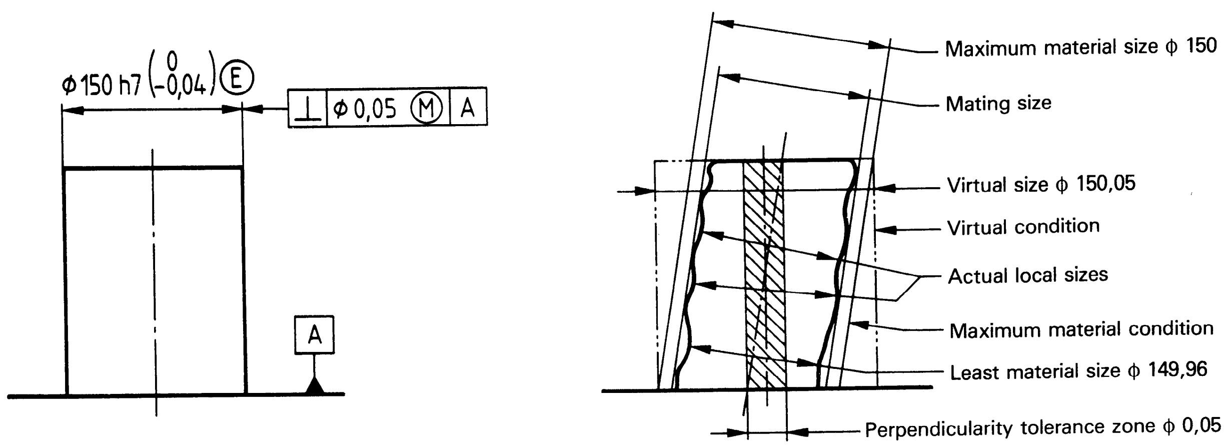
3.4 maximum material size (MMS): The dimension defining the maximum material condition of a feature (see figure 1).

3.5 least material condition (LMC): The state of the considered feature in which the feature is everywhere at that limit of size where the material of the feature is at its minimum, e.g. maximum hole diameter and minimum shaft diameter.

Indication on the drawing | **Interpretation**



a) **Dimensioning in accordance with the independance principle**



b) **Dimensioning in accordance with the envelope principle**

Figure 1

3.6 least material size (LMS): The dimension defining the least material condition of a feature (see figure 1).

3.7 virtual condition: The limiting boundary of perfect form permitted by the drawing data for the feature; the condition is generated by the collective effect of the maximum material size and the geometrical tolerances.

When the maximum material principle is applied, only those geometrical tolerances followed by the symbol Ⓜ shall be taken into account when determining the virtual condition (see figure 1).

NOTE — The virtual condition represents the design dimension of the functional gauge.

3.8 virtual size: The dimension defining the virtual condition of a feature.

4 Maximum material principle

4.1 General

The maximum material principle is a tolerancing principle which requires that the virtual condition for the toleranced feature(s) and, if indicated, the maximum material condition of perfect form for datum feature(s), shall not be violated.

This principle applies to axes or median planes and takes into account the mutual relationship of size and the geometrical tolerance concerned. The application of this principle shall be indicated by the symbol Ⓜ .

4.2 Maximum material principle applied to the toleranced feature(s)

When applied to the toleranced feature(s), the maximum material principle permits an increase in the stated geometrical tolerance when the toleranced feature concerned departs from its maximum material condition provided that the feature does not violate the virtual condition.

4.3 Maximum material principle applied to the datum feature(s)

When the maximum material principle is applied to the datum feature(s), the datum axis or median plane may float in relation to the toleranced feature if there is a departure from the maximum material condition of the datum feature. The value of the float is equal to the departure of the mating size of the datum feature from its maximum material size [see figures 27 b) and 27 c)].

NOTE — The departure of the datum feature from its maximum material size does not increase the tolerance of the toleranced features in relation to each other.

5 Application of the maximum material principle

In all cases, the designer has to decide whether the application of the maximum material principle may be permitted on the tolerances concerned.

NOTE — The maximum material principle should not be used in such applications as kinematic linkages, gear centres, threaded holes, interference fit holes, etc., where the function may be endangered by an increase in the tolerance.

5.1 Positional tolerance for a group of holes

The maximum material principle is most commonly used with positional tolerances, and therefore positional tolerancing has been used for the illustrations in this sub-clause.

NOTE — In the calculations of virtual size, it has been assumed that the pins and holes are at their maximum material size and are of perfect form.

5.1.1 The indication on the drawing of the positional tolerance for a group of four holes is shown in figure 2.

The indication on the drawing of the positional tolerance for a group of four fixed pins which fit into the group of holes is shown in figure 4.

The minimum size of the holes is ϕ 8,1 — this is the maximum material size.

The maximum size of the pins is ϕ 7,9 — this is the maximum material size.

5.1.2 The difference between the maximum material size of the holes and the pins is

8,1 − 7,9 = 0,2

The sum of the positional tolerances for the holes and pins shall not exceed this difference (0,2). In this example, this tolerance is equally distributed between holes and pins, i.e. the positional tolerance for the holes is ϕ 0,1 (see figure 2) and the positional tolerance for the pins is also ϕ 0,1 (see figure 4).

The tolerance zones of ϕ 0,1 are located at their theoretically exact positions (see figures 3 and 5).

Depending on the actual size of each feature, the increase in the positional tolerance may be different for each feature.

Indication on the drawing | **Interpretation**

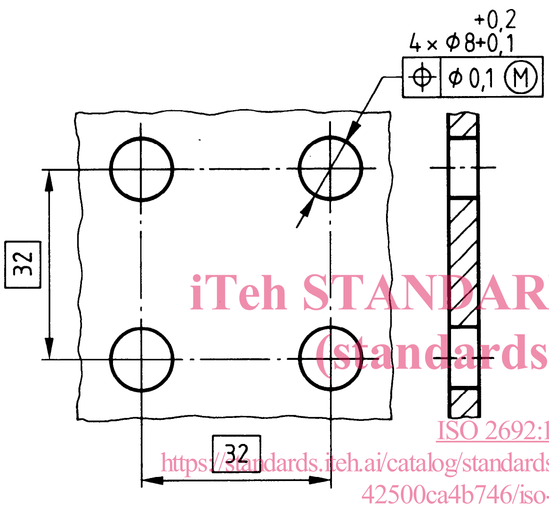


Figure 2

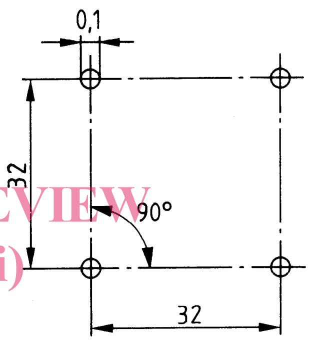


Figure 3

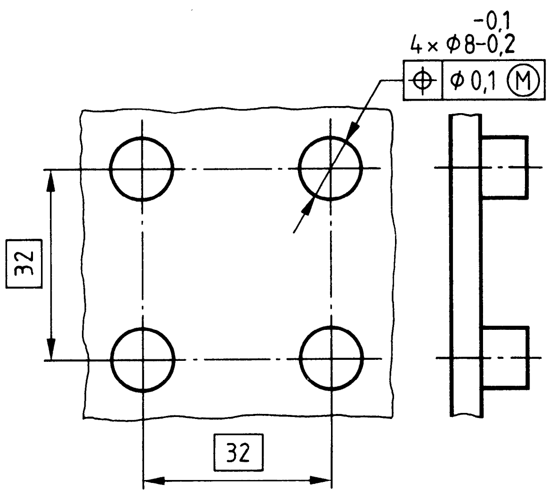


Figure 4

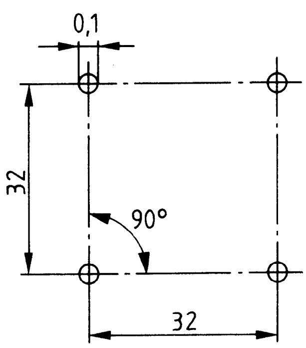


Figure 5

5.1.3 Figure 6 shows four cylindrical surfaces for each of the four holes all being at their maximum material size and of perfect form. The axes are located at extreme positions within the tolerance zone.

Figure 8 shows the corresponding pins at their maximum material size. It can be seen from figures 6 to 9 that assembly of the parts is still possible under the most unfavourable conditions.

5.1.3.1 One of the holes in figure 6 is shown to a larger scale in figure 7. The tolerance zone for the axis is ϕ 0,1. The maximum material size of the hole is ϕ 8,1. All ϕ 8,1 circles, the axes of which are located at the extreme limit of the ϕ 0,1 tolerance zone, form an inscribed enveloping cylinder of ϕ 8. This ϕ 8 enveloping cylinder is located at the theoretically exact position and forms the functional boundary for the surface of the hole.

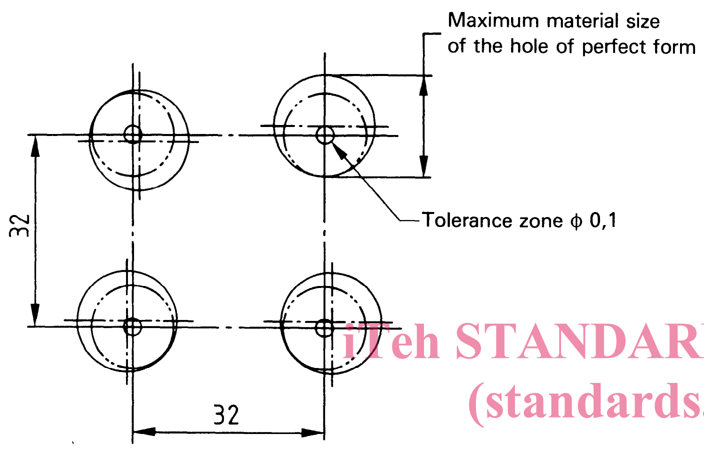


Figure 6

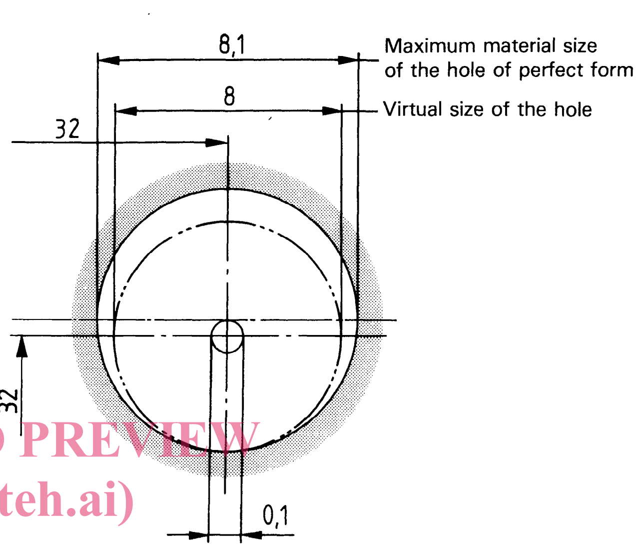


Figure 7

5.1.3.2 One of the pins in figure 8 is shown to a larger scale in figure 9. The tolerance zone for the axis is ϕ 0,1. The maximum material size of the pin is ϕ 7,9. All ϕ 7,9 circles, the axes of which are located at the extreme limit of the ϕ 0,1 tolerance zone, form a circumscribed enveloping cylinder of ϕ 8, which is the virtual condition of the pin.

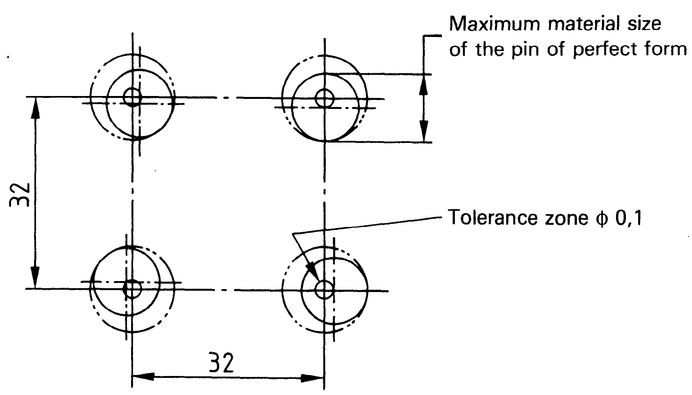


Figure 8

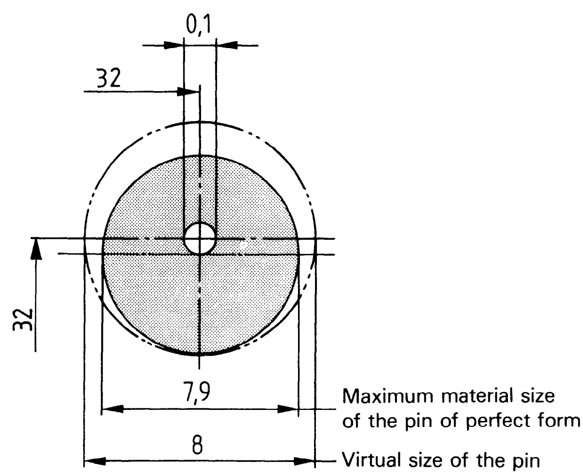


Figure 9

5.1.4 When the size of the hole is larger than its maximum material size and/or when the size of the pin is smaller than its maximum material size, there is an increased clearance between the pin and hole which can be used to increase the positional tolerances of the pin and/or the hole. Depending on the actual size of each feature, the increase in the positional tolerance may be different for each feature.

The extreme case is when the hole is at the least material size, i.e. ϕ 8,2. Figure 10 shows that the axis of the hole may lie anywhere within a tolerance zone of ϕ 0,2 without the surface of the hole violating the cylinder of virtual size.

Figure 11 shows a similar situation with regard to the pins. When the pin is at the least material size, i.e. ϕ 7,8, the diameter of the tolerance zone for position is ϕ 0,2.

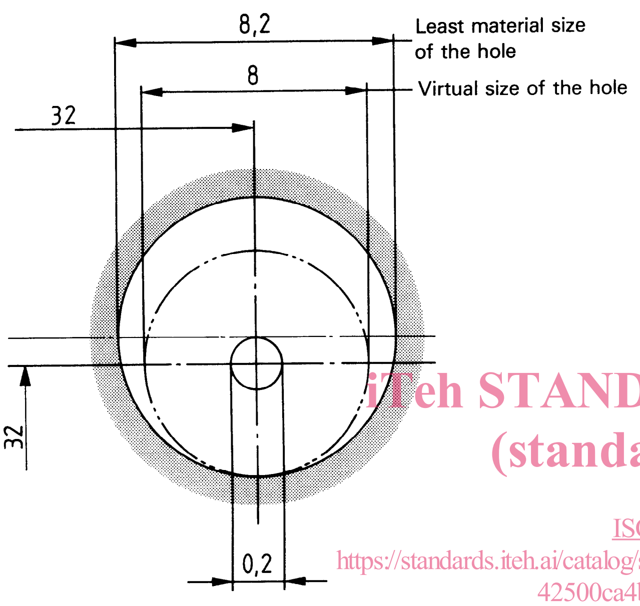


Figure 10

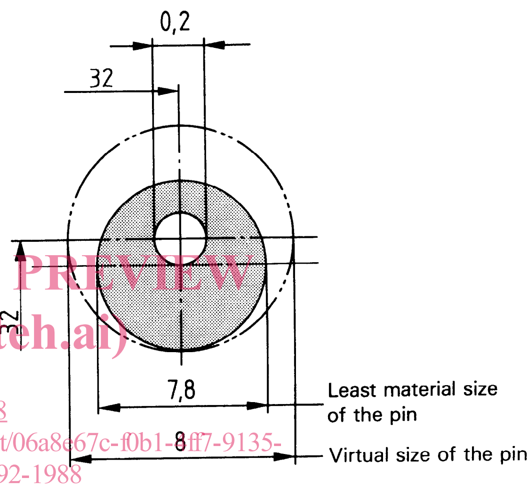


Figure 11

5.1.5 The increase in geometrical tolerance is applied to one part of the assembly without reference to the mating part. Assembly will always be possible even when the mating part is manufactured on the extreme limits of the tolerance in the direction most unfavourable for the assembly, because the combined deviation of size and geometry on neither part is exceeded, i.e. their virtual conditions are not violated.

5.2 Perpendicularity tolerance of a shaft related to a datum plane

5.2.1 The toleranced feature in figure 12 a) has to meet the conditions shown in figure 12 b), i.e. the feature shall not violate the virtual condition, i.e. ϕ 20,2 (ϕ 20 + 0,2), and as all actual local sizes shall remain between ϕ 19,9 and ϕ 20, the straightness deviations of the generator lines or of the axis cannot exceed 0,2 ... 0,3 depending on the actual local sizes, e.g. 0,2 if all actual local sizes are ϕ 20 [see figure 12 c)] and 0,3 if all actual local sizes are ϕ 19,9 [see figure 12 d)].

Indication on the drawing

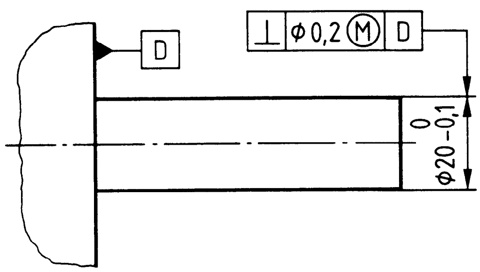
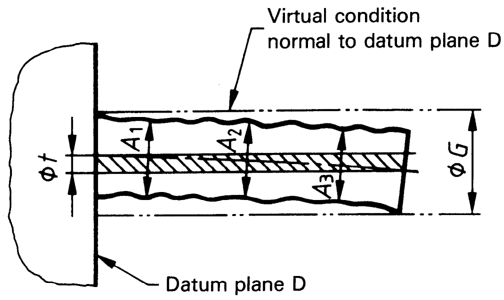


Figure 12 a)

Interpretation



A_1 to A_3 = actual local sizes = 19,9 ... 20 (maximum material size = ϕ 20)

G = virtual size = ϕ 20,2

ϕt = orientational tolerance zone = 0,2 ... 0,3

Figure 12 b)

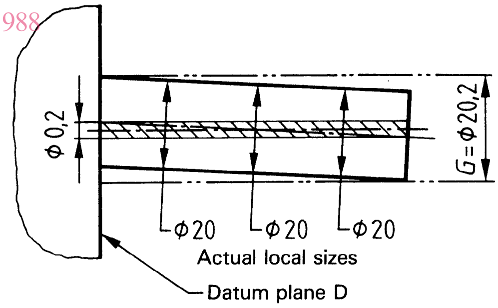


Figure 12 c)

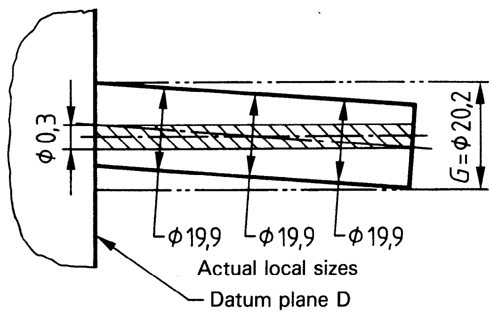


Figure 12 d)