INTERNATIONAL STANDARD 2560

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Covered electrodes for manual arc welding of mild steel and low alloy steel — Code of symbols for identification

First edition — 1973-03-01

UDC 621.791.042.001.3

Ref. No. ISO 2560-1973 (E)

Descriptors : welding, arc welding, carbon steels, low alloy steels, welding electrodes, covered electrodes, identifying, symbols, tension tests, impact tests, impact strength, notch strength.

Price based on 7 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

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.

International Standard ISO 2560 was drawn up by Technical Committee ISO/TC 44, *Welding.*

It was approved in March 1972 by the Member Bodies of the following countries :

Australia	Ireland	Sweden
Austria	Israel	Switzerland
Belgium	Japan	Thailand
Czechoslovakia	Korea, Rep. of	Turkey
Egypt, Arab Rep. of	Netherlands	United Kingdom
Finland	New Zealand	U.S.S.R.
France	Norway	U.S.A.
Germany	Romania	
India	Spain	

The Member Body of the following country expressed disapproval of the document on technical grounds :

Italy

Printed in Switzerland

Covered electrodes for manual arc welding of mild steel and low alloy steel — Code of symbols for identification

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies a code for the identification of electrodes by means of symbols related to covering composition and to weld metal characteristics.

It only deals with covered electrodes for manual arc welding of mild steel of normal strength and of low alloy steel of nominal strength between 490 and 590 N/mm² *.

The purpose of this codification is to facilitate international understanding among welders, welding technicians, etc., by specifying electrodes according to certain comparable rules.

2 REFERENCES

ISO/R 615, *Methods for determining the mechanical properties of the weld metal deposited by electrodes 3,15 mm or more in diameter.*

ISO 2401, *Covered electrodes — Determination of the efficiency, metal recovery and deposition coefficient.*

3 GENERAL

The codification is divided into four parts :

1) the first part gives a general symbol indicating the product to be identified;

2) the second part gives a symbol indicating a further identification of the product generally related to the composition;

3) the third part gives a symbol indicating certain mechanical properties;

4) the fourth part gives symbols indicating the type of covering, the efficiency and the operational characteristics.

4 SYMBOLS AND REQUIREMENTS

4.1 Symbol for the product

The general symbol for electrodes for arc welding is the letter E.

It shall be placed at the beginning of the designation.

The purpose of this symbol is to establish a difference between the designation of arc welding electrodes, as a filler metal for welding, and other filler metals for welding, when other power sources are used, like gas welding. For all other processes different from manual arc welding (like gas shielded metal-arc welding) a further symbol is used for a closer identification.

For covered electrodes for manual arc welding, only the symbol E is used.

4.2 Symbol for the composition

In general the second part gives a symbol indicating a further identification of the product in relation to composition. However, in this code the composition is not considered and the symbol is based on a division into two ranges of tensile strength of the weld metal determined under the conditions given in section 6.

Two ranges of tensile strength are specified, namely :

1) Tensile strength from 430 to 510 N/mm² — Symbol 43.

2) Tensile strength from 510 to 610 N/mm² — Symbol 51.

In view of possible variations in welding and testing, the upper limits of 510 and 610 N/mm² respectively may be exceeded by 40 N/mm².

* 1 N/mm² = 1 MPa = 0,102 kgf/mm²

4.3 Symbol for the mechanical properties

For each class of tensile strength, a division into six groups has been specified on the basis of Charpy V-impact values and elongation, established under conditions stated in section 6.

Symbols : 0, 1, 2, 3, 4 or 5.

Requirements :

Electrode designation	Tensile strength 1)	Minimum elongation on $L = 5d$	Temperature for minimum impact value of 28 J 2)
	N/mm²	%	°C
E 43 0	430 to 510	–	–
E 43 1	430 to 510	20	+ 20
E 43 2	430 to 510	22	0
E 43 3	430 to 510	24	– 20
E 43 4	430 to 510	24	– 30
E 43 5	430 to 510	24	– 40
E 51 0	510 to 610	–	–
E 51 1	510 to 610	18	+ 20
E 51 2	510 to 610	18	0
E 51 3	510 to 610	20	– 20
E 51 4	510 to 610	20	– 30
E 51 5	510 to 610	20	– 40

1) Upper limit tolerance : + 40 N/mm²

2) 1 J = 0,102 kgf·m (see also 6.8).

4.4 Symbols related to operational characteristics

The last part of the codification comprises four symbols indicating the type of covering, the efficiency, the welding positions and the characteristics of the electric current required.

4.4.1 The type of covering is symbolized by the following letters :

A = Acid (iron oxide)

AR = Acid (Rutile)

B = Basic

C = Cellulosic

O = Oxidizing

R = Rutile (medium coated)

RR = Rutile (heavy coated)

S = Other types.

These names have come into use historically and have no longer a proper scientific meaning. The designations are to be understood as follows :

A – Electrodes of the acid type have a medium or thick covering and produce an iron oxide-manganese oxide-silica slag, the metallurgical character of which is acid. The covering contains, besides oxides of iron and/or manganese, a fairly high percentage of ferro-manganese and/or other deoxidizers. The slag solidifies in a characteristic honeycomb structure and is easily detached.

This type of electrode usually has a high fusion rate and may be used with high current intensities. Penetration can be good, particularly if the covering is thick. These electrodes are most suitable for welding in the flat position but can also be used in other positions. Either direct or alternating current can be employed. With this type of electrode the weldability of the parent metal must be good, as otherwise hot cracking may occur. Susceptibility to hot cracking is more particularly marked in horizontal/vertical or vertical fillet welds when the actual carbon content exceeds approximately 0,24 %, killed steel being more susceptible than rimmed steel, and when the sulphur content exceeds 0,05 % in killed steels and 0,06 % in rimmed steels.

AR – Electrodes of the acid-rutile type usually have a thick covering, producing a slag very similar to the slag described under A. Usually this slag is somewhat more fluid. The properties of this electrode are in general very similar in all aspects to the acid type, the difference being that the covering contains titanium oxide, the amount normally being not higher than 35 %.

Between the two types A and AR several mixtures are possible, but when the amount of titanium oxide is larger than the total amount of iron and/or manganese oxide, the covering is considered to be of the AR type. If, instead of a mixture of iron oxide and titanium oxide, the mineral ilmenite is used, the same rule is applied.

B – Electrodes of the basic type usually have a thick covering containing considerable quantities of calcium or other basic carbonates and fluorspar so that metallurgically they are basic in character. There is a medium quantity of dense slag, which often has a brown to dark-brown colour and a glossy appearance. It is easily detached, and as it rises to the surface of the weld very quickly, slag inclusions are not likely to occur. This type of electrode gives an arc of average penetration, and is suitable for welding in all positions. This type of electrode is often used on direct current, electrode positive, but there are electrodes that can be used on alternating current.

As the weld metal is highly resistant to hot and cold cracking, these electrodes are particularly suitable for welding heavy sections and very rigid mild steel structures. They are also recommended for welding low alloy steels and steels the carbon and sulphur content of which are higher than those of mild steel of good weldable quality.

In order to avoid porosity, the coverings of the basic electrodes must be very dry; consequently these electrodes must be stored in a very dry place or, if they have already absorbed moisture, must be dried before use, according to the recommendation of the manufacturer. This ensures that the weld metal will have a low hydrogen content, and

there is less risk of underbead cracking when welding steels likely to show a marked hardening in the heat-affected zone.

To be included in this group, the covering of the electrodes shall in general not have a higher water content than 0,6 %. The water content can be established according to the method described in Document IIS/IIW 314-68[1], Recommended procedure for the determination of total water contents of electrode coatings by combustion (potential hydrogen contents).

C – The covering of electrodes of the cellulosic type contains a large quantity of combustible organic substances, so that the decomposition of the latter in the arc produces a voluminous gas shield. The amount of slag produced is small and the slag is easily detached.

This type of electrode is characterized by a highly penetrating arc and fairly high fusion rate. Spatter losses are fairly large and the weld surface is somewhat coarse, with unevenly spaced ripples. These electrodes are usually suitable for welding in all positions.

O – Electrodes of the oxidizing type have a thick covering composed mainly of iron oxides with or without manganese oxides. The covering gives an oxidizing slag, so that the weld metal contains only small amounts of carbon and manganese. The slag is heavy, compact and often self-detaching. This type of electrode gives a poor penetration and a fluid molten pool, and is particularly suitable when only a small weld is required. Usually its use is restricted to welding in the horizontal/vertical fillet weld and flat fillet weld positions.

These electrodes are used mainly for welding steels when the appearance of the weld is more important than the mechanical strength of the joint.

R and RR – Rutile type electrodes have a covering containing a large quantity of rutile or components derived from titanium oxide. Usually this amounts to 50 % by mass (not taking into account cellulosic material).

The R type can be distinguished from the AR type by its heavier slag. Sometimes this difference is not readily discernible, especially with electrodes having a medium covering, but the amount of rutile in the covering is well above 45 %.

Because of the difference in application and also mechanical properties, a subdivision is made according to the thickness of the covering.

R – The covering is of medium thickness[2]. Small amounts of cellulosic material, up to a maximum of 15 %, may be present in the covering. These electrodes are particularly suitable for welding in the vertical and overhead positions.

RR – The covering is of heavy thickness[2]. Small amounts of cellulosic material, up to a maximum of 5 %, are sometimes present in the covering. The slag is heavy, compact and usually self-detaching. The appearance of the weld resembles that of an O-type electrode.

Although the susceptibility to hot cracking in relation to the parent metal is not so high as that of the acid type, care must be taken in view of the fact that usually a weld is made with a much smaller throat thickness than with acid electrodes. The maximum current to be used is lower than that of an AR-type, because of a lower melting rate.

S – The symbol S is reserved for the designation of the other types of electrodes and it is understood that these correspond to coverings other than those specified under A, AR, B, C, O, R and RR.

In particular, electrodes with coverings containing iron powder or other materials which would not affect the characteristics specified for the types of covering defined above, shall be classified under the said types and not in type S.

If, in national standards, it is necessary to incorporate certain other types of covering, the symbols A, B, C, O and R can be supplemented by a second symbol in brackets to indicate the type.

4.4.2 The efficiency is symbolized by a figure determined according to the method described in ISO 2401.

In this code, only the nominal electrode efficiency is taken into consideration.

Symbols to be used :

1) The figure found using the above-mentioned method is rounded off to the nearest multiple of 10, values ending with 5 being rounded off to the higher multiple of 10. As an example, efficiencies rounded off in accordance with this rule are

. . . 90 – 100 – 110 – 120 – 130 – 140 . . . etc.

2) No symbol is used for efficiencies less than 110, which implies an experimental nominal efficiency < 105 %[3].

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1) Published in the International Institute of Welding journal, *Welding in the World*, Vol. 7, No. 1, 1969.

2) The limit between coverings of medium and heavy thickness corresponds approximately to a ratio of 1,5 between the outer diameter of the covering and the core wire diameter.

3) The combined application of provisions 1 and 2 gives the following grading system :

Experimentally determined efficiency < 105 % : no symbol.

Experimentally determined efficiency ≥ 105 < 115 % : symbol 110.

Experimentally determined efficiency ≥ 115 < 125 % : symbol 120.

Experimentally determined efficiency ≥ 125 < 135 % : symbol 130.

etc.

4.4.3 The welding positions are symbolized by a digit designating the general welding positions for which the electrode is recommended, as follows :

1 : all positions;

2 : all positions, except vertical downward;

3 : flat butt weld, flat fillet weld, horizontal/vertical fillet weld;

4 : flat butt weld, flat fillet weld.

5 : as 3 and recommended for vertical downward.

4.4.4 The welding current and open-circuit voltage are symbolized by a digit corresponding to the characteristics of the welding equipment required in order to ensure working conditions free of incidents such as instability or interruptions of the arc.

The open-circuit voltage necessary for striking the arc varies according to the diameter of the electrode. A reference diameter is required for symbolization.

The table below applies to electrode diameters greater than or equal to 2,5 mm. If electrodes of smaller diameter are used, a higher voltage may be necessary.

The frequency of the alternating current is assumed to be 50 or 60 Hz. The open-circuit voltage necessary when electrodes are used on direct current is closely related to the dynamic characteristics of the welding power-source. Consequently no indication of the minimum open-circuit voltage for direct current can be given.

Symbol	Direct current Recommended polarity**	Alternating current Nominal open-circuit voltage
		V
0*	+	
1	+ or −	50
2	−	50
3	+	50
4	+ or −	70
5	−	70
6	+	70
7	+ or −	90
8	−	90
9	+	90

* Symbol reserved for electrodes used exclusively on direct current.

** Positive polarity +, negative polarity −.

4.4.5 Symbol for the diffusible hydrogen content (H). In general, electrodes of the basic type (B), by virtue of the low water content of the covering, give weld metal with a relatively low hydrogen content. In view of the sensitivity of welds to hydrogen, electrode manufacturers aim at the production of electrodes that give a low hydrogen content in the weld deposit and they like to specify this.

For this reason an extra symbol (H) is introduced, indicating that the hydrogen content fulfils certain requirements. These conditions relate to a maximum content of 15 ml of hydrogen per 100 g of deposited metal, determined in accordance with the method given in Document IIS/IIW-315-68[1]. The electrode manufacturer is free to use this symbol or not. The symbol (H) is to be placed at the end of the optional part (see 5.2).

5 INSTRUCTIONS FOR USE

In order to promote the use of this identification, the codification is split into two sections.

5.1 Compulsory section

This section includes the symbols for the type of product, the mechanical properties and the type of covering, i.e. the symbols defined in 4.1, 4.2, 4.3 and 4.4.1.

5.2 Optional section

This section includes the symbols for the efficiency, the welding positions for which the electrode is suitable, the characteristics of the welding equipment required and, if necessary, an extra symbol for the hydrogen content, i.e. the symbols defined in 4.4.2, 4.4.3, 4.4.4 and 4.4.5.

Examples :

a) Covered electrode for manual electric arc welding having a rutile covering of medium thickness and depositing weld metal with the following minimum mechanical properties :

- Tensile strength : 500 N/mm^2
- Elongation : 23 %
- Impact strength : 71 J at + 20 °C
  31 J at 0 °C
  20 J at − 20 °C

It may be used for welding in all positions.

It welds satisfactorily on alternating current, minimum open-circuit voltage 50 V, and direct current, positive polarity.

1) Published in the International Institute of Welding journal, *Welding in the World*, Vol. 7, No. 1, 1969.

For routine purposes, the procedure defined in the German standard DIN 8572 or in essentially equivalent procedures are suggested as alternatives, to be applied for a transition period in laboratories not accustomed to the use of mercury. In this case the conditions relate to a maximum content of 10 ml of hydrogen per 100 g of weld metal.

The complete codification for the electrode will therefore be E 43 2R 13 and the compulsory part will be E 43 2R.

b) Covered electrode for manual electric arc welding having a basic covering, with a high efficiency and depositing weld metal with the following minimum mechanical properties :

- Tensile strength : 560 N/mm^2
- Elongation : 22 %
- Impact strength : 47 J at − 20 °C.

Nominal efficiency : 158 %

It may be used for welding in all positions except vertical downward, direct current only.

The complete codification for the electrode will therefore be E 51 3B 160 20 (H) and the compulsory part will be E 51 3B.

6 MECHANICAL TESTS

Tensile and impact tests shall be executed according to the prescriptions of ISO Standards and Recommendations, on metal deposited from the electrodes.

6.1 Preparation of the assembly

The assembly shall be prepared as shown in Figure 1, in the form of a butt joint with a single V groove with a backing plate 10 mm thick and a root gap of 16 mm. The backing plate shall be tack welded to the test assembly.

In an assembly prepared in this way, the influence of the parent metal is eliminated.

6.2 Welding procedure

Electrodes with a core diameter of 4 mm shall be used. Each pass shall be carried out at normal welding speed and with a welding current specified by the manufacturer. If the electrode can be used with both a.c. and d.c., a.c. shall be chosen.

Welding shall be done in the flat position, each layer being made up of one or several passes, but each pass shall not be more than 16 mm wide. Each electrode shall be consumed completely (up to a stub end of no more than 50 mm). The direction of deposition of each layer shall alternate from each end of the plate. The reinforcement of the total weld shall not be more than 3 mm.

After each run, the assembly shall be left in still air until it has cooled to a temperature not exceeding 250 °C, the temperature being taken on the weld surface midway along the run.

NOTE – Instead of 6.1 and 6.2, the provisions of ISO/R 615, sections 2 and 3, are applicable, subject to the following conditions :

a) the length of the test assembly is sufficient to allow for the preparation of six impact test pieces;

b) the welding current is a.c. if the electrode can be used either with a.c. or with d.c.;

c) after each run the assembly is left in still air until it has cooled to a temperature not exceeding 250 °C.

The testing of electrodes having a nominal diameter equal to or greater than 3,15 mm and other than 4 mm shall be carried out according to sections 2 and 3 of ISO/R 615.

6.3 Weld metal tensile test piece

The tensile test piece shall be machined to the dimensions shown in Figure 2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

The gauge length of the test piece shall be 50 mm. The ends of the test piece may be of any shape suitable for fixing in the testing machine.

6.4 Heat treatment of the tensile test piece

The tensile test piece shall be heat-treated in an electrically heated furnace at 250 °C for a period of not less than 6 h and not more than 16 h. The purpose of the heat treatment is to remove any hydrogen from the weld metal.

6.5 Determination of tensile properties

The tensile strength and the elongation shall be determined at room temperature.

6.6 Weld metal impact test pieces

The impact test pieces shall be of the Charpy-V notch type. Six test pieces shall be taken from the test assembly. Their longitudinal axes shall be transverse to the weld and the upper surface 5 mm from the upper surface of the plate.

The notch shall be positioned in the centre of the weld and shall be cut in the face of the test piece perpendicular to the surface of the plate.

All dimensions shall be in accordance with the instructions given in Figure 3 and shall be carefully checked.

6.7 Testing temperatures for impact tests

The testing temperature for electrodes receiving symbol 1 (defined in 4.3) shall be about 20 °C (room temperature)[1]. For symbols 2, 3 and 4, the temperatures shall be 0 °C, − 20 °C and − 30 °C respectively. The temperature shall be controlled to within ± 1 °C.

Both the test piece and the handling tongs shall be cooled for a sufficient length of time to reach the test temperature. The test piece shall then be quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than 5 s.

1) To conform to usage by Technical Committee ISO/TC 17, *Steel*, this temperature may be increased to 27 °C in tropical countries.

6.8 Determination of impact strength

An energy level of 28 J is required at the temperature prescribed for the respective symbol.

This value shall be evaluated in the following way :

6.8.1 *First series of test pieces*

The average $\bar{x}_6$ of the results of the tests on the first series of six test pieces is assessed as follows :

if $\bar{x}_6 \leqslant 16$ J, the requirements are not fulfilled;

if $\bar{x}_6 \geqslant 35$ J, the requirements are fulfilled;

if $16 < \bar{x}_6 < 35$ J, a second test assembly shall be welded according to 6.1 and 6.2. From this test assembly only impact test pieces shall be machined, according to 6.6. A second series of twelve test pieces is thus obtained.

6.8.2 *Second series of test pieces*

The average $\bar{x}_{18}$ of the results for the twelve test pieces of the second series, together with the results for the six test pieces of the first series, shall be assessed as follows :

if $\bar{x}_{18} \geqslant 28$ J, the requirements are fulfilled;

if $\bar{x}_{18} < 28$ J, the requirements are not fulfilled.

6.8.3 Defective impact test piece.

If a test piece in a series whose average value does not fulfil the above requirements shows weld defects which could have affected the results of the test, then that test piece may be discarded and replaced without necessarily rejecting the series as a whole.

6.9 Rounding off of the results

For the tensile strength and the elongation, the established value shall be rounded off to the nearest whole number. Values to the decimal 5 shall be rounded off upwards.

The mean value for the impact tests shall be rounded off to the nearest whole number. Values to the decimal 5 shall be rounded off upwards.

Dimensions in millimetres

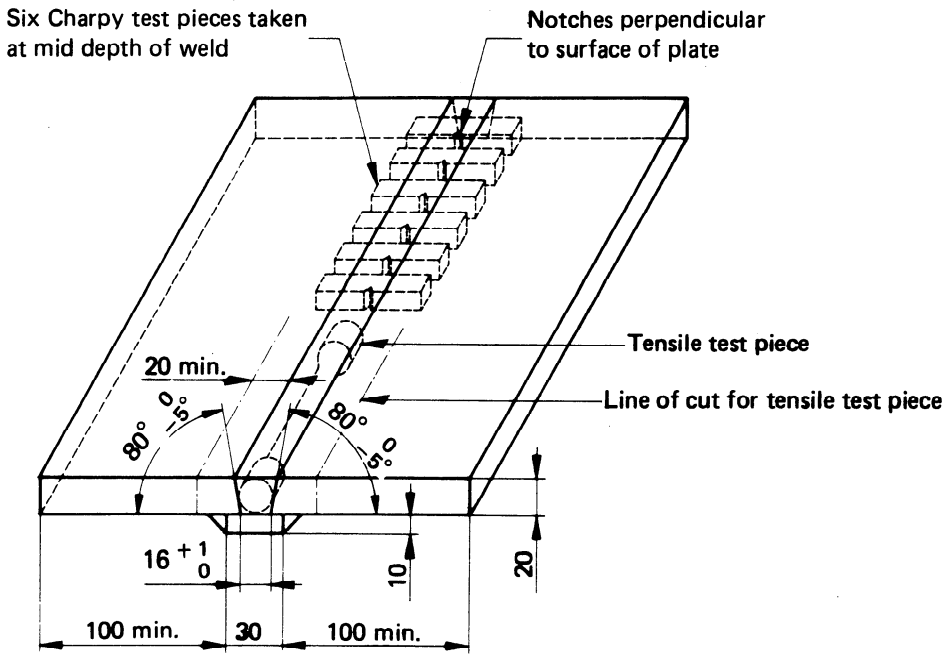

FIGURE 1 — **Test assembly**

Dimensions in millimetres

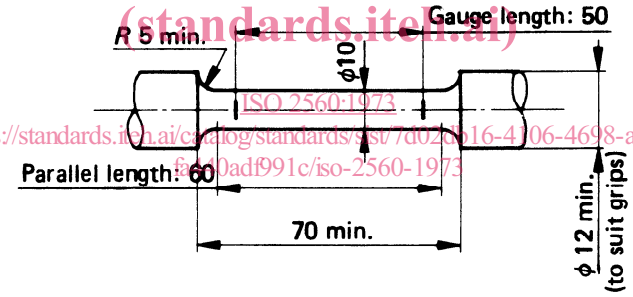

FIGURE 2 — **Tensile test piece**

Dimensions in millimetres

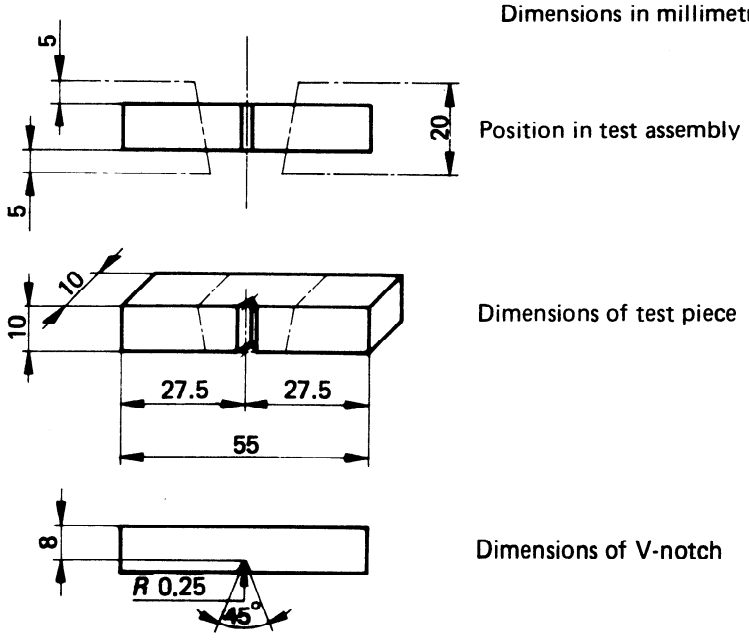

FIGURE 3 — **Impact test piece**