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Manual Reaming – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Table of Contents

Manual Reaming – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Arbeitsmaterial für den Lernenden
“Reiben von Hand”

Author: Frank Wenghöfer

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13187 Berlin

Order No.: 90–35–3108/2

1. Purpose of reaming

Reaming is applied after drilling in order to

- make bore holes true to size, e.g. for plain pin connections (in ranges from hundredth to thousandth millimetres)

- fine–finish the inside surfaces of bore holes

- align offset bores with riveted joints

- make conical bore holes for machine taper or taper pin joints

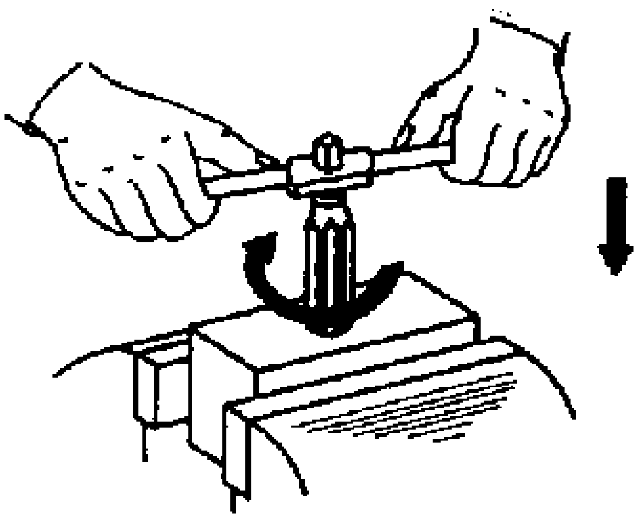

Figure 1 – Reaming

Reaming always necessitates the existance of a bore hole.

2. Tools for reaming

Tools for reaming are the reamers. According to the mode of operation, there are hand and machine reamers which may be provided with straight or spiral−fluted cutting portion.

Reamers are adapted to their respective purpose.

Shell reamers:

They are used for large bore hole diameters; only the cutting portion consists of high−grade tool steel, the shank is made of ordinary steel.

Various cutting parts can be put on one shank.

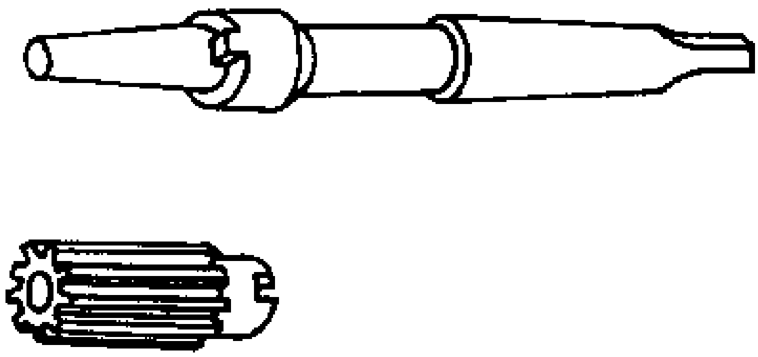

Figure 2 − Shell reamer

Readjustable reamers:

Used for reworking of worn out bore holes as well as for making non−standardized bore holes true to size. They can be adjusted to various diameters within a small range.

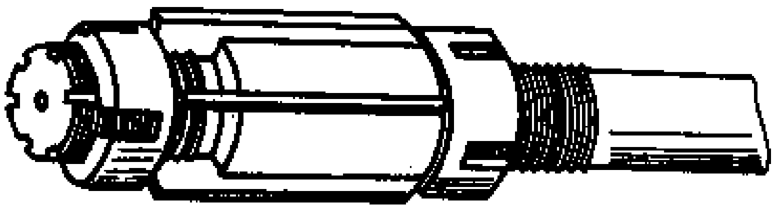

Figure 3 − Readjustable reamer

Taper reamers:

Used in sets (roughing reamer, semi−finishing reamer and finishing reamer) for large machine taper joints. For smaller taper pin joints, individual reamers of various nominal diameters are used.

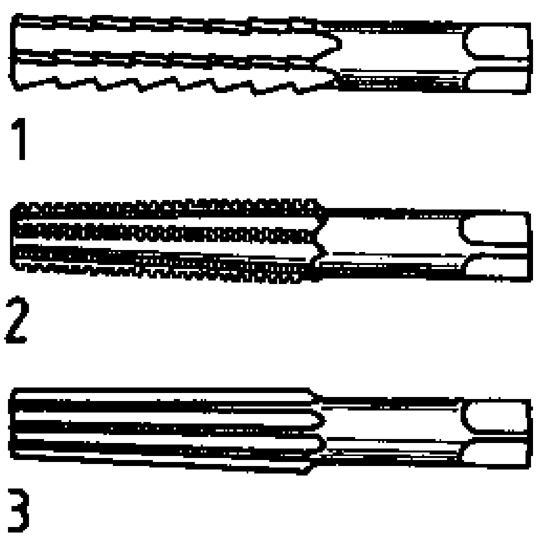

Figure 4 − Serial taper reamers

1 – Roughing reamer
2 – Semi–finishing reamers
3 – Finishing reamer

Structural reamers:

Used for aligning offset bore holes when making riveted joints; structural reamers are spiral–fluted, big–taper reamers of a strong cutting effect.

Figure 5 – Structural reamer

3. Construction of hand reamers

Straight reamer:

It consists of a cutting portion with axial, straight or spiral–fluted peripheral cutting edges and the shank which is equipped with a square (for being received by a tap wrench).

The end of the straight reamer is tapered – the taper lead. At the taper lead, the greatest quantity of chips is taken off. The nominal diameter is at the straight part of the cutting portion.

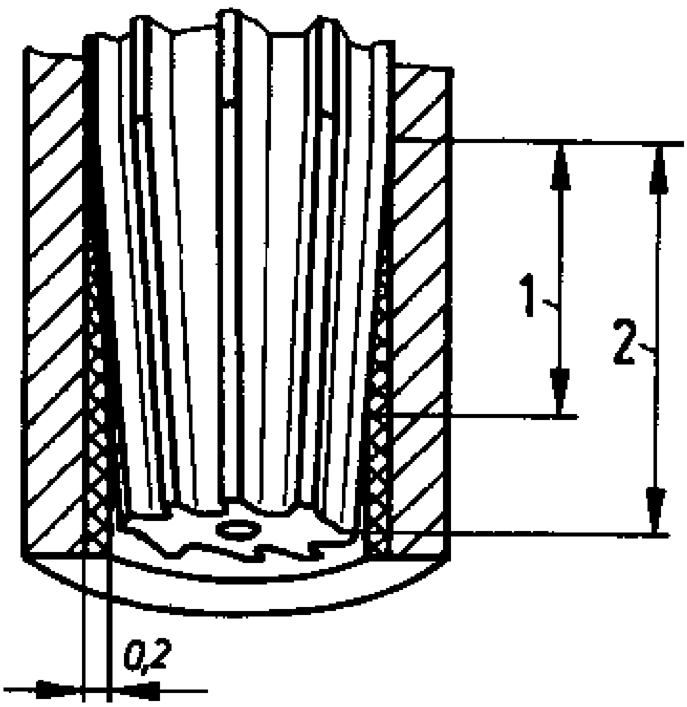

Figure 6

1 – Effective length of cutting portion
2 – Taper lead

For better guiding and aligning of the reamer in the bore hole, the taper lead is longer than that of a machine reamer the guiding of which is guaranteed by the machine spindle.

Conclusion:

The hand reamer can only be used with through holes, because a blind hole cannot be completely cylindrically reamed due to the long taper lead.

Taper reamer:

It consists of a long, conical cutting portion of a certain conicity (for instance 1:50); the shank is equipped with a square so that it can be received by a tap wrench. The nominal diameter is at the beginning of the cutting portion. Taper reamers belonging to a set (serial taper reamers) have differently shaped cutting portions with special chip–breaking grooves, because they must be abler to remove great quantities of chips. Only the finishing reamer leads to the required surface quality.

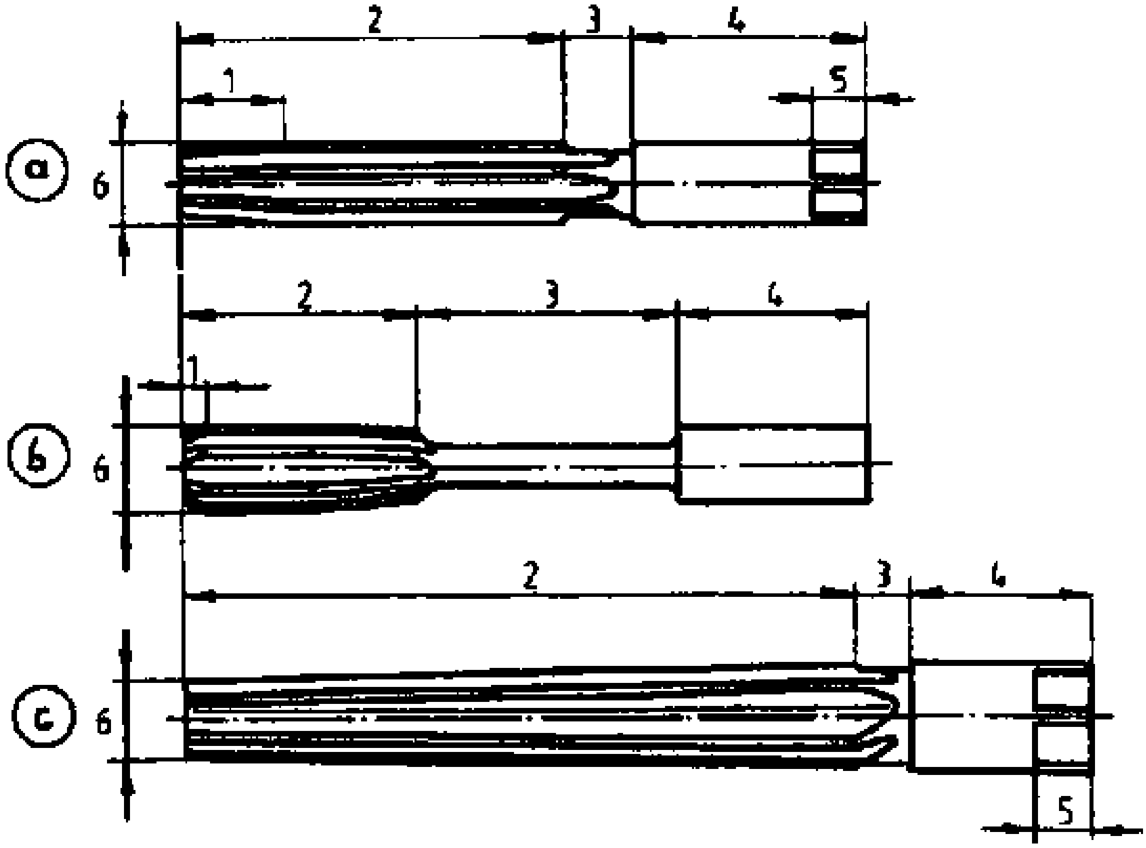

Figure 7 – Comparison of reamers in use

a straight reamer
b machine reamer
c Taper reamer
1 Taper lead
2 Cutting portion
3 Neck
4 Shank
5 Square
6 Nominal diameter

What is the task of the taper lead at the straight reamer?

____

Why must the straight hand reamer have a relatively long taper lead?

____

____

Why is the straight machine reamer allowed to have a relatively short taper lead?

____

____

Why can the straight hand reamer be used only with through holes?

____

____

4. Operation of reamers

Reamers take off material at the circumference of the cylindrical bore hole. This happens when they are turned with the help of a tap wrench with little pressure from above in <u>clockwise</u> direction in the bore hole.

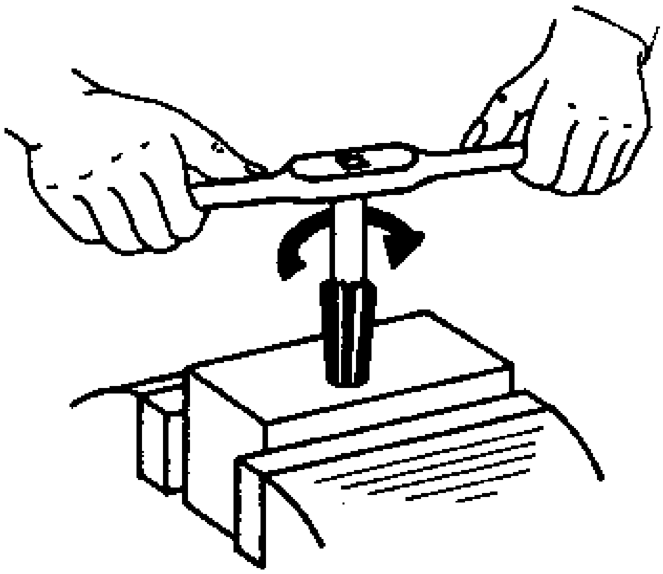

Figure 8 − Reaming

In doing so, lubricating and cooling agents roust be fed.

Straight and spiral−fluted reamers cannot carry off any chips during the process, the chips remain in the chip grooves filling them after a short time.

<u>Conclusion</u>:

Especially with longer bores, reamers must be taken out and cleaned during the reaming process, otherwise they will become jammed and break.

Why must reamers − after the process has begun − not be turned in reverse (anticlockwise) direction?

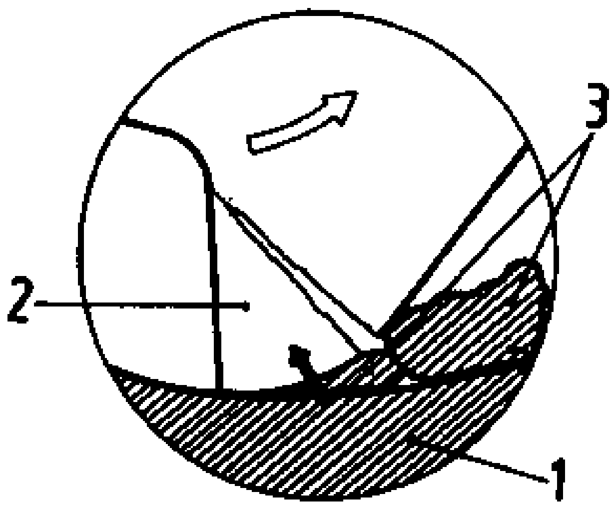

Figure 9 − Chipping of the cutting edge when turning the reamer in reverse direction

1 – Workpiece,
2 – Cutting edge,
3 – Chips

With spiral–fluted reamers – in contrast to the drill – the hand of the helix is opposite to the direction of rotation (sole exception: the structural reamer) in order to prevent the reamer from being drawn into the bore.

Such reamers are used, if there are pockets or grooves in the bore (feather or oil grooves).

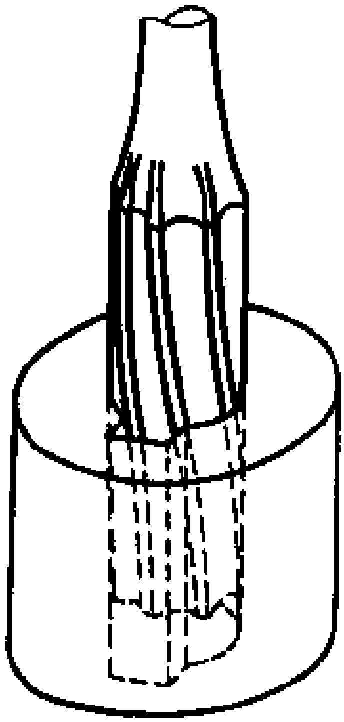

Figure 10 – Spiral–fluted reamer applied to a bore hole with feather groove

What happens, if with reaming a bore with feather groove a straight–fluted reamer is used?

____
____
____

5. Technological process of reaming

With making a cylindrical bore true to size as well as with the preparation of plain pin connections, the following steps are required:

5.1. <u>Clamping</u>

The workpieces, as far as possible, should be clamped in such way, that they can be drilled, counterbored/countersunk and reamed in succession without the clamping being loosened in between.

5.2. <u>Scribing/prick–punching</u>

This operation has to be carried out as described under “Drilling and counterboring/countersinking”; it can also be done before clamping.

5.3. <u>Drilling</u>

Since the reamer must remove material from the inside of the bore, the bore roust be made smaller than the nominal diameter of the bore true to size indicates. This difference is called “<u>undersize</u>”

Empirical values for undersizes of bore holes in steel are:

N in mm	U in mm
up to 5	0.1 – 0.2
5 – 20	0.2 – 0.3
21 – 32	0.3
33 – 50	0.5

N = nominal diameter
U = undersize

With tough materials and light metal, the undersizes are larger than with steel.

The diameter (D) of the drill is calculated by the following formula:

$$\boxed{D = N - U}$$

D = diameter of the drill

The calculation of the rotational speed (n) of the drill is explained in the lesson "Drilling and counterboring/counter–sinking"

General formula:

$$\boxed{n = \frac{V \cdot 1000}{D \cdot \pi}}$$

V = cutting speed (approx. 22 m/min)
? = 3.14

5.4. Countersinking

The bore must be spot–faced by a 90° countersink on either side. In doing so, the diameter of the countersinking (D_s) is to be calculated with the help of the following formula:

$$\boxed{D_s = N + 0.2 \text{ m}}$$

D_s = diameter of the countersinking

The rotational speed for countersinking bores up to a diameter of 10 mm can be approx. 350 r.p.m. with larger bore holes it must be lower.

$$\boxed{n \text{ ? } 350 \text{ r.p.m}}$$

5.5. Reaming

With through bores, always hand reamers can be used; for bores with pockets, the reamer must be spiralfluted (blind holes must be reamed by machine reamers only.) Tap wrenches are used as auxiliary means

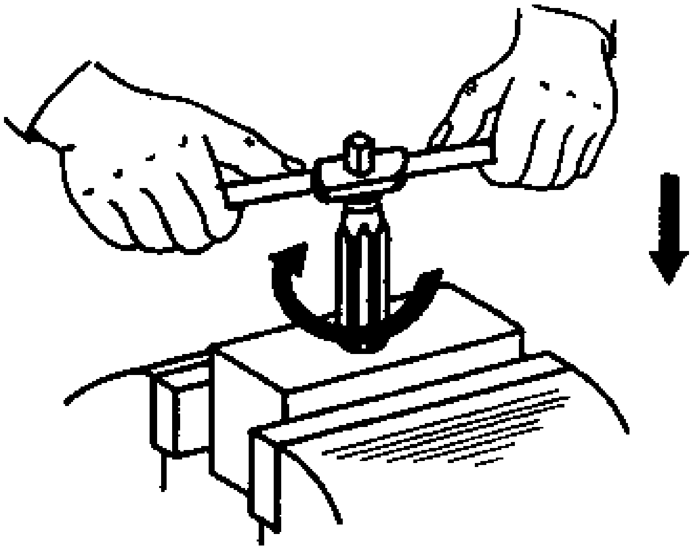

Figure 11 – Reaming operation – clockwise rotation

Lubricating and cooling agents are to be seen from the following table:

Steel:	cutting oil
Aluminium alloys:	spirit
Chromium–nickel alloys:	colza oil, petroleum

5.6. Cleaning the bore

After reaming, the chips and remaining oil have to be removed from the bore with the help of compressed air or brush.

5.7. Checking/pinning

Standardized bore holes which are made true to size are checked with the respective plug limit gauge, nonstandardized bore holes true to size may be checked with the help of an internal micrometer.

Pin connections are checked as to functioning after the pins are set in.

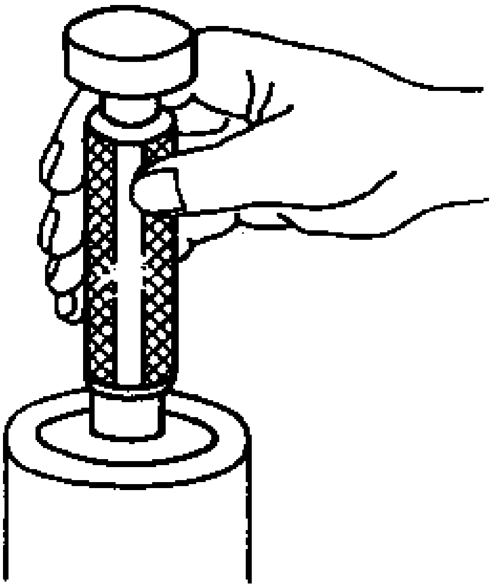

Figure 12 – Testing by plug limit gauge

6. Checking of straight reamers

Mostly, these reamers have an even number of cutting edges two of which are facing each other. As a result, the diameter of the reamer can be determined by an external micrometer. However, this is not very useful.

Straight reamers produce a bore hole within a set range of accuracy.

One cannot infer the exact diameter of the bore from the exact diameter of the reamer.

Faults with the process of reaming or dull reamers may cause deviations of several hundredth of a millimeter.

Therefore, a test bore must always be made: on the basis of the checked bore it can be found out whether the respective reamer can be used or not.

Note

Readjustable reamers must be adjusted by a ring gauge or external micrometer before reaming; then, a test bore has to be made.

7. Indication of fits on the straight reamer

In assembly and interchangeable manufacture, a system of standardization of fits is internationally accepted:

It classifies fits in definite ranges of accuracy. Such range is called range of tolerance and is limited by a maximum limit and a minimum limit.

ISA SYSTEM OF TOLERANCES AND FITS

Example of a bore true to size:

(This designation is indicated on the shank of the reamer.)

Ø 8K7

Ø 8 = nominal diameter 8 mm
K7 = range of tolerance

The tolerance limits can be 8.005 mm – maximum limit
taken from a relevant table: 7.990 mm – minimum limit

Conclusion:

By a reamer of Ø 8K7 a bore true to size can be made within the range of 7.990 mm and 8.005 mm.

For the operation itself knowledge of the maximum and minimum limits is not required if the fit is known.

Note:

The designation of the fit is identical on the tools and on the testing equipment – in connection with a certain tool the corresponding testing instrument roust be used.

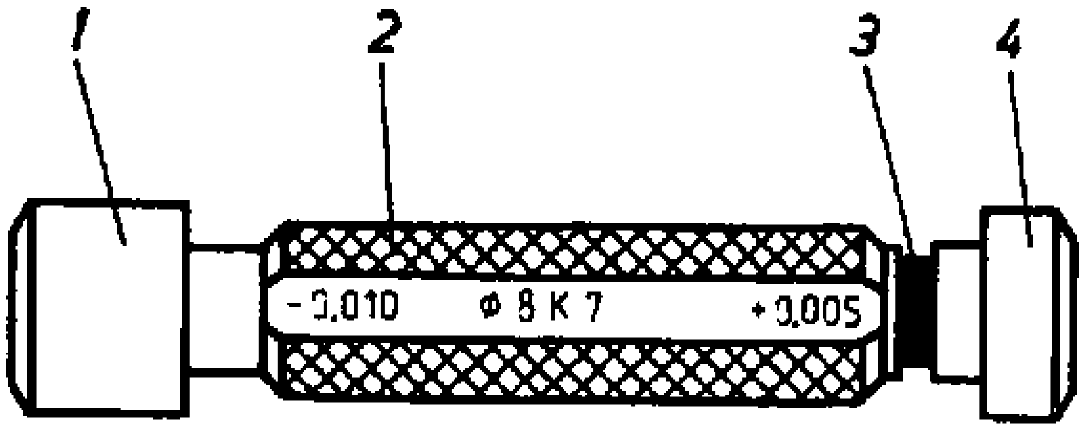

Figure 13 – Plug limit gauge Ø 8K7

1 – Go end (minimum size),
2 – Handle with indication of fit,
3 – Red colour ring indicating the not–go end,
4 – Not–go end (maximum size)

What is the designation of the plug limit gauge by which a bore shall be checked that was reamed by a reamer marked Ø 8K7?

____

By the plug limit gauge it can only be tested whether or not the bore is within the fixed range of tolerance – the exact diameter cannot be determined by the plug limit gauge.

Exercise:

The following tool and machine values have to be determined for making a cylindrical through hole in steel true to size and of a diameter of Ø 8K7:

Diameter of the drill (D): ____________________

Rotational speed (n): ____________________

Countersinking diameter (D_s): ____________________

Rotational speed (n): ____________________

Enter the individual steps of operation and the values calculated for this bors in the below table; fill in blank spaces:

No.	Operation	Tools, testing and auxiliary equipment	Tool and machine values
1.	Clamping		–
2.	Scribing/ prick–punching		–
3.	Drilling	Drill vernier caliper lubricating and cooling agents	D = n =
4.	Countersinking	Countersink vernier caliper	D_s = n =
5.	Reaming	Hand reamer tap wrench cutting oil	Ø 8K7
6.	Cleaning		–
7.	Testing	Plug limit gauge	Ø

This form of table can be used for preparing the practical exercises in reaming.

Exception

This sequence of operations does not apply to the use of structural reamers – the reaming of offset holes is no fitting operation.

8. Special recommendations for making conical bore holes true to size

Conical bore holes are required if machine taper or taper pin connections shall be made. With large bore holes serial taper reamers cannot be used without special preparation; such bore holes must be cylindrically predrilled in steps. The calculation of the diameter of the drill is to be derived from the conicity:

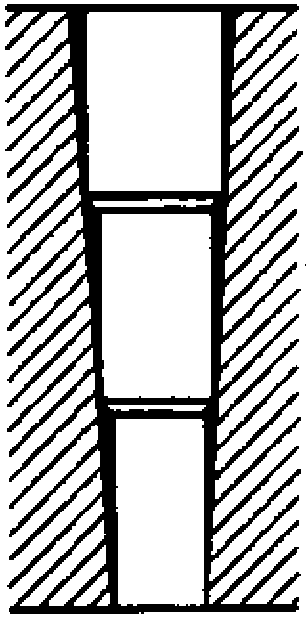

Figure 14 – Taper bore predrilled in steps

A conicity of 1:50 means:
Over a length of 50 mm the diameter changes by 1 mm.

Example:

A taper pin of a nominal diameter of 6 mm and a length of 50 mm has a diameter of 7 mm at its upper end.

With making a taper pin connection, step no. 7 – pinning and checking – is characterized by the preliminary fitting–in of the pin:

After reaming, the pin is pushed by the thumb into the cleaned bore hole. The upper edge of the pin roust project over the edge of the bore by an amount depending on the nominal diameter. If the measure achieved is identical with the empirical value (below table), the pin is driven in by two or three short strokes.

Empirical values for the preliminary fitting–in of taper pins of a conicity of 1:50

Nominal diameter of the taper pin (in mm)	Measure for the preliminary fitting–in (in mm)
5	3
6	4 – 5
8	5 – 6
10	8

The following condition applies to the length of the taper pin (illustration):

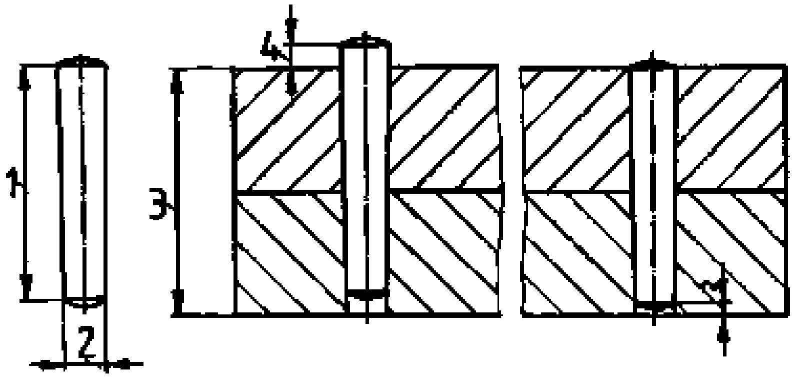

Figure 15 – Conditions of the fitting in of taper pins

1 – Length of the taper pin
2 – Nominal diameter of the taper pin
3 – Thickness of the parts to be connected (total)
4 – Measure for prefitting

It must be 2 mm shorter than the total of the thicknesses of all parts to be connected.

If this condition is observed, the pin – after being driven in – sits in the bore hole in such a way that a drift can be applied from the opposite side in order to remove the pin. The upper edge of the pin is at level with the edge of the bore hole of the upper portion.

Plain pins and taper pins mostly consist of unhardened steel. Therefore, for driving the pins in, aluminium hammers or locksmith's hammers are used in connection with a drift of non–ferrous metal.

Why must the locksmith's hammer not hit the pin directly?

____
____

How can the pin connection be undone?

____
____
____

For making a taper pin joint, the length of the taper pin is important.

What condition must be observed when determining the length?

____

What instructions concerning labour safety have to be observed with reaming?

____
____
____

Manual Reaming – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

Table of Contents

Manual Reaming – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Lehrbeispiele für die berufspraktische Ausbildung
"Reiben von Hand"

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Order No.: 90–33–3108/2

Introduction

The present material includes 5 selected instruction examples where the main methods of manual reaming can be practised. This serves to practise straight and tapered fitting holes, press–type fits and clearance fits in plain pin joints, taper pin joints and reaming of offset holes for riveted joints.

The instruction examples are mainly confined to the manufacturing of fitting holes, because these techniques of manual working can be mastered only by much training.

Only the lock of the screw represents a part which can be used as a component for a C clamp. As a complex work the joint combines all previously practised techniques of reaming.

In order to facilitate the preparation and implementation of the work, the necessary materials, working tools, testing and measuring tools as well as accessories are specified for each training example. Moreover, previous knowledge is named that is necessary to perform the exercises.

Besides the enclosed working drawing, the sequence of operations is explained in a convenient variant.

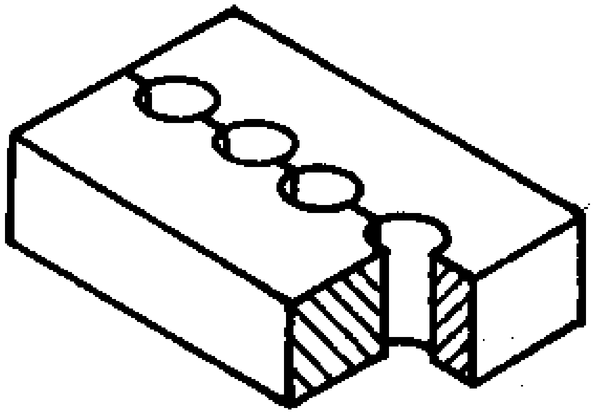
Explanation on the indication of the material:

The steel indication is done according to the value of the tensile strength in the unit "Megapascal" (MPa).

Instruction example 8.1. Training workpiece with straight fitting holes

To practise the making of straight fitting holes

<u>Material</u>



2 x square steel (380 MPa)

thickness: about 24 mm

length: 90 mm

Working tools

Steel scriber or marking gauge, centre punch, locksmith's hammer, drills (normal type) Ø 4.8 mm; Ø 7,8 mm; Ø 9,8 mm, countersink 90°, straight manual reamer Ø 5K7; Ø 8H8; Ø 10E8, adjustable reamer Ø 10–12 mm

Measuring and testing tools

Steel rule, vernier caliper, external micrometer, internal micrometer, limit plug gauge Ø 5K7; Ø 8H8; Ø 10E8

Accessories

2 C clamps, machine vice, vice, tap wrench, soluble oil, cutting oil.

Necessary previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, sawing, filing, drilling, countersinking/counterboring

Sequence of operations	Comments
1. Arrange the working place. Prepare the working material	– Check for completeness
2. Check the initial length of the material; if necessary, saw to 90 mm and remove the burr	
3. Clamp together the parts with the clamps, scribe and punch the central line being visible by the edges of the parts	– Conditions: The space between the finished upper edges of the holes shall be 11 mm each!
4. Fix the clamped parts in a machine vice and prepare the drilling machine	
5. Drilling	

5.1. For hole Ø 5K7 make a through hole Ø 4.8 mm	– n = 2,240 r.p.m.
5.2. For hole Ø 8H8 make a through hole Ø 7.8 mm	– n = 1,400 r.p.m.
5.3. For hole Ø 10E8 make a through hole Ø 9.8 mm	– n = 1,120 r.p.m.
5.4. For hole Ø 10,61 mm make a through hole Ø 9.8 mm	– n = 1,120 r.p.m.

6. <u>Countersinking/counterboring</u>

6.1. Countersink/counterbore hole Ø 4,8 mm to 5.2 mm	– n = 350 r.p.m.
6.2. Countersink/counterbore hole Ø 7,8 mm to 8.2 mm	– Countersink/counterbore all holes on both sides
6.3. Countersink/counterbore holes Ø 9,8 mm to 10.2 mm	

7. Fasten the workpiece in a vice.	– Do not unfasten the clamps

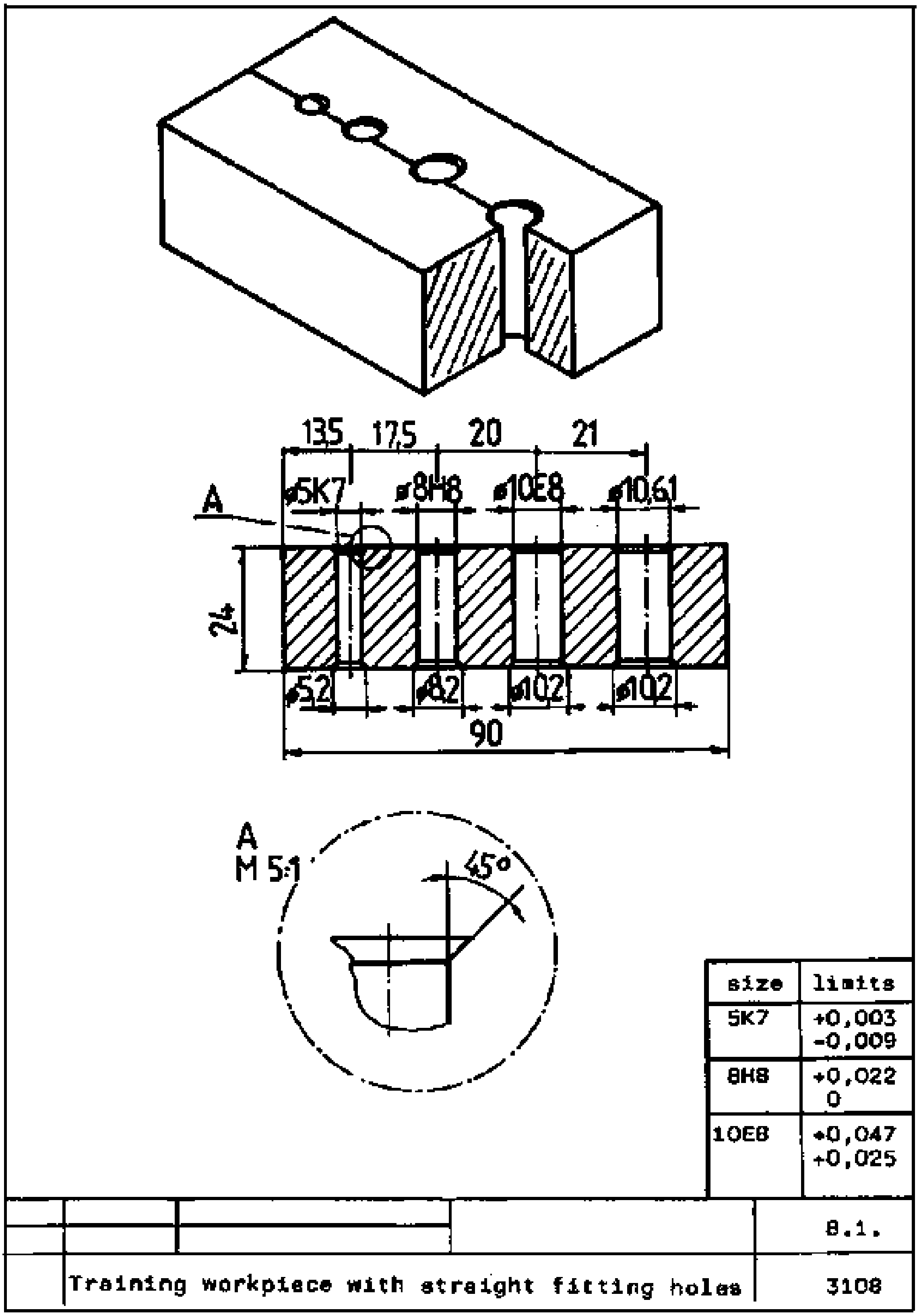
8. Reaming the holes

8.1. Ream hole Ø 4,8 mm with a manual reamer Ø 5K7	– Clamp the reamer tightly in the tap wrench
8.2. Ream hole Ø 7.8 mm with a manual reamer Ø 8H8	– Turn constantly in clockwise direction
8.3. Ream is hole Ø 9.8 mm with a manual reamer Ø 10E8	– Add cutting oil
8.4. Ream 2nd hole Ø 9.8 mm with an adjustable reamer (set the reamer with the external micrometer to the specified diameter)	– Remove chips from time to time

9. Clean the holes

10. Check the accuracy of fit of the holes with the appropriate limit plug gauges and the internal micrometer

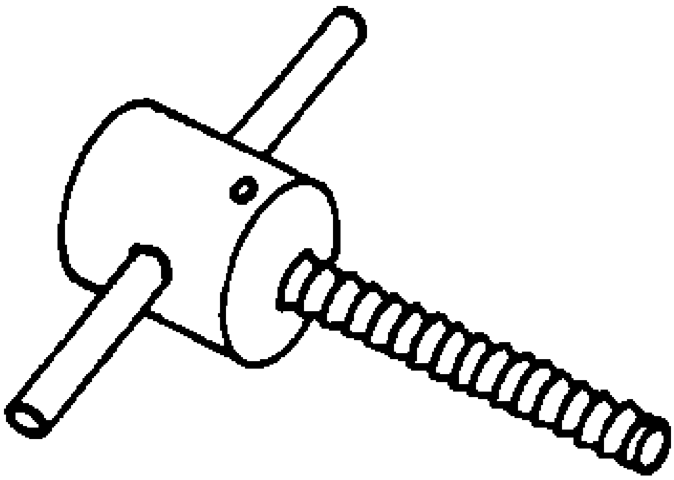
11. Unfasten the parts and check surface of the holes for finish quality



Instruction example 8.2. Screw lock

To practise reaming of straight fitting holes for the press−type fit of plain pins.

<u>Material</u>



round bar steel (420 MPa)

diameter: 15 mm

length: 20 mm

screw bolt: (600 MPa) nominal diameter: M 10

length: 106 mm (or both parts from training example 9.5)

plain pin Ø 6m6
length: 60 mm

plain pin Ø 3m6
length: 15 mm

Working tools

Marking gauge, centre punch, locksmith's hammer, drills Ø 2,8 mm; Ø 5.8 mm, countersink 90°, manual reamer Ø 3K7 and Ø 6K7.

Measuring and testing tools

Vernier caliper, limit plug gauge Ø 3K7 and Ø 6K7.

Accessories

Machine vice with vee jaws, light metal plug, tap wrench, soluble oil, cutting oil.

Necessary previous knowledge

Reading of drawings, scribing, prick−punching, measuring, testing, drilling, countersinking/counterboring

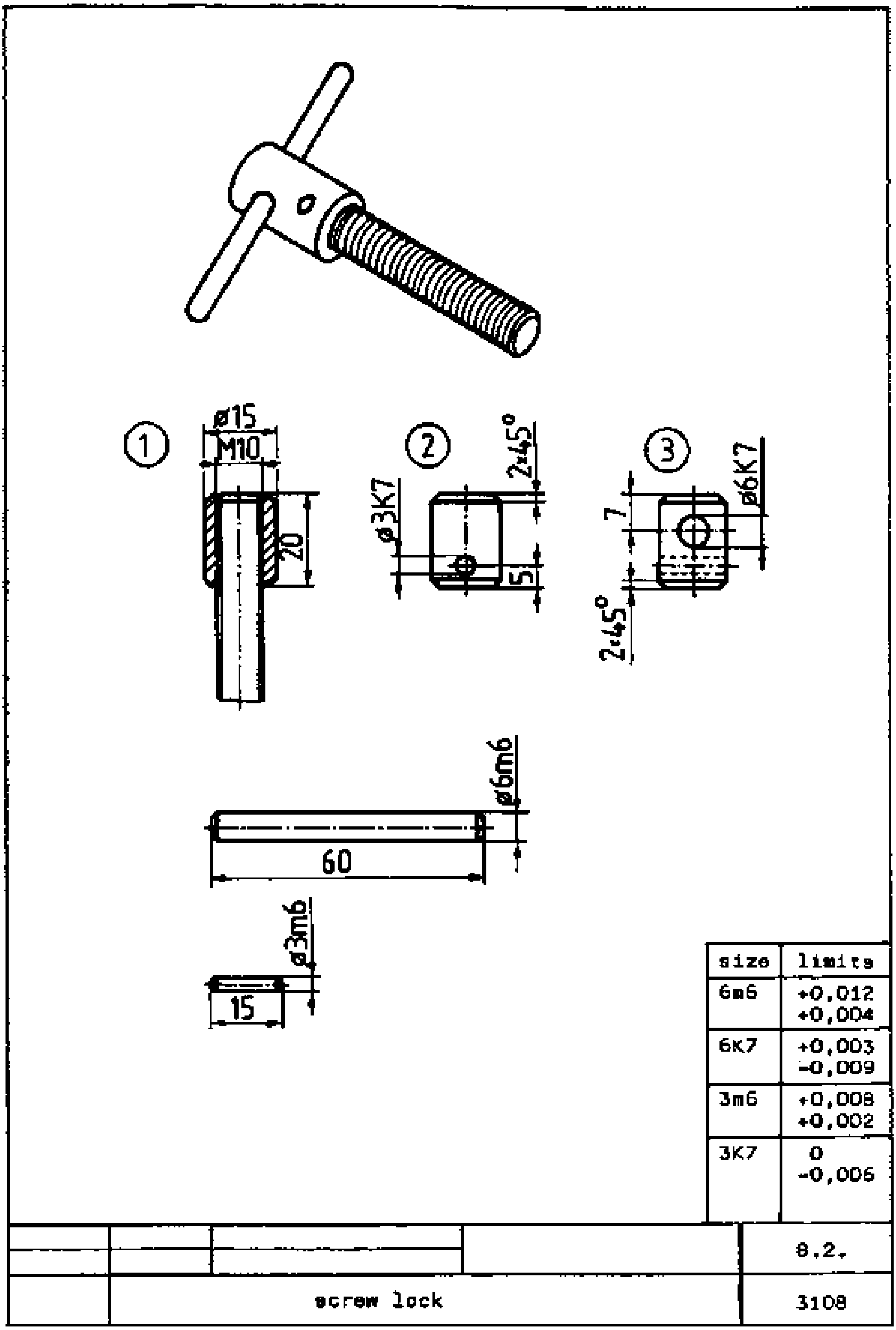
Sequence of operations	**Comments**
1. Arrange the working place. Prepare the working material.	− Check for completeness
2. Screw in the bolt into the round bar material with internal thread	− Stage (1)
3. Fasten in the machine vice, scribe and prick−punch the hole Ø 3K7	

4. Drill the hole Ø 2.8 mm, countersink at both ends to Ø 3.2 mm; ream with manual reamer Ø 3K7 and check.	– Stage (2) n = 1,800 r.p.m. Apply cutting oil
5. Insert the plain pin Ø 3m6 x 15 and check for press fit.	– drive in with the light metal plug and a hammer
6. Fasten in the machine vice, scribe and prick–punch the hole Ø 6K7 (turned by 90° to the previous hole)	– Stage (3)
7. Drill the hole Ø 5.8 mm countersink at both ends to Ø 6.2 mm; ream with a manual reamer Ø 6K7 and check.	– n = 900 r.p.m.
8. Insert the plain pin Ø 6m6 x 60 and check for press fit.	

<u>Remark</u>

Together with the training examples	2.5. (C clamp bow)
	2.6. (rotary head for threaded spindle)
and	9.5. (screw bushings and screw bolts for a C clamp)

this lock, as a component of a screw, forms a complete C clamp for workshop use.

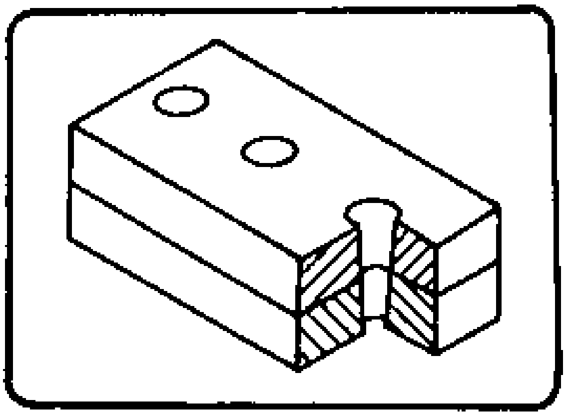


size	limits
6m6	+0,012 +0,004
6K7	+0,003 -0,009
3m6	+0,008 +0,002
3K7	0 -0,006

Instruction example 8.3. Training workpiece with tapered fitting holes

To practise the making of tapered fitting holes for taper pins 1:50.

<u>Material</u>



2x square steel (380 MPa)

thickness:	26 mm
length:	68 mm
taper pins	Ø 6 x 50
	Ø 8 x 50
	Ø 10 x 50

Working tools

Marking gauge, centre punch, locksmith's hammer, aluminium hammer, drills (normal type) Ø 6 mm, Ø 8 mm, Ø 10 mm, taper reamer (1: 50) Ø 6 mm, Ø 8 mm, Ø 10 mm, countersink 90°.

Measuring and testing tools

vernier caliper

Accessories

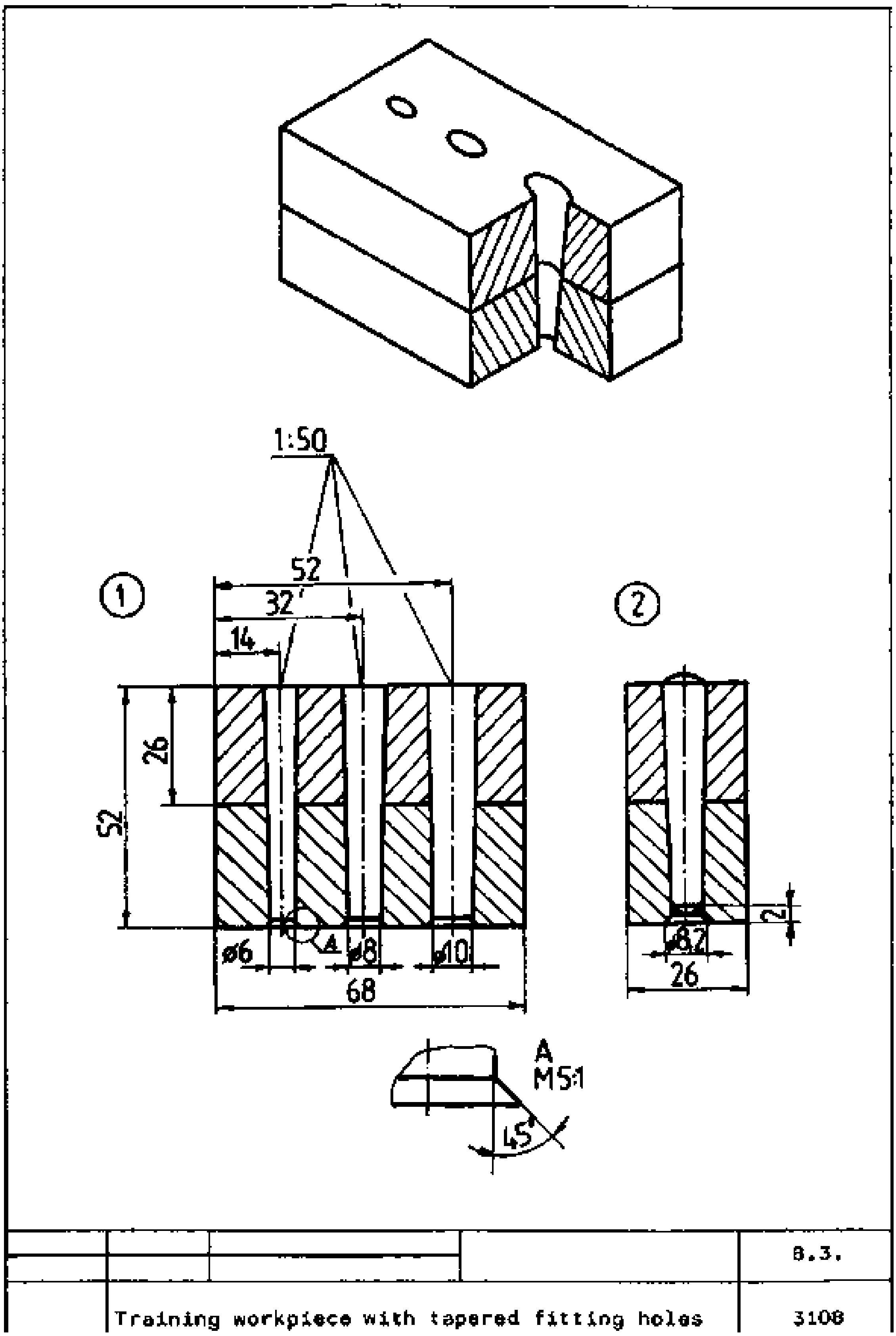
2 C clamps, machine vice, light metal plugs Ø 6, Ø 8, Ø 10, tap wrench, soluble oil, cutting oil.

Necessary previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, sawing, filing, drilling, countersinking/counterboring

Sequence of operations	**Comments**
1. Arrange the working place. Prepare the working material.	Check for completeness
2. Check the initial dimensions of the parts, if necessary, rework, remove the burr.	
3. Clamp together the working parts with C clamps, scribe and punch as to given size.	
4. Fasten the clamped parts in a machine vice and set up the drilling machine.	

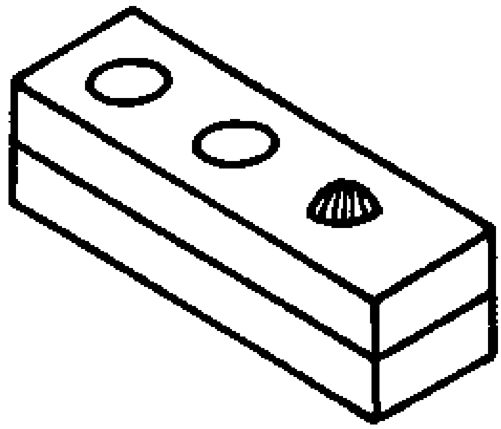
5. Drilling the holes: Ø 6 mm Ø 8 mm and Ø 10 mm	– n = 1,400 r.p.m. – n = 1,400 r.p.m. – n = 1,120 r.p.m.
6. Countersinking: both ends to a countersinking diameter of Ø 6.2 mm, Ø 8,2 mm and Ø 10.2 mm, each.	– n = 350 r.p.m.
7. Fasten the working parts in a vice.	Do not unfasten the clamps.
8. Reaming the holes Ø 6:	– stage (1)
Turn the 6 mm dia. taper reamer through until little before leaving the hole.	Turn in clockwise direction. – Add cutting oil. – Pull out with a clockwise rotation,
Pull out the taper reamer, clean the hole.	
Push the taper pin with the thumb tightly into the hole.	
The taper pin should now protrude above by the pre–fitting size.	– pre–fitting size: Ø 6 = 4 – 5 mm Ø 8 = 6 mm Ø 10 = 8 mm
If the pin protrudes too much it should be knocked out and reamed again.	– Use a light metal plug for driving out.
If the pin fits right, fix it with 2–3 blows of the aluminium hammer.	– stage (2)
9. Check if it fits tight.	– Both parts should not twist after removing the C clamps.
10. Remove the taper pin with a light metal plug.	– Hammer against it from below.
11. Repeat the operations 8–10 for the holes Ø 8 and Ø 10.	
12. Check for tight fit and alignment of the head with the upper edge of the hole after each operation.	



Instruction example 8.4. Training workpiece for reaming rivet hole

To practise reaming of offset holes.

<u>Material</u>



2x steel sheets (380 MPa)

thickness: 5 mm

width: 20 mm

length: 80 mm

button−head notched nail Ø 4 x 10 2 button−head rivets Ø 6 mm

Working tools

Marking gauge, centre punch, locksmith's hammer, drills (normal type) Ø 4.0 mm and Ø 6.4 mm, rivet hole reamer Ø 5 mm.

Measuring and testing tools

vernier caliper

Accessories

2 C clamps, machine vice, soluble oil, tap wrench, cutting oil.

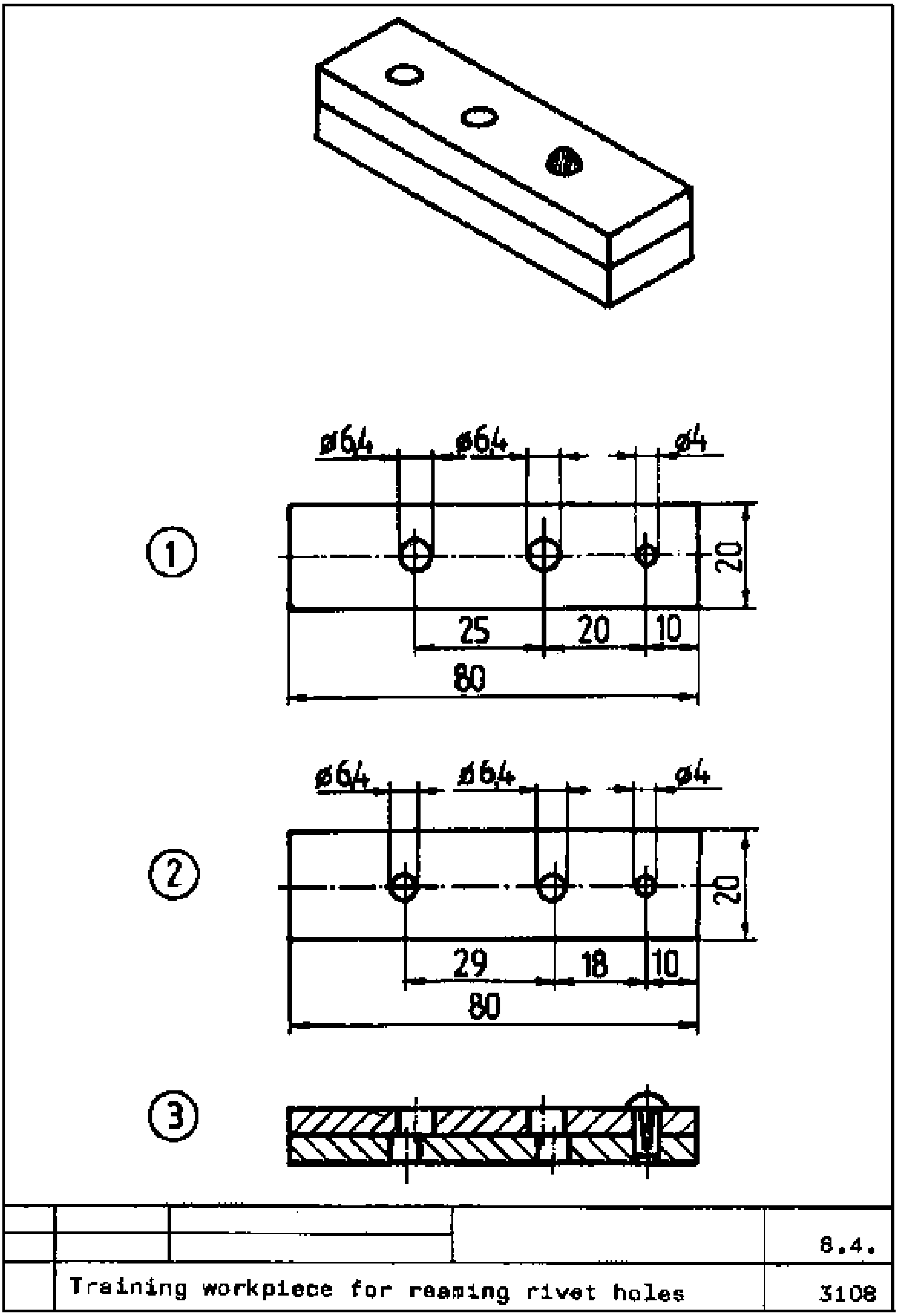
Necessary previous knowledge

Reading of drawings, scribing, prick−punching, measuring, drilling, testing.

Sequence of operations	**Comments**
1. Arrange the working place. Prepare the working material.	− Check for completeness
2. Scribe, punch and drill the parts separately according to the drawing.	− stage (1) − stage (2)
3. Clamp together the parts with C clamps, place the notched nail into the appropriate hole.	− stage (3)
4. Fasten the clamped sheets in a vice, ream the offset holes with the rivet hole reamer until the rivet can be easely placed into them.	

5. Check the holes. – with vernier caliper rough size: Ø 6.1

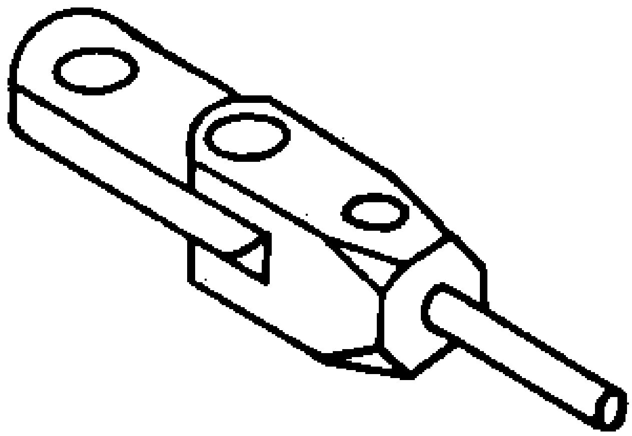
Completion: Rivet the sheets together.



Instruction example 8.5. Joint

To practise making of cylindrical and tapered pin connection as combined press−type fits and clearance fits.

Material



flat steel (380 MPa)

thickness: 10 mm

width: 20 mm

length: 70 mm

square steel (380 MPa)

thickness: 20 mm

width: 20 mm

length: 70 mm

round bar steel (380 MPa)

diameter: 10 mm

length: optional

plain pin Ø 10m6

length: 20 mm

taper pin Ø 3 x 18 (1:50)

Working tools

Hand hacksaw, bastard files and smooth files 200 mm (flat and square), steel scriber, centre punch, locksmith’s hammer, aluminium hammer, drills Ø 3 mm and 9.8 mm, hand hacksaw Ø 10K7 and Ø 10E8, taper reamer Ø 3 mm (1:50).

Measuring and testing tools

Vernier caliper, limit plug gauge Ø 10K7 and Ø 10E8.

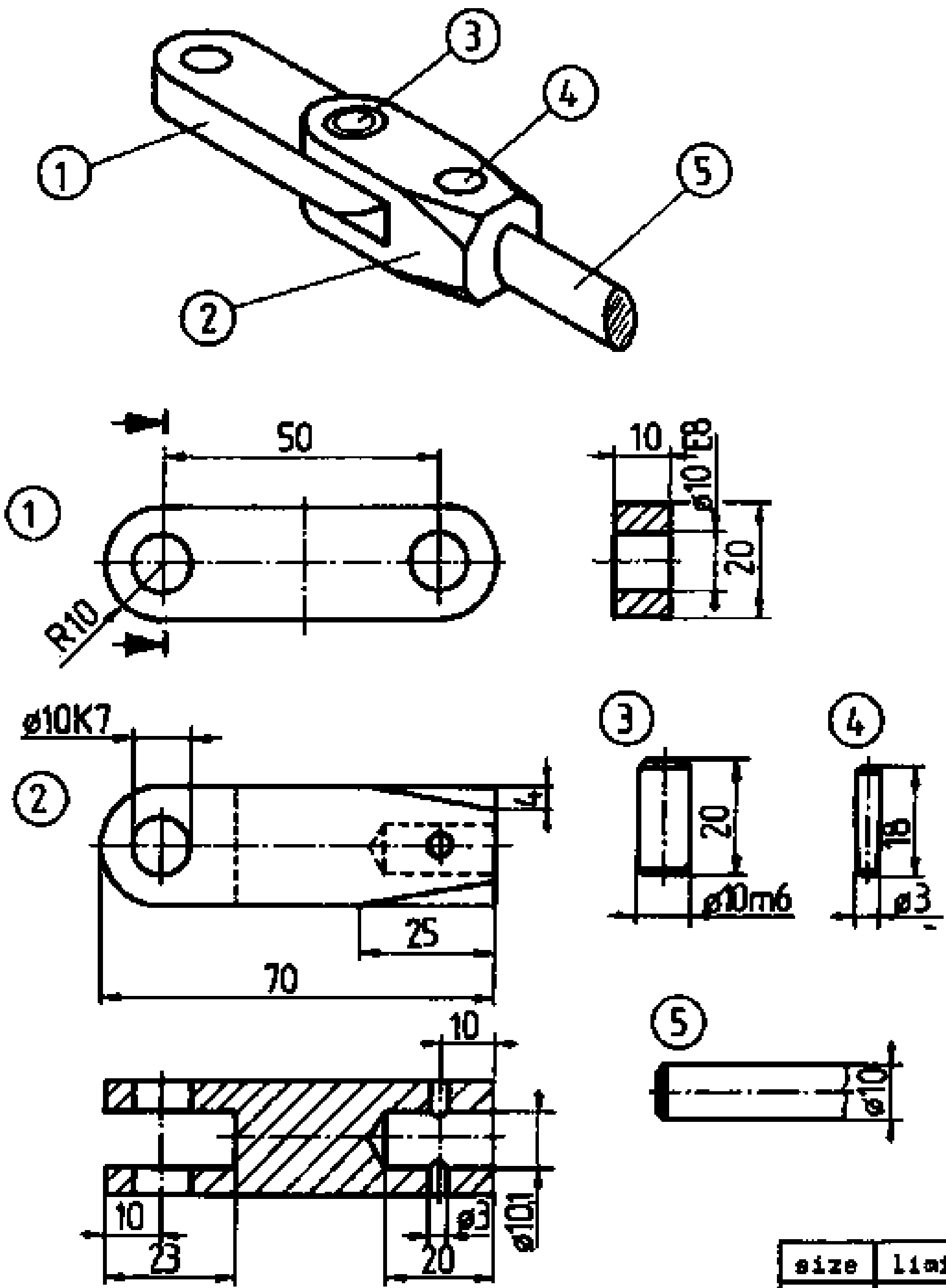
Accessories

Machine vice, vice, tap wrench, soluble oil, cutting oil.

Necessary previous knowledge

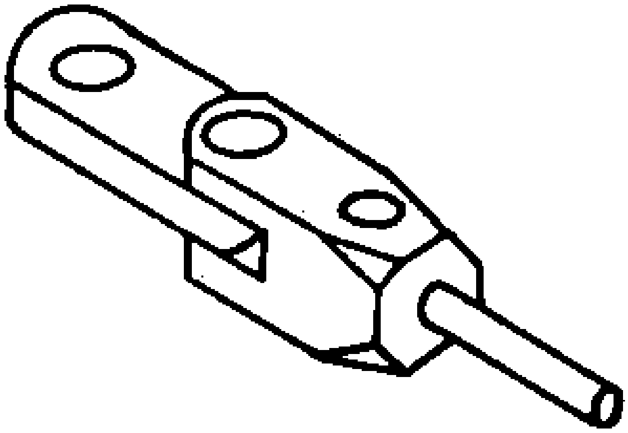
Reading of drawings, scribing, prick−punching, measuring, testing, sawing, filing, drilling, countersinking/counterboring.

Sequence of operations	**Comments**
1. Arrange the working place. Prepare the working material.	− Check for completeness
2. Prepare the external outlines of parts (1) and (2) according to the drawing, smooth the surface throughout.	− Saw, file, drill
3. Provide part (1) with fitting holes Ø 10E8.	
4. Provide part (2) on the slotted side with a fitting hole Ø 10K7.	
5. Check the holes.	
6. Connect part (1) and (2) by a plain pin (3).	− Clearance fit in part (1) − Press−type fit in part (2) − Part (l) must be slewable
7. Scribe hole Ø 3 mm on part (2), Place the round bar steel (5) Ø 10 mm into the hole Ø 10,1 mm, drill together and ream conically.	
8. Insert taper pin (4) and check for tight fit.	
9. Final control.	− Function of the pin joints



		size	limits
		10E8	+0,047 +0,025
10m6	+0,015 +0,006	10K7	+0,005 -0,010

	8.5.
Joint	3108



Manual Reaming – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

Table of Contents

Manual Reaming – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

Institut für berufliche Entwicklung e.V.
Berlin

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Author: Frank Wenghöfer

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1. Objectives and contents of practical vocational training in the working technique of "Manual Reaming"

By concluding their training, the trainees shall have a good command of the working technique of "Manual Reaming". Therefore, the following objectives have to be achieved:

<u>Objectives</u>

- Knowledge of purpose and application of the reaming technique,

- Proper command of reaming straight and tapered holes and capability of making pin–type connections.

- Capability of selecting the appropriate reamers and of using them appropriately.

- Capability of carrying out the necessary calculations and quality control independently.

The following contents have to be imparted to the trainees:

<u>Contents</u>

- Purpose of reaming
- Tools for reaming
- Design and action of reamers
- Technological process of reaming
- Special knowledge of straight and tapered fitting holes.

2. Organizational preparations

In order to guarantee a trouble–free development of the instructions, exercises and practical work it is necessary to prepare this training properly:

The following steps have to be taken:

2.1. <u>Preparation for instructions on labour safety</u>

Prior to the exercises a brief instruction on the proper use of tools and equipment has to be given. This comprises also hints for accident–free work.

The main points are similar to that of the working techniques of "Drilling, Countersinking and Counterboring". The respective hints have to be repeated, and some supplementary points concerning the new working technique have to be added.

Supplementary points:

– Firm clamping of reamer in a tap wrench
– Never turn a reamer in anticlockwise direction – risk of breakage
– Use of lubricants and coolants during reaming processes
– Put down reamers carefully and make sure that they cannot drop
– Never leave the reamer in a hole when interrupting your work

Familiarity with these hints has to be confirmed by the trainees signatures in a control book.

2.2. Provision of the necessary teaching aids

For demonstration purposes during the instructions a vice should be installed at the place of instruction.

The "Trainees' Handbook of Lessons – Manual Reaming" is to be handed out to the trainees in sufficient numbers.

When using the transparencies series of "Manual Reaming", check whether they are complete (transparencies nos. 8.1. – 8.4.) and whether the overhead projector is functional.

(Check the operating conditions at the place of instruction and make sure of the proper mains supply!)

Surveys etc. which are to be written on the blackboard have to be completed prior to instruction.

All the tools and accessories for reaming mentioned in section 3 should be kept ready for illustration purposes.

2.3. Provision of working tools and materials

– Sufficient copies of the "Instruction Examples for Practical Vocational Training – Manual Reaming" must be handed out to the trainees to provide them with the theoretical foundations for the exercises to be carried out.

– The initial materials necessary for the exercises have to be prepared and laid out in sufficient numbers according to the materials mentioned in the "Instruction Examples..."

– Each trainee is to be provided with a workbench at which a vice is firmly installed (check the proper height of this vice!).

– The trainees' workbenches have to be fully equipped with tools and accessories according to the planned exercises.

Recommended basic equipment:

– steel rule, vernier caliper, external micrometer

– steel scriber, marking gauge, centre punch

– locksmith's hammer, aluminium hammer, hand hacksaw

– drills – countersinks 90°, hand reamers (straight and tapered), rivet hole reamers.

– Bench– and column–type drilling machines and the necessary clamping devices (machine vices, holding clamps, C–clamps) must be provided for the necessary preliminary work (drilling and counterboring/countersinking).

– Prior to the start of the exercises, the drilling machines – have to be checked for a good working order according to the points contained in the regulations on labour safety.

2.4. Time schedule

Time planning is recommended for the following training stages:

– introduction to the working technique in the form of instructions
– necessary demonstrations
– calculations for the technological process to prepare the exercises
– job–related instructions to prepare the exercises
– carrying–out the exercises
– recapitulations and tests.

The necessary time share depends on the respective training conditions. The instructor has to bear in mind that waiting times will occur at the machines, if there are not enough drilling machines available. Such waiting times should be bridged by minor subject–related tasks.

3. Recommendations for practical vocational training in the working technique of "Manual Reaming"

The following paragraphs comprise proposals on conducting trainee instruction, demonstration of working techniques as well as exercises and tests.

Two course variants are offered:

Variant no. 1

This variant should be used for trainees with previous knowledge and generally good achievements and receptiveness:

1.1. Introductory instruction for the whole subject with demonstrations according to the "Trainees' Handbook of Lessons".

1.2. Practice in reaming according to the "Instruction Examples nos. 8.1. – 8.5." and subsequent evaluation.

1.3. Final test of theory knowledge according to the "Examples for recapitulation and tests".

Variant no. 2

This variant should be used for trainees with only little previous knowledge or poor achievements:

2.1. Introductory instruction for the subject of "straight fitting holes" with demonstrations according to the "Trainees' Handbook of Lessons".

2.2. Exercises on straight fitting holes according to the "Instruction examples 8.1. and 8.2." and subsequent evaluation.

2.3. Supplementary instruction for the subject of "tapered fitting holes" according to the "Trainees' Handbook of Lessons"

2.4. Exercises on tapered and straight fitting holes according to the "Instruction examples 8.3. – 8.5." and subsequent evaluation.

2.5. Final test on theory knowledge according to the "Examples for recapitulation and tests".

Practical knowledge and skill should be checked immediately after handing over the completed workpieces.

Theory knowledge can be checked constantly, however, it is recommended to have a final written test (item 1.3. or, resp., 2.5.) after the exercises.

3.1. Introductory instruction

If possible, this instruction should be conducted in a classroom. Make sure that the trainees put down necessary and supplementary notes or answers to questions in their “Trainees’ Handbook of Lessons”.

The subject of instruction can follow the main points contained in the “Trainees’ Handbook of Lessons”. A good command of the working techniques of “Drilling, Countersinking and Counterboring” is an essential prerequisite for learning the working technique of “Reaming”. When imparting knowledge to the trainees it is recommended to repeatedly refer to these working techniques. Instruction in the main subjects of “purpose of reaming; tools; design and action of reamers” is to be heavily supported by all those teaching aids available.

Purpose of reaming

To illustrate the purpose of reaming it is recommended to show to the trainees for comparison cut workpieces which are drilled or, resp., finished with reamers. It would be favourable to demonstrate examples of gears and shafts, machine taper connections and pin–type connections, if available. The findings should be summarised with the help of the descriptions contained in the “Trainees’ Handbook of Lessons”.

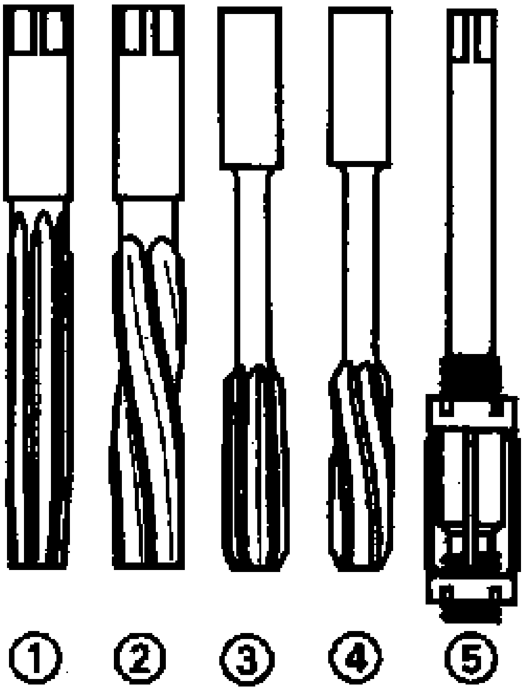
Tools, design and action of reamers

Practice–related training can be continued based on main points contained in the “Trainees’ Handbook of Lessons”. In addition to the prepared original tools the transparencies nos. 8.1., 8.2. and 8.3. can be used as teaching aids.

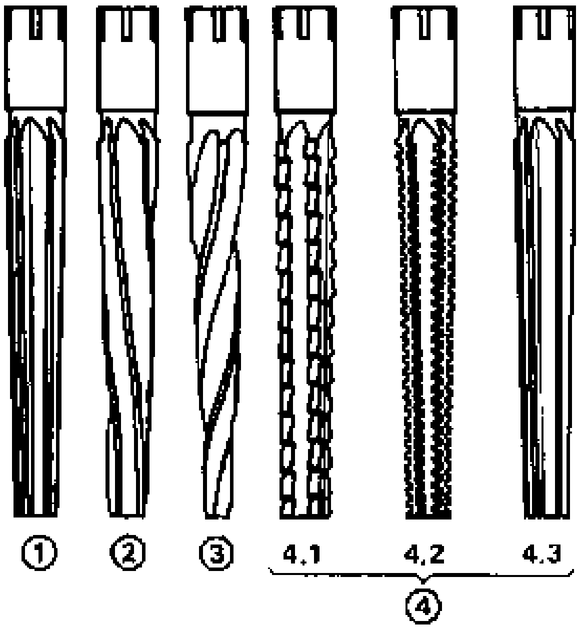
The instructor has to give a detailed description of the use of the individual types of reamers so that the trainees will be in a position to conclude the use of a reamer from its design.

The following original reamers should be demonstrated:

- shell reamer
- adjustable reamer
- taper reamer (single and set)
- rivet hole reamer (structural reamer)
- straight hand reamer
- straight machine reamer



Transparency 8.1



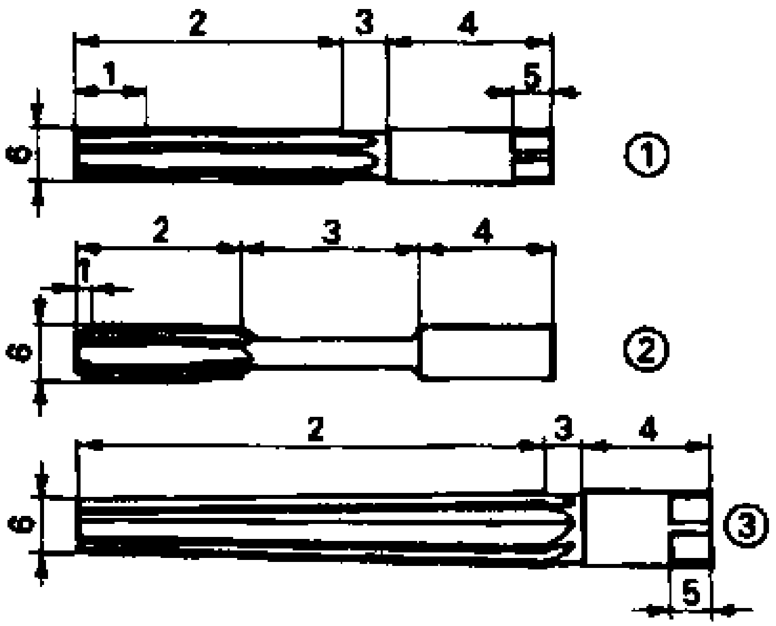
Transparency 8.2

Tap wrench as well as containers for lubricants and coolants (with brush) should be shown as accessories.

The description of the cutting portion of straight hand reamers should be supported by showing machine reamers.

The comparison of the relationship of the cutting portions makes it easy to see and understand where to use these reamers. A demonstration of the action of reamers should be included in the instruction.

As it is necessary to have a workbench with a vice for this purpose, the instructor has to check the local conditions in advance so that it will not be necessary to interrupt the instructions by a time−consuming change of place (classroom − workshop).



Transparency 8.3

This demonstration has to be carefully prepared:

– A drilled and counterbored steel part must be clamped in the vice.

– A straight hand reamer (nominal diameter 8 mm), clamped in a tap wrench, has to be placed close to the vice.

– A small container with cutting oil and a brush has to be placed there too.

The trainees should stand around the vice and the instructor has to see to it that everyone can see this process and that no trainee stands behind him. Now, the reaming demonstration can begin. The trainees must learn that reamers have to be turned clockwise (even when removing the reamer) and that a permanent supply of cutting oil is necessary. It must be made clear that reamers have to be removed from their holes from time to time in order to remove the chips with the brush.

During this process the instructor has to explain why he handles the reamer in such a way.

The trainees must learn that reaming operations need extreme attention, calmness and experience in order to achieve the required precision.

The trainees, who have to achieve a good command of this skill, will take the instructor as an example. Thus, the example of the instructor becomes decisive for the trainees' motivation.

After this demonstration the trainees go on working with their "Trainees' Handbook of Lessons". Now they should answer the questions in the sections of "design and action of reamers". The trainees must have the change to put questions.

Technological process of reaming

The technology of this working technique has to be shown in detail and particularly distinctly. Therefore it will be necessary to explain the tables nos. 1, 2 and 3 (written on the blackboard).

Table no. 1 Technology of producing a fitting bore−hole

No. operation	working tools, testing tools and accessories	tool and machine values
1 clamping	vice, C−clamps	–
2 scribing and prick−punching	steel scriber and prick−punch	according to drawing

3 drilling	drill, vernier caliper, lubricant and coolant	drill diameter, depth of hole, rotational speed–
4 countersinking	90° – countersink vernier caliper	countersink diameter rotational speed 350 r.p.m.
5 reaming	hand reamer tap wrench	to fit tolerances
6 cleaning	compressed air or brush	–
7 testing	limit plug gauge	to fit tolerances
In order to prepare a pin–type connection:		
7 pinning and testing	cylindrical pin or tapered pin aluminium hammer	length of pin

Table no. 2 Empirical values for undersizes of holes in steel

N in mm	U in mm
up to 5	0.1 – 0.2
5 – 20	0.2 – 0.3
21 – 31	0.3
33 – 50	0.5

Table no. 3

Formulae for calculating the tool values for reaming

1. For drilling the hole:

$$\boxed{D = N - U}$$

D = diameter of drill
N = nominal diameter of a fitting hole
U = undersize (empirical value)

2. For counterboring/countersinking:

$$\boxed{D_s = N + 0.2\ m}$$

D_s = diameter of countersink/counterbore
N = nominal diameter of fitting bore holes

Table no. 1 gives a detailed description of the work cycle. The individual stages of work can be comprehensively described by using numerical examples.

It is recommended that the trainees do calculations at the blackboard using the data contained in the tables 2 and 3 or enter the values on the blackboard.

During the instructions the trainees should make notes in the margin of the “Trainees’ Handbook of Lessons”.

Testing of straight reamers, designations of fits on straight reamers

If it is quite clear that the exercises will be carried out by standardised reamers according to the “ISA system of tolerances and fits”, the respective sections should be taught on the basis of the “Trainees’ Handbook of Lessons”.

If this is not the case, the designations of reamers and limit plug gauges must be taught in another way.

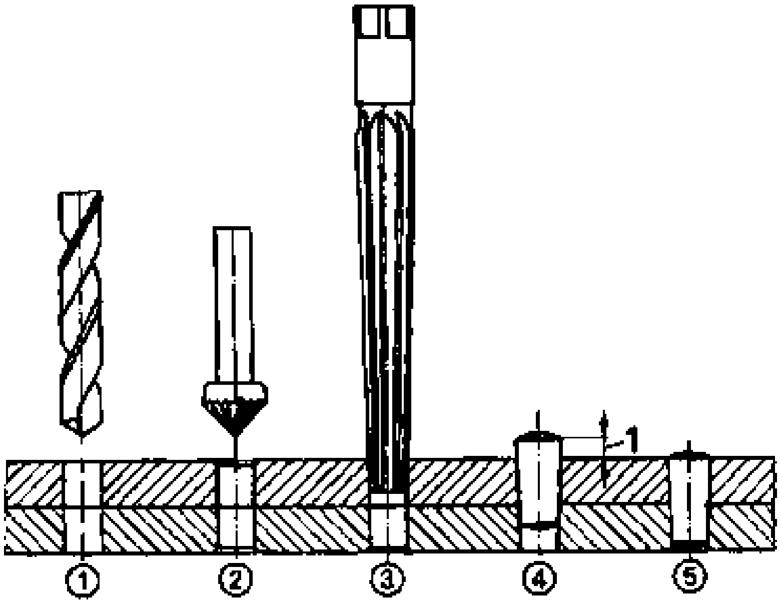
To consolidate the knowledge acquired, the question in the “Trainees’ Handbook of Lessons” (table) can be answered.

If major problems occur, the instructor has to give and discuss further examples based on the tables.

The trainees must not begin with practical exercises until all the trainees have a good knowledge of this technology.

<u>Special hints as to producing tapered fitting holes</u>

The purpose of tapered connections has to be described once again. Illustrative objects (tools, finished connections with tapered pins, machine taper connections) as well as transparencies nos. 8.2. and 8.4. have to be employed appropriately. The use of rivet hole reamers, serial taper reamers and single taper reamers is to be described clearly. Special attention is to be drawn to single taper reamers for tapered–pin connections.

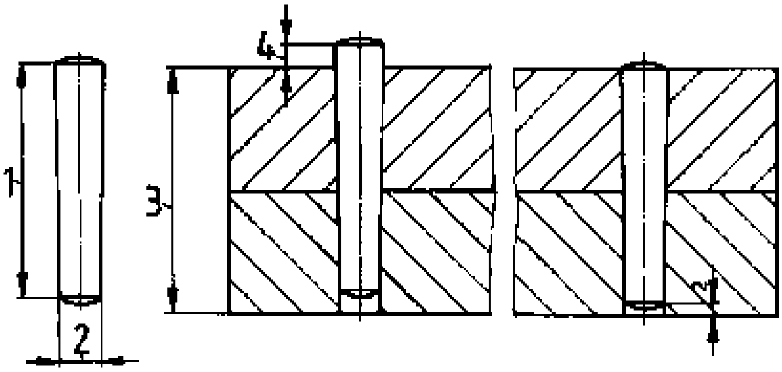


Transparency 8.4

Table no. 4 and Figure no. 5 (on the blackboard) can serve to show the special features of the stages of this working process.

<u>Table no. 4 Empirical values for prefitting of taper pins with a taper ratio of 1:50</u>

Nominal diameter of taper pin in mm	dimension for prefitting in mm
5	3
6	4 – 5
8	5 – 6
10	8



Conditions for fitting tapered pins:

1 – length of tapered pin
2 – nominal diameter of tapered pin
3 – thickness of the components to be connected
4 – dimension for pre–fitting

It is recommended to demonstrate how a taper pin connection can be made. Therefore, a workbench with vice must be available. However, the instructor has to check whether the local conditions make this possible or not. Otherwise the demonstration can be carried out after the instruction in a workshop. The demonstration is to be prepared as follows:

– Two steel parts mounted in a C–clamp and provided with drilled and countersunk hole when mounted together are to be clamped in a vice.

– A taper reamer (fixed in a tap wrench) as well as a matching taper pin are to be placed close to the vice.

– A container with cutting oil and a brush as well as an aluminium hammer (or, a locksmith's hammer) and a non–ferrous metal plug must also be placed close to the vice.

During the demonstration each operation of the instructor has to be described. The instructor has to stress again that the parts are drilled, counterbored and fixed in the vice while being clamped together.

Make sure that the C–clamp is fixed in such a way that it does not interfere with performing the work!

The instructor has to show the interaction of reaming and checking processus in order to achieve a precise pre–fitting result. The driving–in of the pin and the removal of the holding clamp give evidence that the pin holds both parts firmly together. This is the conclusion of the demonstration.

Subsequently, the instructor has to demonstrate how such a connection can be detached by the appropriate non–ferrous metal plug. (Demonstration of separability of taper pin connections.) After this demonstration the trainees can answer the respective questions contained in the "Trainees' Handbook of Lessons" and referring to the process observed before.

3.2. Exercises

If it has not been possible to include the demonstration of the action of reamers in the instructions, this should be done right now before the exercises in the workshop begin. If the trainees avail of little practical skill only, they should carry out some preliminary exercises on any steel parts:

– simple straight fitting holes
– small–size connections with cylindrical pins
– simple taper–pin connections of smaller diameters
– reaming of offset rivet holes.

However, it is also possible to begin with the first exercise immediately – based on the "Instruction examples for practical vocational training".

However, it is necessary to prepare every individual exercise by a brief "job−related instruction", during which the trainees are shown a finished workpiece in order to demonstrate the objectives and crucial points of this exercise.

> The instructor must have finished such a workpiece himself in order to be familiar with all the problems which might arise in producing such a workpiece.

Thus, the instructor is capable of mentioning the crucial points of evaluation as well as the difficult areas in manufacturing such a workpiece. During these instructions the sequences of operations and the working drawings should be placed on the desks so that the trainees can make notes therein.

> The trainees must not operate the drilling machines before they are familiar with the function of the control elements.

The instructor has to check whether the trainees had been given the instruction in operating drilling machines (based on the control book of labour safety instructions).

If this is not the case, this must be done now.

When giving his instruction the instructor must permanently monitor the trainees: No practice without supervision!

Special attention is to be drawn to producing bore holes. It is recommended to check whether the objects are firmly held by the clamping devices.

It is advisable that the instructor demonstrates again the operation of the machine, the clamping of the workpiece and of the drill. Special emphasis is to be laid on the process of centring (alignment of bore hole and work spindle) if the workpiece had been unclamped between the stages of drilling, countersinking and counterboring.

As it will not be possible to provide each trainee with a drilling machine, the instructor has to determine the proper succession in which the trainees will operate the machines.

This instruction must be job−related (based on the instruction example).

> During the exercise the instructor has to make sure that only one trainee operates the machine. Several trainees at one machine could distract each other from working and increase the risk of accidents!

If waiting times occur, caused by using the machines during the exercise, these times should be bridged by performing some other subject−related tasks.

3.3. Examples for recapitulation and tests

This section comprises questions which are to consolidate and check the previously acquired knowledge and skills.

Each question is provided with the respective answer. Questions which are also contained in the "Trainees' Handbook of Lessons" are marked with the letter "A".

1. What is the purpose of reaming?

   (Precise finishing of bore holes, production of tapered and fitting bore holes, compensation for offset rivet holes.)

2. What is the design of a straight hand reamer?

   (Long cutting portion − 1/4 of it is lead; shank with square)

3. Where do we find the nominal diameter on a taper reamer?

(At the narrow end of the cutting portion)

4. What is the task of leads on straight hand reamers?

“A” (The lead removes the biggest amount of chips.)

5. Why must a straight hand reamer have a relatively long lead?

“A” (To ensure better guidance when starting.)

6. Why are relatively short leads on straight machine reamers possible?

“A” (Because the precise guidance of the reamer is guaranteed by the machine spindle.)

7. Why can we use the straight hand reamer for through holes only?

“A” (Because of the long lead the blind hole would not be reamed at the bottom of the hole.)

8. Why must we never turn a reamer in anticlockwise direction?

“A” (Because the chips could jam behind the cutting edges and cause a chipping of the cutting edges.)

9. Why is it necessary to draw out the reamers from the holes from time to time?

(Because the chips have to be removed, otherwise the chips would block the flute)

10. What is the effect of using straight–fluted reamers when reaming a hole with feather keyway?

“A” (The straight cutting edges collide with the edges of the feather keyway over the whole length, they are overloaded and can break off.)

11. When do we use reamers with helical flutes?

(In bore holes with recesses – such as feather keyways etc.)

12. Which steps are necessary for producing a fitting hole?

(Clamping, scribing, prick–punching, drilling, counterboring/countersinking, reaming, cleaning, testing.)

13. How can we calculate the drill diameter?

(Nominal diameter minus undersize.)

14. What is the designation of a limit plug gauge for checking a bore hole which was reamed with a Ø 8K7 reamer?

“A” (Ø 8K7 limit plug gauge.)

15. Determine the following tool and machine values for the

“A” production of a fitting straight through hole in steel with a diameter of Ø 8K7:

diameter of drill:	(D = 7.8 mm)
rotational speed:	(n ? 1400 r.p.m.)
counterbore diameter:	(D_s = 8,2 mm)
rotational speed for counterboring:	(n ? 350 r.p.m.)

Supplement of tables in the “Trainees’ Handbook”: (machine vice; scriber, prick−punch; 90° countersink; brush; limit plug gauge Ø 8K7.)

16. How is prefitting for making a taper−pin connection performed?

(Your thumb presses the taper pin into the bore hole. The pin must protrude from the bore hole by a given measure.)

17. Why must we not hammer directly on the pin with the locksmith’s hammer?

“A” (The pin is not hardened and it would bend under the impact of the hammer.)

18. How can we separate pin connections?

“A” (We place a non−ferrous metal plug mating the nominal diameter of the pin against the opposite side on which the pin was driven in and begin with hammering on it.)

19. The length of a taper pin is important for producing a taper connection. What is to be taken into account when determining its length?

“A” (It must be 2 mm shorter than the thickness of all parts to be connected.)

20. Which basic principles of labour safety are to be considered

“A” when performing reaming work?

(Selection:
- fix the reamer firmly in the tap wrench
- never turn the reamers counterclockwise
- put down reamers carefully
- use lubricant and coolant for reaming.)

4. Application of the working technique of “Manual Reaming”

Based on the variants described in section 3, the exercises can be designed as a single instruction or divided into two stages. Both variants envisage the production of the same complex workpiece on which the trainees can practise this working technique. Based on the “Instruction examples for practical vocational training – manual reaming”, five workpieces with gradually increasing degree of difficulty can be produced. These “Instruction Examples” also comprise a list of materials (initial materials, working tools, measuring and testing tools, accessories) as well as the sequence of operations for the manufacture of such a workpiece. Also contained is an illustrative working drawing.

Thus, the trainees avail of all the necessary information to begin their exercise−related work.

Due to the high degree of difficulty encountered in the working technique of “Manual Reaming” the selection of instruction examples was mainly restricted to the manufacture of fitting bore holes. Only the instruction examples 2 and 5 are objects which can be used and which are characterised by complex processes (acquisition of new working techniques and consolidation of previously acquired skills).

The following hint for organising the work should be taken into consideration:

> The trainee has to do all the necessary work alone – from cutting the initial material up to the completion of the workpiece.

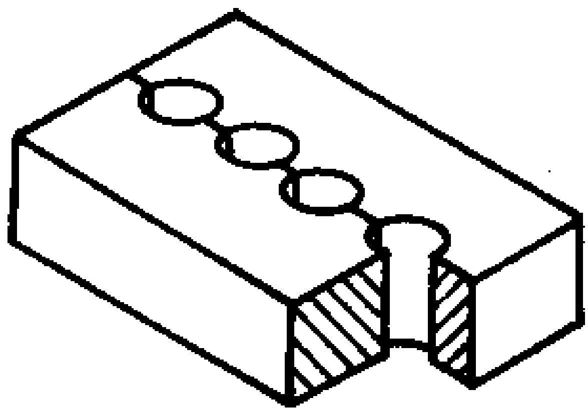
This is the only way to guarantee a just evaluation of the achievements.

If the proposed “Instruction Examples...” are not used for the exercises, it will be also possible to select other workpieces. In this case all the working techniques acquired earlier should be also practised when working on these pieces.

4.1. Instruction Examples

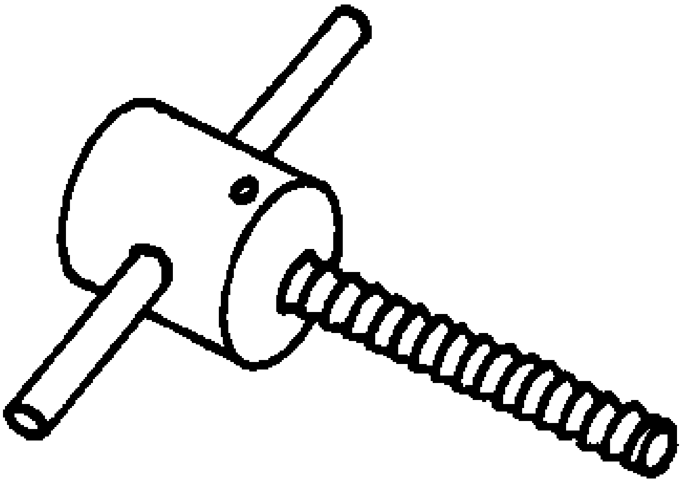
What follows is a brief description of the individual instruction examples in order to give a survey of the workpieces on which the previous knowledge can be employed:

Instruction example 8.1. Training workpiece with straight fitting holes



This is a training workpiece consisting of two square steel bars clamped together to be provided with straight fitting holes on the dividing line of the square steel bars. After this process the two components can be separated again. The trainees will now have an optical impression of the precisely finished bore hole walls.

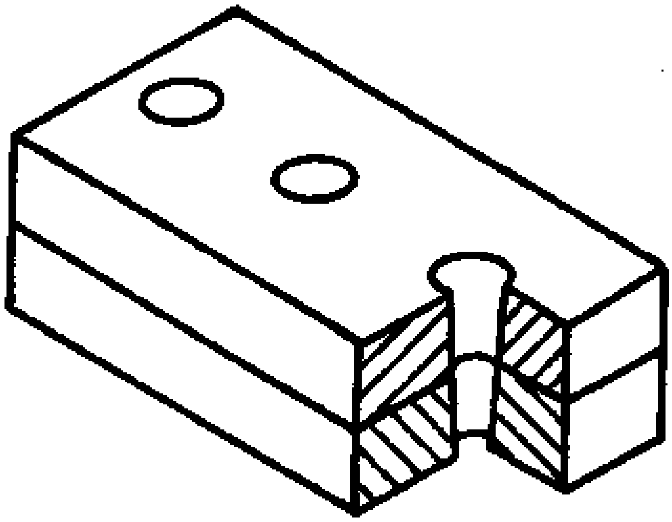
Instruction example 8.2. Screw lock



This exercise serves to practise reaming processes for fitting cylindrical pins in a press−fit manner.

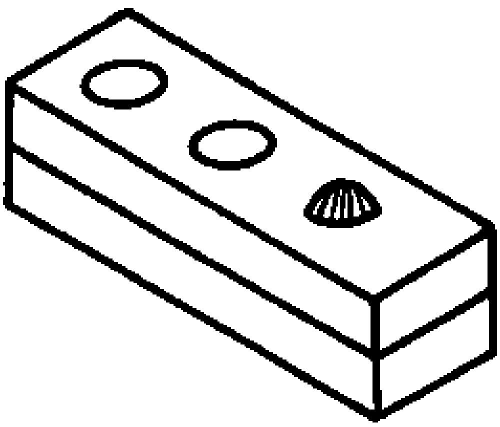
This part will be a component of a C−clamp which is to be completed by adding the components mentioned in the instruction examples 2.5., 7.6. and 9.5.

Instruction example 8.3. Training workpiece with tapered fitting holes



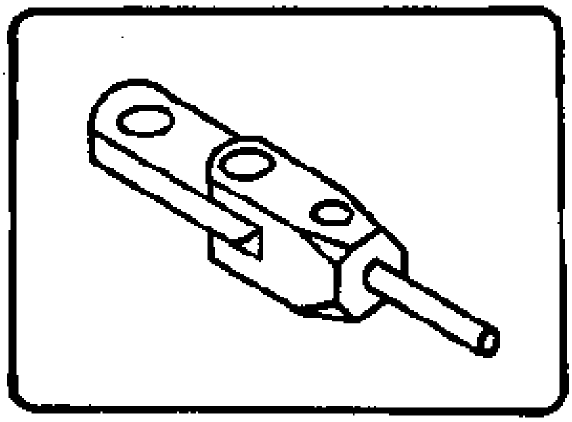
This is a workpiece consisting of two square steel bars clamped together which are to be connected by means of taper pins. Fitting−in the taper pins is performed pin by pin so that the firm fit can be checked properly.

Instruction example 8.4. Training workpiece for reaming rivet holes



Two metal sheets will be provided with bore holes and connected by means of a notched nail so that the bore holes are slightly offset. The trainees are to practise the rivet hole reamer technique in order to ream bore holes in such a way that the appropriate rivets will fit.

Instruction example 8.5. Joint



This exercise serves to practise cylindrical and tapered pin connections. Combined press− and clearance−type fits serve to produce rigid and movable connections which function together.

4.2. Criteria for practical training

It is recommended to determine some crucial points of evaluation and supervision. The following criteria can serve as a guideline

Operation no. 1 – clamping/fixing together

– Did the trainees select the appropriate clamping tool?

– Did the trainees prepare a pin connection by means of clamps in such a way that the fixing of the components to be connected will last throughout all the working operations?

Operation no. 2 – scribing and prick−punching

– Is the marking precise?
– Is the bore−hole centre sufficiently pre−punched?

Operation no. 3 – drilling

– Did the trainee choose the correct drill?
– Is the drill properly chucked and is the correct rotational speed selected at the machine?
– Is a large−size tapered bore hole pre−drilled in steps (considering the taper ratio)?
– Does the bore−hole diameter comply with the specified size?

Operation no. 4 – counterboring/countersinking

– Did the trainee use the 90° countersink?
– Did he set the correct rotational speed and were counterbore diameter and depth correct?
– Did the trainee countersink/counterbore both sides of a through hole properly?

Operation no. 5 – reaming

– Did the trainee choose the proper reamer?

– Does the trainee use the reamer properly, i.e. perpendicular to the plane?

– Does the trainee always turn the reamer clockwise and exert a slight pressure from above?

– Does the trainee use lubricants?

– Does the trainee observe the principle of cleaning the reamer from time to time?

– Does the trainee interrupt the reaming process in order to perform the preliminary fitting for taper–pin fittings?

Operation no. 6 – cleaning of bore holes

– Does the trainee remove chips and oil residues after reaming or does he try to check the hole without cleaning it?

Operation no. 7 – checking and pinning

– Does the trainee choose the correct limit plug gauge and use it properly for checking cylindrical fits?

– Does the trainee check both sides of a straight through hole?

– Does the trainee fix the pin appropriately i.e. using an aluminium hammer or locksmith's hammer and a non–ferous metal plug?

– Do the pins fit well after pinning?

– Do the pin connections last after the removal of the clamps?

Prior to the start of the exercises the trainees should be made familiar with the main points of evaluating the exercises.

5. Captions and legends of the "Manual Reaming" transparencies series

Transparency no. 8.1. Straight reamers

(1) hand reamer – straight–fluted
(2) hand reamer – helical–fluted
(3) machine reamer – straight–fluted
(4) machine reamer – helical–fluted
(5) adjustable reamer

Transparency no. 8.2. Taper reamers

(1) taper reamer (ratio 1:50) – straight–fluted
(2) taper reamer (ratio 1:50) – helical–fluted
(3) rivet–hole reamer (ratio 1:10)
(4) serial taper reamers
4.1.– roughing reamer
4.2.– semi–finishing reamer
4.3.– finishing reamer

Transparency no. 8.3. Comparison of common reamers

(1) hand reamer (straight)
(2) machine reamer (straight)
(3) taper reamer (ratio 1:50)
1. lead
2. cutting portion
3. neck
4. shank
5. square
6. nominal diameter

Transparency no. 8.4. Process of producing a taper–pin connection

(1) making a bore hole
(2) using a countersink of 90°
(3) reaming with taper reamer
(4) pre−fitting of tapered pin
(5) proper pinning of tapered pin

1. pre−fit dimension.

Thread Cutting by Dies and Taps – Course: Techniques for Machining of Material – Instruction Examples for Practical Vocational Training.

Table of Contents

Thread Cutting by Dies and Taps – Course: Techniques for Machining of Material – Instruction Examples for Practical Vocational Training.

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Lehrbeispiele für die berufspraktische Ausbildung
"Gewindeschneiden mit Schneideisen und Gewindebohrer"

Author: Horst Köth

Institut für berufliche Entwicklung e.V.
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13187 Berlin

Order No.: 90–33–3205/2

Introduction

This material presents four selected instruction examples for applying and consolidating knowledge and skills in "thread cutting by dies and taps".

The necessary materials, tools, measuring and checking means, and accessories have been indicated for each instruction example to ease preliminary work and execution. In instruction example one the steel has been designated in "megapascal" (MPa) units.

Furthermore, basic knowledge which is required in addition to facts about "thread cutting by dies and taps" is set out. We recommend that all basic knowledge is repeated prior to commencing operations.

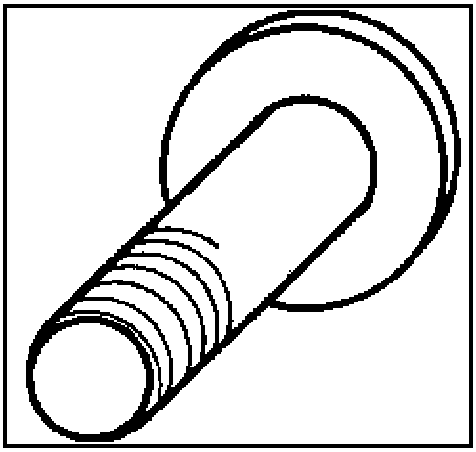
The respective work sequences feature all steps required to turn out a certain workpiece. Adhere to this sequence in order to attain good quality.

Each instruction example has attached a workshop drawing from which the desired shapes and dimensions of the workpiece can be determined. The following table shows dimensional deviations where no tolerances are involved:

Nominal dimension	Permissible deviation in mm
0.5 – 6	± 0.1
6 – 30	± 0.2
30 – 120	± 0.3
120 – 315	± 0.5

Instruction example 5.1. Spring bolt

This example focuses attention on thread cutting by dies on simple cylindrical workpieces.



<u>Material</u>

stand. 42 (steel with a tensile strength of up to 420 MPa)

<u>Dimensions</u>

Ø 38 x 96

<u>Tools</u>

recessed right−side cutting turning tool, die M 20, chucking spanner

<u>Measuring and testing tools</u>

vernier caliper, thread ring gauge M 20

<u>Accessories</u>

extendable chucking jaws, rotating tip, log measure 45 mm, coolants and cutting compounds

<u>Required previous knowledge</u>

drawing comprehension, measuring and testing, thread cutting by hand, longitudinal turning and surfacing, possibilities and employment of chucking and accessories

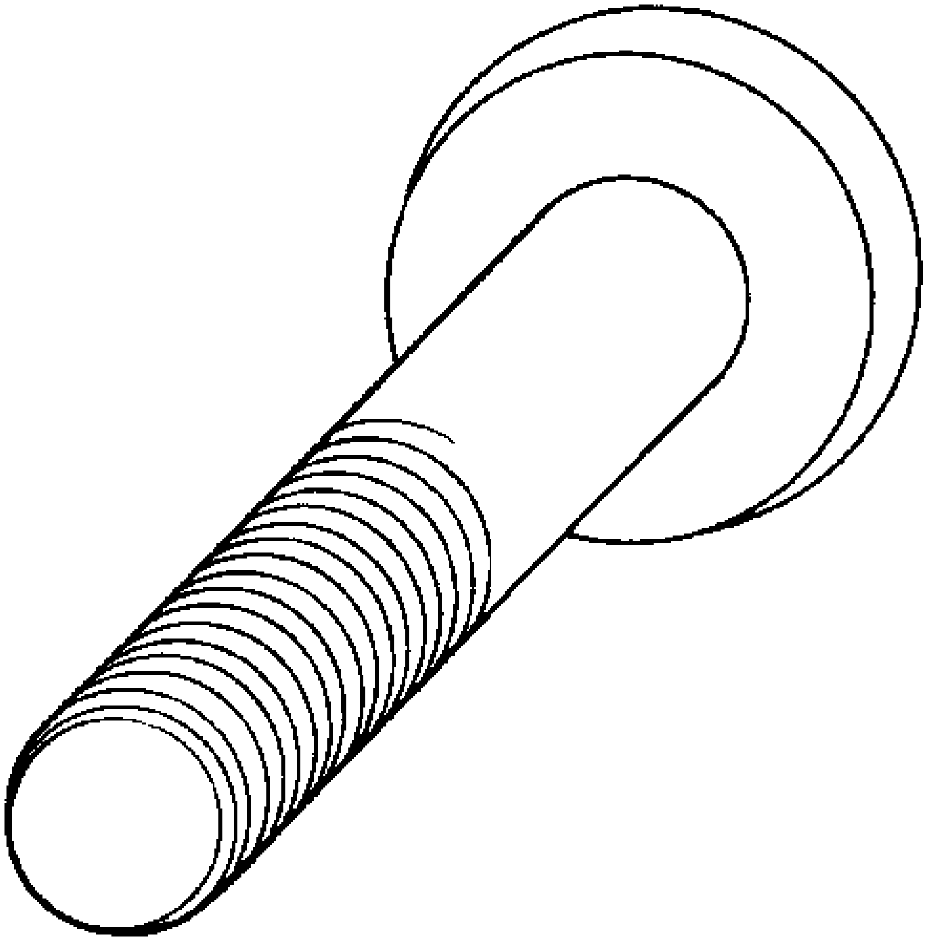
<u>Workshop drawing explanations</u>

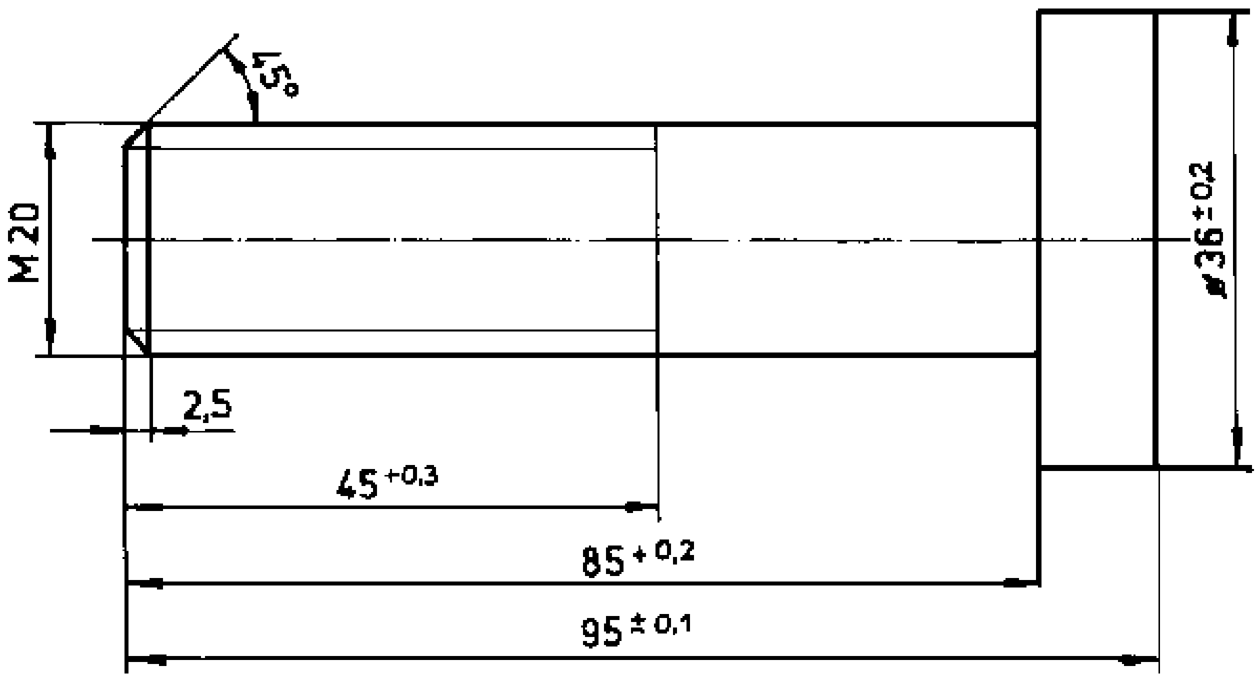
M 20: M = metric thread — All surfaces have been machine−finished.

20 = nominal diameter

Sequence of operations	**Remarks**
1. Dimensional inspection	
2. Clamp workpiece	Clamping in extendable jaws to Ø 36 mm
3. Clamp tool	
4. Set the cutting values for longitudinal turning	

5. Yield thread Ø M 20	Clamping – rotational tip in diameter 20 mm x 45 mm to 19.8 mm as, whilst cutting, the external diameter increases by about 1/10 of the thread increment amount. Deburring of the workpiece 2.5 mm x 45°!
6. Set the cutting values for thread cutting	For steel v = 3 – 4 m min^{-1}
7. Position die	Straight positioning by pressing down the quill
8. Cut the thread	It is sensible to cut a few turns by hand whilst the machine is switched off. Ensure proper cooling and lubrication. Keep the chip chambers clean. Ensure that the tool frame of the die holder is supported. Prior to machine reverse also turn back several times by hand.
9. Unload the workpiece	
10. Dimensional inspection	





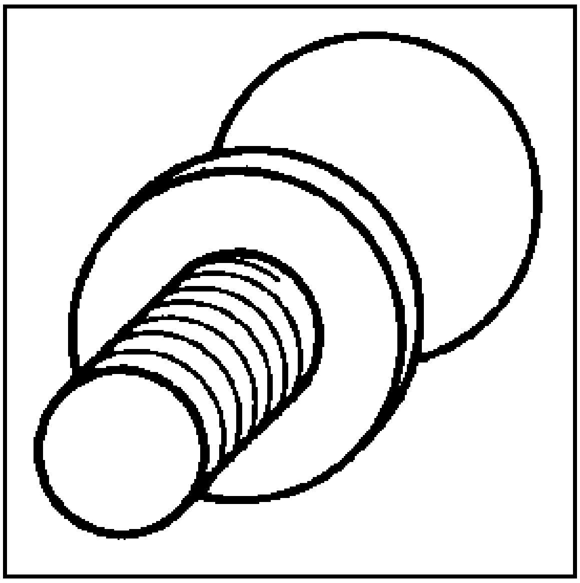
5.1.

Spring bolt

3205

Instruction example 5.2. Ball handle

In this example thread cutting by dies on recessed cylindrical workpieces is practised.



Material

16 Mn Cr 5 (low−alloyed steel, alloy components: 0.16 % carbon, 1.25 % manganese, less than 1 % chrome, rest iron)

Dimensions

Ø 42 x 87

Tools

offset right−hand cutting turning tool, die M 24, clamping spanner

Measuring and testing tools

vernier caliper, thread ring gauge M 24

Accessories

extendable chucking jaws, coolants and lubricants

Required previous knowledge

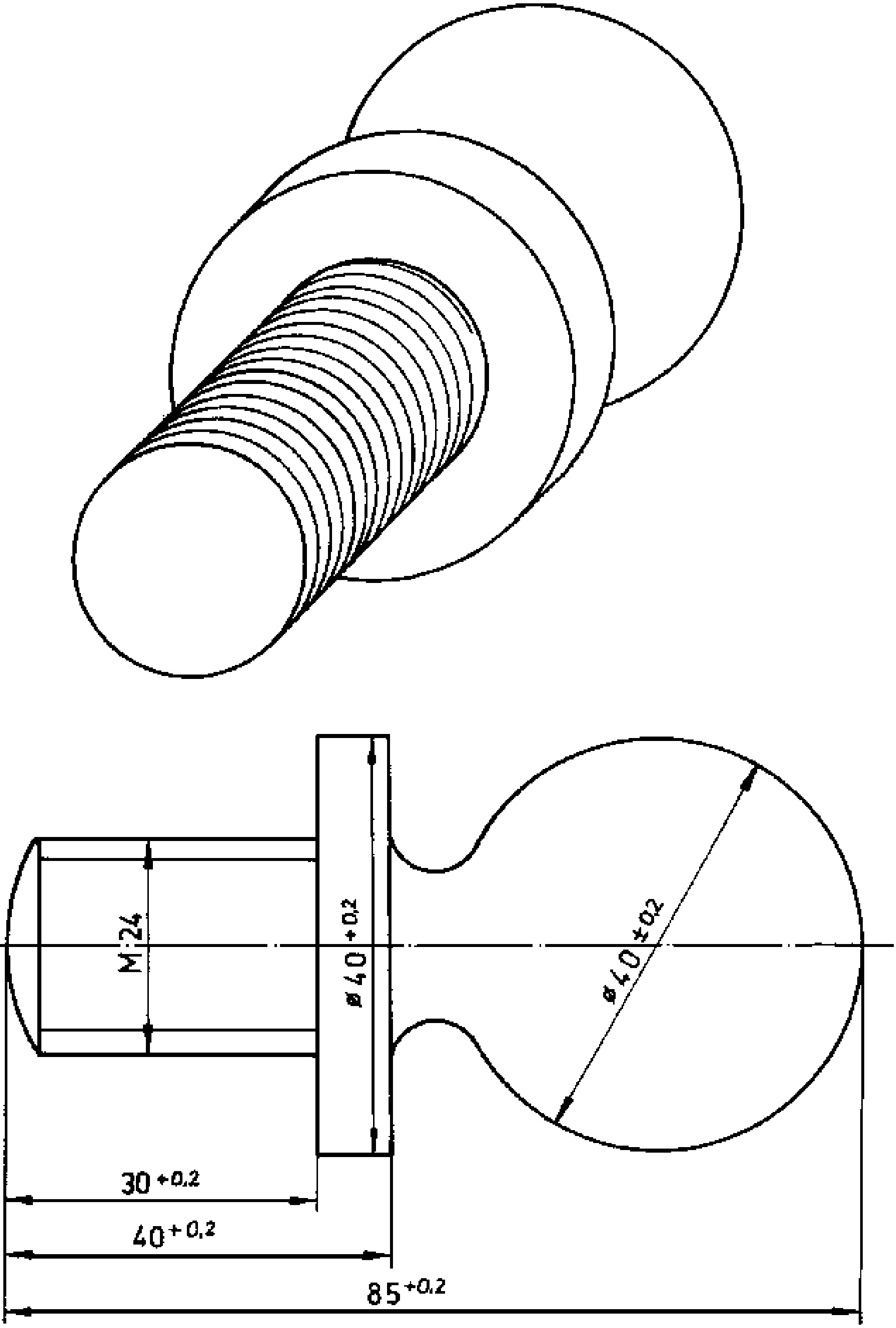
drawing comprehension, measuring and checking, thread cutting by hand, longitudinal turning and surfacing

Workshop drawing explanations

M 24:	M= metric thread	All surfaces have been machine−finished.
	24 = nominal diameter	

Sequence of operations **Remarks**

1. Dimensional inspection	
2. Clamp workpiece	Clamping in extendable jaws to Ø 40 mm (collar)
3. Clamp tool	
4. Set the cutting values for longitudinal turning	
5. Yield thread Ø M 24	Clamping in extendable chucking jaws. Diameter 24 x 30 mm to 23.7 x 30 mm as, whilst cutting, the external diameter increases by about 1/10 of the thread increment amount. Deburring of the workpiece.
6. Set the cutting values for thread cutting	For steel v = 3 – 4 m min^{-1}.
7. Position die	Straight positioning by pressing down the quill
8. Cut the thread	It is sensible to cut a few turns by hand whilst the machine is switched off. Ensure proper cooling and lubrication. Keep the chip chambers clean. Switch off the machine about 2 – 3 mm before attaining the collar Ø 40 mm and cut the last turns by hand.
9. Unload the workpiece	
10. Dimensional inspection	



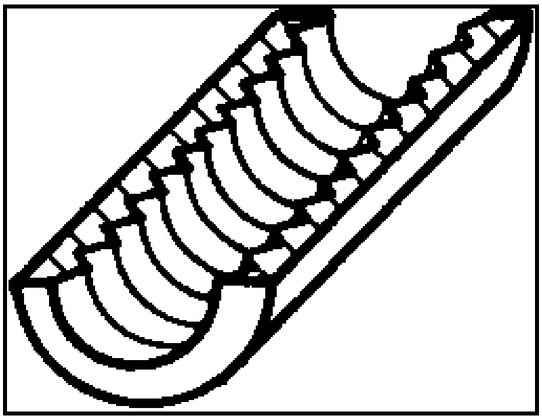
5.2.

Ball handle

3205 8

Instruction example 5.3. Lance

In this example particular attention is given to practising thread cutting by tap on through holes.



Material

35 Cr Al 6 (low−alloyed steel, alloy components: 0.35 % carbon, 1.5 % chrome, 1 % aluminium, rest iron)

Dimensions

Ø 52 x 87

Tools

bent right internal roughing lathe, clamping spanner, one set of hand taps M 30

Measuring and testing tools

internal thread gauge M 30, vernier caliper

Accessories

extendable chucking jaws, tap wrench, coolants and lubricants

Required previous knowledge

drawing comprehension, measuring and checking, thread cutting by hand, centring, boring, counter−boring

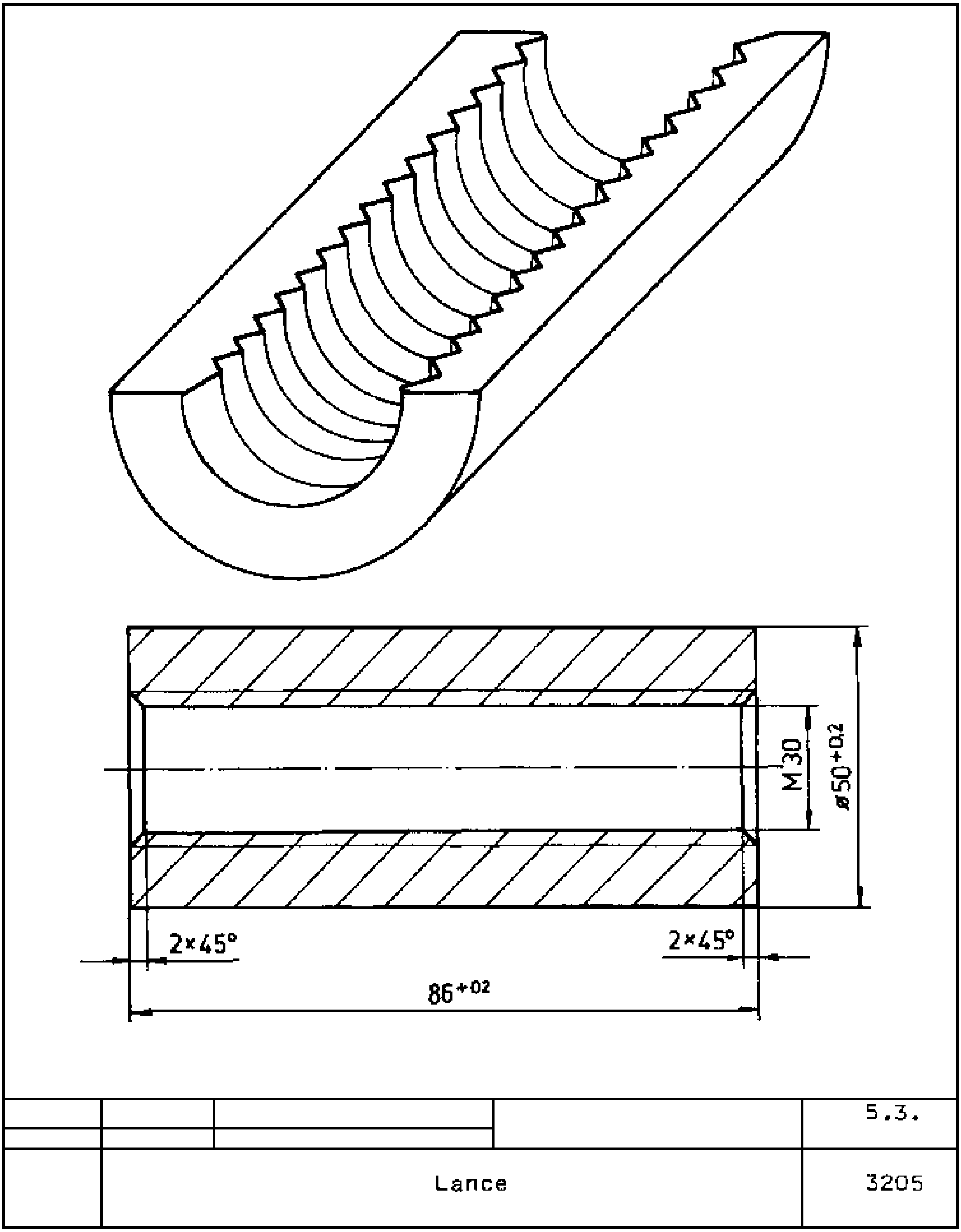
Workshop drawing explanations

M 30: M = metric thread
30 = nominal diameter

All surfaces have been machine−finished.

Sequence of operations	**Remarks**
1. Dimensional inspection	
2. Clamp workpiece	Clamping in extendable chucking jaws. Ensure true running.

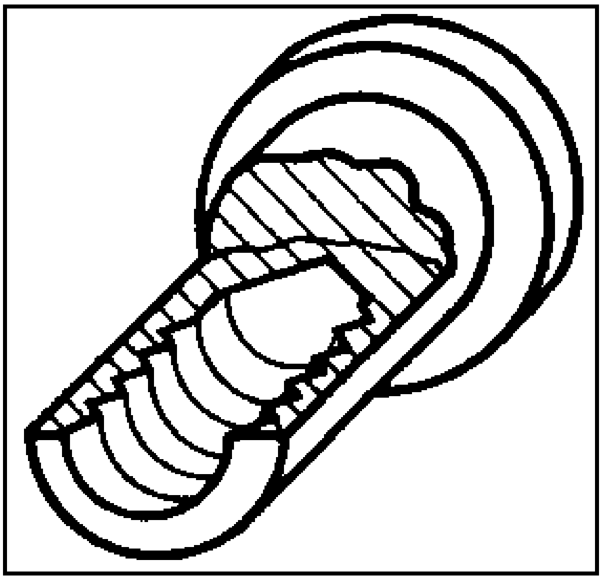
3. Clamp tool	Use prismatic base as lathe has a round shank.
4. Set the cutting values for boring	
5. Yield thread Ø M 30	Bore to Ø 26.7. Material is compressed during thread cutting resulting in a bore diameter decrease. Debur 2 mm x 45°!
6. Set the cutting values for thread cutting	For steel v = 4 – 15 m min^1 according to material and thread size
7. Position tap	Select manual tap. Position the railstock tip to centring of tap.
8. Cut the tap	Sequence – entering tap, plug tap thread, plug (third) tap. Initially use the plug tap and plug (third) tap to undertake several turns by hand so that the tap sets to the prenotched thread. Ensure tap wrench support. Keep the chip grooves clean by turning back the tap several times. Ensure proper cooling and lubrication. Indicate possible accident hazards 1
9. Unload the workpiece	
10. Dimensional inspection	



Lance

Instruction example 5.4. Piston

In this example thread cutting is undertaken in blind holes by means of taps.



Material

16 Cr Mo 4 (low−alloyed steel), alloy components: 0.16 % carbon, 1 % chrome, less than 1 % molybdenum, rest iron.

Dimensions

Ø 45 x 93

Tools

spiral drill Ø 17.5 mm, machine tap M 20, chucking spanner

Measuring and testing tools

vernier caliper, steel measure

Accessories

extendable chucking jaws, tap wrench, reducing collars, coolants and lubricants

Required previous knowledge

drawing comprehension, measuring and checking, thread cutting by hand, centring, boring, counter−boring

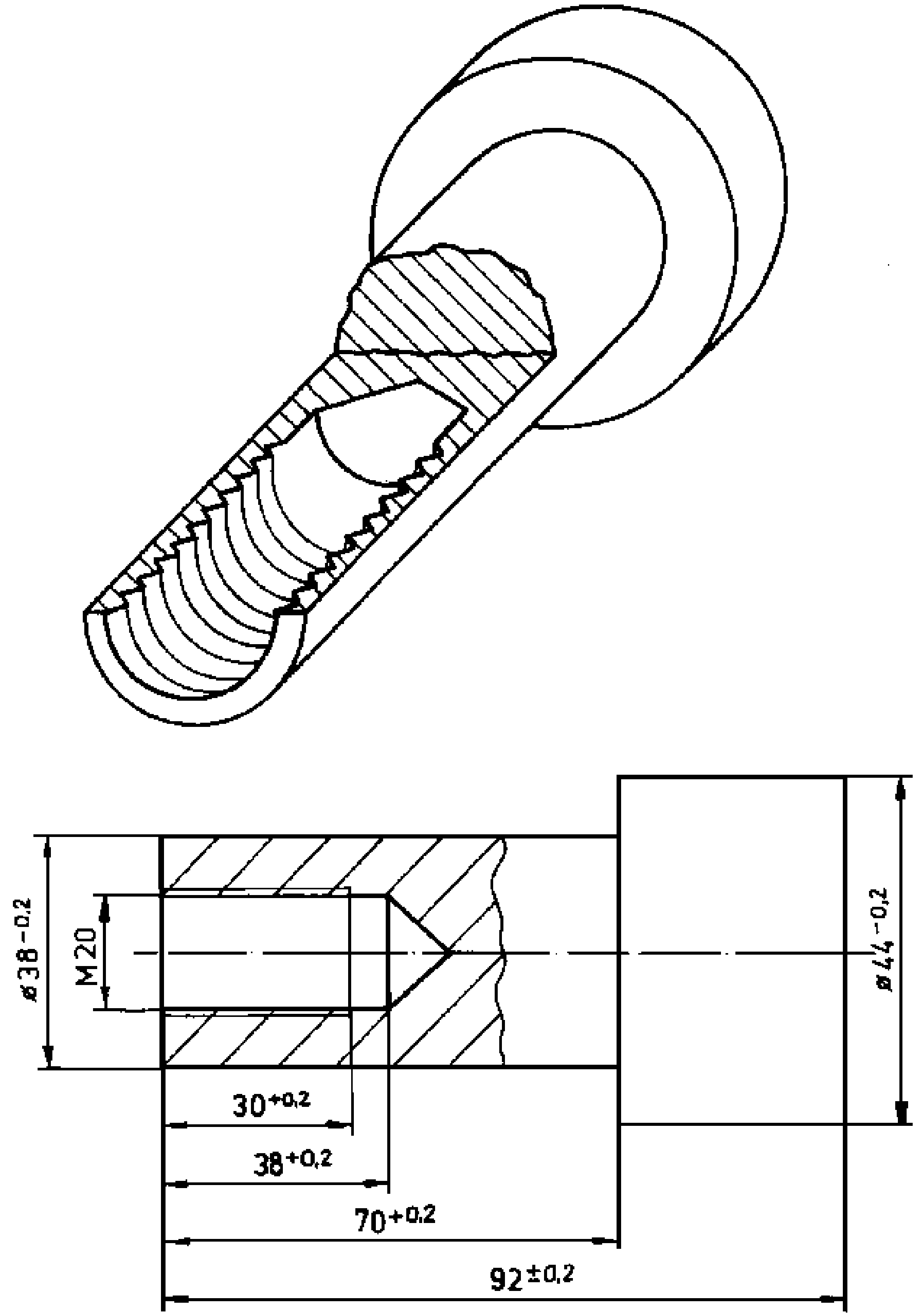
Workshop drawing explanations

M 20: M = metric thread
20 = nominal diameter

All surfaces have been machine−finished.

Sequence of operations	Remarks
1. Dimensional inspection	
2. Clamp workpiece	Clamping in extendable jaws to Ø 38 mm

3. Clamp tool	Fix spiral drill to tailstock by means of reducing collars
4. Set the cutting values for boring	Spiral drill is made of quick–cutting steel v = 25 – 50 m min^{-1}
5. Undertake a Ø 17.5 x 38 mm bore	Ensure proper cooling. Check bore depth with steel measure on the quill. Debur the workpiece.
6, Set the cutting values for thread cutting	For steel v = 4 – 15 m min^{-1} heeding the material and thread size
7. Position tap	Select machine tap. Position the railstock tap to centring of tap.
8. Cut the tap	Ensure tap wrench support. Check on proper alignment through the railstock tip. Keep the chip grooves clean by turning the tap back several times. Ensure proper cooling and lubrication. Ensure adherence to 30 mm length.
9. Unload workpiece	
10. Dimensional inspection	



		5.4.
	Piston	3205

Thread Cutting by Dies and Taps – Course: Techniques for Machining of Material. Trainees' Handbook of Lessons

Table of Contents

Thread Cutting by Dies and Taps – Course: Techniques for Machining of Material. Trainees' Handbook of Lessons

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Arbeitsmaterial für den Lernenden
“Gewindeschneiden mit Schneideisen und Gewindebohrer”

Author: Horst Köth

Institut für berufliche Entwicklung e.V.
Parkstraße 23
13187 Berlin

Order No.: 90–35–3205/2

1. Purpose and importance of thread cutting by dies and taps

Threads are disconnectable, solid connections of machine parts. Where the parts are held against one another such threads are called fastening threads, i.e. vee–threads. Similarly, where the parts are set in motion towards each other they are known as travelling threads, i.e. acme threads (in the leadscrew of the lathe).

The two threads each consist of a couple of parts, namely an internal thread and an external thread. The mode of operation is determined by shape, diameter and pitch of the thread. Thread cutting is a sort of chip removal and can be undertaken by mean of a die, tap or lathe. Thread cutting by dies and taps is very easy and serves to manufacture vee–threads which, in turn, are perfectly adequate for moat fastening threads regarding:

- dimensional accuracy,
- forming,
- top surface quality, and
- sound fitting.

Vee–threads are either metric or inch–measure screw threads (Whitworth threads)

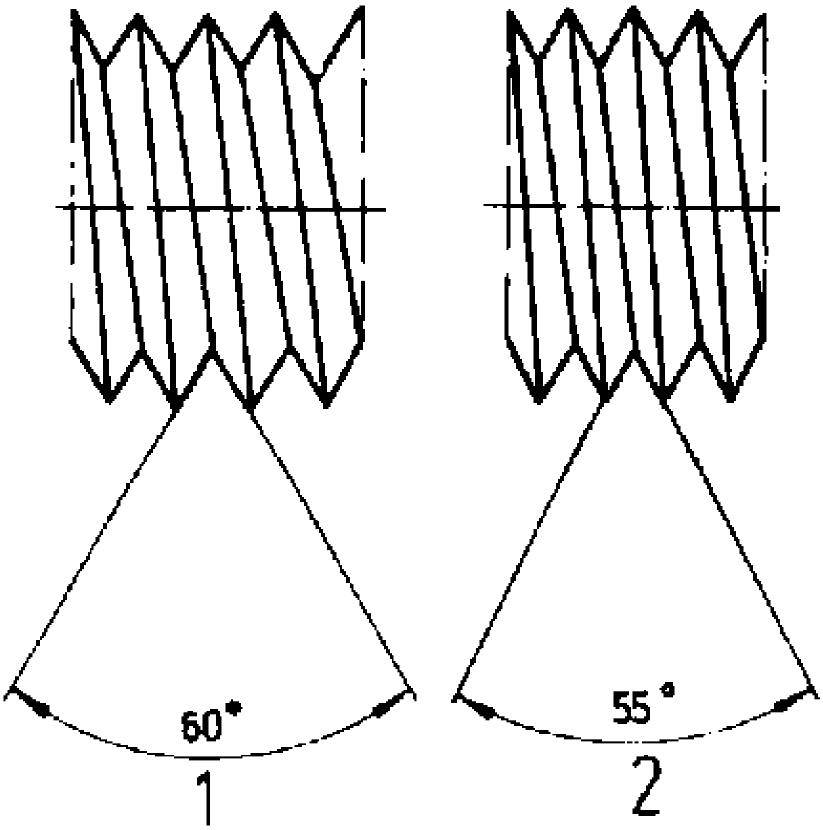


Figure 1. Different flank angles in vee−threads

1 metric thread, 2 Whitworth thread

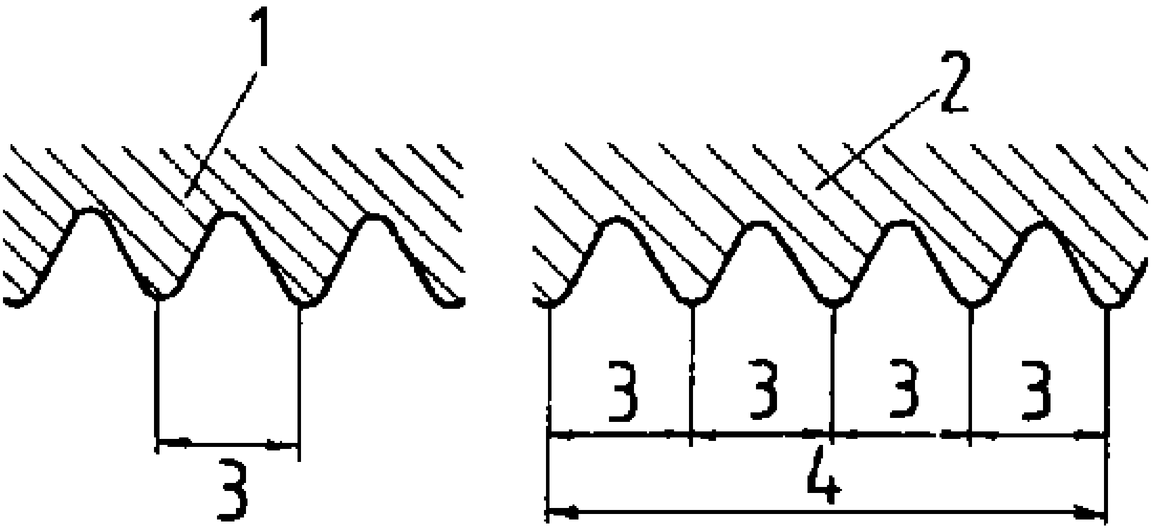


Figure 2. Thread increase

1 metric thread (thread increase in mm), 2 inch thread (thread increase = ¼ inch = 4 turns = 1 inch), 3 thread increase, 4 = one inch

What are the differences between a metric thread and a Whitworth thread?

____
____
____

2. Construction and types of dies and taps

Thread cutting on the external cylindrical surface is made by means of a die. The internal cylindrical surface is processed by using a tap.

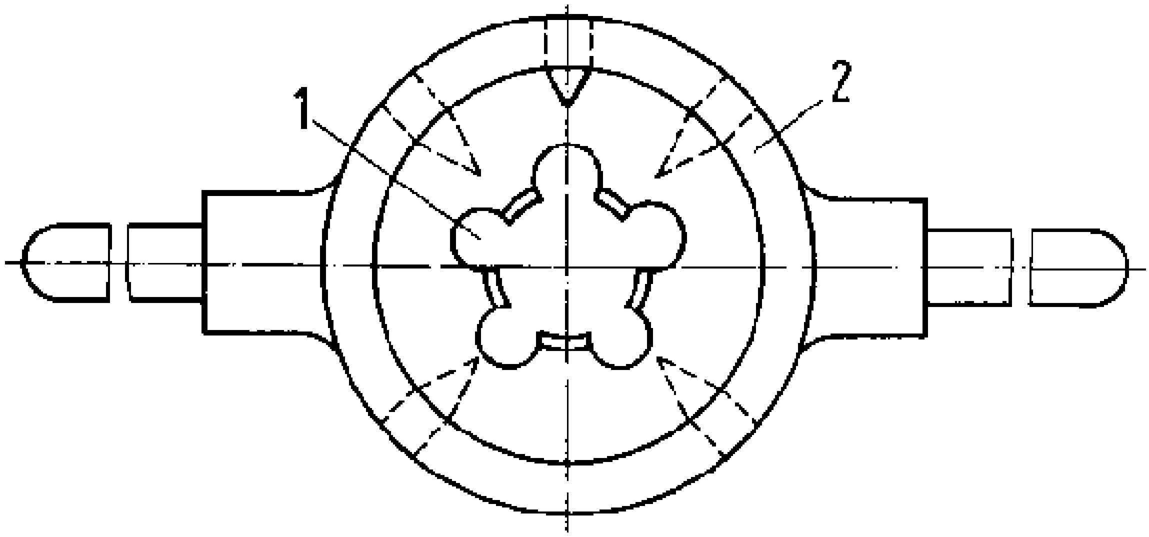


Figure 3. Die with holder

1 die, 2 holder

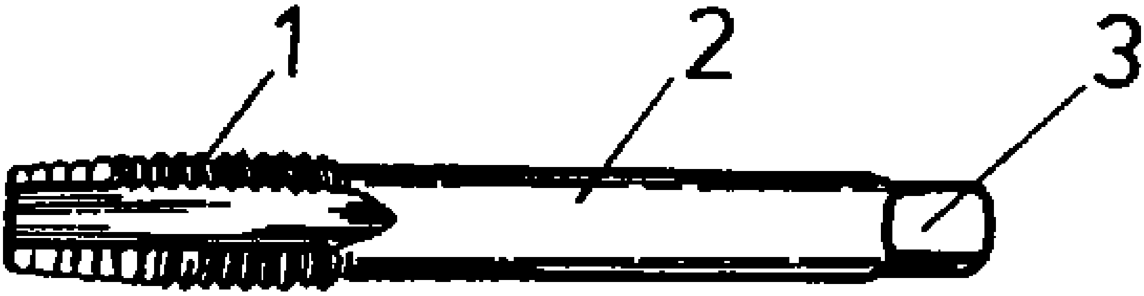


Figure 4. Machine tap

1 tap head (with entering, plug and plug third taps), 2 tap shank, 3 square to hold the tap wrench

The die consists of a die body, chip chambers and starting taper. The rake angles are formed by the chip chambers. Chip removal is made by means of the starting tapers produced by tapered counter–borings. The remaining thread turns are used for ensuring alignment and smoothing.

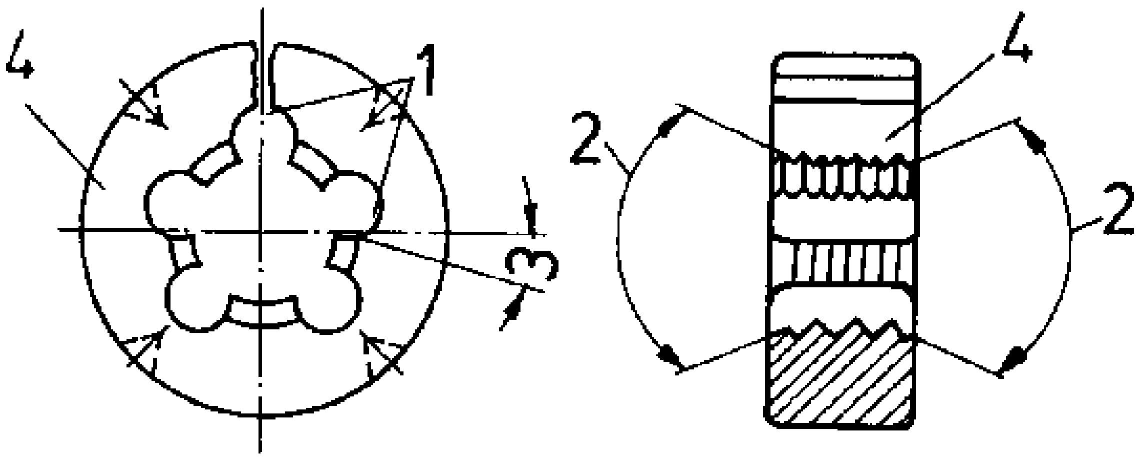


Figure 5. Die arrangement

1 chip chambers, 2 starting taper, 3 chip angle, 4 die body

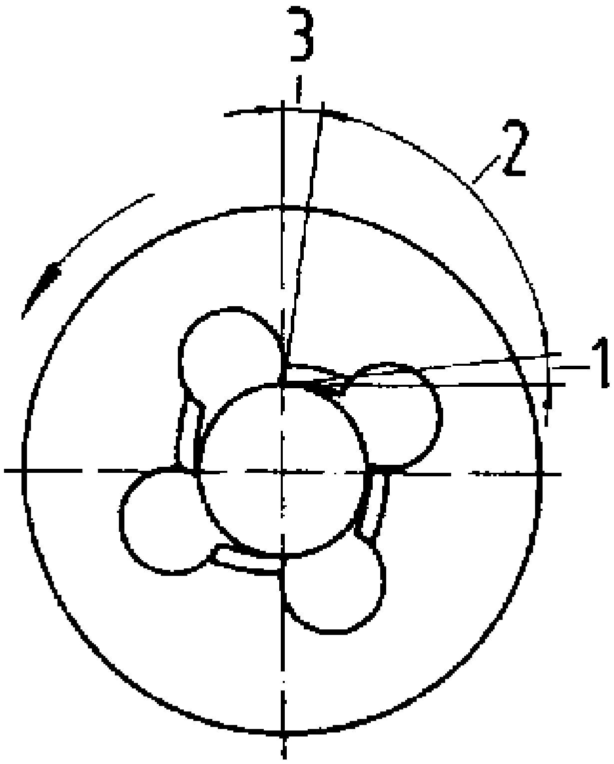


Figure 6. Die and tap angles

1 free angle, 2 taper angle, 3 chip angle

What is the purpose of the rake angle and which are its functions?

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The following types are distinguished:

- open dies,
- closed dies, and
- prenotched dies.

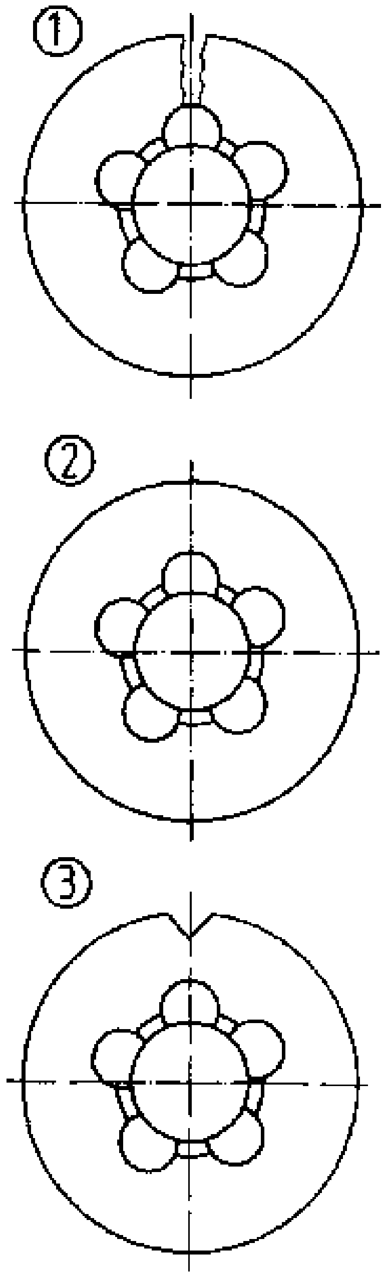

Figure 7. Types of dies

① open die, ② closed die, ③ prenotched die

A closed die cannot be adjusted. The die featuring a groove−like prenotching may initially be used like its closed counterpart.

If required, the web is removed by grinding and it is then used like an open die.

The open die can also be varied in diameter, that is to say either increased or decreased.

The following taps are distinguished:

– hand tap, and
– machine tap.

Cutting generally pertains to entering, plug and plug (third) taps.

In the case of manual taps, one distinguishes between

– entering tap,
– plug tap, and

– plug third tap.

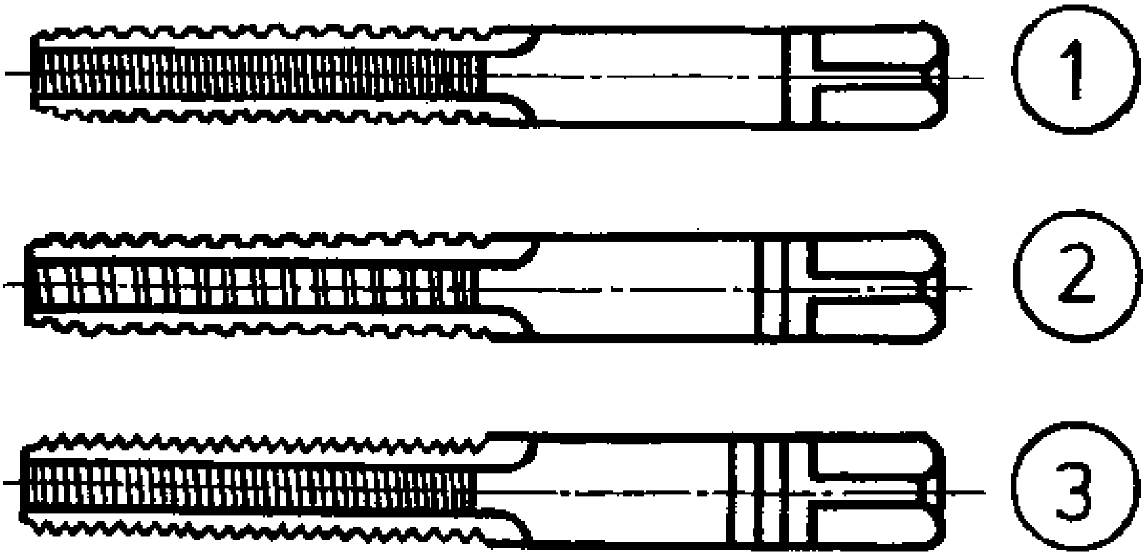

Figure 8. Hand tap

① entering tap
② plug tap
③ plug third tap

Thereby, the globe–like starting taper ensures proper chip removal, the remaining thread section serves to guarantee alignment.

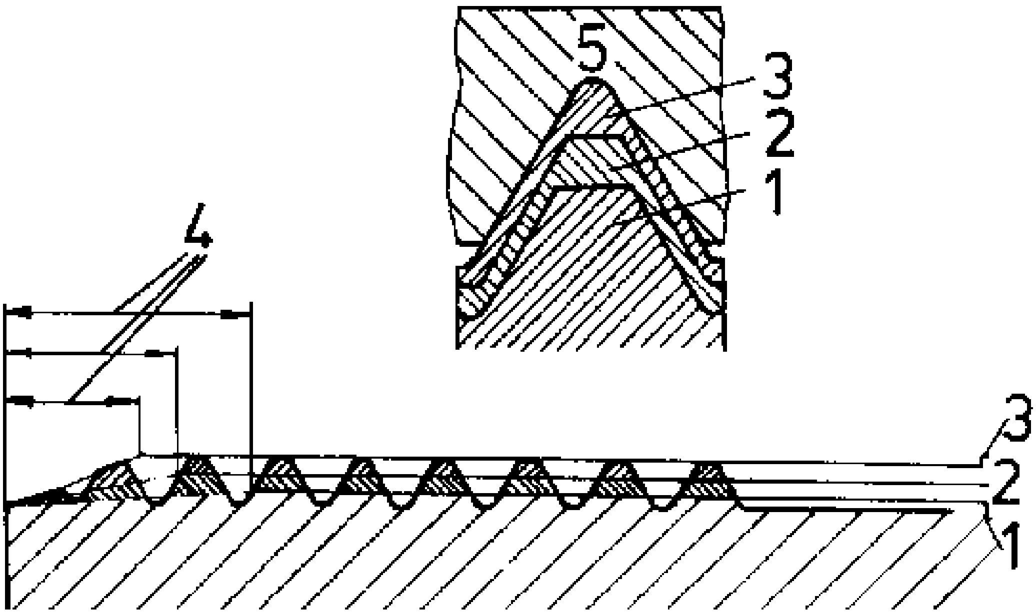

Figure 9. Starting taper of the hand tap

1 entering tap, 2 plug tap, 3 plug third tap, 4 starting taper, 5 internal thread

Plug and plug third taps are turned in a little by hand so that the tap fits into the prenotched thread.

In the case of machine taps (see Fig. 4) all cutting is made by only one tap with a relatively short starting taper.

Nut taps are used in order to cut the thread with one cut in short through holes or in nuts.

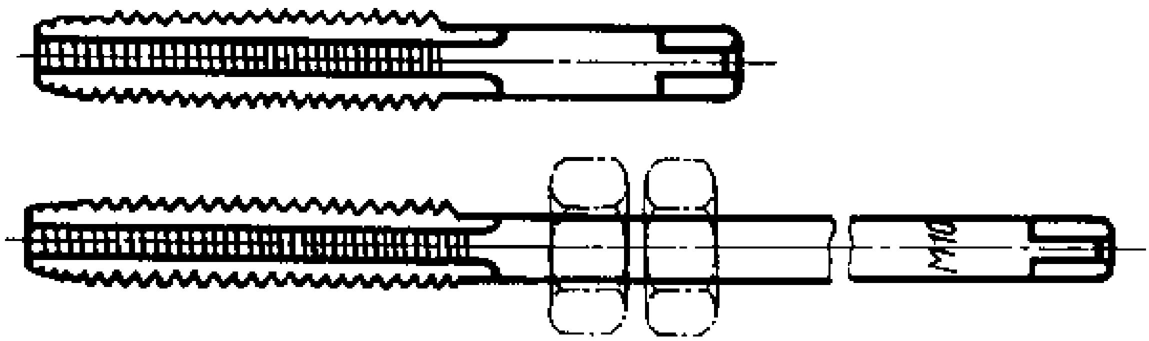

Figure 10. Machine internal tap

The drills combine entering, plug and plug third taps in one long starting taper.

The starting taper is five to sixfold on the thread pitch.

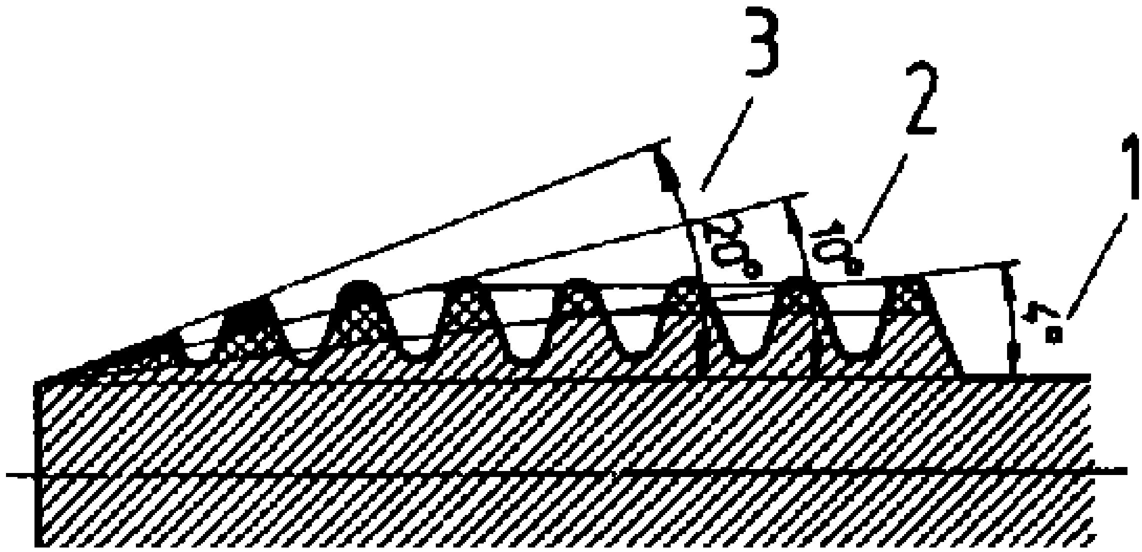

Figure 11. Starting taper of the machine tap

1 entering tap, 2 plug tap, 3 plug third tap

Which types of dies are known?

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____

____

Which are the principal parts of dies and taps?

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____

3. Preparations for thread cutting by dies and taps

Prior to thread cutting by dies and taps, position in readiness and in proper order all required tools and auxiliary means, allowing so quickest possible access times.

In this connection, pay attention to the following rules:

– Check that all tools function properly; do not use defect tools.

– Working means to be used must not be stacked one above the other.

– Place all measuring and testing tools at the places provided therefore.

– Lay aside tools only when properly cleaned.

– Select all necessary auxiliary means in line with the work assignment and position solely on the provided supports.

Which parameters must be followed when checking the functionality of the tools?

____
____
____

The setting–up of the lathe is mainly made according to the following points:

– Chucking the workpieces for thread cutting

• Extending soft chuck jaws as, normally speaking, the lathe parts to be processed have already been preworked. Extending the chuck jaws ensure the true running of the parts and the workpiece surfaces are not impaired.

• Checking the proper dimensional preparation of the thread diameter and deburring.

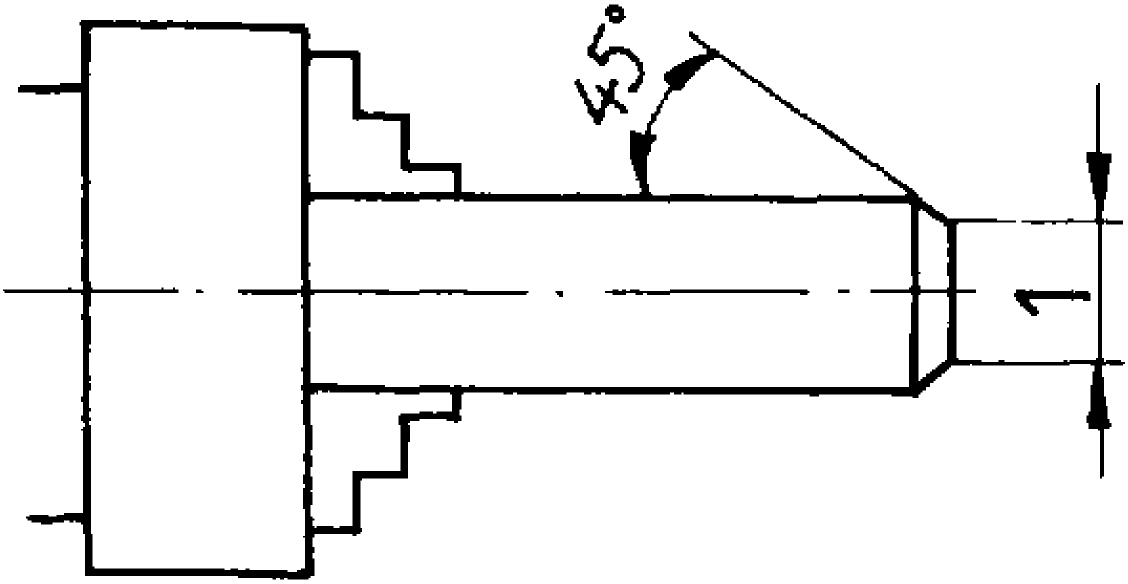

Figure 12. Deburring the workpiece

1 minor diameter

The thread diameter roust be turned about 1/10 smaller than the thread pitch as, whilst cutting, the tool somewhat compresses the material, pressing it outwards. Consequently, the external diameter increases and the die may tear out the thread turns.

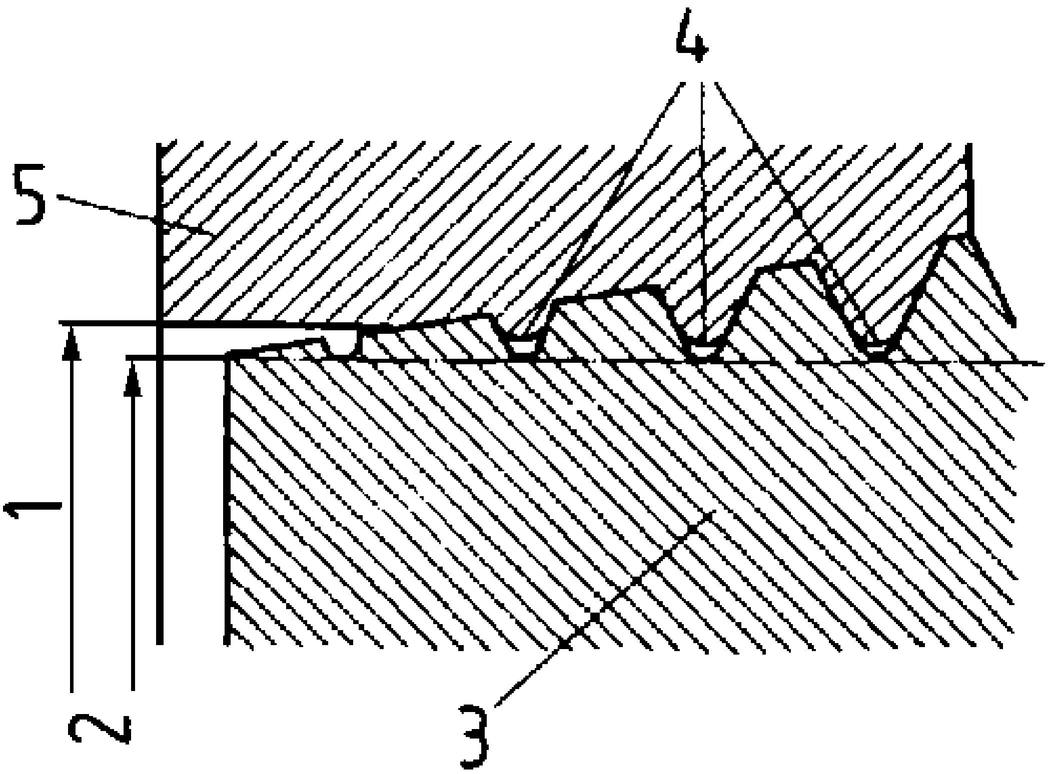

Figure 13. Compression during thread cutting (1/10 greater pitch)

1 minor diameter of the bore, 2 thread minor diameter, 3 tap, 4 compression, 5 workpiece

<u>Example:</u>

Thread M 16
– thread increase 2 mm
1/10 of 2 mm a 0.2 mm
the thread diameter is turned to 15.8 mm

A thread M 30 is to be cut on a shaft. What must be the nominal diameter of the turn?

____
____
____

If the diameter is too small the thread cannot be fully cut. Sound deburring ensures a faultless starting taper. Precise true running of the workpiece is the precondition for a uniform starting taper of the thread turns.

Why must the nominal or minor diameters when thread cutting be 1/10 less or greater than the corresponding increase?

____
____
____

– Clamping the tools for thread cutting

• The die is fixed to a die capsule and then, together with the capsule, accommodated in a die holder (or directly in the die holder).

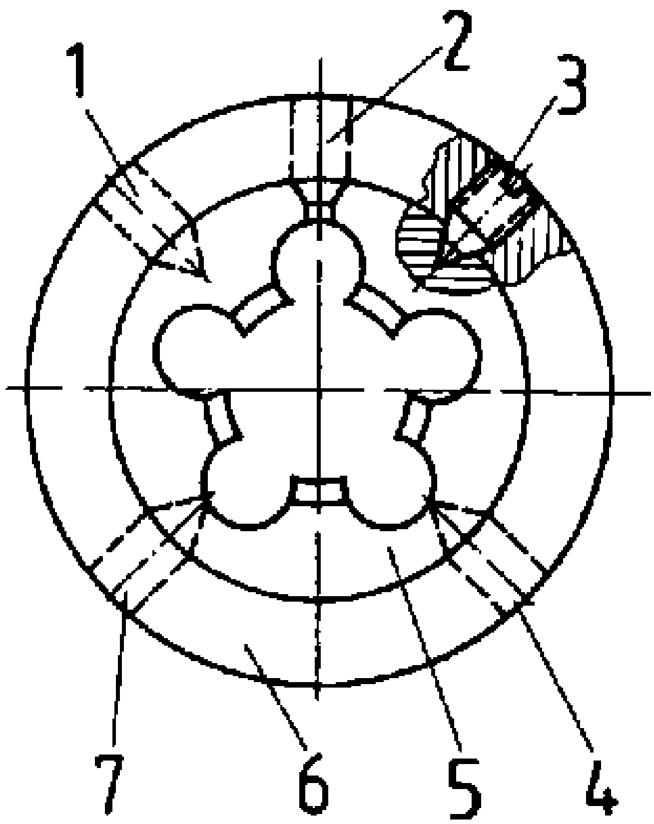

Figure 14. Die capsule

1 clamping nut, 2 expanding nut, 3 clamping nut, 4 holding nut, 5 die, 6 die capsule, 7 holding nut

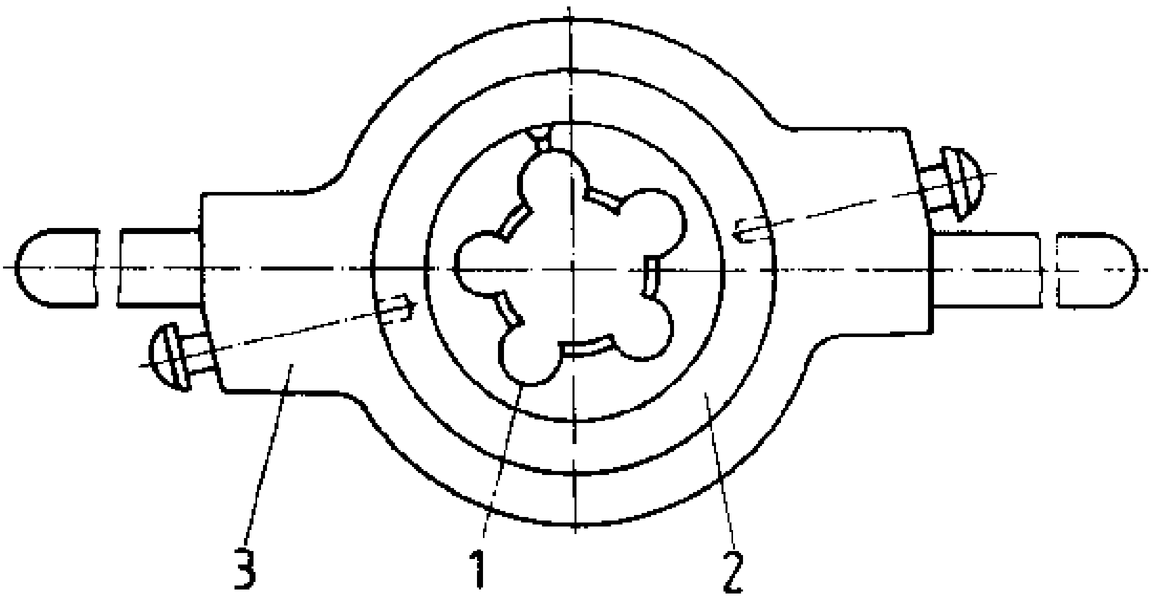

Figure 15. Die holder with capsule

1 die, 2 die capsule, 3 die holder

• The die holder inclusive of the capsule and die must be thoroughly cleaned so that the front surfaces are positioned properly and in a distinctly angular manner.

• The expanding screw roust mesh into the slot of the die. The expanding screw opens the die whilst the adjusting screw closes it (see Fig. 12).

• Use an unhardened thread bolt to set the die.

• A support for the die holder is chucked in the tool holder.

• The support for the die or tap wrench holder must be securely chucked and selected according to the thread length.

• The tailstock quill is brought into working position (Fig. 14) whereby special attention must be given to quill cleanliness.

• When thread cutting by a tap, the tap wrench is positioned on the tap square.

• When thread cutting by a tap ensure correct centring and tailstock middle−positioning.

− Set the cutting values.

Generally speaking, low cutting speeds are selected because of the substantial cutting operation (entering, plug tap and plug third tap in one work sequence), coupled with complicated chip removal. The selected cutting speed depends on the workpiece material and the thread size. When using a die on steel workpieces the cutting speed is 3 – 4 m min^{-1} and 4 – 15 m min^{-1} when employing a tap.

Which rotational speed shall be selected where a thread M 24 x 100 is required for 100 bolts given an St. 60 material?

Formula:

$$v = \frac{d \cdot \pi \cdot n}{1000} \text{ m min}^{-1}$$

$$n = \frac{v \cdot 1000}{d \cdot \pi} \text{ min}^{-1}$$

Calculation:

____
____
____

Explain your reasons for selecting the speed?

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____
____

Why is only a low speed chosen when thread cutting by a die and tap?

____
____
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4. Thread cutting by dies on simple cylindrical workpieces

Thread cutting by dies produces an external thread. The work−pieces are processed on the external surface.

− Operations are carried out in chucked conditions.

− Often extended chuck jaws are employed in order to ensure true workpiece running and not to damage the surface of the pre−worked parts.

− The die is positioned in the die holder.

− The die is positioned by means of the quill.

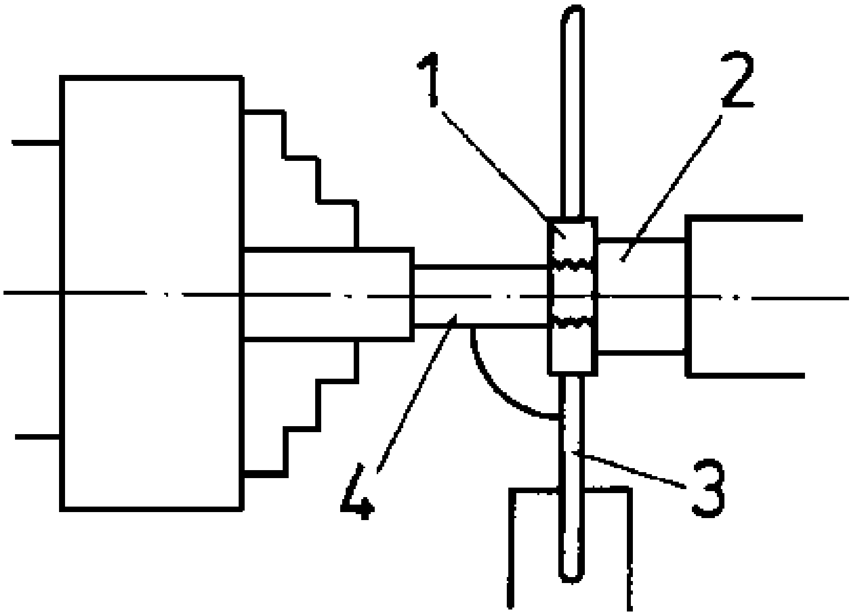

Figure 16. Positioning the die

1 die, 2 quill, 3 support for die holder, 4 workpiece

– The first thread turns must be cut by hand.

– After the initial cut machine processing follows with the help of a support for the die holder. (see Fig. 14)

– Ensure proper cooling and lubrication.

– The chip chambers must always be kept clean.

– Turn back the die by hand after having completed the work sequence.

– The thread is checked by means of a thread ring gauge.

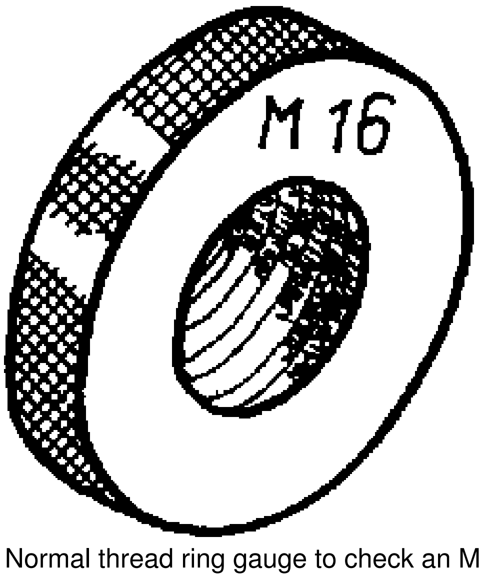

Figure 17. Normal thread ring gauge to check an M 16 thread

What is checked by means of the thread ring gauge and what must be heeded?

5. Thread cutting by dies on recessed cylindrical workplaces

External thread results from outer surface processing of the workpiece.

– Work is made in the chuck.

– The workpiece is clamped in the extended chuck jaws.

– The die is positioned in the die holder.

– The die is brought into position with the help of the quill.

– The first thread turns are cut by hand.

– Following the starting cut machine processing is made with the help of a support for the die holder.

– Ensure that the chip chambers are kept clean.

– Switch off the lathe 2 – 3 mm before reaching the shoulder and cut the remaining thread turns by hand in order to prevent tool breakage and ensure sound quality.

– Turn the die back by hand upon ending the work sequence. Having completed the thread, deburr all sharp edges with a finishing file.

– Ensure proper cooling and lubrication. Only measure and check with the machine at rest.

– The thread is checked by means of a thread ring gauge.

How is the die positioned on the workpiece?
____
____

6. Thread cutting by taps on through holes

Internal threads are produced by thread cutting by using taps. The workpiece surfaces are processed by means of bores.

– Work is made in the chuck.

– The workpieces are clamped in the extended chuck jaws in order to guarantee true running and top surface quality as the parts have generally already been processed.

– The tap wrench is positioned on the square of the tap.

– The tap is positioned by means of the tailstock tip which is aligned to the centring of the tap.

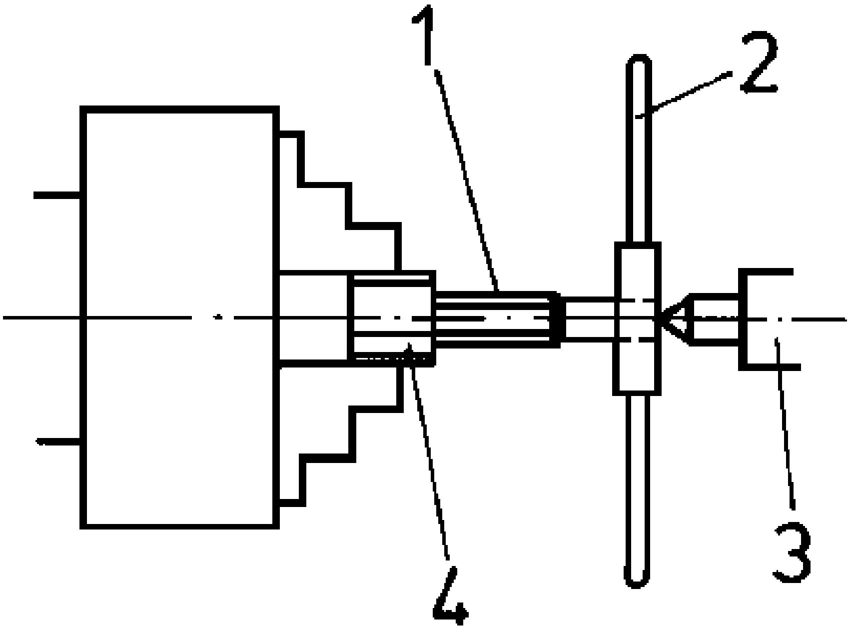

Figure 18. Positioning the tap

1 tap, 2 tap wrench, 3 tailstock quill, 4 workpiece

– The tap wrench holder is positioned on a surface clamped into the tool holder.

– Generally speaking, the machine tap is used (economical mode of operation).

– Turn back the tap several times to remove the chips and clean the chip grooves.

– Ensure proper cooling and lubrication.

– Turn back the tap by hand upon completing the work sequence.

– The thread is checked by means of a thread ring mandrel.

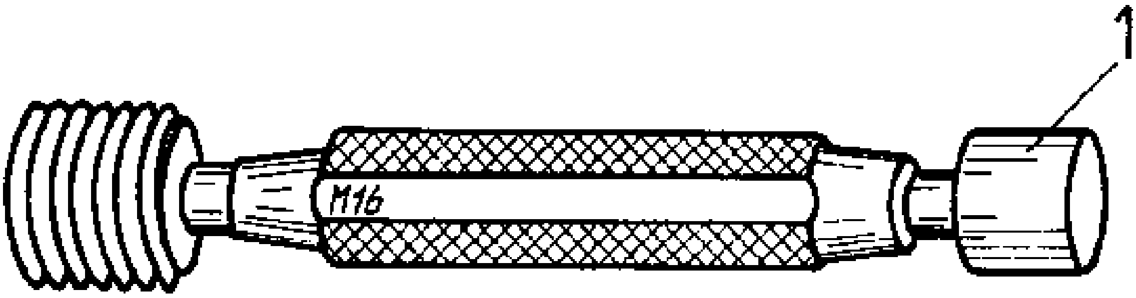

Figure 19. Normal thread ring mandrel

1 thread mandrel for minor diameter

What must be heeded when thread cutting by taps?

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7. Thread cutting by taps on blind holes

The internal threads are produced by processing the workpiece surfaces by means of bores.

– work is made in the chuck.

– the workpieces are clamped in extended chuck jaws.

– the tap wrench is positioned on the square of the tap.

– the tap wrench holder is on a support.

– turn back the tap several times to remove the chips.

– the required thread depth is controlled on the quill by means of a steel band measure.

– switch off the machine 2 – 3 mm before ending the work sequence and cut the remaining thread turns by hand in order to prevent tool breakage and ensure sound quality.

– ensure proper cooling and lubrication.

– turn back the tap by hand after having completed the work sequence.

– the thread is checked by means of a thread ring mandrel.

When are dies and taps used for thread cutting?

____
____
____

Appendix 1

Metric thread (standardized)		Metric fine thread (standardized)						Whitworth thread (standardized)		
Thread	Drill diameter mm	Thread	Drill diameter mm	Thread	Drill diameter mm	Thread	Drill diameter mm	Thread inch	Drill diameter	
									series 1	series 2
M 6	5.00	M 6 x 0.75	5.2	M 22 x 1.5	20.5	M 42 x 4	38.0	1/4	5.0	5.10
M 8	6.75	M 8 x 0.75	7.2	M 22 x 2	20.0	M 45 x 2	43.0	5/16	6.40	6.50
M 10	8.50	M 8 x 1	7.0	M 24 x 1	23.0	M 45 x 3	42.0	3/8	7.70	7.90
M 12	10.25	M 9 x 1	9.0	M 24 x 1.5	22.5	M 45 x 4	41.0	7/16	9.10	9.25
M 14	12.00	M 10 x 0.75	9.2	M 24 x 2	22.0	M 48 x 2	46.0	1/2	10.25	10.50
M 16	14.00	M 10 x 1	9.0	M 27 x 1	26.0	M 48 x 3	45.0	5/8	13.25	13.50
M 18	15.50	M 10 x 1.25	8.8	M 27 x 1.5	25.5	M 48 x 4	44.0	3/4	16.25	16.50
M 20	17.50	M 12 x 1	11.0	M 27 x 2	25.0	M 52 x 2	50.0	7/8	19.00	19.25
M 22	19.50	M 12 x 1.25	10.8	M 30 x 1	29.0	M 52 x 3	49.0 1	–	21.75	22.00

M 24	21.00	M 12 x 1.5	10.5	M 30 x 1.5	28.5	M 52 x 4	48.0 1	1/8	24.50	24.75
M 27	24.00	M 14 x 1	13.0	M 30 x 2	28.0	M 56 x 2	54.0 1	1/4	27.50	27.75
M 30	26.50	M 14 x 1.25	12.8	M 30 x 3	27.0	M 46 x 3	53.0 1	3/8	30.00	30.50
M 33	29.50	M 14 x 1.5	12.5	M 33 x 1.5	31.5	M 56 x 4	52.0 1	1/2	33.00	33.50
M 36	32.00	M 16 x 1	15.0	M 33 x 2	31.0	M 60 x 2	58.0 1	5/8	35.00	35.50
M 39	35.00	M 16 x 1.5	14.5	M 33 x 3	30.0	M 60 x 3	57.0 1	3/4	38.50	39.00
M 42	37.50	M 18 x 1	17.0	M 36 x 1.5	34.5	M 60 x 4	56.0 1	7/8	41.00	41.50
M 45	40.50	M 18 x 1.5	16.5	M 36 x 2	34.0	M 64 x 2	62.0 2		44.00	44.50
M 48	43.00	M 18 x 2	16.0	M 36 x 3	33.0	M 64 x 3	61.0			
M 52	47.00	M 20 x 1	19.0	M 39 x 2	37.0	M 64 x 4	60.0			
M 56	50.50	M 20 x 1.5	18.5	M 39 x 3	36.0	M 68 x 2	66.0			
M 60	54.50	M 20 x 2	18.0	M 42 x 2	40.0	M 68 x 3	65.0			
M 64	58.00	M 22 x 1	21.0	M 42 x 3	39.0	M 68 x 3	64.0			
M 68	62.00									

Series one **Materials which squeeze up slightly**		**Series two** **Materials which squeeze up considerably**	
grey cast iron	brittle copper alloys	steel	zinc alloys
bronze	some aluminium alloys	cast steel	some aluminium alloys
brass	magnesium, iron, die and wrought alloys	malleable cast iron	pressed materials

Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Trainees' Handbook of Lessons

Table of Contents

Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Trainees' Handbook of Lessons

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Preliminary Remarks

The present material has been drawn up for training workers in occupations which require a knowledge of assembly operations in addition to manual and mechanical metal working techniques.

This material contains descriptions of the types of joints which can be made with bolts and nuts or tapped screws. The main technological steps of making and unmaking threaded joints are described. The questions at the end of each section are intended to help the trainees check their newly acquired know–how.

Hints on Labour Safety

Generally, the precautions for safe boring, drilling, counterboring and thread cutting apply. The following points, however, should always be emphasized:

– All tools must be in good condition and used only for the purpose for which they were made.

– All workpieces must be securely held in position for drilling, boring or thread cutting. Excessive holding pressure may damage the work.

– Select tools of the right size for tightening or loosening bolts, nuts and screws. Tools of the wrong size tend to damage the workpiece and may slip off causing injuries.

– Make sure that large parts cannot drop to the ground when the bolts and nuts or screws are removed.

– It is regarded as good craftsmanship to store all tools properly and individual components always together with their counterparts.

1. Purpose of Threaded Joints

Threaded joints are detachable joints of two or more component parts either directly connected with each other or by standardized fasteners, i.e. bolts, nuts and screws.

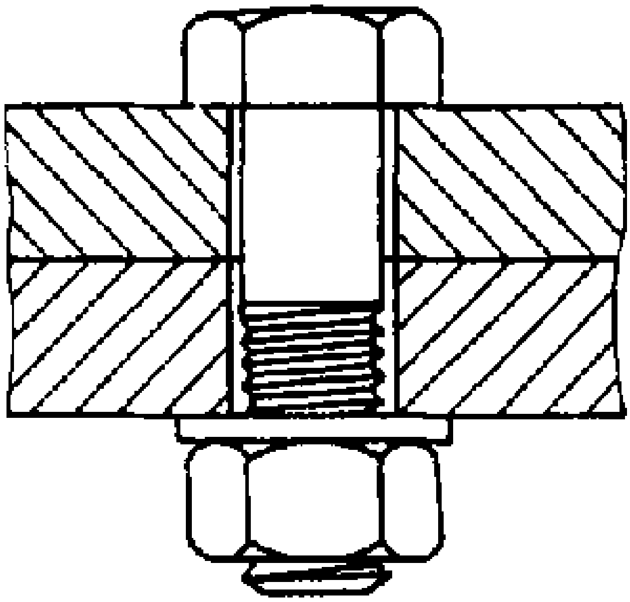

Figure 1. Typical example of a threaded joint

Threaded joints are made

– to keep the component parts of the detachable joint in a desired position,

– to provide the force required to produce a joint and maintain this force for the intended period.,

– to transmit motions and forces of component parts.

Suitable locking devices are used where detachable joints have to be secured against the accidental loosening due to the action of dynamic stresses, such as vibration or shock.

No locking devices are required on temporary joints with fine–pitch thread and joints in which the component parts are self–tightening by the sense of their rotation (e.g. drill chucks on hand drills).

What is a threaded joint?

____
____
____

What requirements must be met by a threaded joint under a dynamic stress?

____
____
____

2. Selected Types of Bolts and Screws

Bolts and screws made of steel are used in machines, steel structures, vehicles and ships because of their strength and toughness. They may be electrically plated with cadmium, zinc, copper or brass.

Bolts and screws made of copper, brass or light metal are used in electrical equipment because they conduct electricity and do not corrode easily.

Hexagon head screws

Used mainly for iron and steel work and in machines generally. There are hexagon head screws of different sizes and lengths of thread in accordance with ISO metric coarse and fine threads.

Typical designation:

Hexagon Head Screw M6 x 20

– Nominal diameter of the ISO metric thread (coarse): 6 mm
– Length of engagement (without the head): 20 mm

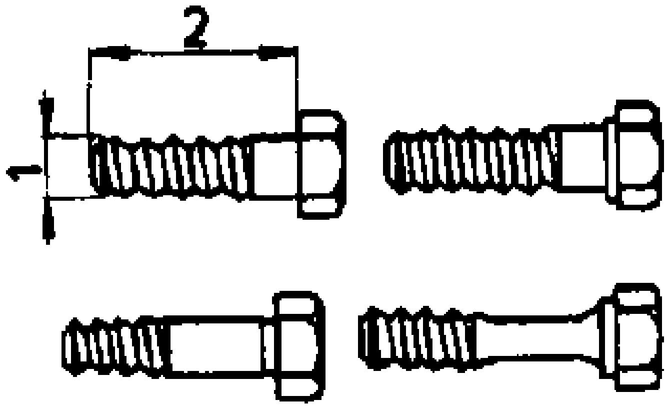

Figure 2. Hexagon head screw

1 nominal diameter, 2 length of engagement

Countersunk head screws

Used in industrial plant and equipment, where safety requires that no head projects the surface of any component. There are countersunk head screws of different sizes and lengths of thread according to ISO metric coarse thread, with different shapes of slots and tops of heads.

Typical designation:

Countersunk bolt with cross slot M6 x 20

– Nominal diameter of the ISO metric coarse thread: 6 mm
– Length of engagement (with the head): 20 mm

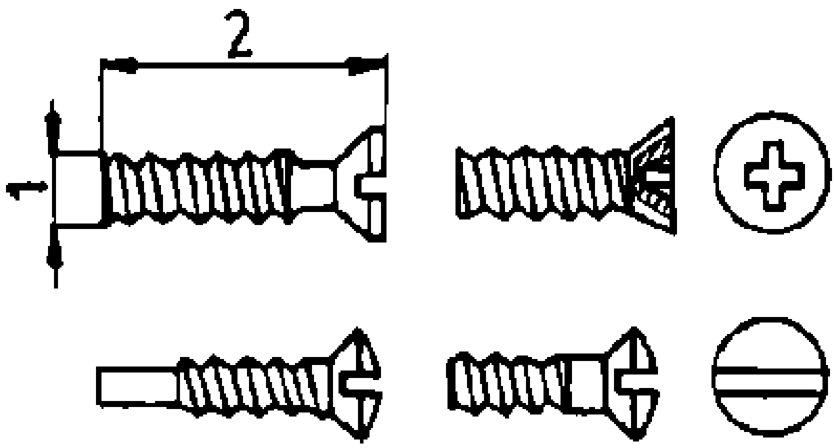

Figure 3. Countersunk–head screw

1 nominal diameter, 2 length of engagement

Cheese head screws

Used for light–weight structured and in general engineering. There are cheese head screws of different sizes and lengths of thread according to ISO metric coarse thread, with different shapes of head. Fillister socket–head screws can accept draw–in forces.

Typical designation:

Cheese head screw with cross slot M6 x 20

– Nominal diameter of the ISO metric coarse thread 6 mm
– Length of engagement (without the head) 20 mm

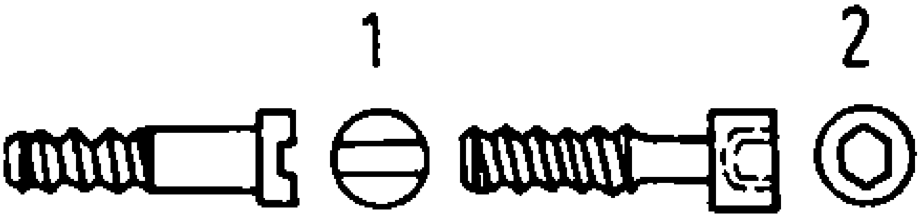

Figure 4. Cheese head screw

1 with cross slot, 2 with hexagonal socket head

Other ISO metric thread bolts and screws

Generally used in the field of engineering, restricted use in machines. There are different sizes and shapes of the head as well as various designs in bolts.

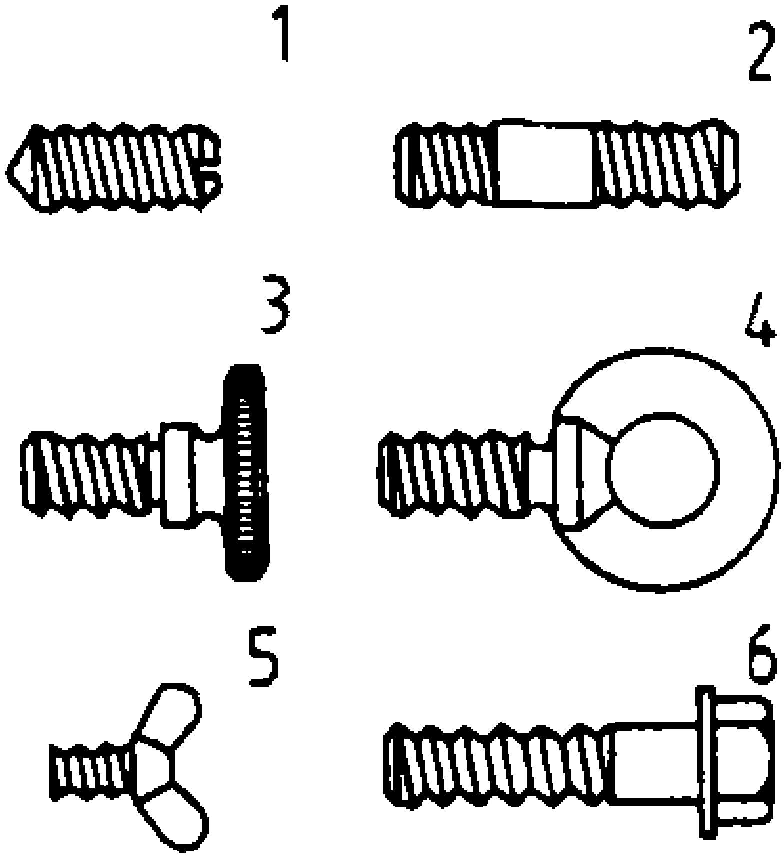

Figure 5. Other bolts and screws

1 threaded pin, 2 stud bolt, 3 knurled head screw, 4 eye–bolt, 5 thumb screw, 6 square bolt

Sheet metal screws

Generally used for car bodies, vessels and light–weight structures. The thread on the cylindrical portion of the screw (with the tip) cuts itself the thread in soft sheets. There are sheet metal screws of different sizes, lengths and shapes of the head. The threaded portion always extends over the entire length of the shank (with the tip), just up to the head.

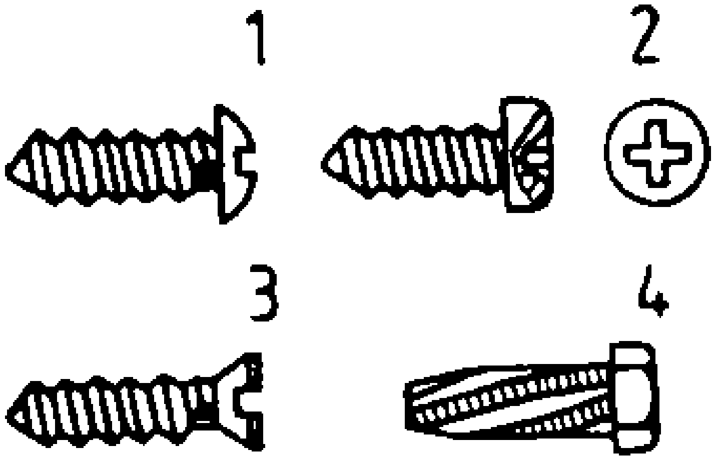

Figure 6. Sheet metal screws

1 button–head sheet metal screw with cross slot, 2 oval head sheet metal screw with intersecting slots, 3 countersunk–head sheet metal screw with cross slot, 4 metric self–tapping screw

Wood screws

Wood screws are used in wood structures. The thread on the tapered portion of the shank (with the tip) cuts itself the thread in the wood. There are wood screws of different sizes, lengths and shapes of the head. Only the tapered portion of the shank is threaded, followed by a cylindrical neck.

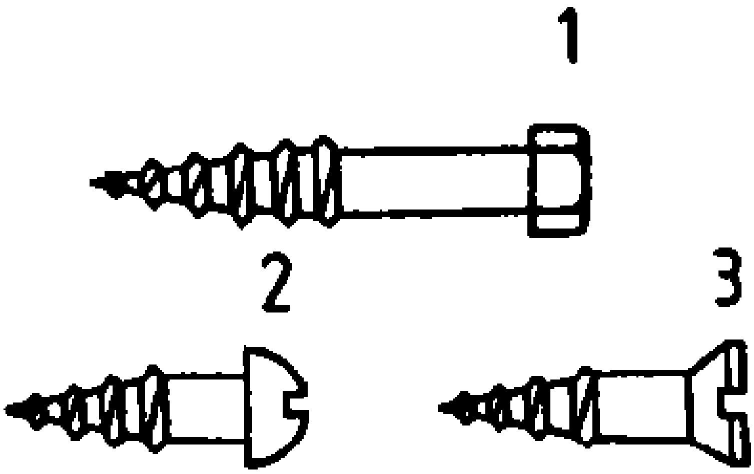

Figure 7. Wood screws

1 hexagon head wood screw, 2 button–head wood screw, 3 countersunk wood screw

Where are countersunk head screws used?

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____
____

What is the difference in the lengths of engagement of a cheese head screw and a countersunk head screw?

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____
____

Where does the shape of a sheet metal screw differ from that of a wood screw?

____
____
____

3. Selected Types of Nuts

Nuts are made of the same material as bolts and screws and can have the same kind of plating.

> Precise bolt−and−nut joints can only be achieved when they are made of the same materials, grade of material and have the same type of coating.

Hexagon nuts

Used in structural steel engineering and mechanical engineering. There are hexagon nuts of different sizes of ISO metric coarse and fine threads and of flat or wide shape. The cap nut is a special design. Cap nuts provide caps on bolted or screwed joints. They are used as a safety precaution or for better looks. Cap nuts keep the thread clean.

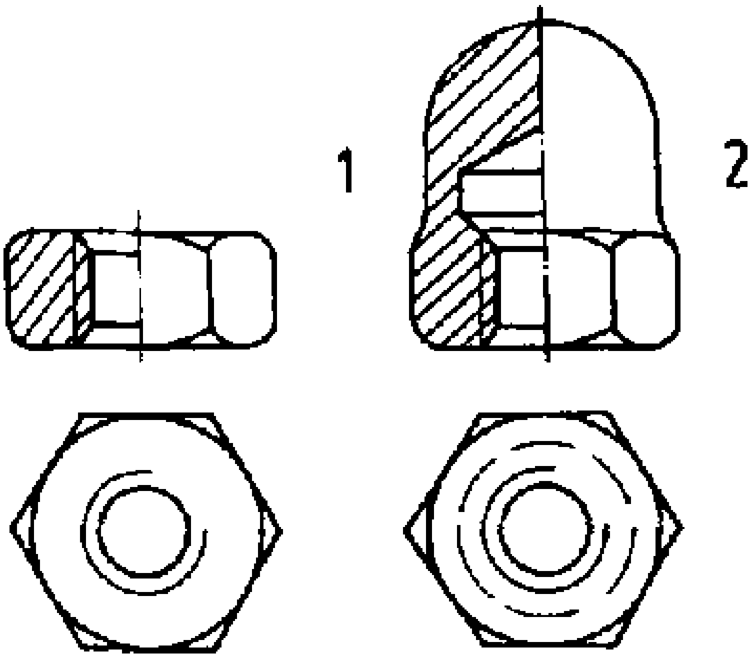

Figure 8. Nuts

1 hexagon nut, 2 cap nut

Knurled nuts and wing nuts

Used for producing detachable joints of component parts by hand, without the use of tools.

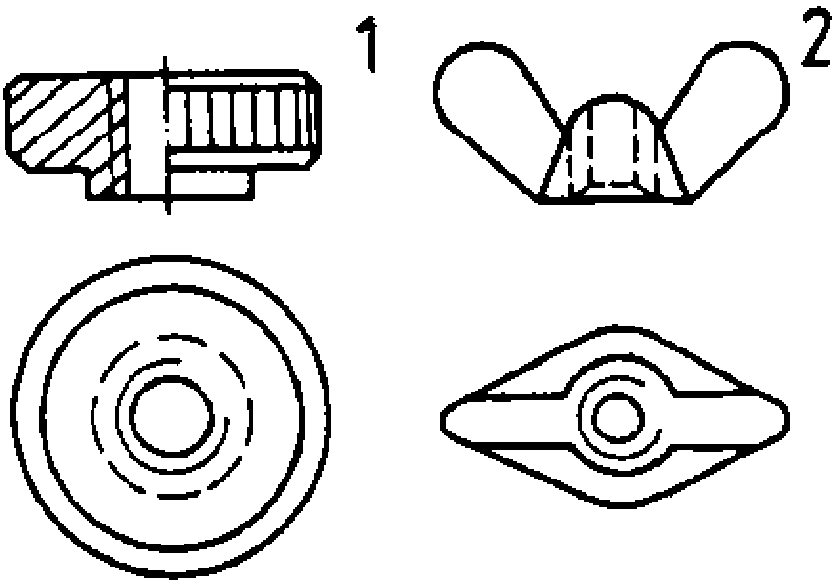

Figure 9. Nuts

1 knurled nut, 2 wing nut

Slotted nuts and nuts with two holes

These nuts are used mainly for electrical components where space is limited and the joint is not easily accessible.

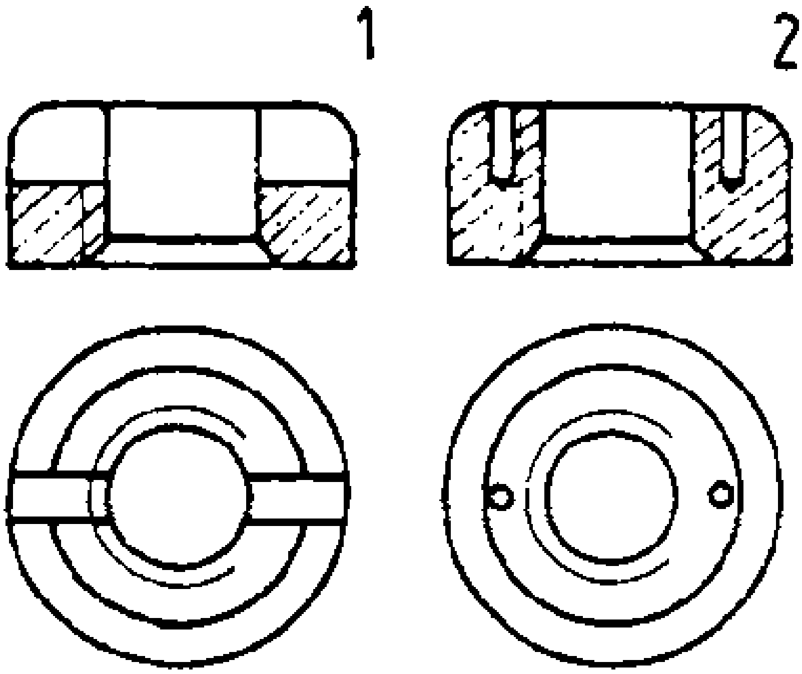

Figure 10. Nuts

1 slotted nut, 2 nut with two holes

What conditions must be satisfied by the materials of which bolts, screws and nuts are made?

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Give uses of knurled nuts and wing nuts.

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4. Selected Types of Locking Devices for Bolts and Screws

Locking devices can be acting positively, non−positively or by the retention of self−substance.

> Locking devices, particularly cotter pins, spring rings and toothed washers, are used only once.

Use new, unused locking devices when re−assembling parts which have been dismantled. Locking devices, once used, will deform permanently and not be safe to use another time.

Non−positive locking devices

These are available mainly as spring lock washers and toothed washers. They maintain a slight tension between the bolt, or nut, and the component to which they are fastened.

The sharp edges on the spring lock washers and toothed lock washers have a “seizing” effect on the component tightened in the joint, thus preventing it from coming loose accidentally.

An additional locking effect can be obtained on bolts with a long, projecting shank by screwing a counternut on the projecting shank. Both nuts must be screwed sufficiently tight. The friction on the thread flanks prevents the nuts from coming loose.

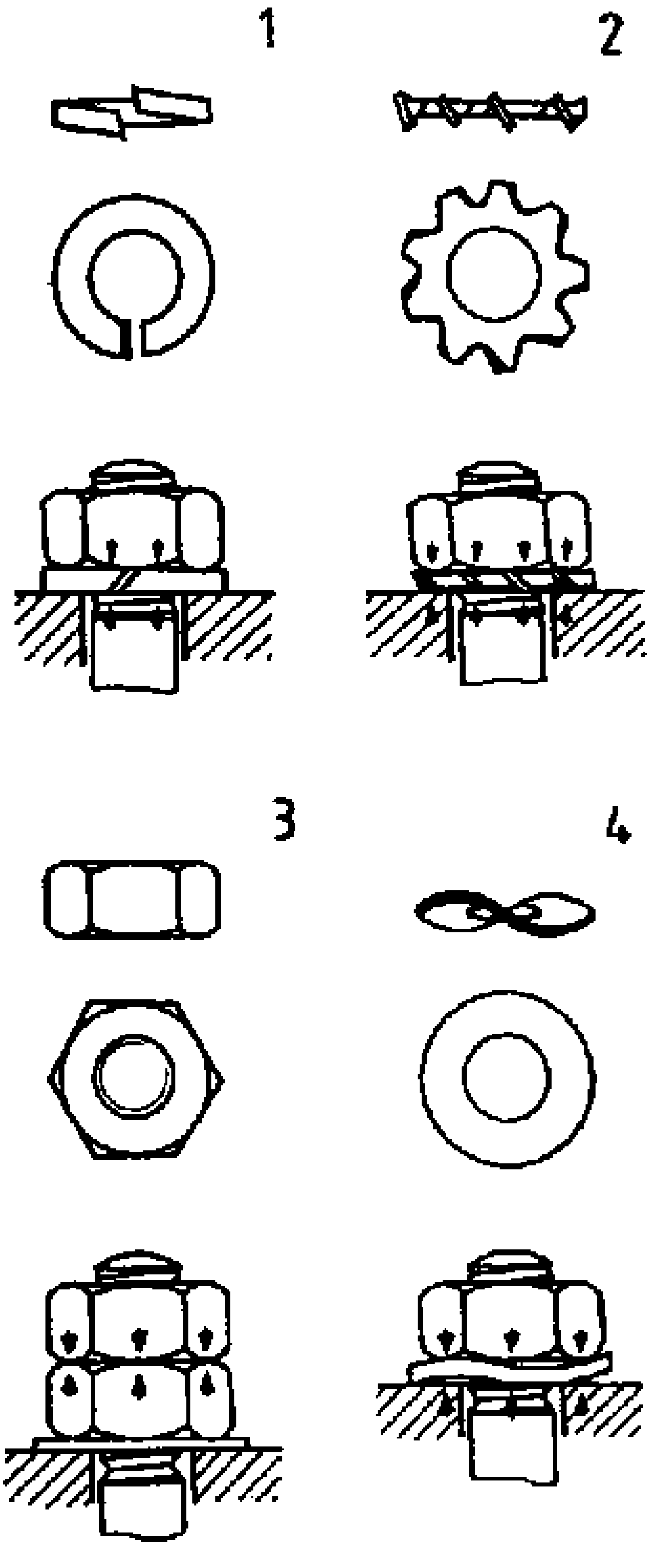

Figure 11. Non−positive locking by

1 spring ring, 2 toothed washer, 3 counter nut, 4 spring lock washer

Positive locking devices

These are available mainly as locking plates, retaining rings and crown nuts with split pins. They are used primarily with hexagon head screws and where their shape prevents the joint from coming loose.

Locking plates and retaining rings are provided with tangs or lugs, which are fastened to the component in the joint and the connecting part by blows with a hammer. When crown nuts are used, a hole must be drilled through the threaded portion, which takes up the cotter pin, after nut has been tightened.

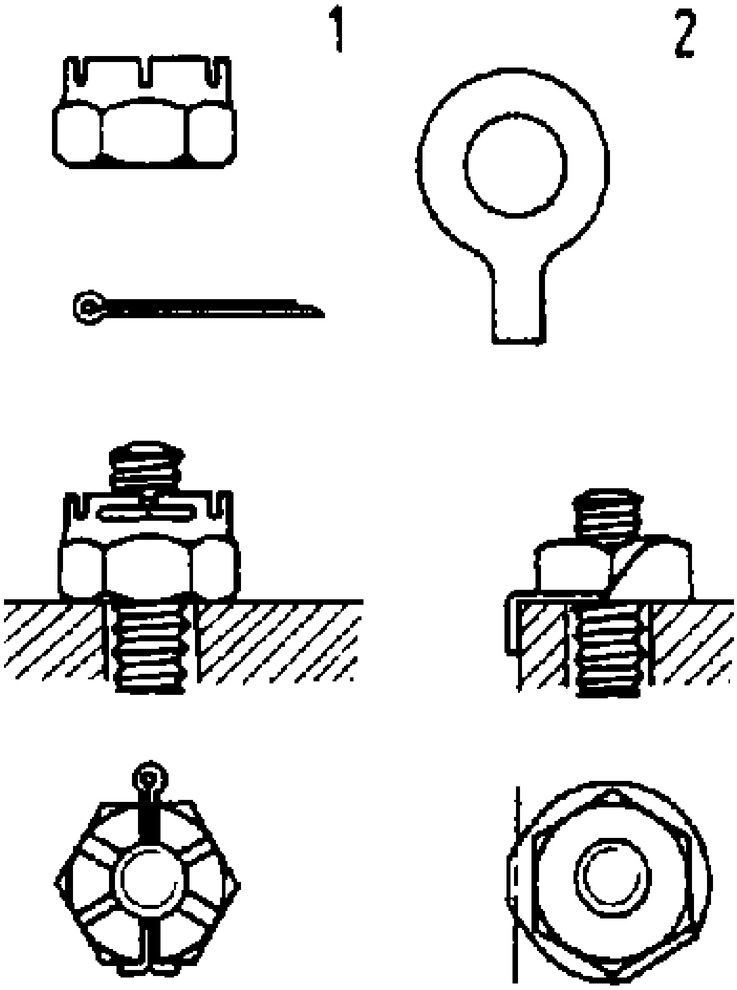

Figure 12. Positive locking by

1 crown nut with split pin, 2 locking plate with tang

Locking by retention of self−substance

The locking effect is achieved by the application of paint, varnish or paste. Used primarily on electrical assemblies and in precision instruments. Where the forces acting on the joint are slight, the locking effect is sufficiently strong and provides protection against tampering.

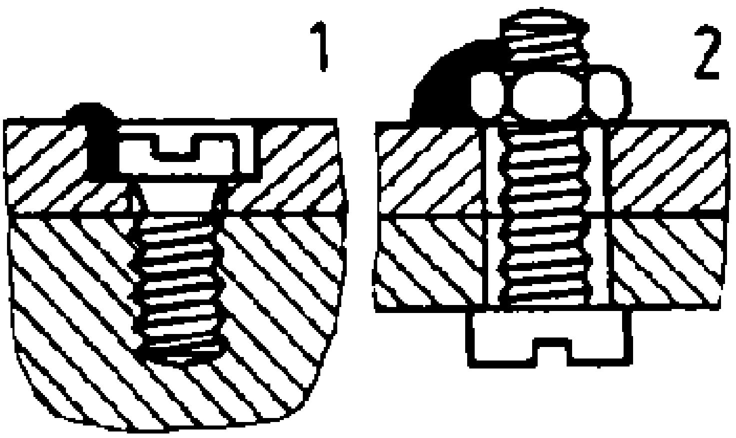

Figure 13. Locking by retention of plaint

1 on the bolt head at a blind bore, 2 on the nut at a through bore

Identify elements of locking devices which must be used once only.

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Suggest an effective way of locking with the shank of the bolt projecting beyond the nut.

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5. Selected Types of Washers

Washers are placed under the heads of bolts or screws or under nuts, where

– the bearing faces are not properly machined,
– bolts, screws and nuts are to be tightened on oblong holes,
– slopes of the bearing face must be componensated.

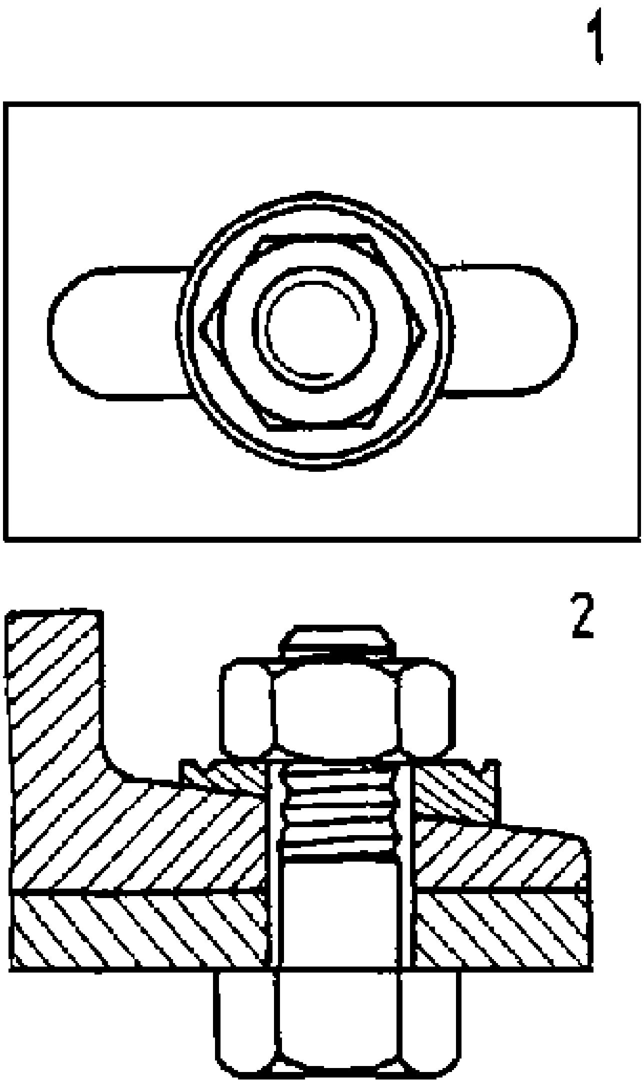

Figure 14. Uses of washers

1 washer on an oblong hole, 2 wedge–shaped washer on an inclined face

Washers are made of the same materials as bolts, screws and nuts and can have the same kind of plating.

There are washers of different sizes and thicknesses and to account for different properties in the proportion of hole diameter and width of the edge.

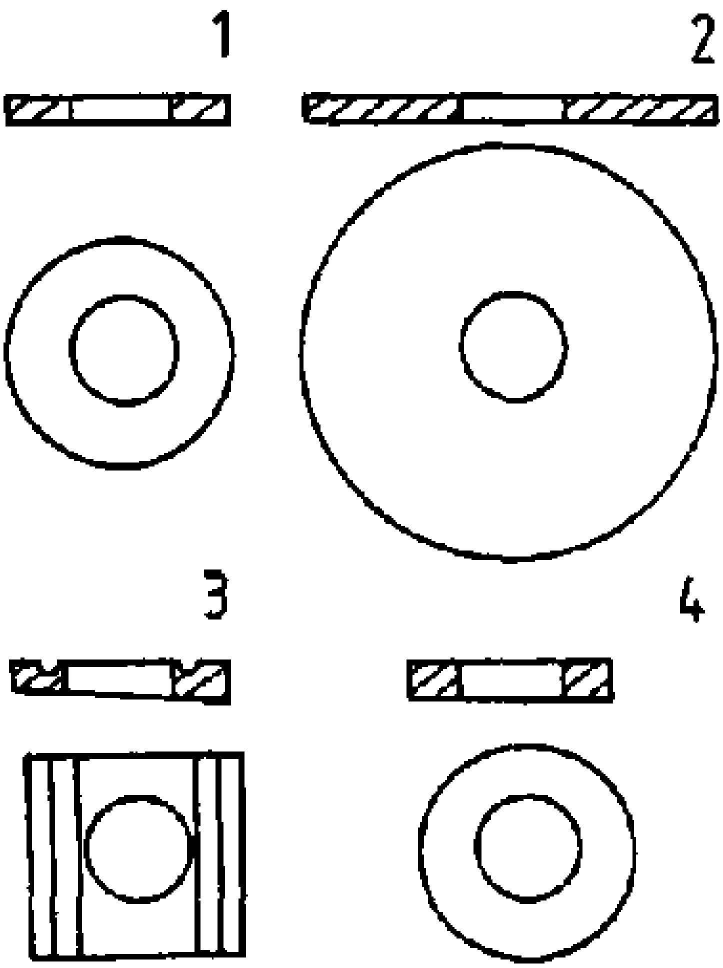

Figure 15. Washers

1 common washers for bolts and screws, 2 washers for elongated holes, 3 wedge–shaped washer for inclined surfaces, 4 washer for iron and steel work

Give uses of washers.

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6. Types of Threaded Joints

Threaded joints are specified below for the way a joint is made, or for its purpose.

Direct joints

The component parts to be joined have internal or external thread and are directly screwed together. No additional fastening elements are needed.

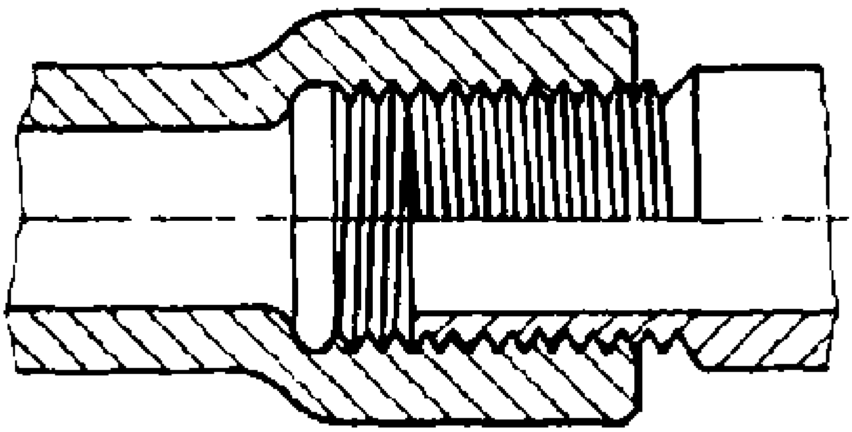

Figure 16. Direct joint

Indirect joints

The component parts to be joined are held together by standardized components, i.e. bolts, screws and nuts. Locking devices and washers may be used additionally.

Where a component part has a female thread, the joint may be made without a nut. The walls of the work−piece must be sufficiently thick for this kind of joint.

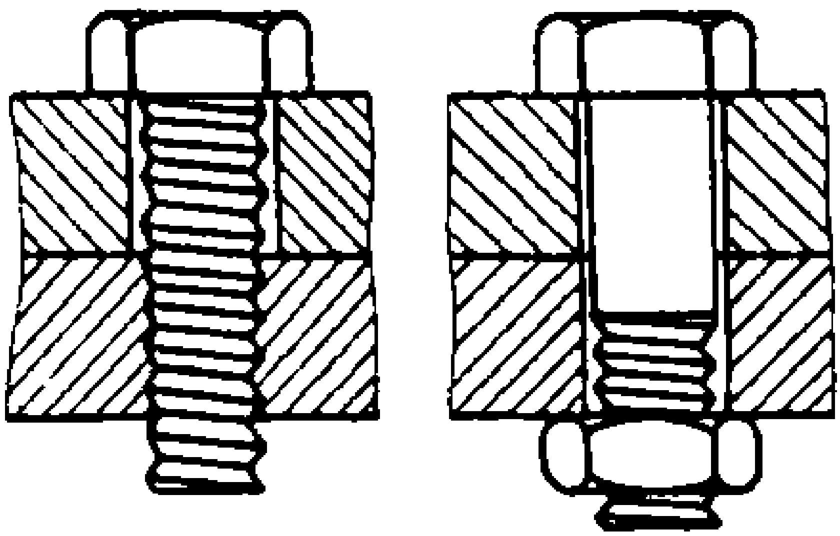

Figure 17. Indirect joint

Fastening joints

The component parts are to be joined directly or indirectly only for the purpose of connecting them. The vee−thread, ISO metric vee−thread or Whitworth thread, are the preferred types of thread. Both threads are self−retaining.

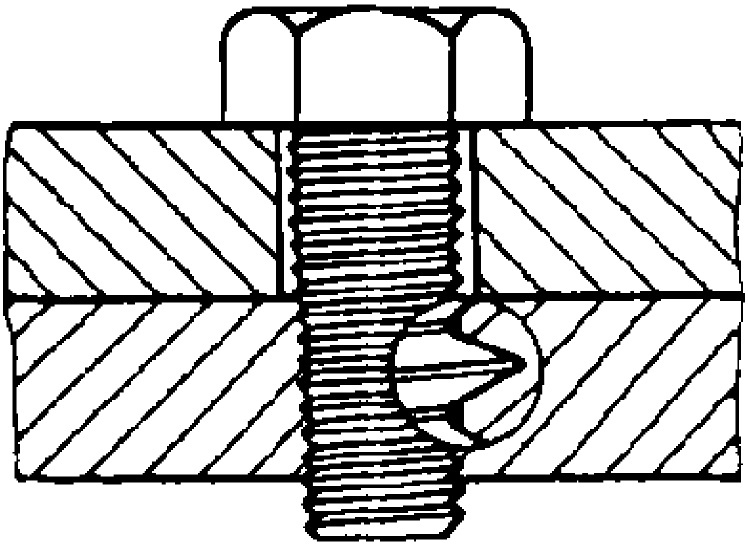

Figure 18. Screwed joint for fastening purpose

Adjustable joints

The component parts are joined for the purpose of connecting them and transmitting movements or forces. The preferred types of thread are round thread, acme standard screw thread or saw−tooth thread.

These are less self−retaining.

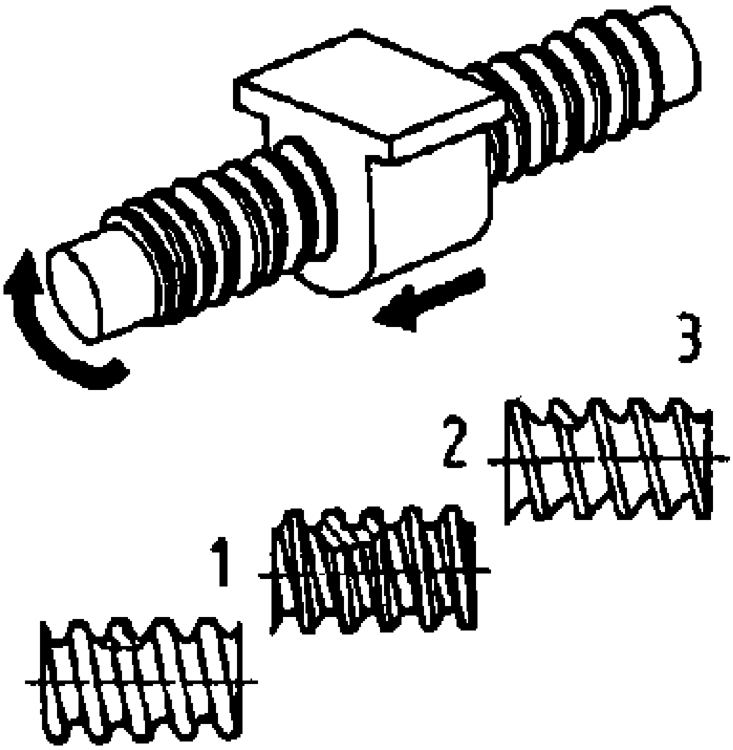

Figure 19. Adjustable joint

1 round thread, 2 acme standard screw thread, 3 saw−tooth thread

Name different types of threaded joints.

7. Stresses in Threaded Joint

A threaded joint is formed when two parts, one with an internal thread and the other with an external thread of the same description are joined by turning them in opposite directions. A positive joint exists between the internal and the external thread, while friction produces a non−positive connection between thread flanks. The latter prevents an accidental loosening of the joint (i.e. it is self−retaining) when the pitch of thread is low.

Shallow pitch − more self−retention
Steep pitch − less self−retention

Indirect joints for fastening purposes are made by firmly pressing the component parts together. The intensity of pressure produces a non−positive joint between them. When the contact pressure is overcome by the service stress which acts laterally, the threaded bolt comes under shearing stress.

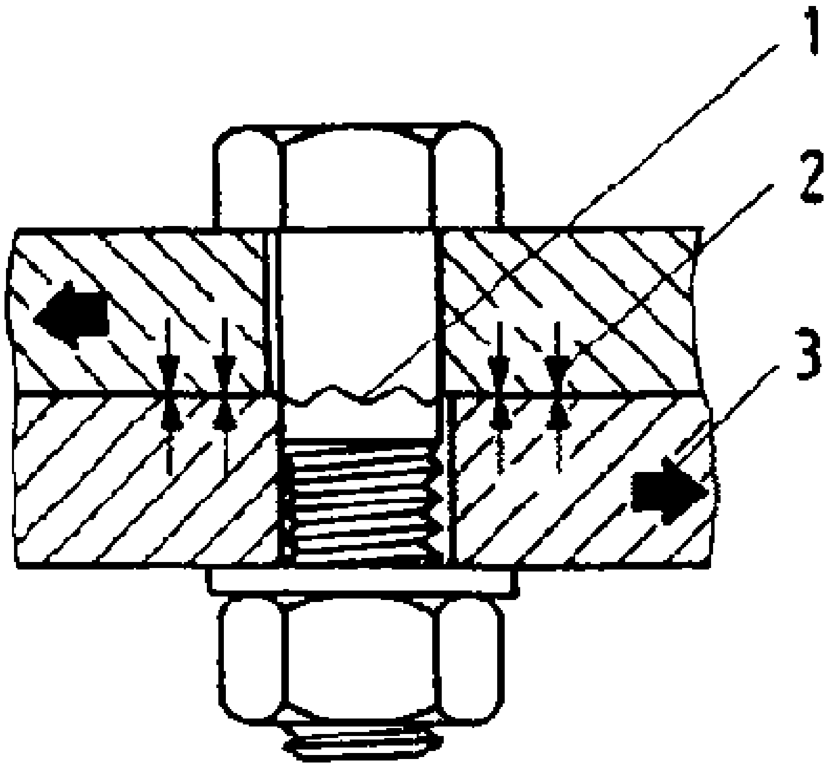

Figure 20. Shearing stress at a fastening screwed joint

1 shearing stress, 2 contact stress by prestressing, 3 laterally acting service stresses

When a joint for fastening purposes is tightened, the threaded bolt will expand and produce "pre−stressing". The elasticity of the threaded bolt which counteracts the expansion, causes the bolt to press the component parts of the joint together tightly. When external (tensile or compressive) forces act along the longitudinal axis of a threaded joint, a "service stress" is produced in addition to the pre−stressing.

Tensile forces − act in the direction of the prestress and increase the stress in the bolt.

Compressive forces − act in the opposite direction of the prestress and lessen the stress in the bolt.

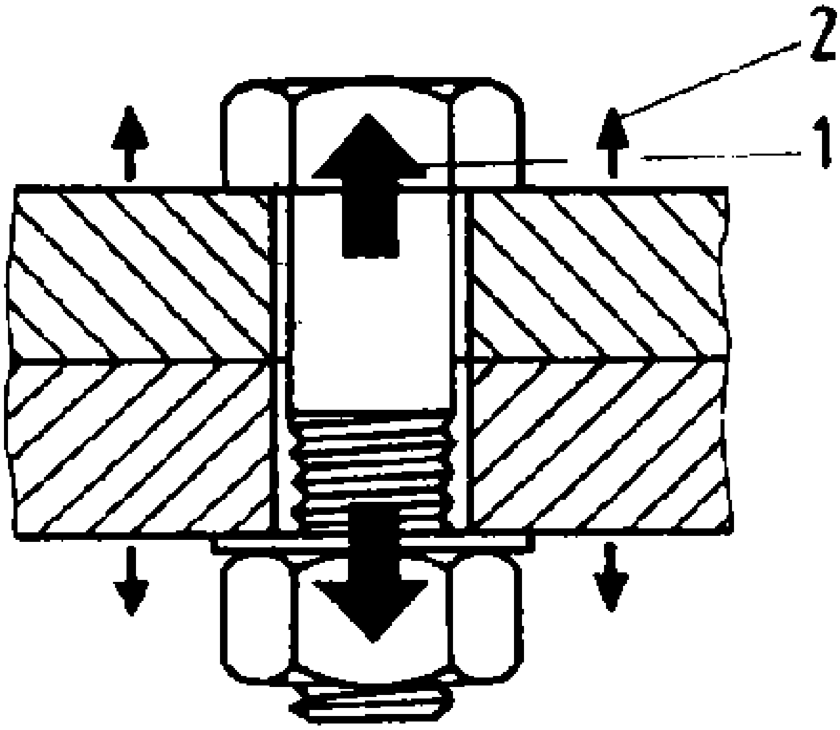

Figure 21. Tensile stress at a screwed joint for fastening

1 prestressing, 2 service tensile stress

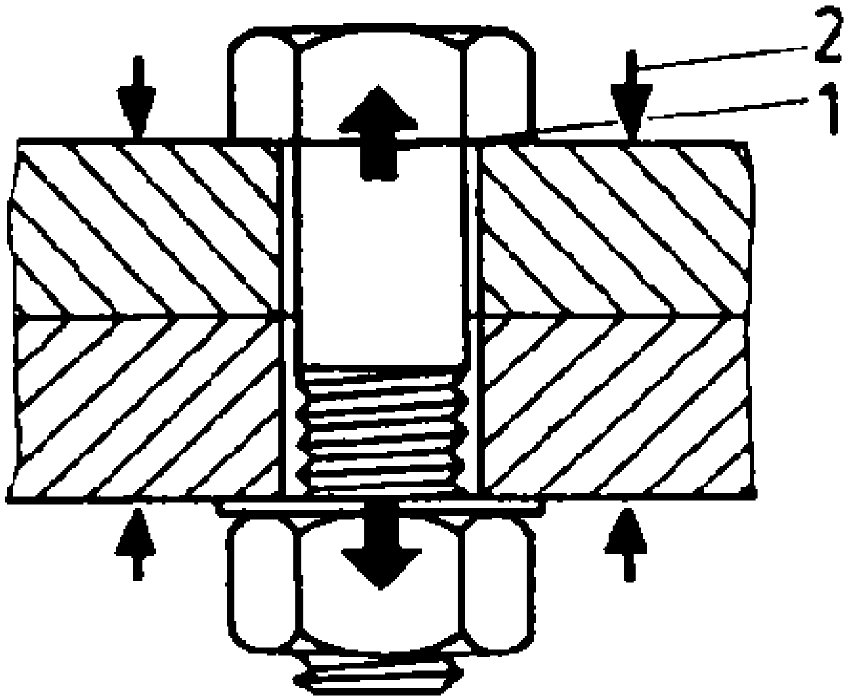

Figure 22. Compressive stress at a screwed joint for fastening

1 prestressing, 2 service compressive stress

Note:

– The sum of service stress forces and prestressing forces must be higher than the maximum permissible tensile strength of a bolt. Otherwise the bolt will fail.

– Compressive service stress forces must never neutralize the prestressing force in a threaded bolt. Otherwise the threaded joint will come apart.

– A threaded bolt will be bent and eventually fail when the bearing face for the bolt head is not level. Remember: Bearing faces for bolt heads must always be level.

Identify the strain and stress of a thread for fastening purposes is exposed to.

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Name different types of stress in threaded joints.

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8. Tools

Drills, countersinks, counterbores, thread taps, threading dies

There are various kinds of drills, 60° included angle countersinks, cutting dies, serial taps and nut taps for producing through bores and tapped holes. Threading dies are preferred for re–threading screws or threaded bolts.

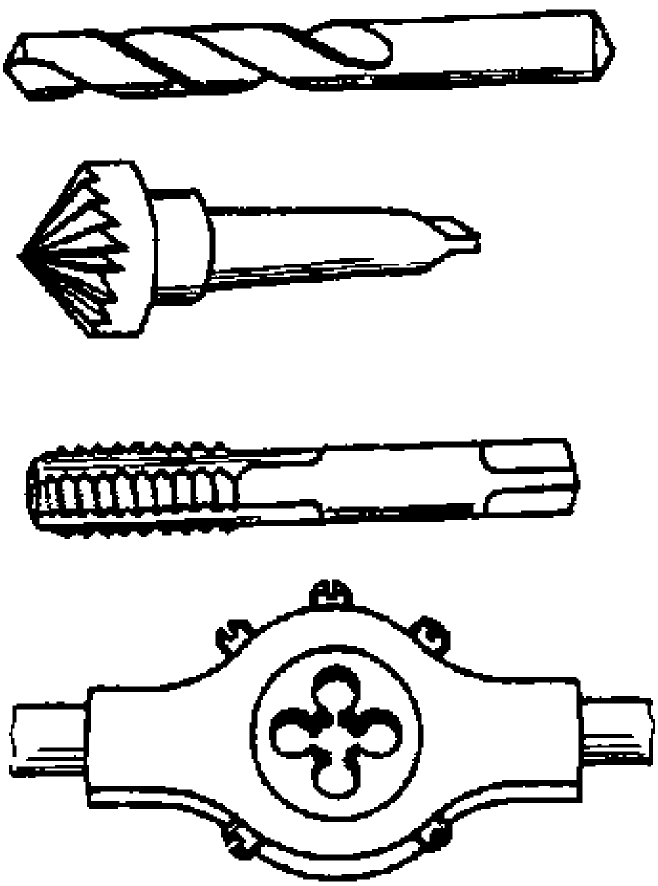

Figure 23. Drills, countersinks, thread–tap, threading die

Die stock

There are various die stocks for larger ISO metric threads (12 mm diameter and more) for cutting thread in bolts and die stocks for Whitworth pipe thread for the direct joining of pipes.

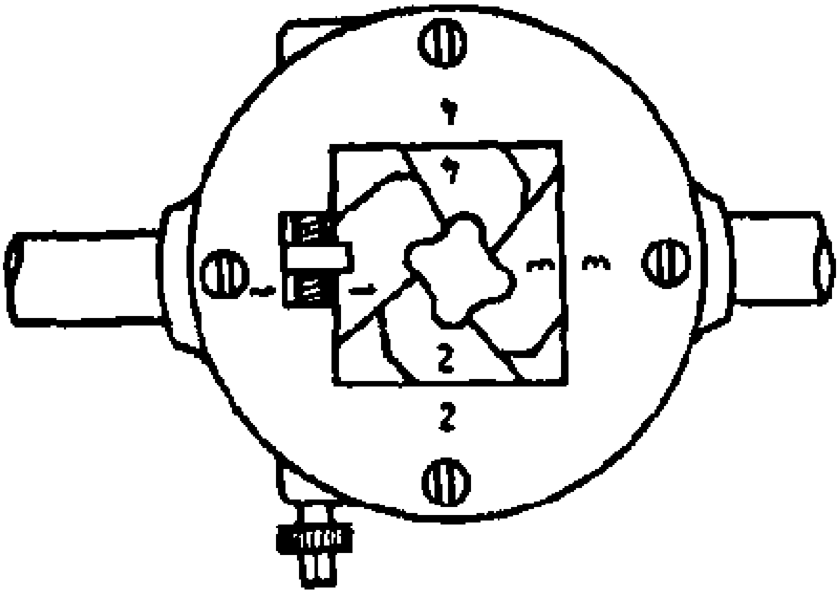

Figure 24. Die stock

Screw drivers

Screw drivers are used for tightening or screws with a slot across or intersecting slots. Angular designs of screw drivers are known for screws to which access is difficult.

> If between the blade and the slot there is a wide clearance, do not use the screw driver. The tolerance between the blade thickness and the slot should be close. The blade width should be marginally smaller than the diameter of the screw head.

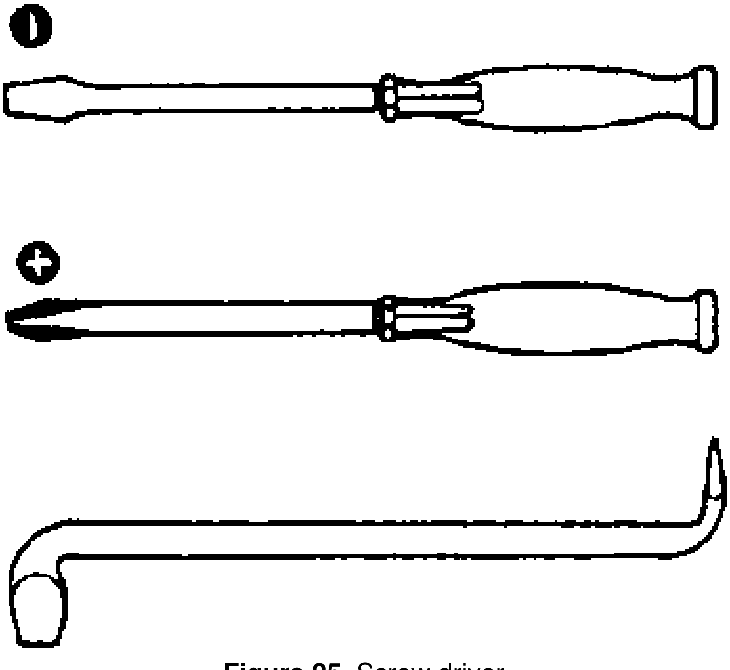

Figure 25. Screw driver

Open ended wrenches

There are open ended wrenches of different standard sizes for tightening and loosening hexagon head bolts, screws and nuts. The lengths of open end wrenches are such that the ratio of the median force applied by human arm and nominal thread diameter does not exceed the permissible shearing stress produced when tightening a bolt, screw or nut.

> Never use a piece of tube to extend the length of an open ended wrench in a attempt to apply a higher tightening force. The prestress in the joint will be too high.

Nominal thread diameter	M4	M5	M6	M8	M10	M12	M16	M20
Dimension across jaws (mm)	7	8	10	13	17	19	24	30

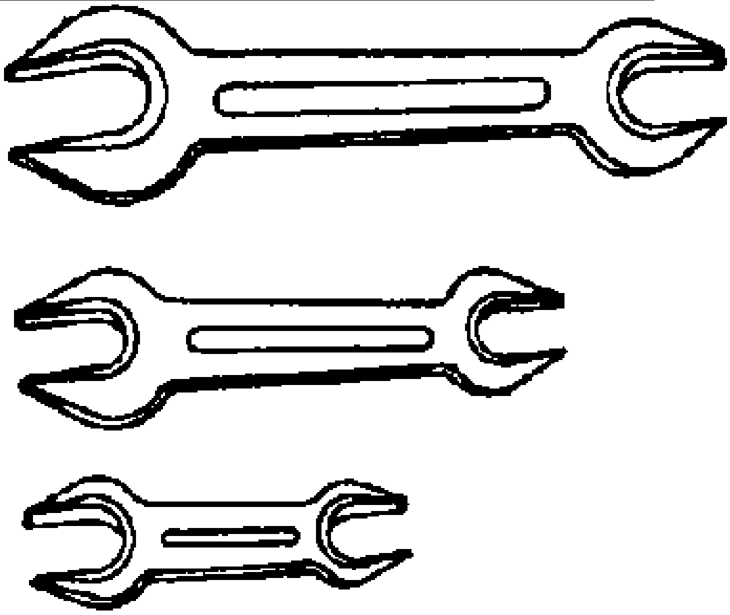

Figure 26. Open ended wrench

Ring spanners

There are cranked and flat types of ring spanners of different sizes for the tightening and loosening of hexagon head bolts, screws and nuts of higher strength specifications.

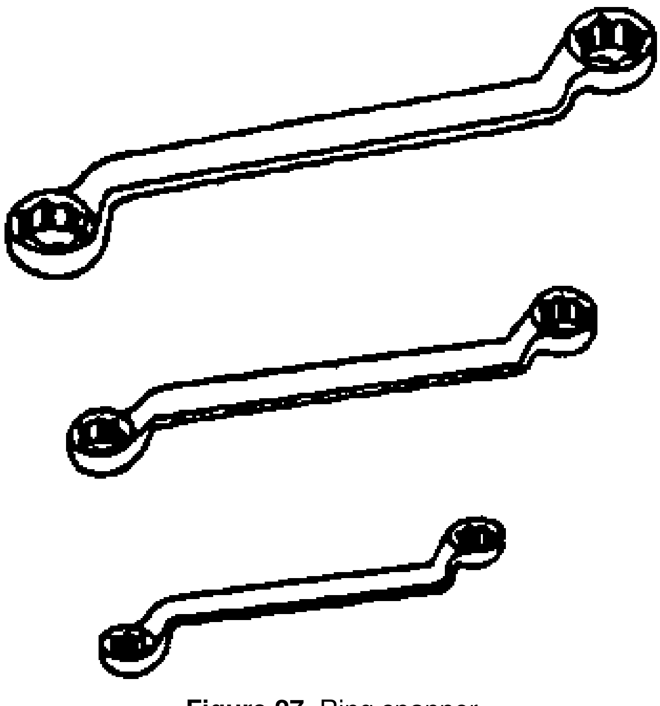

Figure 27. Ring spanner

Box spanners

There are box spanners of different sizes for use on hexagon head bolts, screws and nuts where these are accessible only in the axial direction.

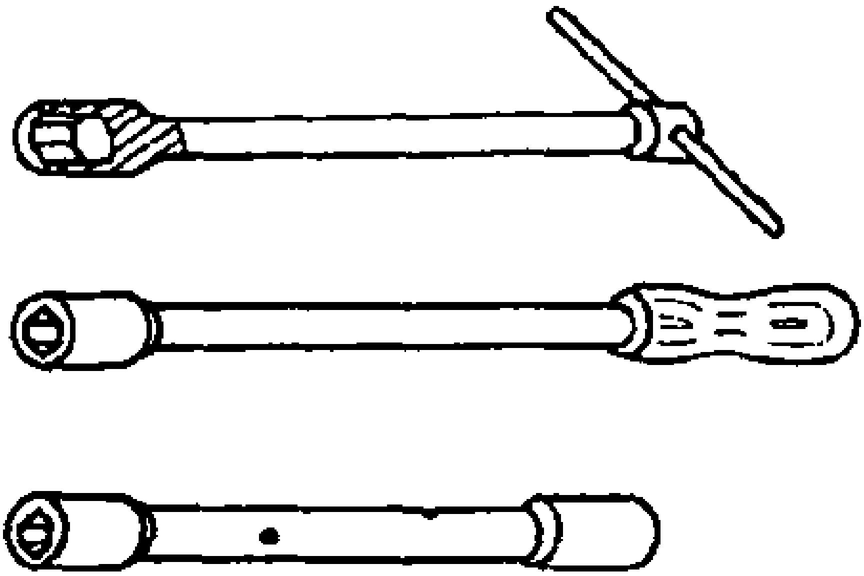

Figure 28. Box spanner

Hexagon pin−type wrenches

There are hexagon pin−type wrenches of different sizes for the tightening and loosening of hexagonal socket head screws.

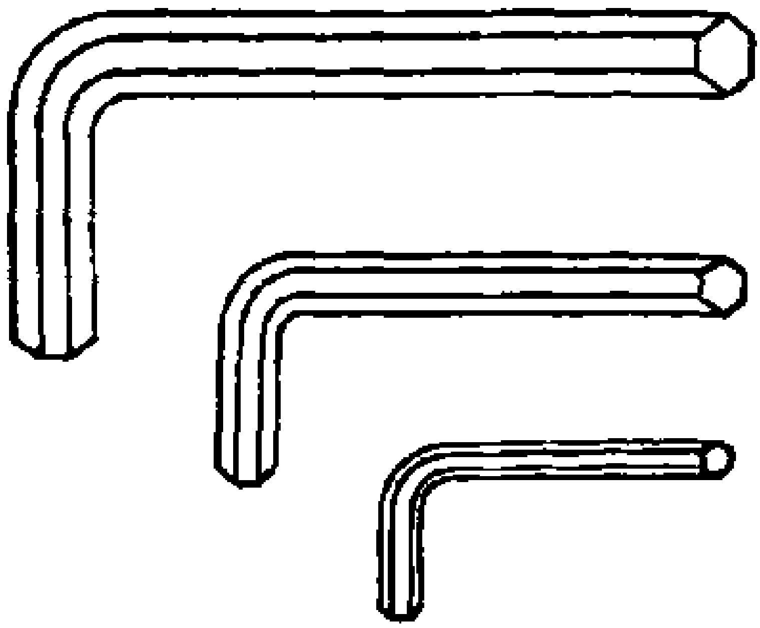

Figure 29. Hexagon pin−type wrench

Adjustable wrenches

Adjustable wrenches are used on hexagon head bolts, screws and nuts where there are different head sizes and no sets of open ended wrenches are available.

Adjustable wrenches replace certain size ranges of open ended wrenches, but they are heavier and less handy.

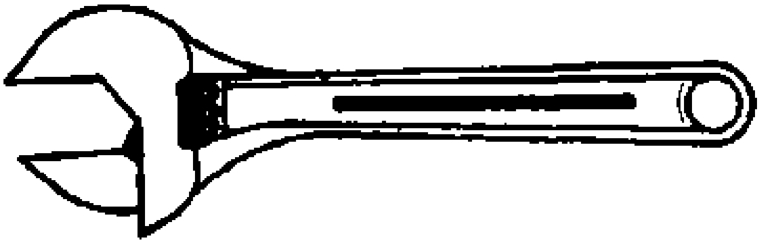

Figure 30. Adjustable wrench

Torque spanners

Several types of torque spanners are available. They are used where high−strength bolted or screwed joints are required to have a specific torque (tightening torque) or where there are several bolted or screwed joints on one component part and their prestressing is to be the same. The torque can be read at a dial during tightening.

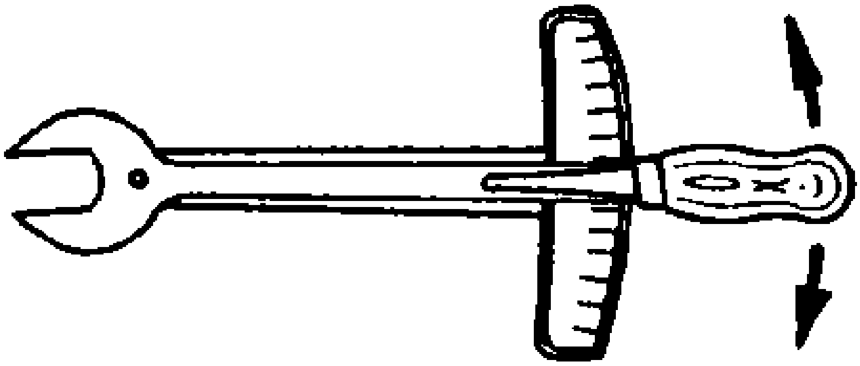

Figure 31. Torque spanner

Electrically actuated wrenches

Electrically actuated wrenches are used in industrial volume production. Various tools can be used on electrically actuated wrenches to tighten or loosen different types of bolts, screws and nuts. Electrically actuated wrenches may be adjustable for torque.

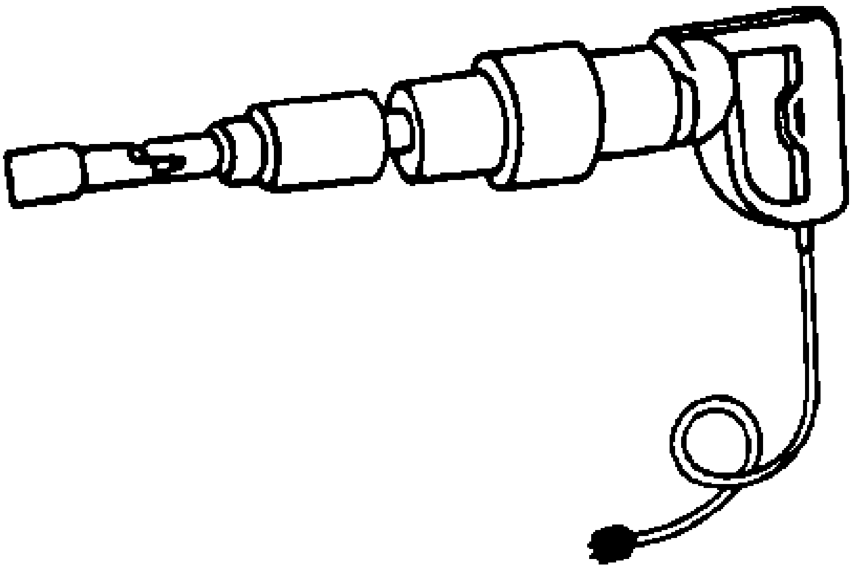

Figure 32. Electrically actuated wrench

What may happen when the blade of a screw driver is too narrow?

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What may happen when an extension is used on the open ended wrench for tightening a threaded joint?

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Name applications of the torque spanner.

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9. The Technological Steps of Making Threaded Joints

The preparations for direct threaded joints differ from those for indirect joints.

9.1. Direct Joints

Direct joints can be found mainly in parts or assemblies of machines. Most threads are cut mechanically and the component parts are simply joined by screwing. Make sure that the parts which are to be joined by screwing coincide in their nominal thread diameters, pitch and sense.

Example:

Drill chuck on a machine spindle in a hand drill.
Closing caps on containers.

Pipes may be directly joined by screwing as well. Most connecting parts (pipe bells) and fittings (angles, bends) are manufactured industrially and only an external thread needs to be cut on the pipe.

Task:

An unthreaded 1−inch (25−mm) steel pipe is to be screwed into an elbow fitting heaving internal thread. A short external thread is to be cut on the pipe.

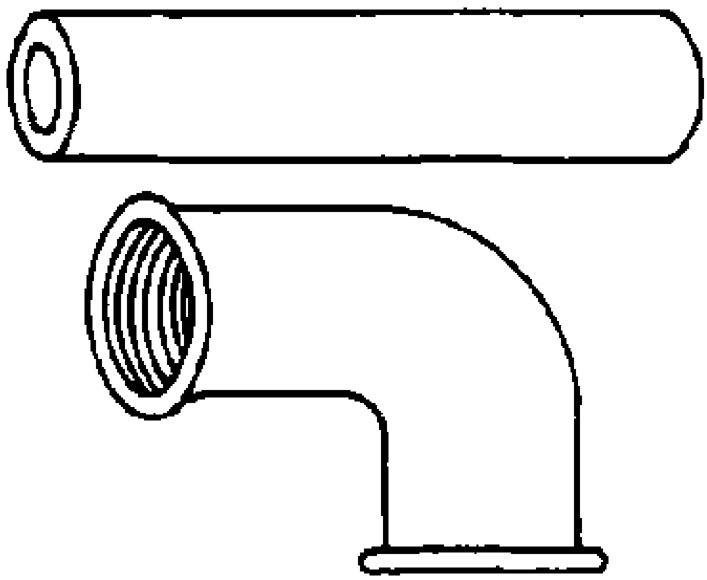

Figure 33. Pipe and elbow fitting

Sequence of operation:

1. Prepare the die stock

   − Mount the cutting dies with pipe thread R 1−inch in the sequence of operations 1 to 4.

– Set the fine adjustment for the entering tap.

– Open the pilot.

2. Chuck the pipe, apply cutting fluid to the deburred end of the pipe.

3. Place the die stock, pilot end first, on the pipe end, and adjust the pilot.

4. Make an entering cut and rough cut over 19 mm length by turning evenly in clockwise direction. Then loosen the clamping screw and break the burr with a short jerk to the right.

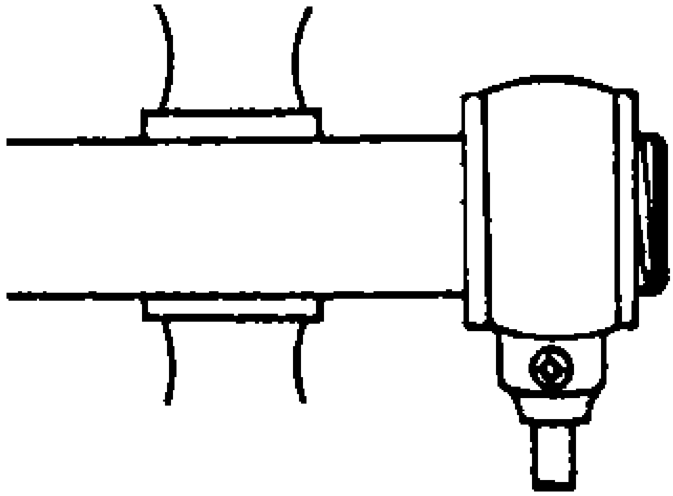

Figure 34. Cutting a pipe thread

5. Open the die stock and remove it. (Do not turn it to remove it).

6. Set the fine adjustment for re−threading.

7. Place the die stock on the pipe and adjust the pilot.

8. Re−thread, then loosen the clamping screw and deburr the pipe.

9. Open the stock and remove it from the pipe (Do not turn it to remove it).

10. Clean the thread and apply some grease to it.

11. Screw the pipe into the elbow fitting until it stops. Use a pipe wrench.

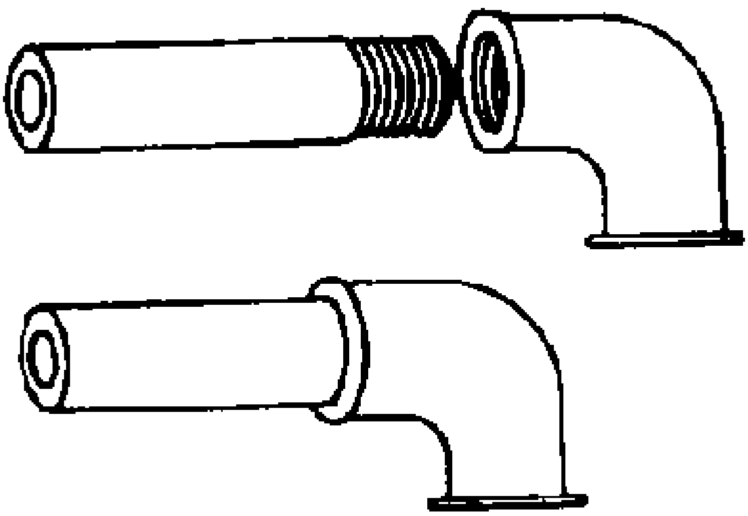

Figure 35. Making a joint by screwing

Note:

– Where tight joints are to be made of pipes, apply a packing of hemp tightly, starting from the front end of the pipe backwards. Apply in right–hand direction if the thread is right–hand. Then apply acid–free grease and screw into the internal thread, first by hand, then with a pipe wrench.

– Where the pipe joint is to be made as a part of a permanent pipe installation, use a pipe with long thread to ensure that the screwed joint can be loosened even after a long time. Screw a pipe bell over the full length of the thread. Use short thread on the pipe and press it flush on the long thread. Then turn back the pipe bell and join both pipes without twisting either of them.

9.2. Indirect Joints

Most threaded joints for fastening purposes are indirect joints. When making the joint, make sure that the nominal diameters, pitches and senses of rotation as well the material of bolts, screws and nuts coincide.

There are two main ways of making a threaded joint the indirect way.

1. Bolt – component parts – nut
2. Bolt – component parts – component part with female thread

Task:

Two steel parts are to be joined firmly by a hexagon head bolt and a nut. The bolted joint will be exposed to dynamic stress, hence it must be locked.

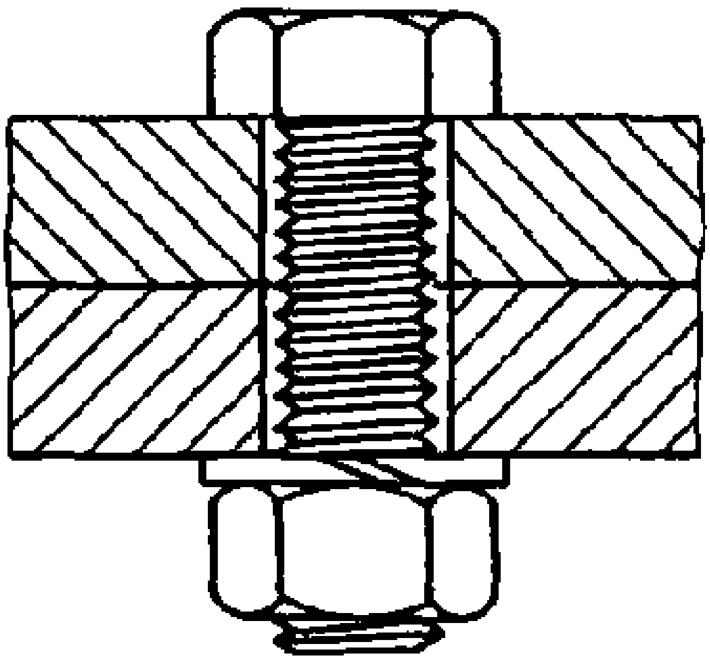

Figure 36. Joint made with a bolt and a nut, locked with a spring ring

Sequence of operations:

1. Mark out the steel parts and punch a mark for the bore hole centres.

2. Set up the steel parts for drilling. Drill holes together, where possible. (The bore hole diameter should be slightly bigger than the thread diameter).

3. Deburr both ends of the bore hole with a spotfacer.

4. Apply some grease to the bolt. Insert the bolt into the bore hole and place a locking element (such as a spring ring) onto the end projecting from the hole.

5. Screw on a nut for a few turns by hand, then tighten with an open ended wrench.

Note:

– Use washers where the surface of the work is unclean or smoothen the surface.

– Where the bore hole is provided when the part is supplied, use a flat or pilot–type countersink to level the face which bears the bolt head.

Task:

Three steel parts are to be joined firmly by a hexagon head bolt. The receiving thread is to be in the last of the three component parts. The bolted joint will be exposed to dynamic stress.

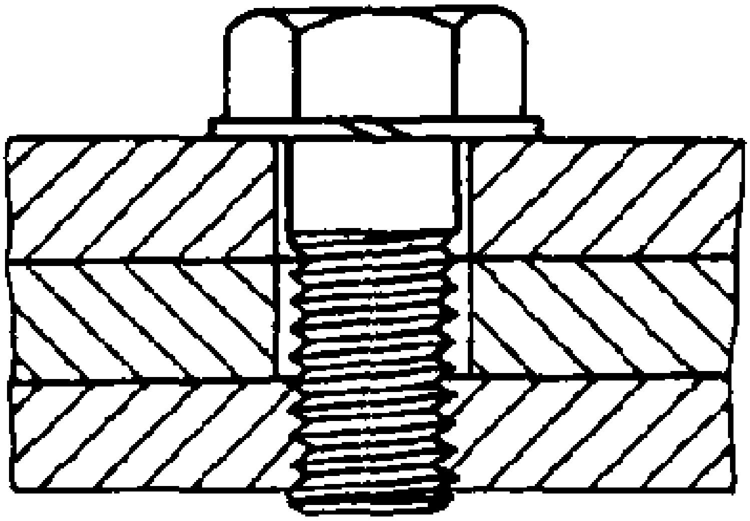

Figure 37. Joint made with a bolt and a component part, locked with a spring ring

Sequence of operations:

1. Mark out all steel parts, punch a mark for the bore hole centre.

2. Set up the steel parts for drilling, drill the holes together, if possible. The bore hole diameter should be of the same dimension as the minor diameter of the thread.

• Use the following formula to calculate the drill diameter:

$$\boxed{D = N - S}$$

where:

D – minor diameter of the thread/hole diameter
N – nominal diameter
S – pitch

• For blind holes, consider the length of thread engagement and the run–out depth of the thread tap. The tap hole must be made deeper by that dimension. Formula:

$$\boxed{T_B = T_G + T_A}$$

where:

T_B – hole depth
T_G – depth of thread
T_A – depth of run–out

Where no values can be taken from handy tables, calculate approximate values using the following formula:

$$\boxed{TA = 0.7 \cdot D}$$

• Read the speed of the drill from the table or calculate it with the following formula:

$$\boxed{n = \frac{V \cdot 1000}{D \cdot 3.14}}$$

where:

n – speed (rpm)
V – cutting speed (m/min)

3. Take the component parts apart and work them separately. Face both sides of the hole with a 60° included angle countersink. The hole to be faced is that in the last component part in the joint. The sink diameter is to be the same as the thread diameter.

Then cut the thread.

$\boxed{D_S = N}$

4. Bore an oversized hole in the two other component parts. The dimension of the oversize depends on the nominal diameter of the bore:

Nominal diameter	M3	M4	M5	M6	M8	M10	M12	M16	M20
Through hole diameter	3.4	4.5	5.5	6.6	9	11	14	18	22

5. Put the component parts are together, push the locking element, such as a spring ring, onto the threaded bolt and apply some grease to the threaded portion. Srew in by hand and then tighten with an open ended wrench.

Five details of making a tapped hole for a screw.

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Rules for assembly:

– Where several component parts are screwed together without a nut, the receiving thread must only be in the last part as seen from the head of the screw. All in between parts have through holes.

– Heads of bolts and screws, when they are not to rise above the surface of the workpiece, must be mounted flush. Cheese head screws are countersunk with a piloted counterbore. Hat–headed screws are countersunk with a 90° included angle countersink.

– Locking devices are always assembled at the side with the highest torque.

– Joints which consist of a bolt or screw and a nut always have the highest torque on the nut. Hence, the head of the bolt or screw is held and the nut is tightend.

– Always assemble a locking component at the nut end in joints which consist of a bolt or screw and a nut.

– Where several nuts are tightened on a component part (for example, the lid of a container), always start from the centre and proceed outwardly, crosswise.

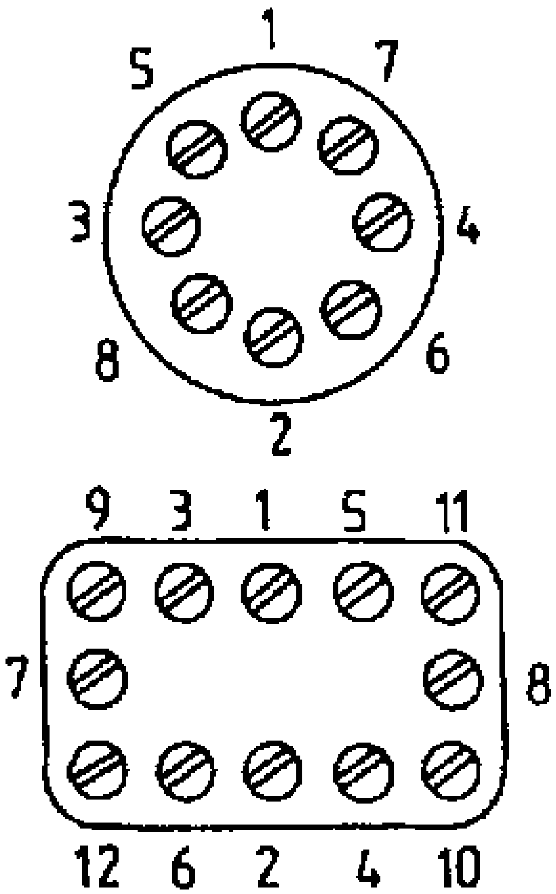

Figure 38. Sequence of operations in tightening a screwed joint

Where several component parts are to be joined by a screw, which part must have a receiving thread?

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How will you proceed in tightening a joint which consists of a bolt and a nut?

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Where should the locking device be placed in a bolt−and−nut joint?

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How will you proceed in tightening several screws or bolts in a lid of a container?

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10. Undoing Threaded Joints

– Bolts and screws which have grown rusty should be treated with a suitable rust solvent, to loosen them.

– Bolts and screws which cannot be loosened despite the use of a rust solvent must be bored out. Bore when you have removed the head and the nut with a chisel.

– Where component parts are to be taken apart, all screwed joints should be loosened before the parts are fully dismantled.

– Use a suitable support for large parts which are to be dismantled so that they cannot drop onto the ground. Put the support in place before you unscrew the joints.

– Make sure that you remember the correct mounting position of parts which were removed for repairs.

Mark the parts suitably for re–assembly.

Use the right size of tools for disassembly work.

Beware that bolt threads or nuts are not damaged or you slip and cause injuries.

Give important details of dismantling component parts.

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What general requirements must be met by assembly tools?

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Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Instruction Examples for Practical Vocational Training

Table of Contents

Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Instruction Examples for Practical Vocational Training

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Preliminary Remarks

The present material includes four selected instruction examples by means of which methods of making threaded joints can be practised. In doing so, the trainees use different types and kinds of bolts, screws, nuts and locking elements.

In the exercises which are described in this material they shall practise making simple threaded fastening joints with bolts, screws and nuts, consolidating at the same time their abilities in thread cutting. In another exercise, a container is to be made by screwing together sheets. In the final example two pipes are to be joined through a bell piece. The prepared parts which are to be joined should merely be accurate in size and angle. The trainees are required to cut all threads.

For each instruction example, the necessary materials, tools, measuring and testing means, as well as auxiliary accessories are specified to facilitate the preparation and execution of the work. Furthermore, the previous knowledge is given that is required to carry out the exercises. The working drawings and sequences of operations which are attached to the respective exercises shall help the trainees to accomplish them independently.

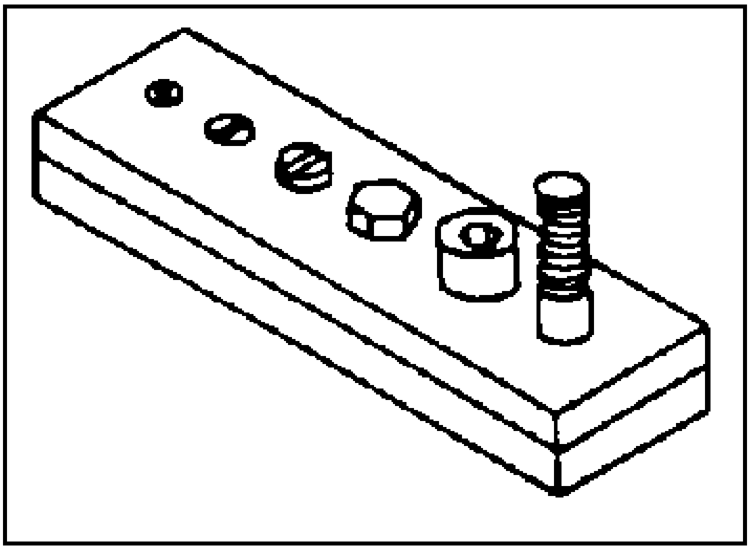
Instruction Example 33.1. Making a Threaded Joint

The purpose of this exercise is to assemble component parts using different types of screws and bolts. The techniques of cutting internal thread is involved, and knowledge of this has been assumed.

Material

– 2 pcs. of flat metal, any type 10 mm thick, 20 mm wide, 140 mm long

– 1 pc. countersunk bolt with intersecting slot M4 x 12, (1)
– 1 pc. countersunk bolt with cross slot M5 x 14, (2)
– 1 pc. Cheese head bolt with cross slot M6 x 16, (3)
– 1 pc. Hexagonal head screw M8 x 18, (4)
– 1 pc. Hexagonal socket–head screw M10 x 20, (5)
– 1 pc. Stud bolt M12 x 8, (6)



Tools

Drilling machine with accessories, marking gauge, steel scriber, centre punch, locksmith's hammer, drills acc. to the dimensions of the minor thread diameter and the through holes, 60° and 90° included angle countersinks, nut taps for the dimensions of the bolt threads, screw drivers for cross slot and intersecting slot screws, open ended wrenches 13/17, hexagon pin–type wrench 8 mm, two open ended wrenches 17/19.

Measuring and testing means

Vernier calliper, try square

Auxiliary accessories

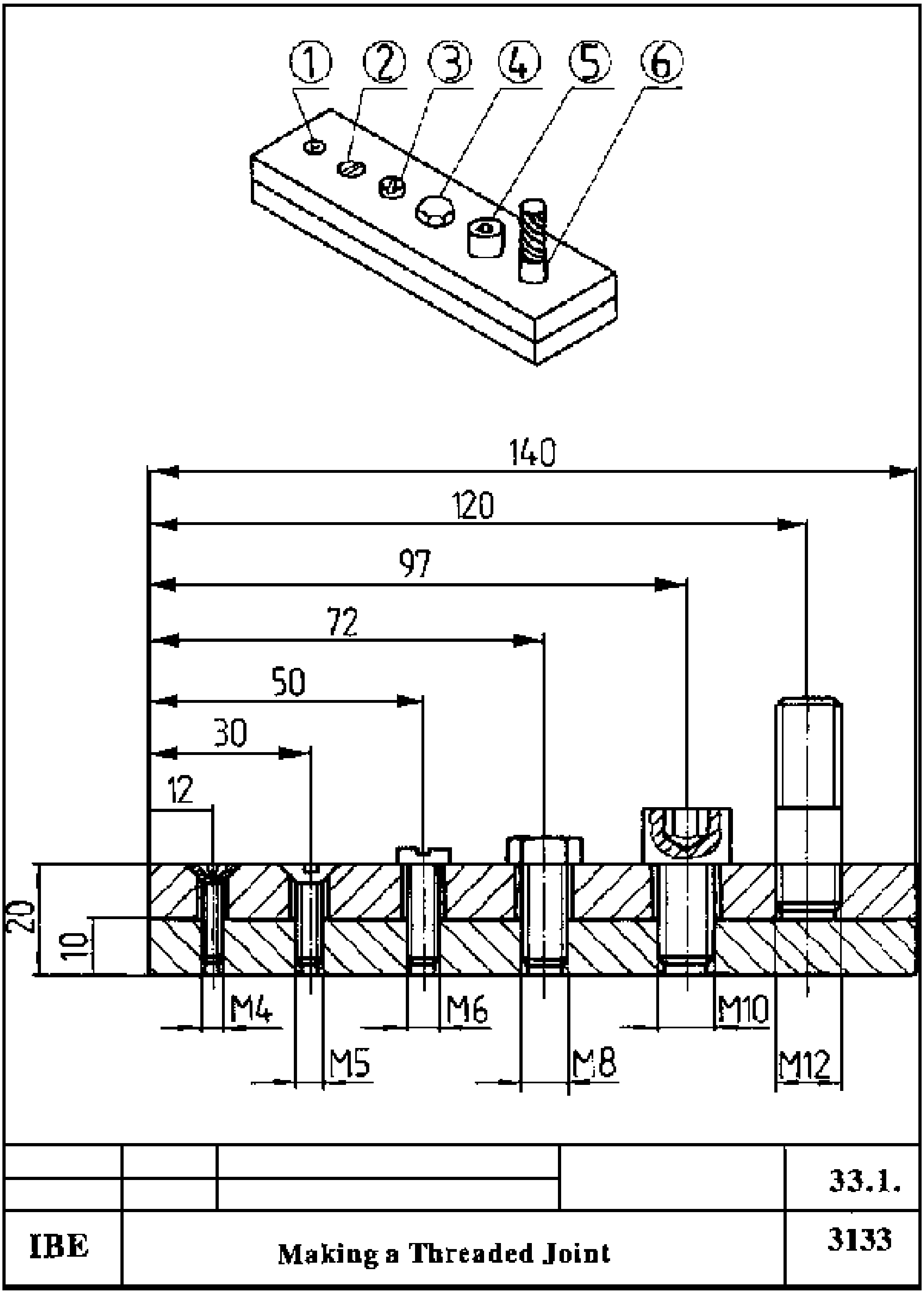
Vice, tap wrench, cutting fluid, two hexagon nuts M12, clamp, machine grease

Necessary previous knowledge

Manual material working: Measuring, testing, marking, punching, drilling, countersinking, thread cutting.

Sequence of operations	**Comments**
1. Prepare your workplace, make all tools, component parts, etc. available	Check for completeness
2. Check all dimensions and angles for correct specifications.	All faces should be clean and even.
3. Clamp the flat component parts together.	Use clamping fixture.
4. Mark the drill centres, punch and drill all holes with drills of the sizes of the minor threaded diameters.	Calculate the bore hole diameter from the equation D = N – S.
5. Take the components apart, spotface the bottom ends of the bore holes and cut internal thread for the intended bolt dimension.	Use 60° included angle countersink.

6. Cut internal thread in the upper portion of hole (6), bore all other holes for the intended bolt sizes in the through holes.	
7. Bore and countersink holes for bolts (1) and (2) in the upper portion.	Use 90° included angle countersink.
8. Put the flat component parts together and insert bolts (1) to (5) successively.	Apply grease to the thread.
9. Screw a nut and a counternut on bolt (6) and tighten, then screw in.	Remove nut and counternut again.
10. Check the threaded joint.	Check for tightness and the flush seat of the bolt heads. Heads are to be flush with the surface of the component of the joint.



Making a Threaded Joint

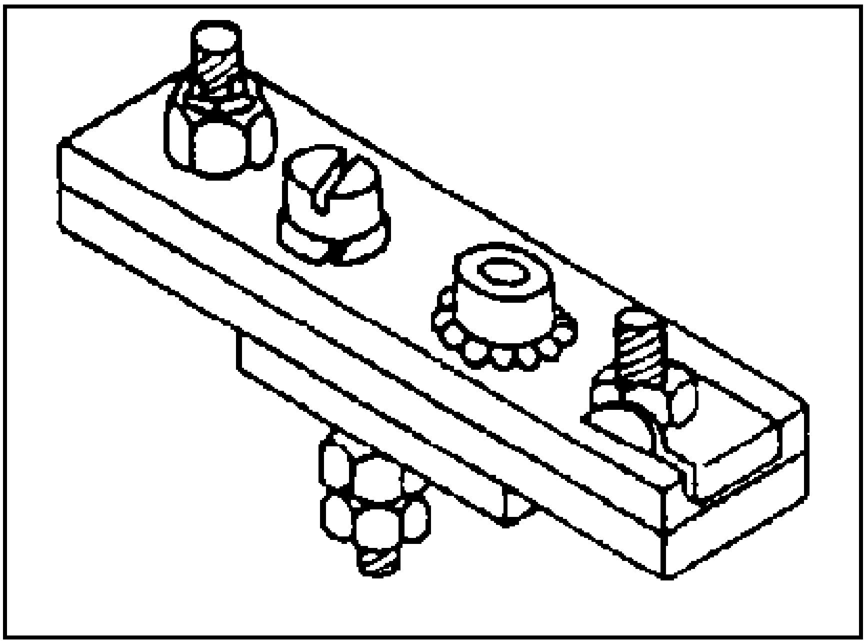
Instruction Example 33.2. Making a Threaded Joint with Locking Devices

The purpose of this exercise is to assemble component parts using different types of locking devices.

Material

– 2 pcs. of flat metal, any type 10 mm thick, 20 mm wide, 140 mm long
– 1 pc. of flat metal, any type 5 mm thick, 20 mm wide, 50 mm long

– 2 pcs. Hexagon head bolt M8 x 30, (1) and (4)
– 1 pc. Cheese head bolt with cross slot M8 x 15, (2)
– 1 pc. Hexagonal socket–head screw M8 x 15, (3)
– 1 pc. Stud bolt M8, (5)
– 3 pcs. Hexagon nut
– 1 pc. Crown nut M8 with cotter pin
– 1 pc. each of spring ring, toothed lock washer, locking plate with tang for threaded bolt M8



Tools

Drilling machine with accessories, marking gauge, steel scriber, centre punch, locksmith's hammer, drills 2 mm, 6.75 mm and 9 mm diameters, 60° included angle countersink, nut tap M8, screw drivers, hexagon pin–type wrench 6 mm, two open ended wrenches 13/17, flat chisel.

Measuring and testing means

Vernier callipers, try square

Auxiliary accessories

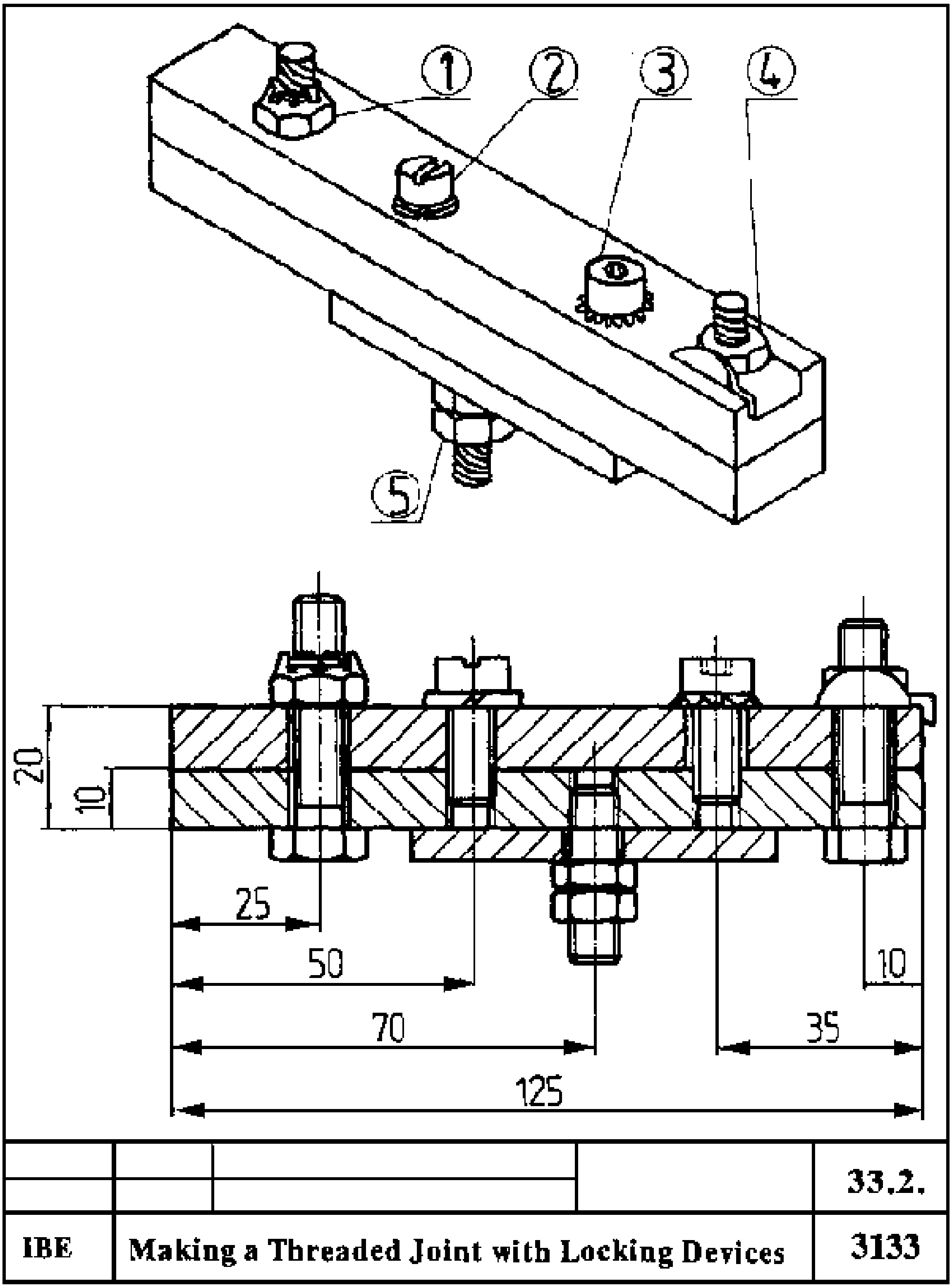
Vice, tape wrench, cutting fluid, clamping fixture, machine grease

Necessary previous knowledge

Manual material working: Measuring, testing, marking, punching, drilling, countersinking, thread cutting

<u>Sequence of operations</u>	<u>Comments</u>
1. Prepare your workplace, make all component pieces, tools etc. available.	Check for completeness.
2. Check the dimensions and angles for correct specifications.	All faces should be clean and level.
3. Clamp together the two flat components 10 x 20 x 140.	Use clamping fixture.

4. Mark, punch and drill the through holes (1) to (4). Use 6.75 mm drill.	Read marking dimensions from the workshop drawing.
5. Take the two parts apart, clamp the lower component together with the flat component 5 x 20 x 50 and drill hole (5).	
6. Take the two components apart and cut thread in holes (2), (3) and (5) of the lower component 10 x 20 x 140. Bore all holes with 9 mm drill.	Check the components carefully for boring. Make sure that they cannot be displaced.
7. Grease the bolts, put the locking devices in place and screw in tightly.	
Hole (1): Crown nut with cotter pin	– Drill hole cotter pin (2 mm dia.) after tightening.
Hole (2): Spring ring	
Hole (3): Toothed lock washer	
Hole (4): Locking plate with tang Hole (5): Nut and counternut	– Lift the side of the locking plate with a flat chisel and turn over.
8. Check the joints and locks.	Check the joints for tightness, the dimensions and position of the locking devices.



Making a Threaded Joint with Locking Devices

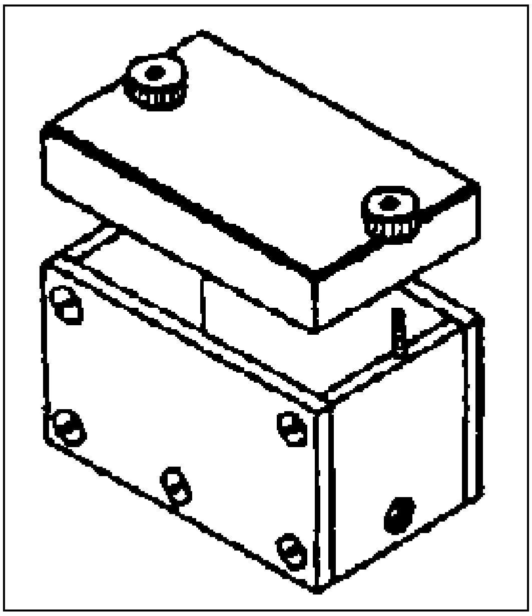
Instruction Example 33.3. Making a Container with Lid

The purpose of this exercise is to make screwed joints using countersunk screws and stud bolt.

Material

– 2 pcs. of metal plate, any type 8 mm thick, 84 mm wide, 100 mm long
– 3 pcs. of metal plate, any type 8 mm thick, 100 mm wide, 150 mm long
– 1 pc. of metal plate, any type 8 mm thick, 84 mm wide, 134 mm long

– 12 pcs. Countersunk screws M4 x 14, (1)
– 2 pcs. Stud bolt M4, (2)
– 2 pcs. Knurled nut M4, (3)



Tools

Drilling machine with accessories, marking gauge, steel scriber, centre punch, locksmith's hammer, drills 3.3 mm, 4.2 mm diameter, 90° included angle countersink, serial tap M4, screw driver, two open ended wrenches 5.5/7

Measuring and testing means

Vernier callipers, try square

Auxiliary accessories

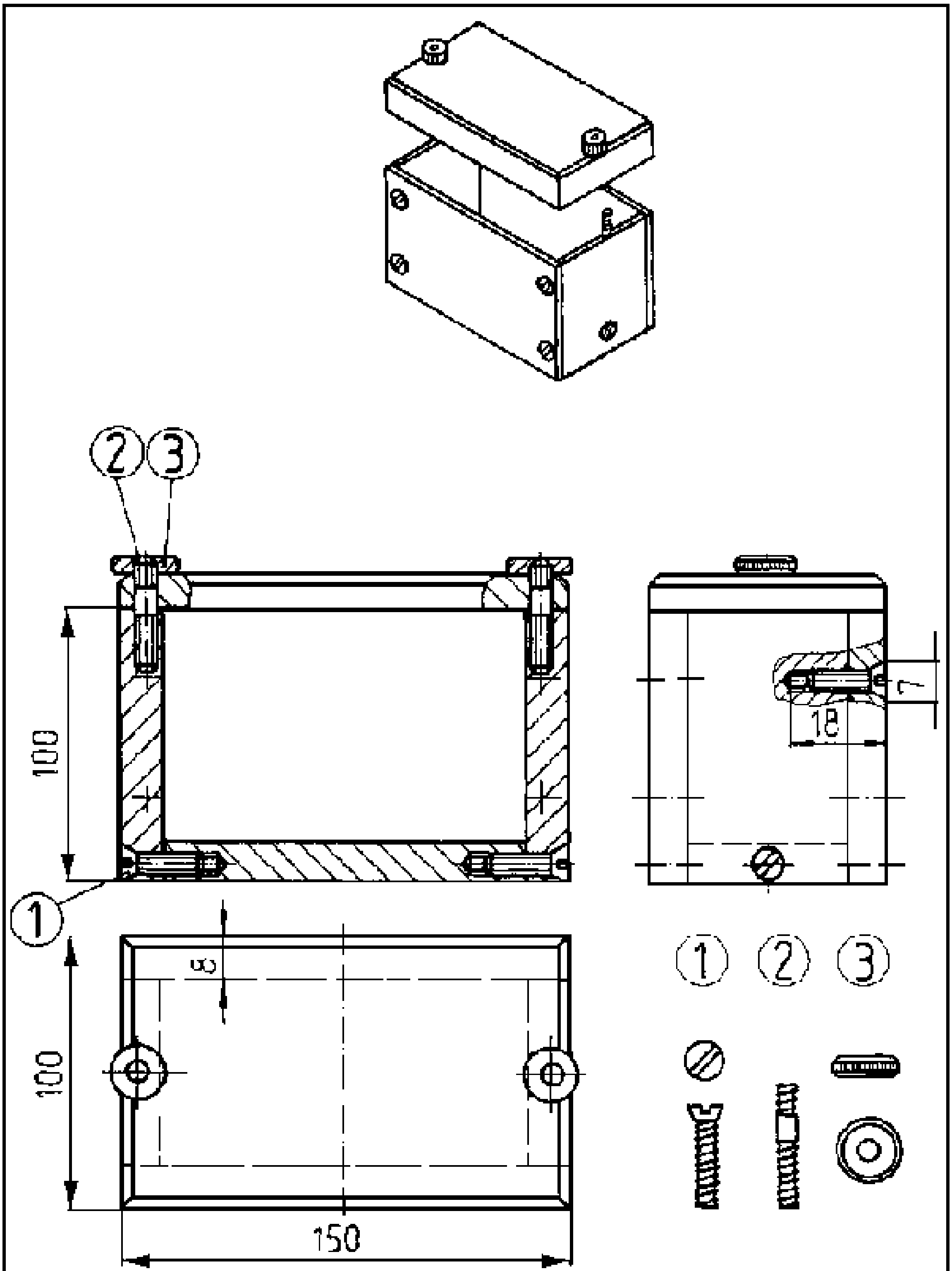
Clamping fixture, two hexagon nuts M4, lap wrench, cutting fluid

Necessary previous knowledge

Manual material working: Marking, testing, measuring, punching, countersinking, thread cutting

<u>**Sequence of operations**</u>	<u>**Comments**</u>
1. Prepare your workplace, make all component parts, tools, etc. available.	Check for completeness.
2. Check the dimensions and angles for correct specifications.	All faces must be clean and even.
3. Clamp on front end part with the bottom of the container.	Use clamping fixture.
4. Mark, punch and drill hole of 3.3 diameter, 18 mm deep.	

5. Take the clamped components apart, drill front end part up to hole diameter of 4.2 mm and countersink with 90° included angle tool. Countersunk hole diameter is 7 mm.	
6. Tap container bottom, use serial tap M4.	Consider correct angles.
7. Fit second front end part to container bottom.	Repeat operations Nos. 3 to 6.
8. Screw together the two front end parts and the bottom part.	Use countersunk screws M4, (1).
9. Chuck the two side plates to the assembled parts and proceed.	Repeat operations Nos. 4 to 6.
10. Remove screws from side plates. Put on the lid.	Bore holes in the lid and the container to 3.3 mm dia. Bore holes in the lid up to 4.2 mm dia. Cut thread in container.
11. Screw stud bolts (2) into container, use hexagon nuts.	Screw in the shorter thread end.
12. Remove the hexagon nuts, fit the lid on.	Screw on knurled nuts (3).
13. Check the screwed joints.	check for flush seat of the heads.



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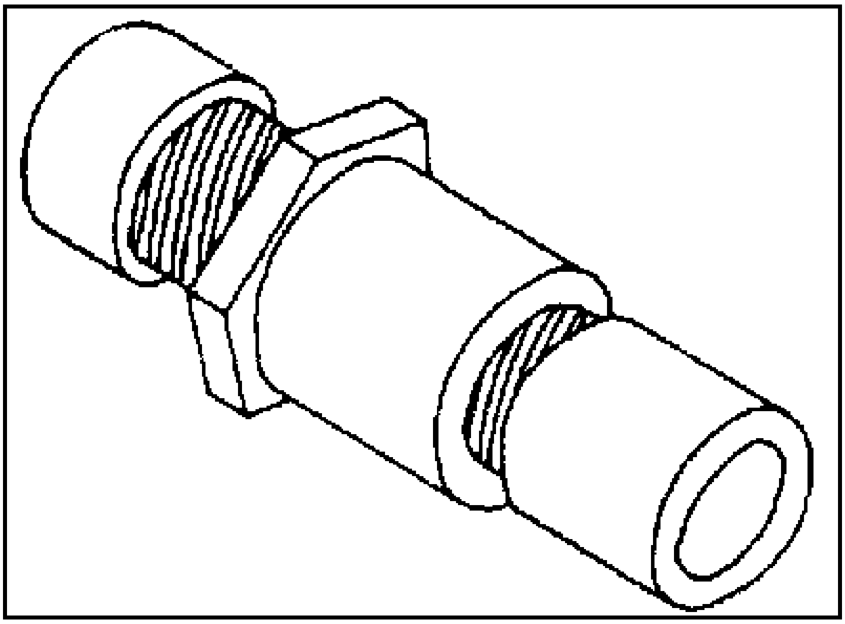
Making a Container with Lid

Instruction Example 33.4. Making a Pipe Joint

The purpose of this exercise is to make a long−thread joint of two pipes using a bell piece.

Material

– 2 pcs. Pipe (1) and (2), 1−inch diameter, abt. 400 mm long
– 1 pc. Pipe nut (2), R 1−inch
– 1 pc. Ring gasket (3)
– 1 pc. Pipe bell with internal thread (4), R 1−inch



Tools

Die stock with cutting dies, R 1−inch, open ended wrench to fit the pipe size, half−round file

Measuring and testing means

Steel rule

Auxiliary accessories

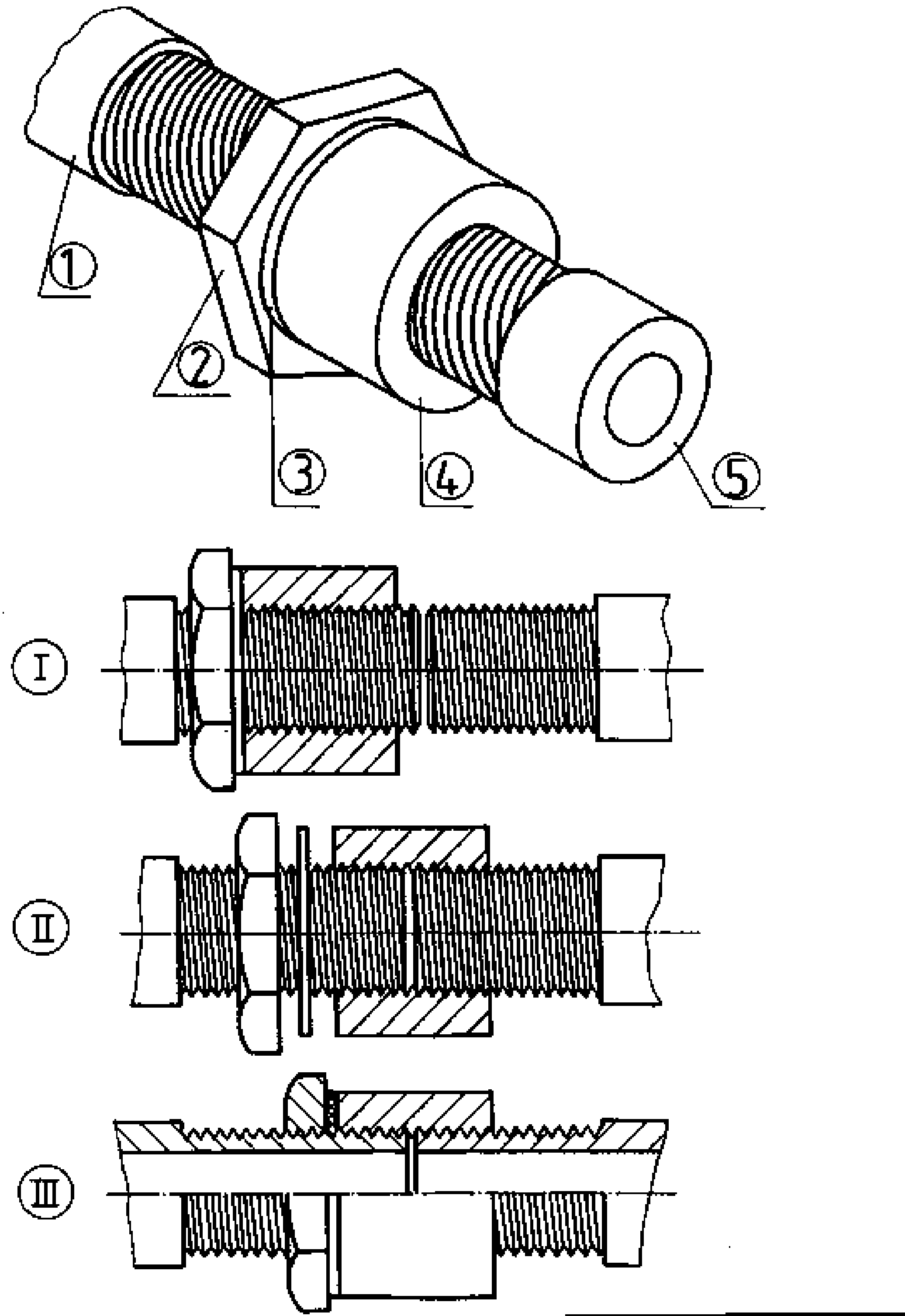
Cutting fluid, hemp, vice, acid−free grease

Necessary previous knowledge

Manual material working: Measuring, testing, marking, thread cutting

Sequence of operations	**Comments**
1. Prepare your workplace, make all component parts, tools, etc. available.	Check for completeness.
2. Check the original dimensions of the pipe pieces.	Check angles, edges inside and outside for burrs.
3. Prepare the die stock, mount R 1−inch cutters.	Mount the cutters in the right 1 to 4 sequence.

4. Mount the fast piece of pipe (2), rough−cut and re−thread the long thread.	Apply cutting fluid to the pipe end. After rough−cutting, set fine adjustment for re−threading.
5. Mount second pipe piece (2) and cut short thread (abt. 19 mm).	Rough−cut and re−thread.
6. Clean the thread and check.	Allow no defects in the thread.
7. Screw pipe nut (2) and the ring gasket (3) onto long thread. Continue screwing the bell (4) until it stops.	Stage (I): Bell to be flush with the pipe.
8. Hold the short thread against the long thread and screw back the bell.	Stage (II): Apply a hemp packing if required, to make the joint tight.
9. Tighten the pipe nut with the ring gasket on the bell.	Stage (III): Use a pipe wrench and open ended wrench.
10. Check the joint.	Check the pipe bell for correct and tight fit.



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IBE	Making a Pipe Joint			3133

Making a Pipe Joint

Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Methodical Guide for Instructors

Table of Contents

Threaded Joints – Course: Techniques of Fitting and Assembling Component Parts to Produce Simple Units. Methodical Guide for Instructors

Institut für berufliche Entwicklung e.V.
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1. Objectives and Contents of the Practical Training in the Techniques of Making Threaded Joints

Trainees who have completed the course are supposed to have a good command of the techniques of making threaded joints. To achieve this, the following is required:

Objectives of training

– The trainees will have a ready knowledge of the purpose and the types of threaded joints and the stresses in these joints.

– The trainees will master the various techniques of making direct and indirect screwed joints for fastening purposes.

– The trainees are in a position to select those joints which serve an intended purpose.

– They can choose the right type of tools, auxiliaries and aids and use them properly, strictly keeping to all regulations on health and labour safety as well as fire protection.

To meet these requirements the instructor or teacher should emphasize the following points of content:

Content of training

Know–how

- Purpose and types of bolts, screws, nuts, locking devices, washers and threaded joints
- Stresses in threaded joints
- Types of tools and their uses
- The technological steps of making direct and indirect bolted and screwed joints for fastening purposes
- Undoing threaded joints
- Safety regulations

Abilities

– Preparing the component parts for assembly
– Assembling the component parts and inserting bolts, screws, nuts and locking devices
– Checking the component parts before and after assembly
– Undoing a threaded joint.

2. Organizational Preparations

Instructions, demonstrations and exercises should be prepared thoroughly and meticulously. This includes:

2.1. Planning the Practical Training in the Techniques of Making Joints

Set an approximately appropriate number of hours in which you want to complete the instruction in the individual techniques of making threaded joints. Plan an appropriate number of hours for the theoretical introduction into each technique, the practical demonstrations, the task–related instructions in preparation of the exercises, the proper execution of the exercises for recapitulations and controls.

When planning your time schedule, remember the level of knowledge attained by your trainees, the conditions of training, the future jobs which your trainees will take on, the degree of difficulty of this training.

The emphasis at each stage of training is always on the teaching of manual skills. They must be given the biggest chunk of time in your schedule.

2.2. Preparing Labour Safety Instructions

A short labour safety instruction should precede any practical exercise, where the major points of the safe handling of all working tools are explained to avoid injuries. The details of the safe handling of drills, countersinks and thread cutting dies will be explained.

These main points should be repeated serval times:

– Make sure that the tools are of the right type and size and in proper working order.

– Make sure that the workpiece is clamped tightly and safely. Do not use excessive force in clamping a workpiece as it will cause damage.

– Use assembly tools of the right size for tightening or loosening bolted and screwed joints. Tools of the wrong size tend to damage the workpiece and may slip off causing injuries.

– Make sure that large parts cannot drop to the ground when the bolts and nuts or screws are removed.

– Always keep your workplace in order, storde all tools properly and place individual parts always together with their matching parts.

A notebook or file should be at hand to keep minutes of these instructions. All trainees are required to certify with their signature that they were instructed accordingly.

2.3. Teaching Aids and Materials

– Every trainee should be given a copy of the “Trainees’ Handbook of Lessons – Threaded Joints”.

– Surveys and tables should be prepared as blackboard drawings prior to the instructions.

– Different kinds of tools, bolts and screws, a number of threaded joints, as well as functional models of assemblies using threaded joints should be used in the demonstrations.

2.4. Working Tools

– Each trainee should have a copy of the “Instruction Examples for Practical Vocational Training – Threaded Joints” as a theoretical basis of the exercises.

– Make a sufficient number of component parts and joints always available for practical exercises, as described in the “Instruction Examples...”.

– Make sure that a sufficient number of tools, measuring and testing means as well as auxiliaries are available as specified in the “Instruction Examples... – Threaded Joints”.

The following basic stock of tools, measuring and testing means as well as auxiliary accessories is recommended:

– Marking gaugers, steel scribers, centre punches

– Locksmith’s hammers, flat chisels

– Vernier callipers, try squares

– Drills, countersinks, thread taps, die stocks, dies

– Screw drivers, wrenches and spanners of different types and sizes

– Cutting fluid, machine grease, tap wrenches

– Vice with protected jaws, suitable types of clamping devices.

– A bench–type drilling machine or column–type drilling machine and the required work–holding devices should be available for necessary preparatory work, such as drilling, boring and countersinking.

– Check the safe and reliable operations of these machines before your trainees use them.

3. Recommendations for the Practical Training in the Techniques of Making Threaded Joints

The following paragraphs make suggestions for the theory instructions, the demonstration of the techniques of bolting and screwing as well as for checking and assessing the trainees’ newly acquired know–how.

3.1. Introductory Instruction

The trainees should be instructed on the fundamentals of the subject. For this, use a room where they can sit down and take notes, or answer the questions in the “Trainees’ Handbook...”. The trainees are supposed to have a good command of the techniques of boring, drilling, countersinking and thread cutting before they are instructed in the techniques of making threaded joints. The essential details of these techniques should be explained occasionally.

The contents of the “Trainees’ Handbook...” follow the system of the introductory demonstration and instruction. The main points in that “Handbook” can be discussed in the order given there.

Purpose, Types of Bolts, Screws, Nuts, Locking Devices, Washers and Joints

To start with, explain to your trainees the advantages of joining component parts by bolting or screwing. Use demonstration models to explain the mechanical details and functions of the different kinds of threaded joints.

From this, your trainees will understand the uses of the different joints discussed. Discuss with them the various kinds of joints and their uses. Explain the designations of all bolts and screws to enable your trainees identify the right type of bolt or screw from a piece list. They should be able to identify the nominal diameter and the length of engagement in order to select the right kind of drill and know the depth of the hole to be drilled. Where no original bolts, nuts, screws or joints are available, use the figures in the “Trainees’

Handbook...” to make your trainees familiar with them.

Stresses in Threaded Joints

Make frequent use of the blackboard drawings to explain the stresses in threaded joints. Your trainees should understand that in order to make a properly bolted or screwed joint, they must choose two component parts, one having an external thread, the other with an internal thread, and screw them together by turning in opposite directions.

Illustrate the details of positive and non−positive joints and what they have in common. Explain to them the details of all stresses that may occur in a threaded joint and make them understand how to take them into account when assembling the component parts. Discuss and compare the various ways stresses can act in a joint, i.e. prestressing, service stress, tensile and compressive stresses as well as shearing stress. Say why there is a self−retaining effect in threads for joints that are made for fastening purposes.

Tools

Introduce the tools and explain their uses. Your trainees will have some knowledge of that from the instruction in techniques of manual material working. Discuss these points again with your trainees. Ask them questions to find out what they remember.

Explain the following tools to your trainees:

- Drills, countersinks, thread taps, die stocks, dies
- Screw drive for screws with cross slots and intersecting slots.
- Open ended wrenches, ring spanners, box spanners
- Hexagon pin−type wrenches, adjustable wrenches
- Torque spanners, electrically actuated wrenches

Use the figures in the “Trainees’ Handbook...” to illustrate your points.

When you describe the tools, always tell your trainees how to use them properly and safely: Tell them what may happen when they use the wrong type or size of tool, such as a screw driver, spanner or wrench. Show them damaged bolts, screws and nuts to reinforce their understanding. Do not forget to mention the bodily injuries that can be caused by slipping tools.

The Technological Steps of Making Threaded Joints

The differences in bolted and screwed joints lie mainly in the preparations for making them. It is recommended to illustrate these differences by examples.

Direct and indirect threaded joints should be dealt with separately.

A screwed pipe joint is a good example to illustrate a direct screwed joint. A detailed explanation of a screwed pipe joint is given in the section on the cutting of external thread in the “Trainees’ Handbook...”. The example of a pipe joint there will be understood clearly by your trainees. It is that of a simple screwed joint using a piece of pipe and joining it to another piece by a short thread. Another typical example of a pipe joint is joining pipes by a bell piece and a long thread. This technique is mainly used in permanent pipe installation systems whose position cannot be changed. The technique is practised in the example no. 33.4., but it is good to explain it now to give the trainees a full picture of all techniques.

Most parts that are made for fastening purpose are indirectly bolted or screwed. The details of indirect joints are explained in the “Trainees’ Handbook...”. The two examples are those of a joint comprising a bolt, component parts and a nut, and of a bolt, component parts and another component part with a receiving thread.

It is recommended to repeat the details of these joints when discussing the technique of thread cutting.

(A good time is when the calculation of the drill diameter and the bore depth from the available kind of screws is the topic.)

Give examples in figures. Use blackboard drawings on the basis of the respective diagram in the “Trainees' Handbook...” and enter dimensions for the calculation. Require your trainees to describe by exactly calculated values the techniques of drilling, boring, countersinking and thread cutting. Then give them the most important details of the assembly operations.

Tell them that these are “rules”. A summary of these rules is given in the “Trainees' Handbook...”. The trainees should give the answers to the questions in their “Handbooks”.

Undoing Threaded Joints

The undoing of threaded joints should be explained with particular reference to safety aspects. Emphasize the need of using tools of the right type and size, the safe handling of all dismantled components and their identification for re−assembly. The loosening and dismantling of bolted or screwed joints is certainly a most requisite procedure. However, the fact should be stressed and repeatedly explained that bolts and screws and nuts which cannot be loosened despite the use of rust solvents, must be removed with a drill (bored out). This is in most striking contract to what the trainees were told about the specifics of bolted and screwed joints. It is a main point to make them understand that some way out of a given situation must always be found, even if by destruction.

It is most important that the component parts in the joint remain undamaged. The trainees should be told that this is the rule, and follow it.

Safety at Work

The main points of safe boring, drilling, counterboring and thread cutting should be discussed again. These main points can be taken from the “Trainees' Handbook...”.

3.2. Exercises

Instruct your trainees to observe the labour safety regulations, before they start doing practical exercises. Then show every trainee his place of work and check that the machines and equipment in the workshop are in working order.

Begin each exercise by explaining the theoretical background and follow it with the practical execution of the exercise. Tell your trainees to go about their work with a sense of good craftsmanship. Also tell them where to expect difficulties. The practical exercises can be done in the order in which they are given in the “Instruction Examples...”.

Using the “Instruction Examples for Practical Vocational Training − Threaded Joints” the trainees can do four exercises in different techniques.

The “Instruction Examples...” contain lists of component parts (material), tools, measuring and testing means, auxiliary accessories and a workshop drawing. The trainees will find there the information they need to exercise the examples properly and thoroughly. The instructor is advised to make the trainees aware of the weak spots, where they may be facing difficulties, and enable them to assess the results of their own exercises correctly.

The instructor will do good to do the exercises himself, using the same tools his trainees will have to use, before he asks them to do the exercises themselves.

To make the instructor more aware of the major points which his trainees are to achieve in practice, we will now describe the exercises of the “Instruction Examples...”.

Instruction Example 33.1. Making a threaded joint

Different kinds of bolts and screws are screwed into two flat pieces of metal, the choice being open. The flat component part which is on top has through holes, the holes in the bottom component part are tapped. The purpose of the exercise is to practise the use of different types of tools for heads of different shapes. Further practice in the techniques of cutting internal thread is intended. (Figure 1)

Instruction Examples 33.2. Making a threaded joint with locking devices

Different kinds of bolts and screw with locking devices are screwed into two flat pieces of metal, the choice of the metal being open. The purpose of the exercise is to practise the proper use of different kinds of locking devices. Further practice in the techniques of cutting internal thread and making threaded joints is intended. (Figure 2)

Instruction Example 33.3. Making a container with lid

A container is made of 8 mm plate sections, the joints are made with countersunk screws. The lid is fitted on stud bolts and knurled nuts and can be screwed on the container. (Figure 3)

Instruction Example 33.4. Making a pipe joint

Two pieces of a 1–inch pipe are to be joined by a pipe bell on a long thread. The purpose of the exercise is to practise the use of the die stock for cutting pipe thread and making the joint of the two pieces of pipe by a pipe bell without turning the pipes. (Figure 4)

All trainees can do the exercises together if sufficient pieces of metal, bolts, tools, etc. are available.

This will give every trainee a chance of doing all exercises himself. Allow them as much time as they need to complete the exercises.

Where not enough component parts, bolts, tools, etc. are available, the trainees can work in groups. Each group should do one exercise at a time.

Other exercises can be done without prejudice to those suggested above. In that case the instructor should make sure that the techniques previously taught in this course can be practised extensivily.

Major Points for Practical Training

We recommend that the instructor selects certain aspects which he will give his particular attention. Here are a few suggestions:

- Do the trainees prepare their places of work with sufficient care and circumspection?
- Do they select the right type and size of tools for a particular assembly job?
- Will they do a job in the correct sequence of operation?
- Do they grease the bolts before they screw them in the metal component?
- Are the trainees able to meet the quality requirements?

In particular:

- Are all screws properly tightened?
- Have the locking devices been properly used?
- Will the threaded joint perform the intended task?
- Have the holes been tapped properly?
- Are the trainees able to asses their own work correctly?
- Have all labour safety regulations been observed?

3.3. Recapitulation and Controls

A list of questions has been compiled for this paragraph, which are to check the trainees' newly acquired knowledge. Most of these questions have been asked in the "Trainees' Handbook of Lessons...".

1. What is a bolted or screwed joint?

(Bolted or screwed joints are detachable joints where two or more individual component parts are joined by bolts, screws and nuts, directly with each other.)

2. What conditions must be satisfied by a threaded joint which is exposed to dynamic stress?

(Suitable locking devices are used where detachable joints have to be secured against accidental loosening due to the action of dynamic stress.)

3. Give uses of countersunk bolts and screws.

(They are used in industrial plant and machinery, where safety requires that no screw head projects from the surface of a component part.)

4. What is the difference in the length of engagement of a cheese head bolt or screw and a countersunk bolt or screw?

(As to cheese head bolts or screws the threaded shanks are inserted into a component part. As to countersunk bolts and screws the heads are flush with the surface of the part into which they are screwed.)

5. Where does the shape of a sheet metal screw differ from that of a wood screw?

(On sheet metal screws, there is thread on the entire cylindrical portion of the screw, with a tip, whereas on wood screws the thread is only as long as the tapered portion of the shank.)

6. What conditions must be satisfied by the materials of which nuts, bolts and screws are made?

(Bolts, screws and nuts must be made of the same material and have the same kind of coating.)

7. Identify uses of knurled nuts and wing nuts.

(Knurled nuts nad wing nuts are used for producing detachable joints of component parts by hand.)

8. Identify elements of locking devices which must be used once only.

(Cotter pins, spring rings and out−bent locking devices are used once only.)

9. Suggest an effective way of locking when the shank of a bolt projects the nut.

(The locking effect can be enhanced on bolts which have their shanks projecting beyond the nut by screwing a counternut onto the projecting portion of the shank. Both nuts must be screwed tight.)

10. Give uses for washers.

(Washers are used on bearing faces when the latter are not properly machined, where bolts, screws and nuts are to be tightened on oblong holes and where slopes of the bearing face must be compensated.)

11. Name different types of threaded joints.

(There are direct joints, indirect joints, fastening joints and adjustable joints.)

12. Identify a critical specification of a thread for fastening purpose.

(It must have a high self−retaining effect.)

13. Name different kinds of stress in threaded joints for fastening purpose.

(There are prestressing and service stress, which act as tensile or compressive forces, and shearing stress.)

14. What may happen when the blade of a screw driver is too narrow?

(The clearance between the blade and the slot is too big, the blade may slip and damage the screw head. Injuries can be caused.)

15. What may happen when an extension is used on an open ended wrench for tightening a bolted or screwed joint?

(The joint will be overly prestressed, the threaded bolt will fail either when being tightened or later, under the action of the service stress.)

16. Name applications of the torque spamnner.

(The torque spanner is used on high−strength bolted and screwed joints which require a specific torque or where there are several bolted or screwed joints on one component part and their prestressing is the same.)

17. Give details of making a tapped hole for a screw.

(For blind holes, consider the length of thread engagement and the run−out depth of the thread tap. The tap hole must be made deeper by that dimension.)

18. Where several component parts are to be joined by a screw, which part must have a receiving thread?

(The receiving thread must be in the part which is the last as seen from the head of the screw.)

19. How is a trainee to proceed in tightening a joint which comprises a bolt and a nut?

(Grip the bolt head tightly and tighten the nut.)

20. Where should the locking element be placed in a joint consisting of a bolt and a nut?

(At the side where the nut is applied.)

21. How will you proceed in tightening several screws or bolts in the lid of a container?

(Start from the middle and proceed outwards, crosswise.)

22. Give important details of dismantling component parts.

(Use a suitable support so that the parts cannot drop to the ground. Mark the parts for re−assembly. Loosen the joints before you dismantle the parts fully.)

23. What general requirements must be met by assembly tools?

(The tools must be of the right type and size for the job in hand, and they must be in proper working order.)

4. Teaching Aids

Use visual aids to reinforce the trainees' understanding of your instruction. Visual aids, or other illustrative material, can be bolts, screws, nuts, locking devices, threaded joints or component parts or assemblies of machines with threaded joints. Instructors are advised to use the sample joints made by the trainees during their practical exercises and illustrate good and bad joints.

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

Table of Contents

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

Institut für berufliche Entwicklung e.V.
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1. Objectives and contents of practical vocational training in the working technique of "Manual Thread Cutting"

By concluding their training, the trainees shall have a good command of the working technique of "Manual Thread Cutting". Therefore, the following objectives are to be achieved:

<u>Objectives</u>

– Knowledge of purpose and application of the technique of manual thread cutting.

– Proper command of internal and external threading operations and capability of producing bolted connections.

– Capability of selecting and properly using the appropriate tools.

– Capability of making calculations for the working process and of performing quality control independently.

The following contents must be imparted to the trainees:

<u>Contents</u>

– Purpose of thread cutting
– Thread–cutting tools
– Action of thread cutting
– Special hints for designating threads
– Technology of the internal and external thread–cutting operations.

2. Organizational preparations

In order to guarantee a trouble–free development of the instructions, exercises and practical work it is necessary to prepare this training properly.

The following steps have to be taken:

2.1. <u>Preparations for instructions on labour safety</u>

Prior to the exercises a brief instruction on the proper use of tools and equipment has to be given. This comprises hints for accident−free work too.

The main points of the working techniques of "Drilling and Counterboring/Countersinking" should be recapitulated and supplementary hints for the new working technique be given..

Supplementary hints:

- Clamp the tap firmly in the tap wrench.
- Clamp the threading die firmly in the die holder.
- Use lubricants and coolants.
- Prevent the tools from dropping and put them down carefully.
- Break the chips constantly during this process, otherwise you run the risk of tool breakage.

Familiarity with these hints has to be confirmed by the trainees signatures in a control book.

2.2. Provision of teaching aids

− For demonstration purposes during the instructions a vice should be firmly installed at the place of instruction.

− The "Trainees' Handbook of Lessons − Manual Thread Cutting" is to be handed out to the trainees in sufficient numbers.

− When employing the "Manual Thread Cutting" transparencies series, check whether they are complete (transparencies nos. 9.1. − 9.4.) and whether the overhead projector is in working order. (Check the operating conditions at the place of instruction and make sure of the proper mains supply!)

− Surveys etc. which are to be written on the blackboard have to be completed prior to the instruction.

− All the tools and accessories mentioned in section 3 (for thread−cutting purposes) should be kept ready for illustration purposes.

2.3. Provision of working tools and materials

− The "Instruction Examples for Practical Vocational Training−Manual Thread Cutting" must be handed out to the trainees in sufficient numbers in order to provide them with the theoretical foundations of the exercises to be carried out.

− The initial materials necessary for the exercises have to be prepared and laid out in sufficient numbers − based on the materials mentioned in the "Instruction Examples ...".

− Each trainee is to be provided with a workbench at which a vice is firmly installed. (Check the proper height of the vice!)

− The trainees' workbenches have to be fully equipped with tools and accessories based on the envisaged exercises.

Recommended basic equipment:

steel rule, vernier caliper with depth gauge, try square, steel scriber, marking gauge, centre punch
bastard and smooth files 200 mm (flat)
hand hacksaw, locksmith's hammer, aluminium hammer, flat chisel
serial hand taps and nut taps M3 to M20 for right−hand thread limit plug gauges for threads M3 to M20
matching drills and countersinks
dies M6 to M12
ring thread gauges M6 to M12

− Bench− or column−type drilling machines with the necessary clamping tools (machine vices, holding clamps, C clamps) are required for preparatory work, e.g. drilling and counterboring/countersinking operations.

– Before the exercises can be carried out, the drilling machines' working order and compliance with the regulations on labour safety have to be checked.

2.4. Time schedule

Time planning is recommended for the following training stages

– introduction to the working technique in the form of instructions
– necessary demonstrations
– calculations for the technological process (preparation of exercises)
– job–related instructions to prepare the exercises
– carrying out the exercises
– recapitulations and tests.

The necessary time shares depend on the respective training conditions.

If waiting times occur at the machines (due to the fact that there are more trainees than machines) during practical work, these times can be bridged by minor tasks which are related to the subject.

3. Recommendations for practical vocational training in the working technique of "Manual Thread Cutting"

The following paragraphs comprise proposals on conducting trainee instructions, demonstrations of the working technique and the exercises as well as the tests.

Two course variants are recommended:

Variant no. 1

This variant should be chosen for trainees with previous knowledge and generally good achievements and receptiveness:

1.1. Introductory instruction for the whole subject accompanied by demonstrations which are based on the "Trainees' Handbook of Lessons".

1.2. Exercises in producing internal and external threads based on the "Instruction Examples 9.1. – 9.6." with subsequent evaluation.

1.3. Final test of theory knowledge based on the "Examples for recapitulation and tests".

Variant no. 2

This variant should be chosen for trainees with little previous knowledge or poor achievements:

2.1. Introductory instruction for the subject of "internal thread cutting" (tapping) with demonstrations based on the "Trainees' Handbook of Lessons".

2.2. Exercises in "internal thread cutting" (tapping) based on the "Instruction examples 9.1. – 9.3." with subsequent, evaluation.

2.3. Supplementary instruction for the subject of "external thread cutting" based on the "Trainees' Handbook of Lessons"

2.4. Exercises in external and internal thread cutting operations based on the "Instruction examples 9.4. – 9.6." with subsequent evaluation.

2.5. Final test of theory knowledge based on the "Examples for recapitulation and tests".

Practical skills should be evaluated immediately after handing in the finished workpieces.

Theory knowledge should be constantly checked. However, it is recommended to have a final test written (item 1.3. or, resp., 2.5.) after concluding the exercises.

3.1. Introductory instruction

If possible, this instruction should be conducted in a classroom. Make sure that the trainees put down necessary supplementary notes or answers to questions in their "Trainees' Handbook of Lessons".

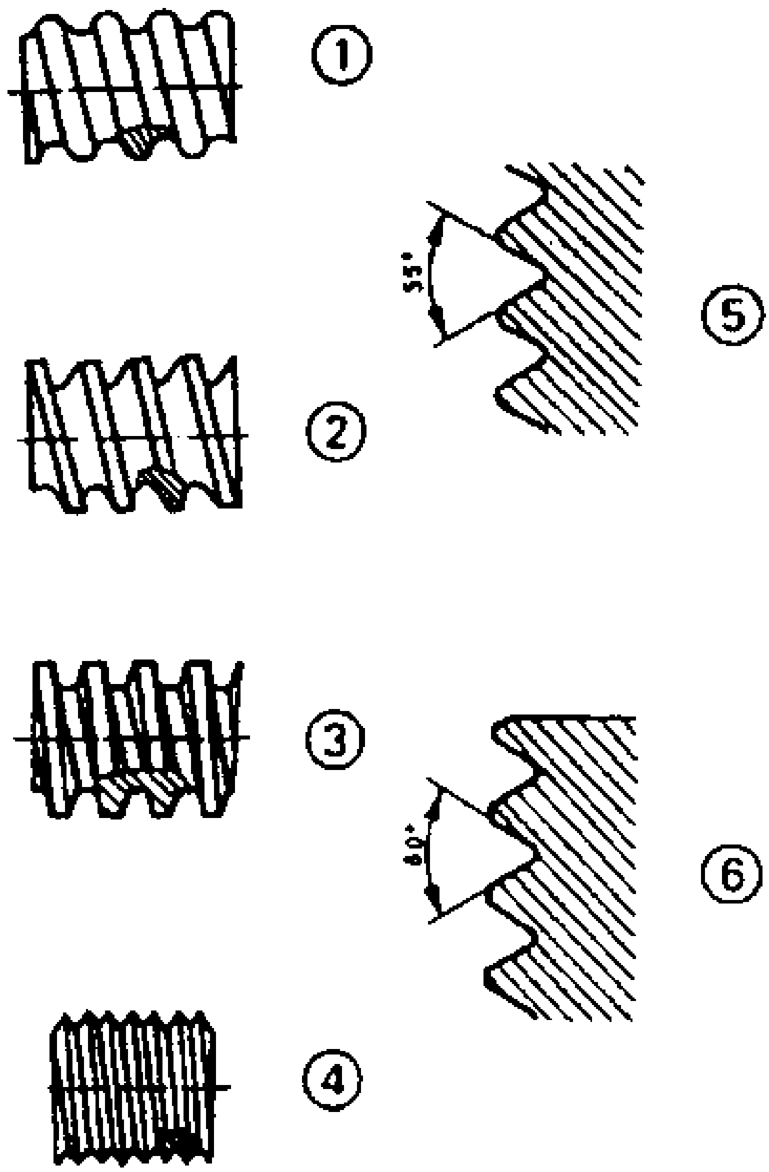
Instruction can be carried out on the basis of the main points contained in the "Trainees' Handbook of Lessons". In order to acquire the skills of the working technique of "thread cutting" the trainees must have a good command of the working techniques of "drilling and counterboring/countersinking". This knowledge must be re−trained at an appropriate moment.

The subjects of "purpose of thread cutting, kinds of threads" as the description of the "tools for thread cutting" should be taught by employing all the teaching aids available.

Purpose of manual thread cutting

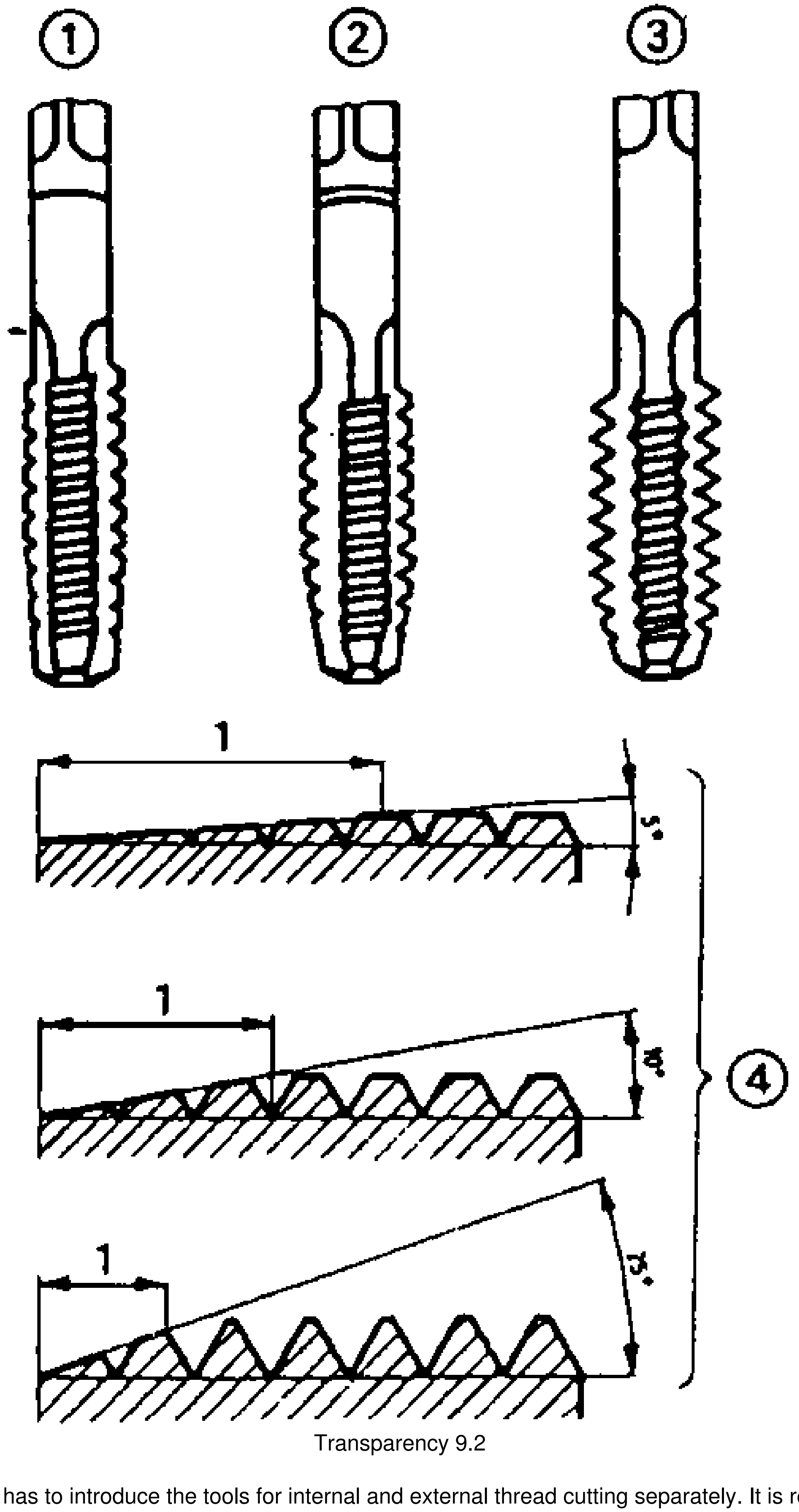
To demonstrate the purpose of thread cutting by hand it is advisable to show various examples of bolted connections, worn and torn bolts as well as cut workpieces (if available). This may serve to point out the single−piece nature of this working technique. The trainees have to understand that this technique is especially important for repair and maintenance work (when technical and economic reasons run counter to machine operation).

The summary should be based on the "Trainees' Handbook of Lessons". The instructor has to give a survey of the types of threads. However, he has to restrict his description to fastening screw threads which are the only ones cut by hand. Here, the instructor should employ transparency no. 9.1.



Transparency 9.1

Thread–cutting tools



Transparency 9.2

The instructor has to introduce the tools for internal and external thread cutting separately. It is recommended to demonstrate original tools mainly. However, transparency no. 9.2. can also be employed here.

The following original tools should be demonstrated:

– serial tap
– nut tap
– die with holder
– die–stock

Tap wrench as well as lubricant and coolant containers (with brush) are shown as accessories to the trainees. The description of the tool design must be structured in such a way that the trainees will understand the ranges of application immediately. To check the knowledge, the questions contained in the "Trainees" Handbook of Lessons" should be answered subsequently. The trainee must be in a position to infer the use from the shape of the tools.

Action of thread cutting

A demonstration of the tools should be included into the instructions. As it is necessary to have a workbench with a vice for this purpose the instructor has to check the local conditions in advance in order not to interrupt the instructions by a time–consuming change of place (classroom – workshop). This demonstration has to be prepared carefully:

– A steel body with drilled and counterbored holes has to be clamped into the vice.
– A nut tap (nominal diameter 8 mm) clamped in a tap wrench is to be placed close to the vice.
– A small container with cutting oil and a brush is also to be placed close to it.

The trainees should stand around the workbench in such a way that they can watch the process. None of them must be standing behind the instructor.

The trainees should carefully watch the process and not distract each other from concentrating on the demonstration. Subsequently, the instructor demonstrates the thread–cutting technique on an internal thread.

The instructor has to show the careful placing of the tool, the sensitive turning in up to the start of the cut and the subsequent permanent forward and backward movements which must be accompanied by a steady supply of lubricant and coolant.

The instructor has to explain to the trainees why he operates the tool in such a way. The trainees have to learn that thread–cutting operations need extreme attention, calmness and understanding. The more precisely the demonstration is carried out, the more the role of the instructor will grow in the eyes of the trainees.

Having completed this demonstration, the instructor has to decide whether he will demonstrate the operation of external thread–cutting now or later.

The next stage is to discuss the main points of action contained in the "Trainees' Handbook of Lessons" to recapitulate what the trainees have seen during the demonstration. The respective questions in the "Trainees' Handbook..." can then be answered.

Special hints for the designation of threads

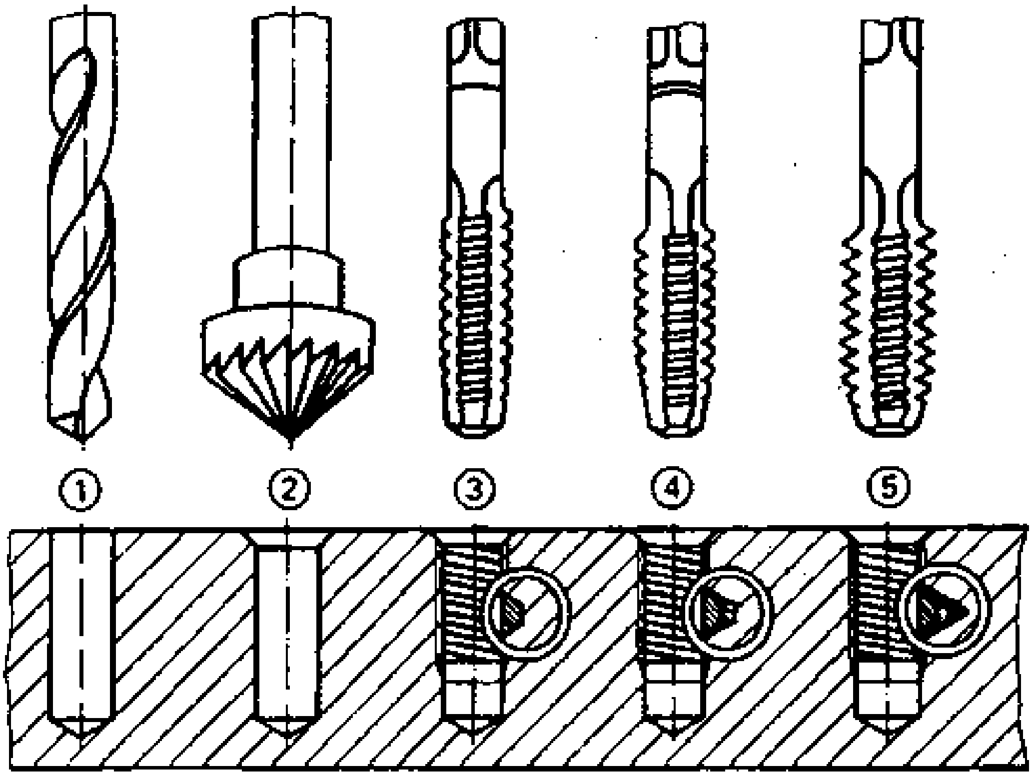
Based on the range of threads employed at the workplace the instructor has to comment on these designations. The "Trainees' Handbook of Lessons" gives the example of "metric ISO threads" to show the connection between coarse and fine threads on the one hand and between the necessary cutting tools and testing tools on the other hand.

A similar form of instruction can be chosen to describe Whitworth and/or other kinds of threads. To check the trainees' knowledge they have to answer the questions contained in their "Trainees' Handbook of Lessons".

Technology of internal thread cutting (tapping)

The "Trainees' Handbook of Lessons" contains a very comprehensive description of the individual operations.

Optically, this can be supported by employing transparency no. 9.3.



Transparency 9.3

It will be necessary to put the tables nos. 1, 2 and 3 on the blackboard in order to have a detailed discussion of the individual steps of internal thread cutting operations. These tables contain data and information which can be used in numerical, examples.

Table no. 1
Table no. 2
Table no. 3

Table no. 1
Technological process of producing an internal thread

no.	Operation	working tools, measuring tools and accessories	tool and machine values
1	clamping	vice. C clamps	–
2	scribing and prick–punching	steel scriber, prick–punch	as per drawing
3	drilling	drill, vernier caliper lubricant and coolant	drill diameter, depth of bore hole; rotational speed
4	countersinking	60º countersink vernier caliper	countersink diameter, rotational speed
5	thread cutting	serial or nut tap ; tap wrench lubricant and coolant	as per nominal dimensions
6	cleaning	compressed air or brush	–
7	testing	limit plug gauge	as per nominal dimensions

Table no. 2
Pitch and tap runout depth with metric coarse threads

N = nominal diameter/mm	**S = pitch/mm**	**T_A = tap runout depth/mm**

3	0.5	2.8
4	0.7	3.4
5	0.8	3.6
6	1	4.5
8	1.25	5
10	1.5	5.5
12	1.75	6
16	2	6.5
20	2.5	7.5
24	3	8.5

Table no. 3
Formulae for calculating the tool values (internal thread cutting)

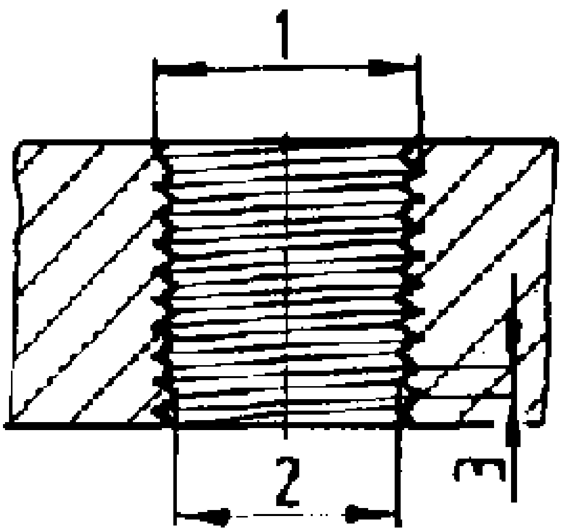
1. Making the hole:	
$D = N - S$	$T_B = T_G + T_A$
D – drill diameter	T_B – depth of hole
N – nominal diameter	T_G – depth of thread
of thread S – pitch	T_A – runout depth
2. Making a counterbored/countersunk hole:	
$D_s = N$	D_s = diameter of counterbored/ countersunk hole
	N = nominal thread diameter

Table no. 1 gives a clear and comprehensive description of the working process. Numerical examples will help to illustrate the individual activities.

Based on the tables nos. 2 and 3 and the figures 4–6 the ′necessary calculations can be made.

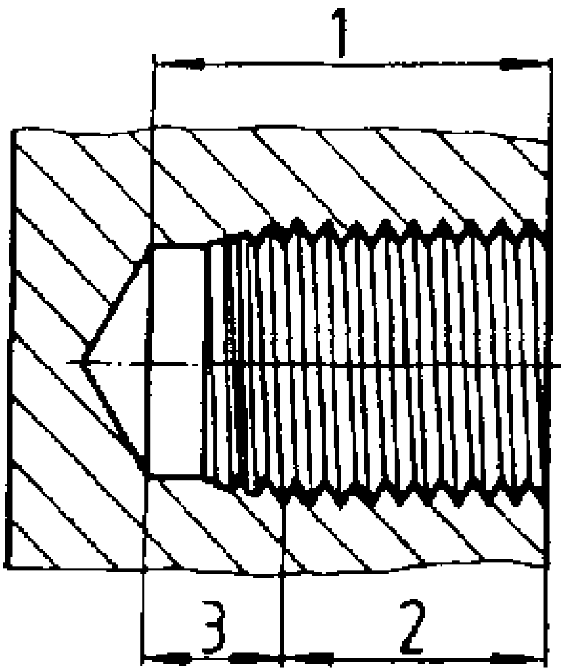
dimensions of internal threads

1 nominal diameter (N)
2 minor diameter (D)
3 pitch (P)



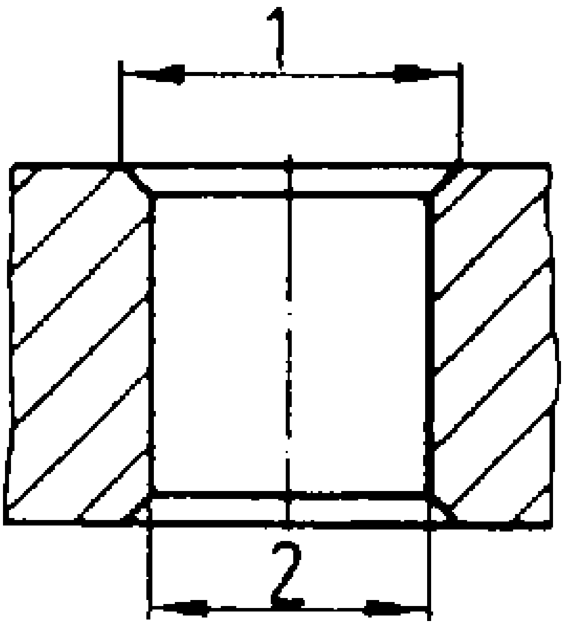
depths on internal threads

1 depth of hole (d_h)
2 depth of thread (d_{th})
3 runout depth (d_s)



counterboring/countersinking of internal thread

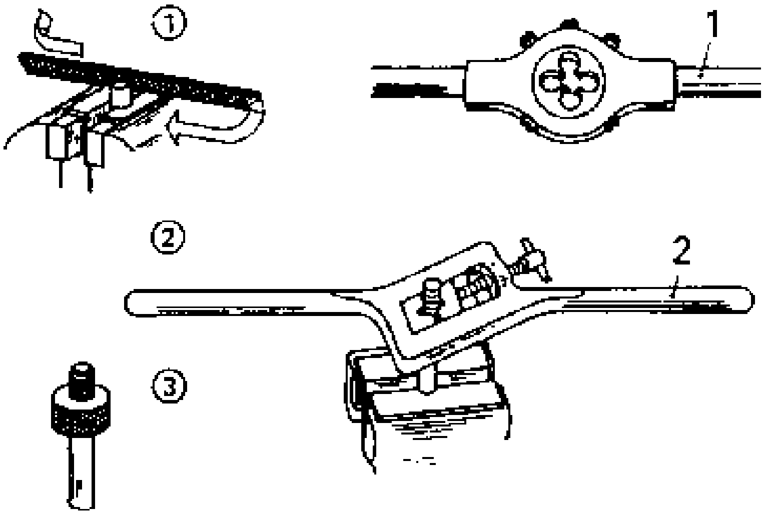
1 diameter of counterbored/countersunk hole (D_s)
2 minor diameter (D)



It is recommended that the trainees do some calculations on the blackboard where they should enter the calculated values in the formulae. In case of mistakes the instructor is in a position to correct them immediately. The respective question contained in the "Trainees' Handbook of Lessons" must be answered by the trainees independently. Practical exercises should not be started before the trainees have a good knowledge of the technological process.

<u>Technology of external thread cutting</u>

The instruction should be based on the main points contained in the "Trainees' Handbook of Lessons" and supplemented by transparency no. 9.4.



Transparency no. 9.4

A demonstration has to be included now:

– A steel bolt (nominal diameter 8 mm) is to be clamped with appropriate accessories (vee jaws, vee attachments) in a vice.

– The appropriate die, a file and container with lubricant/ coolant and brush are to be placed close to the vice.

This demonstration is similar to the first one, i.e. all the activities need a comprehensive explanation. The chamfering operation needs special attention, because a bad start of the cut (due to a bad chamfer) would render a continuation of cutting useless.

After the completion of this process each of the trainees has to hold such a cut thread in his hand and to look for faults.

Even a badly cut thread can serve as a teaching aid, if the instructor clearly indicates the faults and their causes.

In addition to such an "optical inspection", the hints contained in the "Trainees' Handbook of Lessons" may serve as a teaching aid.

3.2. Exercises

If it has not been possible to include the demonstration of the action of external and internal thread–cutting tools in the instructions, this should be done right now before the workshop exercises begin.

If the trainees avail of little practical skill only, they should carry out some preliminary exercises at any steel parts:

Cutting of

– simple threaded through holes
– short external threads on bolts.

However, it is also possible to begin with the first simple exercises immediately – based on the "Instruction examples for practical vocational training".

But it is necessary to prepare every individual exercise by a brief job–related instruction during which the trainees are shown a finished workpiece, in order to demonstrate the objectives and main points of this exercise.

The instructor must have finished such a workpiece by himself in order to be familiar with all the problems which might arise in producing such a workpiece.

Thus, the instructor can mention the crucial points of evaluation as well as the difficult areas of manufacturing such a workpiece. During these instructions the sequences of operations and the working drawings of the instruction examples should be placed on the desks so that the trainees can make notes therein.

The trainees must not operate the drilling machines unless they have been made familiar with the function of the control elements before!

The instructor has to check whether the trainees had been given such an instruction in operating drilling machines (based on the respective entries in the control book of labour safety instructions). If this is not the case, such an instruction has to be given now.

During the exercises the instructor must permanently supervise the trainees – no practice without supervision! Special attention must be drawn to the production of bore holes. The instructor is recommended to check the clamping tools for firm clamping.

It is advisable that the instructor demonstrates again the operation of the machine the clamping of the workpiece and the proper drilling process. Special emphasis is to be laid on the process of centring (alignment of bore hole and work spindle) if the workpiece was unclamped between the stages of drilling and counterboring/countersinking.

As it will not be possible to provide each trainee with a drilling machine, the instructor has to determine the proper succession in which the trainees will operate the machines during this job–related instruction.

In this exercise the instructor has to make sure that only one trainee operates the machine. Several trainees at one machine could distract each other from working and increase the risk o accidents!

If waiting times occur during the exercises, caused by using the machines, these times should be bridged by performing some other subject–related task's.

In this case the trainees can prepare the workpieces for the sub sequent process of external thread cutting (sawing–off of bolts, chamfering of bolt heads).

3.3. Examples for recapitulation and tests

This section comprises questions which are to consolidate and test the previously acquired knowledge and skills. Each question is provided with the respective answer. Questions which are also contained in the "Trainees' Handbook of Lessons" are marked with the letter "A".

1. What is the purpose of manual thread cutting?

(Cutting of helical turns of thread in tapping–size holes or on bolts in order to provide bolted connections; manual thread cutting is mainly employed in the fields of single–piece production and repair work, i.e. in fields where the use of machines would be too expensive.)

2. What can be the purpose of screw–thread connections?

(Fastening, movable connections, sealing connections, pipe connections.)

3. Which kinds of thread are cut by hand?

(Fastening bolt threads – e.g. metric and Whitworth threads; pipe .threads – e.g. Whitworth pipe threads.)

4. Which tools are used for cutting internal and external threads by hand? (Serial and nut taps; threading dies and die–stocks.)

5. How do the applications of serial and nut taps differ?

"A" (Serial taps used for blind holes; nut taps used for short through holes.)

6. How do the applications of threading dies and die−stocks differ?

"A" (Dies are used for diameters of up to 12 mm; die−stocks are used for diameters exceeding 12 mm.)

7. What kind of movement is involved in the process of thread cutting?

"A" (Continuous forward and backward movement.)

8. Why must we always move taps or, resp., dies or die−stocks backwards?

"A" (To break off the chips in the thread grooves.)

9. Why must we use lubricating and cooling agents?

"A" (To reduce friction at the cutting edges, to protect the tool from excessive heat, and to make the cutting process more smooth.)

10. What is the designation of a thread limit plug gauge which is used for checking a hole cut with an M8 nut tap?

"A" (M8 thread limit plug gauge.)

11. What does the designation "M 6 x 0.5" mean?

"A" (Metric thread with a nominal diameter of 6 mm and a pitch of 0.5 mm − fine pitch thread).

12. Which operations are involved in manufacturing an internal thread?

(Clamping, scribing/prick−punching, drilling, counterboring/countersinking, thread−cutting, cleaning of hole, testing.)

13. How can we calculate the minor diameter of an internal thread?

"A" (−Nominal diameter minus pitch.)

14. How do we have to consider the chamfer (pointing) of a tap when determining the depth of a bore hole?

"A" (It has to be added to the given depth of thread.)

15. How must tapping−size holes be countersunk?

(Through holes must be countersunk on both sides with a" 60° countersink to the nominal diameter.)

16. Which testing tools are used to test a completely tapped hole?

(Vernier caliper for depth measurement, thread limit plug gauge, for true−to−size testing.)

17. Determine the following tool and machine values for producing a 15 mm deep internal thread M 10 in a steel part made of general structural steel:

drill diameter:	(D = 8.5 mm)
rotational speed:	(n = 1100 r.p.m.)
depth of hole:	(T_B = 20.5 mm)

diameter of counterbored/countersunk hole: (D_s = 10 mm)

rotational speed for counterboring/countersinking: (n = 350 r.p.m.)

Supplement of table in "Trainees' Handbook":

"A" (machine vice; scriber/punch; 60° countersink; serial tap M 10; tap wrench, cutting oil; brush; thread limit plug gauge M 10)

18. Which operations are necessary to produce an external thread? (Clamping, chamfering, thread cutting, cleaning, testing.)

19. How do we fix bolts in a vice?

"A" (By means of vee attachments, insets, vee jaws or clamping jaws for round material.)

20. Why must a bolt be provided with a chamfer?

"A" (Otherwise it would be impossible to use the tool in an angular position.)

21. What kinds of faults on external threads can we detect by eyesight?

(Oblique thread, rough and cracky turns.)

4. Application of the working technique of "Manual Thread Cutting"

Based on the variants described in section 3, the exercises can be designed as a single subject–oriented instruction or divided into two stages. Both variants envisage the production of the same complex workpieces on which the trainees can practice this working technique. Based on the "Instruction examples for practical vocational training – Manual thread cutting", six work–pieces can be produced with a gradually increasing degree of difficulty. These "Instruction examples ..." also comprise a list of materials (initial material, hand tools, measuring and testing tools, accessories) as well as the sequence of operations associated with the production of the workpiece. Also contained is an illustrative working drawing.

Thus, the trainees avail of all the necessary information to begin their exercise–related work.

The training examples are of a complex nature: the trainees will acquire new working techniques and consolidate skills acquired in the past.

If the course of the exercises shows that the achieved quality of the workpieces is not sufficient, the trainees have to perform more comprehensive preliminary exercises.

In this case it is possible to use any waste parts to practise the skills. The envisaged complex exercise can only begin when the respective skill has been practised sufficiently.

The following hint should be taken into account:

The trainee has to do all the necessary work alone – from cutting the initial material up to the completion of the workpiece.

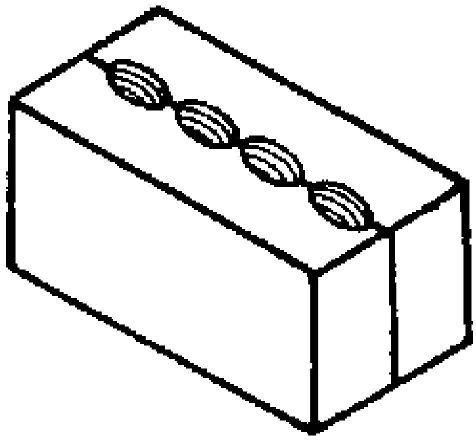
This is the only way to guarantee a just evaluation of the' trainees' achievements.

If the proposed "Instruction Examples ..." are not used for the exercises, it will be also possible to select any other workpiece In this case care should be taken that all the working techniques acquired earlier in the field of thread cutting will be also practised when working on these pieces.

4.1. Instruction Examples

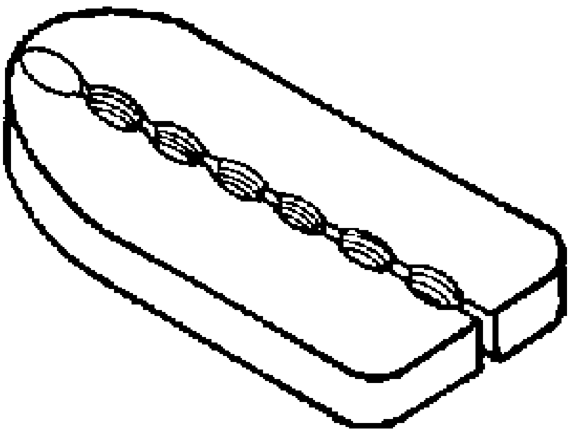
What follows is a brief description of the individual instruction examples, in order to give a survey of the workpieces on which the previous knowledge can be practised:

Instruction example
9.1. Training workpiece for internal thread cutting



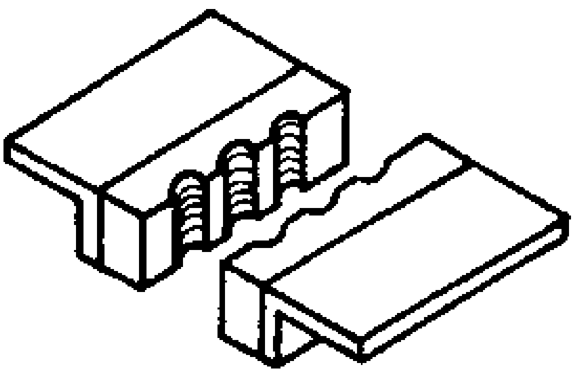
This is a workpiece of two square steel bars clamped together and into which the trainee has to tap through and blind holes on the dividing line of the square steels. After this process both parts can be separated again. The trainee can now get an optical impression of the tapped holes.

Instruction example
9.2. Thread holding clamp



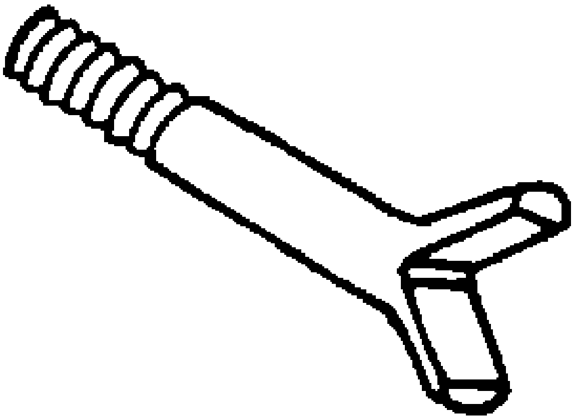
This serves to clamp threaded bolts or screws for further processing in a vice. Metric coarse threads M3 to M10 will be produced in short through holes.

Instruction example 9.3.
Clamping jaws for threaded bolt



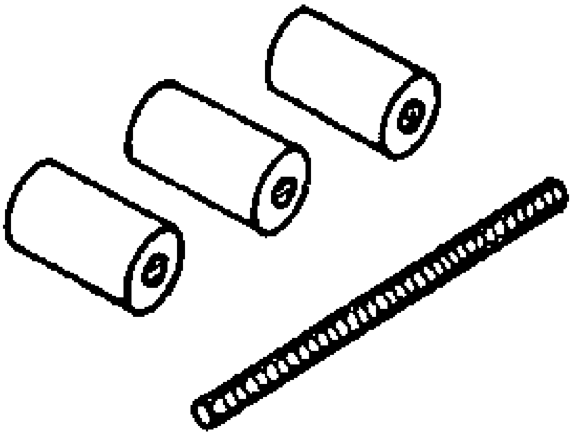
This also serves to clamp bolts or screws. However, M12, M16 and M20 threads will be produced now.

Instruction example 9.4.
Stone bolt



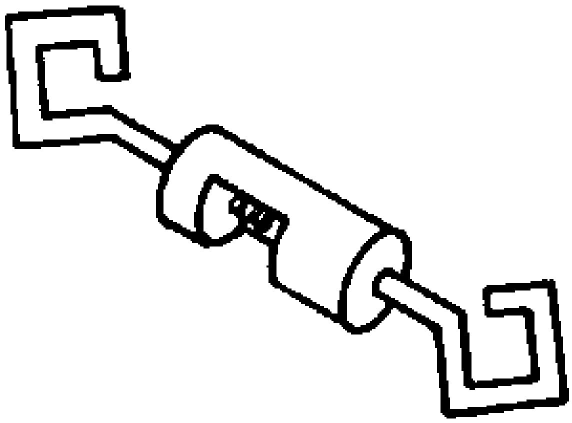
A short thread is to be cut on a bolt. This part can serve as a mounting component for wall installations.

Instruction example 9.5.
Threaded bushes and threaded bolts for C−clamp



The trainee has to produce central and precisely aligned tapped holes in round material as well as a mating long external thread on a bolt. These components are parts of a C−clamp which has to be completed by adding the components as per instruction examples 2.5.; 7.6. and 8.2.

Instruction example 9.6.
Rope turnbuckle



The trainee has to produce an internal thread in combination with two mating external threads. This component can be used as a connecting and tightening component of rope systems.

4.2. Criteria for practical training

It is recommended to determine some crucial points of evaluation and supervision. The following criteria can serve as a guideline

Cutting of internal threads

Operation no. 1 – clamping

- Did the trainee select the appropriate clamping tool?

- Are the workpieces firmly fixed and protected from being pulled up or twisted on the machine table?

Operation no. 2 – scribing and prick–punching

- Is the marking precise?
- Is the hole centre sufficiently pre–punched?

Operation no. 3 – drilling

- Did the trainee select the correct drill?
- Is the drill properly chucked and is the machine set to the correct rotational speed?
- Is the punch mark precisely aligned with the drill?
- Did the trainee use lubricant and coolant during the drilling process?
- Does the drilled hole diameter comply with the given values?

Operation no. 4 – counterboring/countersinking

- Did the trainee use the 60 countersink?
- Did he set the correct rotational speed, and is the diameter of the countersunk hole correct?
- Did the trainee countersink both sides of a through hole properly?

Operation no. 5 – thread cutting

- Did the trainee select the proper tap?
- Does the trainee use the tap properly?
- Are the forward and backward movements in compliance with the requirements?
- Does the trainee use lubricant and coolant?

Operation no. 6 – cleaning of holes

- Does the trainee clean the hole or does he try to test the hole without cleaning it?

Operation no. 7 – testing

- Did the trainee select the proper thread limit plug gauge and did he employ it correctly?

Cutting of external threads

Operation no. 1 – clamping

- Did the trainee clamp the bolt appropriately in the vice (using the proper accessories)?

Operation no. 2 – chamfering

- Is the chamfer even and wide enough?

Operation no. 3 – thread cutting

- Did the trainee choose the proper cutting tool?
- Is the die correctly inserted into the die holder?
- Is the movement of the die–stock correct, i.e. a movement from bottom to top?
- Is the rotary movement evenly smooth?

– Does the trainee use lubricant and coolant?

Operation no. 4 – testing

– Does the trainee choose the proper measuring and testing tools for checking the quality of the workpiece (ring thread gauge, vernier caliper)?

– Is the trainee capable of evaluating the surface quality of the thread by eyesight?

Prior to the start of the exercises the trainees should be made familiar with the main points of evaluation.

5. Captions and legends of the "Manual Thread Cutting" transparencies series

Transparency no. 9.1.: Kinds of threads

(1) round thread (knuckle thread)

(2) saw–tooth thread

(3) acme thread

(4) V–shaped thread

(5) Whitworth thread

(6) metric ISO thread

Transparency no. 9.2.: Serial taps

(1) taper tap (No. 1 tap)

(2) plug tap (No. 2 tap)

(3) finishing tap (No. 3 tap)

(4) comparison of length and angle of chamfer

1 – chamfer length

Transparency no. 9.3.: Operations associated with internal thread cutting

(1) drilling of tapping–size hole

(2) counterboring/countersinking of hole

(3) roughing out

(4) re–cutting with plug tap

(5) finishing

Transparency no. 9.4.: Operations associated with external thread cutting

(1) chamfering of bolt with flat file

(2) thread cutting with

1 – die and holder or

2 – die–stock

(3) testing with ring
thread gauge

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

Table of Contents

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

Institut für berufliche Entwicklung e.V.
Berlin

Introduction

The present documentation comprises six selected instruction examples by means of which the essential manual threading methods can be exercised. In doing so, through hole threads and blind hole threads of different diameters are tapped and external threads are threaded onto bolts.

Apart from only exercising on the training workpiece for internal thread cutting, these instruction examples can fulfill another purpose as well: the thread holding clamp and the clamping jaws for threaded bolts make the tool outfit of the trainee at the workplace complete; threaded bushes and threaded bolts are components for a C−clamp; the stone bolt can be used as a holding element for wall structures; the rope turnbuckle is a connecting and clamping element for rope fastening systems. To facilitate the preparation and execution of the work, the materials, hand tools, measuring and testing tools as well as accessories required for each instruction example are given.

Moreover, the previous knowledge is mentioned which is necessary for the individual exercises.

On the basis of the working drawing enclosed and the appertaining sequences of operations the workpieces can be manufactured.

Explanations as to material indication:

Marking of the steel is done with the value of tensile strength in the unit "Megapascal" (MPa).

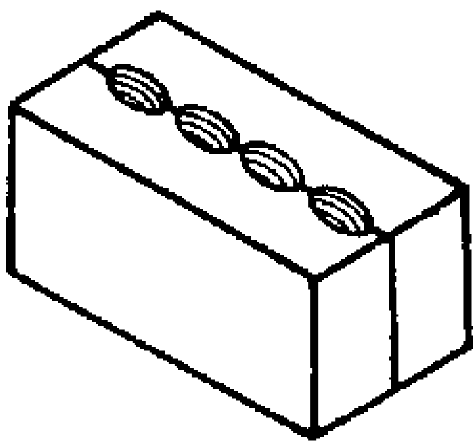
Instruction example 9.1. Training workplace for internal thread cutting (tapping)

To practise tapping of through hole and blind hole threads.

Material

– 2x square material of steel (380 MPa)

Thickness:	abt. 20 mm
Length:	80 mm



Hand tools

Steel scriber or marking gauge; centre punch; engineers' hammer; drill of 4.2 mm dia.; 5 mm dia.; 6.75 mm dia.; 8.5 mm dia.; countersink – 60°; nut tap M5 and M8; serial hand tap M6 and M10;

Measuring and testing tools

Steel rule, vernier caliper for depth measurement; thread cylindrical limit plug gauges M5, M6, M8 and M10

Accessories

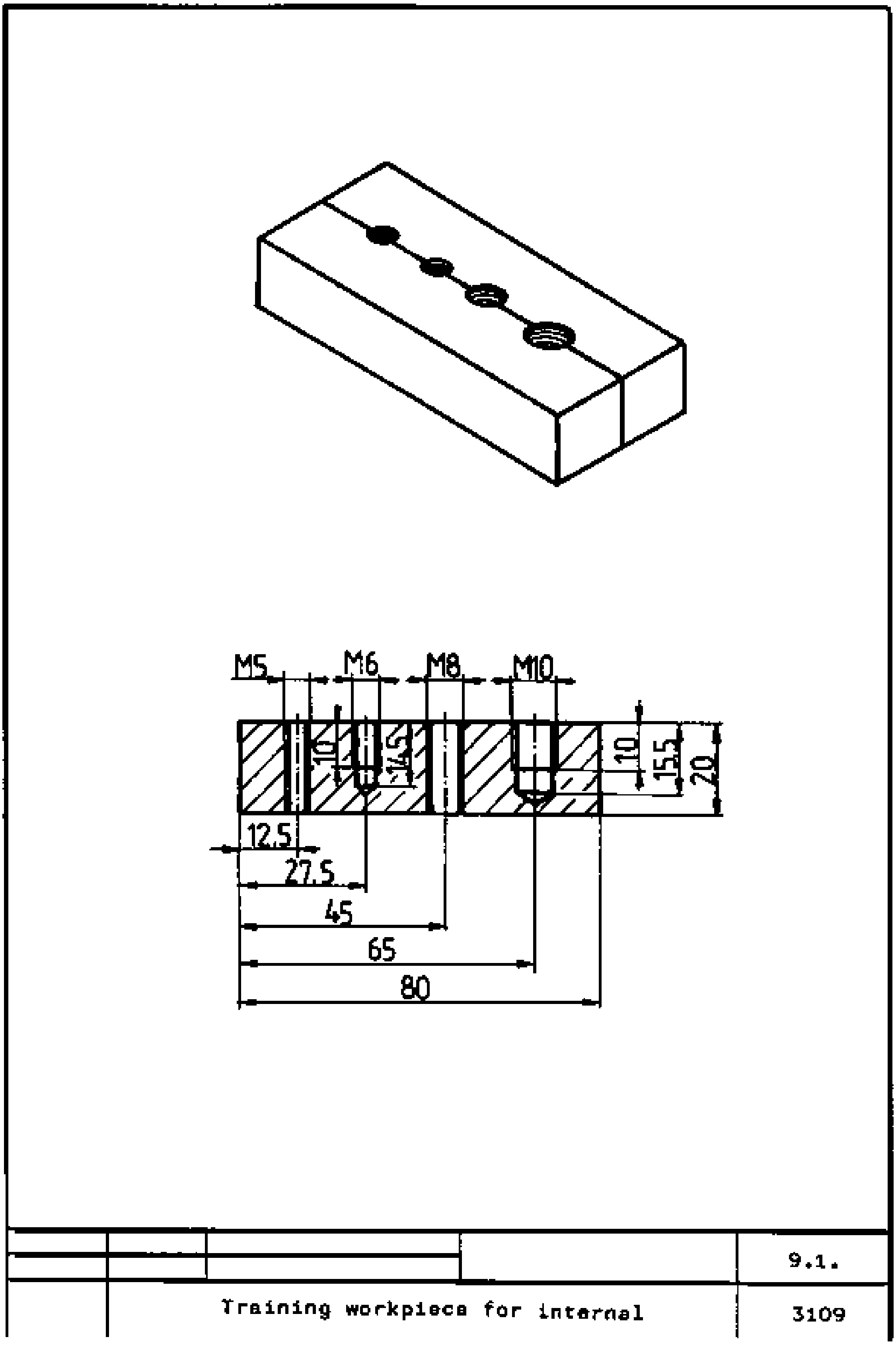
Vice, 2x C–clamps, machine vice, tap wrench, soluble oil, cutting oil

Required previous knowledge

Reading of the drawings, measuring, testing, scribing, prick–punching, sawing, filing, drilling, countersinking/counterboring

Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	– check for completeness
2. Checking of initial length of the workpieces, sawing to size 80 and deburring, if necessary.	
3. Clamping together of the workpieces by means of clamps, scribing and punching on the center line visible through the body edges	
4. Fixing of the workpieces clamped together into a machine vice and setting up of the drilling machine	
5. Producing the holes	
5.1. for hole M5:	
– making of a through hole of 4.2 dia.	– n = 2240 r.p.m.
5.2. for hole M6 x 10	
– making of the blind hole of 5 dia. to a depth of 14.5 mm	– n = 2240 r.p.m.
5.3. for hole M8:	
– making of the through hole of 6.75 mm	– n = 1400 r.p.m.
5.4. for hole M10 x 10:	
– making of the blind hole of 8.5 dia. to a depth of 15.5 mm	– n a 1400 r.p.m.

6. Countersinking of all holes to the measure of the nominal dia.	– countersinking of the through holes at both ends. n = 350 r.p.m.
7. Fixing of the workpiece into the vice	– Do not undo the clamps!
8. Tapping of the holes	
8.1. Tapping of the hole of 4.2 mm dia, by the nut tap M5	– Fix the tap firmly into the tap wrench!
8.2. Tapping of the hole of 5 mm dia. by the serial hand tap M6	– Break regularly the chips!
8.3. Tapping of the hole of 6.75 mm dia. by the nut tap M8	– Add cutting oil!
8.4. Tapping of the hole of 8.5 mm dia. by the serial hand tap M10	
9. Cleaning of the holes	
10. Checking of the accuracy of fit and screwing–in depths of the threads by the appropriate thread cylindrical limit plug gauges and marked threaded bolts (slotting of the thread length)	
11. Undoing of the workpieces and checking of the surfaces of the turns of the thread for tears	



Training workpiece for internal thread cutting

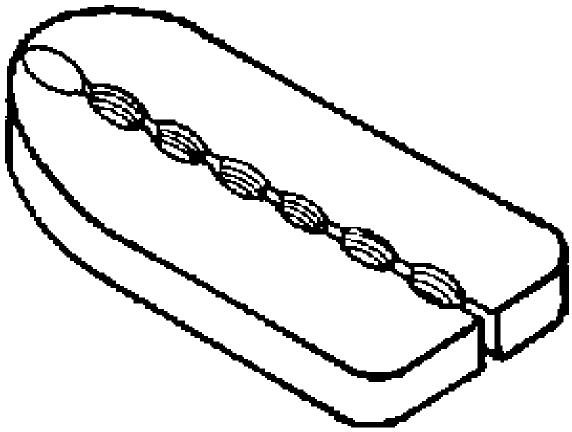
Instruction example 9.2. Thread holding clamp

To practise tapping of short through hole threads of small sizes

<u>Material</u>

– flat material of steel (420 MPa)

Thickness:	8 mm
Width:	36 mm
Length:	100 mm



Hand tools

Steel scriber, beam trammels, centre punch, engineers' hammer, drill of 2.5 mm dia., 3.3 mm dia., 4.2 mm dia., 5.0 mm dia., 6.75 mm dia., 8.5 mm dia., 12 mm dia., Countersink – 60.

Nut taps M3, M4, M5, M6, M8, M10, Smooth file 200 mm (flat), hand hacksaw

Measuring and testing tools

Steel rule, vernier caliper, thread cylindrical limit plug gauges M3, M4, M5, M6, M8, M10, try square, radius gauge 18 mm;

Accessories

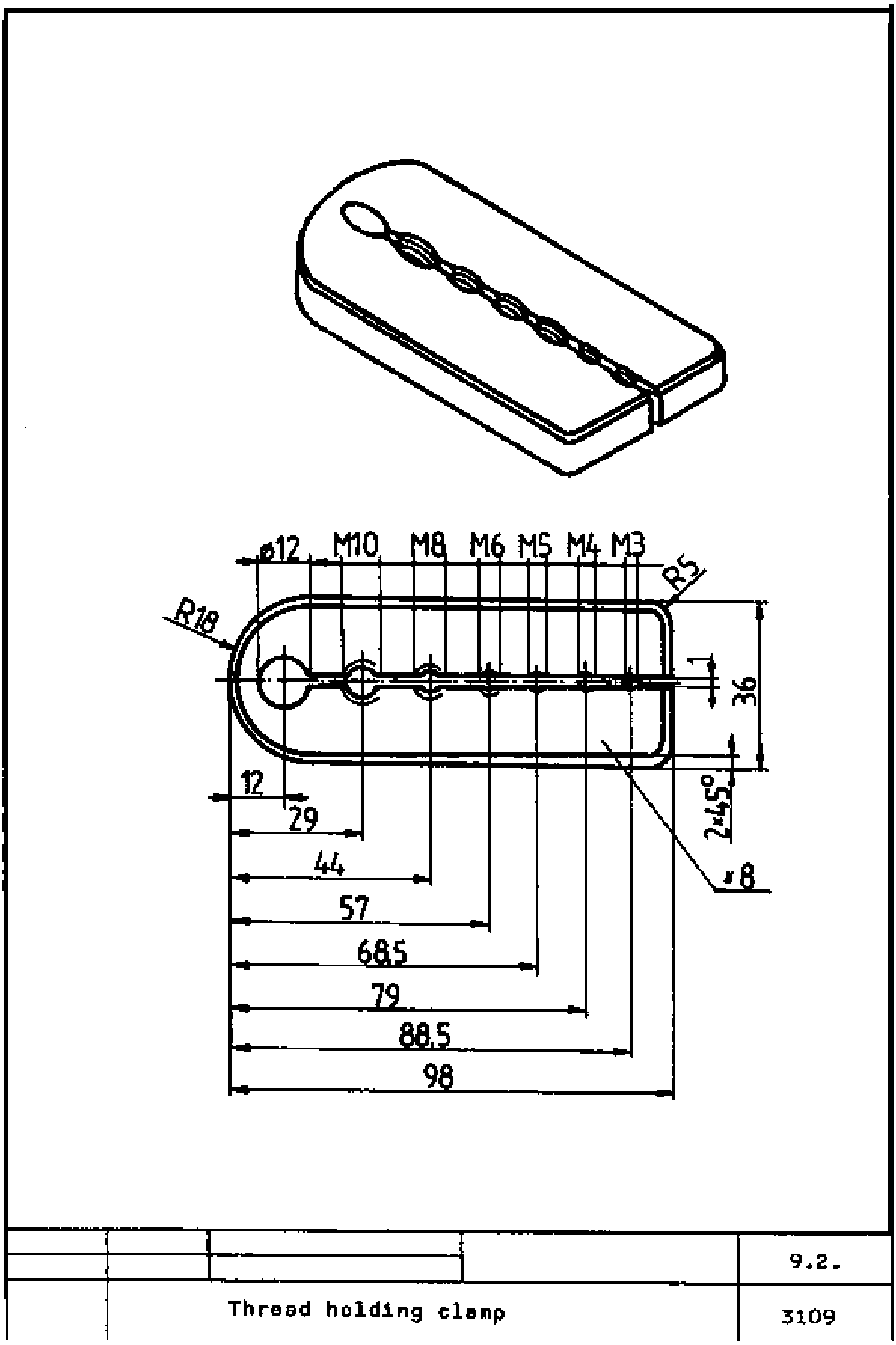
Vice, machine vice, saw sharpening vice, tap wrench, soluble oil, cutting oil

Required previous knowledge

Reading of the drawings, measuring, testing, scribing, prick–punching, sawing, filing, drilling, countersinking/counterboring

Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	– Check for completeness
2. Smoothing of the flat material at all sides, providing it with radius and chamfer according to the drawing	– File and saw sharpening vice
3. Scribing of the holes and prick–punching	
4. Drilling, subsequently countersinking at both ends (to the nominal diameter)	

5. Tapping as per drawing	
6. Checking of the tapped holes for accuracy of fit	– Use appropriate thread cylindrical limit plug gauges!
7. Sawing of the slot	– Vertical position of the saw!
8. Final check	– Accuracy to size, appearance



Tread holding clamp

Instruction example 9.3. Clamping jaws for threaded bolts

To practise tapping of through−hole threads of bigger diameters

<u>Material</u>

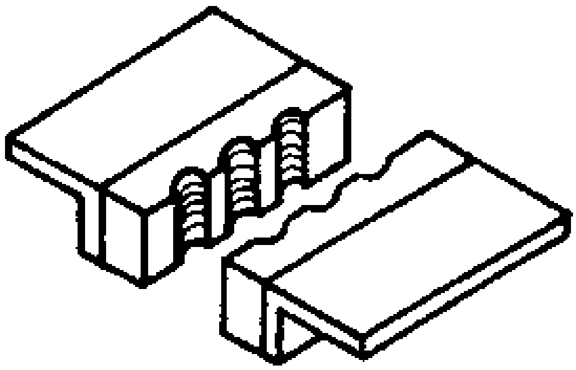
– 2x steel plate (380 MPa)

Thickness:	2.5 mm
Width:	82 mm
Length:	104 mm

– 2x square material of steel (420 MPa)

Thickness:	20 mm
Length:	104 mm

– 4x countersunk bolt M4 x 22



Hand tools

Steel scriber, centre punch, engineers' hammer, aluminium hammer, hand hacksaw, bastard and smooth files 200 mm (flat), drill of 3.3 mm dia., 4.3 mm dia., 10.25 mm dia., 14 mm dia., 17.5 mm dia.;

Nut taps M4, M12, M16, M20

Countersinks – 60° and 90°;

Measuring and testing tools

Steel rule, vernier caliper, try square, thread cylindrical limit plug gauges M12, M16, M20

Accessories

Vice, machine vice. 2 x clamps, spacer (2 mm plate), tap wrench, soluble oil, cutting oil

Required previous knowledge

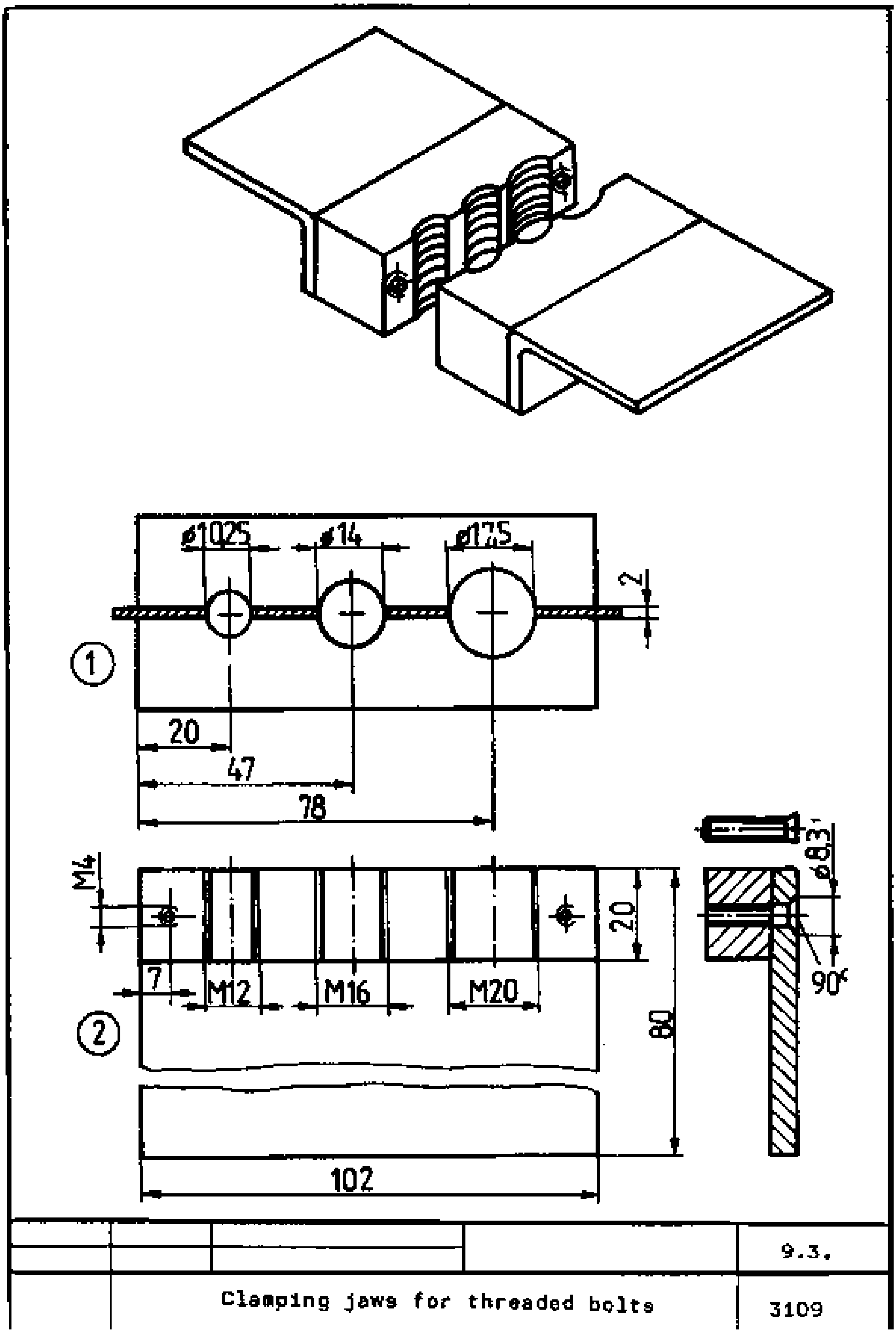
Reading of the drawings, measuring, testing, scribing, prick–punching, sawing, filing, drilling, countersinking/counterboring

Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	– Check for completeness
2. Working of steel plate to size, smoothing of edges	– Filing Observe angular accuracy
3. Sawing of square material to the required length, smoothing of end faces	

4. Securing in place of square material in clamps with spacer, scribing and punching of holes	– Hammer the punch marks
5. Fixing of fastened workpieces into the machine vice and drilling and countersinking as per drawing	– Stage (1)
6. Tapping with nut taps, subsequently cleaning	– Do not undo the fastening!
7. Checking of tapped holes for accuracy of fit	– Use the appropriate cylindrical limit plug gauges!
8. Undoing of the workpieces, checking of the turns of the thread for tears	–
9. Clamping together of one plate and one square material each time and providing them with a hole for screwing, subsequently tapping of thread M4 into the square material	– Stage (2) Square material to be provided with a hole of 3.3 mm dia. – Steel plate to be provided with a hole of 4,3 mm dia, and a countersinking 90° to 8.3 mm dia.
10. Checking of the thread by screwing in of the counter–sunk bolt	
11. Final check	– Accuracy to size, appearance

<u>Completion</u>

Tangent bending of the plates behind the square material by means of an aluminium hammer (90)



Clamping jaws for thread bolts

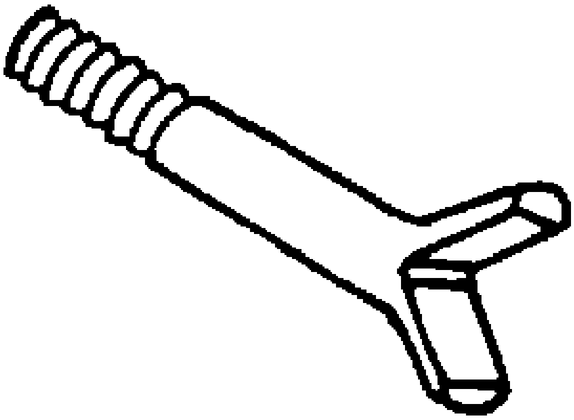
Instruction example 9.4. Stone bolt

To practise threading of short external threads

<u>Material</u>

– Round steel (380 MPa)

Diameter:	M6 to M12
Length:	100 mm



Hand tools

Steel scriber or marking gauge, hand hacksaw, smooth file 200 mm (flat), threading dies M6 up to M12, flat chisel, engineers' hammer

Measuring and testing tools

Vernier caliper, ring thread gauges M6 up to M12

Accessories

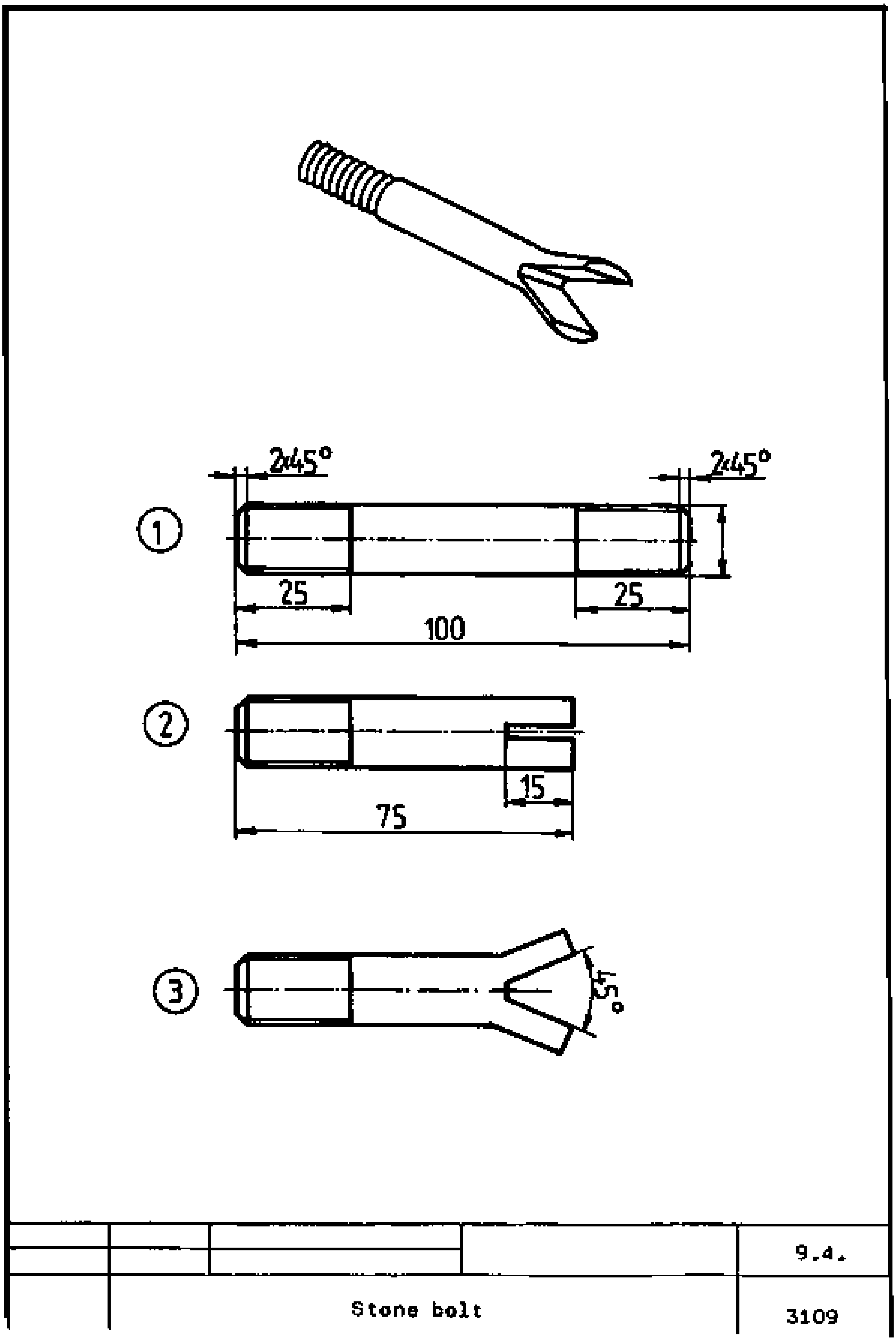
Vice, clamping jaws for round material, cutting oil

Required previous knowledge

Reading of the drawings, measuring, testing, scribing, sawing, filing

Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	– Check for completeness
2. Checking of initial length, sawing to the required length, if necessary	
3. Chamfering of the round material	– Fixing into clamping jaws for round material
4. Cutting of a thread at both ends 25 mm long	– Stage (1)
5. Checking of the threads for accuracy of fit, tears and straightness	
6. Sawing off of the worse part of the thread and sawing in of a slot at this end of the bolt	– Stage (2)

7. Bending part of the slot to 45°	– Stage (3) By means of a flat chisel and a hammer
8. Final check	– Accuracy to size, appearance



Stone bolt

Instruction example 9.5. Threaded bushes and threaded bolts for C–clamp

To practise cutting of centric internal threads in round material as well as of long external threads

Material

– 3 x round steel (420 MPa)

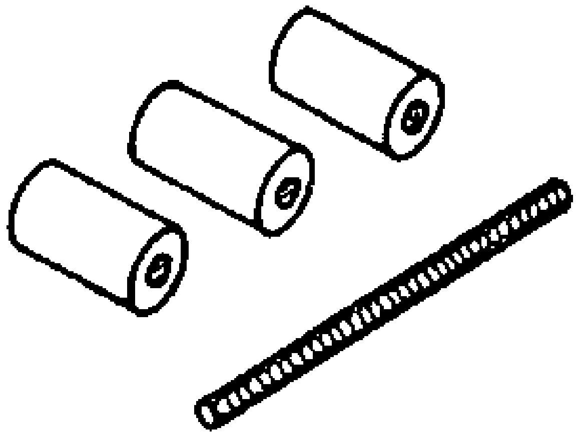
Diameter: 15 mm

Length: 20 mm

– 1 x round steel (600 MPa)

Diameter: 10 mm

Length: 108 mm



Hand tools

Steel scriber or marking gauge, centre punch, engineers' hammer, drill of 8.5 mm dia., countersink – 60°, nut tap M10, smooth file 200 mm (flat), threading die M10

Measuring and testing tools

Vernier caliper, centre square, try square, thread cylindrical limit plug gauge M10, ring thread gauge M10

Accessories

Vice, machine vice, V–block, clamping jaws for round material, soluble oil, cutting oil, tap wrench

Required previous knowledge

Reading of the drawings, measuring, testing, scribing, prick–punching, sawing, filing, drilling, countersinking/counter–boring

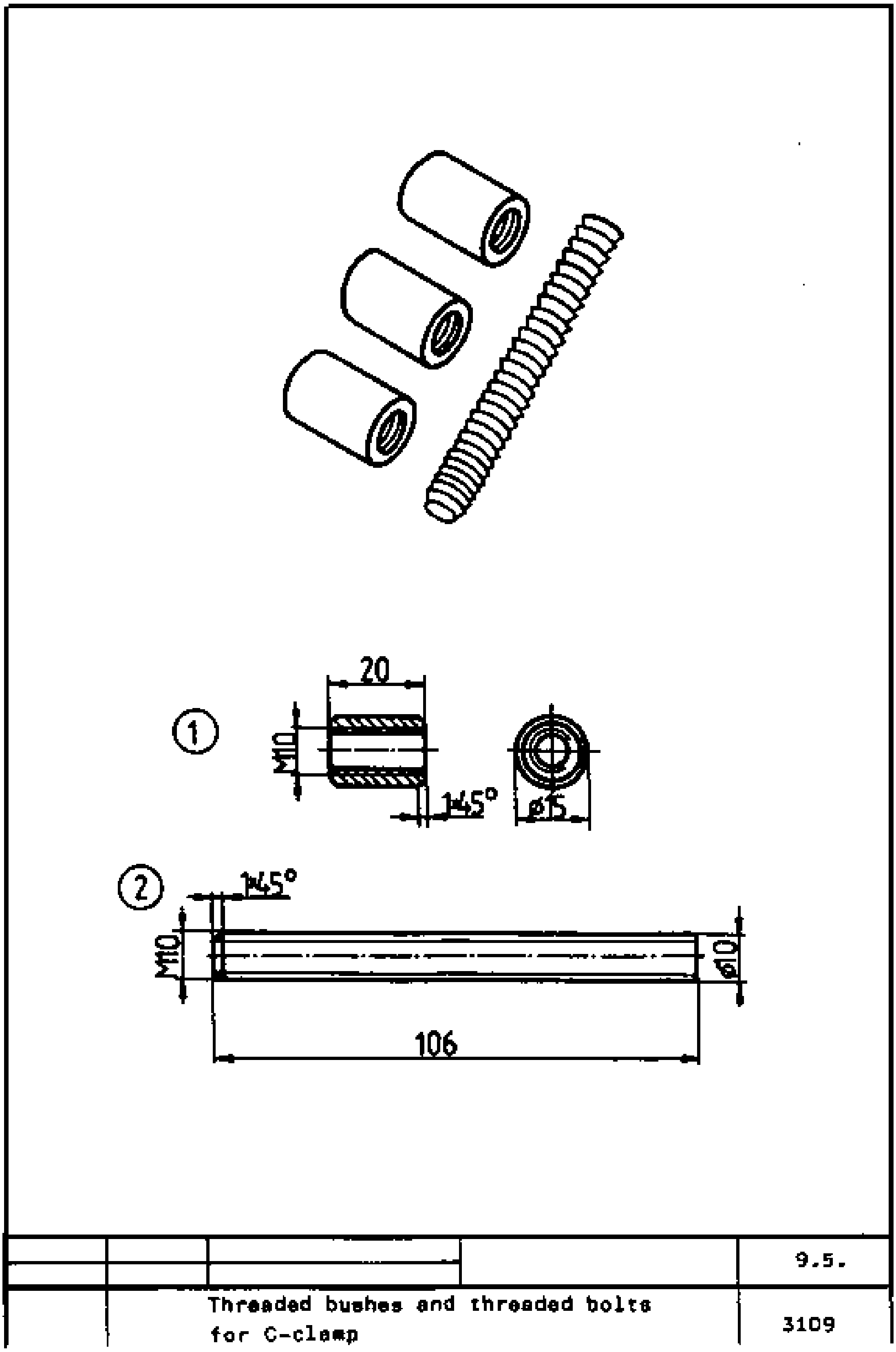
Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	– Check for completeness
2. Checking of the initial length of the workpieces sawing of them to the required size and filing, if necessary	
3. Scribing of the centres on the end faces of the parts (1) by a marking gauge or steel scriber and a centre square	

4. Punching, drilling and counter sinking at both ends	
5. Tapping with nut tap, subsequently cleaning	– Fix into V–block!
6. Checking of the threads for accuracy of fit and parallelism to the outer edge	– Screw in the thread cylindrical limit plug gauge and compare alignment!
7. Providing of part (2) with a chamfer 1 x 45°, subsequently threading; cleaning of the bolt	– Fix into clamping jaws for round material! – Place threading die horizontally! – Break regularly the chips!
8. Checking of the thread for accuracy of fit, tears of the thread as well as for straightness	

Note:

These parts form a complete C–clamp for the use in a workshop together with the parts produced as per instruction examples

2.5. (frame for clamp)
7.6. (rotary head for threaded spindle)
8.2. (screw lock).



Treaded bushes and treaded bolts for C−clamp

Instruction example 9.6. Rope turnbuckle

To practise cutting of a centric internal thread and of two mating external threads

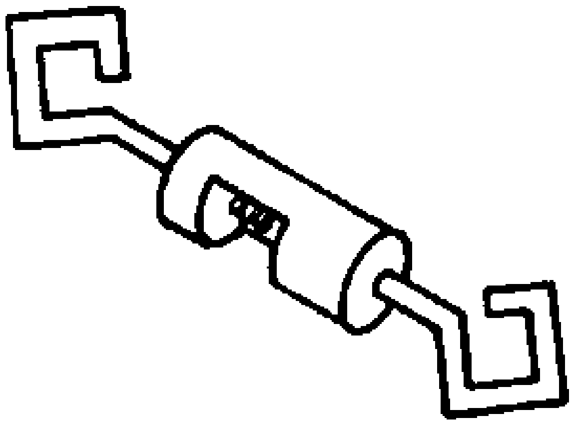
<u>Material</u>

− round steel (600 MPa)

Diameter:20 mm
Length:70 mm

− 2x round steel (600 MPa)

Diameter:	8 mm
Length:	abt. 150 mm



Hand tools

Steel scriber or marking gauge, centre punch, hammer, drill of 6.75 mm dia., countersink − 60, serial hand tap M8 for right−hand and left−hand threads, threading die M8 for right−hand and left−hand threads, smooth file of 200 mm (flat)

Measuring and testing tools

Vernier caliper, try square, centre square, thread cylindrical limit plug gauge M8 for right−hand and left−hand threads, ring thread gauge M8 for right−hand and left−hand threads

Accessories

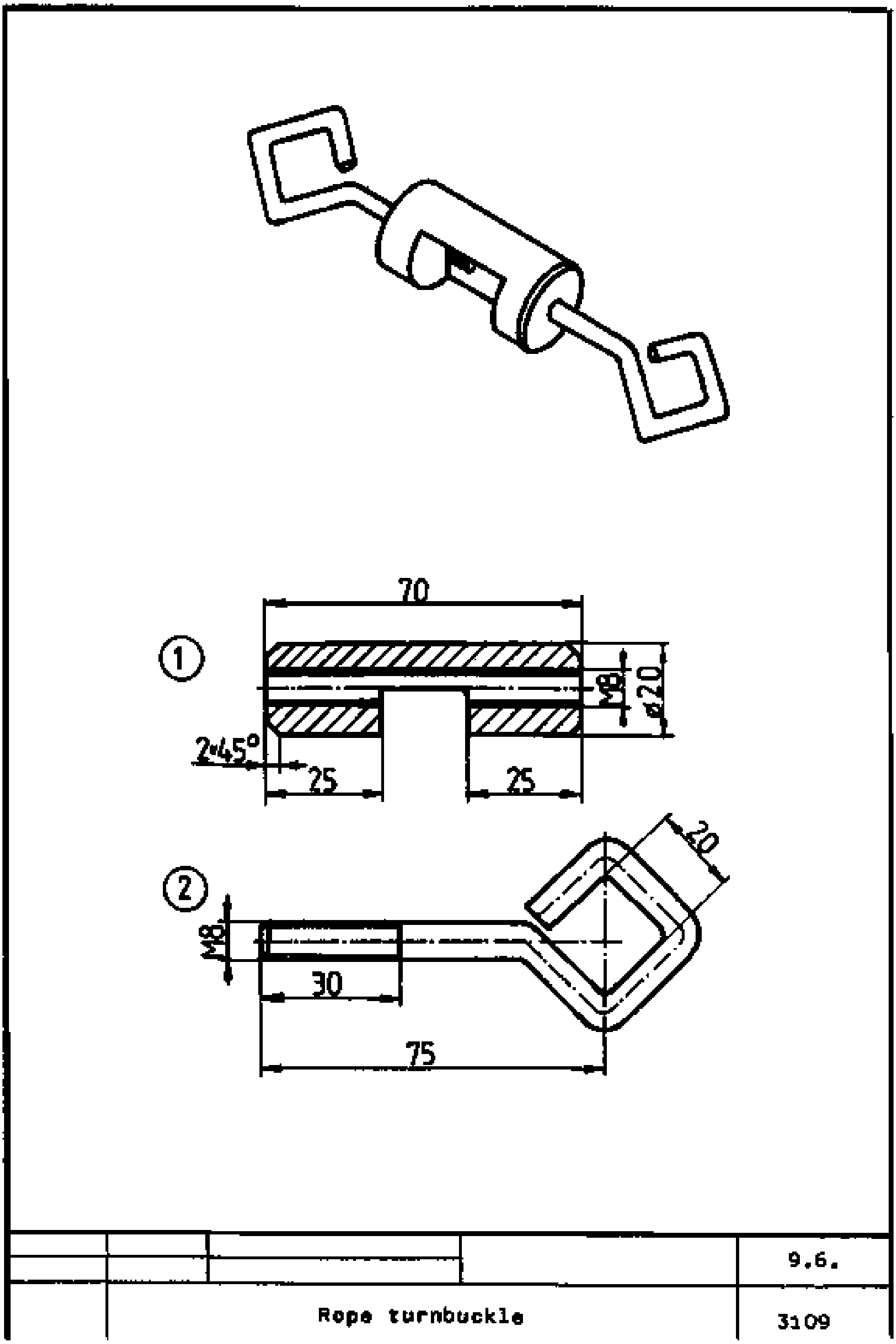
Vice, machine vice, V−block, soluble oil, cutting oil, tap wrench, spacer made of square steel 20 mm for bending

Required previous knowledge

Reading of the drawings, measuring, testing, scribing, prick−punching, sawing, filing, drilling, countersinking/ counterboring, bending

Sequence of operations	**Comments**
1. Arrange the workplace, prepare working material	− Check for completeness
2. Checking of the initial length of the workpieces, sawing them to the required size and filing, if necessary	
3. Scribing of the bore centre on part (1); punching, drilling and countersinking	− Marking gauge or steel scriber and centre square

4. Tapping from both end faces of the part (1) (one end right−hand thread, the other end left−hand thread)	– Screw in the tap only up to the middle – Do not intersect!
5. Filing of the chamfers at the end faces, filing of the opening in the middle of part (1) and deburring of it	
6. Checking of the threads for accuracy of fit and straightness	
7. Bending of the eyes at part (2) by means of a spacer	– Provide the spacer with a radius of 2 mm at the bending points
8. Sawing of 2x parts (2) to the final length, chamfering and cutting of a 30 mm thread (providing one part (2) with a right−hand thread and one part (2) with a left−hand thread)	
9. Checking of the external threads for accuracy of fit and straightness	
10. Screwing in of the parts (2) into part (1)	– Screw in external right−hand thread into internal right−hand thread
11. Final check	– Functional test: When turning the part (7), the parts (2) have to move simultaneously either towards outside or towards inside.



Rope turnbuckle

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Table of Contents

Manual Thread Cutting – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Arbeitsmaterial für den Lernenden
"Gewindeschneiden von Hand"

Author: Frank Wenghöfer

Institut für berufliche Entwicklung e.V.
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13187 Berlin

Order No.: 90–35–3109/2

1. Purpose of thread cutting

Thread cutting is cutting of helical turns of threads out of the tapping–size hole or bolt in order to create screwed connections.

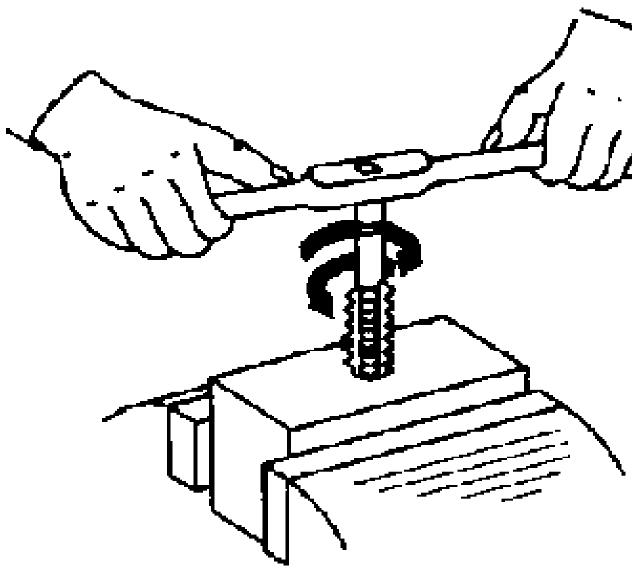

Figure 1 – Thread cutting

A complete screwed connection requires an internal thread and a matching external thread **as** a counterpart. With single–piece manufacture or with repair work, manual thread cutting is a necessary working technique, because – due to technical and economical reasons – machines cannot be used in every case.

2. Kinds of threads

Fastening screw threads:	metric threads (V–shaped threads)
	Whitworth threads (V–shaped threads)
Power–transmission screw threads:	knuckle threads, acme threads, saw–tooth threads

Figure 2 – Kinds of threads

1 – Vee thread
2 – Knuckle thread
3 – Acme thread
4 – Saw–tooth thread

Sealing threads: tapered threads (metric and Whitworth)

Pipe threads: Whitworth pipe threads

By manual thread cutting, only fastening screw threads and partially pipe threads are made. These kinds of threads are made as left–hand or right–hand threads as well as coarse screw threads and fine screw threads..

3. Tools for internal threading (tapping)

Internal threads are cut by serial taps or by nut taps.

Serial taps:

They consist of two or three tools the distinguishing feature being the design of the cutting part.

The entering tap (1st pass) has a long chamfer and trapeziform cutting edges; it does approximately 60 % of the cutting work.

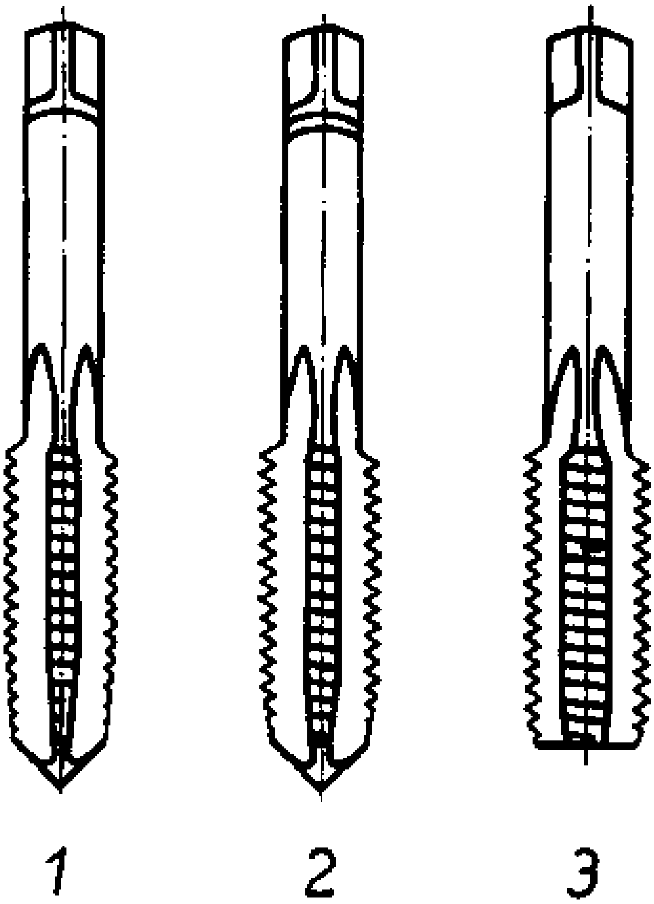

Figure 3 – Serial taps

1 – Entering tap
2 – Plug tap
3 – Third tap

The plug tap (2nd pass) has a short chamfer and trapeziform cutting edges which are deeper; it does approximately 30 % of the cutting work.

The (finishing) third tap (3rd pass) has a short chamfer and cutting edges which create the final sharp form of the thread groove; it cuts the thread to nominal size and finishes the thread flanks.

The individual tools are additionally distinguished by marks in the form of engraved rings at the shank below the square. Modern versions of serial taps consist of entering tap and finishing tap only.

Nut taps:

The nut tap (also called single–pass hand tap) in its cutting part unites the cutting parts of the three serial taps. Consequently, it has a long chamfer representing about 70 % of the total length of the cutting part; the cutting edges are initially trapeziform and become sharp only towards the end. The cutting part is not essentially longer than that of the serial tap.

Yet this cutting part has to do all the cutting operation. The shank with the square is relatively long.

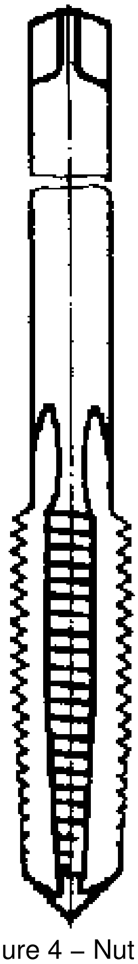

Figure 4 – Nut tap

3.1. Application of the tools

– Serial taps divide the cutting operation into several passes and thus enable easy but time–consuming threading; the third tap – due to its short chamfer – is able to almost completely cut out blind holes.

Conclusion:

Serial taps are mainly used for tapping blind holes.

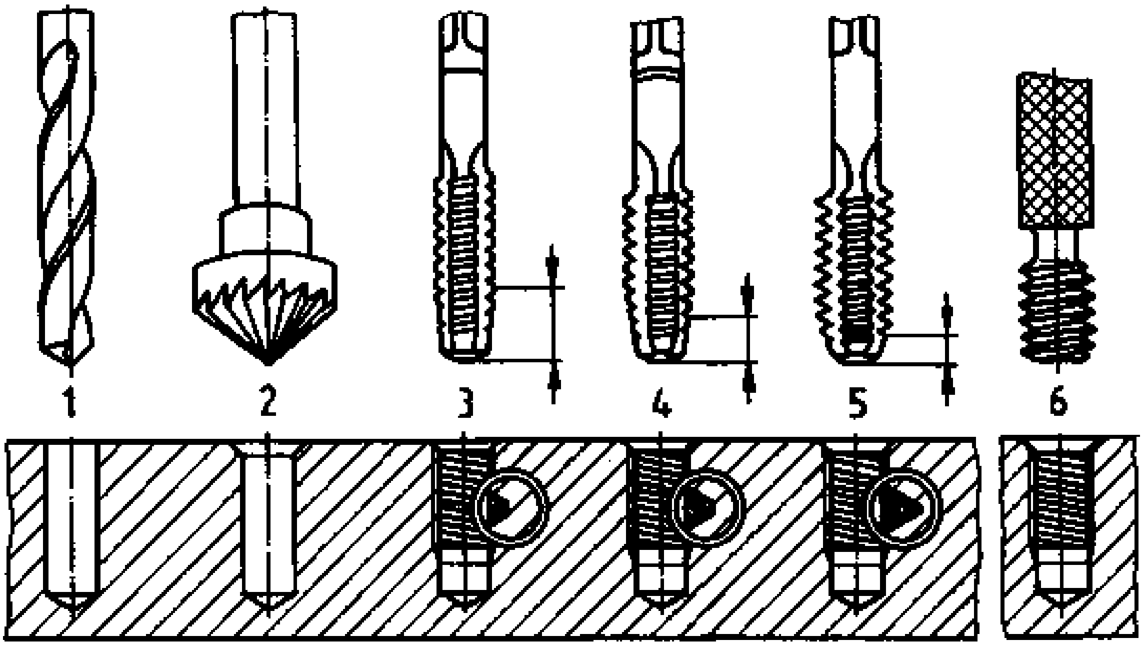

Figure 5 – Technology of internal thread cutting (tapping)

1 – Drilling
2 – Countersinking
3 – Rough–cutting by entering tap
4 – Finish–cutting by plug tap
5 – Finish–cutting by third tap
6 – Checking

– Nut taps enable quick threading which, however, involves a great cutting power (tearing of the thread may occur). Due to its long chamfer, this tool cannot be used for blind holes.

Conclusion:

Nut taps are used for tapping short through holes.

What are the distinguishing features for the use of serial taps and nut taps?

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____

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4. Tools for external threading

External threads are made with the help of a threading die or die–stock.

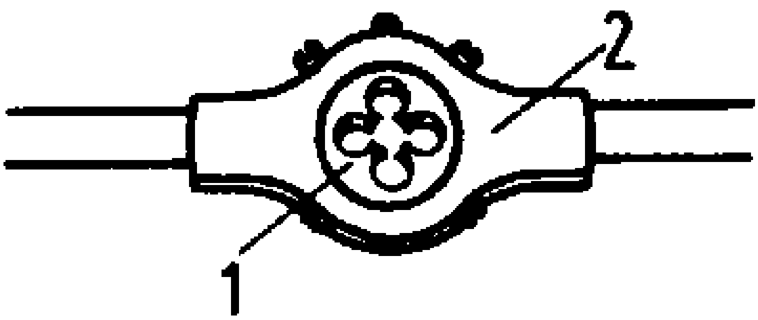

Figure 6 – Threading die

1 – Threading die
2 – Die holder

Threading die:

It consists of a cutting body (similar to a nut with milled−in chip grooves) with a chamfer on either side so that it can be applied both−way.

The threading die is put into a die holder which is equipped with two handles.

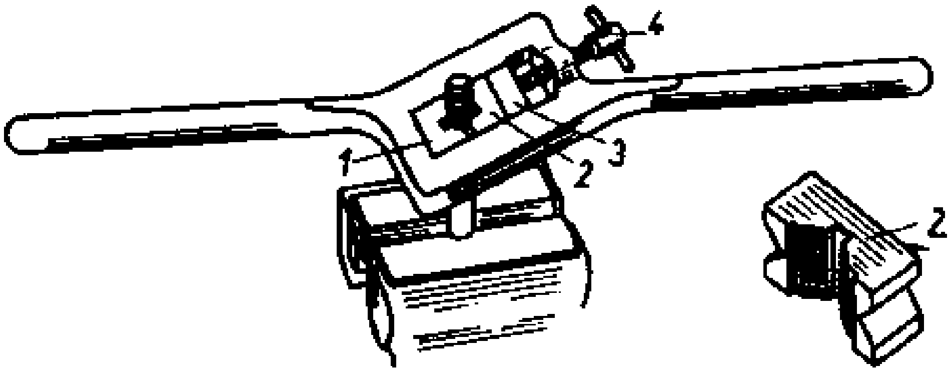

Figure 7 − Die−stock

1 − Fixed die
2 − Movable die
3 − Pressure piece
4 − Locking screw

Die−stock:

It consists of a handle−equipped holder in which two threading dies are placed. One of them is fixed, the other one can be moved by means of a pressure piece via a locking screw. Three to five pairs of exchangeable threading dies for various sizes of threads belong to a die−stock.

4.1. Application of the tools

− Threading dies cut the thread in one operation; they are used with bolt diameters up to 12 mm. Bolt diameters between 12 mm and 30 mm can be cut by threading die or die−stock as well.

− Die−stocks are mainly used with bolt diameters over 30 mm; they are drawn over the bolt in several operations. Readjustment before every new operation is necessary. In the course of the last operation, the thread is accurately cut to size by a threading die,

Hints for starting the cutting operation

− The threading die is set in exactly horizontal position on the bevel of the bolt and turned clockwise slowly and with slight pressure from above (with right−hand thread). Only when the starting end of the thread is cut and the threading die guides itself, the breaking of chips can begin.

− The die−stock is opened as much as is necessary to shove it over the bolt − a small piece of the bolt must project above. The die−stock is adjusted to horizontal position and the movable threading die is tightened. Then, the die−stock is turned up to the bevel so that it is still guided. The movable threading die is further tightened. Then, the thread can be cut by turning the die−stock up and down adjusting the threading die simultaneously.

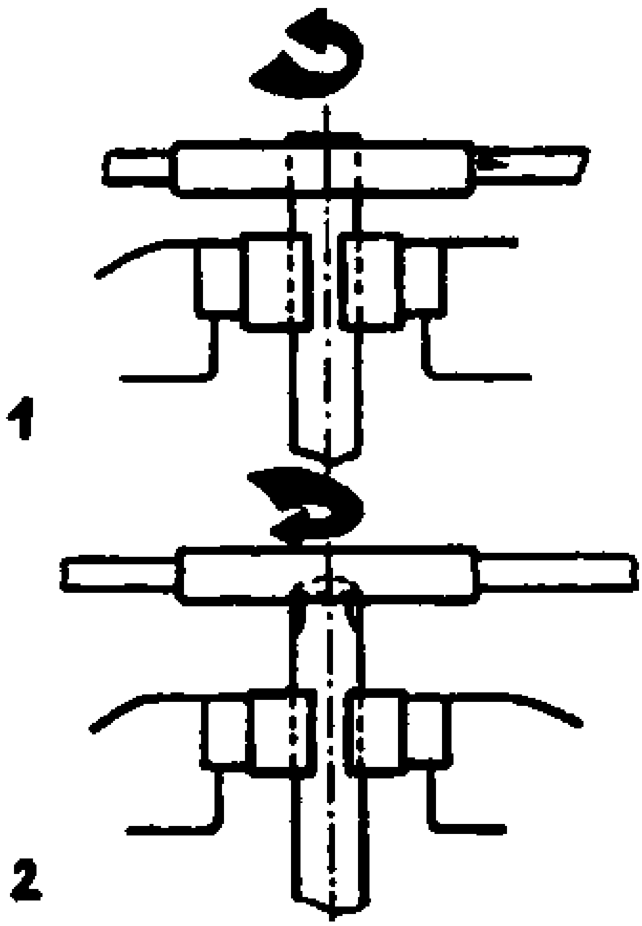

Figure 8 – Application of the die–stock

1 – Putting–on and turning–up
2 – Turning–down

What are the distinguishing features in the use of threading dies and die–stocks?

5. Operation of thread cutting

Thread taps take off material from the periphery of the bore hole. This is done by permanently turning them forwards and backwards alternately with the help of a tap wrench.

In doing so, lubricating and cooling agents must be fed in.

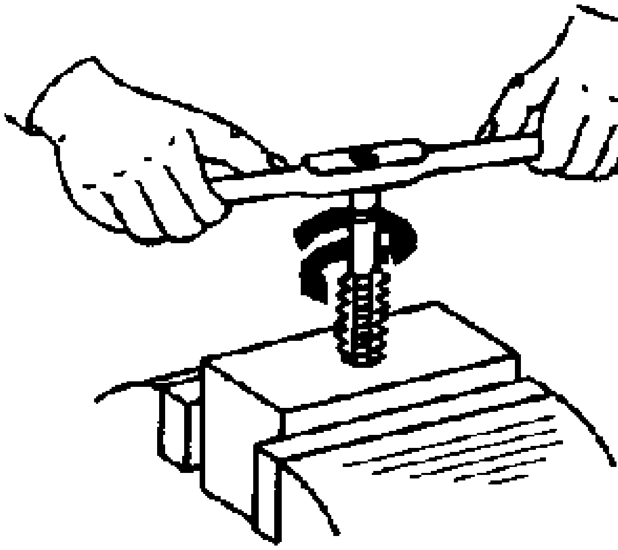

Figure 9 – Thread cutting

The forward turn should amount to half a rotation approximately, the backward turn to a quarter−turn. The material is squeezed and removed within the thread groove the total quantity of chips sticking in the thread grooves.

The backward rotation causes the crushing of the chips, so that they can fall out of the chip grooves of the thread tap.

Note:

> The backward turn up to the crushing of the chips, with medium hard and hard materials, is marked by a clearly noticeable jerk. Only then one can be sure that the chip is really broken.
>
> If one fails to crush the chips continuously, the thread grooves and chip grooves become stuffed up. The thread tap becomes jammed and breaks. It can no more be screwed out of the bore hole. The same applies to the cutting of external threads.

Describe the movements with the cutting of threads.

Why is it necessary to move the thread tap or threading die or die−stock, respectively, backwards at regular intervals?

Why must lubricating and cooling agents be used?

6. Special hints on the designation of threads by the example of the metric threads

Fastening screw threads are internationally standardized in a different way. A large group of these kinds of threads is the group of the metric ISO threads marked by a uniform designation.

Metric ISO threads

Example of the designation of a coarse screw thread:

M 8

M = metric thread
8 = nominal diameter 8 mm

Example of the designation of a fine screw thread:

M 10 x 1.25

(The fine screw thread is additionally marked by the indication of the thread pitch)

M = metric thread
10 = nominal diameter 10 mm
1.25 = thread pitch 1.25 mm

The designation is to be found on the shank of the thread tap or on the surface of the threading die or the die–stock dies, respectively. In addition, symbols for left–hand threads may appear after the designation.

Note:

The designation of the threads is identical on cutting tools and testing tools – with a certain cutting tool the matching testing tool must be used.

What is the designation of a thread limit plug gauge by which a bore shall be checked cut by a M 8 nut tap?

____

What is the meaning of the designation M 6 x 0.5?

____
____
____

7. Technological process of cutting internal threads (tapping)

On principle, the following steps are necessary for cutting threads into blind holes as well as through holes:

7.1. Holding/clamping

Workpieces that shall be bolted to one another have to be clamped together and to be drilled and counterbored jointly, so that the alignment of the bore is maintained.

7.2. Scribing/prick–punching

These operations are carried out as described under "drilling and counterboring/countersinking"; it may also be done before clamping.

7.3. Drilling

Since the thread tap takes material out of the bore hole, this bore hole roust be made smaller to a certain degree depending on the nominal diameter of the thread. This bore hole diameter is called "minor diameter" and is calculated with the help of the following formula:

$$\boxed{D = N - S}$$

D = minor diameter of the internal thread $\hat{=}$ diameter of the drill
N = nominal diameter
S = thread pitch

Thus, the bore hole must be made smaller than the nominal diameter of the thread by the value of the thread pitch. With coarse screw threads, the "thread pitch" depends on the nominal diameter; with fine screw threads, different thread pitches are possible with the same nominal diameter; therefore, the indication of the thread pitch must be included in the designation of these threads.

The thread pitch is the value (in mm) of the longitudinal movement of a thread tap resulting from one complete revolution of the thread tap.

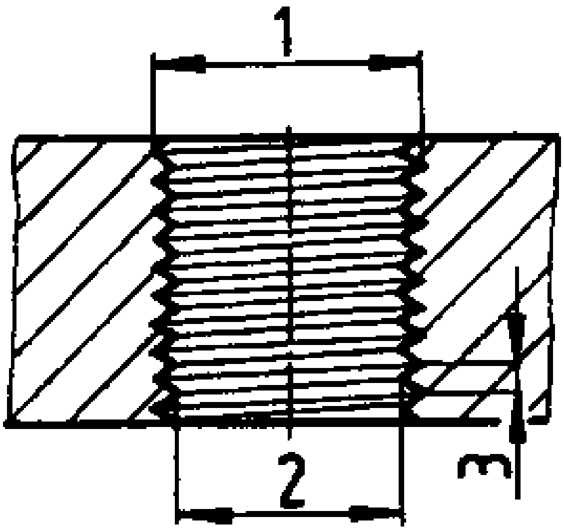

Figure 10 – Dimensions at the internal thread

1 – Nominal diameter (N)
2 – Minor diameter (D)
3 – Pitch (S)

For making the bore holes, the calculation of the rotational speed of the drill (n) is to be taken from the lesson "drilling and counts boring/countersinking".

Selected metric coarse and fine screw threads:

Coarse screw threads		**Fine screw threads**	
Nominal diameter (N)	Thread pitch (S)	Nominal diameter x Thread pitch	
2.5	0.45	2.5 x 0.35	24 X 2
3	0.5	4 x 0.5	42 X 1
4	0.7	6 x 0.5	42 X 1.5
5	0.8	6 x 0.75	42 X 2
6	1	10 x 0.5	42 X 3
8	1.25	10 x 0.75	42 X 4
10 +)	1.5	10 x 1	
12	1.75	10 x 1.25	
16	2	16 x 0.75	
20	2.5	16 x 1	
24	3	16 x 1.5	
30	3.5	24 x 0.75	
36	4	24 x 1	
42	4.5	24 x 1.5	

Generally applicable formula:

$$n = \frac{V \cdot 1000}{D \cdot \pi}$$

V = cutting speed (22 m/min)
? = 3.14

With blind holes, the chamfer of the thread tap (third tap) is to be taken into consideration as follows:

The blind hole must be made deeper than required by the depth of the thread by the size of the chamfer (runout depth).

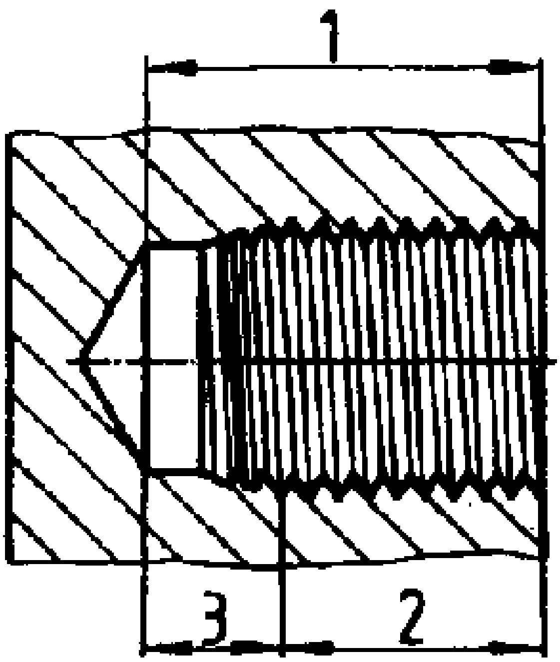

Figure 11 – Indication of the depths at the internal thread

1 – Depth of hole (T_B)
2 – Depth of thread (T_G)
3 – Runout depth (T_A)

This is expressed by the following formula:

$$\boxed{T_B = T_G + T_A}$$

T_B = depth of hole
T_G = depth of thread
T_A = runout depth

The following formula is considered as a "rule of thumb" for the calculation of the runout depth of small threads:

$$\boxed{T_A = 0.7 \times D}$$

The exact value of the runout depth for metric coarse and fine screw threads can be taken from the following table:

N		**T_A**
M	3	2.8
M	4	3.4

M	5	3.6
M	6	4.5
M	8	5
M	10	5.5
M	12	6
M	16	6.5
M	20	7.5
M	24	8.5
M	30	10
M	36	11
M	42	12
M	48	13

Example:

A bore hole shall be made for a metric coarse screw thread with a nominal diameter of 6 mm; the depth of the thread shall be 12 mm.

How must the bore hole be made?

1. Diameter of the drill:

$D = N - S$
$D = 6 \text{ mm} - 1 \text{ mm}$
$\underline{D = 5 \text{ mm}}$

2. Depth of hole:

$T_B = T_G + T_A$
$T_B = 12 \text{ mm} + 4.5 \text{ mm}$
$\underline{T_B = 16.5 \text{ mm}}$

The bore hole of 16.5 mm in depth is made by the drill D = 5 mm.

7.4. Countersinking

Through holes have to be countersunk from either side by a 60° countersinking cutter (also 90° countersinking cutter).

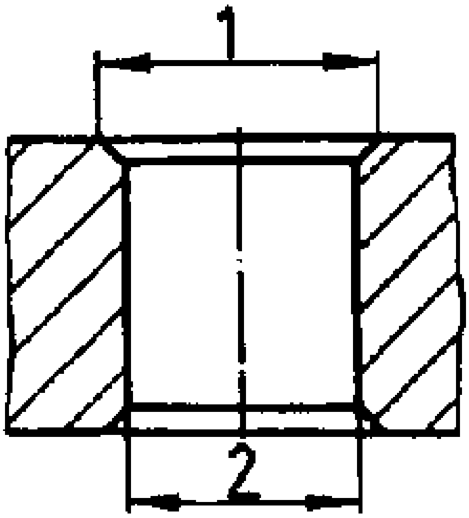

Figure 12 – Countersinking of internal threads

1 – Countersinking diameter (Ds)
2 – Minor diameter

In doing so, the countersinking diameter (Ds) shall be equivalent to the nominal diameter of the thread:

$\boxed{D_s = N}$

The rotational speed for countersinking of bore holes up to a diameter of 10 mm can be 350 r.p.m., for larger bore holes it must be lower.

$\boxed{n \text{ ? } 350 \text{ r.p.m.}}$

7.5. Thread cutting

With short through holes nut taps have to be used; with blind holes only serial taps must be applied. Auxiliary means are tap wrenches. Lubricating and cooling agents are to be seen in the below table:

Steel	Cutting oil
Aluminium alloys:	Spirit
Chromium–nickel alloys:	Colza oil, petroleum

Note:

If several parts shall be connected by screw connection, and if these parts were provided with a bore hole in one clamping, this clamping has to be released before the thread is cut. Only in the last part – starting from the screw head – the thread is allowed to be cut. All parts situated in between are bored; that is to say, they get a through hole which must be larger than the nominal diameter of the thread.

7.6. Cleaning of the bore hole

After the thread is cut, chips and remaining oil must be removed from the bore hole by means of compressed air or brush.

7.7. Checking

Thread depths and minor diameters of internal threads are checked by vernier caliper, the accuracy of fit of the thread is checked by the thread limit plug gauge according to the nominal diameter.

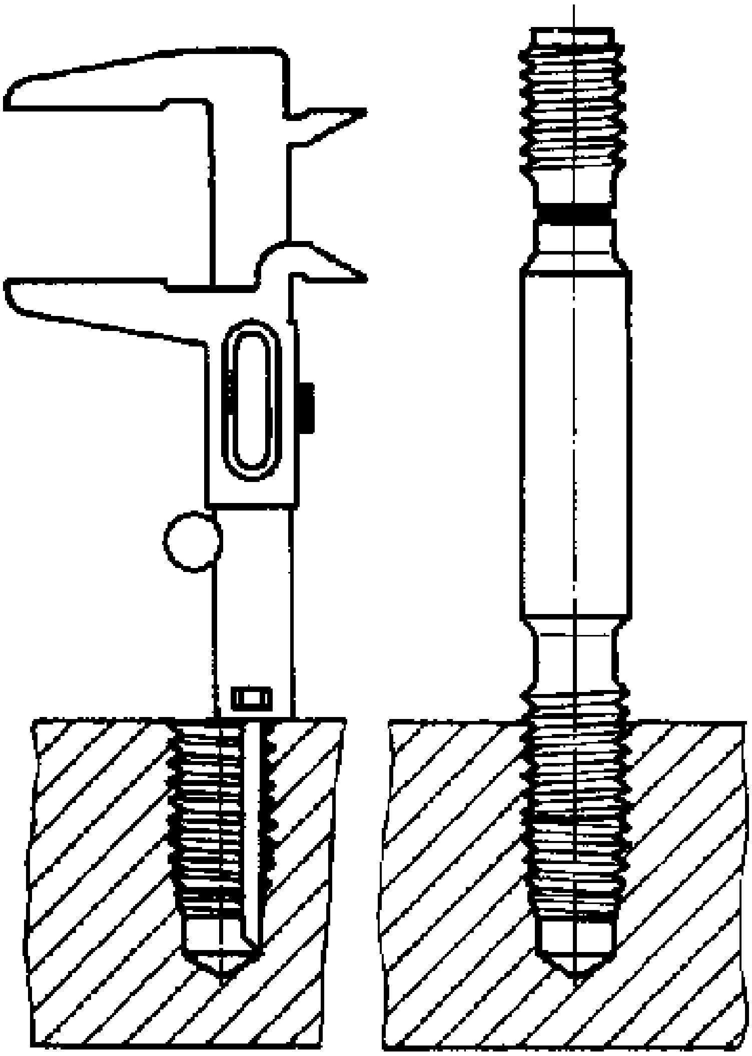

Figure 13 – Checking of the thread

How is the minor diameter of a tapped hole calculated?

____

How must the chamfer of the thread tap be taken into consideration in calculating the depth of the bore?

____

How are tapping−size holes to be countersunk?

____
____
____

<u>Task</u>:

The following tool and machine values have to be determined for making an M 10 internal thread of 15 mm in depth into a steel part of general mild steel:

Diameter of the drill (D): ___________________________
Rotational speed (n) : _______________________________
Depth of hole (T_B): ________________________________
Countersinking diameter (Ds): ________________________
Rotational speed (n) : _______________________________

The individual steps of operation together with the calculated values for the bore hole have to be entered in the following table, blank spaces have to be completed:

No.	**Operation**		

		Cutting tools, testing tools and auxiliary means	Tool and machine values
1.	Clamping		–
2.	Scribing/prick–punching		
3.	Drilling	Drill	D =
		Vernier caliper	T_B =
		Lubricating and cooling agents	n =
4.	Countersinking	Countersinking cutter	Ds =
		Vernier caliper	n =
5.	Thread cutting		
6.	Cleaning		–
7.	Checking	Thread limit plug gauge	

This table may be used as a preparation for practical exercises in thread cutting.

8. Technological process of cutting external threads

On principle, the following operations are necessary for the manual cutting of external threads:

8.1. <u>Clamping</u>

The bolt (round stock) is vertically clamped into the vice between – jaws, attachments or clamping jaws for round stock; with this, only the part of the material which is to be worked shall project over the clamping device in order to reduce the springing of the bolt.

8.2. <u>Chamfering</u>

In order to be able to put the tool in an angular position on the bolt, a chamfer must be made at the head of the bolt. This can be done with the help of a file or by a grinding machine.

The chamfer shall have an inclination of approximately 45° and a width of at least 0.5 mm.

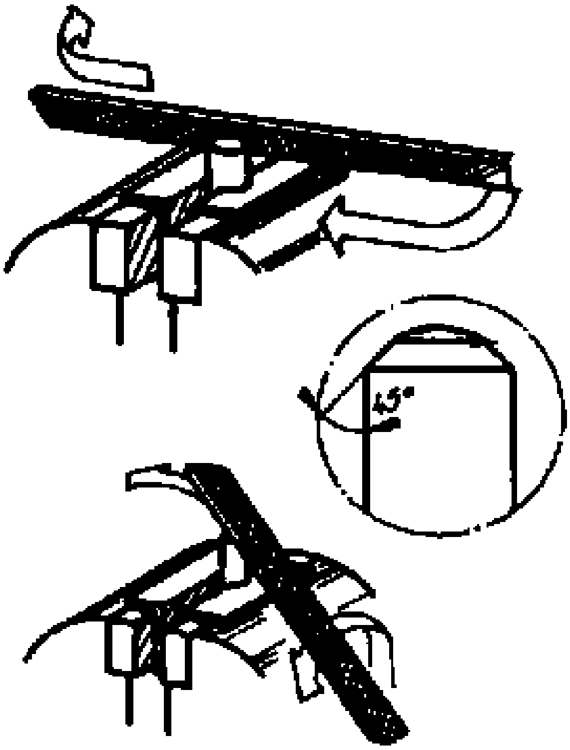

Figure 14 – Chamfering of the bolt

8.3. Thread cutting

According to the nominal diameter of the thread, a threading die or die–stock is used.

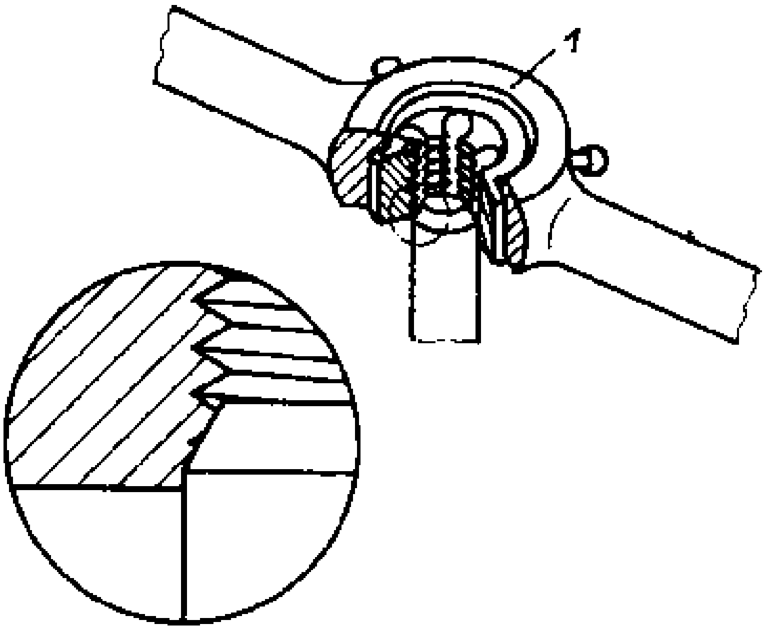

Figure 15 – Application of the threading die

1 – Top surface of the die holder

Note:

– The threading die is applied that way that the top of the die holder points upwards.

(If worn out, the threading die can be turned in the die holder).

– By the die–stock, the external thread (bolt thread) is cut from bottom to top, otherwise an accurate bevel cannot be achieved.

Lubricating and cooling agents are chosen according to the kind of material.

8.4. Cleaning

After thread cutting, the chips and rests of oil are removed from the thread flanks by compressed air or brush.

8.5. Checking

The length of the thread is checked by vernier caliper, the accuracy of fit of the thread by the thread ring gauge according to the nominal diameter. The surface of the thread flanks can be assessed by the eye.

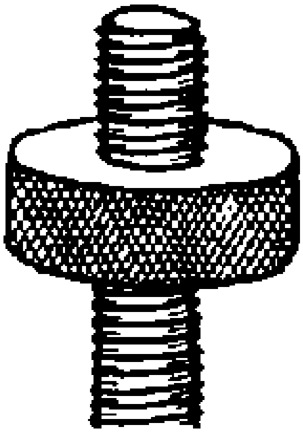

Figure 16 – Checking of the thread

How must bolts be clamped in the vice?

____

____

____

Why must the bolt be provided with a chamfer?

____

____

____

Faults

Irrespective of nonobservation of the sequence of operations, faults in the cutting process may occur which are visible with the naked eye:

Fault	Reason
Thread is not straight	– Tool was not put on vertically – Tool was turned unevenly (jerkily) – With external thread – cut without starting bevel
Thread turns are rough and partially torn	– Tool was turned unevenly and too quickly – No lubricating and cooling agent was used – Minor diameter and/or diameter of the bolt were not calculated accurately

Welder – Transparencies

Table of Contents

Welder − Transparencies

CENTRAL INSTRUCTIONAL
MEDIA INSTITUTE, MADRAS

AN INDO − GERMAN PROJECT

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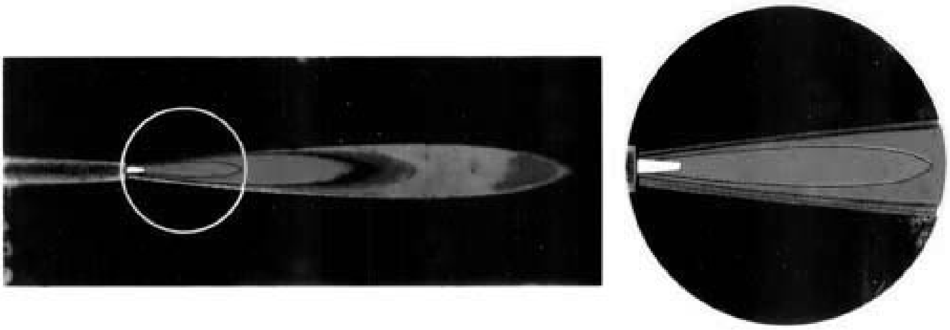
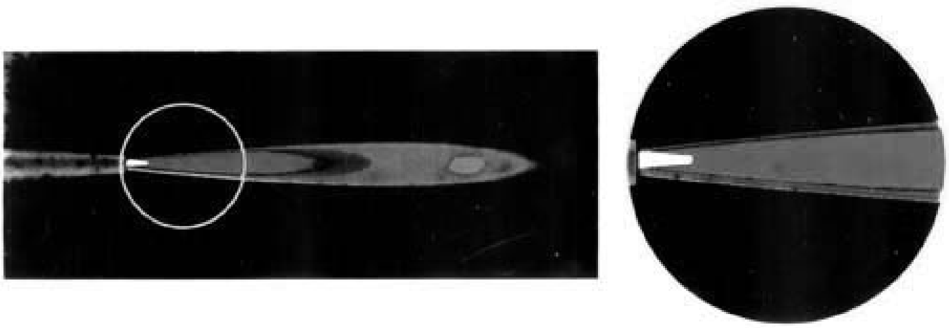
Types of Oxy−acetylene flame

TR 03 01 11 01 95



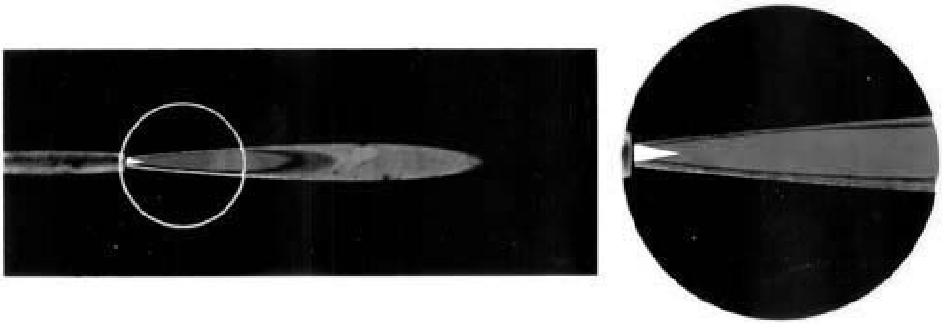
CARBURISING FLAME

Application: Acetylene is proportionally more, useful for stelliting (hard facing).



NEUTRAL FLAME

Application: Both Oxygen and Acetylene are mixed in equal proposition, useful for mild steel, cast iron, stainless steel, copper, and aluminium.

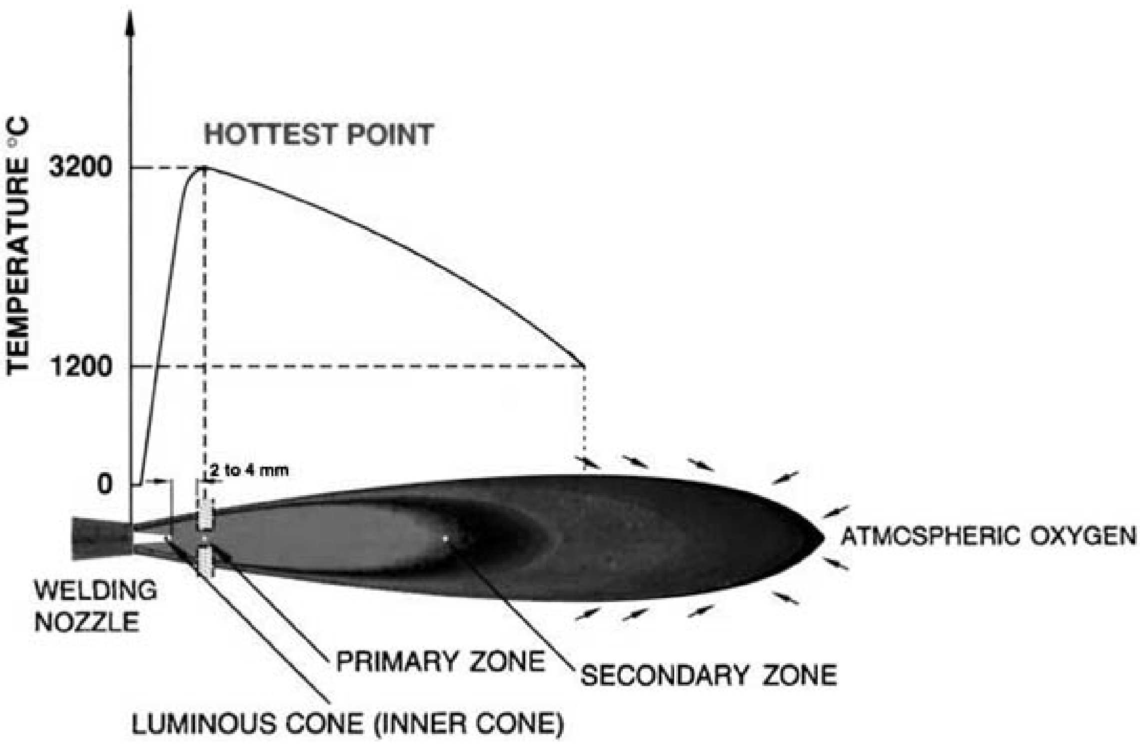


OXIDISING FLAME

Application: Oxygen is proportionally more, useful for welding of brass and brazing of ferrous metals.

Chemistry of Oxygen – Acetylene flame

TR 03 01 11 02 95



The temperature is varying at different zones of the flame.

The hottest zone being 2–4 mm away from the inner cone.

Influence of discharge velocity and amount of heat

TR 03 01 11 03 95

DISCHARGE VELOCITY AND AMOUNT OF HEAT

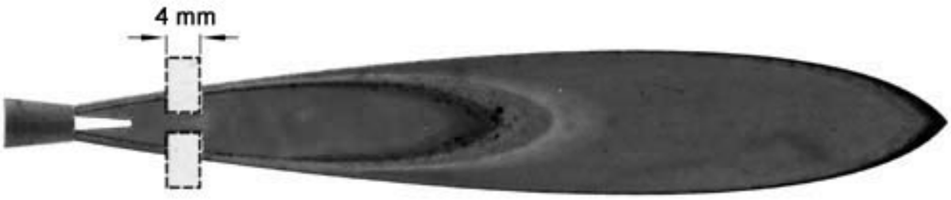
Low – (Soft Flame)

• For soft flame the discharge velocity is low – it is suitable to weld up to 2 mm thickness.

DISCHARGE VELOCITY AND AMOUNT OF HEAT

Medium – (Medium flame)

• For medium flame the discharge velocity is also medium – it is suitable to weld up to 3 mm thickness.



DISCHARGE VELOCITY AND AMOUNT OF HEAT

High – (Hard Flame)

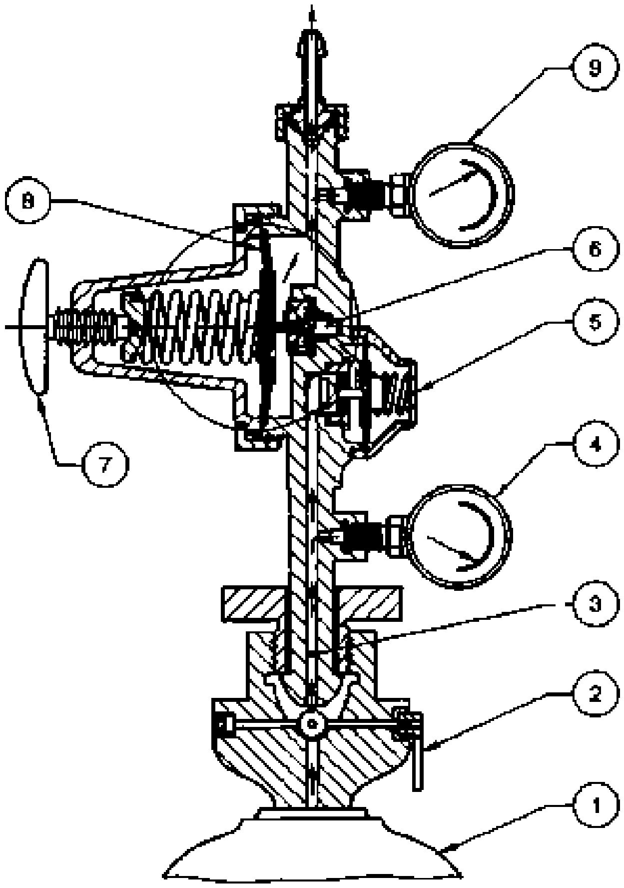
• For hard flame the discharge velocity is high – it is suitable to weld up to 4 mm thickness.

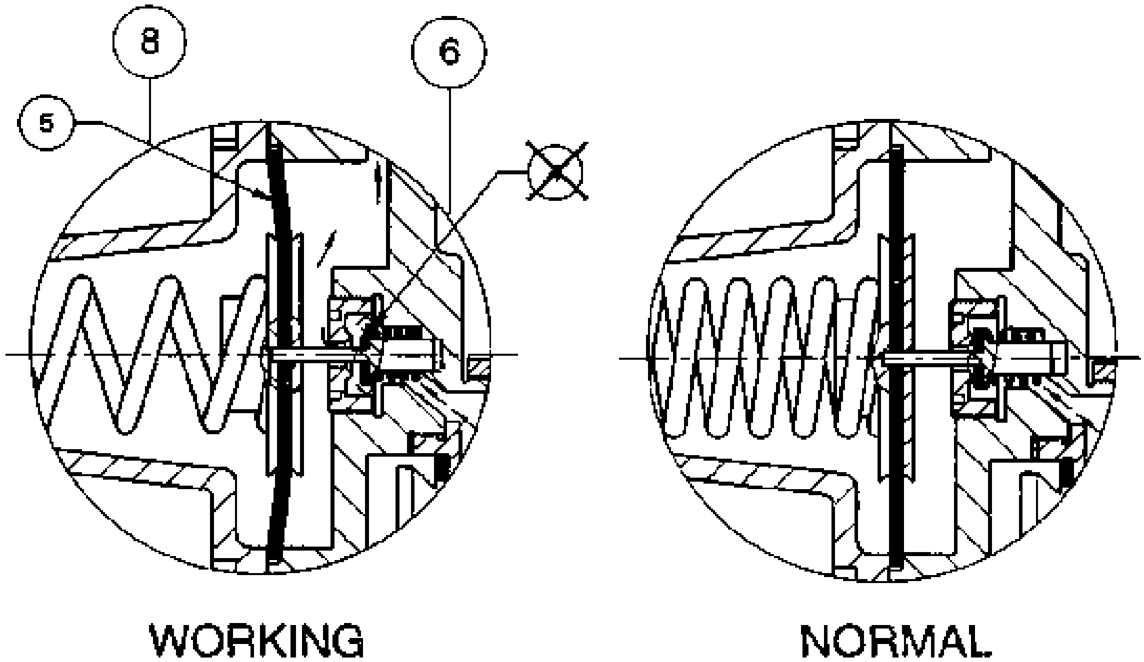
NOTE:

The size of the nozzle being same the velocity and heat can be varied.

Double stage regulator (Function)

TR 03 01 11 04 95





The regulator is fitted on cylinder (1) after removing dust particles from the socket of the cylinder – use the cylinder key (2) open. After opening the cylinder gas enters in regulator passage (3) and gas passes through the cylinder content gauge (4) and reaches stage one pressure reduction mechanism (5). The gas flow is stopped at valve (6). The volume of gas required for welding is adjusted by controlling the screw knob (7). By the actuation of the knob (7) the diaphragm (8) is bent and gas enters through valve (6) to the working pressure gauge (9) and hose pipe

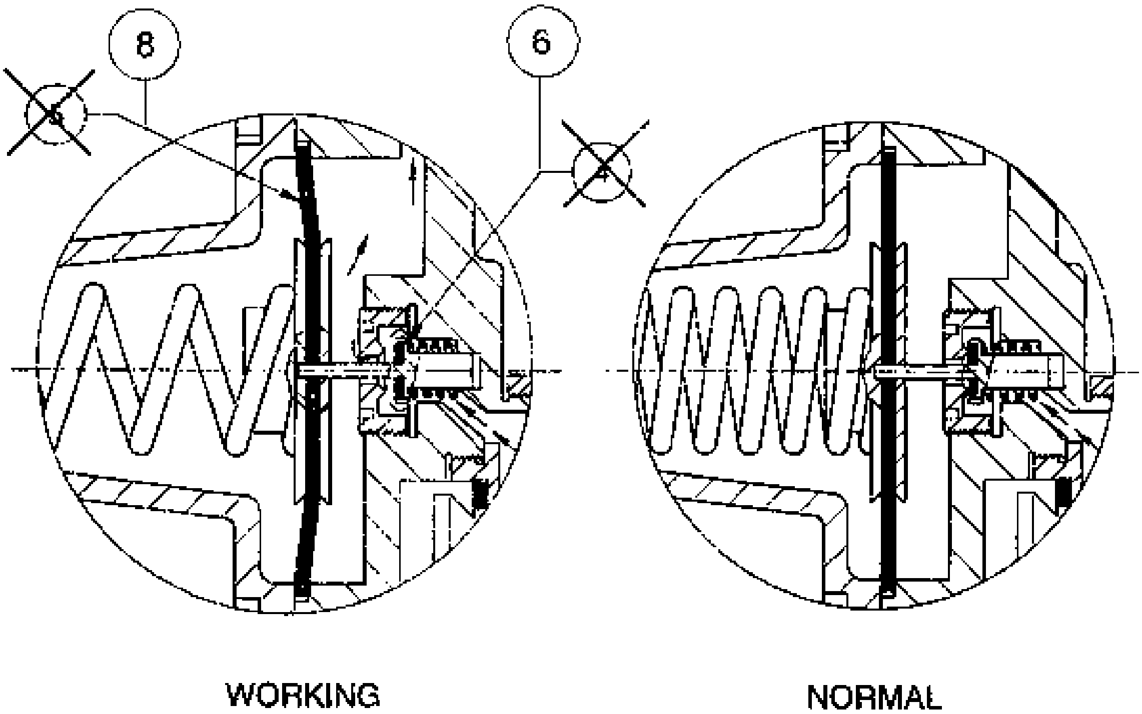
NOTE:

- Use this key for the transparency on double stage regulator and diaphragm (function).
- Note also the correction in numbering.

• Use the wallchart No. CH 03 01 04 02 95 along with this.

Regulator diaphragm (Function)

TR 03 01 04 02 95



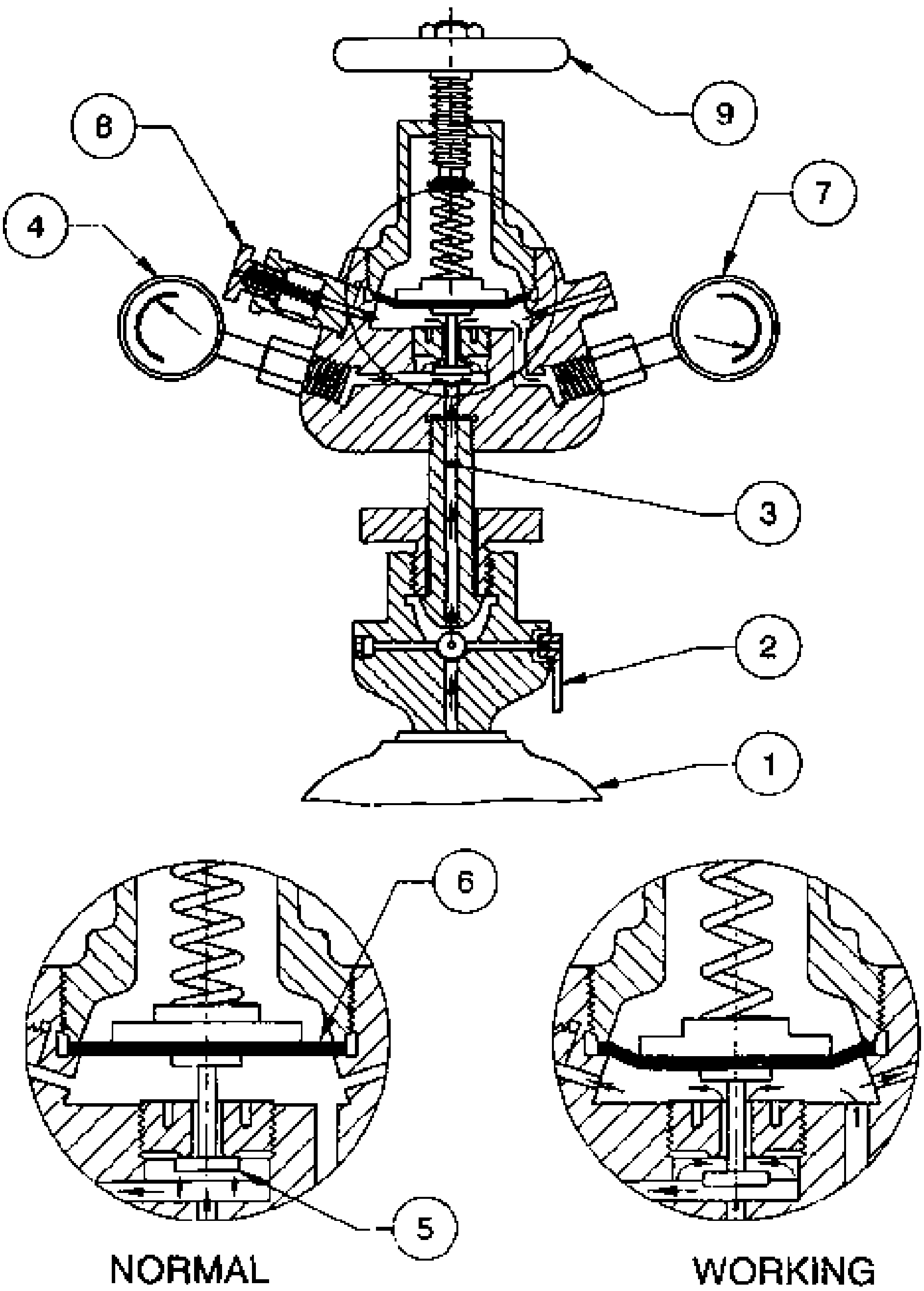
The regulator is fitted on cylinder (1) after removing dust particles from the socket of the cylinder– use the cylinder key (2) to open. After opening the cylinder gas enters in regulator passage (3) and gas passes through the cylinder content gauge (4) and reaches stage one pressure reduction mechanism (5). The gas flow is stopped at valve (6). The volume of gas required for welding is adjusted by controlling the screw knob (7). By the actuation of the knob (7) the diaphragm (8) is bent and gas enters through valve (6) to the working pressure gauge (9) and hose pipe

NOTE:

- Note the correction in numbering.
- Use this wallchart along with CH 03 01 04 01 95

Single stage regulator (Function)

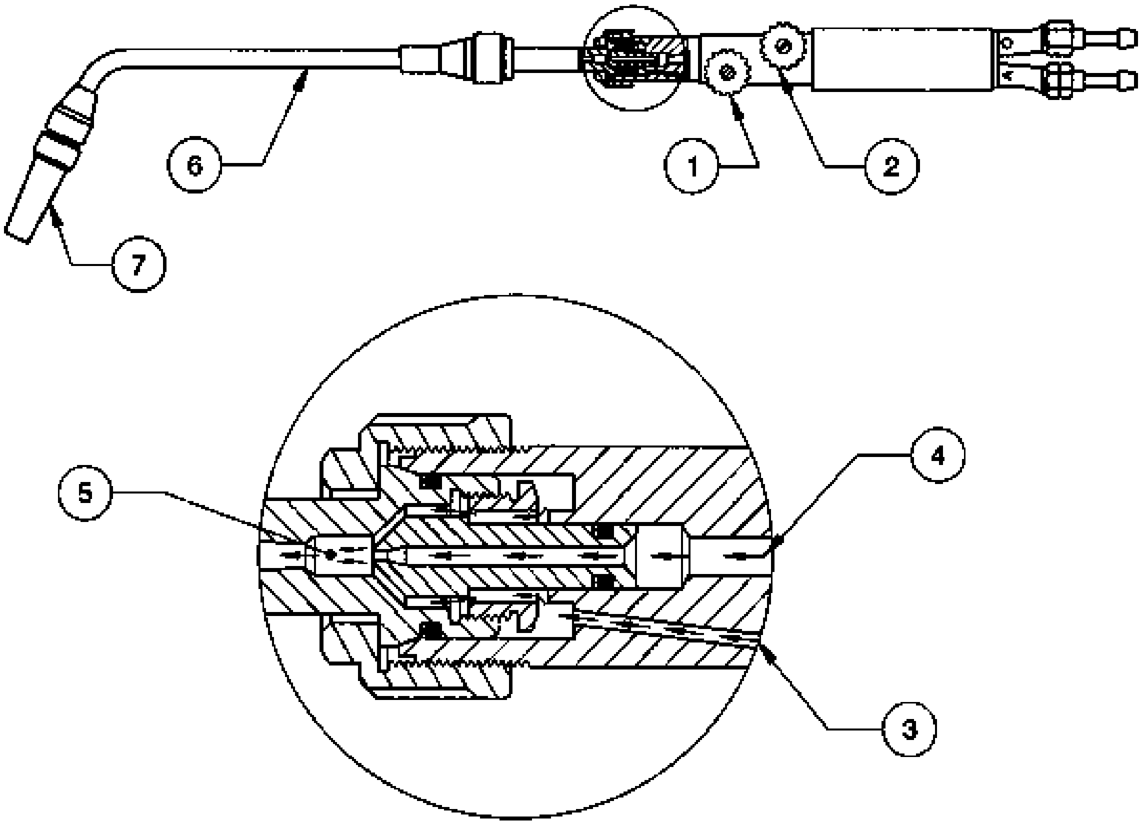
TR 03 01 04 03 95



The regulator is fitted on the cylinder (1) socket after removing the dust particles (cracking). Use cylinder key (2) to open the cylinder. After opening, the gas enters in regulator passage (3) and the cylinder content gauge (4) and he gas flow is stopped at valve (5). When the pressure adjusting screw (9) is tightened the diaphragm (6) is bent and the valve (5) opens. The gas now enters in the working pressure gauge (7). The working pressure is indicated in the gauge (7). A safety valve (8) is provided to release the pressure in case of diaphragm failure.

Low pressure blow pipe (Function)

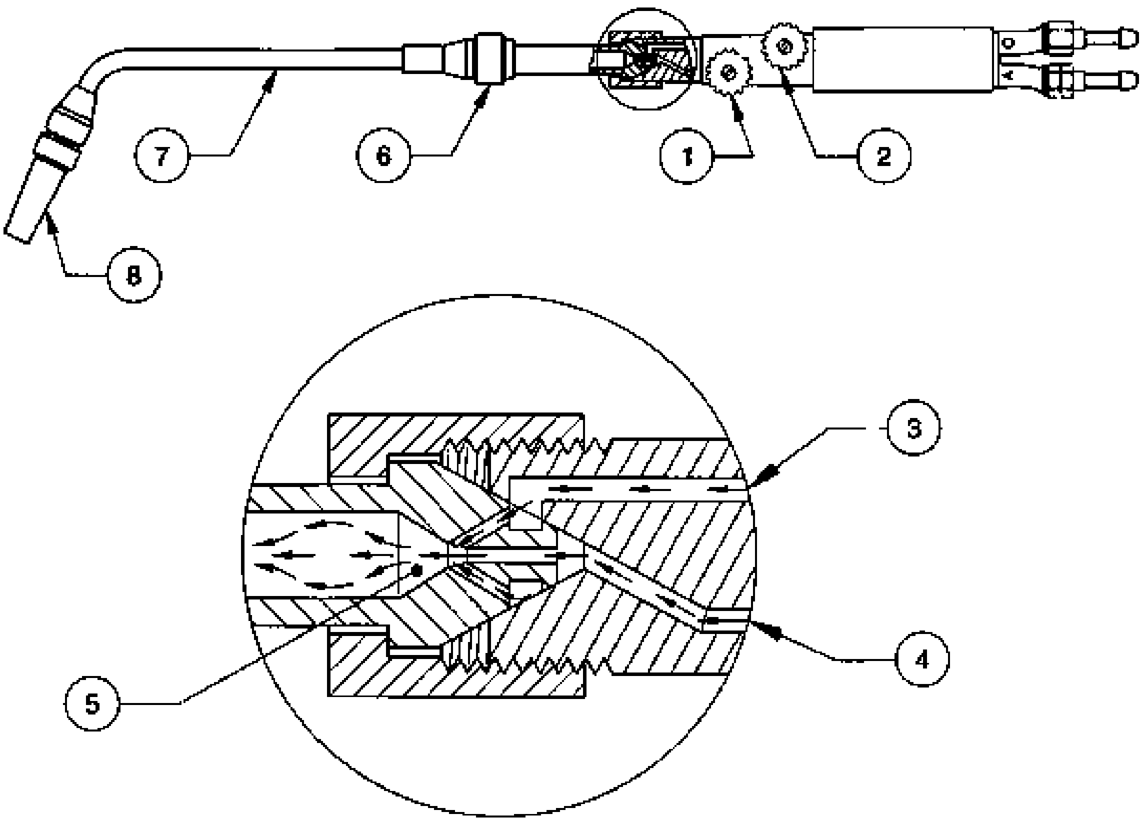
TR 03 01 05 01 95



Acetylene valve (1) when opened the low pressure gas enters into the injector (5) through passage (3). When the valve (2) is opened the oxygen gas enters through passage (4) with high pressure. When gas reaches injector (5) it sucks the low pressure acetylene and reaches the nozzle (7) through the neck (6)

High pressure blow pipe (Function)

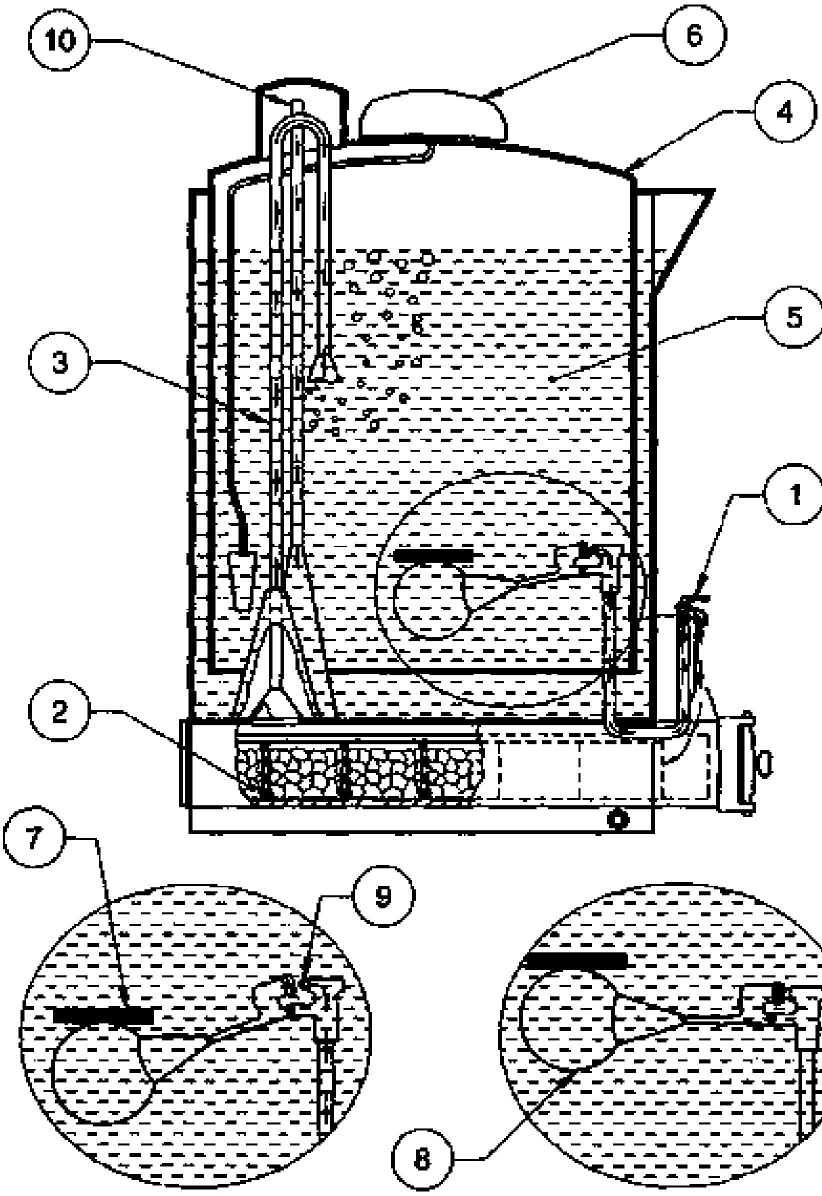
TR 03 01 05 02 95



Acetylene valve (1) when opened, the gas enters into the mixing chamber (5) trough passage (4). When oxygen valve (2) is opened oxygen gas also enters into the mixing chamber (5) through passage (3). Both high pressure gases are mixed in the mixing chamber and passes through neck connector (6) and to the neck (7) and finally reaches the nozzle (8). Long or short neck can be used depending upon the size of the job.

Water to carbide generator (Function)

TR 03 01 06 01 95

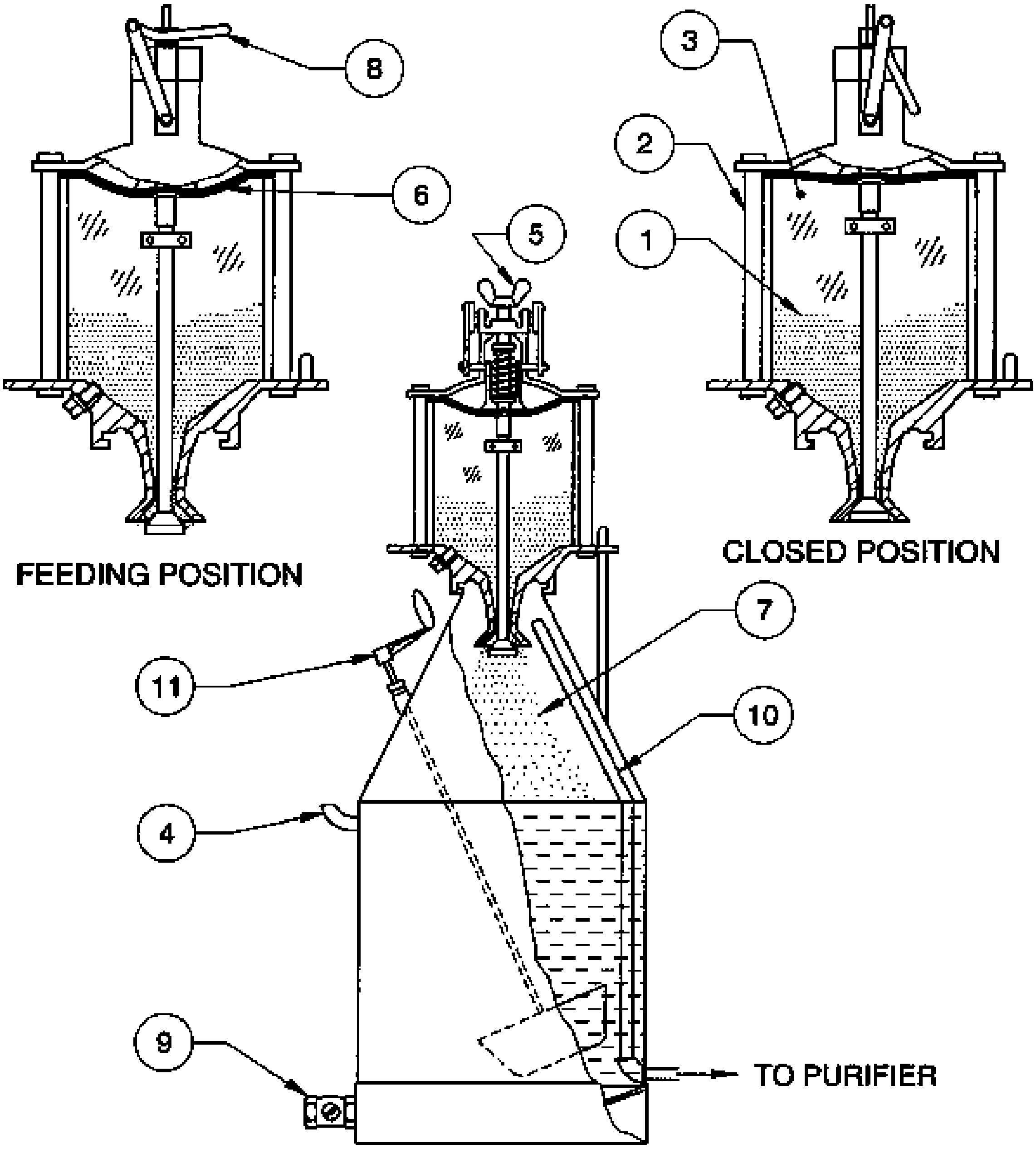


WORKING

When the valve (1) is opened water enters in the carbide chamber (2) and due to chemical reaction acetylene is produced. The gas passes through gas collecting pipe (3) and reaches the raising bell (4) rough water (5). The gas is stored under pressure with the help of a cast iron block (6). The raising bell is automatically lifted because of the gas pressure inside. The bar for operating valve (7) which is connected with gas raising bell will also be moved upward along with the float ball (8) which is connected to water supply mechanism and plugs the water inlet (9). This stops the production of acetylene. The produced gas will be collected through pipe (10) and sent to blow pipe. When the gas is reduced, the gas raising bell comes down along with the bar for operating valve (7). This presses the floater ball and production of acetylene starts again.

Carbide to water generator (Function)

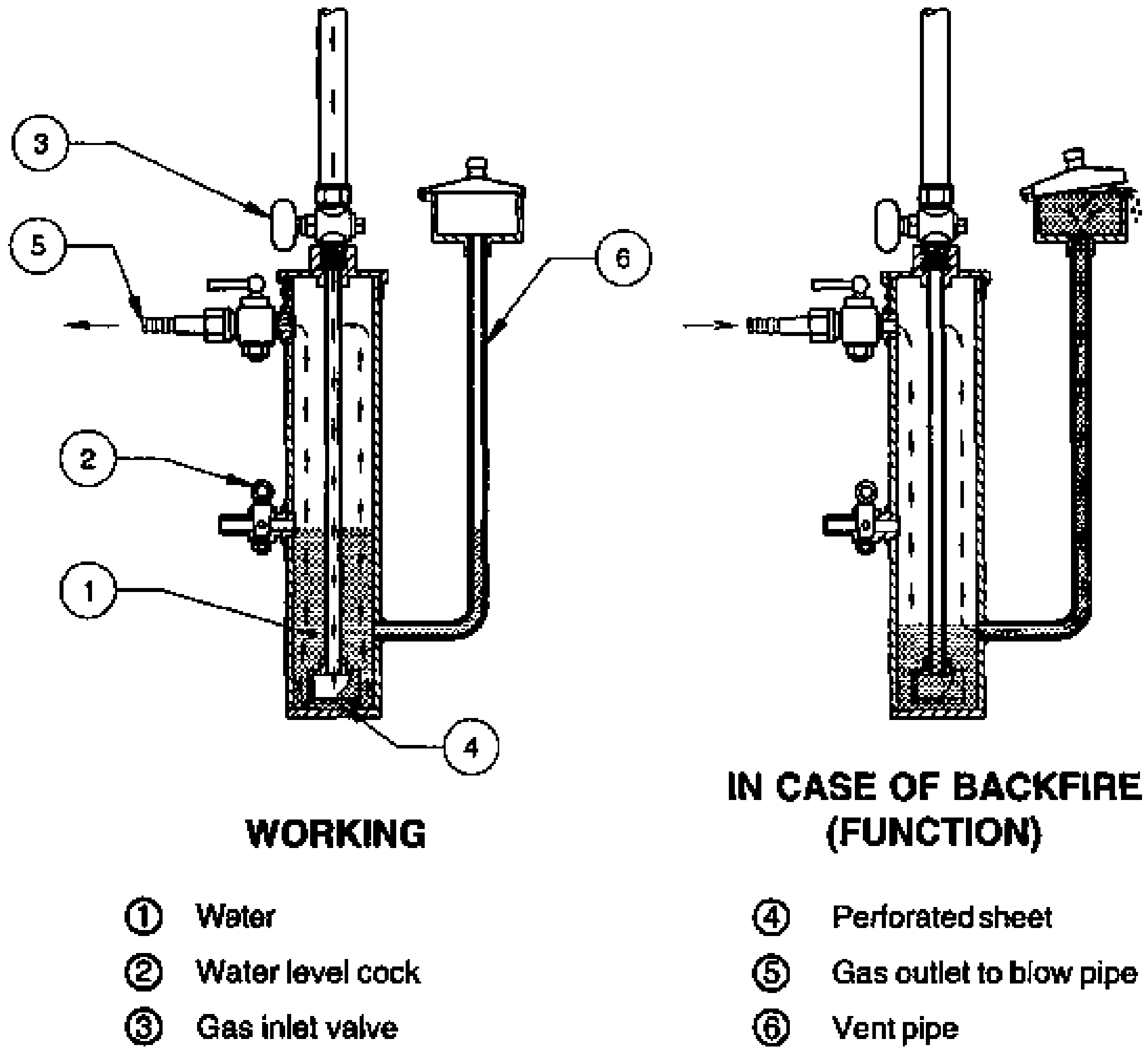
TR 03 01 06 02 95



Check the quantity of calcium carbide powder (1) in the hopper (2) through glass (3). Check the water level by opening the cork (4). Tighten the feeder screw (5) to press the diaphragm (6) and lift the lever (8). Powdered carbide will now pour into water (7) producing gas. Carbide flow is adjusted by moving the feeder lever up and down (8). Use agitator pedal (11) for generating gas without waste of calcium carbide. Drain the sludge through drain cork (9). Produced gas is collected by the tube (10) and goes to the purifier.

Hydraulic back pressure valve (Function)

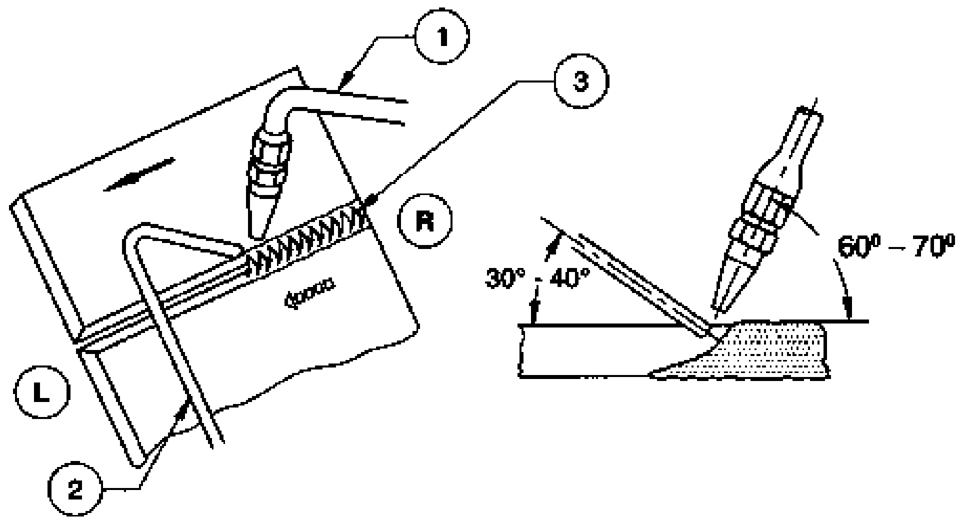
TR 03 01 08 01 95



Fill the water (1) by opening the water level cock (2) and then close. Open the gas inlet valve (3) gas enter into Hydraulic back pressure valve through perforated sheet (4) to blow pipe through tap (5). In the event of back fire or flash back it enters to back pressure valve and depress the water level. Water is then letout through vent pipe (6) to atmosphere and preventing fire getting into the low pressure generator.

Gas welding techniques

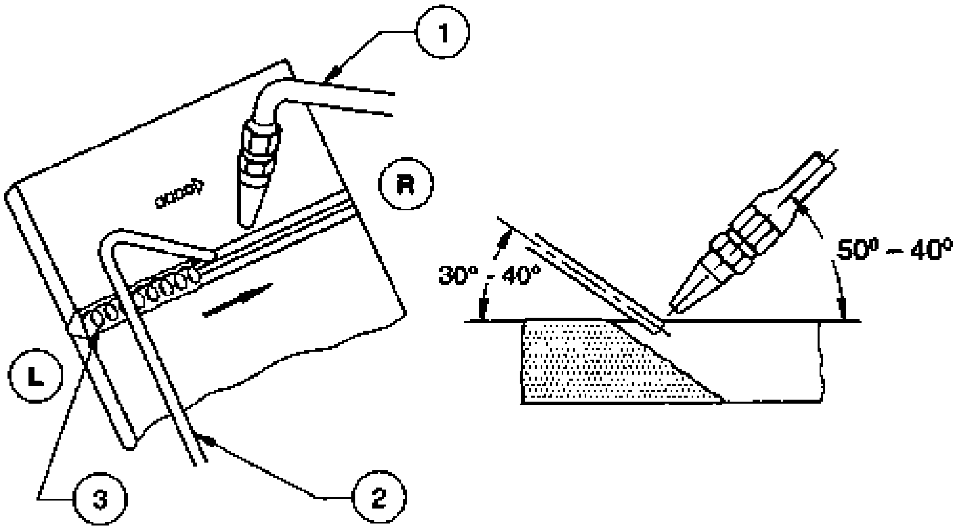
TR 03 01 10 01 95



Leftward welding

Leftward welding

The welding which commences on the right hand edge (R) of the joint and proceeds towards the left (L). The blow pipe (1) and filler rod (2) are given a forward motion with just sufficient side movement (3) to maintain both edges melting at a desired rate.



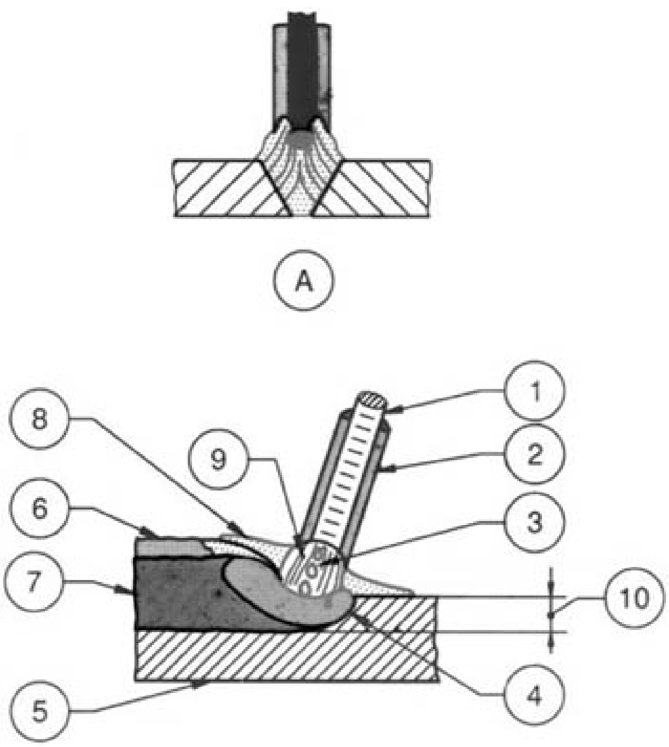
Rightward welding

Rightward welding

The welding which commences at the left hand end (L) and proceeds towards right hand (R) of the joint and the blow pipe (1) and filler rod (2) are moved towards right (R) This welding is quicker than leftward welding and consumes less gas

Metallic arc

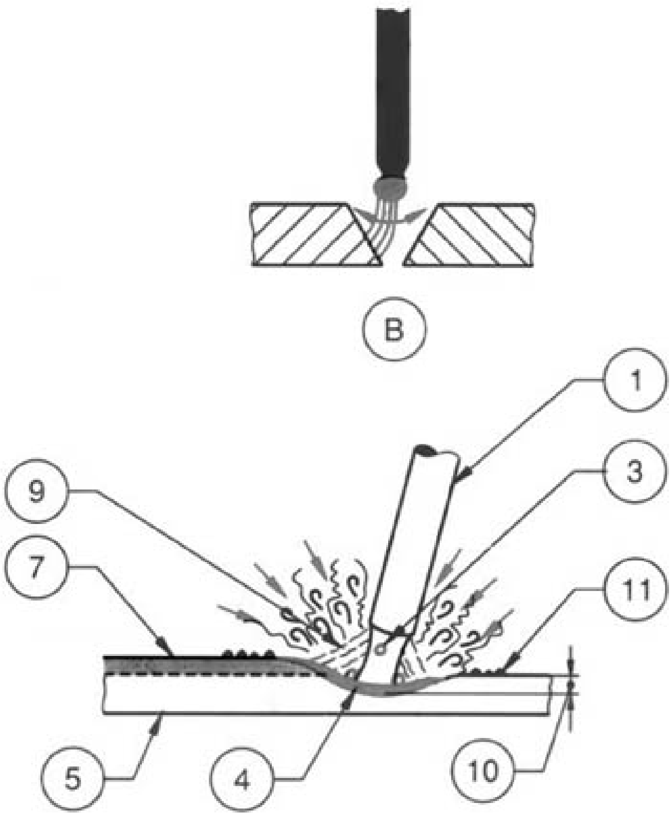
TR 03 01 04 01 95



ARC WITH COATED ELECTRODE

(A) Coated electrodes

- good penetration
- stable arc
- less spatters



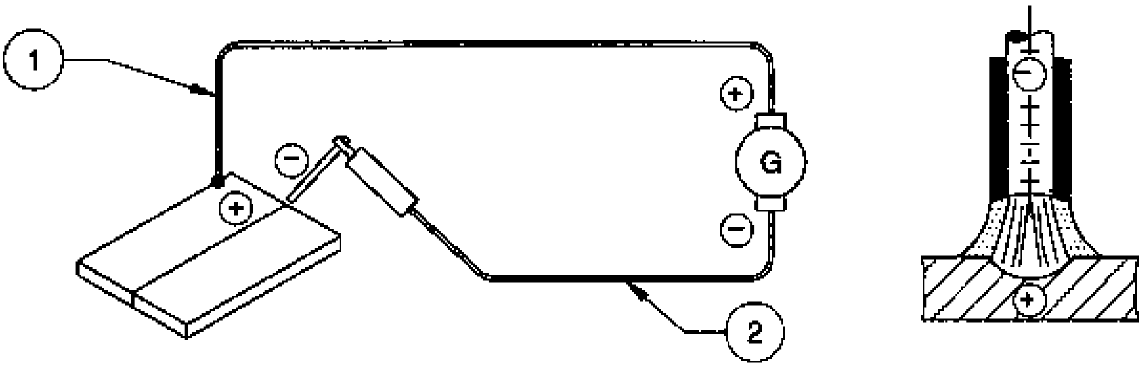
ARC WITH BARE ELECTRODE

(B) Bare electrodes

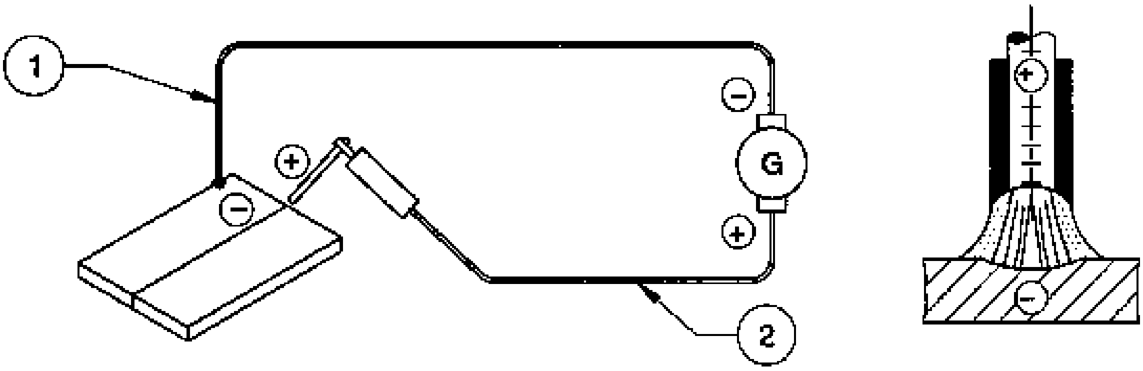
- less penetration
- unstable arc
- more spatters

(1)	Bare electrode	(6)	Slag covering
(2)	Flux coating	(7)	Weld metal
(3)	Globules	(8)	Gaseous shield
(4)	Molten crater	(9)	Arc stream
(5)	Parent metal	(10)	Penetration
		(11)	Spatters

Polarity and its effects



STRAIGHT POLARITY



REVERSE POLARITY

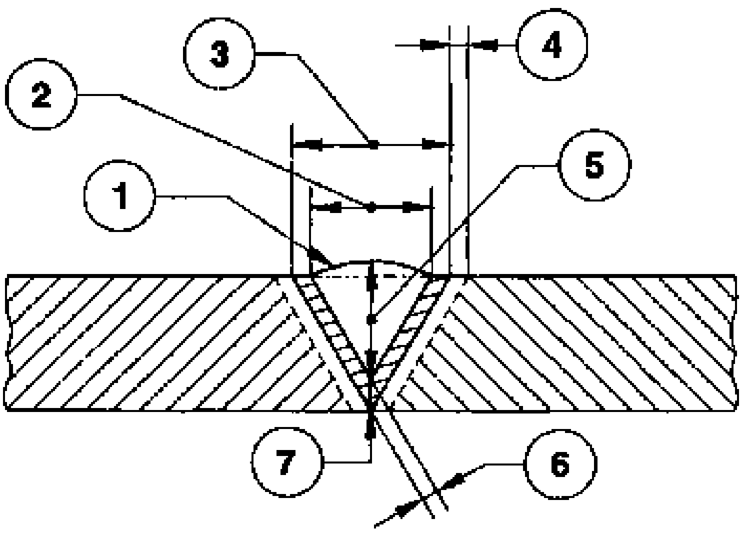
(1) Earth Cable
(2) Holder Cable

In DC welding 2/3 of the heat is produced from the positive end and 1/3 from the negative end.

Because of the unequal distribution of heat in the electrode and the base metal, the polarity is an important factor for successful welding

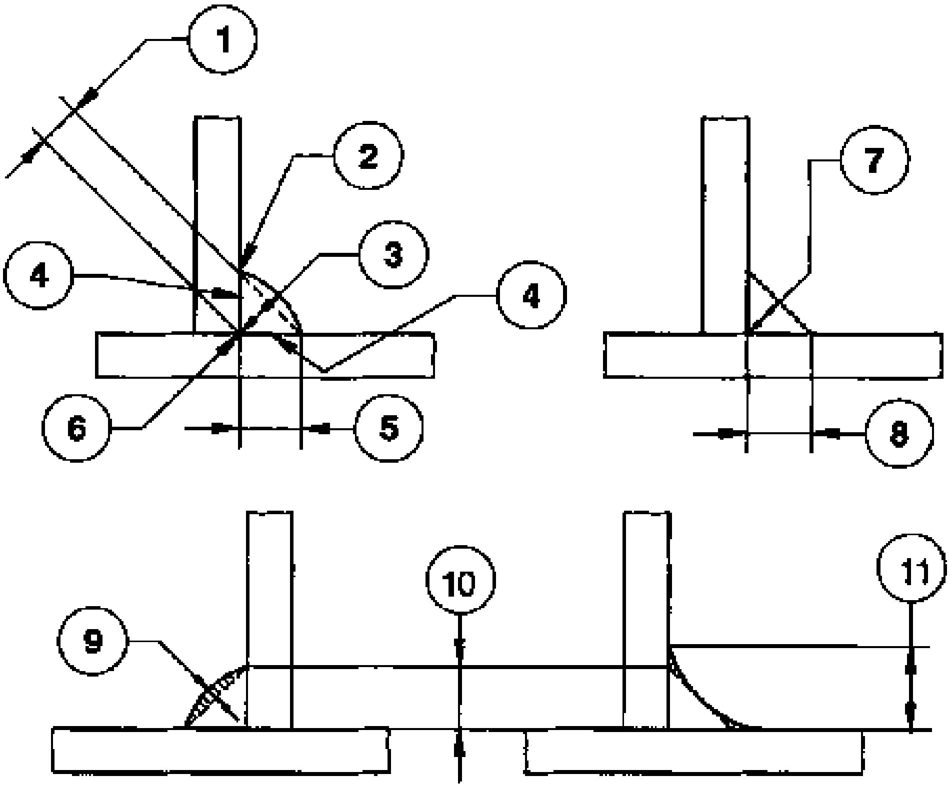
Nomenclature of weldments

TR 03 04 05 01 95



BUTT WELD

(1) Normal reinforcement (1/10th of the Plate thickness)
(2) Deposited metal
(3) Weld metal zone
(4) Heat affected zone
(5) Throat thickness
(6) Fusion zone
(7) Root



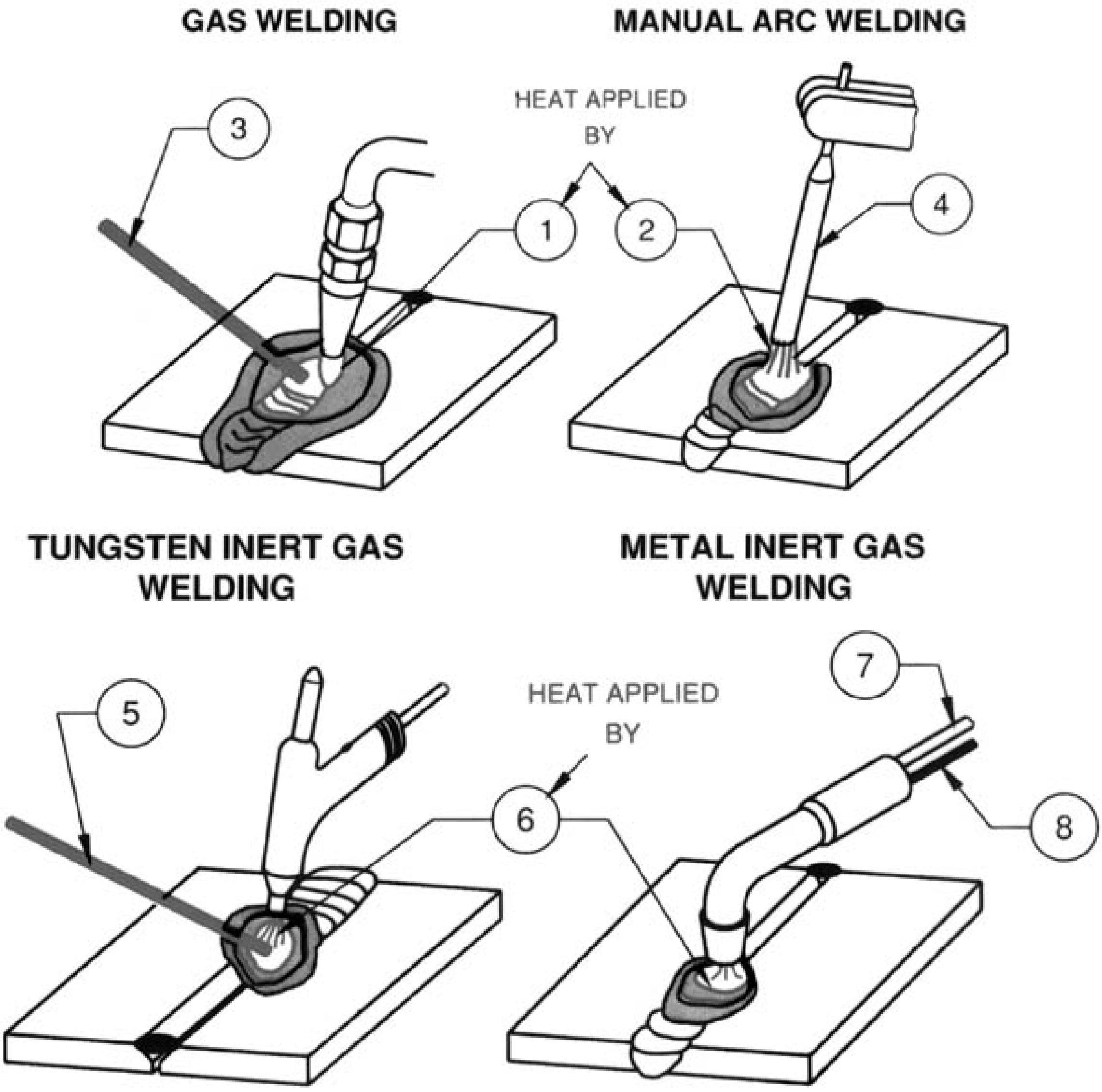
FILLET WELD

Convex & concave fillets with same effective throat thickness

(1)	Effective Throat Thickness	(6)	Root
(2)	Toe	(7)	Throat thickness (0.7 of leg length)
(3)	Throat thickness	(8) & (10)	Specified leg length
(4)	Fusion faces	(9)	Proud metal (Reinforcement)
(5)	Leg length	(11)	Actual leg length

Difference between fusion welding processes

TR 03 06 07 01 95



(1) Heating by flame
(2) Heating by arc
(3) Filler rod
(4) Coated electrode
(5) Filler rod (TIG)
(6)

i. Heating by arc using tungston electrode (TIG)
ii. Heating by arc using bare wire electrode

(7) Fault in weldments
(8) Work piece

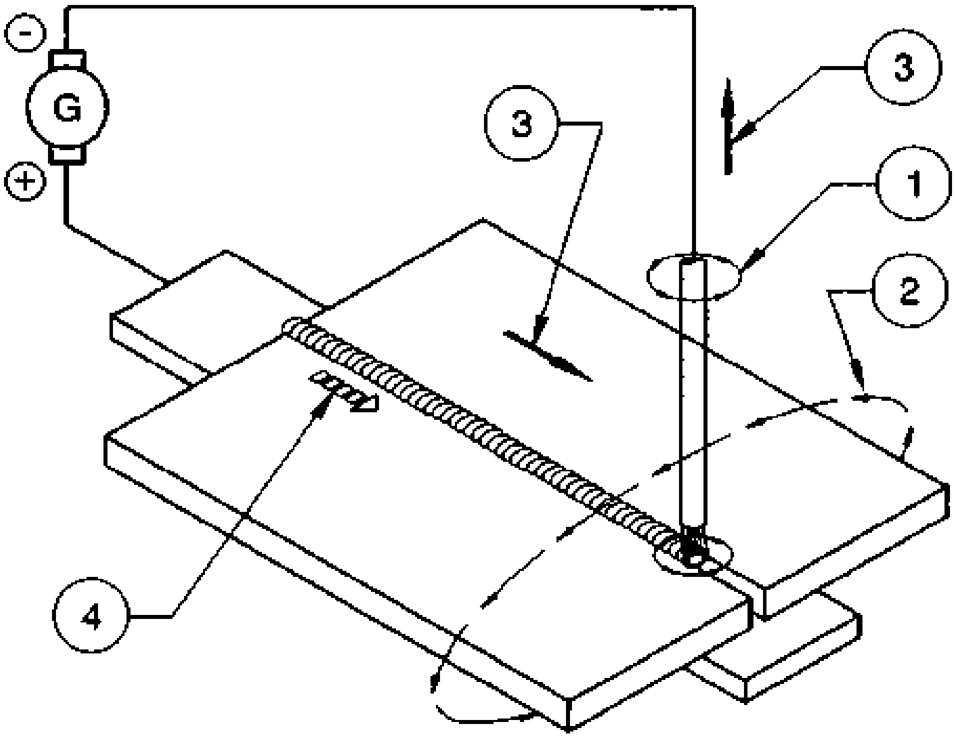
Effects of welding on parent materials

The characteristic of the parent material eg. tensile strength, hardness, toughness, elongation, wear and corrosion resistance are affected by the welding process.

When the weldability of the parent material is better, these characteristics are less affected by welding.

Arc blow and its effects

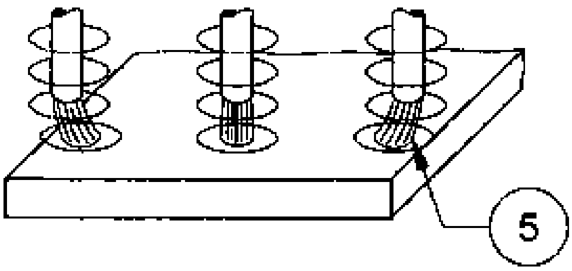
TR 03 01 10 01 95



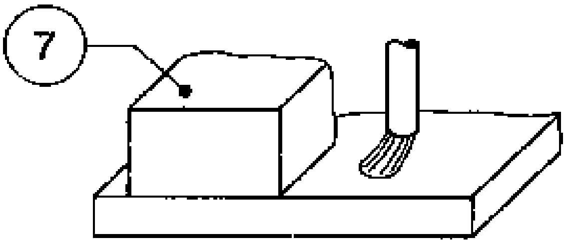
(1) Magnetic field around Electrode (2) Magnetic field around work piece

(3) Current flow (4) Direction of welding

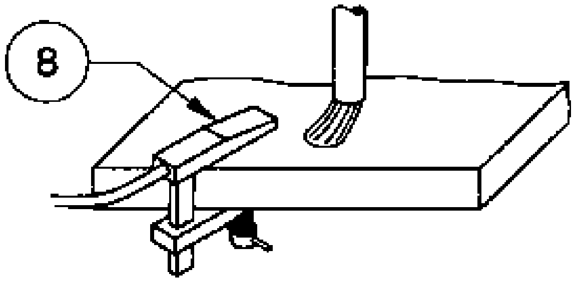
COMMON REASONS FOR THE ARC BLOW EFFECTS IN PARTICULAR WHEN USING DIRECT CURRENT



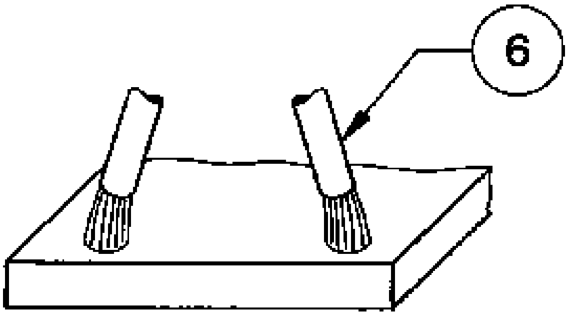
(5) Welding at the edge of work piece



(6) Welding close to large work piece



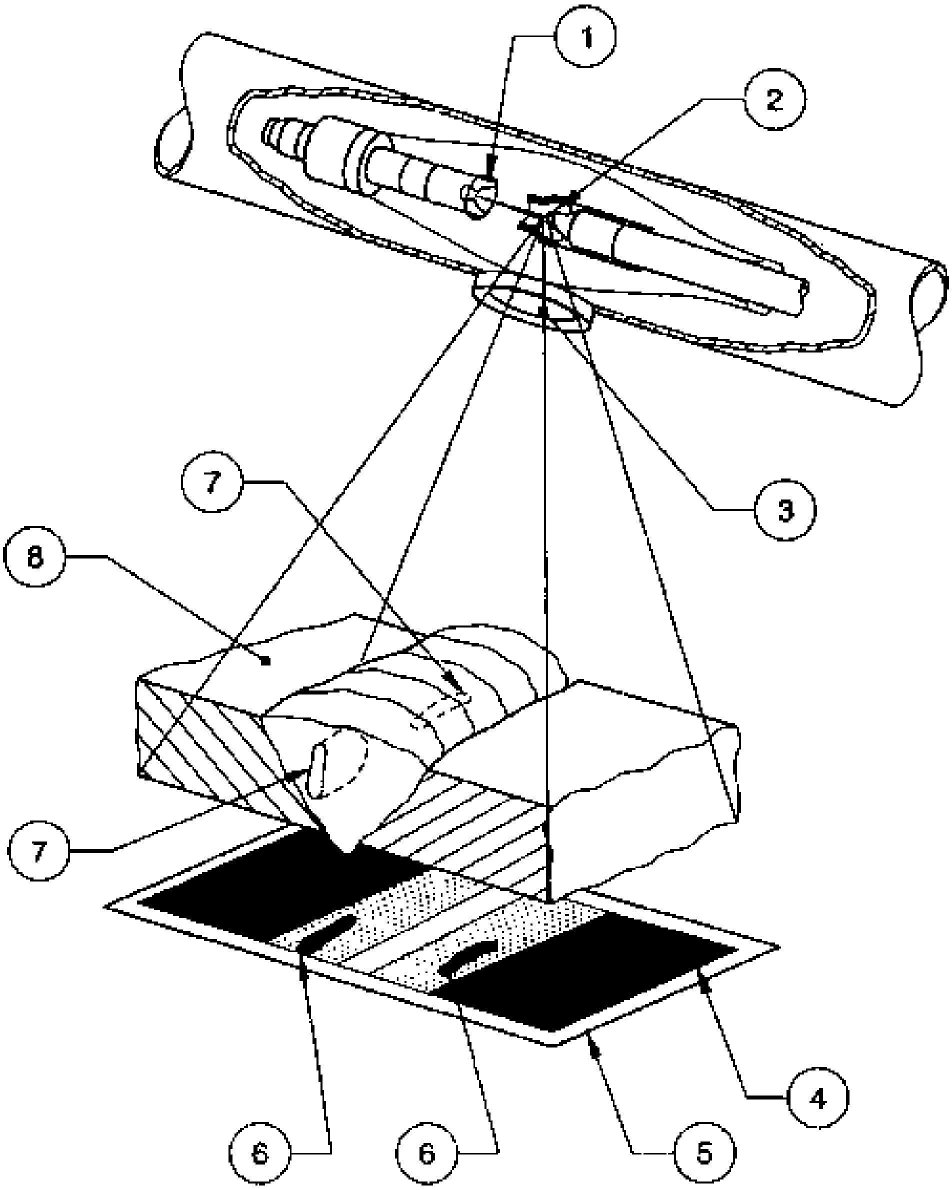
(7) Welding close to earth connection



(8) To avoid Arc blow change the electrode angle

Radiography test

TR 03 05 02 01 95

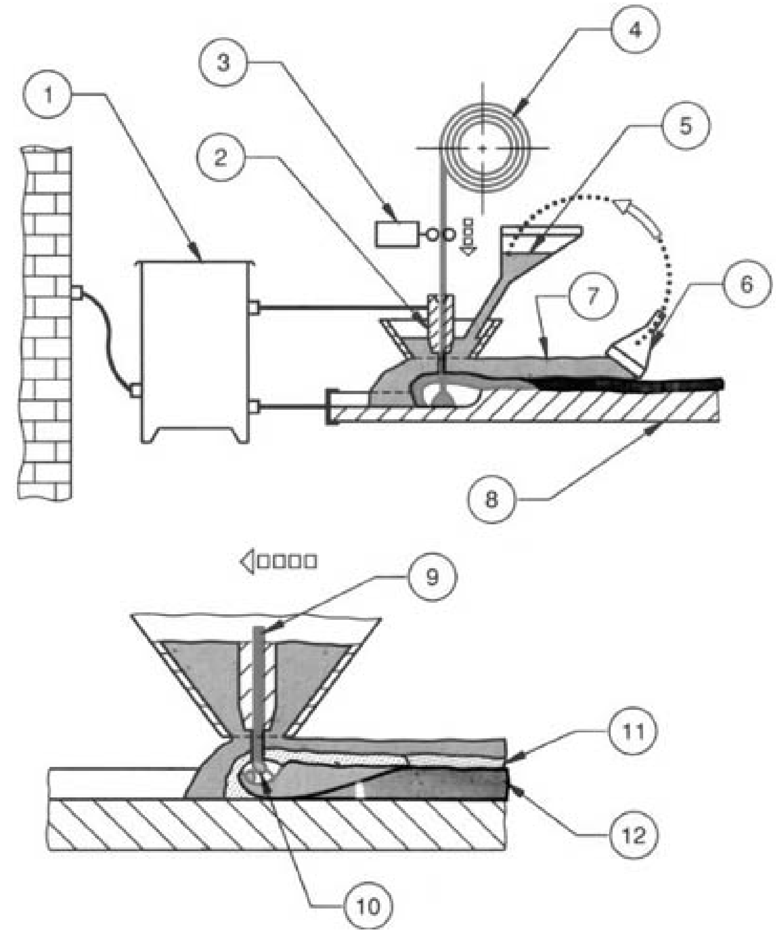


(1) Cathode
(2) Anode
(3) Exit window
(4) X−ray film
(5) Lead sheet
(6) Image of Defect
(7) Fault in weldments
(8) Work piece

The internal aspects of weldments can be verified by the use of this. The test specimen (8) is placed between the x−ray film (4) and cathode tube/radiography ray sources (1) (2) and (3). The defects of weldment are reproduced in the film (6). A leadsheet (5) is placed below the film to prevent further penetration of rays.

Automatic submerged arc welding

TR 03 06 03 01 95

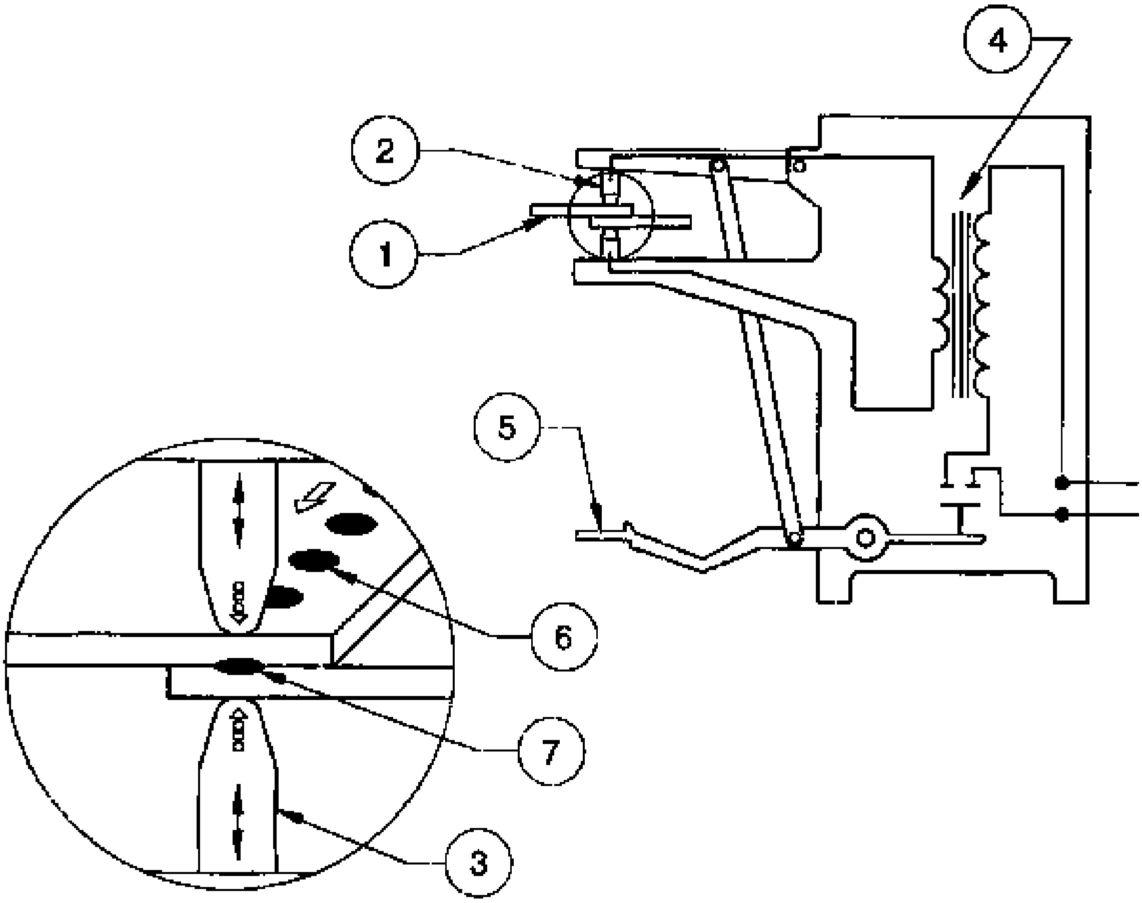


(1)	Welding current source	(5)	Hopper	(9)	Wire Electrode
(2)	Current contact Nozzle	(6)	Powder extration	(10)	Arc
(3)	Wire feed unit	(7)	Granular flux	(11)	Solid slag
(4)	Wire Electrode coil	(8)	Workpiece	(12)	Solid weld metal

The Welding current source is a transformer (1). The electrode wires (4) are in the form of a coil (4) and is fed by a wire feeding mechanism (3). The electrode wire passes through the current contact nozzle (2). When the electrode establishes the arc automatically, the flux contained in the hopper (5) also passes on the weld path thus shielding arc from outside contamination. The unburnt flux (7) is recovered and fed back to the hopper (5).

Spot welding

TR 03 01 19 01 95



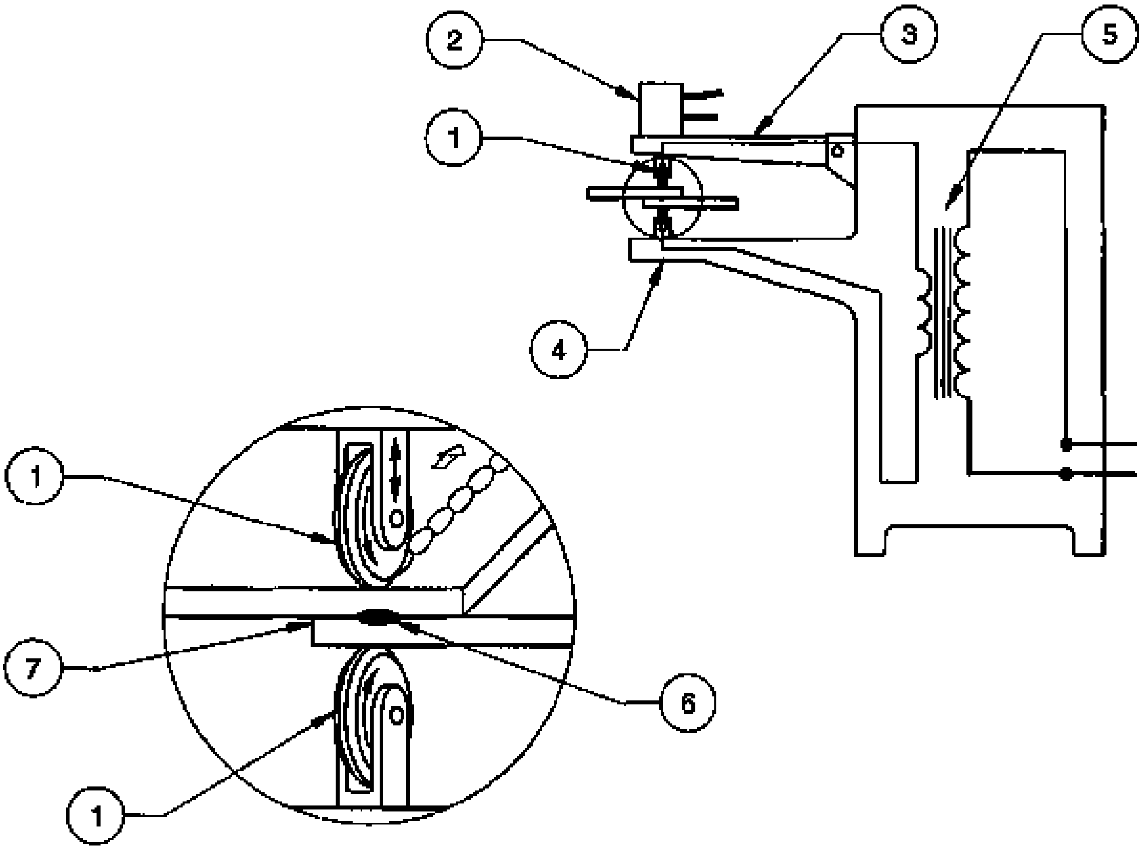
(1)	Base metal	(5)	Foot pedal
(2)	Moveable Electrode	(6)	Spot weld
(3)	Stationary Electrode	(7)	Spot weld nugget
(4)	Transformer		

Principle/Process

• The first step is that the parts to be joined are clamped between the electrodes. In the second step, a high current is allowed to pass through the clamped members and the temperature is raised for welding to take place. In the third step the current is being cut off and high pressure is applied to form the joint. The nugget formed is shown. (7)

• Spot welding is utilized extensively for welding steel. When equipped with an electronic timer, it can be used for other materials, such as aluminium, copper, stainless steel, galvanised metals, etc.

Seam welding



(1) Roller Electrode

(2) Pneumatic or Hydraulic cylinder

(3) Movable Arm

(4) Stationary Arm

(5) Transformer

(6) Weld Nugget

(7) Base Metal

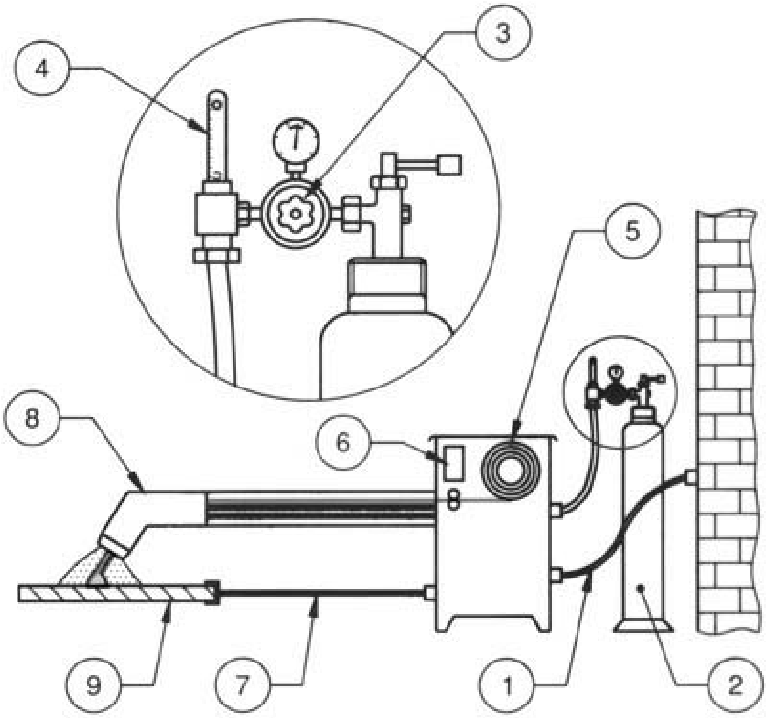
Principle/Process

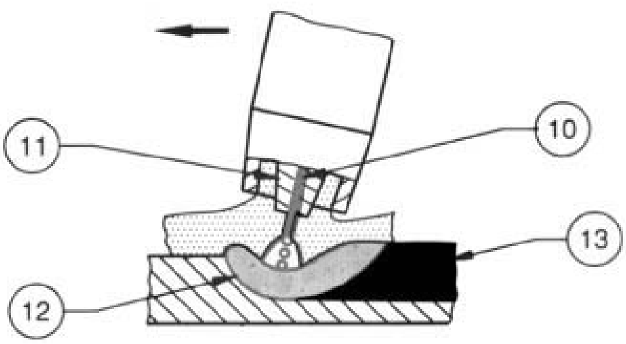
• Seam welding is like spot welding except that the spots overlap one another, making continuous weld seam. As the electrodes revolve, the current is automatically turned 'on' and 'off' at intervals corresponding to the speed at which the parts are set to move. With proper control, it is possible to obtain airtight seams suitable for containers, water heaters, fuel tanks etc.

• Both lap and butt joints are welded by seam welds. In the case of butt joints, foils of filler metals are used on the joints.

Metal inert gas (MIG) welding

TR 03 06 02 01 95



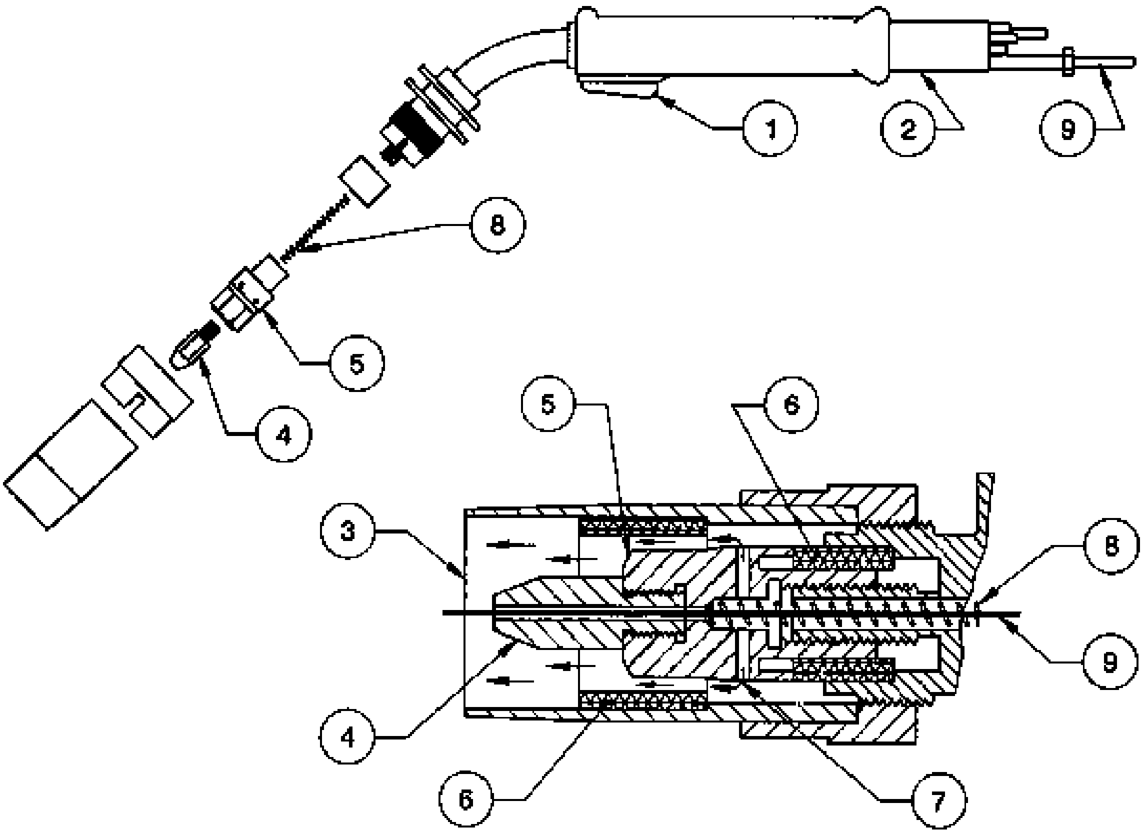


PROCESS/FUNCTION

Connect the current input cable (1). Open the inert gas cylinder (2) and check the gas pressure on gauge (3). Adjust the gas flow meter (4) as required. After setting put it in "AUTO". Run the wire from the wire reel (5) through wire feeding unit (6). Connect the Earth cable (7) to workpiece (9) Draw the wire through cable to welding torch (8). Adjust the electrode wire until the wire appear (10) at the tip of welding torch through current contact nozzle (11). Strike and establish the arc. In the figure molten pool (12) and welded metal (13) are shown.

Metal inert gas welding (MIG) torch

TR 03 01 21 01 95

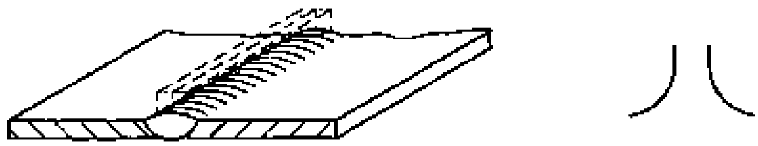


(1) Torch switch
(2) Hose Assembly
(3) Gas Nozzle
(4) Current contact nozzle
(5) Current contact holder
(6) Insulators
(7) Shielding Gas
(8) Spirally wound wire electrode guide
(9) Wire electrode

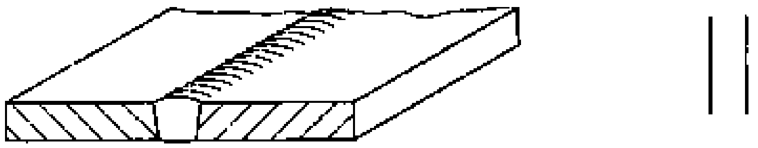
Welding symbols

TR 03 04 16 01 95

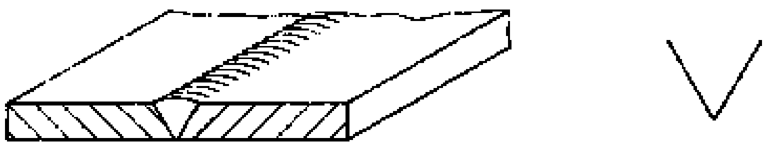
Butt weld between plates with raised edges (the raised edges being melted down completely



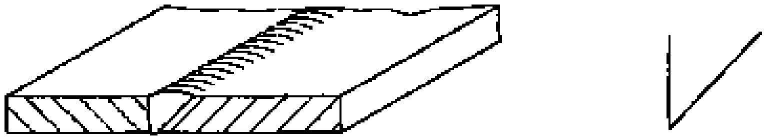
Square butt weld



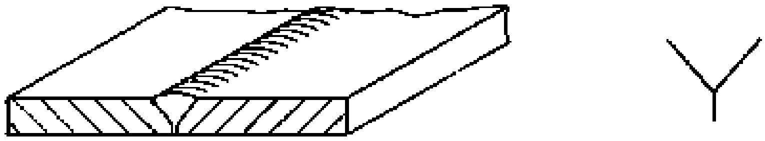
Single V butt weld



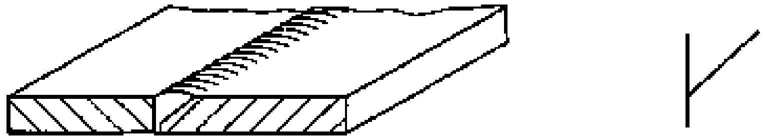
Single bevel butt weld



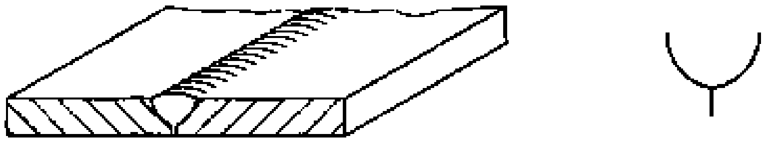
Single V butt weld with broad root face



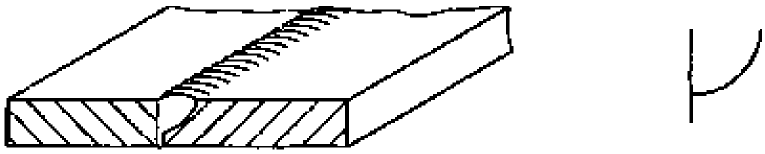
Single bevel butt weld with broad root face



Single U butt weld (Parallel or sloping sides)



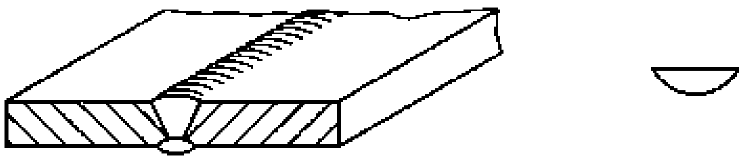
Single J butt weld



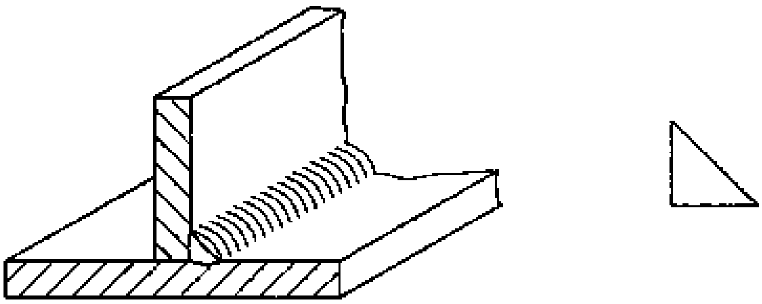
Welding symbols

TR 03 04 16 02 95

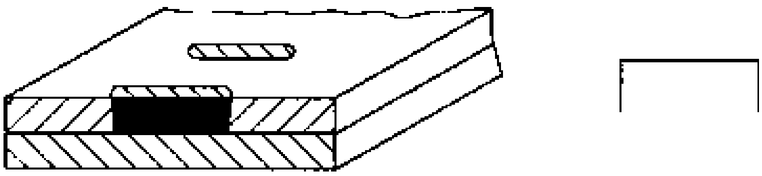
Backing run; back or back weld



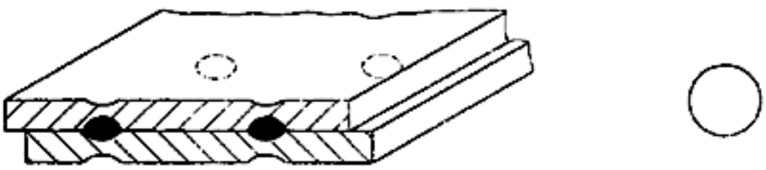
Fillet weld



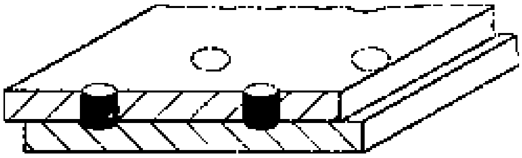
Plug weld: plug or slot weld/ USA

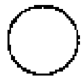


Spot welding

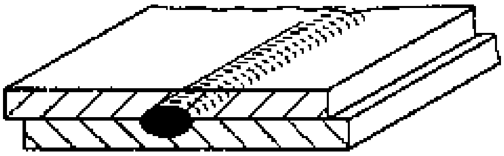


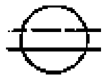
Spot welding



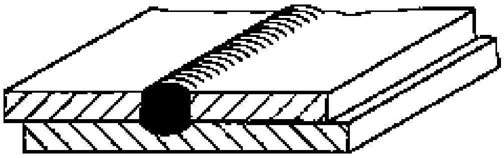


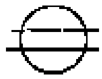
Seam welding





Seam welding





Electric Welding 1 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

Table of Contents

Electric Welding 1 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

CRYSTAL

**Lehr– und Lernmittel,
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Literature, Consulting**

**Moyens didactiques,
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**Material didáctico,
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0. Preliminary Remarks

The present Methodical Instructions are intended for the instructor; they will give him help and assistance in the preparation and realisation of vocational training. They directly apply to the instructor – frequently addressing him personally – submitting suggestions and pointing out focal points for imparting knowledge and skills. For this purpose, pedagogic–didactic ways of solution are proposed. They enable the realisation of the aim of training specified in the course of instruction by the pedagogic activities of the instructor. The Instructions are arranged in such a way that the trainees are in a position to acquire the knowledge, abilities and skills required for electric welding.

Particular attention has been paid to the principle to proceed from the simple to the complicated subjects. The sequence of the individual welding positions, the grasping and practising of them, is bases on experiences in the training of electric weldors gathered during many years.

During training, the trainees

– have to learn how to handle the pieces of equipment and tools.
– have to practise the execution of the various welding positions.
– must be able to coordinate the welding positions with the various applications.

After conclusion of training, the trainees must be in a position

– to judge the quality of the results of their work, identify faults and their causes and remove them.
– to handle and operate the means of work and subjects of labour entrusted to them economically.

Recommendations for and information about the educational work – of the instructors within the scope of the tactical vocational training are incorporated into the Methodical Instructions. After conclusion of the course of training, the trainees shall possess such character attributes and such a behaviour as:

– conscious discipline during the working processes,
– conduct in accordance with labour safety,
– collective and companionable behaviour,
– self–critical assessment of the own work (welding work is a matter of condicence).

The Methodical Instructions should not be considered regulations which are rigid and have to be observed strictly. The users of them have full scope to realize their own ideas.

1. General Methodical–organisational Information

1.1. On the Arrangement of the Vocational Training

In the planning and realisation of vocational training, one has to start from the fact that it is a purposive process at the end of which there is a predetermined, exactly defined and duly evidenced qualification.

This means that complete command of vocational knowledge, abilities and skills, hence,

• the learning,
• the practising,
• the exercising,
• the acquisition of operations, motions, control algorithms for electric welding are the centre of training.

This shows that practical vocational training is a planned, purposive, didactically and methodically prepared process, and it should be arranged accordingly.

The aim of the training consists in the lasting acquisition of knowledge, abilities and skills, in the education of consciously acting personalities. This calls for the use of approved pedagogic, didactic and methodical findings and laws. These findings have been integrated into the Methodical Instructions.

The basic unit for the practical vocational training in electric welding is the job of the trainee, his task as an apprentice or worker.

This task is associated with the equipment for the electric weldor. The curriculum for the practical vocational training of the electric weldor contains, among other things, the learning of the welding positions.

The individual welding positions are self–contained training sections.

At the end of any training section, a practice workpiece or examination workpiece must be welded.

In the directions for examination, the examination pieces required for the weldor's qualification under consideration are mentioned.

Consequently, the various methodical instructions must be compiled in accordance with the aim of the training.

In the practical training, particular attention must be paid to the control and evaluation of the results of work. In this respect, the explanations given in the Section "Control, evaluation and interpretation" have to be observed.

The Methodical Instructions are based on the consideration that the practical vocational training takes place in a training workshop. Training in production is not possible in this case because in vocational training it is only allowed to weld exercise pieces until the final examination.

An important precondition for good performances in practical vocational training are long−term planning and well−devised organisation of training.

It should be noted that maximum two trainees are in the welding booth.

One instructor should be in charge of the simultaneous training of 8 trainees.

He must thoroughly analyse the stage of training or given qualification of the trainees and organise the further training course accordingly.

The sequence of learning the welding positions (methodical instructions) should not be dogmatised. It is quite possible to change the sequence, taking the level of achievement and progress in learning of the trainees into consideration. Basis of planning the practical vocational training is the day of instruction. For such a day of instruction, the trainees can be given the following tasks:

1. acquisition of new knowledge and abilities
2. practising, exercising, acquisition of skills

Especially the skills of electric welding can only be acquired by repeated practising and exercising the electrode position in the various welding positions. Therefore, particular attention should be paid to practising. In this connection, the instructions given in Section "Practising" must be observed in any case.

1.2. Practising

Before the trainees start practising, give them the following information:

− which target or sub−targets have to be achieved,

− which labour safety, health protection and fire protection regulations have to be observed in particular,

− how to proceed (arrangement of operations and special tasks).

After having given this information, ask the trainees to arrange their working places for the operations to be acquired. Show the trainees a properly arranged working place.

Explain the operations to be performed in full detail:

− characteristic of the results of the operations to be carried out (acquisition of the welding position in question)

− condition of the finished subject of labour (peculiarities of the workpiece)

− properties of the material or semi−finished product to be tooled and welded

− explanation of the basic and auxiliary operations which are required for the job to be performed (setting the current intensity, change of the electrodes, etc.)

− handing over the material

- discussing the forms of control and self-control.

Then you must demonstrate the operations of the means of work and show the necessary manipulations and actions of work.

Demonstration is an important criteria of the educational and training activities of the instructor.

At the end of any particular instruction, demonstration must be effected as a foundation of training.

Only when the work to be done or the job, its demonstration and the repetition by one trainee has been understood by all other trainees, you should ask the trainees to perform the work.

For this purpose, allow an adequate number of exercises.

Further, ask the trainees to take advantage of the knowledge, abilities and skills which they have already acquired.

The practical activity of the trainee, the practising and exercising, plays an important role in the training for the acquisition of practical vocational knowledge, abilities and skills.

For practising, you should take into account the following criteria:

- Practising serves for the development, perfection and consolidation of abilities and skills.
- Practising should be based on an increasing degree of difficulty.
- Practising should be organised in such a way that the trainees perform their work readily and joyously and that they are interested in a comparison of their achievements.
- In practising, the trainees should be assisted individually, and the progress in learning should be recorded in surveys of the results obtained.
- Impartation of the subject-matter should be continued only when all trainees have understood the preceding subjects.
- Practising should be supplemented by rules.
- In all practising sections, information should be given about the maintenance of the working tools and equipment and about labour safety.

You should bear in mind that a consistent training always proceeds from the simple to the complicated subjects.

Now, allow the trainees to start their work and to practise the operations involved.

In this process, you should aid the trainees and correct their errors.

If, in a exercise, typical errors are repeated by the trainees, analyse and discuss them with the trainees in order to avoid repetition of these errors.

Familiarise the trainees with rules regarding special technical subjects.

During practising, record the performances and results of learning achieved by the trainees and take care that the labour safety regulations are strictly observed.

Carry out intermediate controls by means of which you are also in a position to find out the productive application of the things learned.

In conclusion of the practising section, carry out an achievement control. Observe the information given in Section "Control, Evaluation and Interpretation".

Analyse and discuss the achievements and results of learning obtained in the preceding section under consideration together with all trainees.

At the end of the training day, request the trainees to clear their working places and to clean the workshop.

All that has been said above shows that the continuous process of practical vocational training is very differentiated and makes great demands on the organisation and, thus, on the methodical skill and pedagogic activities of the instructor. Further, in the process of vocational training, you have to make up your mind as to how you intend to proceed in the impartation of the subject−matter or how you have to proceed in accordance with the given conditions.

A distinction is made between three organisational basic forms of practical vocational training:

1. individual instruction of the trainee (individual procedure)
2. instruction of groups (group procedure)
3. simultaneous instruction of all trainees (frontal procedure)

In any of these procedures, practising, consolidation and depending the knowledge, abilities and skills of the trainees is included under the direction and control of the instructor. The third form is unfavourable for the training of electric weldors. The group procedure plays an important part because the trainees receive the theoretical knowledge required for their practical work in this manner. During the practical work, the instructor guides the trainees individually.

1.3. Control Evaluation and Interpretation

Control, evaluation and interpretation are essential parts of the training process.

They follow the phase of instruction and realisation. Control, however, should already be a constituent part of these two training phases.

Therefore, pay particular attention to the strict observance of control, evaluation and interpretation. In this way, you will always be informed of the stage of the educational and training work achieved.

In particular, you will know at any time whether

– there are successes and deficiencies in your own planning and organisational efforts,
– direction and assistance of the trainees have been effected in the correct way,
– the specified targets have been reached by the trainees,
– the personality of the trainees has been developed.

During training, observe the following hints:

– when you go your rounds, you should obtain a general view of a great number of evaluation criteria and of the progress of work being done by the trainees.

– Check the process of training and give hints

• on the performance of work,
• on the effective arrangement of work,
• on health and labour safety and fire protection, etc.

– Note down your findings for the comprehensive evaluation of the achievements of the trainees.

Take notes of observations necessary for the evaluation of the achievements of the trainees and enter this evaluation in files. When controlling and evaluating the achievements of the trainees, pay particular attention to the following items:

1. control and evaluation of the quality of work,
2. control and evaluation of the mode of work during working,

3. control and evaluation of order and cleanliness at the working place,
4. control and evaluation of how theoretical knowledge is applied in practice.

For an evaluation of them achievements of the trainees, proceed in the following order:

1st step:	Definition of the achievement criteria on the basis of the selected and defined tasks.
2nd step:	Definition of the methods for the acquisition of the achievement criteria.
3rd step:	Coordination of the achievement criteria with the scale of marks.
4th step:	Determination of the learning and working achievements of the trainees on the basis of the achievement criteria.
5th step:	Comparison of the achievement criteria with the specifications of the scale marks in order to find an overall mark for every trainee (see Section on Direction for the Examination).
6th step:	Notifying and discussing the report.

When you think that the trainees possess the required abilities for the performance of the welding position in question, have a practice sample stamped and welded under examination conditions.

Evaluate the stamped practice sample. Ask the trainees to propose the mark; this will educate to self−critical work. Determine the marks for accuracy to size, appearance of the seam and fracture appearance and the final mark according to the specified directions. Enter these marks in an evaluation sheet which is visible to all.

When a trainee fails to reach the required sub−target, then enter this fact into the evaluation sheet. Offer the possibility of making up for the missing knowledge.

The trainees must become aware of their level of achievement and develop purposive activities for the removal of still existing deficiencies. At the same time, the ability for self−assessment of the trainees is to be developed.

Assessment of the results:

For this purpose, it is necessary for you to find errors and deficiencies in training that you may have caused yourself. When you have found out that errors and deficiencies are not due to your own failure, you should trace the cause of them in the trainees or in other factors which might have, or actually have, exerted a negative influence on the process of training. Lay down measures for yourself which will prevent the same errors and deficiencies in further training courses.

Discuss these measures with other instructors and with the management of the training centre, thus, rendering mutual assistance for improving the educational and training results.

1.4. Information about the Maintenance of the Means of Work

Explain to the trainees the importance of the maintenance of the means of work. In this connection, enter into particulars on the following important items:

− means of work which are in a proper condition are an essential precondition for welding the subjects of labour according to the rules of good workmanship (e.g. electrode holder).

− means of work which are subjected to routine maintenance remain serviceable for a prolonged period of time.

Pay attention to the fact that the trainees strictly observe the instructions and requirements given by you as to the maintenance of the means of work in order that their serviceability is warranted. Fall back upon the rules for care and maintenance of the means of work which are already known to the trainees.

Further, bear in mind:

– correctly employed means of work remain serviceable for a prolonged period of time

When controlling the trainees at work, ask them to show you their means of work and single out damaged means of work! Train the trainees to keep their means of work properly and safety!

Allow the trainees to restore their means of work to proper condition provided this is necessary and permissible from the angle of labour safety!

Impart to the trainees the manual skill and abilities necessary for this purpose!

Explain to the trainees which means of work must not be repaired by them!

Impart to the trainees the necessary knowledge so that they are in a position to find out when a means of work has to be repaired or replaced by a new one!

Train the trainees to become responsible workers who replace defective means of work which are no longer serviceable!

Again and again fall back upon the knowledge already acquired by the trainees and see to it that it is practically used.

Pay particular attention to the economic aspects (prime cost of a means of work – repaired means of work).

Avail yourself of the possibility of breeding pride in the trade into the trainees.

A good expert worker is recognised by his means of work which are in proper condition!

2. Principle and Use of Electric Welding

Experience has shown that the urge for knowledge is great at the beginning of a new subject−matter. In order to interest the trainees in electric welding, it is necessary to demonstrate the process of electric welding. For this purpose, station the trainees about the welding table, give each of them a weldor's screen and ask them to hold it in front of their faces. Point out that all of them hold the screen in front of their faces and observe your demonstration. Demonstrate the welding of a single bead in gravity position.

Subsequently, explain the principle of electric welding. For this purpose, use the textbook "Welding of Steel".

Order the trainees to read the literature carefully and to prepare a repetition of the principle of electric welding in the form of a paper to be read.

Evaluate this paper and add missing items. Then explain the different fields of application of electric welding. For illustration, show welded workpieces. Ask the trainees to tell you applications of the method of electric welding.

3. Means of Work for Electric Welding

Advise the trainees that wearing apparel which complies with the labour safety regulations is of particular importance to an electric weldor. When preparing this Section, keep this clothing in readiness. Pay attention to the fact that all trainees have such a weldor's clothing at their disposal.

- weldor's screen
- weldor's gloves (gauntlet−type leather gloves)
- working shoes
- headgear

– weldor's protective clothing or leather apron

Explain the function of the various parts of clothing. Enter into particulars on the weldor's protective screen.

In this connection, point out to the trainees that they should not approach the welding spot too closely in order that the glasses will not become too hot and burst.

Then ask the trainees to put on their wearing apparels. At the end of this Section, one trainee shall repeat the parts of the wearing apparel and their functions. If necessary, supplement him.

Subsequently, show the trainees the means of work of an electric weldor. Make sure of the knowledge present from theoretical lessons. At first, explain the pieces of equipment required for welding.

– welding converter
– electrode holder (negative pole) and electrodes
– lines
– clamp for workpiece (positive pole)
– welding table
– deslagging hammer
– wire brush

Explain the function of the individual pieces of equipment. In this connection, allow the trainees to exercise the inserting of the electrodes into the holder and the putting into operation of the welding equipment.

Show the trainees the main switch of the installation and the installation for adjusting the current intensity, Tell the trainees different current values and ask them to adjust these values. Check the setting of these values. Find a connection to theoretical lessons (negative pole; positive pole). As a conclusion of this sub–section, summarise the pieces of equipment. Then quote one piece of equipment at a time and ask one trainee to show it and explain its function, then ask the next trainee to show and explain the next piece of equipment and so on.

4. Terns of Electric Welding

Train the trainees to use the established expressions and terms. In this way you will facilitate the explanation of the processes and the giving of job orders and the mutual communication.

Give some detailed explanations.

<u>Terms:</u>

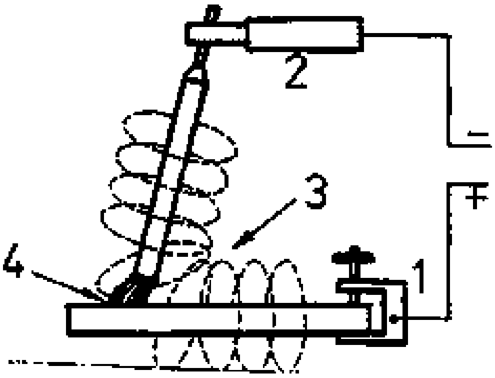
– effects of electrical current
– thermal effect and luminous effect
– magnetic effect
– chemical effect

Show the magnetic effect with the help of the following demonstration. A cardboard disk is slipped on a welding electrode. Iron filings are strewn on the disk. The electrode is short – circuit–ed. Use Fig. for your explanations.

– types of electrical current

• direct current
• alternating current

– blow effect

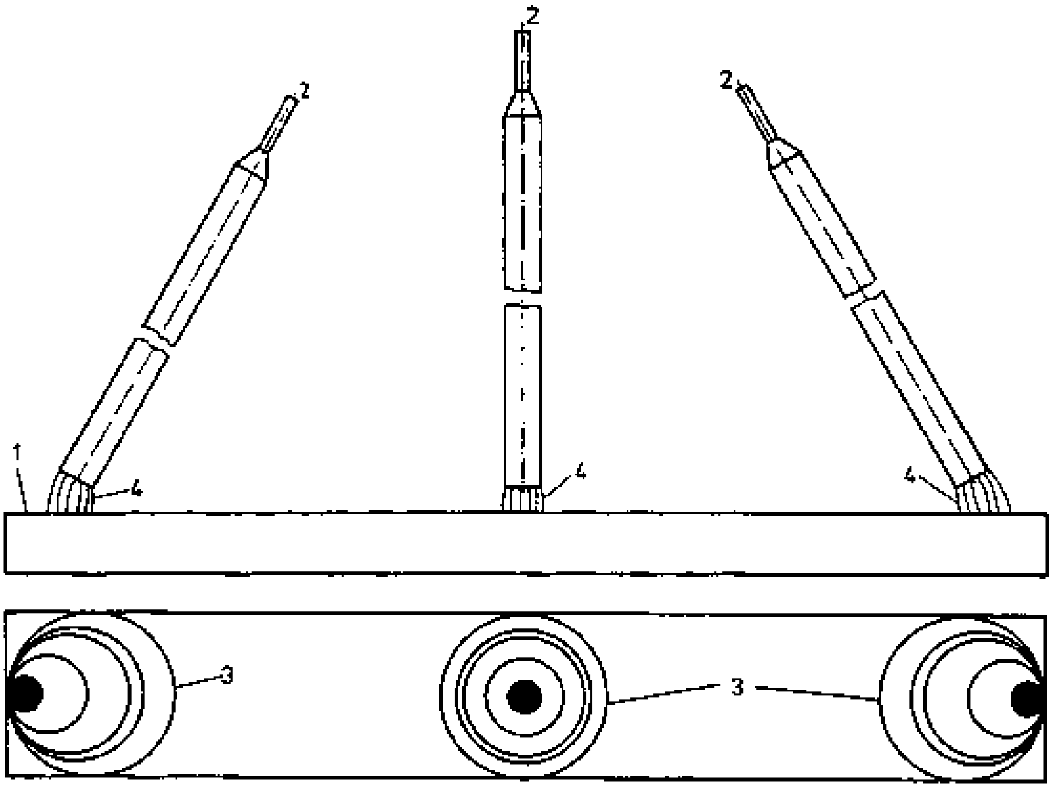


1 positive pole (earth clamp - workpiece)
2 negative pole (electrode)
3 lines of magnetic field
4 deflected arc

Fig. 1 Magnetic field about electrode and workpiece

When explaining the arc blow effect, enter into particulars on the corrective measures because the blow effects renders the production of proper weld seams impossible.

– welding current intensity



1 Positive pole, 2 Negative pole, 3 Lines of magnetic field, 4 Arc

Fig. 2 Magnetic field with the electrode in an inclined position

Give the following rule of thumb to the trainees

"40 Ampere per millimetre of core wire diameter"

– electrode

Make a distinction between bare electrodes and coated electrodes. Further, only tell the trainees that there is a large number of electrodes of which the electrodes for the particular application have to be selected.

– no–load voltage or open–circuit voltage

Explain the term of no–load voltage or open–circuit voltage. In this connection, enter into particulars on labour safety.

• non–insulated electrode holder
• hazards when working in moist rooms and rooms of limited freedom to move or in pits.

– welding positions

Draw simplified blackboard sketches of the various welding positions (see Fig. 4). Ask one trainee to describe the positions briefly. Pay particular attention to this sub–section because it is of fundamental importance to the further sub–sections.

This also applies to the next terms, namely,

– joint (of the metals to be welded)
– form of groove
– type of weld seam.

At first give definitions of the terms and explain them. The proceed as follows.

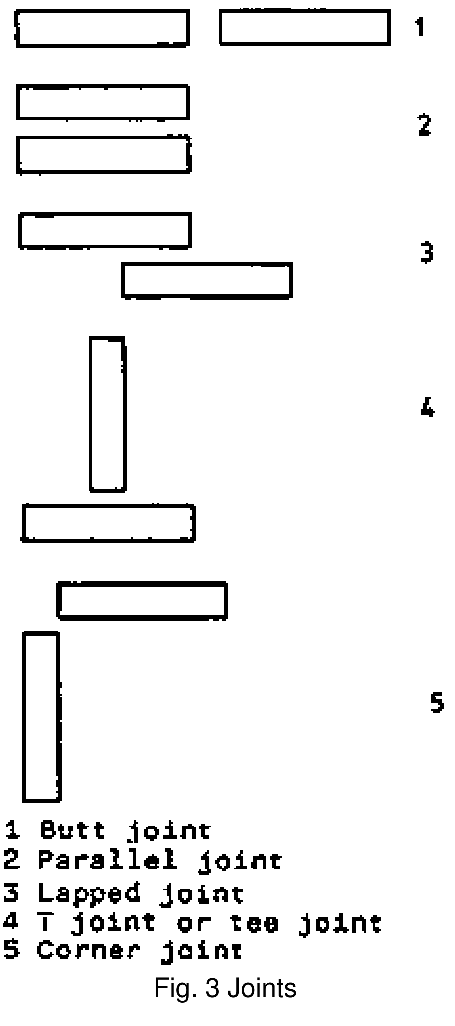
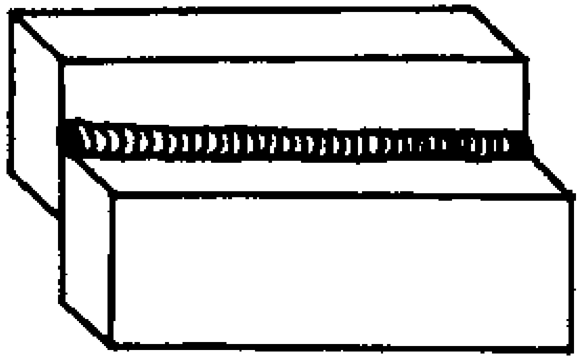


Fig. 3 Joints

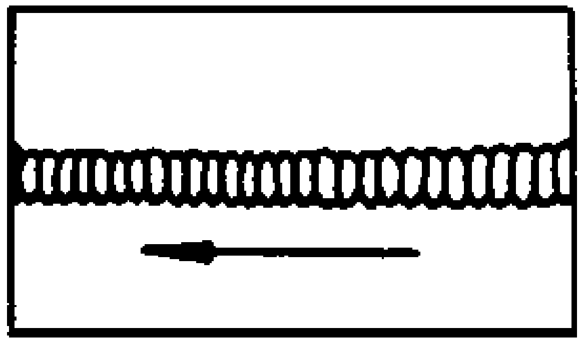
Draw a blackboard sketch of Fig, 3. Coordinate the joint with the relevant weld. Repeat the position of the parts to be welded relative to each other. Pay attention to the fact that the trainees use the correct name for the various joints of the metals to be welded.

Fig. 4 Welding positions

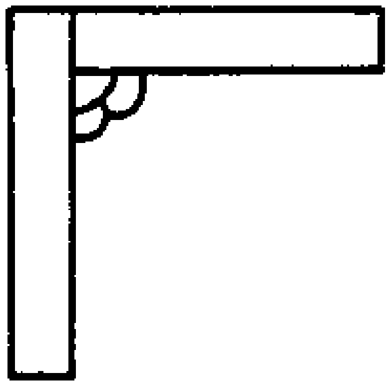
1 "g" – position = gravity or boat–form position



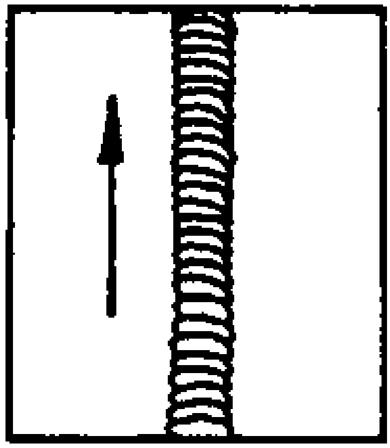
2 "h" – position = horizontal position



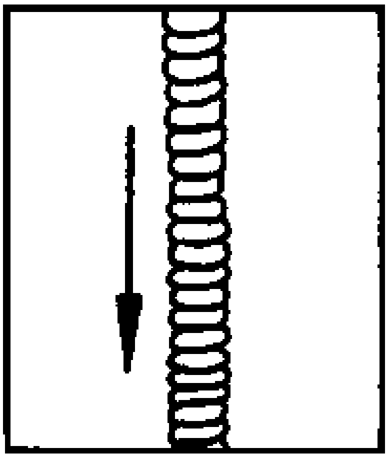
3 "c" – position = cross or transverse position



4 "o" – position = overhead position



5 "v" – position = vertical position



6 "v–d"–position = vertical–down position

5. General Labour Safety

This Section must play a special role in the practical training of electric welding. Preservation of health of the trainees must be the highest maxim in training.

Just in electric welding there are many hazards. Therefore, everything depends on familiarising the trainees with the regulations of labour safety for this method of welding in such a manner that they always bear them in mind and proceed accordingly. Experience has shown that the trainees grow weary when prohibitions and hints are merely enumerated. Their attention will be distracted. Therefore, you should set great store by their active cooperation. Induce the trainees to think over the labour safety regulations and their particular importance by putting relevant questions.

Show illustrations of accidents and describe the consequences of accidents which were due to the non–observance of the relevant regulations of labour safety.

Before the beginning of <u>any</u> practical training, question the trainees about their knowledge of labour safety regulations. Request the trainees to learn the content of these regulations by heart.

During training take care that the relevant regulations of labour safety are strictly observed. Negligence should be discussed with all trainees. Blame trainees for the non–observance of regulations and praise those trainees who pay attention to these regulations and observe them consciously. You should make it a rule to see to it that <u>not</u> a single trainee will weld with incomplete weldor's wearing apparel, defective weldor's screen and defective equipment and tools. In your explanations, place particular emphasis on the following items:

– hazards due to ultraviolet rays, infrared rays, light and heat radiation of the arc
– hazards due to electrical current
– hazards due to gases and weld smoke
– hazards due to fire
– general hazards

  • dalliance and teasing at the working place
  • wearing of rings, watches, neck–laces, etc.
  • leaving welding specimens without supervision, etc.

After having repeated the most important subjects of labour protection, enter into detail on fire protection. Items of particular interest in this respect are:

– fires which can be caused by. the arc

  • spatters flung about (sparks thrown off)
  • slag
  • the electrical current
  • combustible gases and liquids

Inform the trainees of their duty they have to perform when fire breaks out.

Ask the trainees to confirm your instruction about labour safety and fire protection by their signature in a special booklet.

After the your labour safety instructions, which have to take place regularly, you should exercise such an influence on the trainees that they readily pay attention to the observance of the labour safety regulations.

In this connection, pay attention to the following items:

– observance of the labour safety regulations at the own working place,

– drawing the attention of other trainees to possible and concrete hazards that may exist in the scope of responsibility of the latter and of other workers,

– active participation in the removal of hazards, purposeful acquisition of knowledge of health and labour safety and fire protection.

Emphasise the importance of labour safety, using concrete examples of practice. Enter into particulars on the conditions given in the enterprise in question.

Inform the trainees of the ways and possibilities of avoiding industrial accidents.

– Use of weldor's protective clothing, firm shoes, protective helmets, weldor's screen, weldor's gloves, leather apron

– Appearing at the working place in a considerate and not playful attitude

– Working attentively and in a concentrated manner

– Proper and correct use of the specified means of work and accessories

– Execution of the work in accordance with the rules of good workmanship

Always bear in mind that, especially in electric welding, great dangers of accident are involved when the labour safety regulations are not observed. Again and again point out this fact to the trainees.

6. Welding of Single Beads "g"

Explain to the trainees that the welding of single beads forms the basis of all further welding exercises. Bear in mind that the trainees will get into touch with the arc welding process for the first and, therefore, prepare particularly carefully for these sections.

Define the term of "single bead".

Demonstrate all operations involved in single bead welding properly and precisely. Continuously direct the trainees during their exercises and give them the required assistance. Observe the trainees during their exercises closely and correct their errors immediately. Analyse and discuss the errors occurring with <u>all</u> trainees.

6.1. Preparing the Exercise Plates

Tell the trainees the dimensions of the required exercise plates and their condition.

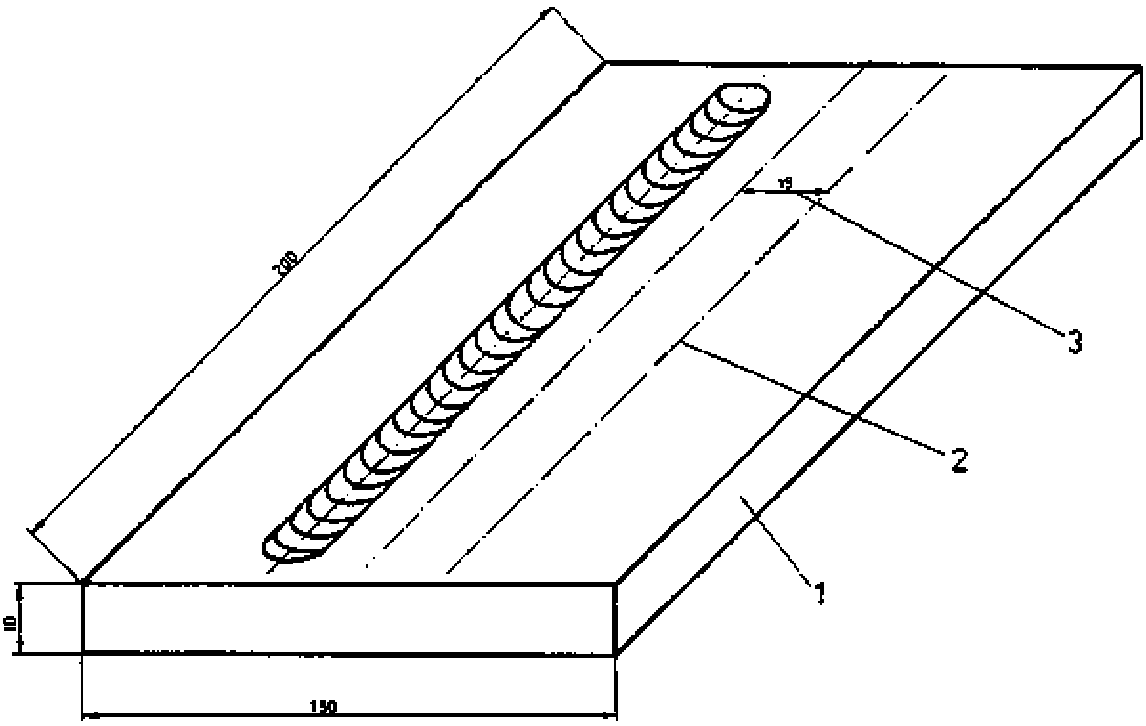
– Welding sample plates are used in the dimension of 200 x 150 mm, 10 to 12 mm in thickness.
– They must be plain and have a clean surface.
– The contour in the specified dimensions is obtained by gas cutting or by shear cutting.

Show a welding sample sheet or plate having an irregular surface with direct accumulation and show how it is straightened and cleaned.

Point out that pores can be formed in the material to be welded when the welding sample plate has not been cleaned in order to remove oil, grease, paint or rust.

– The formation of pores is a decrease in quality.

Place the plane and cleaned plate in front of you in such a manner that the longer side is parallel to you and draw a chalk line across the centre of the plate.



1 Plate
2 Chalk line
3 About 10 to 15 mm

Fig. 5 Welding, sample plate

Now, allow the trainees to prepare their welding sample plates!

6.2. Welding of the Single Beads

For the welding of single beads, have used the electrode E 43 RR (B) with a core wire diameter of 4 ram, 450 mm in length. Now, initiate the trainees with the setting of the current intensity.

Repeat the items upon which the setting of the current intensity is dependent:

– core diameter
– coat thickness of the electrode
– welding position
– form of weld
– pass which is to be welded
– thickness of the material

Explain the setting of the current intensity to the trainees according to the following rule of thumb.

(Explanation: <u>m</u> = medium–thick, <u>t</u> = thin and <u>v</u> = very thick)

– For electrodes with <u>m</u>edium–thick coat <u>40 A per mm of core diameter</u>

– For electrodes with a thin coat, 50 to 50 A are subtracted from the current intensity determined according to the above rule

– For electrodes with a very thick coat, 30 to 50 A must be added to the current intensity determined

Ask the trainees which current intensity is to be set:

– core diameter = 4 mm
– electrode provided with medium–thick coat

Tell the trainees that the correct setting of the current intensity largely depends on the experience of the weldor. Therefore, the current intensity must always be set while considering the arc.

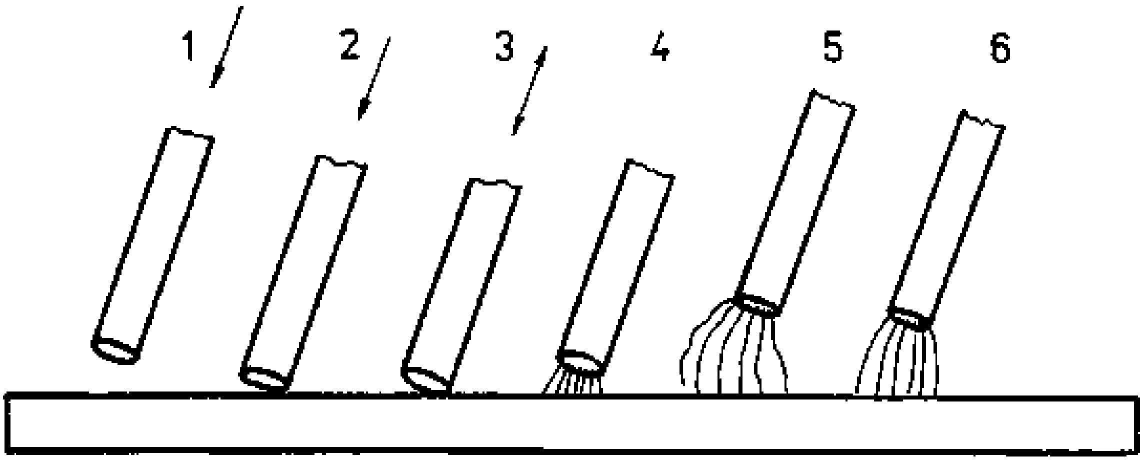
Now, explain the sequence of operations involved in the welding of single beads!

Igniting and maintaining the arc

Demonstrate which operations have to be performed before welding.

– Clamping the electrode in the electrode holder (welding pliers) and connection of the cable with the negative (–) pole of the welding current source.

– Fastening of the earth clamp to the welding table and connection of the cable with the positive (+) pole of the welding current source.



1 Touching the electrode end to the material to be welded
2 Touching the electrode end to the material to be welded
3 Touching and raising the electrode
4 Arc is too short
5 Arc is too long
6 Correct length of arc

Fig. 6 Igniting and maintaining the arc

Information about labour safety

Order the trainees to observe the following remark regarding labour safety.

To avoid an electrical accident, the welding current source is switched on as the last operation!

Enter into particulars on the consequences of the non–observance of this instruction.

Inform the trainees that the length of the arc can also be calculated on the basis of a rule of thumb.

– Up to an electrode thickness of 5 mm, the arc length is equal to the core diameter.

– With an electrode thickness of more than 5 mm, the arc remains constantly 5 mm.

Explain how the arc is ignited and maintained. Point out that this process is not always without a hitch. During the first trials it may occur that, when igniting, the electrode sticks to the workpiece.

Explain and demonstrate how to react to the sticking. Again give information about labour protection.

Electrode position

Describe how – after the igniting of the arc – the electrode must be brought into a certain positions.

– In transverse direction, it must form an angle of 90° with the workpiece while in longitudinal direction the angle between electrode and workpiece should be 70°.

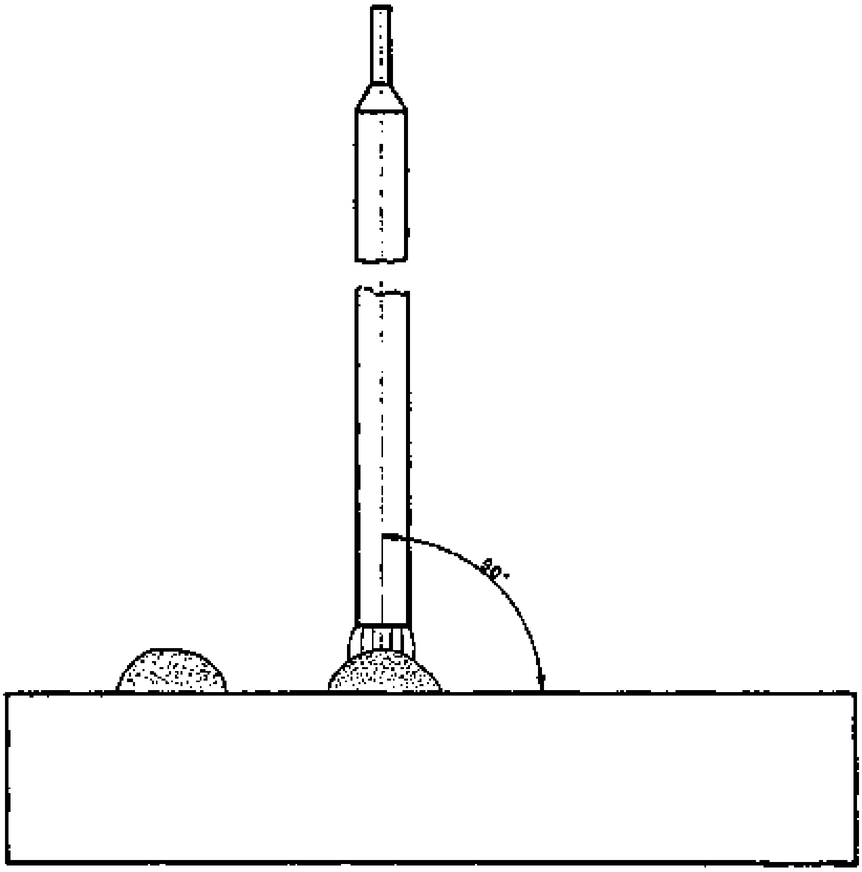


Fig. 7 Electrode position in transverse direction

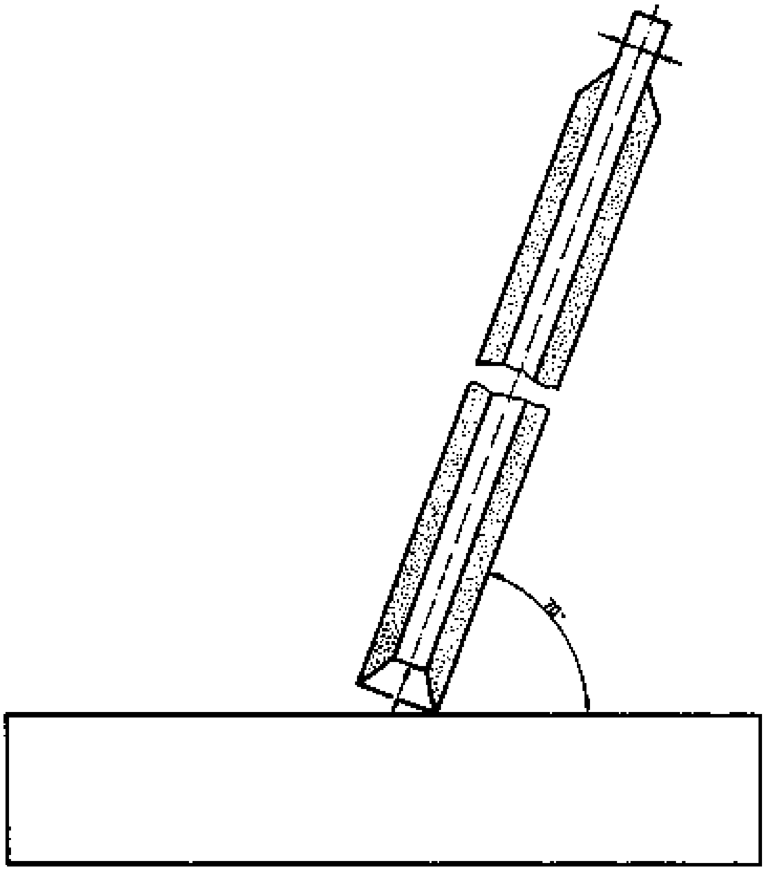


Fig. 8 Electrode position in longitudinal direction

Welding the bead

Now demonstrate the process of welding single beads. Take care that, before welding single beads, the deslagging hammer, wire brush and electrodes must be kept in readiness.

Point out the following items to the trainees:

- For welding single beads, the welding direction is from the left to the right.

- At the end of the chalk line, the electrode is kept stationary at the spot for a moment in order to fill up the end crater.

- Then the electrode is withdrawn in the direction of the already welded bead for about 10 mm and suddenly lifted and, thus, the arc interrupted.

- The bead height should be about 5 mm and the width of the bead about 10 mm

- In order to achieve the desired width, the electrode must be moved in a staggered manner.

- During welding, the arc must be observed in order to be in a position to distinguish between the fusing material and the liquid slag. (The colour of the parent material is always darker than that of the slag.)

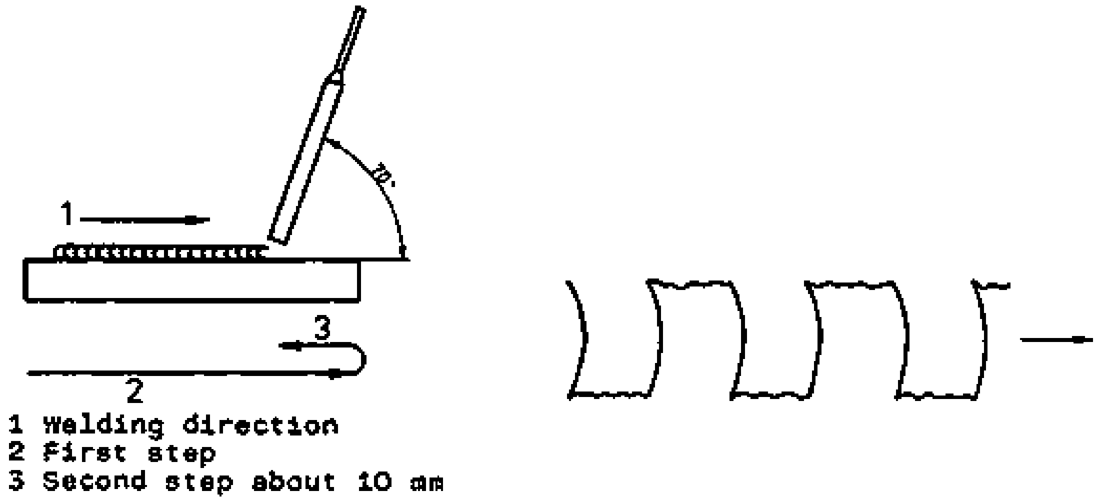


Fig. 9 Sequence of steps in electrode motion

Now show the welding sample plate finish−welded

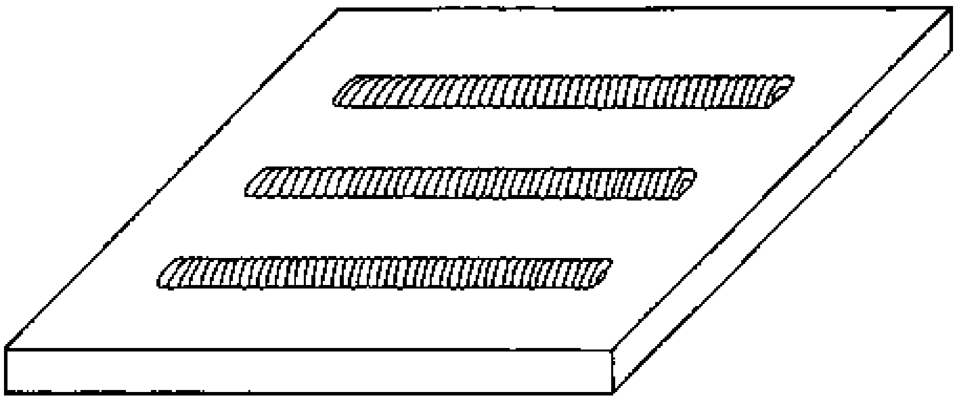


Fig. 10 Welding sample plate finish−welded

<u>Blow effect and corrective measures</u>

In summarising the above instructions point out that the position of the arc, the oscillating motion and guidance of the electrode are of decisive importance to the appearance of the single bead.

To this it should be added that these factors alone do not decide the issue because the <u>blow effect must also be controlled.</u>

Repeat the origin of the blow effect.

Demonstrate how to counteract the blow effect.

After the trainees have welded the beads, ask them to remove slag and weld spatters and carefully clean the surface of the plate.

Then the welding samples can be judged.

<u>Instructions for labour safety</u> Take care that protective goggles, are worn for cleaning the welding sample plates. Before cleaning the plates must be allowed to cool down!

For illustration, keep in readiness a sufficient number of weld samples or welded specimens.

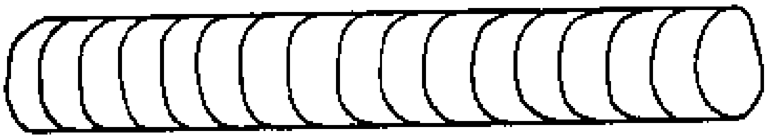
<u>Evaluation of the surface of single beads</u>

Disclose the evaluation directions for an optical assessment.

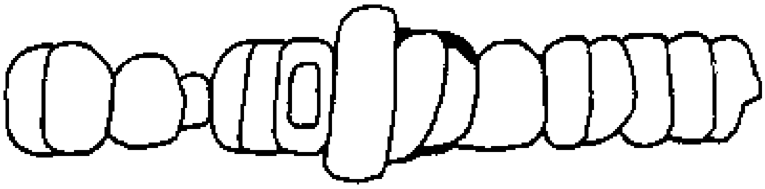
– Uniformity of the height and width of the beads
– Straightness of the beads
– Formation of ripple
– Cleanliness of the weld sample (weld spatters and particles of slag removed).

Show welded specimens which you should have kept in readiness and explain the faults involved.

Fig. 11 Welded specimens



1 Good single bead



2 Welded bead with weld defects

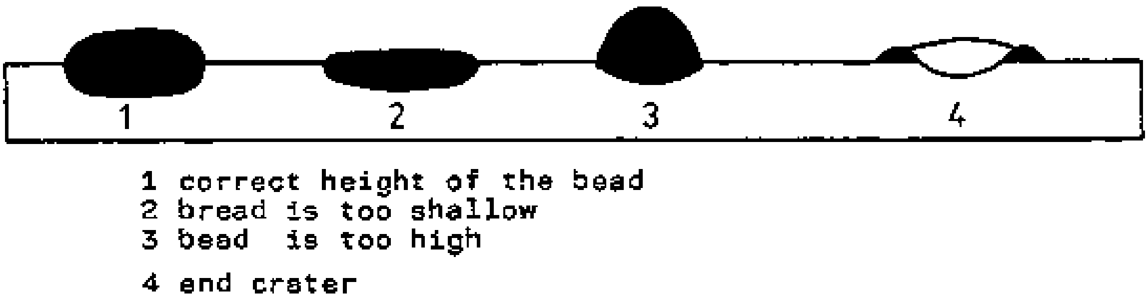


Fig. 12 Welded specimen (cross–section of the bead)

Causes of weld defects

Once more allow the trainees to have a lock at the welded specimens including defects and then give them the respective leaflet.

Subsequently, allow the trainees to exercise the welding of single beads.

Remove the defects together with the trainees. Take care that the trainees observe discipline, order and tidiness at the working place.

Help the trainees by individual demonstrations or by guiding their hands to achieve the require partial aim of training!

Again and again point out to the trainees that they have to use sparingly both basic materials and filler metals. If typical welding errors occur in exercising, analyse and discuss them in the collective.

Evaluation of the Section "Welding of Single Beads – g –"

With the conclusion of the above Section, the trainees should have acquired the following knowledge, abilities and skills:

– observance of the relevant labour safety regulations and order and tidiness at the working place
– preparation of the welding sample plates
– selection of the electrodes and setting the welding current intensity
– igniting the arc
– maintaining the length of the arc
– moving the electrode for welding single beads

– measures for neutralising the blow effect of the arc
– optical control and judgement of the welded specimen
– identification for weld defects

Examples of questions and problems for the Section "Welding of Single Beads – g –"

1. Outline the operations for preparing the welding of single beads!
2. Quote the rules of thumb for setting the welding current intensity and the length of arc!
3. Explain the operation of igniting and maintaining the arc!
4. Which are the corrective measures for counteracting the blow effect of the arc?

7. Building–up Welding "g"

Explain the use of building–up welding in horizontal position to the trainees.

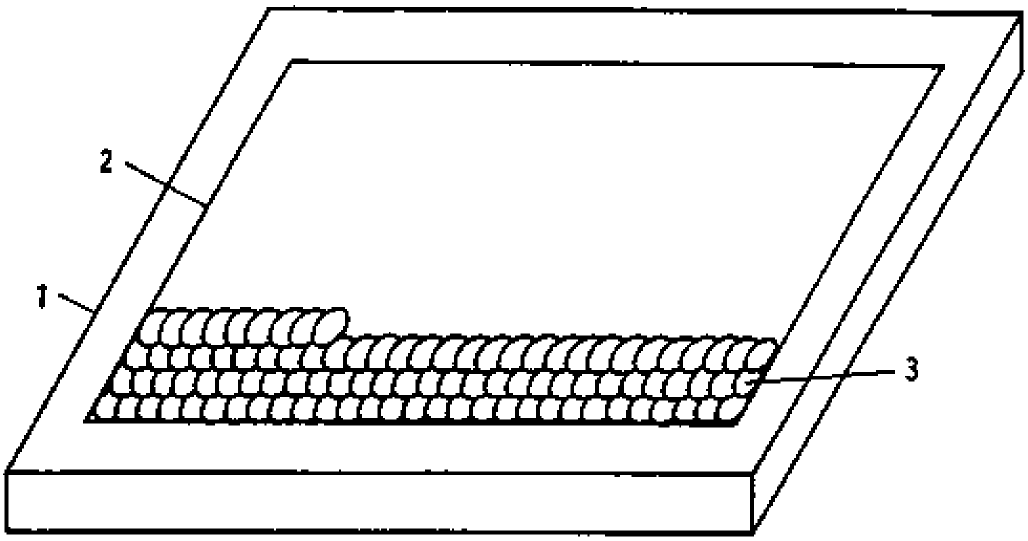
Define the term of building–up welding which is also known as surface welding. Compare the process of building–up welding with the process of welding single beads.

Tell the trainees the welding electrodes to be used. In this connection establish the link to theoretical lessons. Repeat the designation of electrodes and show them to the trainees. Indicate the welding current intensity.

7.1. Preparing the Exercise Plates

Tell the trainees the condition and dimensions of the plates to be used for the exercises?

– The plate used has the dimensions of 80 x 100 mm, 10 to 12 mm in thickness (see Fig. 13),
– The exercise plate must be plane and have a clean surface.



1 Exercise plate
2 Contour of the area to be welded
3 Weld beads

Fig. 13 Building–up welding in horizontal position

The trainees should take a mental note of the following rule.

Successful building–up welding calls for metallically clean plate surfaces!

Show a plate with an irregular surface which is not clean and show how it is straightened and cleaned.

The plate surface must be cleaned with a wire brush to remove rust, scale, remains of paint, oil and grease, Grinding over may be required.

Check the preparation of the exercise plates!

7.2. Welding a Surfacing Weld

- An area of 60 x 80 mm is to be welded.
- The height of the seam should be 3 to 4 mm.

Draw the contour of the area to be welded, having the dimension of 60 x 80 mm, on the exercise plate by means of chalk or a lead pencil.

Ask the trainees to draw the above contour on their exercise plates. Check this operation, measure the contour and do not allow any deviation from the specified dimensions!

Now demonstrate the execution of the building−up welding.

Place the exercise plate in front of you in such a manner that it is parallel to you. Point out the following steps in operation to the trainees:

- Setting the current intensity to about 160 A

- Igniting the arc on the upper left border of the drawn line. Welding is from the left to the right.

- Maintain the length of the arc at about 4 mm. The electrode is not oscillated but draw straight ahead, taking into consideration that, for the first pass, the electrode must form an angle of 90 with the plate.

- When the right−hand border of the marked area has been reached with the electrode, the arc is shortened in order that the end crater will be filled well.

Pay particular attention to the counteracting to the blow effect. Experience has shown that this item of training presents great difficulties to the trainees.

- For the following weld bead, the electrode should form an angle of 70° with the horizontal surface of the work−piece.

- It should be borne in mind that the weld bead cover one third of the first pass.

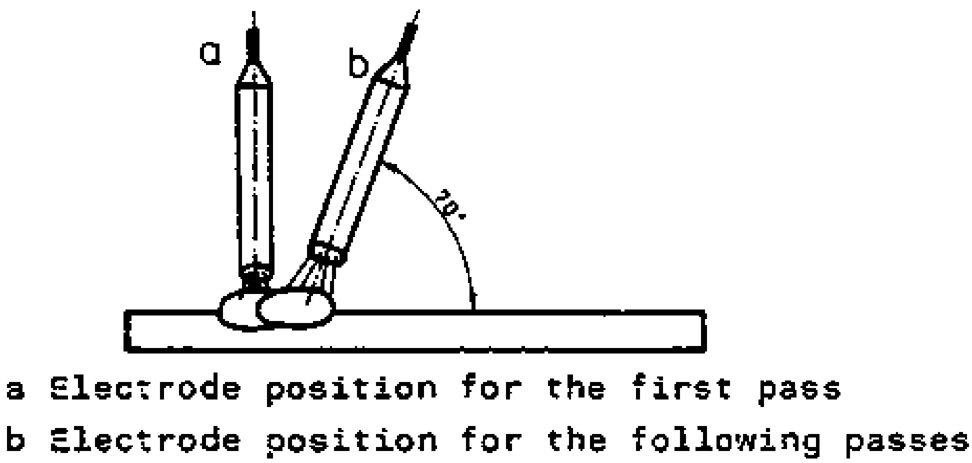


Fig. 14 Electrode position for building−up welding

In this way, a notch−free transition from the first to the second pass and the further passes is ensured.

- So−called filling of the end crater.

– Cleaning the seam and the plate to remove slag and spatters!

– The following passes have to be welded in the same way as the second weld has been welded until the area of 60 x SO mm has been completed.

– Removing slag and spatters from the plate.

Critical examination of the welded exercise plates – welding defects and their causes.

Give comments on the build–up weld together with the trainees. Tell the trainees the assessment criteria to be used! Give your comments on the appearance of the seam and the accuracy to size.

Appearance of the seam

– Straightness of the beads
– Uniformity of ripple
– Points of start
– End craters
– Undercuts
– Weld spatters
– Slag inclusions

Accuracy to size

– Control of the dimension of 60 x 80 mm
– Control of the height of seam

Discuss the weld seam defects and their causes also in this case with the trainees.

Evaluation of the Section "Building–up Welding "g"

With the conclusion of the Section "Building–up Welding – g –". the trainees should have acquired the following knowledge, abilities and skills:

– observance of the relevant labour safety regulations and order and tidiness at the working place
– preparation of the weld sample
– control of the process of building–up welding in "g"–position
– identification of typical welding defects in fillet welds
– assessment of their work

Examples of questions for the Section Building–up Welding "g"

1. Explain the term of "building–up welding" also know as surface welding!
2. What is the field of application of building–up welding?
3. What are the effects of dirty plate surfaces on the quality of the build–up weld?
4. Which measures are taken to prevent undercuts?

Electric Welding 2 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

Table of Contents

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0. Preliminary Remarks

The present Methodical Instructions have been developed for instructors in practical vocational training and serve to impart knowledge, abilities and skills in electric welding.

These Instructions will give help and assistance to the instructor in the preparation and realisation of practical vocational training. Ways of solution are suggested to the instructor; they enable the realisation the aim of training specified in the course of his pedagogic activities.

The Methodical Instructions are arranged in such a way that the trainees are in a position to acquire systematically

- fillet welding "h",
- corner–seam welding "h",
- V–seam welding "g".

Subjects of particular importance are the preparation of the plates, the selection of electrodes, and the various ways of moving the electrode as well as the assessment of and the commenting on the various welds involved.

The acquisition of the above weld seams and the welding positions in question is the continuation of the Instructions of electric welding 1. On the basis of the experiences gathered in the training of electric weldors, the sequence in the acquisition of the types of seams and the welding positions required for the production of them have been specified. Consequently, the mastering of welding of individual seams "g" and building−up welding "g" is the basis for the acquisition of the knowledge and skills for welding the seams and the execution of the work involved in the various welding positions specified in these Instructions. When the trainees have passed the examination, then they are entitled to weld

− fillet welds and corner welds in "h"−position and
− V−welds in "g"−position

in 3−mm plates.

1. Fillet Welding "h"

At the beginning, repeat the terms of fillet weld "h"−position, T−joint, parallel joint, edge fillet weld and side fillet weld.

− For fillet welds, a distinction is made between the weld thickness "a" (also known as seam thickness) and the weld height "a".

Draw a blackboard picture of Fig. 1 and explain the terms of seam thickness and seam height.

Also show the various cross−sections possible of fillet welds. Also draw sketches of the latter on the blackboard (see Fig. 2). According to the mass of filler metal used, a distinction is made between

• concave fillet weld, flat fillet weld and convex fillet weld.

Also enter into particular on the path of lines of force in the concave fillet weld and convex fillet weld. For this purpose, take advantage of Fig. 3.

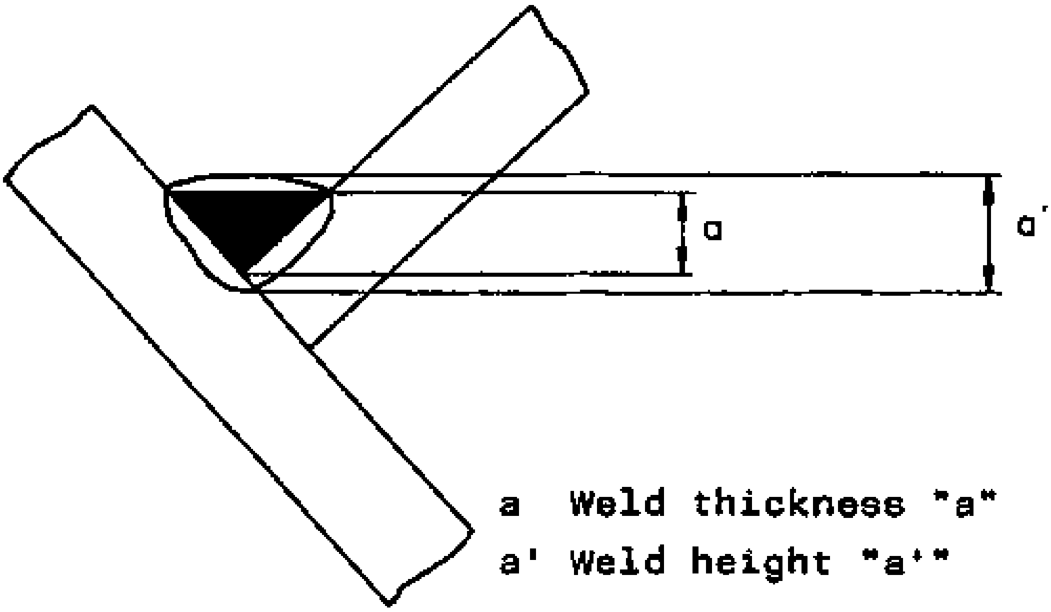
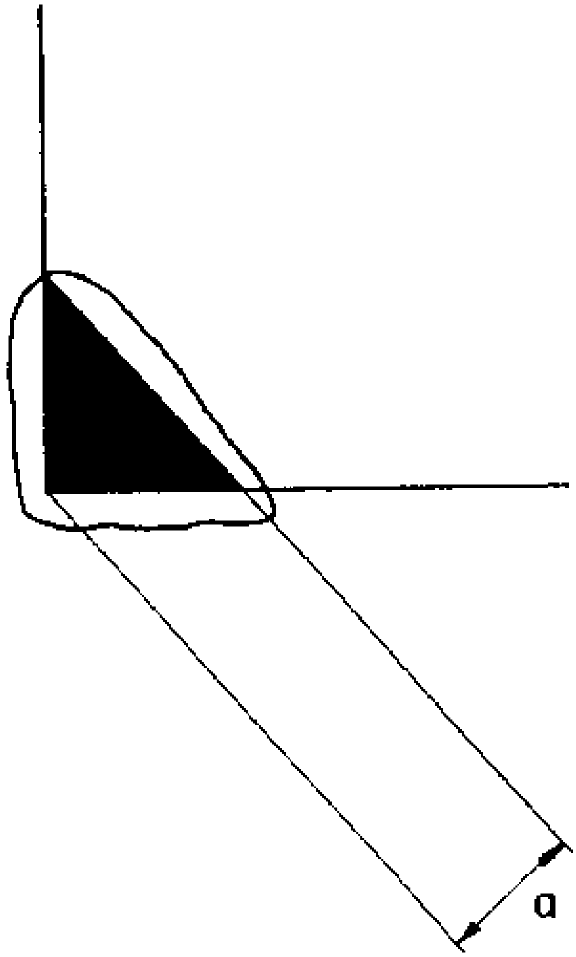
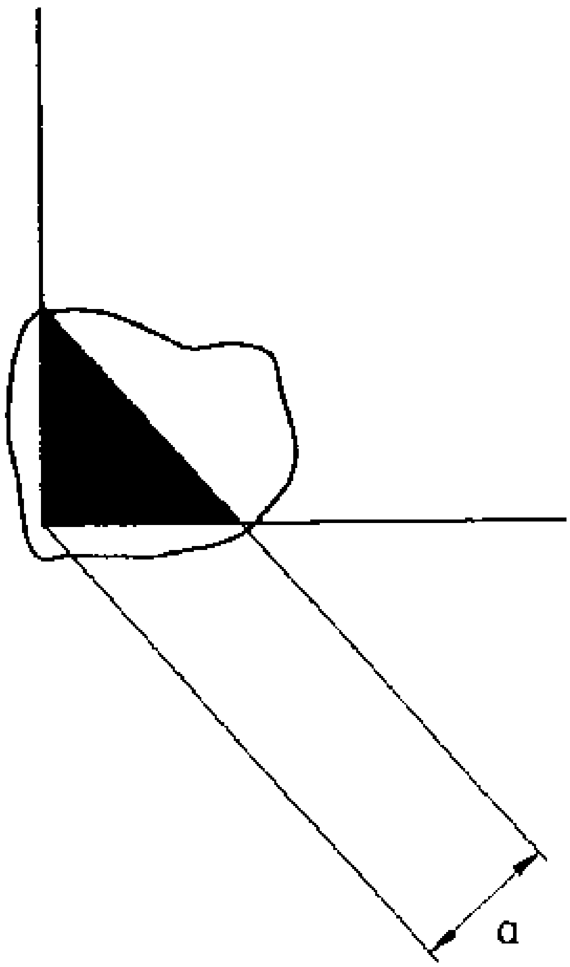


Fig. 1 Dimensions of the fillet weld

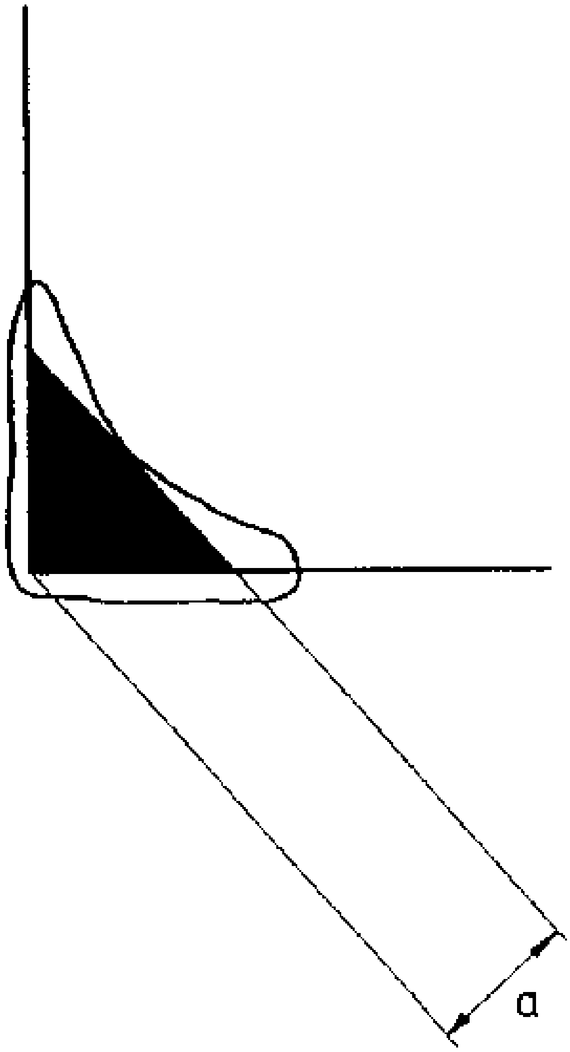
Fig. 2 Fillet welds in different forms



1 Flat weld



2 Concave weld



3 Convex weld

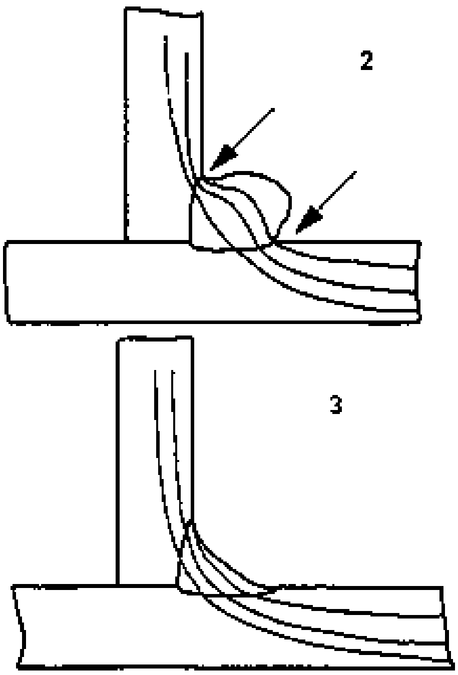


Fig. 3 Path of lines of force in the convex seam (2) and the concave seam (3)

1.1. Preparation of the Exercise Plates

Tell the trainees the dimensions of the plates. Enter into particulars on the state of the plates.

- One chord plate and one web plate of the dimensions 80 x 200, 10 to 12 mm thick, are used.
- They must be plane and have a clean surface.

Check the preparation of the exercise plates!

Again point out to the rule:

Successful welding calls for the preparation of clean and exact welding areas!

1.2. Tacking the Fillet Weld

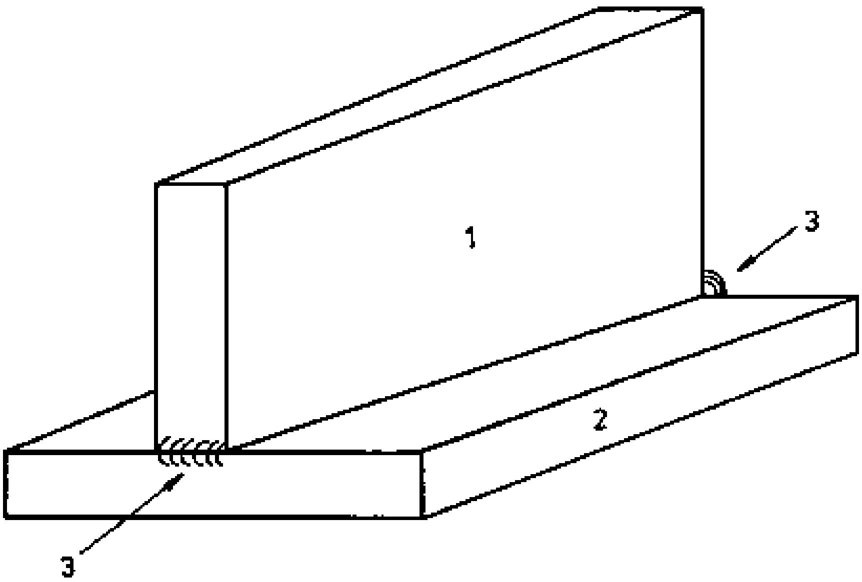
Demonstrate the assembling and tacking the parts forming the fillet weld. Again explain the steps involved:

- Place the web plate (1) on the chord plate (2) in the centre of the latter and fix the web plate by means of a C−clamp.

- Check that the two plates are fitted one upon another without forming a gap by holding the fixed T−joint against the light.

When there is a gap between web plate and chord plate, slag will penetrate into it when the root is welded so that welding defects will be caused.

- If necessary, the plates must be adjusted by pressure or grinding.



1 Web plate, 2 Chord plate, 3 Ends of the T−joint

Fig. 4 Fillet weld tacked

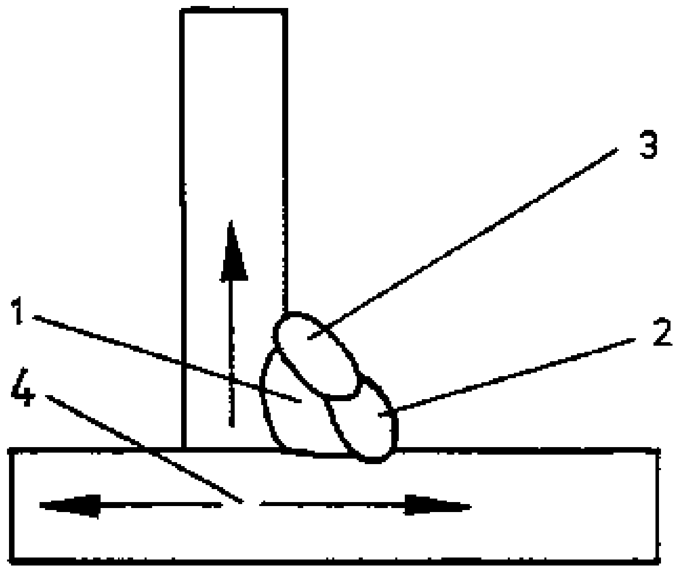
Now, demonstrate the tack welding.

- The ends (3) of the T−joint are tacked each by means of a string bead.
- The length of the tack weld should be equal to the thickness of the web plate.
- The C−clamp can be removed.
- The tack welds must be cleaned, i.e. slag and spatters must be removed by means of deslagging hammer and wire brush.

Check that the trainees properly tack the fillets.

1.3. Welding the Fillet

Give explanations to the trainees to the effect that, with plates having a thickness between 10 and 12 mm, a seam height "a" of 5 to 6 mm is required. Therefore, the welding of one root pass (1) and two cover passes (2) and (3) is necessary.



fillet seam "h"

1 Root pass
2/3 Cover passes
4 Heat dissipation

Fig. 5 Weld buildup of the fillet seam "h"

Before you demonstrate the welding of the root, point out to the trainees that, in fillet welds, the heat is dissipated to three directions (4).

1.3.1. Welding the Root Pass

Show the trainees how to weld the root pass.

Place the fillet on the welding table parallel to the viewing direction of them. Again indicate the steps involved in welding.

- Setting the current to 180 to 190 A.
- Igniting the arc at the left−hand end of the T−joint.
- Welding the root pass without oscillating motion in the form of a string bead while uniformly touching and retouching the work with the electrode.

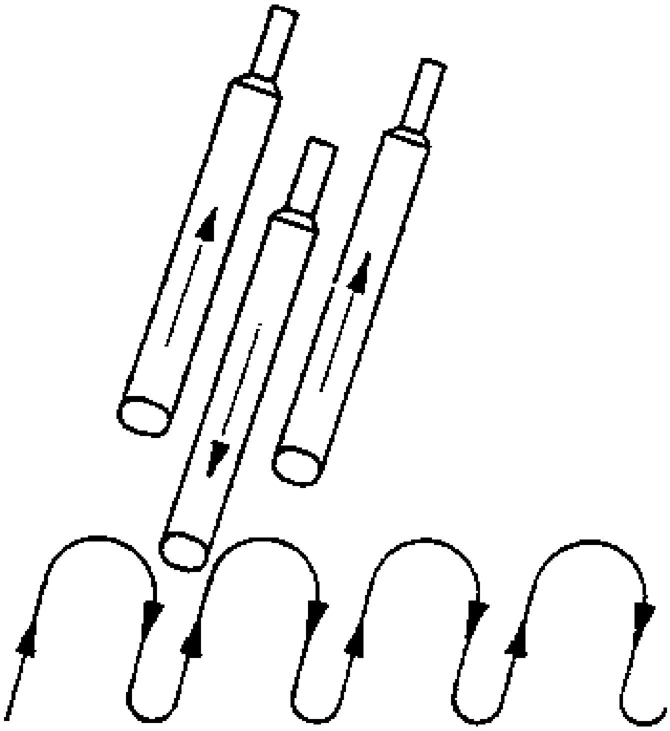


Fig. 6 Touching and retouching motions of the electrode for welding the root pass

The trainees should commit to their memory the following rule:

To ensure an isosceles weld buildup located in the centre, the electrode must be kept in such a manner that it forms an angle of exactly 45 with the chord plate and with the web plate.

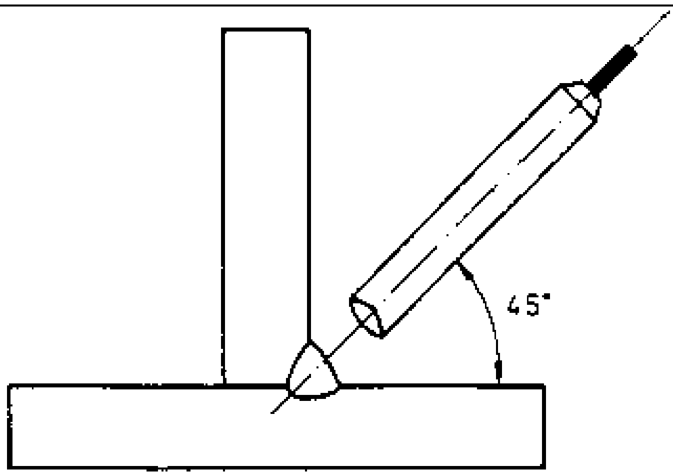


Fig. 7 Electrode position for fillet, horizontal, root pass

Inform the trainees of the consequences when the blow effect is not counteracted.

When the blow effect is not observed, such welding defects will be the cause as

- interrupted seam,
- slag inclusions,
- many spatters on the seam sides

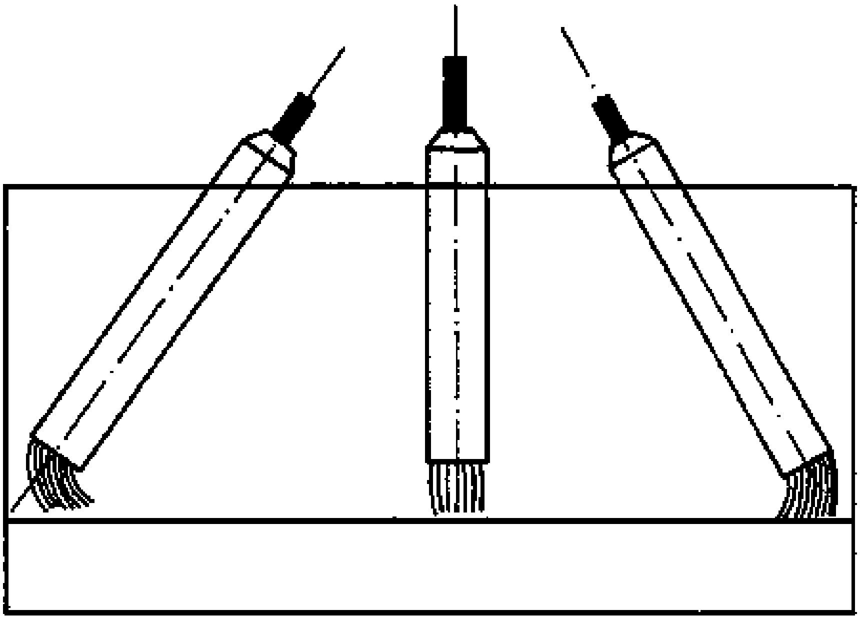


Fig. 8 Inclination of the electrode against the blow effect

– The end crater of the root pass must be filled properly.

When having finished the root welding, the fillet weld is carefully cleaned from slag and weld spatters.

Point out to the trainees that remains of slag and slag pockets cannot be removed by overwelding. Therefore, pay particular attention to the careful cleaning of the weld seams.

Check the root welded for proper central position of the root pass and welding defects such as pores, slag pockets and undercuts.

1.3.2. Welding the First Cover Pass

Demonstrate the first cover pass to the trainees.

Steps:

– Setting the current to 170 A.

– The first cover pass is deposited in the form of a string bead, performing slightly oscillating motions, so that it cover 2/3 of the root.

– The electrode must be kept so that it forms an angle 70° with the chord plate.

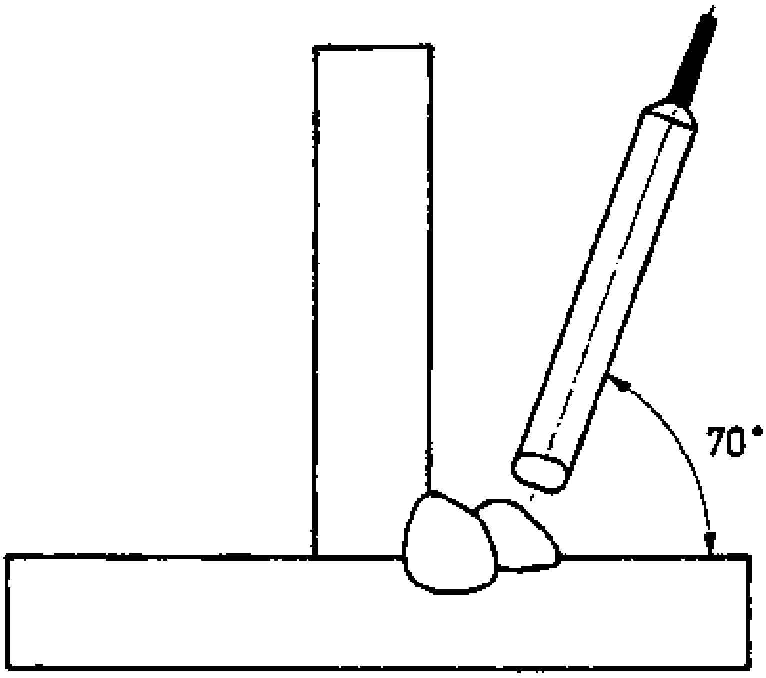


Fig. 9 Electrode position for fillet weld, horizontal, second pass

- The blow effect must be taken into account.
- The end crater must be filled properly.
- After welding, the weld must be checked for welding defects.

1.3.3. Welding the Second Cover Pass

Explain in an instructive talk why the second cover pass, that is the third pass of the fillet, must be welded with particular care. Instruct the trainees that the electrode must be kept at an angle of 60° formed with the web plate.

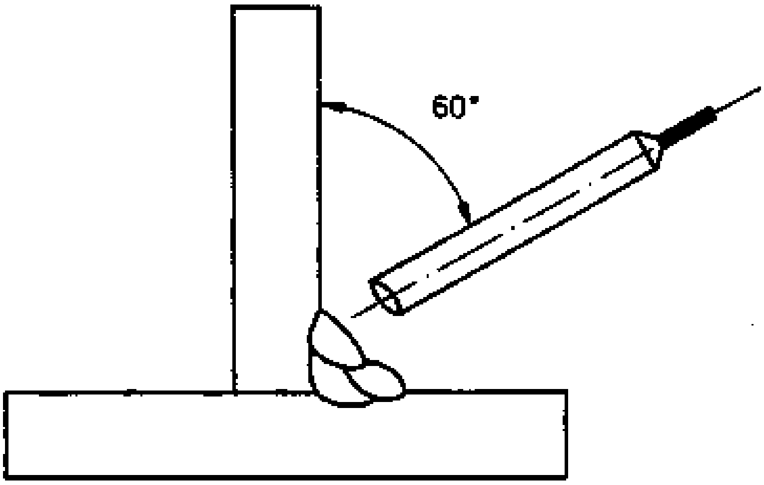
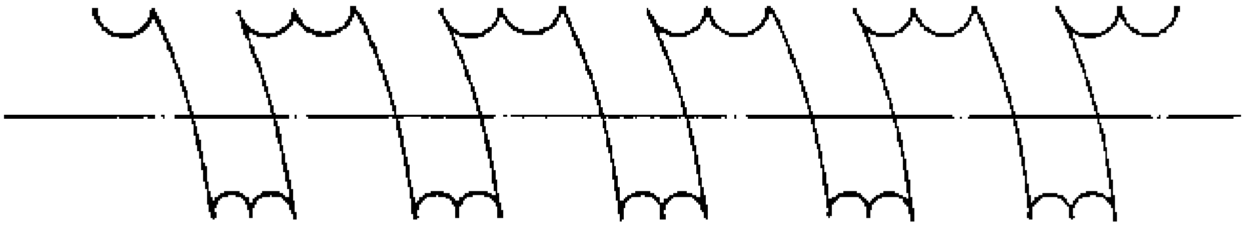
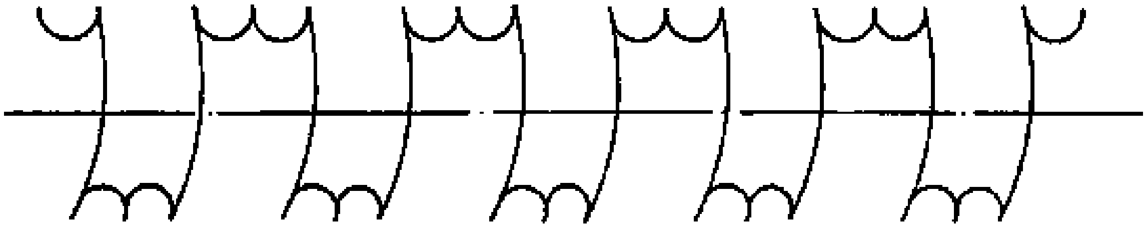


Fig. 10 Electrode position for fillet, horizontal, third pass

The trainees must pay particular attention to the fact that the line of the oscillating motion must be displaced, that is to say, the lower leg is drawn forth slightly while the upper leg of the seam is retained.

Fig. 11 Electrode motion in welding the second and third passes


3rd pass


2nd pass

– The arc must be kept very short at the web plate. The displacement mentioned above is necessary in order that the weld metal cannot run off from the upper edge but will get a hold by the drawing forth.

1.4. Assessment of the Welded Fillet – Welding Defects and Their Causes

Discuss the welded fillet together with the trainees in order to arrive at an opinion. Tell them the assessment criteria. The following items should be assessed by you

– the appearance of the weld,
– the accuracy to size,
– the appearance of the fracture.

– Appearance of the weld

• Symmetry of the weld buildup
• Uniformity of bead ripple
• Points of arc strike
• End craters
• Undercuts
• Weld spatter

– Accuracy to size

By means of a weld gauge, three points of measurement have to be determined.
Demonstrate the testing for accuracy to size. Ask a trainee to show the procedure once more.

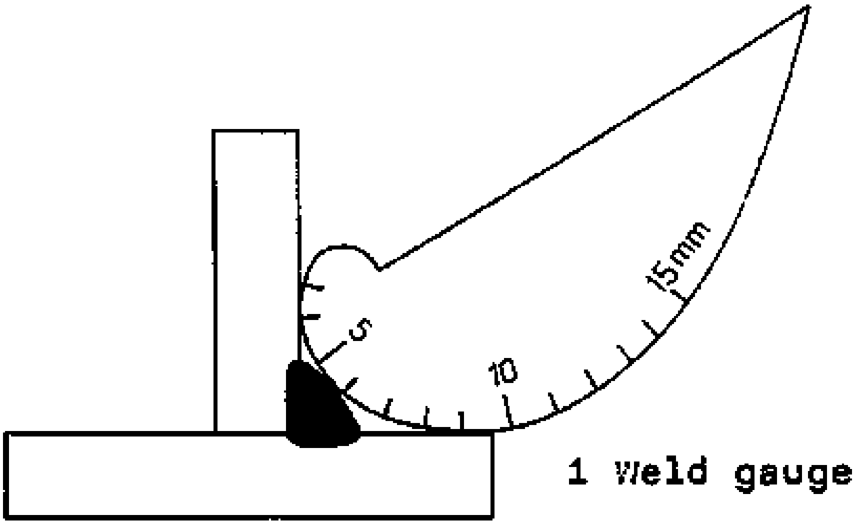


Fig. 12 Use of the weld gauge for the measurement of the height of fillets

Weld gauge (1) for the measurement of the fillet height. For fillet welds in "h" – position. a deviation of the weld height of + 1.0 and −0.5 is permissible.

– Appearance of the fracture

To be in a position to assess the appearance of the fracture, the fillet weld must be broken in a special device. For the purpose, the use of the following device is recommendable. Point out to the relevant labour protection regulations.

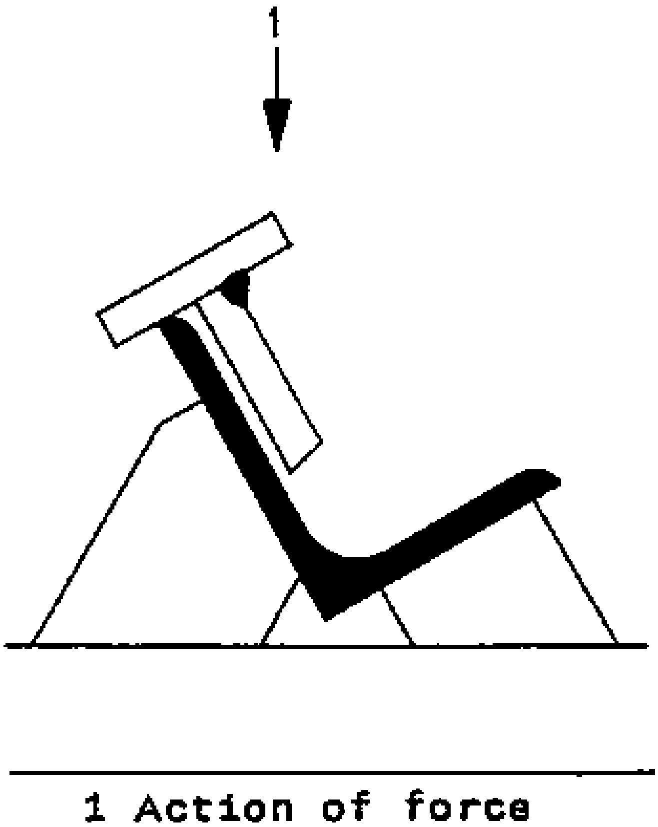


Fig. 13 Device for breaking the fillet weld

Criteria for the assessment of the appearance of fracture are:

- Fusing of the edge of the web plate
- Slag inclusions
- Pores
- Lack of fusion

Point out to welding defects. Discuss them together with the trainees. Compare properly welded workpieces with those showing welding defects.

Evaluation of the Section "Fillet Welding "h" "

With the conclusion of the exercise section "Fillet Welding "h" ", the trainees should have acquired the following knowledge, abilities and skills:

- observance of the relevant labour safety regulations and order and tidiness at the working place,
- preparation of the welding sample
- mastering the fillet welding in h–position,
- Identification of typical welding defects in fillet welds.
- Comments on their own work.

Examples of questions regarding the Section Fillet Welding "h"

1. Describe the buildup of a fillet to be welded in horizontal position!
2. Which design of a fillet is the most economical one?
3. How do you achieve sufficient root penetration in fillet welds?
4. How is the heat dissipation in fillet welding?

2. Corner Welding "h"

Repeat the terms and their definitions of corner weld and "h"–position by purposive questioning. Then tell the aim of this exercise Section. Pay particular attention to this Section because corner welding is the most important preliminary exercise for the V–joint welding.

Great store should be set by the mastering of the root welding.

2.1. Preparing the Exercise Plates

Tell the trainees the dimensions of the exercise plates and how their state must be.

- One chord plate and one web plate 80 × 200 mm in size and 6 to 12 mm thick are used.
- They must be plane and their surface must be clean.

Instruct the trainees that the plates must be prepared by flame cutting or by cutting by means of shears. Show a plate of an irregular and unclean surface and demonstrate how it is straightened and cleaned.

- The cutting edges of the plates must be free from scale, scores and other irregularities. Sometimes grinding is required.

Control the preparation of the exercise plates.

2.2. Tacking the Corner Joint

Demonstrate the assembling and tacking of the plates. Tell the trainees the steps involved.

- Plate (1) and plate (2) have to be arranged between two angle–steel profiles in such a way that the plates form an angle of 90°.

One or two electrode remains having a diameter of 3.25 mm must be placed between the edges of the plates where they contact each other.

- Exactly align the plates

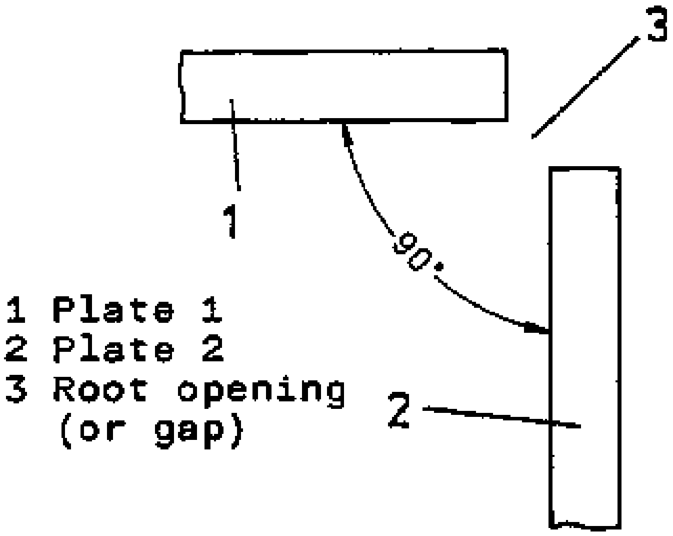


Fig. 14 Arrangement of the plates for tacking

– Tacking the plates on the back of an external seam end.
– Correcting the position of the plates relative to each other.
– Tacking the second seam end.

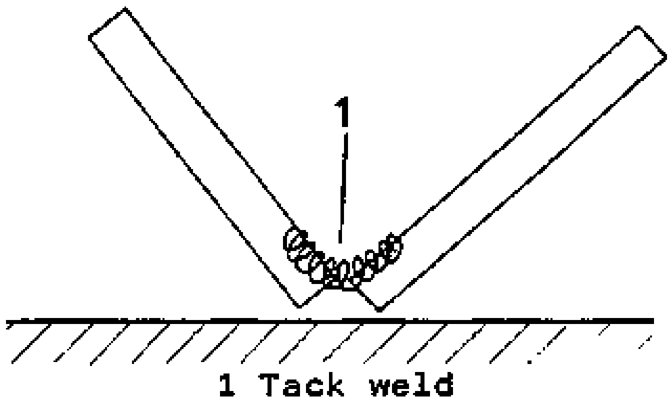


Fig. 15 Position of the tack weld immediately at the plate edge

The trainees should commit to their memory the following rule:

A successful root welding is dependent on the exactly observed root gap (3.25 mm).

2.3. Welding the Corner Seam

Familiarise the trainees with the weld buildup of a corner seam or corner weld.

– For a plate having a thickness of 10 mm, one root pass, five filler passes and four cover passes are executed. Depending on the individual electrode guidance, deviations from this number of passes are allowed.

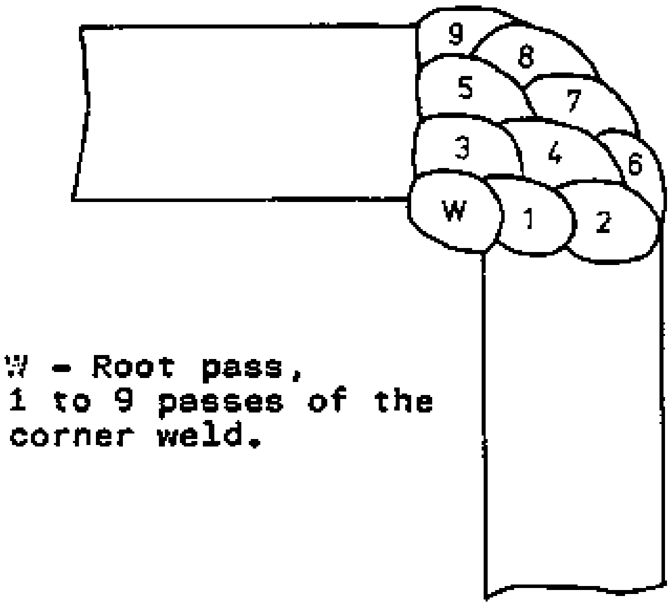


Fig. 16 Buildup of passes of a corner weld

2.3.1. Welding the Root Pass

Demonstrate the welding of the root to the trainees.

For this purpose, mount the fillet sample in a position stand in such a way that the horizontal welding position is ensured.

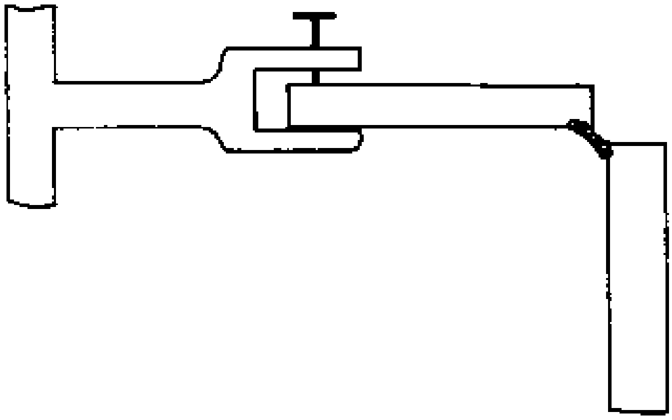


Fig. 17 Corner seam fastened in horizontal position in a position stand

Point out to the trainees that the welded root pass must be uniformly welded through. In this connection, enter into particulars on the special electrode movement.

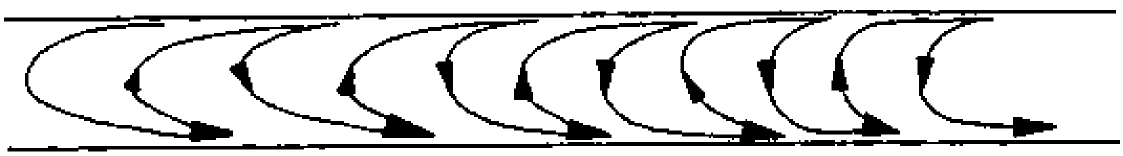


Fig. 18 a) Moving the electrode for the root welding

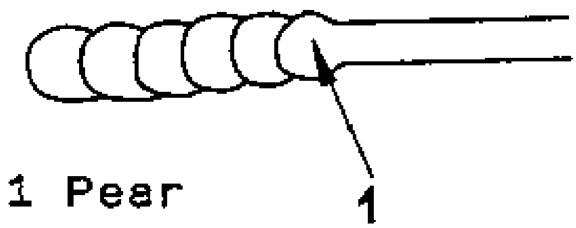


Fig. 18 b) Formation of the root with the pear

– The electrode is moved in an arc which is open in welding direction. The web edged must be fused adequately in order that lack of fusion at the seam sides are avoided.

This is achieved reliably when a "pear" is formed.

Quote the following rule for the trainees:

Long arc – much heat – ample penetration Short arc – little heat – poor penetration

In your demonstration and explanations, you should set great store by the heat conduction by the arc. The trainees must master the arc heat conduction.

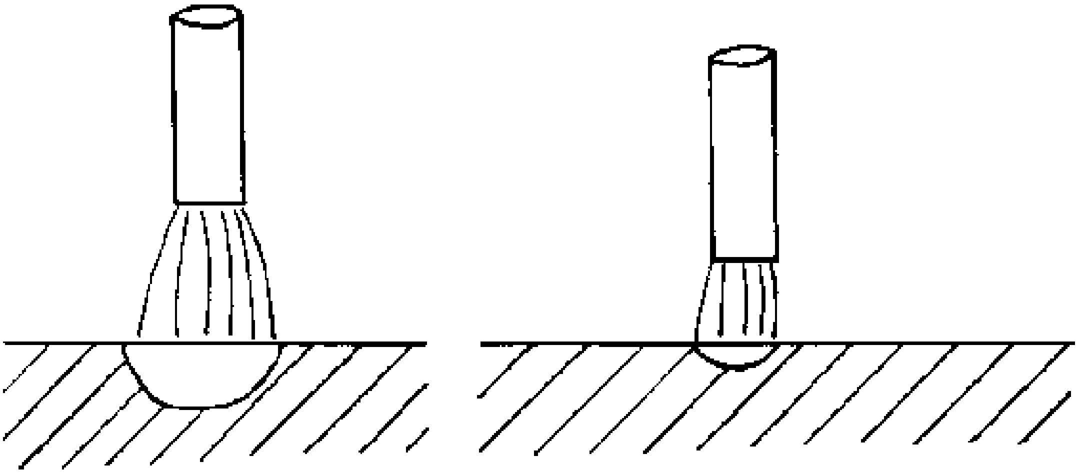


Fig. 19 Heating the plate by differently long arcs

Explain to the trainees how the heat input to the seam sides and the penetration effect obtained in this way can be controlled by the welding speed. Quote the following rule for the trainees:

Small molten pool (pear closes) – Low welding speed – Moving the electrode in a small arc or curve with a long electric arc large molten pool (pear becomes too large, weld metal runs throught) – High welding speed – Moving the electrode in a large curve with short electric arc

Point out to the trainees that a uniform root formation is achieved by continuously changing the length of the arc and the welding speed in accordance with the requirements.

Weld the entire length of the root from the left to the right.

Draw the trainee's attention to the fact that the root gap becomes smaller and smaller with progressing welding operation towards the seam end.

This phenomenon is due to the expansion and shrinkage of the exercise plate.

Explain to the trainees that heated material zones considerably expand.

For this purpose, allow the trainees to measure a workpiece before and after heating.

– To ensure a uniform root fusion, a constant root gap is required. This is achieved in the following way: at first 30 mm of the root are welded from the right to the left and then the remaining root is welded from the left: to the right.

Pay attention to the correct execution of the further steps of the work.

– When the two root sections meet, one must allow the electrode to dwell for a moment with a short arc without moving it.

– It may be necessary to change the electrode several times because the length of extension of one electrode will not suffice for the length of the root.

Demonstrate the electrode change. The trainees should make a mental note of the following steps:

1. When the electrode comes to an end, enlarge the arc length in order to obtain a large pear.

2. With the new electrode, start about 10 mm in front of the pear on the root and move the electrode into the pear, and allow the arc to burn long enough inside the pear. Then continue to move the electrode in the manner required for the root welding.

Due to this measure, defective place in the root pass are avoided and a uniform root formation is ensured.

Show how the root pass is properly cleaned. Flaws due to starting points in the seam side area must be removed by means of a chisel. Summarise the moist important items of the welding of roots.

2.3.2. Welding the Filler Passes

Demonstrate the welding of the filler passes.

– The filler passes are executed as string beads without oscillating motions.

Ask the trainees to adjust the current to 140 to 170 A. Explain to the trainees that this increased current intensity is necessary in order to obtain a sufficiently deep penetration and to flush the slag out of the molten pool.

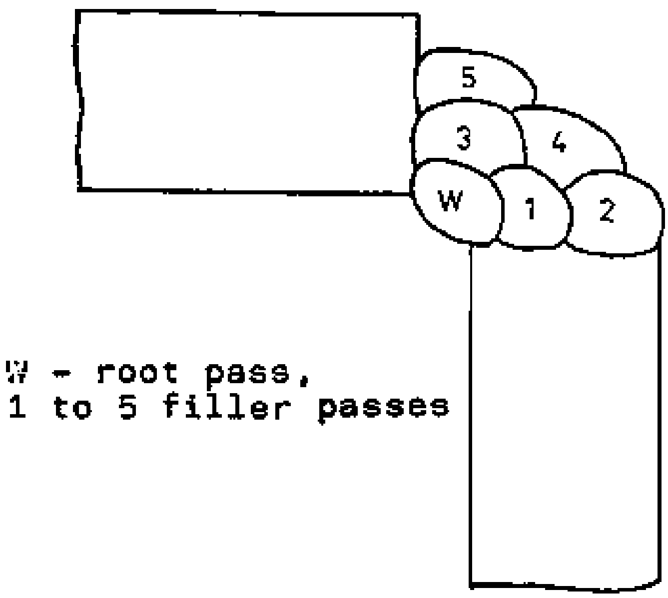


Fig. 20 Buildup of the filler passes

In welding the filler passes, the blow effect of the arc is considerable. Intense spatter and unclean appearance of the seam are the consequences.

During the exercising, pay attention to the fact that the trainees oppose this effect by an adequate inclination of the electrode.

Quote the following rule to the trainees:

> At the beginning of the seam, the electrode must be inclined in the welding direction.
>
> In the centre of the seam, the electrode must be kept steeper.
>
> In the range of the last third of the seam, the electrode must be inclined opposite to the welding direction.

Now start demonstrating the welding of the filler passes.

– Filler passes 1 and 2 are welded on the face of the vertical plate.

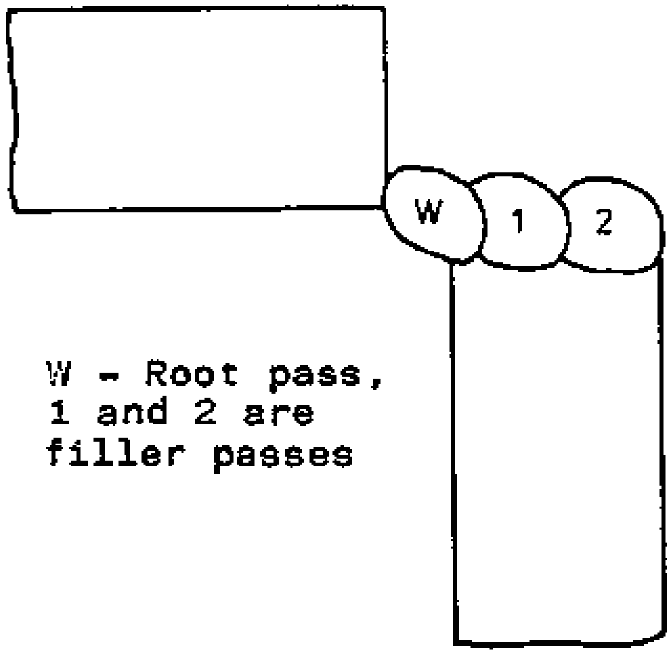


Fig. 21 Arrangement of the filler passes 1 and 2

– Point out to the trainees that the filler pass number 2 properly covers the plate edge of the vertical plate, and

– that, in the event of a change of electrodes, the end crater is properly fused by means of a long arc.

After every filler pass, slag and spatters must be properly removed from the seam.

2.3.3. Welding the Cover Passes

Demonstrate the welding of the cover passes. Explain the following to the trainees:

– The cover passes are executed as string beads without oscillating motion.
– The current is adjusted to anything between 120 and 140 A.
– The blow effect is counteracted by the same working technique as in welding the filler passes.

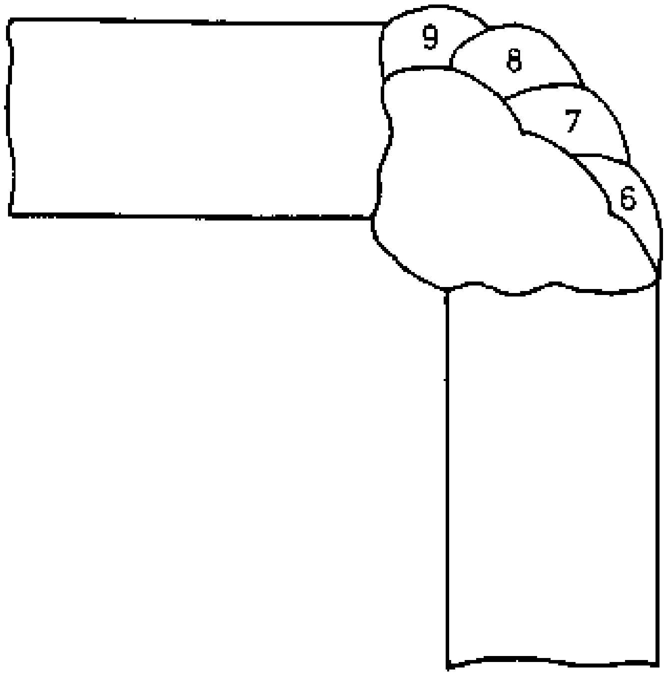


Fig. 22 Arrangement of the cover passes

In general, four cover passes will suffice.

Point out to the trainees the items to be observed in welding the cover passes:

– The first string bead on the upright plate must properly cover the edge of the seam. Undercuts must not form.

– The next string bead must cover 1/3 of the first string bead. The formation of undercuts is avoided when keeping the arc short.

– After any string bead, the seam must be carefully cleaned, especially slag and spatters must be removed. The last string bead should be executed particularly carefully because it must cover properly the edge of the plate in horizontal position. Undercuts must not be formed in this bead, too.

When having finished the cover pass welding, the corner weld is cooled in cold water and cleaned by means of a wire brush.

2.4. Assessment of the Welded Corner

Give comments on the welded corner seam together with the trainees. Tell them the assessment criteria. The following items should be assessed by you.

<u>Appearance of the seam</u>

– Symmetry of the weld buildup
– Uniformity of the cover pass buildup
– Uniformity of the root sag (maximum 3 mm)
– Points of arc strike
– End craters
– Undercuts
– Weld spatters

<u>Appearance of the fracture</u>

In order to assess the appearance of the fracture, the corner seam must be broken.

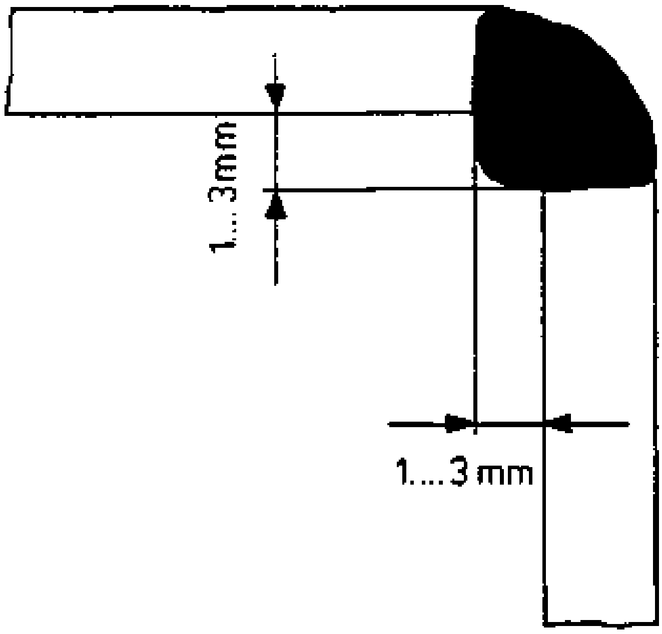


Fig. 23 Welded Corner with a root height of 1 to 3 mm

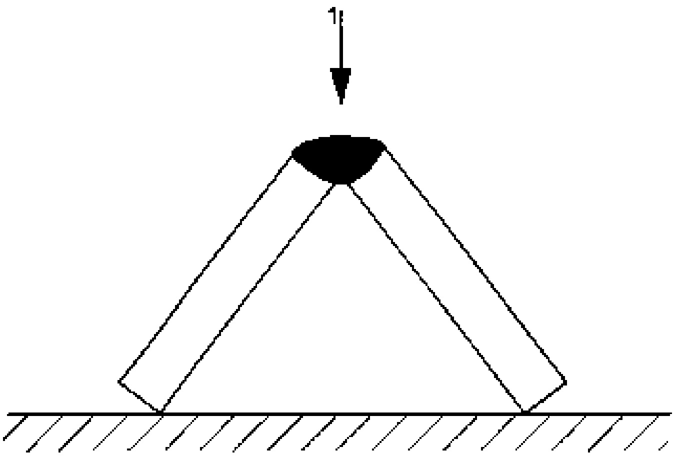


Fig. 24 Position of the corner seam for breaking 1 Force

Criteria for the assessment of the appearance of the fracture are:

- Fusion of the edges of the plate within the range of the cover passes
- Covering the plate edges within the range of the root pass
- Slag inclusions
- Pores
- Lack of fusion

<u>Weld defects and their causes</u>

Discuss weld defects, if any, and their causes. Proceed in the same way as in the previous Sections.

Then, allow the trainees to exercise the welding of corners according to your demonstration. Once more, summarise the most important items. Analyse and discuss the results of the exercise together with the trainees.

<u>Evaluation of the Section on Corner Welding "h"</u>

With the conclusion of the exercise Section Fillet Welding, the trainees should have acquired the following knowledge, abilities and skills:

– observance of the relevant labour safety regulations and order and tidiness at the working place
– preparation of the welding sample
– mastering the corner welding in "h"–position
– identification of typical welding defects in corner welds
– comments on their own work

<u>Examples of questions regarding the corner welding "h"</u>

1. Describe the buildup of a corner seam in horizontal position!
2. How do you achieve a thorough and uniform fusion at the root pass?
3. Which are the hazards to which a weldor is exposed by the arc? How to face them?
4. How do you counteract the blow effect?

3. V–seam Welding "g"

Only start with this Section, when <u>all</u> trainees are in a position to weld a fillet.

Here, also repeat and define the terms V–weld and "g"–position. Then familiarise the trainees with the aim of this Section. In a lecture, impart the necessary knowledge of the welding of a V–groove, i.e. the production of a V–weld. Prepare a blackboard picture of the following illustrations. Subsequently, give the leaflet or instructional pamphlet to the trainees. Explain the terms associated with a V–weld. Ask the trainees to enter the terms into the sketches of the pamphlet.

Check the terms entered into the pamphlet by the trainees. As one trainee to do this at the blackboard. The other trainees compare with their records. Immediately correct errors occurring.

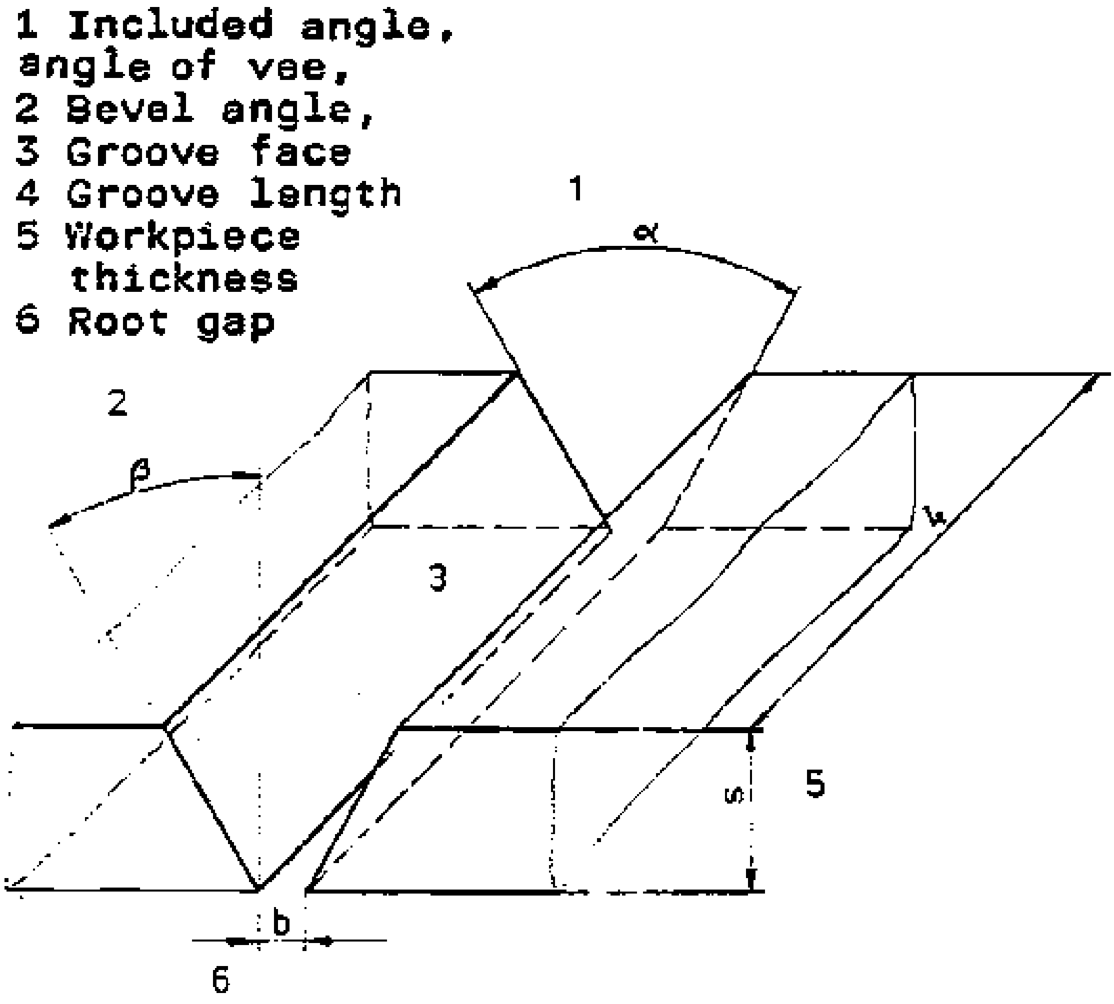


Fig. 25 Groove preparation for a V–weld, terms

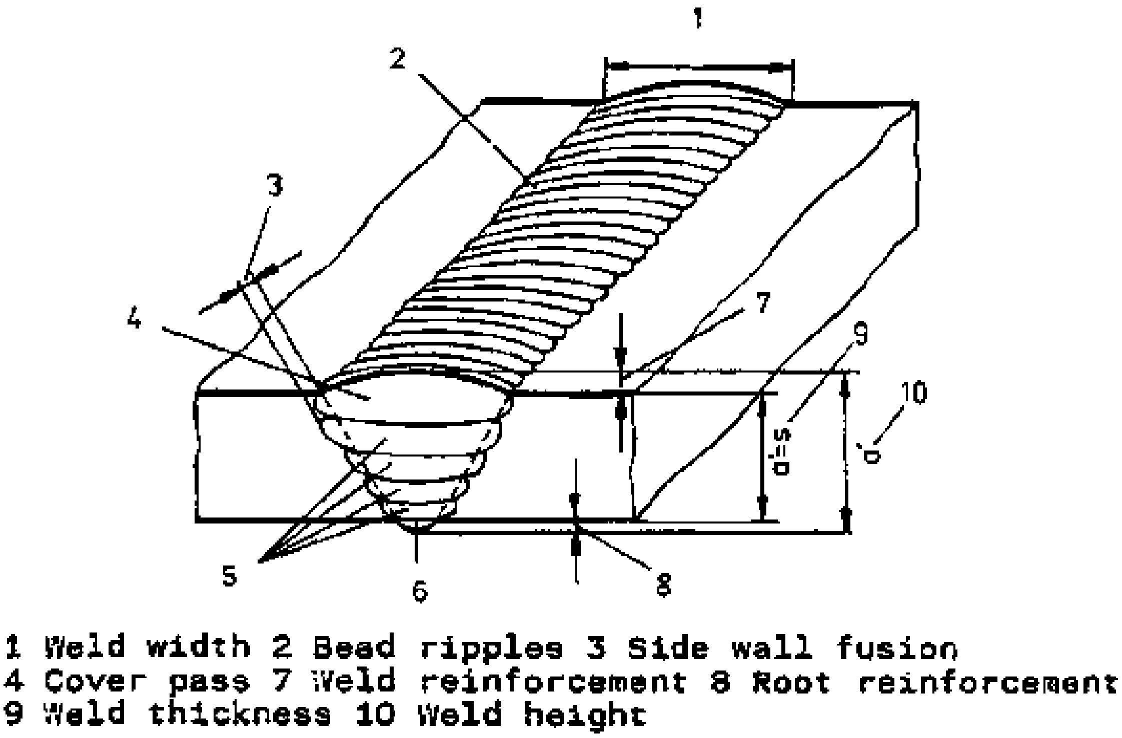


Fig. 26 Terms of the V–weld

3.1. Preparation of the Exercise Plates

Tell the trainees the dimensions of the exercise plates and how their condition must be.

– Two plates having the size of 100 x 200 mm and a thickness of anything between 10 and 12 mm are to be used.

– The bevel angle of the plates is 30º.

– The plates must be plane and have a clean surface.

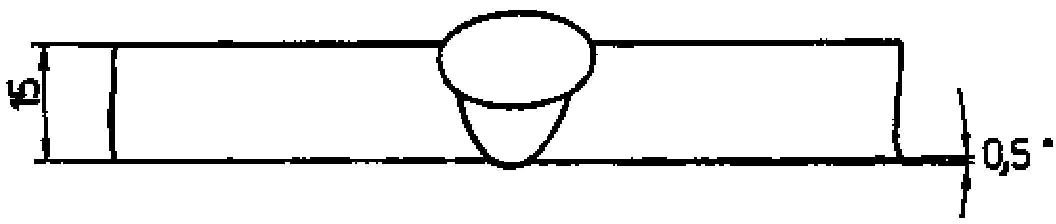
Check the preparation of the exercise plates by the trainees. Take into consideration the information given in the previous instructions.

3.2. Tacking the V – groove

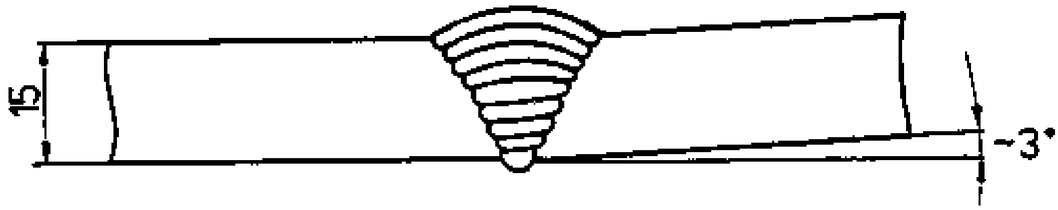
Demonstrate the assembling and tacking of the plates forming the V–groove. Point out to the trainees that during welding and after this process a shrinkage occurs in the longitudinal direction of the weld and across the weld in all types of welds. The transverse shrinkage of the weld contracts the two plates and, in V–welds, effects an angular shrinkage towards the cover pass which draws the two external edges upwards.

Fig. 27 Angular shrinkage in V–welds

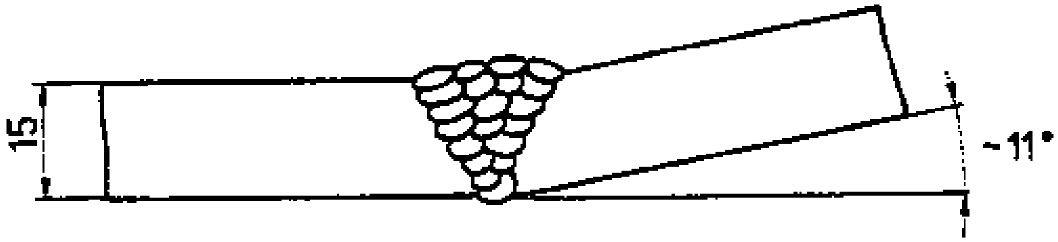
a.) Dependence of the angular shrinkage on the number of passes



2 passes

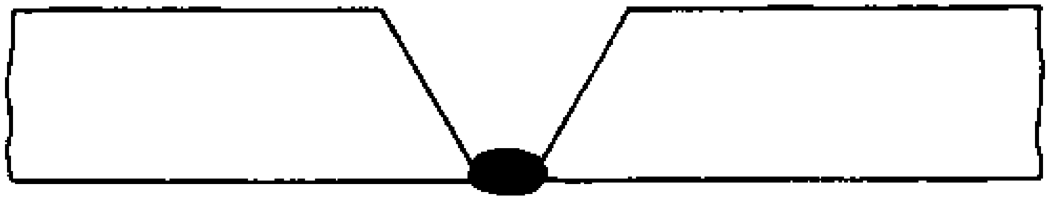


9 passes

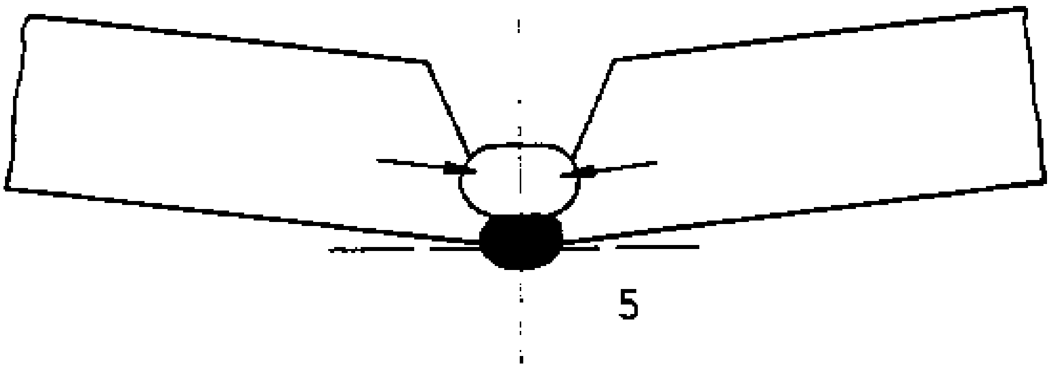


20 passes

b.) Originating of the angular shrinkage by a hinge effect produced by the root pass

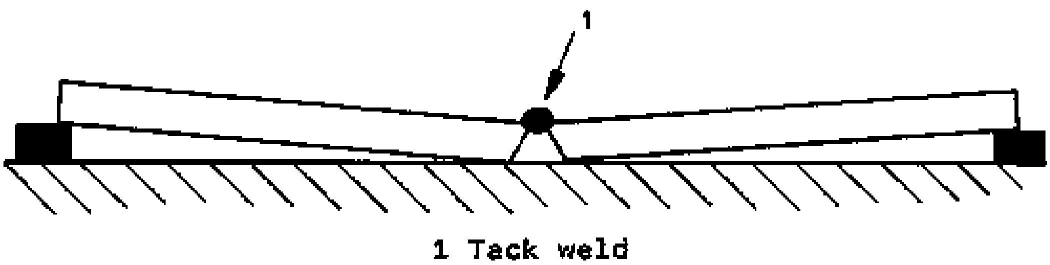


Root welded – no angular shrinkage present



First central pass welded –angular shrinkage occurs

Any welded V–weld should remain straight after welding, however. For this purpose, before tacking the two plates are arranged in the form of a roof, that is to say, small strips of sheet metal having a thickness of anything between 2 and 2.5 mm are placed under the left–hand and right–hand ends.



1 Tack weld

Fig. 28 Roof–shaped tacking of the plates for the V–weld

– The plates must be arranged in such a way that a root gap of 3 to 3.5 mm is present between the faces.

Quote the following rule to the trainees:

For V−welds, the root gap should be equal to the core wire diameter.

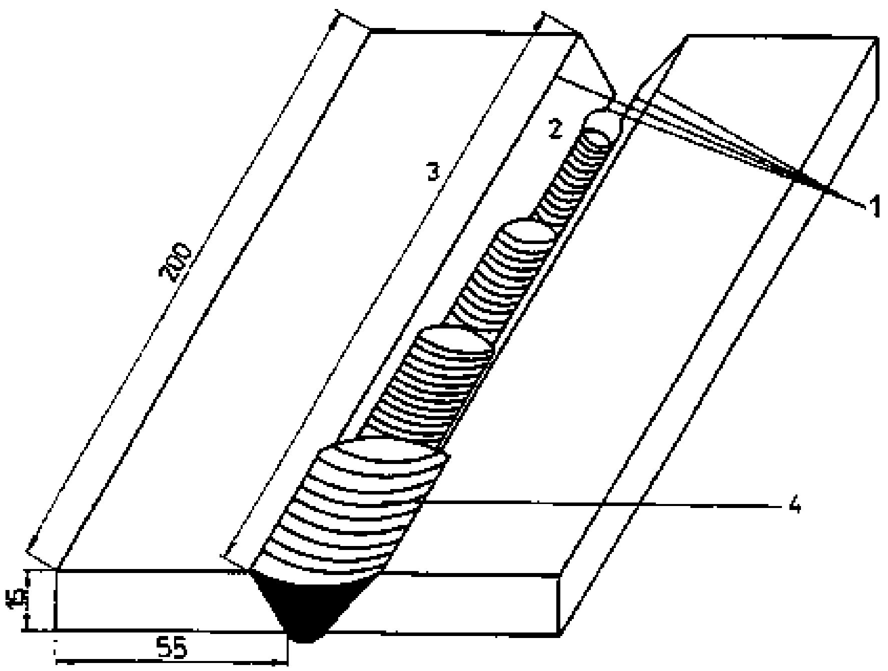
The tack welds have to be applied directly to the plate edges. The tack welds must be strong and clean. When the tack welds break during the root welding, the welding of the root cannot be continued.

When the tack welds have been finished, slag remains and spatters must be carefully removed from these tack welds.

Carefully watch the proper tacking of the V−groove performed by the trainees.

3.3. Welding the V−weld

With a plate having a thickness of anything between 10 and 12 mm, multi−pass welding is carried out, namely, the root pass by means of electrodes having a diameter of 3.25 mm, two to three inner passes with 4−mm electrodes and one cover pass with 4−mm electrodes. The weld reinforcement should be −0 +1.5 mm.



1 Longitudinal edges of the groove 2 Groove face
3 Length of the seam 4 Surface of sean and bead ripples

Fig. 29 Buildup of passes in the V−weld

− As electrode, the "Garant" E 43 4B 110 20 (H) has to be used. This electrode with a basic coating must be welded at the direct−current positive pole.

− Take care that only dried electrodes are used. Otherwise intense pore formation may be inevitable. With this electrode, a particularly short arc must be maintained. It is suitable for all welding positions with the exception of the vertically down position.

3.3.1. Welding the Root Pass

Show the trainees how to weld the root.

The trainees should make a mental note of the following sequence of operations:

− Placing the plates on two strips of sheet metal having a thickness of about 10 mm. This ensures that the formation of the root pass will not be disturbed.

– Arrangement of the V–groove parallel to the direction of viewing on the welding table. Care should be taken that the exercise piece is properly located on the welding table.

– The current is set to 130 A roughly with respect to the core wire diameter of 3.25 mm used.

– It should be noted that the electrode to be used must have a base coating and, consequently, must be connected to the positive pole of the current source.

– The electrode is moved in a U–shaped curve which is open towards the welding direction.

Fig. 30 Welding the root with the electrode moving in a U–shaped curve

– The electrode must be allowed to dwell for a sufficiently long time at the root edges in order to fuse them properly.

– The curve open in welding direction must result in a pear–shaped opening, the so–called "pear". Owing to this electrode motion it is ensured that the root fusion complies with the requirements.

– During welding, the arc length must be varied in order to adapt it to the different situations.

It should be borne in mind:

long arc – high thermal effect
short arc – low thermal effect

– If it can be apprehended that there will be a lack of root fusion, the arc must be longer accordingly. By heating the groove faces, the weld metal will run more readily into the root gap.

– When the "pear" becomes too large, the electrode must be kept so that the arc becomes shorter in order to avoid an excessive reinforcement of the seam sides.

– By taking advantage of the welding speed, a uniform formation of the root can be achieved,

– In this connection, it should be noted:

Root welding should not be performed at a uniform welding speed. By varying the welding speed, an influence can be exerted on the heat input.

High welding speed –
Low heat input!
Slow welding speed –
High heat input!

– By varying the arc length and the welding speed, a uniform heat input and thus a uniform root formation are achieved.

– The shaping of the correct size of the "pear" is also of great importance the appearance and evenness of the root.

As a rule of thumb for the pear size, the following holds: it should not fall below the core wire diameter of the electrode used.

The pear size is ideal when the 3,25 mm electrode inclusive of its coat can be inserted into it.

– Further it should be borne in mind that the electrode is allowed to dwell long enough at the seam sides. This is achieved by a rhythmic electrode motion.

As rhythm in welding, a "counting" in the oscillating motion is to be used

– to the left, two, three –
– to the right, two, three –

while the dwell time of the electrode on the seam side is defined by "two, three".

Point out to the trainees that there are grave consequences when this instruction is not observed.

– Undercuts will occur in the seam sides where slag will accumulate. Since this slag can hardly be removed it is usually overwelded and, in this operation, insufficiently fused. Welding defects in the form of slag inclusions are the consequence.

Have the oscillating motion carried out as a dry exercise, that is to say, the oscillating motion is practised without actually welding. For this purpose, the welding converter must be switched off.

Point out to the fact that

– by varying the speed in oscillating, the heat input can also be varied considerably.
– The trainees should make a mental note of the following rule:

– rapid oscillating – small amount of heat – slow oscillating – high amount of heat

– Explain that the quality of a root pass is influenced by three quantities to the trainees

• variation of the welding speed (oscillating motion)
• variation of the arc length
• variation of the rhythmic electrode motion.

The welding of root passes presents difficulties to many trainees because the three quantities can be coordinated only after a long period of exercising.

Therefore, pay particular attention to the exercising of root welding. Encourage the trainees who find it difficult to acquire root welding.

Give the following information to the trainees:

– As a result of root welding, considerable shrinkage of the workpiece occurs. This transverse shrinkage may be so remarkable that, under certain circumstances, the root gap can no longer be retained by the tack weld and is lost. Without the specified root gap, proper root welding, is impossible, however.

– One should proceed as follows:

30 mm of the root pass are first welded from one end and then the remaining length of the root is welded from the other end.

By turning the plate it is ensured that the same welding direction is maintained.

– When welding the root pass, the already know blow effect will again occur.

The blow effect is counteracted by inclining the electrode from the beginning of the weld in welding direction and, towards the end of the weld, opposite to the welding direction.

– The extension length, i.e. the length of the root which can be welded with one electrode, is not sufficient for the length of the seam. Therefore, starting points are necessary.

– When the electrode is molten down sufficiently, the arc is guided in such a way that a large pear is formed. The arc is ignited about 1.5 cm in front of the pear on the root pass and, with a long arc, a thin bead is drawn to the pear. Now, allow the arc to burn in the pear. After the pear has been fused sufficiently, one can continue to weld the root pass.

With this method, defects due to the starting or arc striking are avoided. After root welding, slag and weld spatters are carefully removed from the V−weld.

Check the root weld for welding defects such as insufficient through−welding, excessive root sag, starting defects, pores, slag inclusions, lack of fusion and undercuts. Uneven starting points can be smoothened by means of hammer and chisel.

3.3.2. Welding the Inner Passes

Show the trainees how the inner passes have to be welded. The trainees again should make a mental note of the sequence of operations.

– Electrodes with a core wire diameter of 4 mm are to be used.

– Adjust the current to an intensity of 190 to 200 A. Due to the high current intensity, in the groove faces a good penetration is obtained for the root pass and the bead lies flat without notches in the groove.

– Observe the following procedure for welding the inner passes.

When electrodes with a thick coating are used, the electrode is oscillated in a semi−circle which is closed in the welding direction.

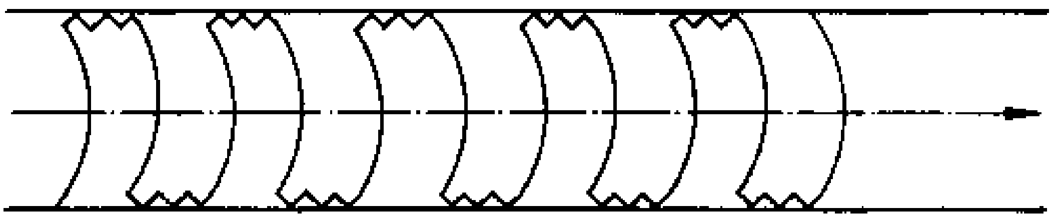


Fig. 31 Motions of the electrode for electrodes with thick coating for welding inner passes and cover passes

This procedure ensures that during the motion of the electrode, also known as electrode manipulation, slag is not included. The teeth in the above illustration shall show the dwell of the electrode at the seam sides. The oscillating motions of the electrode must be effected in a pronounced rhythmic manner. The trainee should count during oscillating in the following manner:

to the left – two – three,
to the right – two – three,
to the left – two – three,
to the right – two – three, etc.

At the same time, the electrode should be moved so as to slightly touching the work or, in other words, during counting, the electro−should be slightly lifted and lowered.

– The success of any weld depends on the exact manipulation of the electrode,

– Pay attention to the fact that the oscillating motions are not too wide; in other words, the external edge of the coating should not move beyond the width of the preceding bead.

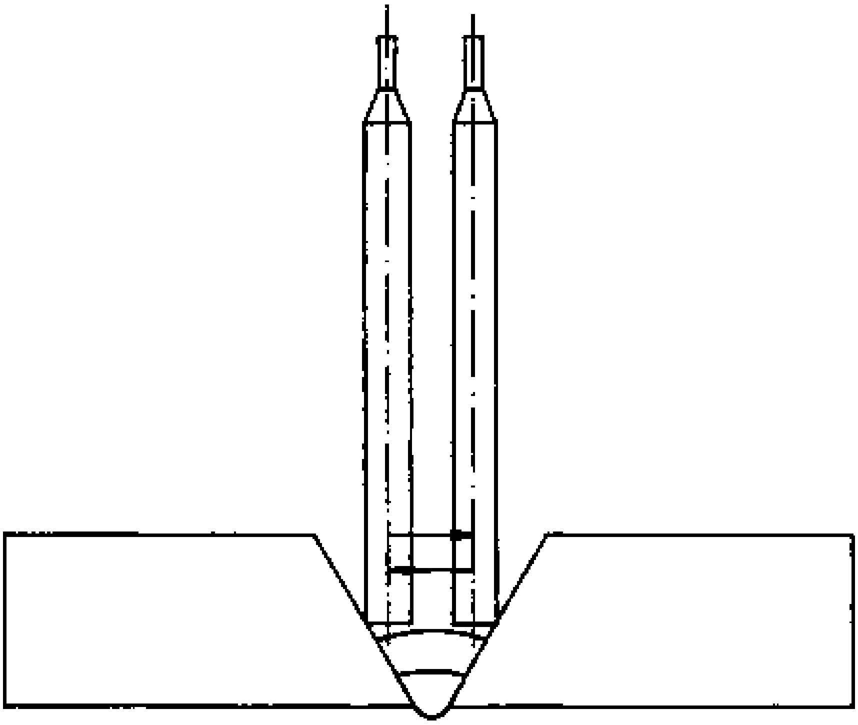


Fig. 32 Electrode position to avoid undercuts at the sides of the seam

– When exceeding this width is oscillating the electrode, the molten pool will become too large and slag runs to the centre.

As a consequence, slag inclusions occur and, in spite of the high current, fusion penetration will remain poor. In this case, too, have the electrodes manipulated by the trainees as a "dry exercise". Point out to the trainees the following items:

– Due to the high currents, the last third of the electrode begins to glow out.

If this glowing piece of electrode is welded, not only an irregular weld surface will be produced but also a large number of pores formed and a poor penetration obtained. The electrode must be replaced in time.

– The electrode stubs should not be thrown always because they can be used for tacking and minor welding operations.

– The electrode stub should not be longer than 40 mm.

– The electrode stubs are collected in tins or sheet–metal boxes. Electrode stubs are valuable secondary raw materials for steel production.

Note for labour safety

– Pay attention to the fact the electrode stubs are not thrown on the floor. They constitute *a* danger of accident because people may slip when stepping on it.

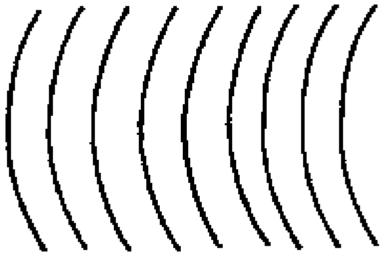
– After welding the first inner pass and removing slag and spatters from it, the next inner pass can be welded.

– All inner passes are welded in the same way as the first one, but the current may be reduced by 20 to 40 A. Electrode manipulation may be carried out invariably.

– During welding, the plat should not become too hot otherwise the weld bead will become poor in appearance. The bead ripples will no longer be round but taper in the direction of the finished pass.

Fig. 33 V–weld, good and poor appearances of the bead ripples of the cover pass

1 poor appearance of the bead ripples



2 good appearance of the bead ripples

– To avoid overheating of the weld, it is necessary to observe a break after any individual pass in order to allow the work to cool down.

– When all inner passes have been welded, then the last one must be so located that 1 to 1.5 mm are free up to the plate surface. The margin left in this way is a guidance for welding the cover pass.

– The end craters of all inner passes must be filled very carefully. This is achieved by shortening the electric arc.

When having finished all inner passes, slag and spatters must be removed from the seam carefully.

Check the uniformity of the last inner pass. Irregularities must be removed by chiselling. The successful outcome of the cover pass is largely depending on the appearance of the last inner pass.

3.3.3. Welding the Cover Pass

Show the trainees how to weld a cover pass. Give the necessary instructions.

– Electrodes with a core wire diameter of 4 mm are to be used.

– The current intensity is 170 A.

– The cover pass must be welded with every care and particularly slowly in order that to the left and right of the groove edge a good penetration with a good transition is obtained without undercuts.

– Electrode manipulation and oscillating motions are the same as those required for the welding of the inner passes.

– The welding speed can be reduced by counting at a lower rate.

– Again the electrode is moved up and down but it is allowed to dwell for a longer time at the seam sides as for the preceding passes.

– When welding at a higher rate, the cover pass will become convex and show undercuts. This allows to draw the conclusion that the filler metals requires a certain time in order to penetrate into the parent metal.

– When welding the cover pass, do not weld beyond the plate edge to the right and left.

– When starting with a new electrode, ignite it in the centre of the end crater, fill the latter by slow oscillating motions and the continue welding in the usual rhythm.

– The end crater of the seam must be filled carefully; this is achieved by shortening the arc,

– When having completed the weld, clean the weld and check it for welding defects.

3.4. Assessment of the Welded V–weld

Give comments on the welded V–seam together with the trainees. Tell them the assessment criteria.

Give assessments on the appearance of the weld, the accuracy to size and the appearance of the fracture.

Appearance of the weld

- Uniformity of the bead ripples
- Appearance of the root
- Points of start and arc strike
- End craters
- Undercuts
- Weld spatters

Accuracy to size

- Three measuring points must be determined by means of the weld gauge.

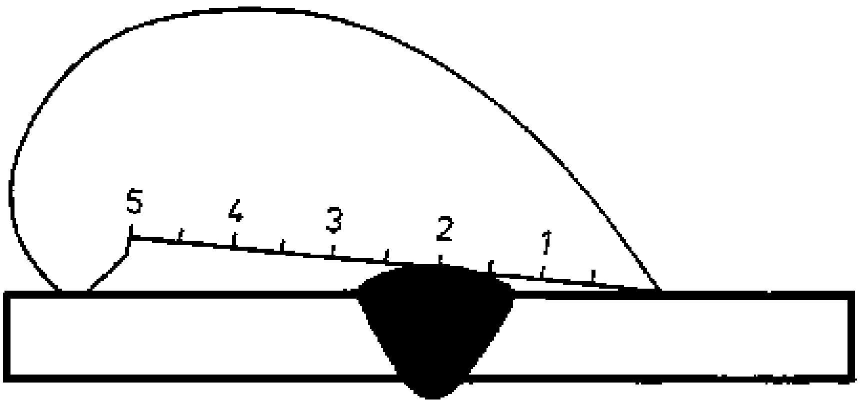


Fig. 34 Measuring the weld reinforcement

Weld gauge (1) for measuring the weld reinforcement. For V–welds in "g"–position, a weld height of + 1.5 mm is permissible.

Appearance of the fracture

For assessing the appearance of the fracture, the V–weld must be notched and broken.

- The V–weld is notched by planing.

Take care that the notch tapers to the bottom and has a depth of at least 4 to 5 mm.

- By means of the device shown in the following illustration, the sample is broken in a hydraulic press.

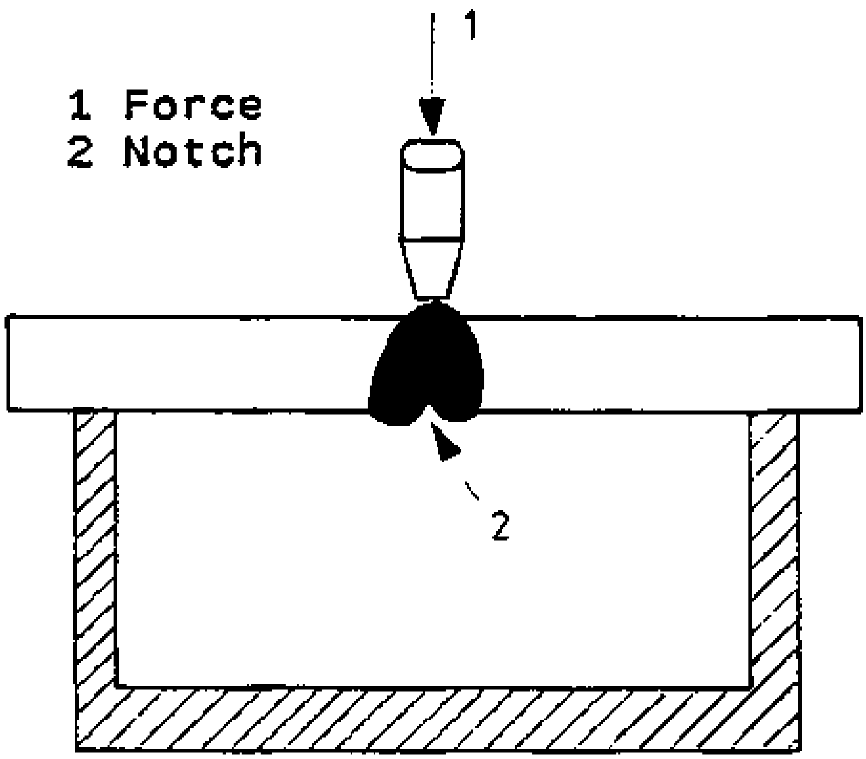


Fig. 35 Breaking the notched V−weld

Criteria for the assessment of the appearance of the fracture are:

– Fusion of the edges of the root
– Slag inclusions
– Pores
– Lack of fusion

Show properly welded and defective welds to the trainees. Give workpieces with defective welds to the trainees. The trainees are then asked to assess the weld, to identify the defects and to tell the causes.

Evaluation of the Section V−seam Welding "g"

With the conclusion of the exercise Section V−welding, the trainees should have acquired the following knowledge, abilities and skills:

– observance of the relevant labour safety regulations and order and tidiness at the working place
– preparation of the welding samples
– mastering V−welding in "g"−position
– identification of typical welding defects in V−welds
– comments on their own work

Examples of questions regarding the Section V−seam Welding "g"

1. Describe the buildup of a V−weld in "g" position!
2. Explain the marking or designation of the welding electrode used!
3. Describe the groove preparation for a V−weld!
4. What are the faults of the weldor that cause pores in the weld?

Electric Welding 3 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

Table of Contents

Electric Welding 3 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

CRYSTAL

Lehr– und Lernmittel,
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Material didáctico,
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0. Introductory remarks

These methodical instructions have been elaborated in order to impart knowledge, capacities and skills in electric welding.

It is the purpose of the methodical instructions to give aid and support to an instructor for practical vocational training in the preparation and realization of his instructional work. What is suggested to the instructor are possible ways to reach the goals of his pedagogical activities.

The methodical instructions are organized in such a way that the trainees are systematically informed of

– fillet welding in the vertical–up position,
– V type welding the vertical–up position,
– V type tacking, 5 tacks,
– welding a profile joint, root pass and two cover passes, and fillet welding in the semioverhead position.

The preparation of the welding specimens (plates), the selection of the electrodes and the respective electrode manipulation as well as the evaluation of the welds are the most important points to be considered.

Learning the above mentioned skills of welding and welding positions carries on the task of Parts I and II of Electric Welding instructions. The order of succession of learning the weld types and welding positions was determined on the basis of experience gained in the training of electric weldors. Thus mastering the weld types and welding positions described in Parts I and II of the Electric Welding instructions is prerequisite to learning the weld types and welding positions explained in the present instructions. Having passed the examination, the trainees are authorized to weld

– fillet welds in the vertical–up position and the semioverhead position,
– V type weld in the vertical–up position,
– V type welds with 5 tacks,
– profile joints with a root pass and two cover passes on plates and profiles with a thickness of 6 – 12 mm.

1. Fillet welding in the vertical–up position

Recapitulate the concepts of a fillet weld and the vertical–up position. Start to discuss this section only if the trainees perfectly master fillet welding in the horizontal position.

Let one of the trainees demonstrate fillet welding in the horizontal position. Tell him also to discuss the most important points to be considered. Evaluate the demonstration together with the trainees. Accord praise for good workmanship. Recapitulate the preparation of the specimen plates for fillet welding in the horizontal position. The same preparations are applicable to fillet welding in the vertical–up position. Therefore, use the methodical instructions for horizontal fillet welding. The same holds for tacking the fillet weld. Discuss the differences between fillet welding in the horizontal and the vertical–up position.

Summarize the differences in a table.

Horizontal fillet welding		Vertical–up fillet welding
4.00 mm 160... 200 A	Welding electrode Amperage	3.25 mm 120... 160 A
adjust amperage to 180... 190 A	root pass welding	adjust amperage to 110 A
at the left–hand end of the T–butt joint	arc starting	at the lower edge of the fillet weld
without weaving, as a string bead carried out with regular stippling	welding the root pass	with triangular electrode manipulation. Initially the fillet weld is still cold and must be preheated using a longer arc.
45°	angle between the electrode and the boom plate	45°
2 cover passes	cover pass welding	1 cover pass
4.00 mm	electrode	3.25 mm
170 A	amperage	110... 120 A
string bead carried out with weaving motion 2/3 of the root covered	welding the 1st cover pass	weave bead arc–type electrode manipulation
tilt the electrode towards the web plate at an angle of 60°, hold the arc very short at the web plate	welding the 2nd cover pass	not applicable

The procedure before welding the root pass is as described in the instructions for horizontal fillet welding.

1.1. Welding the root pass

Demonstrate root welding to the trainees. For that purpose, place the specimen on the welding table with the fillet weld arranged vertically. Point out to the trainees that the specimen must be put on 10 mm thick plate strips. This enables an unobstructed working with the arc at the beginning of the seam.

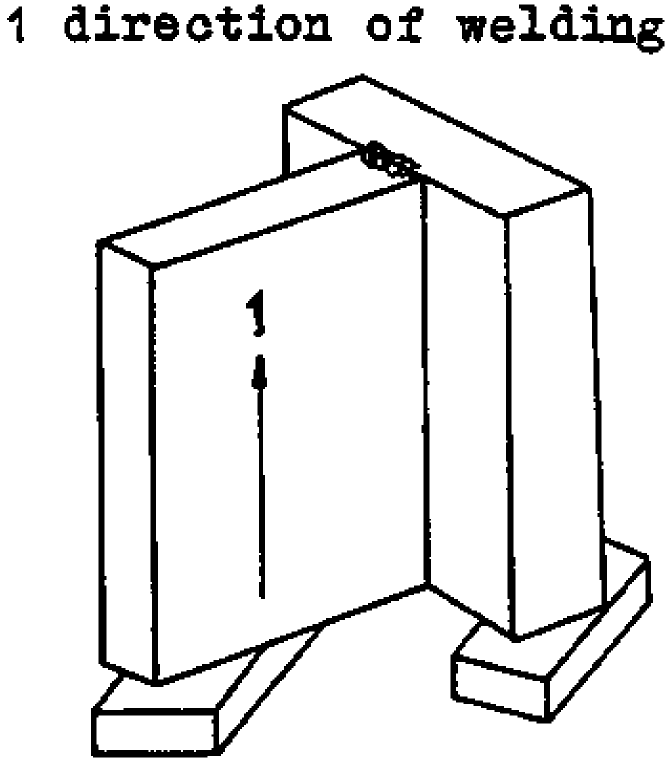


Fig. 1 Specimen arranged for vertical–up fillet welding

Sequence of operation in root welding:

- Adjust the amperage to appr. 110 A
- Start the arc at the lower edge of the fillet weld
- Weld the root pass with, triangular electrode manipulation

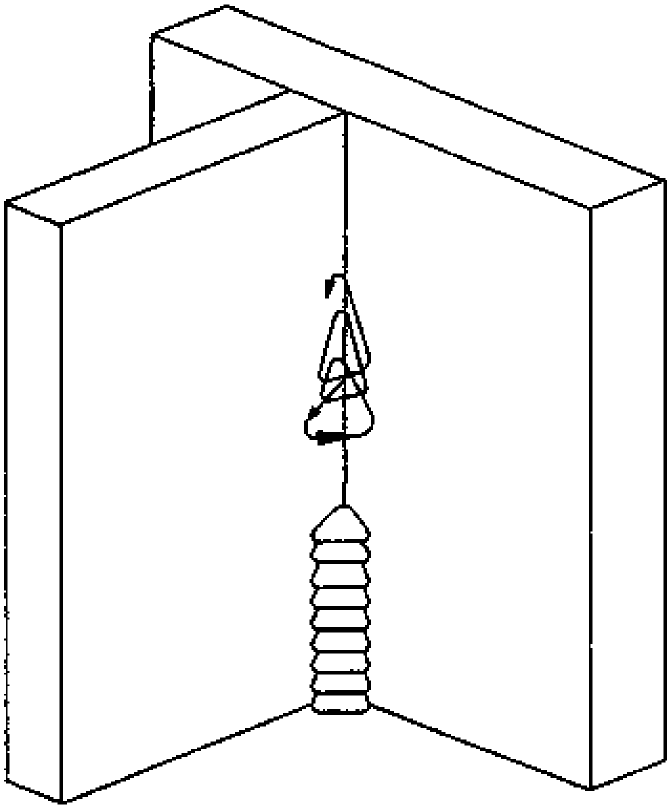


Fig. 2 Electrode manipulation in root welding

Explain to the trainees that at the beginning of root welding the fillet weld is still cold and must be preheated by means of a longer arc.

To obtain a symmetrical, central weld buildup, the position of the electrode must be such that the angle of 45 between the electrode and the boom plate and web plate, respectively, is exactly maintained

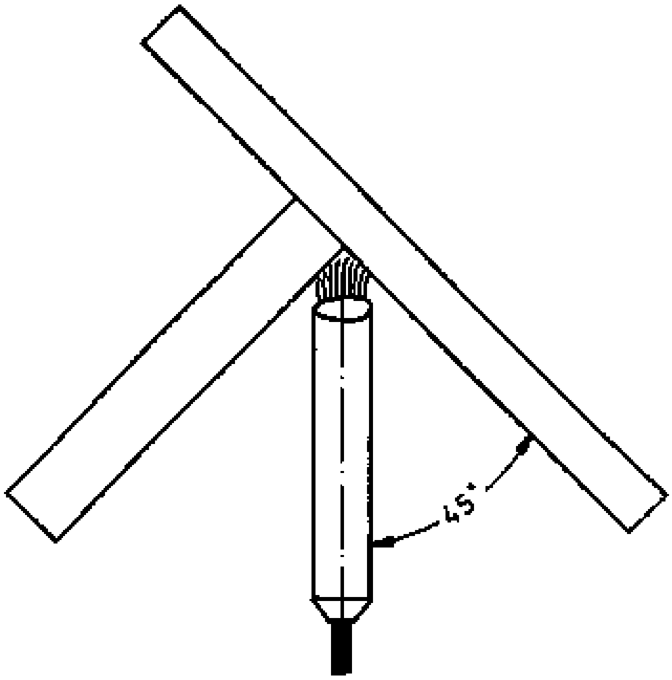


Fig. 3 Electrode position for obtaining a central weld buildup

One again, draw the trainees' attention to the arc blow effect. This effect must be counteracted by tilting the electrode in the direction of welding at the beginning of the seam and in the opposite direction when approaching the end of the seam.

Discuss the consequences of ignoring the arc blow effect with the trainees.

Ignoring the arc blow effect results in welding faults such as

- interrupted weld,
- slag inclusions,
- heavy spattering of the weld sides.

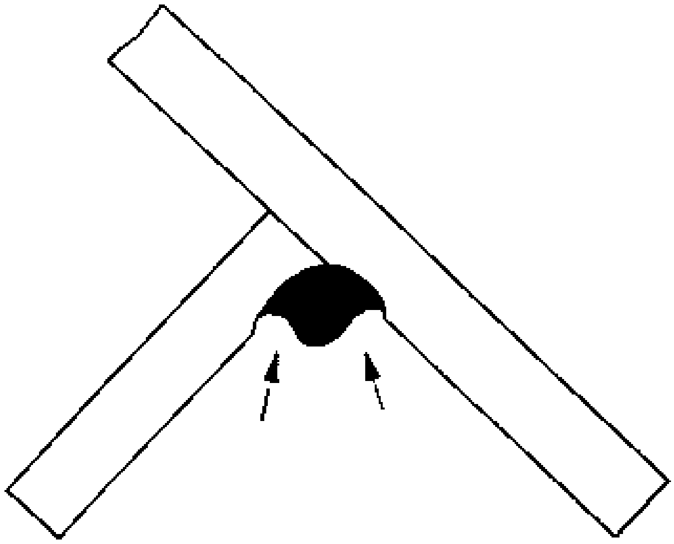


Fig. 4 Excessive reinforcement of the root pass with deep undercutting

Point out to the trainees that the root pass must be welded so as to avoid a reinforcement in the centre of the seam. If this is disregarded, then not only the slag is difficult to remove, but there will also occur slag inclusions at the side walls of the seam when the first inner pass is welded.

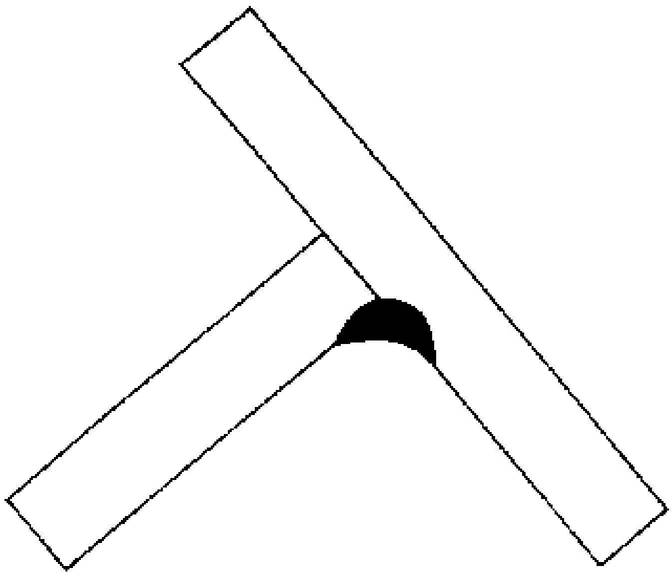


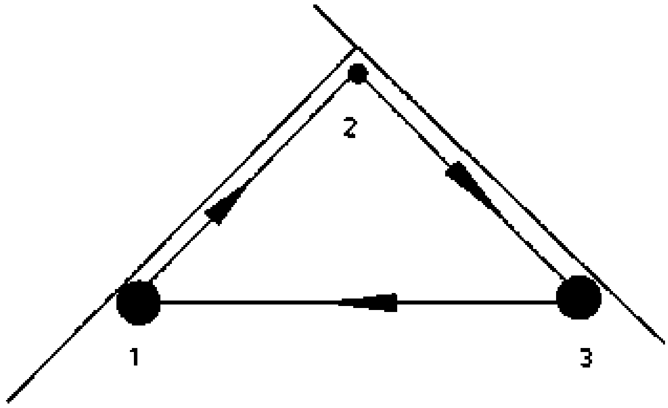
Fig. 5 Central and undercut−free execution of the root pass

Therefore, in the triangular manipulation of the electrode, take care to provide for an adequate dwell time of the electrode at the seam side walls in order to fill the undercuts resulting from the arc.

Take care to carry out triangular manipulation of the electrode in the following rhythm:

left – middle – right, left – middle – right,

where the dwell time of the "left" and on the "right" must be somewhat longer than in the "middle".



1 left, 2 middle, 3 right
Fig. 6 Sequence of electrode manipulation in root welding

– When welding a seam length of 200 mm, an electrode change will be required.

In this case proceed as follows:

Clean the seam end from slag and spatter. Start the arc with the new electrode at the lower end of the end crater.

A gradual preheating will absolutely be necessary in order to melt the end crater; this is achieved by a slight weaving with a long arc. The actual weld buidup is restarted not earlier than the weld metal threatens to flow off.

Demonstrate and explain the procedure of electrode changing.

A slight overhang of the seam is better than a lack of fusion. If necessary, this overhang can be removed by chipping.

– Take care to provide for a good filling of the end crater of the root pass. This is achieved by shortening the arc.

After the root welding has been finished, the fillet weld is carefully cleaned from slag and spatter.

Check the root passes welded by the trainees for central alignment and for possible welding faults such as pores, slag pockets and undercutting.

1.2. Welding the cover pass

Demonstrate cover pass welding to the trainees.

Explain the following sequence of operations:

– Use electrodes with a diameter of 3.25 mm.

– Adjust the amperage to 110... 120 A.

– The cover pass is welded as a weave bead, i.e. with an arc–like electrode manipulation, the arc being closed in the direction of welding.

Take care that the arc is not drawn too steeply, because this would lead to a lack of fusion of the root. To achieve a sufficient fusion of the side walls of the seam and to avoid undercutting, the following rhythm must be kept in the weaving motion of the electrode:

– left 2–3, right 2–3, left 2–3 etc.

Again and again tell the trainees to follow this rhythm. Check that the trainees count the rhythm.

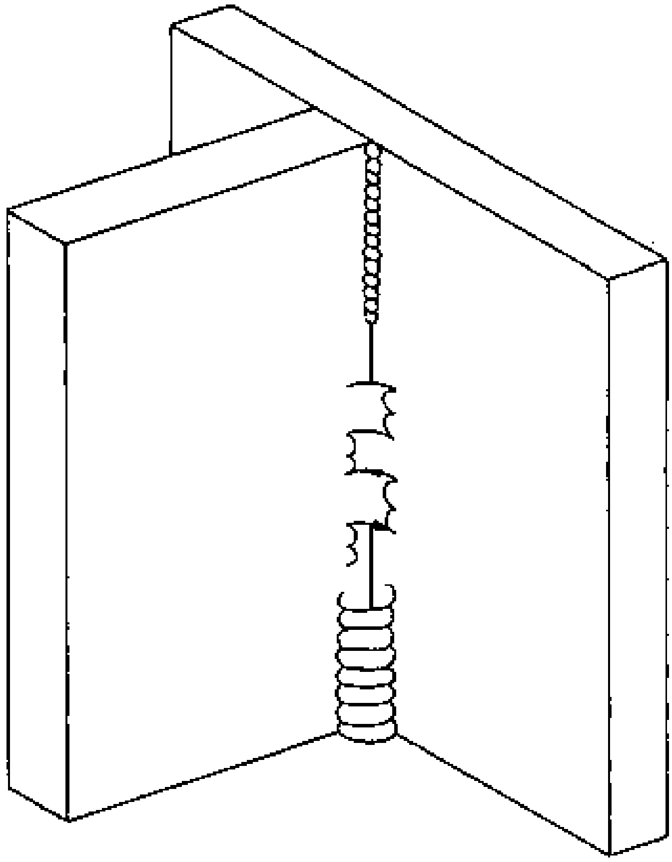


Fig. 7 Electrode manipulation in welding the cover pass

Once again, draw the trainees' attention to the arc blow effect. Demonstrate to the trainees how to manipulate the electrode accordingly; see Fig. 7.

The electrode change is carried out as described for root welding.

Thereafter fill the end crater.

Finally allow the fillet weld to cool down and clean it.

1.3. Evaluation of the finished fillet weld

Evaluate the finished fillet weld together with the trainees.

Informe the trainees of the evaluation criteria.

Evaluate the weld appearance, the accuracy to size and the fracture appearance.

<u>Weld appearance</u>

- Symmetry of the weld buildup
- Uniformity of bead ripples
- Arc strikes
- End crater
- Undercutting
- Spatter

<u>Accuracy to size</u>

Determine the three measuring points by means of a weld gage.

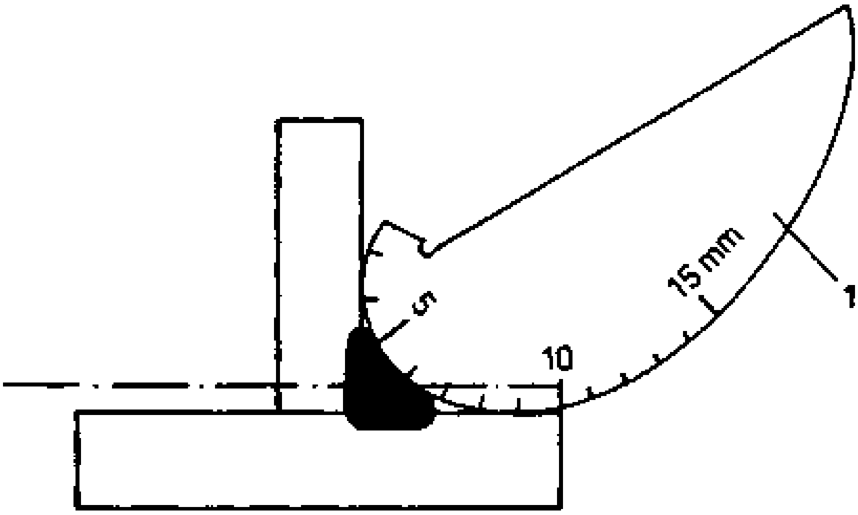


Fig. 8 Weld gage (1) for measuring the fillet weld height

For vertical−up fillet welds, the permissible tolerance of the weld height is + 2.0 − −0,5 mm

Fracture appearance

To evaluate the fracture appearance, break the fillet weld specimen in a suitable fixture.

The criteria for evaluating the fracture appearance are as follows:

- Melting of the web plate edge
- Slag inclusions
- Porosity
- Lack of fusion

Thereafter evaluate the results of work. Take concrete examples to discuss weld faults and their causes.

Evaluation of the Section "Vertical−up fillet welding"

After finishing the training section of fillet welding, the trainees should have acquired the following knowledge, capabilities and skills:

- Obeying the labour safety regulations including order and cleanliness at the working place
- Preparation of the welding specimen
- Mattering vertical−up fillet welding
- Recognition of typical welding faults in fillet welds
- Evaluation of their own work.

Examples of questions on the Section "Vertical−up fillet welding"

1. Describe the weld buildup of a vertical−up fillet weld.

2. What are the typical welding faults which occur in vertical−up fillet welding?

How can these faults be avoided?

3. Explain the marking of the welding electrodes used.

4. What are the dangers the weldor is faced with in his work?

How can he protect himself from such dangers?

2. V type welding in the vertical−up position

Mattering vertical−up fillet welding is an important precondition for V type welding in the vertical−up position.

Explain the differences between V type welding in the gravity and the vertical−up position.

Summarize these differences in the form of a table.

V type weld		V type weld
Gravity position		vertical−up position
core diameter of 3.25 mm	electrode	all passes with a core diameter of 3.25 mm
Inner and cover passes are welded with a core diameter of 4.00 mm,		
type "Garant" E 43 4B 110 20 (H)		type "Titan" E 43 4 RR (B) 22 red colour marking
−0, + 1.5 mm	weld reinforcement	−0, +2.5 mm

2.1. Welding the root pass

Demonstrate root welding to the trainees.

Give the following instructions:

− For the electrode with a core diameter of 3.25 mm, adjust the amperage to appr. 90 − 100 A.

− The lower plate− edge should be adequately preheated using a long arc. As soon as the tack begins to melt, continue welding with a short arc.

− The electrode is guided along an open arc in the direction of welding.

Count in the rhythm "right 2−3, left 2−3" while moving the electrode a little upwards each time.

Take care that the trainees count during the welding operation. Counting is very helpfuhl in learning the correct electrode manipulation.

− When moving the electrode upwards, take care to obtain a good fusion of the seam edges.

− The weld metal is deposited with a short arc in the centre of the groove while counting 2−3,

− To achieve a perfect fusion at the root, the weld metal must be pushed into the prepared groove with a slight pressure.

− When changing the electrode, then after ignition again weave the electrode with a somewhat longer arc at the surface of the weld, and as soon as the metal begins to melt, push the weld metal through the groove with a short arc. The electrode is guided perpendicularly to the specimen.

All the following operations are the same as described for welding the root pass in the gravity position.

Therefore continue the welding process as described in the instructions of gravity V type welding.

Check the root pass for possible welding faults such as insufficient fusion, excessive root sagging, arc strike faults, porosity, slag inclusions, lack of fusion and undercutting.

Unevennesses should be removed using hammer and chisel.

2.2. Welding the inner passes

Demonstrate the inner pas welding to the trainees.

– Use electrodes with a core wire diameter of 3.25 mm. adjust the amperage to 100... 115 A. This high amperage is required to melt the root reinforcement and to flush out minor slag residues at the side walls of the seam.

– The electrode is guided along an arc–like path which is closed in the direction of welding. In this case there should also be a somewhat longer dwell time of the electrode at the side walls of the seam with a stippling arc.

– Point out again that the electrode manipulation should be markedly rhythmic.

– Again count "left 2–3, right 2–3" etc. At 2 – 3, let the electrode dwell at the side wall of the seam with a stippling arc in order to flush out possible minor slag residues. This will also produce a flat shape of the inner pass. Inner passes with a high reinforcement can only be smoothed out very unsatisfactorily.

– In all inner passes, guide the electrode as shown in the figure below.

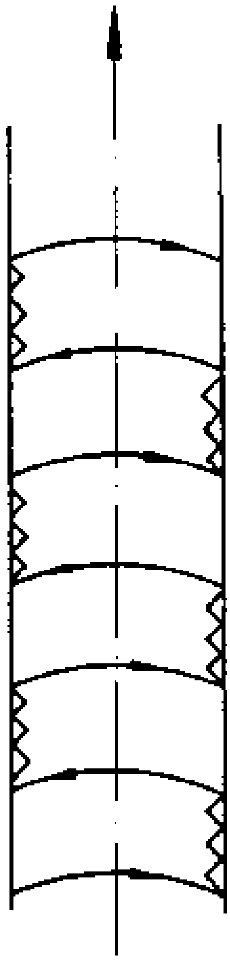


Fig. 9 Electrode manipulation for welding the inner passes and the cover pass

– Mind the arc blow effect in this case, too. It is counteracted in the same way as in welding the root pass.

According to the basical representation of the electrode manipulation, give to the trainees the following instructions for welding the inner passes.

Take care that the amplitude of the weaving motion is not too broad. The outer edge of the electrode coating must not move beyond the existing bead width.

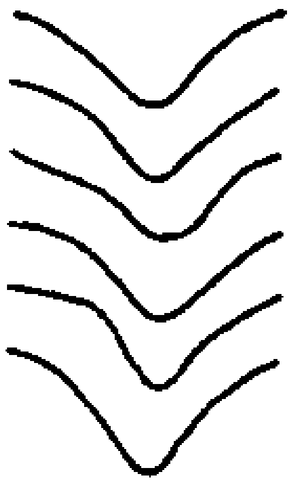
– If the weaving amplitude is broader, then too large a molten bath results and the weld metal flows down in the centre, which leads to a high reinforcement of the inner pass.

– The electrode is to melt to a length of 40 mm.

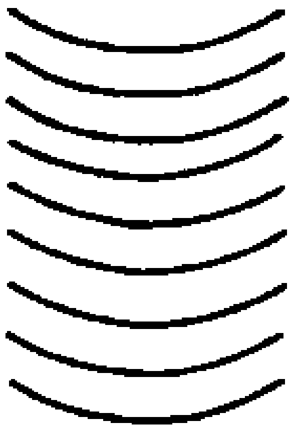
– After the first inner pass has been welded and cleaned from slag and spatter, the next inner pass can be welded.

– All the inner passes are welded in the same way as the first one, only the amperage can be reduced by 20... 30 A. The electrode manipulation can be maintained without any change.

Fig. 10 Poor and good bead ripple pattern of the cover pass



1 – poor ripple pattern



2 – good ripple pattern

Take care that the plate does not become too hot during welding, because this would lead to a poor appearance of the weld bead; the ripple pattern would no longer be straight but with downward–hanging tips in the middle of the seam.

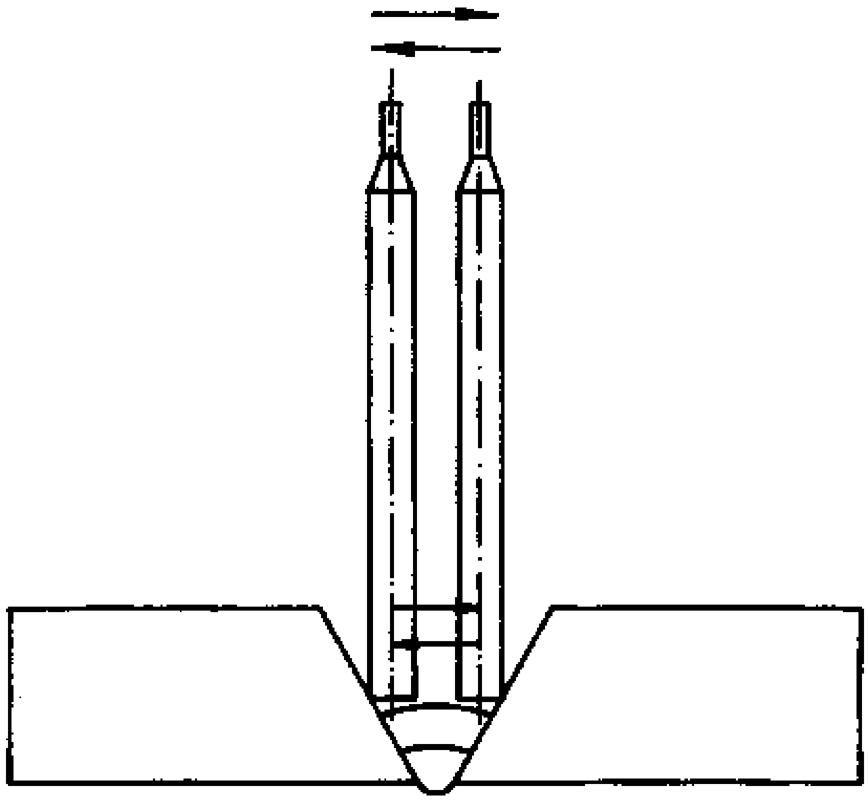


Fig. 11 Electrode position for avoiding undercuts at the side walls of the seam

– To avoid overheating of the weld, it is necessary to have a short interruption after each pass in order to provide for the cooling required.

– After finishing all the inner passes, the upper edge of the last inner pass should be 1... 1.5 mm below the plate surface.

The remaining edge allows an orientation in welding the cover pass.

– The end craters of all inner passes should be filled very carefully. This is achieved by shortening the arc.

After finishing the inner pass welding, clean the weld carefully from slag residues and spatter. Check the uniformity of the last inner pass. Unevennesses should be smoothed out by chipping. A successful welding of the cover pass depends critically on the appearance of the last inner pass.

2.3. Welding the cover pass

Demonstrate cover pass welding to the trainees. Give the following explanations:

– Use electrodes with a core wire diameter of 3.25 mm.

– Adjust the amperage to appr. 110 A.

– Weld the cover pass most slowly and carefully in order to obtain a good weld penetration on the left and right sides of the seam side wall, with a good weld–base metal interface and without undercutting.

– The weaving motion and the manipulation of the electrode correspond to those used in welding the inner passes.

– The welding speed is regulated by slower or faster counting.

– Again a stippling motion is applied, but the dwell time at the seam side walls should be longer than with the preceding passes.

– Take care to draw the arc most quickly over the centre of the seam in order to avoid an excessive buildup of weld metal.

– When welding the cover pass, do not weld beyond the plate edge on the right and left sides of the seam.

– When the arc is re–started, this should be done in the middle of the end crater. The end crater is filled by slow weaving. Subsequently the welding operation is continued in the usual thythm.

Evaluation of the Section "Vertical–up V type welding"

Having finished the training section on V type welding, the trainees should have acquired the following knowledge, capabilities and skills:

– Obeying the labour safety regulations including order and cleanliness at the working place
– Preparation of the welding specimen
– Mattering V type welding in the vertical–up position
– Recognition of typical faults in V type welds
– Evaluation of their own work

Examples of questions on the Section "Vertical–up V type welding"

1. Describe the buildup of a V type weld in the vertical–up position.
2. Explain the marking and the properties in use of the welding electrode employed.
3. What are your possibilities of obtaining a uniform root formation by electrode manipulation?
A. How do you counteract the arc blow effect in vertical–up welding?

3. V type welding with 5 tacks

In a discussion, explain the objective of this training section. Recapitulate the points of importance to be considered in tacking a V type weld.

Subsequently discuss the particularities of welding 4 tacks in the gravity position and 2 tacks in the vertical–up position.

– Each tack must have a length of 30 mm. The quality must correspond to that of a high–quality root weld.

– When welding very long butt welds, several tacks will be required. In cases where this is necessary for constructional reason, the tacks must then be included in the whole root.

This exercise has been included in the scope of training and examination in order to teach placing proper tacks in the middle of a butt joint. Draw the trainees' special attention to this fact.

Root welding in the gravity and the vertical–up position has already been dealt with in the sections on gravity V type welding and vertical–up V type welding. These skills should be taken as a basis. Let the trainees tack a V type weld in the gravity and the vertical–up position.

The following explanations will only give the instructions required for welding the tacks.

3.1. Preparation of the specimen plates

Inform the trainees of the dimensions and the condition required for the specimen plates.

– Four 100 x 100 mm plates 10... 12 mm thick will be used.
– The bevel angle of the plates is 30 °.
– The plates must be flat and have a clean surface.

3.2. Tacking the V type welds

Demonstrate the assembling and tacking of the V type welds. Again point out the angular shrinkage and, in a discussion, recapitulate the measures to be taken to counteract angular shrinkage.

Then go on as described in the methodical instructions on gravity V type welding.

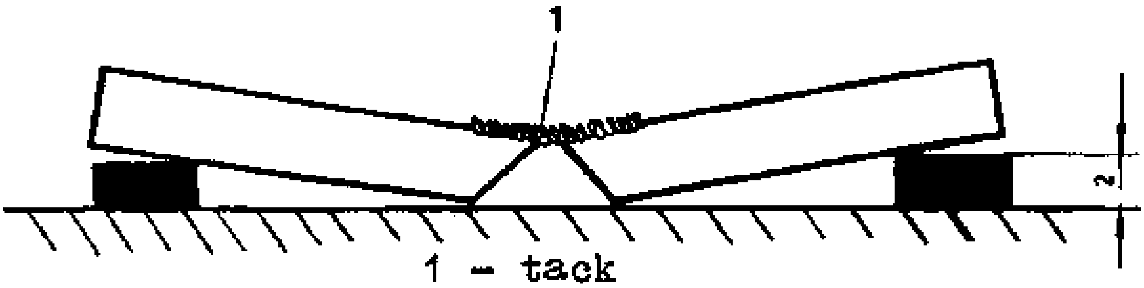


Fig. 12 Tacking the V type weld in a roof–like configuration

Assemble the plates so that a root opening of 3 ... 3.5 mm is left between the side walls of the seam. In a repetition, make clar which value of the root opening is required. Check how the rule for determining this value has been learnt.

Thereafter discuss the further operations:

– Fix the plates by means of two short tacks. Take care that the welded tacks are strong and clean. If the tacks crack during root welding, the welding operation cannot be continued. After finishing the tack welding operation, the tacks must be carefully cleaned from slag residues and spatter.

Check the proper tacking of the V type weld by the trainees.

3.3. Welding the tacks in the gravity position

Weld three tacks with a length of 30 mm each in the gravity position.

The arrangement of the tacks can be observed from the figure below.

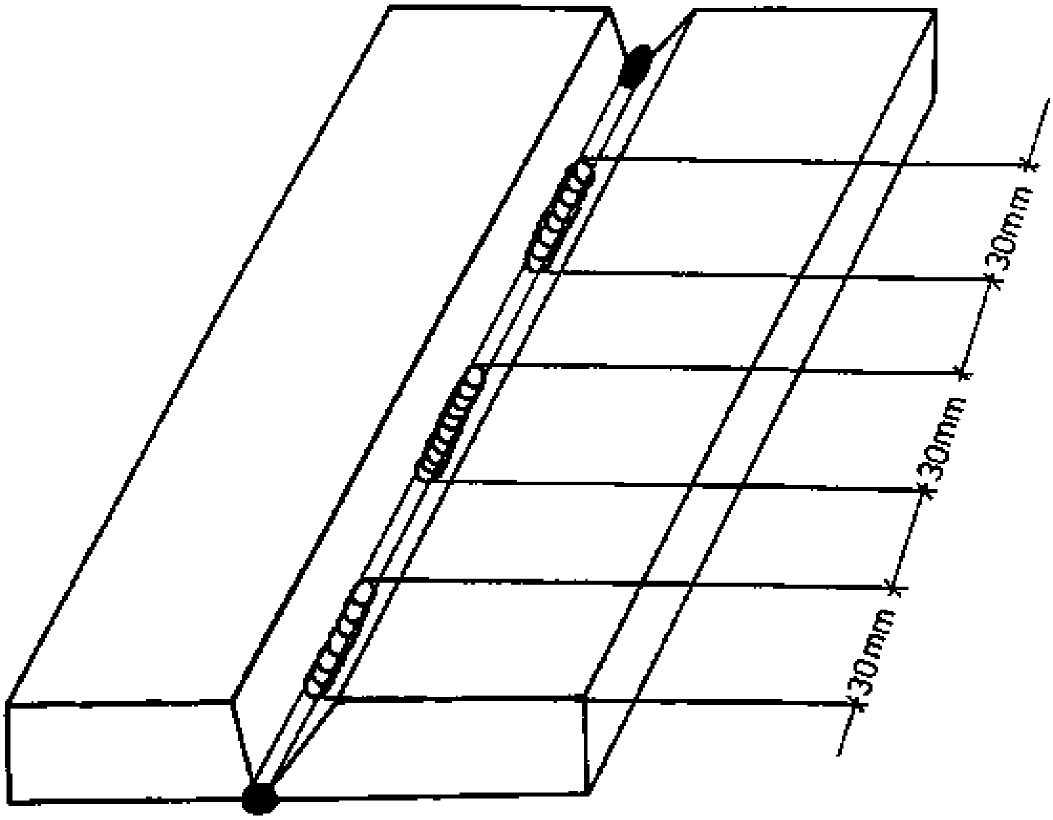


Fig. 13 Tacks in the gravity position

Use an electrode of type "Titan" E 43 4 BE (B) 22 with red colour marking.

Demonstrate the tack welding to the trainees.

Inform the trainees of the following points of importance:

– Adjust the amperage to appr. 110 A.

– The first tack is welded at a distance of 20 mm from the beginning of the seam at the left–hand side.

– The second tack is started at a distance of 50 mm from the right–hand end of the seam.

– The third tack is placed in the middle of the remaining weld groove.

– This welding sequence will avoid a high degree of shrinkage of the V type weld, which would cause the necessary root opening to disappear.

– After ignition, the electrode, with a somewhat longer arc (arc length of appr. 5–6 mm), is moved over a distance of about 10 mm in the direction of the beginning of the seam. At this point let the electrode dwell for a moment, until the beginning of the seam is sufficiently heated up. Then, using an arc length of 3–4 mm, perform a stippling motion without moving the electrode forwards, until the weld metal threatens to sag. At this very moment move the electrode forwards along an arc–like path being open in the direction of welding, as it is done in root welding. After welding a tack 30 mm long, the end crater must be filled. This filling is achieved by pushing the electrode very close to the weld metal in order to obtain a short arc. Then do not move the electrode but hold it in a fixed position until the end crater is filled. Now the electrode must not be drawn in the direction of welding or upwards, but it is moved back to the finished tack weld with a short arc, which is extinguished there. This avoids cracks and pores in the end crater.

– After welding all three tacks, clean the weld carefully from slag and spatter.

3.4. Welding the tacks in the vertical–up position

Weld two tacks with a length of 30 mm each in the vertical–up position.

The arrangement of the tacks can be observed from the figure below.

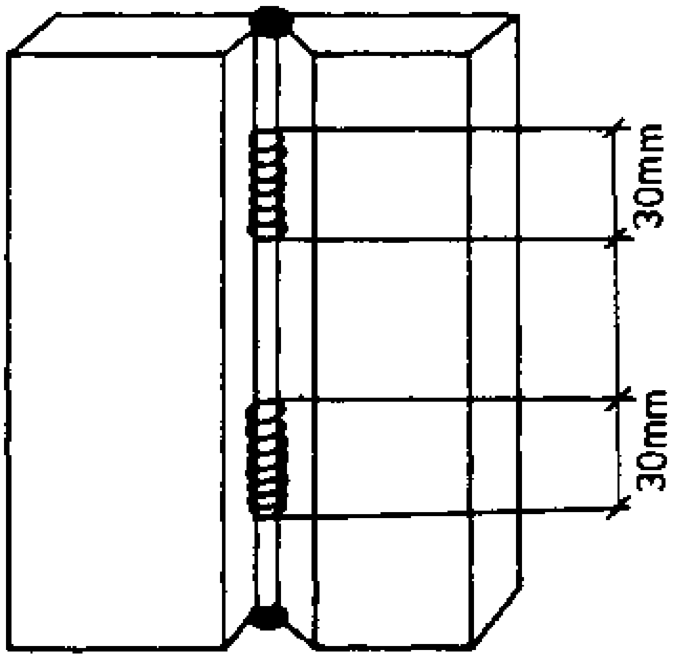


Fig. 14 Tacks in the vertical–up position

– The first tack in the vertical–up position is again started at a distance of 20 mm from the beginning of –the seam; the second tack likewise ends at a distance of 20 mm from the end of the seam.

– Otherwise than in the gravity position, in the vertical–up position the arc is started directly at the beginning of the tack weld. As soon as the arc has been started, the electrode is weaved from left to right and back along a straight line, with an arc length of appr. 5 mm, until the weld is sufficiently heated up. As soon as the weld metal threatens to flow off the arc length is reduced (to appr. 3 mm), and then the electrode is weaved over the specified tacking distance in the same way as in vertical–up root welding.

At the end of the seam, the end crater must again be filled. As described above, this is achieved by holding a short arc in a fixed position until the end crater is filled. At this very moment the electrode is drawn back to the finished weld with a short arc, and the the arc is extinguished.

– After finishing the tack welding, clean the specimen carefully from slag and spatter.

3.5. Evaluation of the finished tacks

Evaluate the finished tacks together with the trainees. Inform them of the criteria of evaluation.

Evaluate

– the weld appearance of the tack,
– the uniformity of bead ripples,
– the end craters,
– undercutting and
– weld spatter.

Discuss the welding faults and their causes very thoroughly.

Evaluation of the Section "V type welding with 5 tacks"

Having finished the training section on tack welding, the trainees should have acquired the following knowledge, capabilities and skills:

- Obeying the labour safety regulations including order and cleanliness at the working place
- Preparation of the welding specimen
- Mastering gravity and vertical–up tack welding
- Recognition of typical welding faults in V type welds
- Evaluation of their own work.

Examples of questions on the Section "V type welding with 5 tacks"

1. Describe assembling and tacking of the V type welds.
2. Th what extent does a non–uniform root opening affect the quality of root welding?
3. Explain the sequence of tack welding in the gravity position.
4. What are the dangers arising for a weldor from wet working gloves?

4. Welding a profile joint with a root pass and two cover passes

The hitherto acquired skills in electric welding are prerequisite to the discussion of the following section. To begin with, clarify and recapitulate, respectively, the concepts of a profile joint, the root, cover passes and the horizontal position.

Let one of the trainees explain and illustrate the concepts of root and cover passes by means of a blackboard sketch before the other trainees.

4.1. Preparation of the welding specimen

Informe the trainees of the dimensions of the welding specimen. Explain the condition the welding specimen must exhibit.

- Use an NT 10... NP 16 channel profile, i.e. a standard profile, with a length of 100 mm to 160 mm and a height of 50 mm.

- Further a base plate 10 to 16 mm thick is required, which is 50 mm longer and wider than the channel profile.

The channel profile must fit properly and closely to the base plate. Therefore it is recommended to cut it to size using a steel sawing machine.

The base plate can be prepared in the usual way by flame cutting. Take care that the base plate is perfectly flat.

If necessary, the plate must be straightened by hammer blows or with a hydraulic press.

The plate surface should be cleaned from rust, scale or paint residues, oil and grease with a wire brush.

The channel profile cut off, with a height of 50 mm, should also be carefully cleaned from cutting burr and rust coatings.

Point out to the trainees that a proper preparation of the component to be welded will avoid many welding faults. In many cases porosity is simply due to contaminated plate surfaces.

Check the preparation of the welding specimen.

Make sure that the dimensions of the welding specimen as specified by you are adhered to.

4.2. Tacking the specimen

Demonstrate assembling and tacking of the specimen. For that purpose, place the channel profile centrally on the base plate and fix the two parts with a screw clamp. Check that there is no gap between the channel profile and the base plate.

Both parts must fit closely to each other.

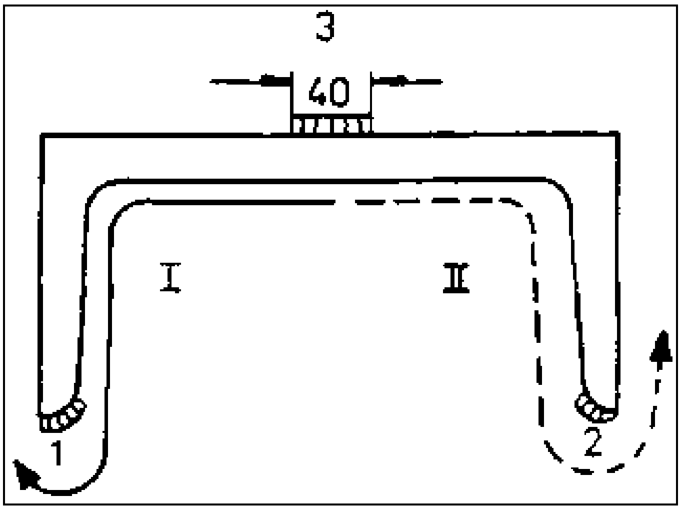


Fig. 15 Channel profile tacked on the base plate; the figure indicates the welding sequence

Now place the tacks No. 1, 2 and 3. Clean the tack spots from slag and the welding specimen from possible spatter. Check the proper tacking of the welding specimen by the trainees.

4.3. Welding the profile joint

The channel profile is joined to the base plate with a fillet weld. One root pass and two cover passes are welded. Draw the trainees' attention to the fact that for fillet welds higher amperages are necessary than for butt welds of comparable plate thicknesses. In welding the profile joint, the arc blow effect will show most evidently; here this effect can only be counteracted by a suitable electrode manipulation.

4.4. Welding the root pass

Demonstrate root welding to the trainees.

Place the tacked specimen so that you face the open side of the channel profile. For the electrode of type "Titan" E 43

4 RR (B) 22, with a diameter of 4 mm, adjust the amperage to 180 A.

Now begin with the demonstration of root welding.

- The root pass is first welded on one half of the inner side of the profile. In this operation the electrode is tilted by an angle of 45 °, being melted off with slightly stippling motions.

  Thus welding is started from the middle of the inner side to the right or to the left.

- When welding to the left, the arc will heavily blow to the left if the electrode is arranged perpendicularly to the web plane. Therefore the electrode is tilted to the left, i.e. in the direction of welding, by such an angle that the arc is perpendicular to the molten bath.

Demonstrate these sequences of motions to the trainees. When the trainees practise welding profile joints, you should also take special care that they counteract the arc blow effect properly.

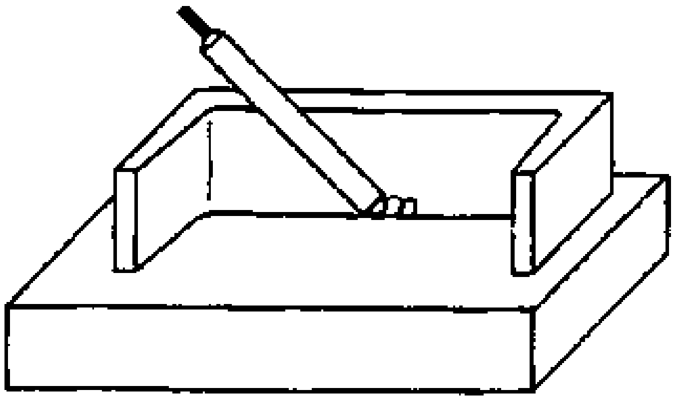


Fig. 16 Electrode position at the beginning of the weld

– After the corner has been welded, the arc blow effect turns the arc towards the seam, so that the electrode must again be given an opposite tilt.

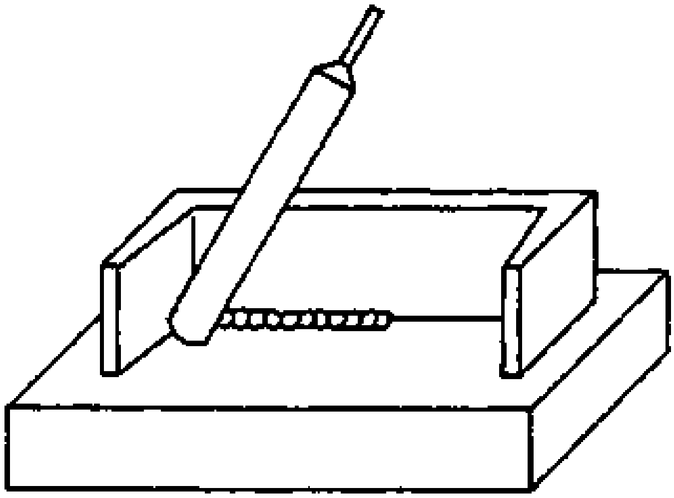


Fig. 17 Electrode position after passing the corner

Now the occurring arc blow effect may also be so strong that the necessary tilt angle cannot be realized, because the web of the channel profile obstructs tilting. In this case the electrode must be slightly bent, but without damaging the electrode coating.

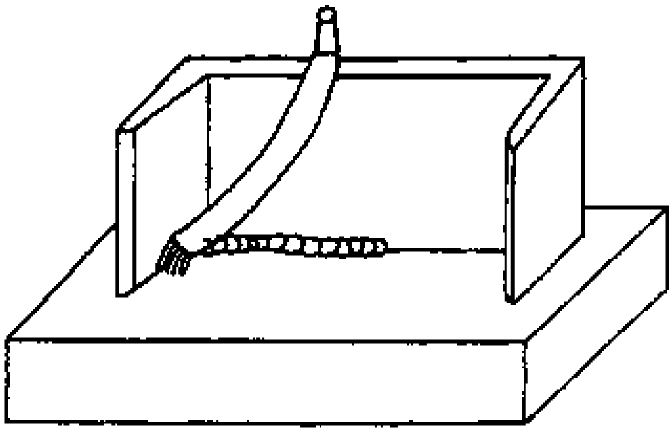


Fig. 18 Electrode bent to counteract an excessive arc blow effect

– The root pass is welded up to the flange edge, i.e. the tack is overwelded. An analogous procedure is adhered to in welding the other half of the profile.

After welding the root pass on the inner side, weld the root pass on the outside of the profile.

Here the arc blow effect is no longer so strong, so that the bead can be laid without an interruption. The direction of welding – to the left or to the right – is arbitrary.

After root welding has been finished, clean the specimen carefully from slag residues and spatter.

Check the root weld for the central arrangement of the root pass and for possible welding faults such as porosity, slag pockets and undercutting.

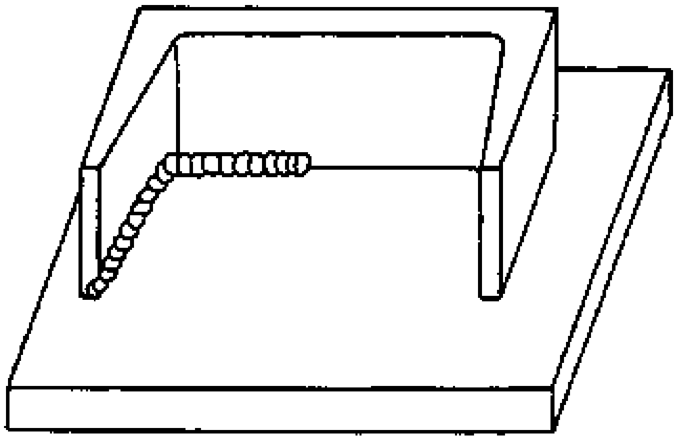


Fig. 19 Finished first half of the root pass

4.5. Welding the first cover pass

Demonstrate welding the first cover pass to the trainees. Place the specimen so that you face the open side of the channel profile.

For the electrode of type "Titan" E 43 4 BE (B) 22, with a diameter of 4 mm, adjust the amperage to appr. 180 – 190 A. Now begin with the demonstration of welding the first cover pass.

Point out to the trainees that the first cover pass must cover two thirds of the root pass.

Use the same technique as in welding a fillet weld.

The welding sequence is the same as in root welding. Take care that the arc strike is displaced from that of the root pass by about 2 cm.

After the first cover pass has been finished, clean the specimen carefully from slag residues and spatter. Check the first cover pass for uniformity, possible porosity, slag pockets, undercutting and faulty arc strikes. Discuss the causes and the prevention of welding faults with the trainees.

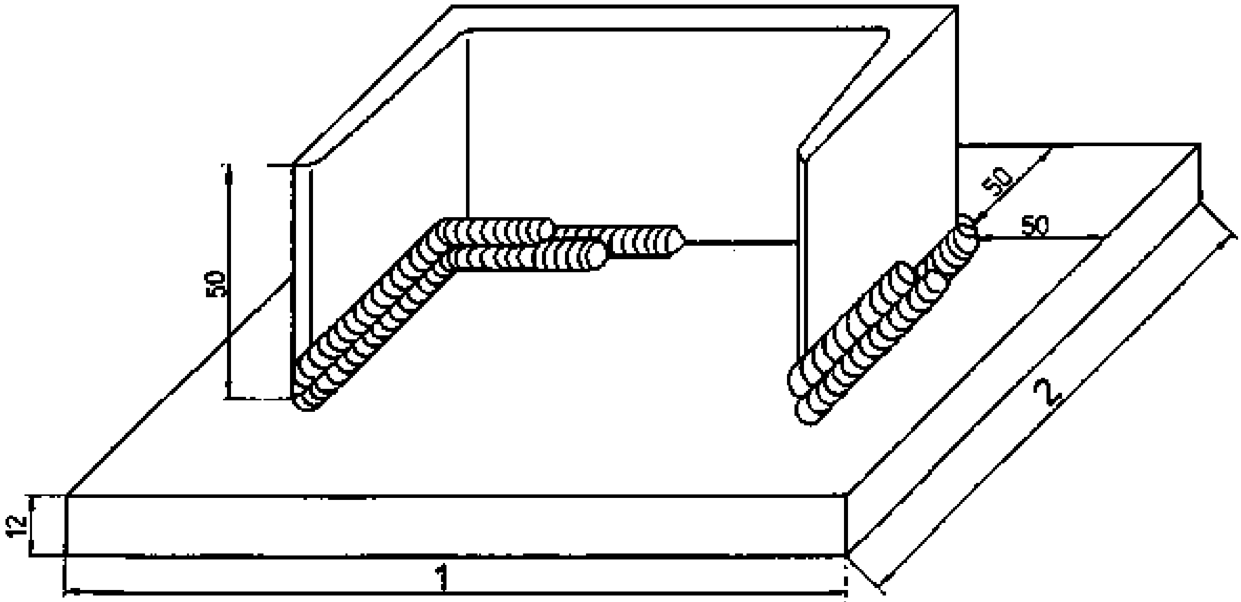
4.6. Welding the second cover pass

Demonstrate welding the second cover pass to the trainees. Place the welding specimen so that you face the open side of the channel profile.

For the electrode of type "Titan" E 43 4 RR (B) 22, with a diameter of 4 mm, adjust the amperage to appr. 180 – 190 A. Now start welding the second cover pass.

Take care that this pass covers one third of the first cover pass as well as the remaining, still visible part of the root pass. Use the same welding sequence as in root welding. Take care that the arc strike is displaced from that of the first cover pass by about 2 cm.

After finishing the second cover pass, clean the specimen most thoroughly from slag residues and spatter.



1 – Longitudinal face of the base plate
2 – Transverse face of the base plate

Fig. 20 Buildup of the individual passes

4.7. Evaluation of the welded profile joint

Evaluate the finished fillet weld together with the trainees. In form them of the criteria of evaluation.

Evaluate the weld appearance and the accuracy to size.

– Weld appearance

• Symmetry of the weld buildup
• Uniformity of the bead ripples
• Arc strikes
• End craters
• Undercutting
• Weld spatter

– Accuracy to size

• Determine the three measuring points by means of a weld gage.

For fillet welds in the horizontal position, a variation of +1.0 mm from your specified weld height is permissible. Just as in the other cases, you should also prepare faulty and properly welded specimens for illustration.

Discuss the causes of the welding faults.

Evaluation of the Section "Welding a profile joint with a root pass and two cover passes"

Having finished the training section on welding a profile joint, the trainees should have acquired the following knowledge, capabilities and skills:

– Obeying the labour safety regulations including order and cleanliness at the working place
– Preparation of the welding specimen
– Welding profile joints
– Recognition of typical welding faults
– Evaluation of their own work.

Examples of questions on the Section "Welding a profile joint with a root pass and two cover passes"

1. What are the measures you take to counteract the arc blow effect in welding a profile joint?

2. What are the dangers a weldor is faced with by weld spatter?

How do you protect yourself from spatter?

3. Explain the welding sequence in welding a profile joint.

4. What is the effect of the welding amperage on the weld appearance?

5. Fillet welding in the semioverhead position

Recapitulate the concepts of a fillet weld and of the semioverhead position.

The procedure up to welding the root pass is the same as in fillet welding in the horizontal position. Therefore, up to the section "Welding the root pass", proceed as described in the instructions on horizontal fillet welding.

5.1. Welding the root pass

Demonstrate root welding to the trainees.

For that purpose, clamp the fillet weld specimen in a positioning fixture with the boom up and the web plate down.

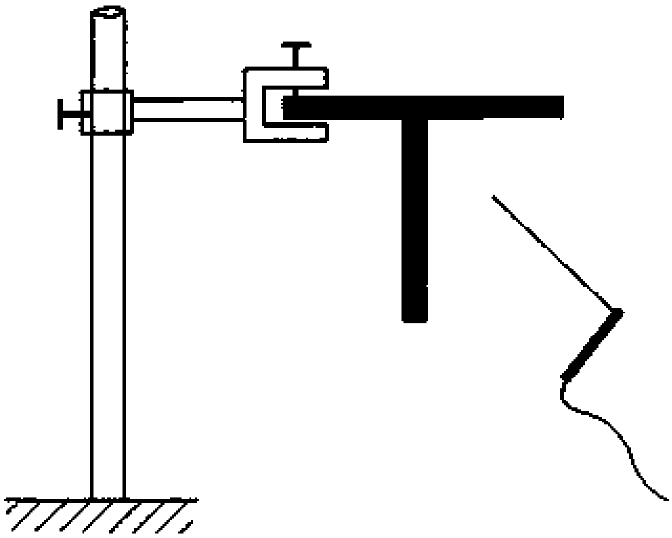


Fig. 21 Fillet weld specimen clamped in a positioning fixture in the semioverhead position

Sequence of operations in fillet welding:

- Adjust the amperage to appr. 140 A.

- Start the arc at the left outer edge of the fillet weld.

- Weld the root pass as a string bead.

- In doing so, consider that at the beginning of the root welding the fillet weld specimen is still cold and must first be preheated with a longer arc.

After one or two centimeters of the root pass, the arc can be shortened to its normal length.

- Generally, use as short an arc as possible in semioverhead welding.

– To obtain a symmetrical, central weld buildup, the electrode position must be such that an angle of 70 ° between the electrode and the boom plate is exactly maintained.

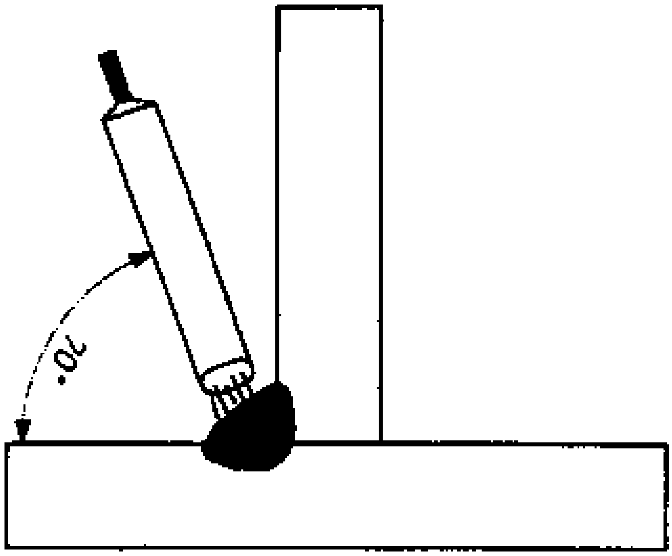


Fig. 22 Electrode position in welding the root pass

– In depositing the string bead, take care to perform a slightly stippling motion in the direction opposite to the drawing direction of the electrode. This "stippling motion" ist intended to yield a better base metal penetration.

– Pay attention to the arc blow effect.

– Counteract the arc blow effect by tilting the electrode in the direction of welding at the beginning of the seam in a direction opposite to that of welding when approaching the end of the seam.

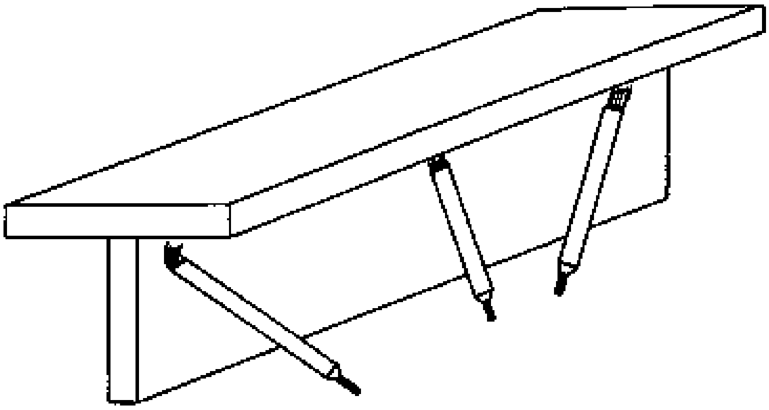


Fig. 23 Electrode manipulation for minimizing the influence of the arc blow effect

Discuss the consequences of disregarding the arc blow effect with the trainees.

This may lead to welding faults such as

– an interrupted seam,
– slag inclusions,
– heavy spattering at the side walls of the seam, etc.

For the seam length of 200 mm, an electrode change will be required.

Tell the trainees to proceed as follows:

Clean the seam end from slag and spatter. Start the arc with the new electrode in the lower part of the end crater. A gradual preheating is absolutely required in order to melt the end crater, which is achieved by a slight weaving motion with a long arc. Start the actual depositing of weld metal not earlier than at the moment when the weld metal threatens to flow off. A slight overhang of the weld is better than a lack of fusion. If necessary, remove the weld overhang by chipping.

– Take care that the end crater of the root pass is properly filled. This is achieved by shortening the arc.

After the root pass has been finished, the fillet weld is carefully cleaned from slag and spatter.

Slag residues and slag pockets cannot be removed by overwelding.

Check the root weld for the central position of the root pass and for possible welding faults such as porosity, slag pockets and undercutting.

5.2. Welding the first cover pass

Demonstrate welding the first cover pass to the trainees. For that purpose, use an electrode 3.25 mm in diameter. Adjust the amperage to appr. 130 A.

Weld the first cover pass as a string bead with a slight weaving motion.

The first cover pass should only cover one half of the root pass. The tilt angle of the electrode should be 80° from the boom plate.

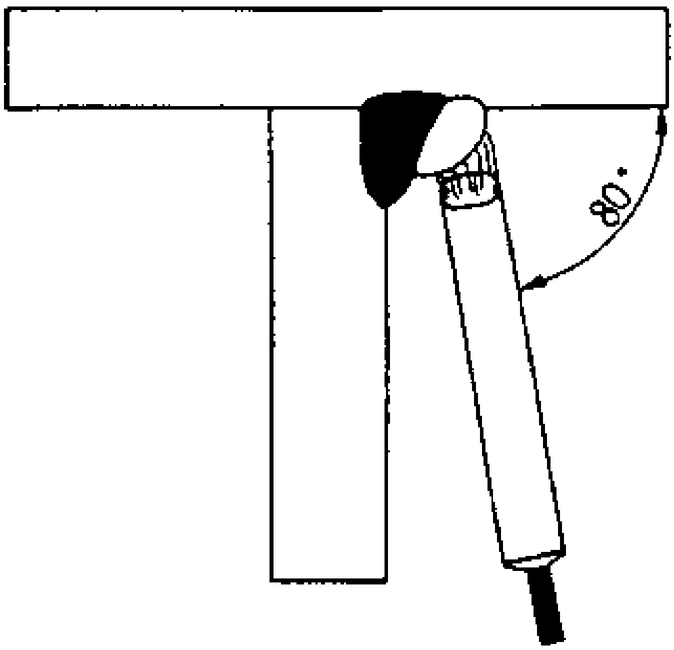


Fig. 24 Electrode position in welding the first cover pass

Cool the fillet weld and clean it from slag residues and spatter.

5.3. Welding the second cover pass

Demonstrate welding the second cover pass to the trainees. Use an electrode diameter of 3.25 mm.

Adjust the amperage to appr. 130 A.

The second cover pass must cover one third of the first cover pass as well as the remaining, visible part of the root pass.

The tilt angle of the electrode should be 75 ° from the boom plate.

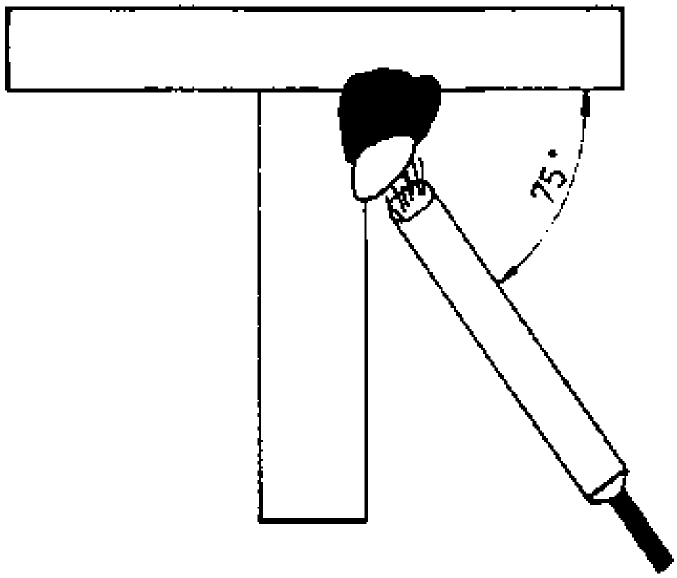


Fig. 25 Electrode position in welding the second cover pass

– When changing the electrode, proceed as described in the root welding instructions.
– Fill the end crater.
– Cool the fillet weld and clean it from slag residues and spatter.

5.4. Evaluation of the finished fillet weld

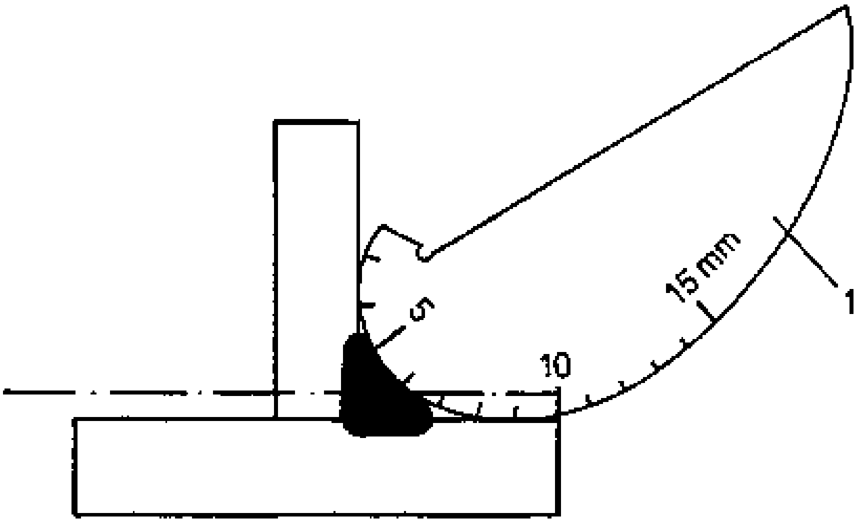
Evaluate the finished fillet weld together with the trainees. Inform the trainees of the criteria of evaluation. Evaluate the weld appearance, the accuracy to size and the fracture appearance by the following criteria:

– Weld appearance

• Symmetry of the weld buildup
• Uniformity of the bead ripples
• Arc strikes
• End craters
• Undercutting
• Weld spatter

– Accuracy to size

• Determine the three measuring points by means of a weld gage. Let one of the trainees check the accuracy to size. Make corrections if necessary.



1 - weld gage

Fig. 26 Weld gage for measuring the fillet weld height

For fillet welds in the semioverhead position, a variation of + 2.0; – 0.5 mm in the weld height is permissible.

– Fracture appearance

To evaluate the fracture appearance, break the fillet weld specimen in a suitable device.

Evaluate the fracture appearance by the following criteria:

- – Melting of the web plate edge
- – Slag inclusions
- – Porosity and lack of fusion

Evaluation of the Section

Having finished the training section on fillet welding, the trainees should have acquired the following knowledge, capabilities and skills:

- – Obeying the labour safety regulations including order and safety at the working place
- – Preparation of the welding sample
- – Matering fillet welding in the semioverhead position
- – Recognition of typical welding faults in fillet welds
- – Evaluation of their own work

Examples of questions on the Section "Fillet welding in the semioverhead position"

1. Describe the buildup of a fillet weld in the semioverhead position.
2. What are the typical welding faults in semioverhead fillet welding?
How can you avoid such faults?
3. Explain the properties of the welding electrodes employed.
4. Explain the necessity of most careful labour safety measures.

Electric Welding 4 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

Table of Contents

Electric Welding 4 – Course: Techniques of Electric Welding. Methodical Guide for Instructors

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0. Preliminary remarks

The present methodical instructions for the impartation of knowledge, abilities and skills in electric welding have been developed for instructors of practical vocational training. These methodical instructions are intended for the instructor to give him help and suggestions in preparing and carrying–out the practical vocational training. Ways of solution are proposed to the instructor showing him how he can reach the aims in his pedagogical activities. The methodical instructions are arranged in such a way that the trainees are systematically familiarised with

- square butt welding in gravity position
- edge fillet welding in horizontal and semioverhead position
- V type horizontal–vertical welding
- pipe butt welding

In this connection the preparation of the plates and the corresponding electrode manipulation are the focal points. Learning the above mentioned welds and welding positions represents a continuation of the methodical instructions of "Electric welding 1, 2 and 3". The sequence of learning the kinds of weld and welding positions has been laid down on the basis of the experiences in the training of electric weldors. Consequently, mastering the welding of the types of weld and welding positions presented in the methodical instructions of "Electric welding 1, 2 and 3" is the basis of learning the types of weld and welding positions of these instructions. After having successfully passed the examination, the trainees are entitled to make

- square butt welding in gravity position
- edge fillet welding in horizontal and semioverhead positions
- V type horizontal−vertical welding
- pipe butt welding

at plates resp. tubes with a thickness of plates resp. wall of 6 to 12 mm.

1. Square butt welding in gravity position

Present several types of welds to the trainees in the form of a blackboard diagram. Let one of the trainees select the square butt weld. In this connection, explain the types of position. Recapitulate the concept of gravity position. Define the concepts of the square butt weld and the gravity position.

Explain to the trainees that for sheet metal with a thickness of less than 4 mm butt welds can be carried out as square butt welds. Other than with V type welds, the side walls of the weld are not beveled. They remain angular.

1.1. Preparation of the training plates

Inform the trainees of the required dimensions and condition of the training plates.

- Two 100 x 200 mm plates 3 mm thick are used.
- The seam edges must be angular.
- The plates must be flat and must have a clean surface.

To meet these requirements, prepare the plates accordingly by plate cutting.

Present an uneven, uncleaned plate and demonstrate how it is straightened and cleaned.

Draw the trainees' attention to the following main points:

- A possible burr due to plate cutting must be carefully removed by means of a file.

- The surface of the plate must be cleaned from rust, scale or paint residues, oil and grease by means of a wire brush.

- The groove faces must be free from scale drag lines, burr and other unevennesses. If required, the faces must be smoothed by "filing or grinding. −

Check the preparation of the training plates.

1.2. Tacking the square butt weld

Demonstrate how the square butt weld is assembled and tacked.

Explain to the trainees that for all butt welds, a shrinkage occurs along and across the seam during and after welding. As for square butt welds little weld metal is deposited, i.e. little heat is introduced, the transverse shrinkage can be neglected as an influencing factor for the tacking of the weld.

Place the two plates on a flat back−up plate in such a way that a root opening of 2.5 ... 3.0 mm is obtained. Let the trainees themselves decide as to which root opening shall be used in the welding operation.

Note that beginners like to use a root opening of less than 2.5 mm. This will result in an inadequate through−welding. Demonstrate this fact by an experiment.

Point out to the trainees that square butt welding requires much practise and patience, that the root opening of 2.5 ... 3.0 mm must absolutely be adhered to, and that the tack−welding is carried out at the two outer ends of the square butt weld.

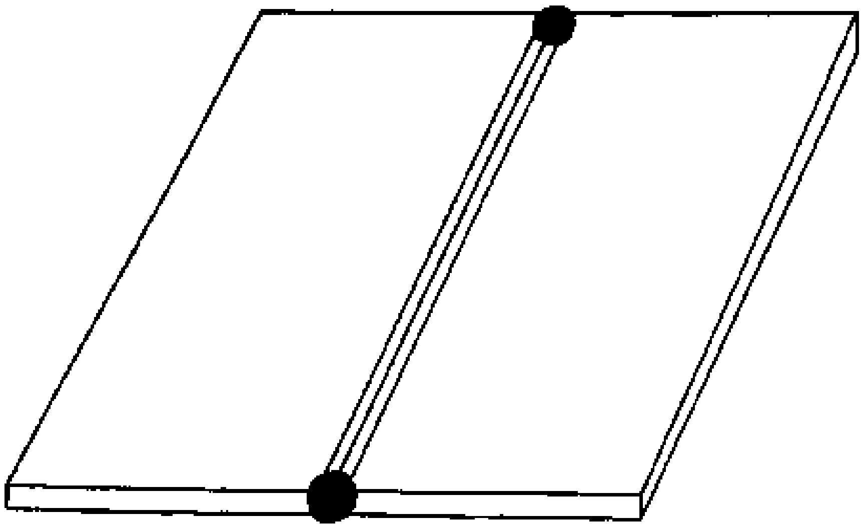


Fig. 1 Tacking the square butt weld

The tacks must be carefully cleaned from slags and spatter. The plates should be re−straightened once again in order arrange them absolutely within one plane.

Check the proper tacking of the V type weld by the trainees.

1.3. Welding the square butt weld

Explain to the trainees that a single−pass weld is carried out for a plate thickness of 3.0 mm, i.e. the cover pass and the root pass are welded within one run. The weld reinforcement is not specified here. However, point out that weld reinforcements must be kept as flat as possible. Such thin−material welding must be carried out very carefully, because a correction in subsequent passes, as it is done with V type welds, is possible.

− For square butt welding, use the "Anker" E 43 2 R 12 type electrode, with white colour marking.

Check the knowledge of the trainees concerning the electrode type. Summarize the advantages of this electrode as follows:

− The large−drop metal transfer provides for a good bridgeability.
− The electrode is suitable for all welding positions.
− It can be welded with d.c. straight polarity current, but also with a.c. current.

Point out to the trainees that, if this electrode is used, a somewhat longer arc must be held and a very smooth electrode manipulation is necessary.

Demonstrate square butt welding to the trainees. Here the trainees note the following sequence of welding operations:

− For the electrode with a core diameter of 3.25 mm, adjust the current strength to appr. 80 A.

− Preheat the tack area with a long arc. As soon as the tack begins to melt, welding is continued with a short arc (length 3.0 mm).

– As in single–pass welding the root and the cover pass must be welded in one run, the triangular electrode manipulation is used.

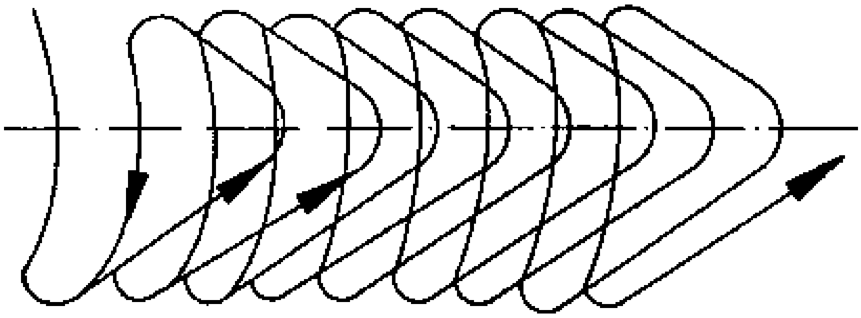


Fig. 2. Electrode manipulation in square butt welding

In your demonstration, discuss especially how the arc blow effect is counteracted.

– The square butt weld should first be carried out from left to right over 30 mm, thereafter the plate is rotated by 180° and the square butt weld is finished. This will counteract transverse shrinkage.

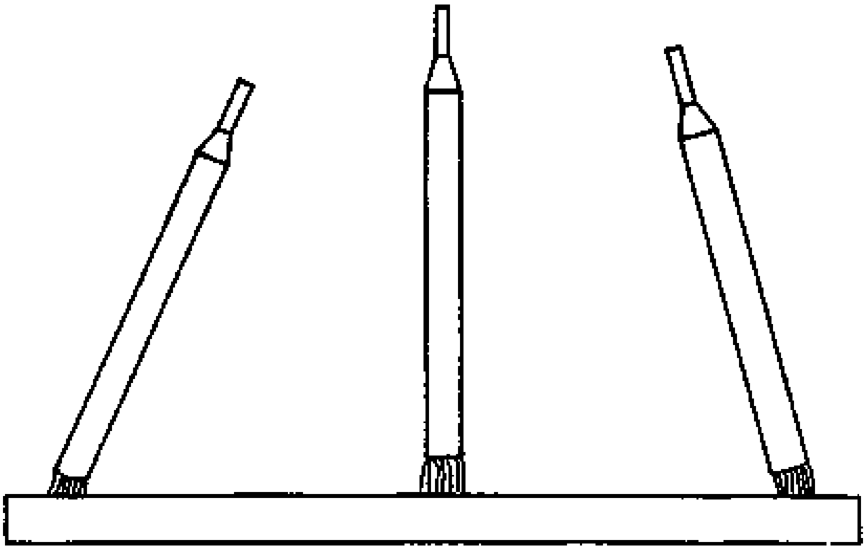


Fig. 3. Electrode position required to counteract the arc blow effect

– Holding the so – called "pear" ensures a satisfactory through–welding and a uniform root fusion.

– When the electrode has been changed, then after ignition the electrode is again held with a somewhat longer arc at the weld surface for a certain time; as soon as the arc strike area begins to melt, welding is continued using the triangular electrode manipulation as described above.

– During the welding operation, the length of the arc should always be adapted to the respective situation.

– A uniform heat input, and hence a uniform welding output is achieved by varying the arc length and the welding speed.

– Slag and weld metal should be observed very carefully. Slag appears light–red, weld metal appears dark – red.

Let one of the trainees again summarize the most important points. In a discussion, work out those points which determine the quality of a square butt weld.

• Variation of the welding speed (weaving)
• Variation of the arc length

• Variation of the rhythmic electrode manipulation
– After the root welding has been completed, the square butt weld is carefully cleaned from slag and welding spatter.

Check the square butt weld for possible welding faults such as insufficient through–welding or excessive through–welding (fusion) of the root.

Let the trainees practise square butt welding.

Evaluate the exercise in a discussion.

Evaluation of the Section "Square butt welding in the gravity position

Having finished the training section of fillet welding, the trainees should have acquired the following knowledge, capabilities and skills:

– Observing the labour safety regulations including order and cleanliness at the working place
– Preparation of the welding specimen
– Mastering square butt welding in the gravity position
– Recognition of typical welding faults in square butt welds
– Evaluation of their own work

Examples of questions on the Section "Square butt welding in the gravity position"

1. Describe tacking and welding of a square butt weld.
2. Explain the marking and the properties in use of the welding electrode employed.
3. What is the effect on the weld quality of a heavy contamination of the plates by oil, grease or paint?
4. What are the personal labour safety devices to be used by a weldor?

2. Edge fillet welding in the horizontal and the semioverhead position

To begin with, recapitulate the points to be considered in fillet welding. Thereafter recapitulate the concepts of an edge fillet weld and the horizontal and semioverhead positions.

Start the discussion of this section only if the trainees master square butt welding in the gravity position. Prepare a blackboard drawing of an edge fillet weld. Let one of the trainees sketch the horizontal and semioverhead positions of the electrode in the drawing.

2.1. Preparation of the plate specimens

Inform the trainees of the plate dimensions. Discuss the condition of the plate specimens.

– 2 100 x 200 mm plates 3 mm thick and 2 50 x 200 mm plates 1 mm will be require.

As described in the preceding instructions, the plates must be prepared in a suitable way. Check the preparation of the plate specimens.

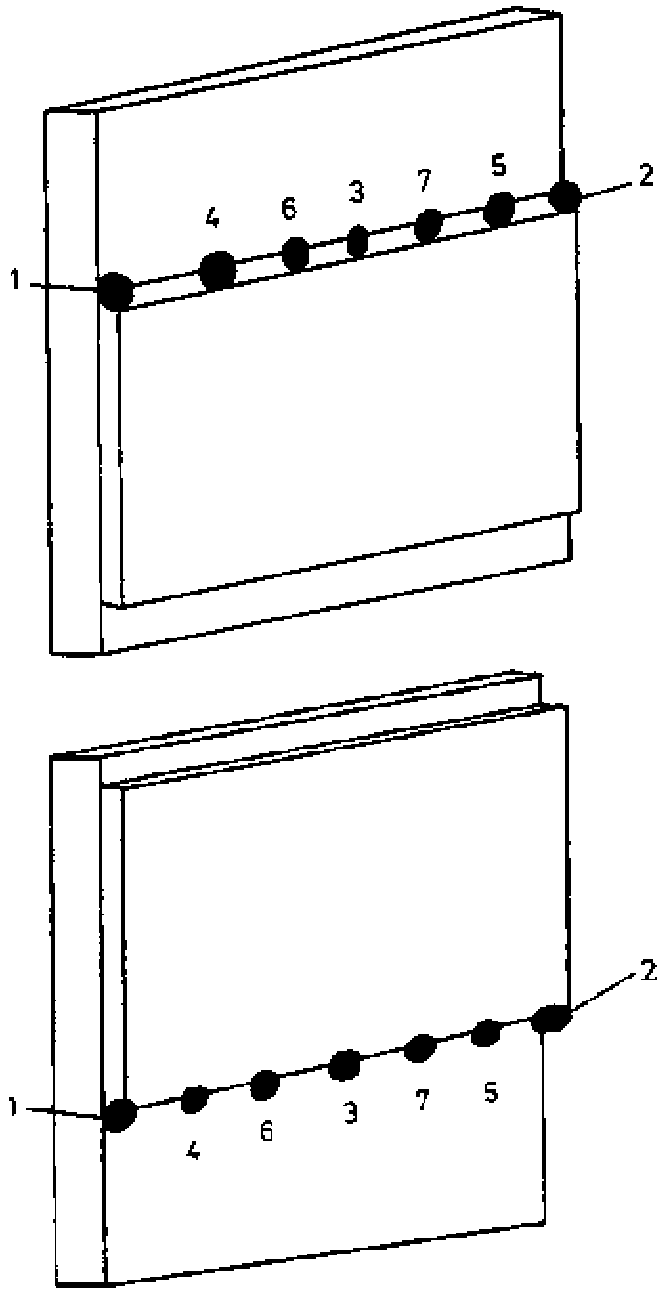
2.2. Tacking the edge fillet weld

Demonstrate the assembling and tacking of the edge fillet weld.

– In this exercise, two main tacks (1) and (2) are placed, one at each end of the welding specimen.

– In addition, another 5 small tacks are necessary in order to prevent the thin sheet lifting off the thicker plate as the seam is welded.

The sequence of tacking can be observed from the figure below.



1 horizontal position
2 semioverhead position

Fig. 4. Edge fillet weld with tacking sequence

Point out to the trainees that there must not be any air gap between the thin and the thick plates. If the two plates do not properly fit to each other, the thinner one will immediately burn away.

After completion of tacking, all the tack spots must be carefully cleaned from slag residues and spatter. Check the orderly tacking of the edge fillet weld by the trainees.

2.3. Welding the edge fillet weld in the horizontal and the semioverhead position

Use an "Anker" E 43 2R 12 type electrode. This electrode is an universal type for joint and tack weldings. Discuss the possible applications of this electrode. Explain to the trainees that this electrode can be used in d.c. straight polarity welding or in a.c. welding. Use electrodes 2.5 mm in diameter.

Demonstrate edge fillet welding to the trainees first in the horizontal position. Subsequently demonstrate fillet welding in the semioverhead position. Point out the differences between fillet welding in the horizontal and the semioverhead position.

– The amperage for the electrode 2.5 mm in diameter is adjusted to 70 A when welding in the horizontal position and to 60 A in the semioverhead position.

– The tacked plate is clamped in the positioning fixture.

Point out to the trainees that an exact position of the electrode is necessary. It must be arranged at an angle of 60° from the thicker plate.

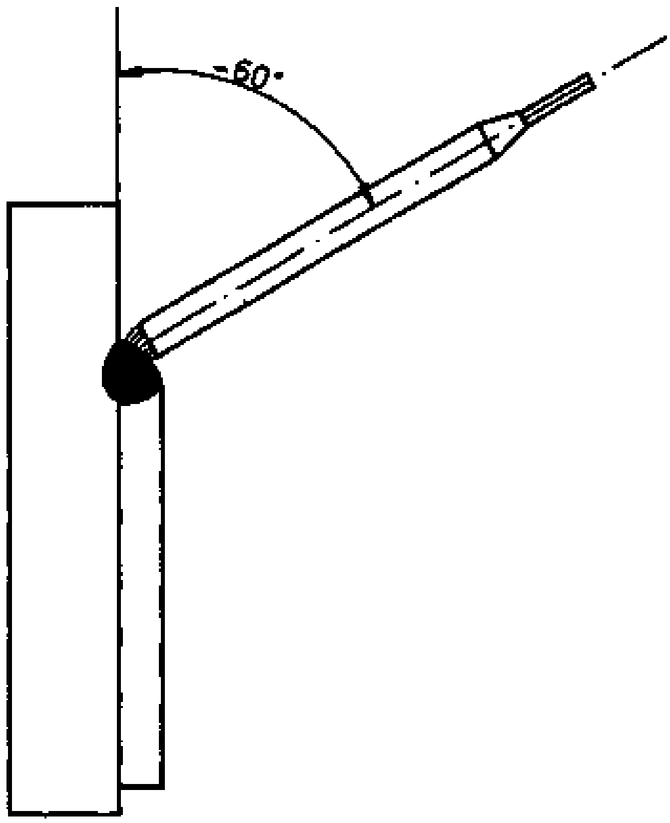


Fig. 5. Electrode position for edge fillet welding in the horizontal position

– To counteract the arc blow effect, the electrode position must be the same as with fillet welds, i.e. at the beginning and the end of the seam it must be tilted towards the centre, whereas in the central range it is held perpendicularly to the weld.

– There is no weaving of the electrode, but the welding is carried out in the stringer bead technique.

– Upon ignition, the thin sheet is touched (stippled) for a moment, and immediately thereafter the electrode is again pointed at the thicker plate.

– After finishing the weld, the plate must be carefully cleaned from slag and spatter.

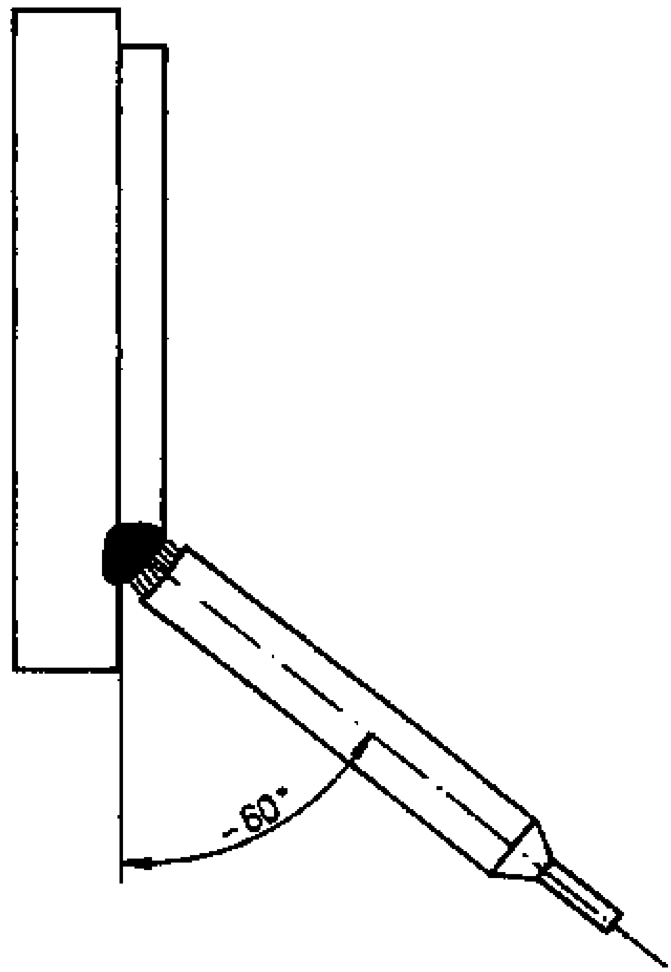


Fig. 6. Electrode position for semioverhead edge fillet welding

2.4. Evaluation of the completed edge fillet welds

Evaluate the completed edge fillet welds together with the trainees. Inform them of the criteria of evaluation. Evaluate the appearance of the weld by

- the uniformity of the string bead
- the undercutting
- the welding spatter
- the end crater.

Discuss the weld faults with the trainees again. Compare properly welded and faulty specimens.

Weld faults and their causes

Weld fault	Cause
Poor bead ripple pattern of the string bead	non−uniform electrode manipulation
Undercutting	excessively long arc, excess current
The thinner plate is perforated	inadequate fitting of to the thicker one the thinner plate
Lack of fusion	amperage too low, excessive welding speed, unsuitable electrode manipulation

Subsequently, let the trainees practise edge fillet welding, first in the horizontal position and thereafter in the semi−overhead position.

Evaluation of the Section "Horizontal and semioverhead edge fillet welding"

Having finished the training section of edge fillet welding, the trainees should have acquired the following knowledge, capabilities and skills:

- Observing the labour safety regulations including order and cleanliness at the working place
- Preparation of the welding specimen
- Mastering edge fillet welding in the horizontal and the semioverhead position
- Recognition of typical welding faults in edge fillet welds
- Evaluation of their own work.

Examples of questions on the Section "Edge fillet welding in the horizontal and the semioverhead position"

1. Describe the properties of the welding electrode employed.

2. What measures do you take to protect yourself from falling weld metal drops and spatter in semioverhead welding?

3. Describe the weld preparation and the tacking of the edge fillet weld.

4. Explain the concept of a lap joint.

3. Horizontal–vertical V type welding

Recapitulate the buildup of a V type weld in a discussion at the beginning of this section. This discussion should also include the positions. Let one of the trainees sum up the horizontal–vertical position.

- If two plates are butt–welded to each other at their edges, then this seam is called a butt–welded seam.
- For a plate thickness of more than 4 mm, a weld preparation is required.
In the range from 4 to 15 mm a V type weld is chosen; for thicker plates double–V welds are applied.

Sketch the buildup of a V type weld on the blackboard. Sum up the terms associated with a V type weld in a discussion by having one of the trainees associate the respective term mentioned by you to an item on the blackboard sketch. For that purpose, use the methodical instructions for V type welding. Subsequently inform the trainees of the objective of this section.

It is useful to start practising horizontal–vertical V type welding not earlier than the trainees have acquired capabilities and skills in horizontal and semioverhead edge fillet welding. Therefore let one of the trainees carry out an edge fillet weld in the horizontal position, and another trainee, in the semioverhead position. Evaluate the weld together with the trainees. Accord praise to a good workmanship.

Summarize the most important points to be considered in horizontal and semioverhead edge fillet welding. Only thereafter enter into the discussion of horizontal–vertical V type welding.

3.1. Preparation of the plate specimens

Inform the trainees of the dimensions and the condition required for the plate specimens.

- Two 100 x 200 mm plates 10... 12 mm thick will be used.
- The bevel angle of the plates is 30°.
- The plates must be plane and must have a clean surface.

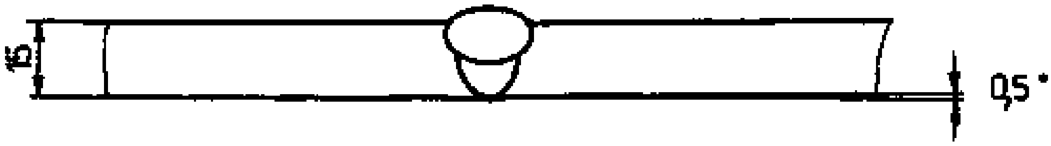
Check the preparation of the plate specimens.

3.2. Tacking the V type weld

Demonstrate the assembling and tacking of the V type weld in the horizontal–vertical position. For all seams, a shrinkage along and across the seam occurs during and after welding. Draw the trainees' special attention to the fact that with horizontal–vertical V type welds there is a very pronounced angular shrinkage.

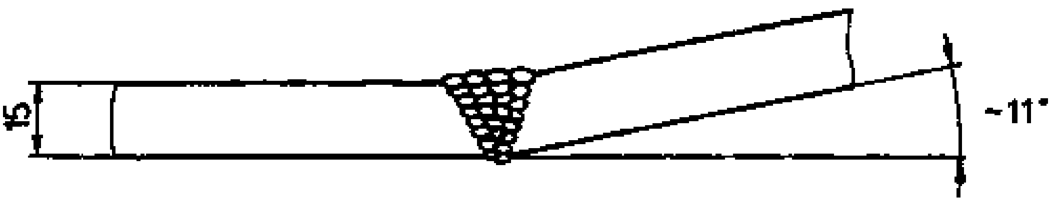
The angular shrinkage increases with increasing number of inner and cover passes.

Fig. 7. Angular shrinkage in V type welds



1 – 2 passes

2 – 9 passes



3 – 20 passes

Recapitulate the tacking of the V type weld in the gravity and the vertical–up position. In a discussion, let the trainees find out how angular shrinkage is counteracted,

– Small plate strips 4 ... 4.5 mm thick are put under the plates to be welded on the left and right sides of the weld.

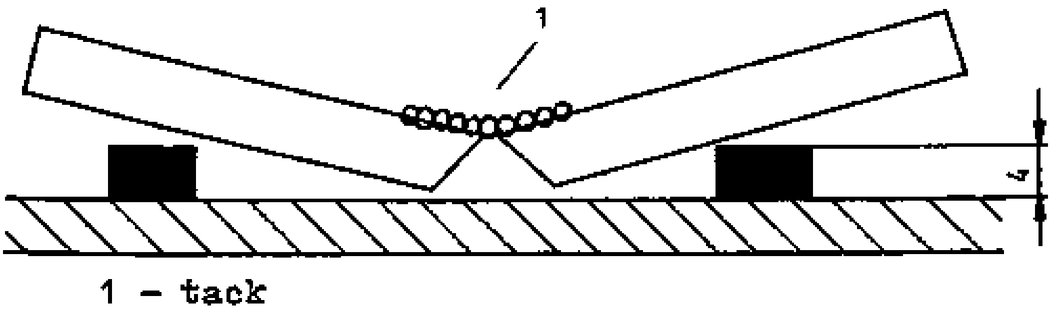
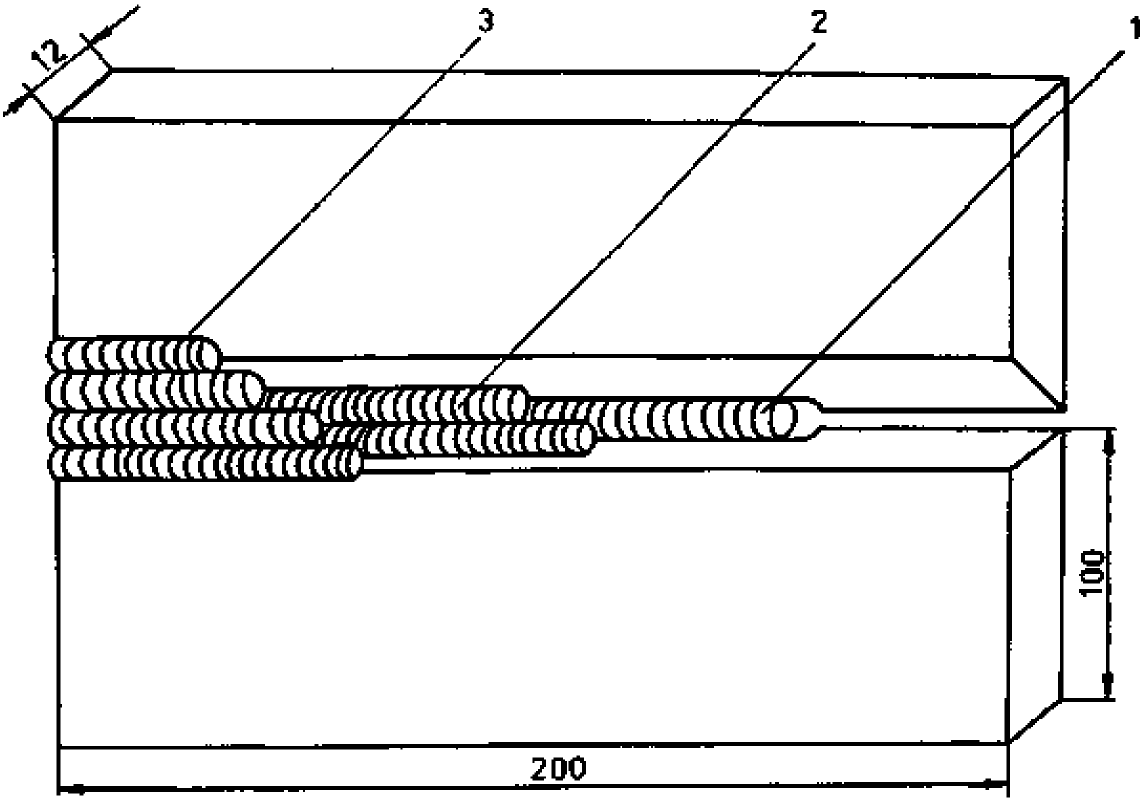


Fig. 8. Tacking the V type weld in a roof–like configuration

Thereafter proceed as specified for tacking the V type weld in the vertical–up position.

Check the proper tacking of the V type weld by the trainees. The tacks should be placed directly at the plate edges. Here care should be taken to achieve strong and clean tacks. If the tacks crack during root welding, the latter cannot be continued. After finishing the tack welding, the tacks should be carefully cleaned from slag residues and spatter. Check the proper tacking of the V type weld by the trainees.

3.3. Welding the V type weld



1 – root pass; 2 – inner passes; 3 – cover passes

Fig. 9. Weld buildup of the horizontal–vertical V type weld

Sum up the vertical–up V type welding. Subsequently, let the trainees discuss the differences between the welding techniques of the respective weld types in the vertical – up position.

<u>Welding in the horizontal–vertical position</u>

– For welding the root, inner, and cover passes, electrodes with a core diameter of 3.25 mm are used.
– The weld reinforcement must be within – 0, +2.5 mm.
– Use a "Titan" E 43 4RR (B) 22 type electrode –with a red colour marking.

Discuss the possible applications of such electrodes.

3.3.1. Welding the root pass

Demonstrate the root welding to the trainees.

Explain the individual welding operations to the trainees.

– The amperage for the electrode with a core diameter of 3.25 mm should be adjusted to appr. 90 to 100 A.

– The tacked specimen is placed on the table in such a way that the orientation of the weld groove is horizontal, i.e. transverse.

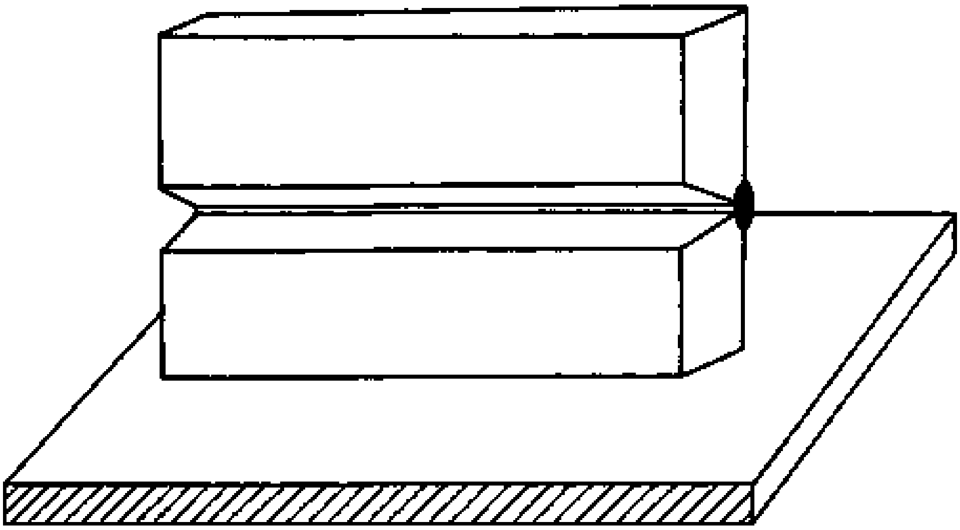


Fig. 9. Plate specimen arranged in transverse position

– In this exercise the direction of welding is from left to right again.
– The root pass is welded in the form of a horizontal U, using as short an arc as possible.

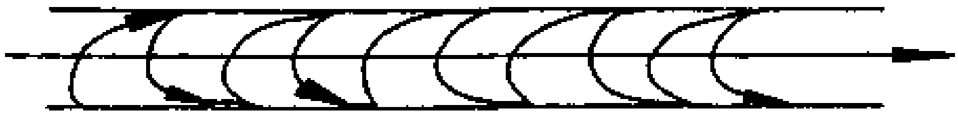


Fig. 10. Electrode manipulation in welding the root pass

In this case, too, the electrode is guided along an arc being open in the direction of welding.

– If the arc touches the seam edge, then again count in the usual rhythm: down two – three, up two – three, down two – three etc.

– The weld metal is deposited with a short arc at 2 – 3 in the centre of the groove in such a way that the arc pushes the weld metal through the web to the left side.

Point out to the trainees that

– the upper and lower seam edges should be melted to a sufficient degree.

Generally this hardly raises any problems in transverse seam welding. Special care should be taken in melting the upper seam edge. Here the arc should be kept particularly short, because otherwise the upper seam edge is heavily overheated. Discuss the consequences of a heavy overheating.

– When the electrode has been changed, then after ignition the weld metal is again pushed through the groove with a somewhat longer arc.

Explain and demonstrate to the trainees very insistently how the arc blow effect can be counteracted.

– At the beginning of the root weld, the electrode must be tilted in the direction of welding, and as the weld approaches the end of the plate, the electrode must be tilted oppositely to the direction of welding.

– In transverse seam root welding, the so–called "pear" (pear–shaped weld nugget) should also be held. This ensures proper through–welding and an uniform root fusion.

Point out to the trainees that

– the pear must form uniformly, because otherwise there will be a heavily sagged root or heavy undercutting (see the figure below).

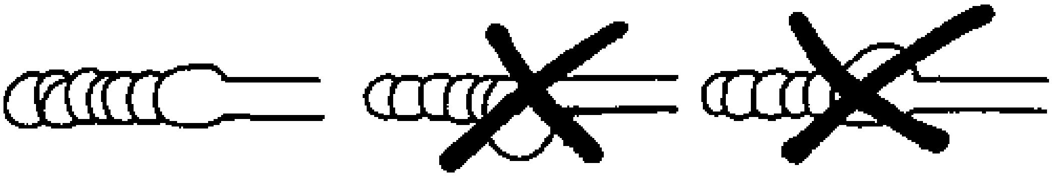


Fig. 11. Right and wrong formation of the pear.

Thereafter proceed as specified in the instructions on "V type welding in the gravity position".

3.3.2. Welding the inner passes

Demonstrate the welding of the inner passes to the trainees. Point out the properties in common and the differences in V type welding between the different positions. The amperage must range between 130 and 140 A. This high amperage is required for the fusion of the root reinforcement and for the removal of minor slag residues at the seam sides.

– The electrode is guided as a string bead without weaving.

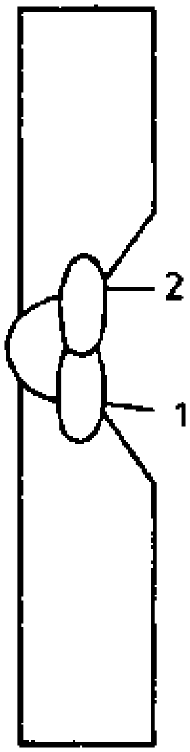


Fig. 12. Welding the 1st and 2nd inner passes

– The inner pass (1) is welded in so that it covers one half each of the root and the lower side wall of the seam.

– Care should be taken to avoid depositing too thick string beads.

– After depositing each string bead, slag and spatter must be carefully removed.

– After finishing the inner passes (1) and (2), the amperage can be adjusted to 120 A.

This lower amperage is intended to avoid overheating of the specimen for the remaining inner passes,

– The arc blow effect is counteracted in the same way as in root welding.

– The other inner passes are built up one upon another. Depending on the thickness of the deposited inner passes, a total of 6 inner passes is required for plates 10... 12 mm thick. The number of inner passes required may also be greater, depending on the individual skill of the weldor.

The buildup of the inner passes is illustrated in the figure below.

– The V type seam is filled so that the last inner passes are 0.5 to 1.0 mm below the plate surface.

The remaining edge permits an orientation for welding the cover pass.

– To avoid overheating of the weld, it is necessary to interrupt the welding operation several times between the inner passes in order to provide for the required cooling.

– The end crater of all inner passes must be filled very carefully, which can be achieved by a reduction of the arc length.

– The electrode should be burnt off to a length of 40 mm.

Check the uniformity of the last inner pass welded by the trainees. Unevennesses must be smoothed out by chipping. Welding a satisfactory cover pass depends essentially on the appearance of the uppermost inner pass.

3.3.3. Cover pass welding

Methodical hint

Demonstrate welding of the cover pass to the trainees. Explain to the trainees that electrodes with a core diameter of 3.25 mm are used.

– The cover pass is welded in the stringer bead technique. Depending on the thickness of the string bead, 4 to 5 cover beads will be required.

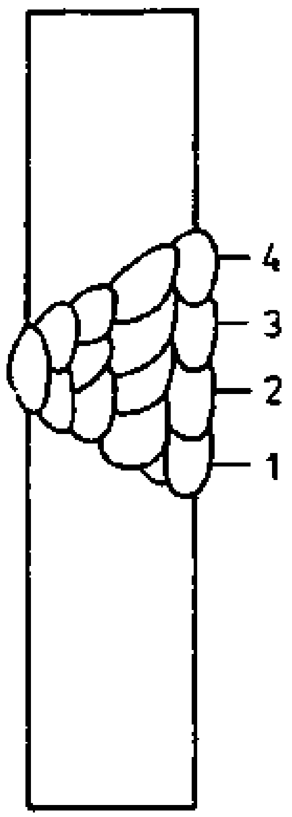


Fig. 13. Buildup of the cover pass

– The first and the last string bead must be carried out most exactly. Take care that the string beads fuse properly with the plate edge.

– For restarts of the arc reignition is done in the centre of the end crater. The end crater is filled by a slow, stippling weaving motion. Then the welding of the string bead is continued.

– The end craters of the cover passes must be filled carefully, which is achieved by reducing the arc length.

3.4. Evaluation of the finished V type weld – weld faults and their causes

Evaluate the finished V type weld together with the trainees. Inform them of the criteria of evaluation. Evaluate the appearance of the weld (cover pass and root pass), the accuracy to size and the appearance of the fracture.

<u>Appearance of the weld</u>

- Uniformity of bead ripples
- Appearance of the root
- Arc strikes
- End craters
- Undercutting
- Weld spatter

<u>Accuracy to size</u>

– Determine the three measuring points by means of a weld gage.

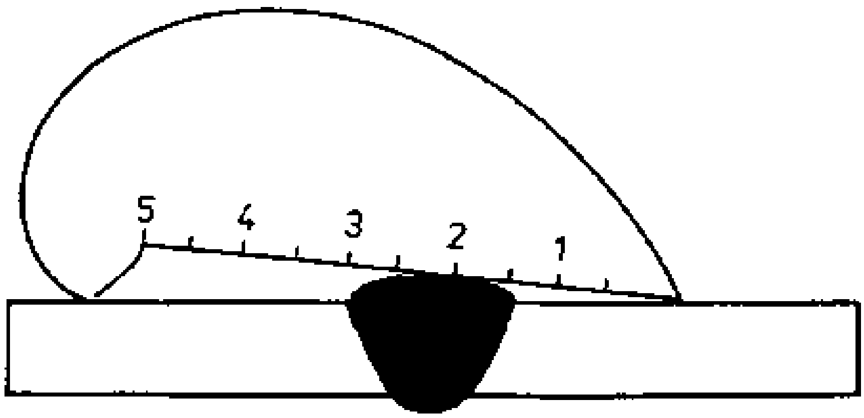


Fig. 14. Measurement of the weld reinforcement

Weld gage (1) for measuring the weld reinforcement. For V type seams welded in the horizontal – vertical position, a maximum weld reinforcement of + 2.5 mm is permissible.

<u>Fracture appearance</u>

To evaluate the fracture appearance, notch and break the V type weld.

– The V type weld is notched by planing–in. Take care that the notch is acute – angled and at least 4 – 5 mm deep.

– The specimen should be broken by means of a hydraulic press using the fixture shown in the figure below.

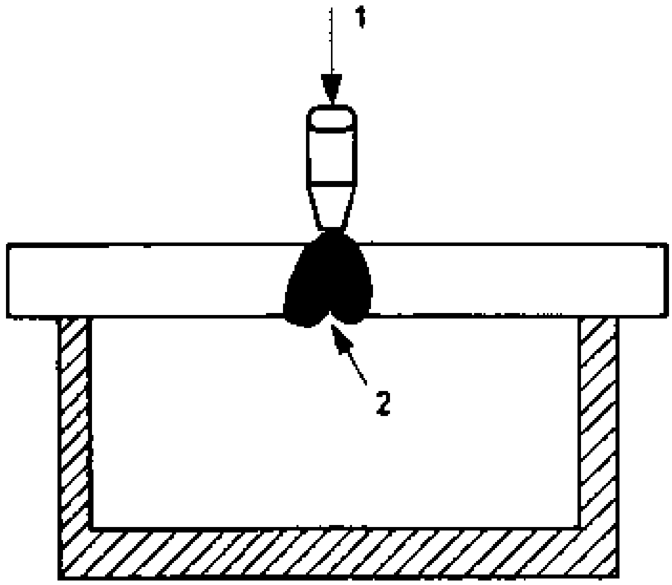


Fig. 15 Breaking of the notched weld (1 – forces; 2 – forces)

Demonstrate the notching and breaking of the welding specimens to the trainees.

Note on labour safety

Take care that the protective grating of the press is closed during the breaking operation. The hydraulic press should be operated with great care and circumspection.

Criteria for the evaluation of the appearance of fracture are:

- Melting of the root edges
- Slag inclusions
- Porosity
- Lack of fusion

Evaluation of the Section "V type welding in the horizontal–vertical position"

After finishing the training section of V type welding, the trainees should have acquired the following knowledge, capabilities and skills:

- Observing the labour safety regulations including order and cleanliness at the working place
- Preparation of the welding specimen
- Mastering V type welding in the horizontal–vertical position
- Recognition of typical welding faults in V type welds
- Evaluation of their own work

Examples of questions on the Section "V type welding in the horizontal–vertical position"

1. Describe the weld buildup of a V type weld in the horizontal–vertical position.

2. Compare the tendency to shrinking for a vertical – up V type weld with that of a horizontal–vertical V type weld.

3. What are the possible mistakes of a weldor which result in slag lines and slag inclusions?

4. Why does your trainer invariably demand order, safety and discipline at your working place?

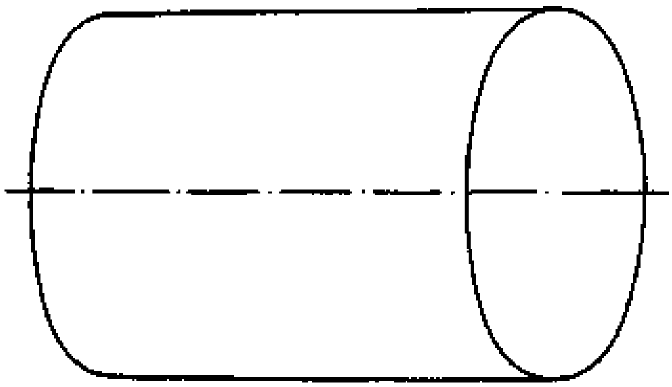
4. Pipe butt welding

In a lecture tell the trainees the necessary information of pipe butt welding in the overhead, vertical – up, gravity and horizontal–vertical positions.

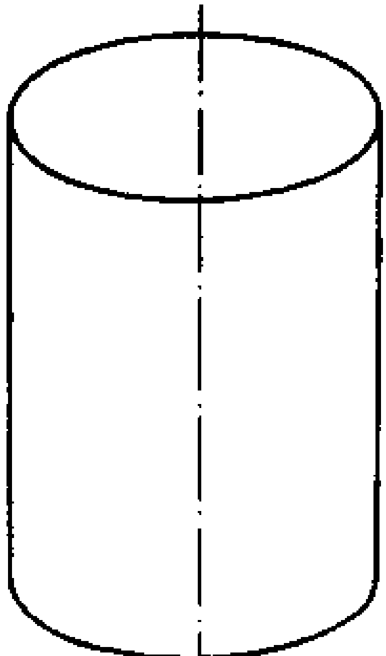
Inform the trainees of the object of this section.

- Acquiring the skill of pipe butt welding with the pipe axis being vertical or horizontal.

Fig. 16. Orientation of the pipe axis



1 – vertical



2 – horizontal

- Particularities of tacking a pipe butt joint
- Mastering the sequence of welding for pipe butt joints

The welding electrode to be provided for is a "Titan" 3 43 4RR(B) 22 type electrode with red colour marking and a diameter of 3.25 mm.

The electrode marking was already explained in the technical part of the training course. You should, however, point out again that this electrode is one with a very thick rutile covering. This electrode distinguishes itself by a small–drop metal transfer, which enables finely rippled seams and weld interfaces free of undercutting. It is suitable for all welding positions except for the vertical–down one. The electrode is used in d.c. straight polarity welding or in a.c. welding. For the electrode diameter, an amperage of 120 ... 160 A is suitable. In your explanations you should start from the previously acquired knowledge of V type welding in the gravity, vertical–up and horizontal–vertical positions. Discuss the overhead position separately.

4.1. Preparation of the pipe specimens

Inform the trainees of the dimensions and the condition required for the welding specimens.

– Two 200 mm pipe lengths, 8 mm thick, nominal bore = 150 mm, are required.

– Chamfer the pipe lengths to prepare a bevel of 30 °. Chamfering is done by flame cutting on a pipe cutting device.

– Clean the pipe length carefully from rust and scale over a distance of 40 mm from the end to be welded.

– Take care that the two pipe length can be fitted to each other without any misalignment.

Possibly the fitting must be achieved by grinding or filing.

Check the preparation of the pipe specimens. Imprint the following principle on the trainees' minds: "A proper and exact weld preparation is prerequisite to successful pipe welding."

4.2. Tacking the pipe butt weld

Demonstrate the assembling and tacking of the fillet weld. For that purpose, place the two prepared pipe lengths on a channel section in such a way that a root opening of 3.5 – 4.0 mm is obtained. Demonstrate the tack welding.

– 4 tacks with a length of 40 mm each are required. The arrangement of the tacks can be observed from the figure below.

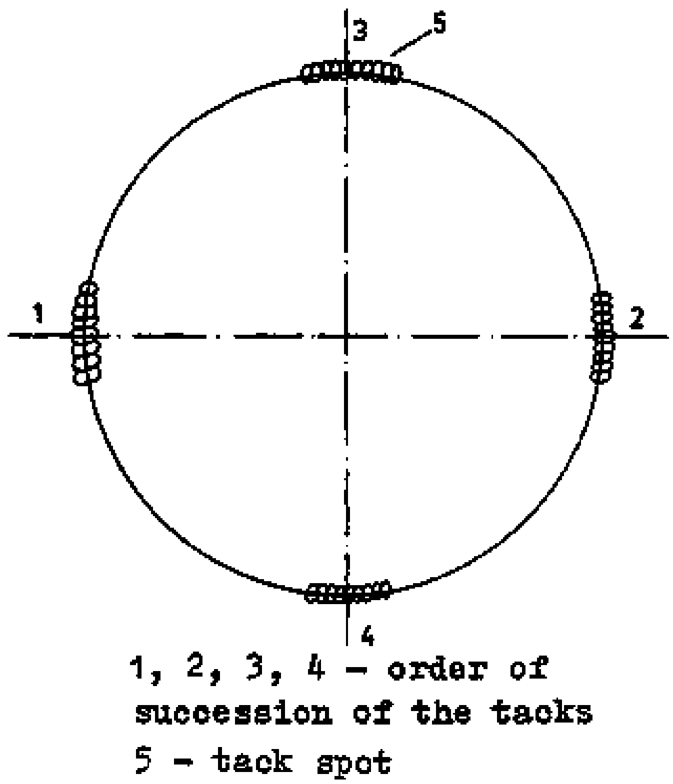


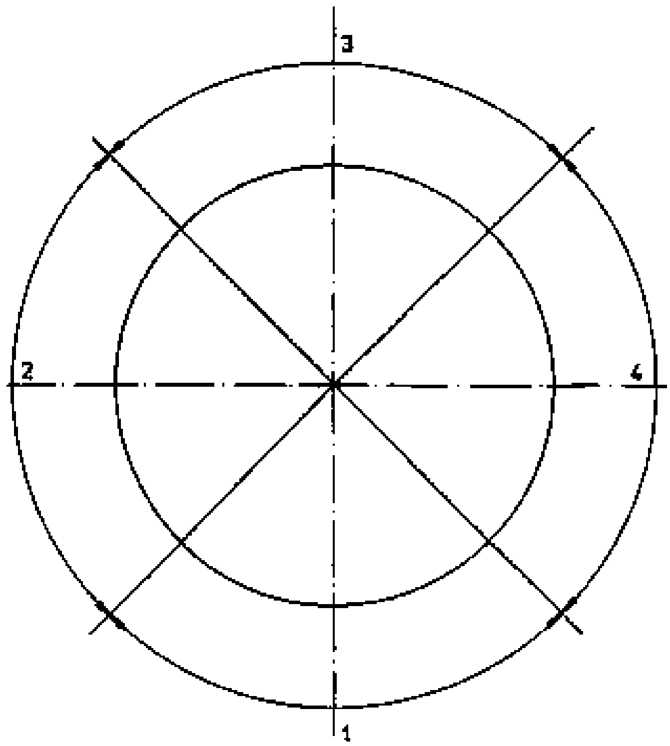
Fig. 17. Arrangement of the tacks

– Each of the tacks should be welded in the vertical–up position. After finishing the tacks 1 and 2, the pipe is rotated until the tacks 3 and 4 are in the vertical–up position.

– Clean the tacks from slag and spatter by means of a deslagging hammer and a wire brush.

Check the proper tacking of the pipe by the trainees. For a better orientation during the welding operation, subdivide the pipe into four equal sections. Mark and identify these sections using oil chalk.

Observe the arrangement of the individual welding positions in the picture below.



Positions:
1 – overhead
2 – horizontal–vertical
3 – gravity
4 – vertical–up

Fig. 18. Arrangement of the welding positions

Check the realization of this measure, which is very important for the trainees.

4.3. Welding the pipe butt weld

Demonstrate the welding of the pipe butt weld. Draw the trainees' attention to the following points of importance:

– The root pass must be welded first over the whole circumference of the pipe, followed by the inner passes and, finally, by the cover pass, which are also welded along the whole circumference.

– For welding in the semioverhead, vertical–up and gravity positions, clamp the pipe so that the pipe axis is horizontal.

Rotating the pipe during the welding process is strictly forbidden. Take special care that this interdict is obeyed.

Welding in the horizontal–vertical position is done with the pipe axis being vertical.

– For welding in the overhead, vertical–up and gravity positions, the pipe is clamped in a positioning fixture so that the pipe axis is horizontal.

Let the trainees adjust the height of the pipe so that the lowermost point of the pipe wall is closely above their head. The bearing of the trainee during the welding operation is of great importance. An unsuitable bearing will fatigue the trainee very rapidly in the overhead position, which has a very detrimental effect on the quality of the weld. Note the bearing of the trainee during welding in the overhead position as shown in the figure below.

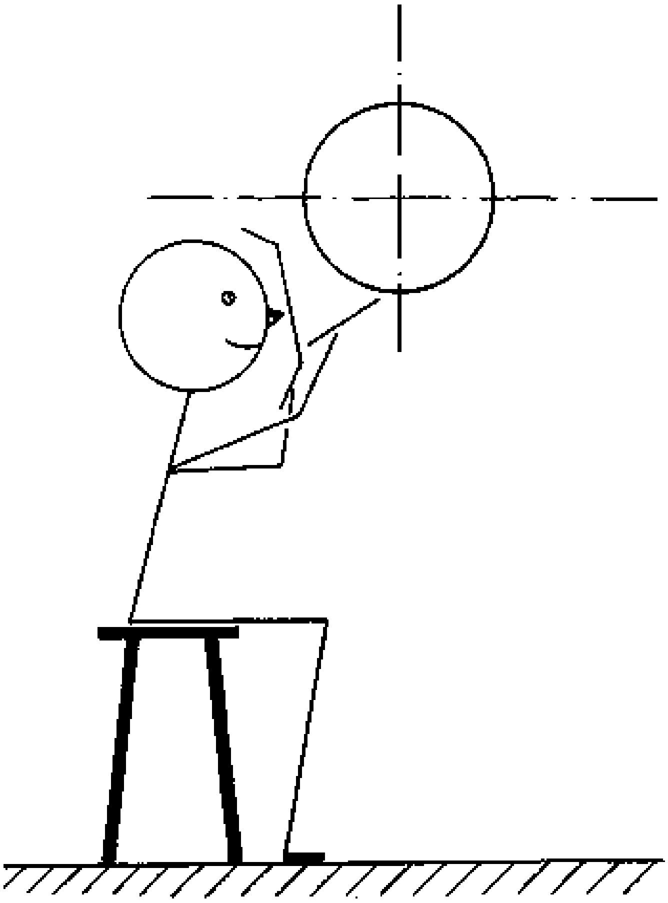


Fig. 19. Bearing during welding in the overhead position

Draw the trainees' attention to the fact that the height of the pipe can be readjusted for welding in the vertical–up position and the gravity position, respectively. Rotating the pipe, however, will affect the welding position and must be strictly forbidden. Take care that this interdict is obeyed.

In the horizontal–vertical position, unclamp the pipe from the fixture and put it on the welding table so that the pipe axis is vertical.

<u>Note on labour safety</u>

In the overhead position, labour safety requires special attention. Palling drops of weld metal and sparking especially endanger eyes and ears as well as the face; sparks may also fall down on the neck. Consequently, take care that the obligatory labour safety measures are obeyed to avoid the risks encountered. Make sure that the trainees obey the pertinent labour safety regulations and wear, for instance, a suitable head–covering, an ear–flap, and a leathern sleeve protector.

Explain the risks of overhead welding to the trainees.

4.3.1. Welding the root pass

<u>Welding the root pass in the overhead position</u>

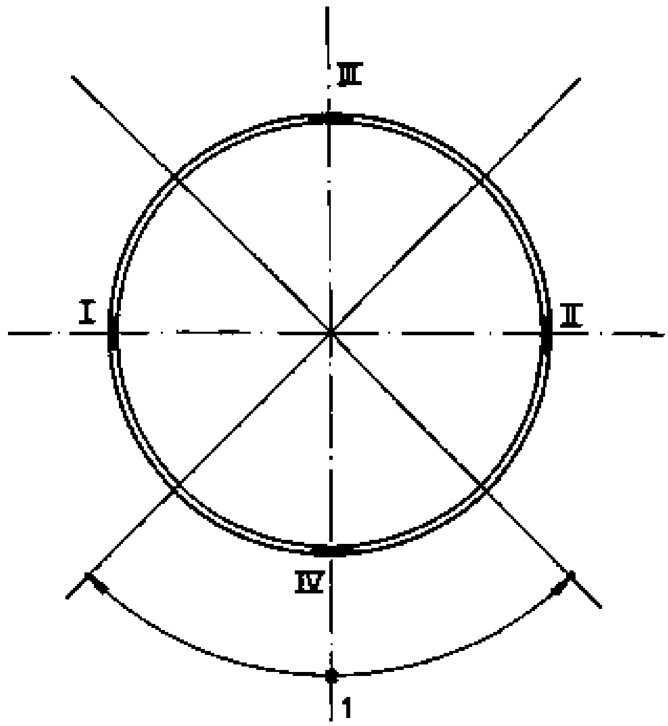
Demonstrate the root pass welding to the trainees. Explain the following points to the trainees:

– The arc should be started at the tack No. 4 and the weld should proceed from there towards the tack No. 2.

– The root parts is "stippled" rather than welded at one stretch.

– The arc is started at the tack spot and then moved to the right towards the side wall of the seam. At the side wall, the arc is pulled away downwards. Now the arc is started at the right–hand side wall. It is moved across the root opening, guided to the left, and pulled away at the left–hand side wall. Thereafter the arc is re–started at the left–hand side. It is moved to the right and pulled away at the side wall of the seam. Now the arc is re–started at the right–hand side and moved to the left.

– Guiding the electrode in this way, weld the root pass up to the point which can be observed from the figure below.



1 – overhead position
I, II, III, IV – tacking sequence

Fig. 20. Welding sequence in the overhead position

– Subsequently, guiding the electrode in the same way as above, the remaining length of the root pass is welded from the tack No. 4 to the tack No. 1 up to the point shown in the figure above.

– Take care that the overhead position covers 1/3 of the total circumference of the pipe.

<u>Welding the root pass in the vertical – up position</u>

– The root pass in the vertical–up position starts from the end of the overhead position and is carried on up to the point shown in the figure below.

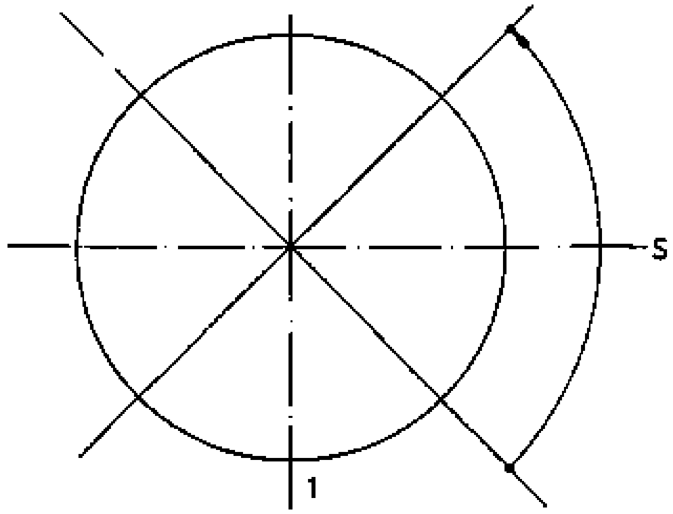


Fig. 21. Welding sequence in the vertical–up position

– The electrode should be guided in the same way as described vertical–up V type welding.

Welding the root pass in the gravity position

– The root pass in the gravity position starts at the end of the vertical–up position and is carried on to the tack No. 3. Beyond this point the weld is carried out from the point shown in the figure below up to the tack No. 3.

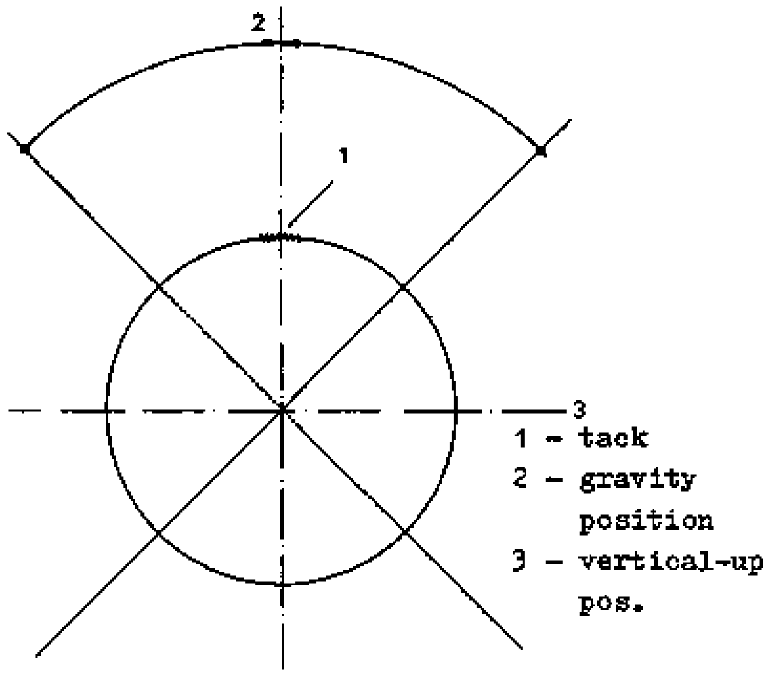


Fig. 22. Welding sequence for the gravity position 1 – Tack No. 3

– Welding the root in the gravity position is done with the same way of electrode guiding as used in gravity V type welding.

Welding the root pass in the horizontal–vertical position

– Unclamp the pipe from the positioning fixture and place it on the welding table so that the pipe axis is vertical.

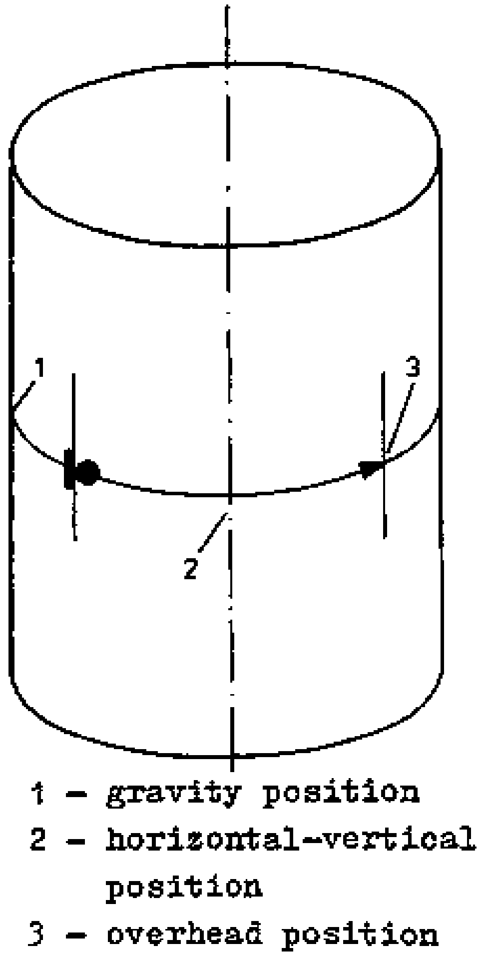


Fig. 23. Welding sequence for the horizontal–vertical position

– The transverse seam is welded on the remaining third of the pipe circumference.

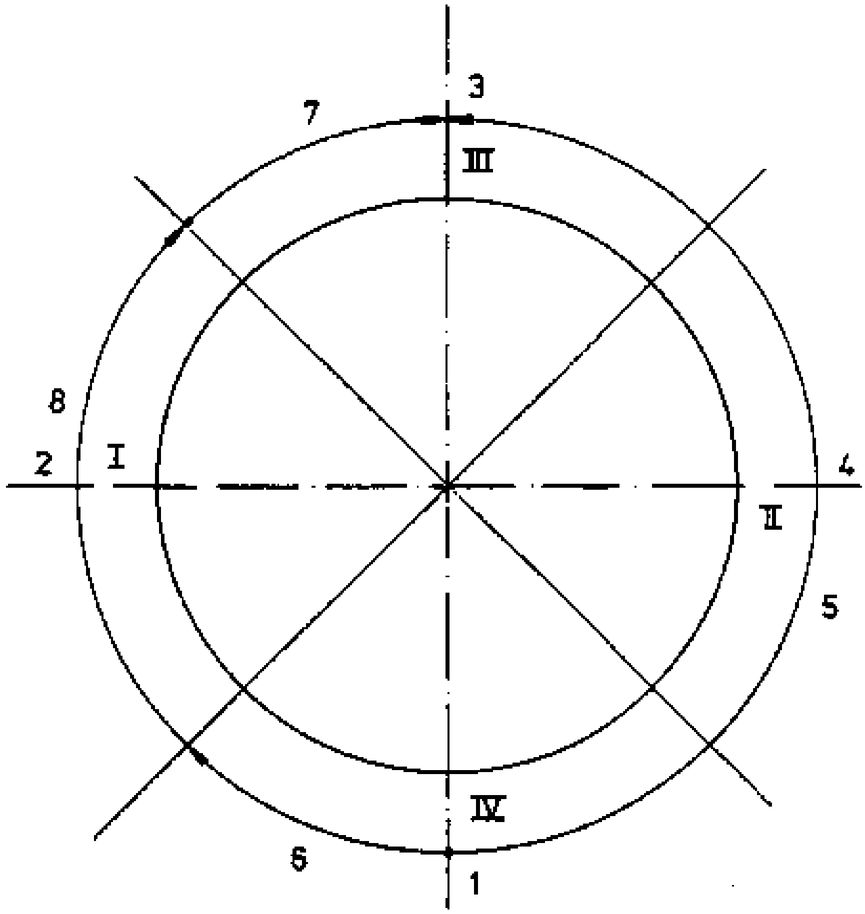
– The electrode manipulation corresponds to that described in connection with horizontal–vertical V type welding.

After the root welding has been finished, the V type weld is carefully cleaned from slag and weld spatter. Check the root weld for possible welding faults such as insufficient through – welding, root sagging, arc strike faults, porosity, slag inclusions, lack of fusion and undercutting. Possible irregularities in arc strike areas should be removed using hammer and chisel. Discuss the welding faults with the trainees. Demonstrate perfect and faulty root welds. Let the trainees find out the causes of faulty welds and their elimination.

4.3.2. Welding the inner passes

Demonstrate the welding of the inner passes to the trainees. For welding the inner passes, the instructions given for V type welding in the horizontal–vertical, gravity and vertical – up positions are also applicable. For welding in the overhead positions, the instructions given for the vertical–up position hold analogously, i.e. weaving of the electrode and dwelling at the side walls of the seam is also applicable in this case.

Point out to the trainees that the welding sequence shown in the figure below should be followed.



Positions:
1 – overhead
2 – horizontal–vertical
3 – gravity
4 – vertical–up
5 – 8 welding sequence

Fig. 24. Welding sequence for welding the inner passes I – IV – tacks 1 – 4

– Starting from tack No. 4, weld the inner pass at one stretch up to tack Ho. 3.

– From tack No. 4, weld towards the starting point of the transverse seam.

– Finally carry out the weld segment in the gravity position from the starting point of the transverse seam to tack No. 3.

– Thereafter place the pipe on the welding table so that the pipe axis is vertical. Now the welding of all the inner passes in the horizontal–vertical position is completed. Take care that the weld metal deposit is still appr. 1 mm below the outer surface of the pipe wall.

– With the pipe axis being horizontal, the pipe is filled up in the overhead, vertical–up and gravity positions so that the cover pass can be welded.

– For the inner passes welded in the overhead, vertical – up and gravity positions, the weld metal deposit shall also be appr. 1 mm below the outer surface of the pipe wall.

This measure yields a good orientation in welding the cover pass.

– In addition, take care that the arc strikes of the individual passes are always staggered by at least 20 mm. This always results in proper and faultless arc strikes.

After the inner passes have been completed, the pipe weld is carefully cleaned from slag residues and spatter. Check the uniformity of the uppermost inner pass. Unevennesses should be smoothed out by chipping. Draw the trainees' attention to the fact that a successful welding of the cover pass essentially depends on the appearance of the uppermost inner pass.

4.3.3. Welding the cover passes

Demonstrate the welding of the cover passes to the trainees. The welding sequence can be observed, from the figure below.

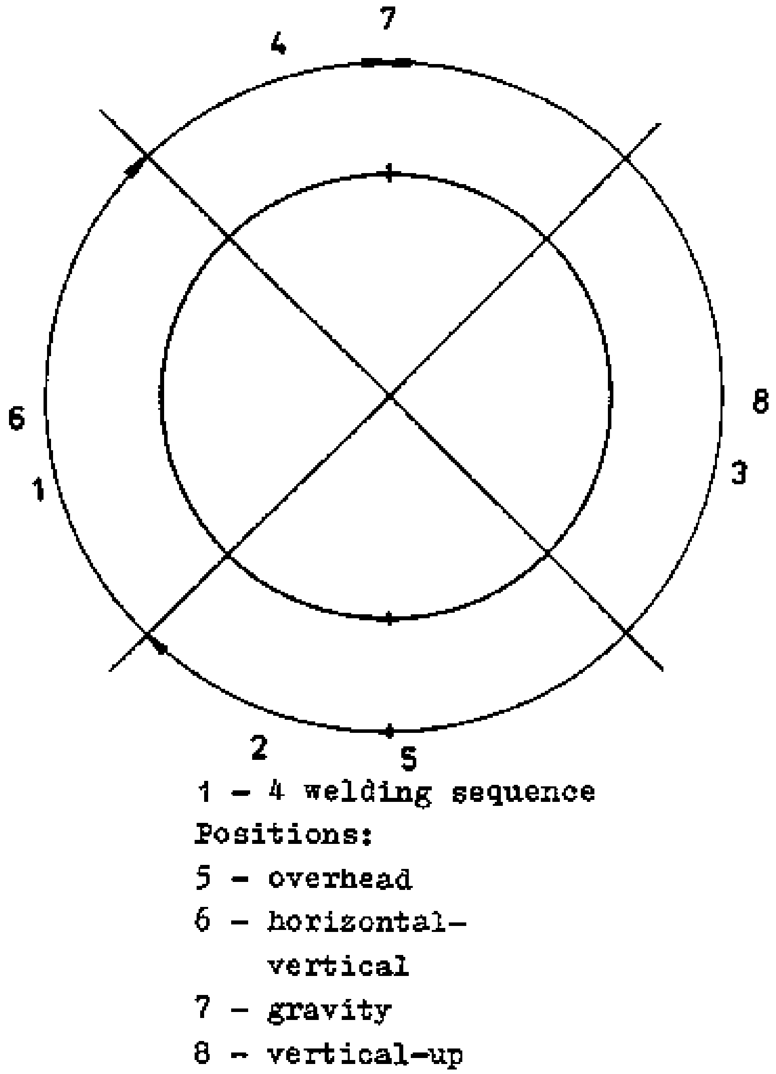


Fig. 25. Welding sequence of the cover pass

It is recommended first to weld the cover pass in the horizontal−vertical position.

The welding sequence and the weld buildup correspond to that of the V type weld in the horizontal−vertical position. The arc strikes and the end crater of the cover pass should slightly be ground off in order to achieve a proper arc strike for the subsequent cover passes in the overhead and gravity positions.

Now section 2 is welded in the overhead position.

The overhead position requires the same electrode − manipulation as it should be known from vertical−up welding.

Thereafter section 3 is welded in the overhead, vertical−up and gravity positions.

Finally section 4 is welded in the gravity position.

After the welding has been finished, clean the pipe weld and check it for welding faults.

4.4. Evaluation of the finished pipe butt weld

Evaluate the finished pipe butt weld together with the trainees. Inform them of the criteria of evaluation. Evaluate the weld appearance (cover pass and root pass), the accuracy to size and the fracture appearance (horizontal−vertical, vertical−up and gravity positions). Evaluate the weld appearance by the following criteria:

- Uniformity of bead ripples
- Root appearance
- Arc strikes
- End craters
- Undercutting
- Spatter

<u>Accuracy to size</u>

Using a weld gage, determine three measuring points for each welding position. Demonstrate the checking for accuracy to size by means of the weld gage.

Inform the trainees of the following permissible weld reinforcements:

Gravity position − 0 mm; + 1.5 mm
Vertical−up position −0 mm; +2.5 mm
Overhead position − 0 mm; + 2.5 mm
Horizontal−vertical position − 0 mm; + 2.5 mm

<u>Fracture appearance</u>

The test specification requires that for the gravity, vertical−up and horizontal−vertical positions a 40 mm wide strip of material shall be taken and fractured.

Such test strips shall be prepared by flame cutting.

The positions from which test strips shall be taken can be observed from the figure below.

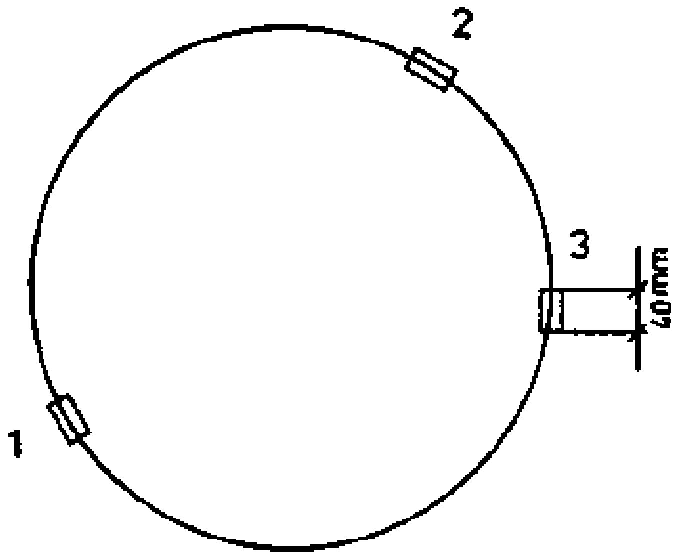


Fig. 26. Taking of test strips

Notch, and fracture the test strips to evaluate the fracture appearance.

- The V type weld is notched by planing − in.

Note that the notch is acute−angled and at least 4 mm deep.

Evaluation of the Section "Pipe butt welding"

Having finished the training section of pipe butt welding, the trainees should have acquired the following knowledge, capabilities and skills:

- Obeying the labour safety regulations including order and cleanliness at the working place
- Preparation of the pipe
- Mastering all of the pipe welding positions
- Recognition of typical welding faults in pipe butt welds
- Evaluation of their own work

Examples of questions on the Section "Pipe butt welding"

1. Explain the subdivision of the pipe by the four welding positions.
2. Describe the welding sequence for a pipe butt weld.
3. What are the special labour safety measures to be taken by the weldor in pipe butt welding?
4. What are the permissible weld reinforcements in pipe butt welding?

5. Guidelines for the examination

After completion of the electric welding course, it is necessary that the trainees undergo an examination. This section will describe guidelines for carrying out such examination These guidelines should be adapted to the conditions and regulations specific to the respective country.

These guidelines are applicable to the examination of electric arc weldors who carry out execution class III welding operations on carbon steels and low−alloy steels suitable for welding. These guidelines are also applicable to execution class III circumferential seam welding operations on steel piping, provided that the basic examination includes pipe welding tests.

5.1. Designation of the examination

The examination should be designated by symbols according to the following table and entered into the certificate of qualification.

Welding technique	Type of examination	Thickness of work−piece up to 3 mm above 3 mm	
Electric welding	B for basic examination without pipe specimen	a	b
	R for basic examination with pipe specimen		

Execution class III entitles the weldor to weld structural steels with a maximum carbon− content of 0.22 %. Welding alloyed low − alloy steels or steels sensitive to upgrading is not permitted.

5.2. Admission to the examination, welding permit

All trainees who have successfully passed through the Electric Welding course (Methodical Instructions) are admitted to the examination.

The examination entitles the trainees to carry out class III welding operations by the welding technique in which the examination has been passed. The examinations of subgroup b exclude those of subgroup a, and the R basic examination includes the B basic examination for the same welding technique.

5.3. Execution of the examination

The examination consists of a practical and a theoretical part.

5.3.1. Practical examination

The specimens for the basic examinations in electric welding shall be welded according to the following tables in the presence of the examining body. The thickness of the fillet welds shall be specified by the examining body, depending on the welding technique.

The examining body may decide to demand an additional specimen which corresponds to the special requirements of the respective factory or branch of industry.

Steel grades with strength values between those of St 34 and St 52 shall be used for the specimens. The specimens shall be at least 200 mm long.

Specimens for the basic Rb or Bb examination in electric welding

Type of exam. & specimen No.		Type of weld	Welding positions	Thickness of work–piece (mm)
RB	Bb			
1	1	fillet weld, root pass and 2 cover passes	horizontal	
2	2	V type weld	gravity	
3	3	fillet weld, root and cover pass	vertical – up	
4	4	V type weld	vertical – up	6 to 12
5	5	V type welds, 5 tacks appr. 30 mm long	3 x gravity 2 x vertical–up	
6	6	profile junction, root and 2 cover passes	horizontal	
7	7	fillet weld, root and 2 cover passes	semioverhead	
8[+3)]	–	pipe butt weld, 1/4 of pipe axis vertical	horizontal–vertical	5 to 12
		pipe butt weld, 3/4 of pipe axis horizontal	overhead, vertical–up, gravity	
–	8	V type weld	horizontal–vertical	6 to 12

5.3.2. Theoretical examination

The theoretical examination is carried out as a programmed examination. This means that the questions and the answers offered are presented to the trainee in writing. For each of the questions, three answers marked by 1, 2 and 3 are offered, one or two of which are correct, the others being wrong. On the answer sheet, the divisions of which correspond to the answers offered, the trainee shall mark off the correct answers by crosses. He has 50 minutes available to answer the questions.

The trainee may cancel wrongly entered crosses by hatching the whole division. The trainee should be informed of the system and the evaluation of the examination.

Compilation of the questions

The examiner compiles 50 questions from a given list. In the selection, the following proportions should be maintained:

- appr. 30 % about material science
- appr. 30 % about electric welding
- appr. 10 % about groove preparation
- appr. 10 % about welding sequences
- appr. 20 % about health protection, labour safety and fire protection

<u>Evaluation of the answer sheet</u>

Every question to which answers are given shall be evaluated separately. Correct answers score + 1 each, negative answers score – 1 each. The plus and minus marks gained for the answer to one question are set off against each other. However, negative results for one question score 0. If three answers to one question have been marked off, then the score is 0. The sum of the scores calculated for each question gives the total score achieved.

$$\frac{\text{achieved total score} \cdot 100}{\text{maximum possible score}} = \text{achieved percentage of correct answers possible}$$

The ratings of percent scores achieved are calculated as follows:

100 ... 96 % = mark 1
95 ... 81 % = mark 2
80 ... 61 % = mark 3
60 ... 45 % = mark 4
44 ... 0 % = mark 5

Evaluation example for 10 questions with 13 correct answers symbolized by 0

Question	Answer No.			Calculated score
No.	1	2	3	
1		x		1
2	0		x	0
3		x	x	2
4	x	0		0
5	x			1
6	x	x	x	0
7		0		0
8	x			1
9		x	0	0
10	x	0		1
achieved score				6

$$\frac{6}{13} \cdot 100\% = 46.2\% = \text{mark } 4$$

1. <u>Materials science</u>

1.1. Which type of steel melting causes a limited suitability for fusion welding?

1. Open–hearth process
2. <u>Thomas Gilchrist process</u>
3. LD process

1.2. What do you understand by the steel fining process?

1. Casting the steel melt into ingot moulds
2. <u>Processing pig iron to steel under the action of oxygen</u>
3. The melting process in the blast furnace

1.3. What are the detrimental properties of Thomas–Gilchrist steel?

1. Sensitivity to hardening
2. <u>Sensitivity to ageing</u>
3. <u>Cold brittleness</u>

1.4. Which element is added to the steel melt for deoxidation?

1. O_2
2. S
3. <u>Si</u>

1.5. Which elements are – apart from O_2 – bonded by the deoxidants Mn, Si and Al?

1. P and C
2. <u>S and N_2</u>
3. H_2 and C

1.6. Which elements cause the limited suitability for welding of Thomas–Gilchrist steel?

1. <u>P</u>
2. Si
3. <u>N_2</u>

1.7. Which element, if contained in steel, effects red shortness?

1. N_2
2. <u>S</u>
3. P

1.8. Why is sulphur an undesirable impurity in steel?

1. <u>It causes red shortness.</u>
2. <u>It accumulates in the core zone of unkilled steels.</u>
3. It causes cold brittleness.

1.9. Which element causes cold brittleness in steel?

1. S
2. <u>P</u>
3. Si

1.10. What is the effect of phosphorus in steel?

1. Red shortness
2. Embrittlement due to ageing
3. <u>Cold brittleness</u>

1.11. What is the value to which the phosphorus content must be reduced in carbon steels for welded structures?

1. 0.006 %
2. 0.080 %
3. 0.060 %

1.12. What are the changes in steel properties caused by an increasing carbon content?

1. It increases the tensile strength.
2. It reduces the elongation.
3. It increases the elongation.

1.13. Which alloying element causes the least reduction in elongation in addition to an increase in strength of carbon steel?

1. C
2. Si
3. Mn

1.14. What is the percent carbon content which must not be exceeded for a steel to be fully suitable for fusion welding?

1. 0.02 %
2. 0.22 %
3. 0.35 %

1.15. Why are steels preheated for welding?

1. To prevent red shortness
2. To achieve a martensitic structure in the heat–affected zone
3. To reduce the rate of cooling

1.16. What are the quantities the preheating temperature for welding depends upon?

1. C content
2. Percentage purity
3. Wall thickness

1.17. What are the possible causes of cracks in the welded joint?

1. Piling–up of seams
2. Preheating
3. Wrong welding sequence

1.18. Under what circumstances in welding can a 0.35 % C steel be expected to have a hardening structure?

1. Cooling in air
2. Cooling in air from the preheated condition
3. Furnace cooling after tempering at 700 °C

1.19. Which types of structure are undesirable in the welded joint?

1. Coarse–grain structure
2. Fine–grain structure
3. Hardening structure

1.20. What is the purpose to be achieved by stress–relief annealing?

1. Structural transformation
2. Elimination of deformations
3. Reduction of residual stresses

1.21. What requirements can only be met by normalizing?

1. A fine−grain structure with good tensile properties shall be achieved.
2. Stresses in the component shall be reduced.
3. Hardness peaks in the heat−affected zone shall be eliminated

1.22. What kind of structure is obtained in steel by normalizing?

1. Coarse−grain structure
2. Fine−grain ferrite−perlite structure
3. Cast structure with elongated crystallites

1.23. What are the temperatures at which normalizing is carried out?

1. 600... 650 °C
2. 30... 50 deg above GS
3. Below Ac_1

1.24. What are the temperatures required for stress−relief annealing?

1. 150... 350 °C
2. 250... 1100 °C
3. 600... 650 °C

1.25. Tell a practical method of cooling welded structures from 600 °C after normalizing.

1. In still air
2. In a furnace
3. By quenching

1.26. For what kinds of welded structures is it possible to use Thomas−Gilchrist steel?

1. Structures subjected to static loads
2. Structures subjected to shock−type loads
3. Structures which are loaded at low temperatures

2. Electric welding

2.1. Which effect of electric current is made use of in the welding generator?

1. Thermal effect
2. Magnetic effect
3. Chemical effect

2.2. Which effect of electric current is prejudicial to the welding process?

1. Welding converter
2. Welding transformer
3. Welding rectifier

2.3. Which welding power source has the highest efficiency?

1. Welding converter
2. Welding transformer
3. Welding rectifier

2.4. Which welding power source applies an asymmetric load to the mains?

1. Welding transformer
2. Welding converter
3. Welding rectifier

2.5. In which, respect can welding converters be considered advantageous?

1. Low open−circuit losses
2. High efficiency
3. Symmetric mains load

2.6. In which respect can welding transformers be considered advantageous?

1. Symmetric mains load
2. Low arc blow effect
3. Allows welding with B type electrodes

2.7. For which technique can the dropping volt−ampere characteristic be used?

1. Electric welding
2. MAG welding
3. WIG welding

2.8. For which technique is the nearly horizontal load characteristic suitable?

1. Electric welding
2. MAG welding
3. MIG welding

2.9. Why is the current density in electric welding lower than in MAG welding?

1. Because of the larger electrode diameter
2. Because of the exposed length of the electrode
3. Because of the dropping volt−ampere characteristic

2.10. What determines the welding voltage in electric welding?

1. Adjustment at the power source.
2. The volt−ampere characteristic of the power source.
3. The arc length

2.11. Which type of welding power source generates alternating current?

1. Welding converter
2. Welding rectifier
3. Welding transformer

2.12. Which type of welding power source generates direct current?

1. Welding converter
2. Welding rectifier
3. Welding transformer

2.13. Which welding amperage is required for a 4 mm electrode?

1. 160 A
2. 250 A
3. 120 A

2.14. Which welding power sources distinguish themselves by a low open−circuit power consumption, low noise and low maintenance cost?

1. Converters
2. Rectifiers
3. Transformers

2.15. Which power sources permit welding with all types of electrodes?

1. <u>Converters</u>
2. <u>Rectifiers</u>
3. Transformers

2.16. How do you weld with common B type electrodes?

1. <u>Electrode at the positive pole</u>
2. Electrode at the negative pose
3. a.c. welding

2.17. What measures can be taken to reduce energy losses in a welding equipment?

1. <u>Shortening the welding cables</u>
2. Reducing the cross section of the welding cables
3. <u>Increasing the cross section of the welding cables</u>

2.18. that is the direction of arc deflection due to the arc blow effect?

1. Towards the work clamp
2. <u>Off the work clamp</u>
3. <u>Towards the larger steel body</u>

2.19. What measures can be taken to counteract the arc blow effect?

1. <u>Tilting the electrode in the direction of the arc blow effect</u>
2. Tilting the electrode in the direction opposite to the arc blow effect
3. <u>Using bifurcated poles</u>

2.20. Under which conditions is it permissible to overweld cracked tacks?

1. <u>Overwelding is forbidden in any case</u>
2. It is permissible in execution class III
3. Overwelding is only permissible in fillet welding

2.21. What is the purpose of the electrode coating?

1. Protection from atmospheric moisture
2. <u>Generation of shielding gas</u>
3. <u>Arc stabilization</u>

2.22. Which electrode types cannot be a.c. welded?

1. <u>Bare wire</u>
2. A types
3. <u>Certain B types</u>

2.23. Can E type electrodes be a.c. welded?

1. Yes, all types
2. No
3. <u>Yes, certain types</u>

2.24. Which electrode types can be used in welding Thomas–Gilchrist steel?

1. A types
2. <u>B types</u>
3. Electrodes with very thick coatings

2.25. What is the thickness of coating of the E 43 4 RR (B) type electrode?

1. Thin coating
2. <u>Very thick coating</u>

3. Medium coating thickness

2.26. Describe the bridgeability of a E 43 2 R type electrode.

1. Poor
2. Good
3. <u>Very good</u>

2.27. How is the transfer of droplet of a B type electrode?

1. Fine droplets
2. Medium droplets
3. <u>Coarse droplets</u>

2.28. How can pore formation be prevented in electric welding?

1. By holding a longer arc
2. <u>By predried electrodes</u>
3. By a higher amperage

2.29. What are the possible mistakes in the drying of B type electrodes?

1. 2 hr at 250 °C
2. <u>Drying the electrodes close stacked in a drying cabinet</u>
3. <u>Drying the electrodes spread out on a radiator</u>

2.30. What are desirable effects of slag on the weld pool?

1. <u>Formation of the weld surface and alloying of the weld metal</u>
2. Generation of shielding gas
3. <u>Reduction of the cooling rate</u>

2.31. What imparts toughness together with a sufficient tensile strength to the weld metal?

1. <u>Reducing the C content to 0.12 % and increasing the Mn content</u>
2. Taking up oxygen and nitrogen from the atmosphere
3. C content up to 0.22 %

2.32. Which type of weld metal has the lowest concentration of oxygen, nitrogen and hydrogen?

1. Weld metal of the E 51 4 RR (B) type electrode
2. Weld metal of the E 43 0 A type electrode
3. <u>Weld metal of the E 43 4 B type electrode</u>

2.33. What is the effect of nitrogen on the weld metal?

1. <u>Ageing embrittlement</u>
2. Hot – cracking susceptibility
3. Susceptibility to pores

2.34. What are the quantities on which the ohmic resistance depends in the circuit?

1. The shape of section of the conductor
2. <u>The wire length and the corss sectional area in mm^2</u>
3. The material

2.35. What is the execution class of welding operations permitted for a weldor who passed an elementary course examination?

1. Class II B
2. Class II A
3. <u>Class III</u>

2.36. What is the voltage across the phases R and T in a 220/380 V three−phase system?

1. 220 V
2. <u>380 V</u>
3. 110 V

2.37. On which pole is the higher temperature generated in d.c. arc welding?

1. <u>On the positive pole</u>
2. On the negative pole
3. Equal temperatures on both the positive and the negative pole

2.38. What is the cause of the high temperatures at the arc strikes?

1. <u>The impingement of electrons and ions</u>
2. The thermal effect of the electric current
3. The ionization of the air gap

2.39. How can the weldor influence the thermal effect (depth of penetration) on the welded component?

1. <u>By the arc length</u>
2. <u>By the manipulation and the position of the electrode</u>
3. By the selection of the welding power source

2.40. What is the cause of the arc blow effect in welding?

1. The non − uniform heating−up of the welded component
2. <u>The compression or expansion of the magnetic fields of force</u>
3. Insufficient ionization of the arc gap

2.41. What is the use of a star−delta switch?

1. <u>To reduce the cut−in current rush</u>
2. To protect the generator winding from overload
3. To reduce the speed of the motor

2.42. What means the symbol "VC" on the rating plate of a welding power source?

1. The power source can be changed over between d.c. and a.c. operation.
2. The power source has a variable welding current range
3. <u>The power source</u> <u>has a variable characteristic</u>

2.43. What is the use of the field coil in the welding generator?

1. To increase the welding current
2. <u>To build up a magnetic field of force</u>
3. A.c.−to−d.c. conversion

2.44. How can the mains voltage be reduced to the welding voltage in a welding transformer?

1. <u>By the primary−to−secondary turns ratio</u>
2. By moving a stray core
3. By the dimensioning of the laminated iron core

2.45. What is the use of the rectifier set?

1. A fine−step variation of the welding current
2. Rectifying the line current
3. Rectifying the transformed three−phase current

2.46. What are the advantages of using *a* welding rectifier?

1. <u>It permits welding with all electrode types.</u>
2. <u>Low open−circuit power consumption</u>
3. Low prime cost

2.47. What demands are made upon B type electrodes?

1. Insensitivity to moisture
2. Suitability for d.c. and a.c. welding
3. <u>Good mechanical property data of the weld metal</u>

2.48. Which electrode type is most suitable for thin−sheet welding?

1. E 43 3A
2. E 43 4 RR(B)
3. <u>E 43 2 R</u>

2.49. Which electrode type is most resistant to cracking?

1. <u>E 43 4 B</u>
2. E 43 2 R
3. E 43 4 RR(B)

2.50. Up to which plate thickness can a square butt weld be electrically welded from one side?

1. <u>3 mm</u>
2. 4 mm
3. 5 mm

2.51. Which shape of the fillet weld is most economical?

1. <u>Flush weld</u>
2. Concave weld
3. Reinforced weld

2.52. Which incorrect technique may be the cause of a lack of fusion in electric welding?

1. Too large an included angle
2. <u>Too small an included angle</u>
3. Too low amperage

3. Groove preparation

3.1. Given the task to electrically weld an St 42b−2 plate, s = 10 mm, in the horizontal position. Which weld type is practical at butt joints?

1. Y type weld
2. <u>V type weld</u>
3. Square butt weld

3.2. Which, type of fillet weld is best suitable for the magnetic field pattern?

1. Flush weld
2. <u>Concave weld</u>
3. Reinforced weld

3.3. Which included angle do you choose for the V type weld?

1. 16 ... 24 °
2. <u>20 ... 40 ° − correct for MAG</u>
3. <u>50 ... 60 ° − correct for electric welding</u>

3.4. Which dimensional data are required for V type weld preparation?

1. <u>Included angle</u>
2. <u>Root opening b</u>
3. Web height c

4. <u>Welding sequences</u>

4.1. Why is it necessary to obey welding sequence schedules in the practice of welding?

1. To achieve short welding times
2. <u>To minimize shrinkage and stresses</u>
3. <u>To save extra cost for straightening work</u>

4.2. Which welding sequences are required to minimize the redidual welding stresses in the welded component?

1. Tack the whole structure to be welded, thereafter carry out the welding
2. <u>Finish–weld the individual components, thereafter join them into the welded structure</u>
3. Prevent shrinkage by clamping

4.3. What determines the extent of shrinkage?

1. <u>The heat input rate</u>
2. <u>The form of the groove</u>
3. The C content of the base material

4.4. How can angular shrinkage in welding be counteracted?

1. By preheating
2. <u>By tacking in a roof–like configuration</u>
3. By increasing the number of weld passes

4.5. Which type of shrinkage results in high residual welding stresses in a 12 mm thick plate which is welded without clamping?

1. <u>Longitudinal shrinkage.</u>
2. Transverse shrinkage
3. Thickness shrinkage

4.6. What are the temperature ranges in which elastic stresses are caused by non – uniform cooling?

1. <u>500 ... 20 °C</u>
2. 850 ... 600 °C
3. 1500 ... 850 °C

4.7. Under which conditions are high stresses likely to to occur in the welded component?

1. <u>No welding distortions</u>
2. Minor welding distortions
3. Heavy welding distortions

4.8. Which type of shrinkage can be neglected for a 12 mm thick plate?

1. Longitudinal shrinkage
2. <u>Thickness shrinkage</u>
3. Transverse shrinkage

4.9. ON which quantities does the angular shrinkage of a V type weld depend?

1. <u>Included angle</u>
2. Number of passes
3. Length of the weld

5. Health protection and labour safety, fire protection

5.1. Which of the following operations can only be performed with a welding permit?

1. Welding of a sprocket in a welding shop on a welding table
2. Repair welding of a heating pipe in an office room
3. Welding of a container which contained inflammable materials

5.2. What is the minimum height of a workshop room which shall be used as a welding shop?

1. 3 m
2. 3.5 m
3. 4 m

5.3. Provided that the labour safety regulations are obeyed, are then welding jobs considered to be

1. of no consequence for the state of health of the weldor?
2. annoying?
3. dangerous?

5.4. What are MAK_D values?

1. Concentration of harmful substances in the atmosphere
2. Concentration of non–explosive gas–air mixtures
3. Maximum welding amperages

5.5. During welding operations in containers, the breathing air deteriorates. What measures should be taken?

1. Supply of oxygen
2. Adequate exhaustion and ventilation with fresh air
3. Use of fresh–air respirators

5.6. When must a weldor wear a fresh – air respirator during welding operations?

1. When a long – distance gas pipeline is newly installed
2. During operations on galvanized or lead–coated weldments
3. When MAG_D values are provably exceeded in the range of the working place

5.7. Which welding technique causes an intensive UV radiation?

1. Gas welding
2. MAG welding
3. Electric welding

5.8. Will UV radiation, in the case of insufficient protective measures, have harmful effects on

1. inner organs?
2. osseine?
3. the skin and the eyes?

5.9. What causes dangerously high open–circuit voltages?

1. Series connection of welding power sources
2. Parallel connection of welding power sources
3. Simultaneous work of several weldors on one and the same weldment (d.c. welding, equal polarity)

5.10. Which open–circuit voltage of the welding power sources is considered harmless for the human body under normal circumstances?

1. 42 V
2. 70 V
3. 100 V

5.11. Which welding power sources can be used in working areas with high electric danger coefficients, if fully insulated electrode holders are used?

1. 100 V welding converters
2. 70 V welding transformers
3. 60 V (peak voltage), 12 % ripple welding rectifiers

5.12. Which welding power sources can be used in working areas with a high electric danger coefficient, if no fully insulated electrode holders are used?

1. 42 V welding converters
2. 85 V (peak voltage), 12 % ripple welding rectifiers
3. 42 V welding transformers

5.13. To which point must a welding return wire be connected in the case of long welding leads?

1. To the structure to be welded with long return wires
2. To the steel structure of the welding workshop building with short return wires
3. To the frame of a swivelling gear which is not equipped with sliding contacts

5.14. In arc welding occur 3 types of beam. Which type of beam causes a dark inflammation of eyes and skin if the measures of protection are not sufficient?

1. light beam
2. heat beam (infrared beam)
3. ultraviolet beam

<table>
<tr><td colspan="5">Answer sheet to the elementary examination for electric welding
Examining board</td><td colspan="5">Name:
First name:
Participant No.:
Place, date:</td></tr>
<tr><td colspan="5">Technical theory</td><td colspan="5">Health protection, labour safety, fire protection</td></tr>
<tr><td>Question</td><td colspan="3">Answer No.</td><td>Score</td><td>Question</td><td colspan="3">Answer No.</td><td>Score</td></tr>
<tr><td>No.</td><td>1</td><td>2</td><td>3</td><td></td><td>No.</td><td>1</td><td>2</td><td>3</td><td></td></tr>
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<tr><td colspan="5">Technical theory
$\frac{\text{Obtained score}}{\text{possible score}} \cdot 100 = ...\% = \text{mark}$
Summary evaluation
$\frac{\text{obtained score}}{\text{possible score}} \cdot 100 = ...\% = \text{mark}$</td><td colspan="5">Examiner</td></tr>
<tr><td colspan="5"></td><td colspan="5">(signature)</td></tr>
</table>

5.4. Evaluation of the examination

Practical examination

The members of the examining board should independently evaluate the test specimens for weld appearance, fracture appearance and accuracy to size. The marks should be entered into the evaluation sheet.

The evaluation of the fracture appearance is not applicable to specimens with work thicknesses of mm. For fracture evaluation, the raw samples should be taken by flame cutting over a width of 40 mm each from weldments carried out in the gravity, vertical−up and horizontal−vertical positions. The evaluation marks can be read from the following table:

Marks	Demands
1 very good	Perfect weld of faultless appearance. Full accuracy to size. Weld−metal − base metal interface entirely free of undercutting. Uniform fusion at the root of the weld. Unobjectionable fracture appearance.
2 good	Weld appearance with minor irregulation and inconsiderable undercutting. Variations in size for fillet welds up to appr. 30 % of the permissible tolerance. Uniform root fusion with inconsiderable irregularities at the arc strikes. Fracture appearance with minor porosity.
3 satisfactory	Weld appearance with irregularities and undercutting, which has no effect on the strength of the weld. Variations in size for fillet welds up to 60 % of the permissible tolerance. Root reinforcement irregular, but full fusion of the root. Fracture appearance with minor slag and medium porosity.
4 fairly satisfactory	Weld appearance with irregularities and edge undercuts, which are not, however, considered to require repair work. Variations in size for fillet welds up to the full permissible tolerance according to the table of weld tolerances. Root fusion over at least 80 % of the length of the specimen. Fracture appearance with isolated larger pores and slags, but without slag lines and slag pockets.
5 unsatisfactory	Weld appearance with irregularities and edge undercuts requiring repair work. Variations in size exceeding the permissible tolerance. Root fusion over less than 80 % of the length of the specimen. Fracture appearance showing porosity with larger faults.

Permissible weld tolerances

Welding technique	Weld thickness	Welding position	Weld reinforcement[9] for butt welds	Variation in the weld thickness for fillet welds
	up to 6		1	
E		gravity horizontal, vertical−down		+ 1.0
	more than 6	−0.5	2	
	arbitrary	vertical−up, overhead, horizontal−vertical	3	+ 2.0
		all positions		− 0.5

[9] Applicable to cover pass and root

The evaluation sheet summarizing the results of the examination should be signed by all members of the examining board.