Text-book Series No. 11

ELECTRIC WELDING

1970

OVERSEAS TECHNICAL COOPERATION AGENCY

JAPAN

FOREWORD

In order to meet the growing requests for the services of Japanese experts in various fields from developing countries, the Overseas Technical Cooperation Agency entrusted with the mission of extending technical cooperation toward those countries by the Government of Japan, is making every possible effort to recruit qualified experts.

However, it is understood that one of the major difficulties encountered by the experts in carrying out training, demonstration, research and experiments abroad is the "language barrier" which sometimes resulted in ineffective implementation of the experts assignment project.

Therefore, in order to settle the difficulty and to obtain a good result in the technical guidance by the experts, the Overseas Technical Cooperation Agency has started to publish a servies of technical text-books.

This technical text-book on "ELECTRIC WELDING" is the translated issue from the Japanese text-book prepared for the vocational training at the Vocational Training Institute by the Ministry of Labour, Government of Japan.

It is hoped that this book will be fully utilized not only by the experts but also by their counterparts and trainees of receipient countries and thereby will serve as an aid to the technical development in the developing countries.

March 1970

Overseas Technical Cooperation Agency

Tokyo, Japan.

CONTENTS

Part 1	Basic Knowledge		
Subject	Arc welding equipment	Work No.	No.1

Fig. 1

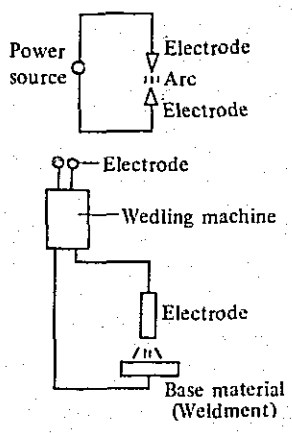


Fig. 2

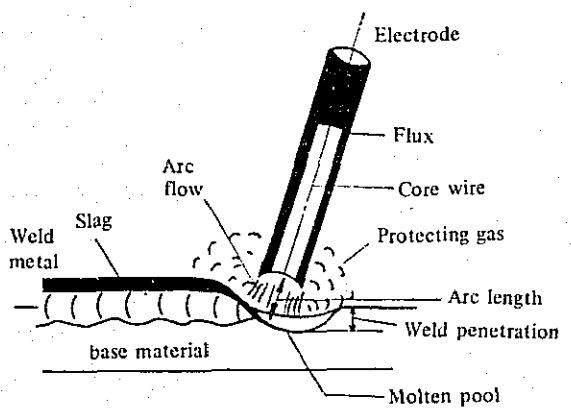


Fig. 3

Fig. 4

No.	Subject	Description
1.	What is arc ?	As shown in Fig. 1, arc is produced when two electrodes, connected to appropriate power sources, come into contact with each other and then are pulled apart slightly and kept at an appropriate distance. The arc produces strong light and heat at this moment..
2.	What is arc welding?	Electric welding are the methods in which insculation is made by fusing the metal locally after the electric energy is changed to heat energy. Arc welding is one of these processes and used widely as a means to inusculate metals. In arc welding, the electrode is brought to come into contact with the base material as shown in Fig. 2 instead of using two electrodes as shown in Fig. A and causes the arc to be produced between the two contact points, using resultant high temperature for welding. Presently, metal arc welding is most commonly used.
3.	What is metal arc welding?	The arc produced between the tip of the electrode and the base material, melts part of the base material and at the same time, the electrode itself melts and deposites on the base material. The metal arc welding is the method which employs a repetition of the foregoing process. For electrodes, coated electrode, which is a core wire coated with flux, is usually used. The state of arc can not be observed with the naked eyes because of its intense glare but it may be illustrated as shown in Fig. 3 when observed through a shield glass.
4.	Welding operation	In actual welding operation, welding equipment such as welding machine, holder, and captire cable are required. Welders are required to wear protective equipment against harmful beam of arc, flying spatter and electric shock. Fig. 4 shows the arc welding operation.

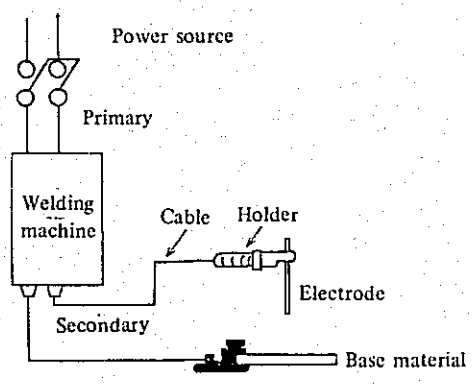


Fig. 1

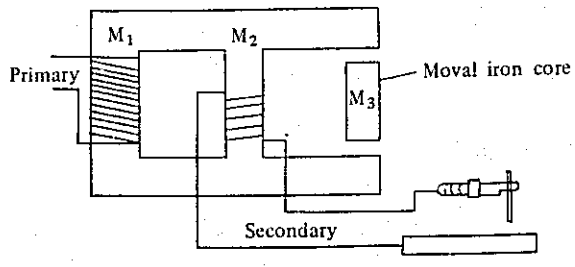


Fig. 2

No.	Subject	Description
1.	Arc welding equipment	Arc welding equipment consists of a welding machine, holder, cable, etc. Completeness of welding equipment has an important bearing on the success of welding operation. As the improper handling of the equipment often causes accidents, utmost care should be exercised in handling these equipment.
2.	Welding circuit	As shown in Fig. 1, electric current is supplied by connecting primary terminal of welding machine to the power source with wires. This is called the primary circuit. One of the secondary terminals of the welding machine is connected to the holder by a cable and another to the earth plate also by a cable, which is further connected to the weld materials (base material) by the earth plate. This is the secondary circuit and is usually referred to as the welding circuit.
3.	Arc welding machine	Arc welding machine is an electric device having characteristics suitable for continued arc generation and is also designed to provide control of welding current. The unit is classified into the direct current arc welding machine and the alternating current arc welding machine according to the type of current the unit is used on. The direct current arc welding machine obtains the direct current either from DC generator which is driven by DC motor or by other prime movers, or from the rectifier. Rectifier mostly in use are selenium rectifier and silicon rectifier. The alternating current arc welding machine is a sort of transformers, having characteristics suitable for the generation and continued existance of arc.
4.	AC arc welding machine (1) Moval iron core type wedlding machine	AC arc welding machines are manufactured in two major types, moval iron core type welding machine and moval coil type welding machine. However, the older type separate leg coil winding type (Tap type) is also in use. This is the type most widely used among the AC arc welding machines. As shown in Fig. 2, an auxiliary iron core is provided in addition to the main iron core, which is movable against the main iron core. Movement of this moval iron core controls electric current.

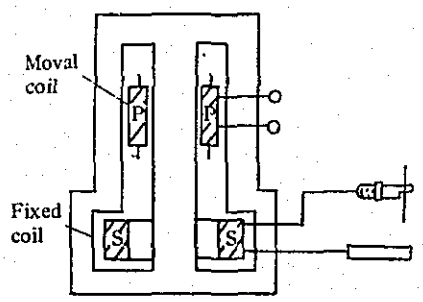


Fig. 3

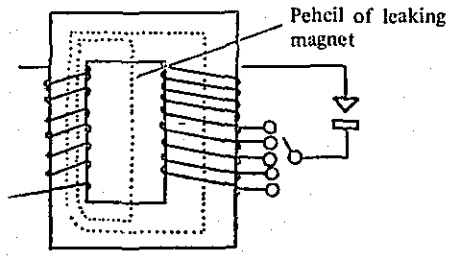


Fig. 4

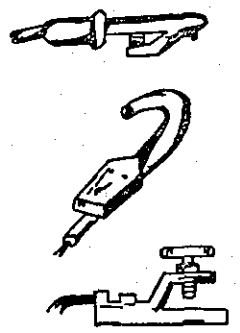


Fig. 5

No.	Subject	Description
	(2) Moval coil type welding machine	The welding machine of this type has a fixed secondary coil as shown in Fig. 3. Movement of the primary coil changes the distance between the primary coil winding and the secondary coil winding to control electric current.
	(3) Separate lag coil winding type welding machine	As shown in Fig. 4, this type has the primary coil and the secondary coil wund separately around each of the iron core legs. Control of electric current is provided by the change in the winding ratio of the primary coil to the secondary coil by shifting the tap. However, precise control of current is not provided with this type.
5	Holder	Holder is used to support the electrode and therefore should be as light as possible in its weight. It must be of the design which provide a rigid holding of the electrode. Holder and captire cable must be joined perfectly in terms of electricity so as to prevent the generation of resistance heat in the joint. The joint is generally soldered.
6.	Earth plate	The device which connects a grounding wire to the base material or to the work bench. Types available are magnet type, clamp type and screw type. The type to be used should provide a secure holding and easy removal.
7.	Welding cables	Cables used to connect the welding machine to the holder or to the earth plate. Rubber insulated captires are used for this purpose. Cables for the holder should be of a high flexibility to provide easy handling during the operation. Cables for the grounding do not require such high flexibility as the one for the holder but should be of the type which provide easy handling. Standard allowable current for single core captire is shown in the table below. When the distance between the welding machine and the work site is great, cable of rather larger size are desirable for the prevention of the loss of electricity and smooth flow of current. For the distance of 2 meters from the holder, cables should be of high flexibility and their size should be smaller than the standard one in view of the fatigue of operator in his hand and the convenience's sake in the work.

Standard allowable current for welding cable (Single core captire cable)

Nominal section area (mm^2)	Allowable current (A)	Voltage drop (V/100 mm)
67	375	12.1
53	300	12.3
42	250	12.6
33.5	200	12.8

Table 1 JIS Z·3211–1961

Type of welding rod	Type of coatings	Position of weld	Electric current to be used
D4300	No provision	F, V. OH, H	AC or DC
D4301	Illuminite type	F, V, OH, H	AC or DC
D4303	Limetitanum type	F, V, OH, H	AC or DC
D4311	High cellulose type	F, V, OH, H	AC or DC (R)
D4313	High titanium oxide type	F, V, OH, H	AC or DC (S)
D4314	Iron powder titanium oxide type	F, V, OH, H	AC or DC (S)
D4316	Low hydrogen type	F, V, OH, H	AC or DC (R)
D4318	Iron power low hydrogen type	F, V, OH, H	AC or DC (R)
D4320	High iron oxide type	F, H-Fil	AC or DC (S) for horizontal fillet welding and AC or DC for flat welding.
D4324	Iron powder titanium oxide type	F, H-Fil	AC or DC
D4326	Low hydrogen type	F, H-Fil	AC or DC (R)
D4327	Iron powder oxide type	F, H-Fil	AC or DC (S) for horizontal fillet welding and AC or DC for flat welding.
D4328	Iron powder low hydrogen type	F, H-Fil	AC or DC (R)
D4330	High iron oxide type	F	AC or DC
D4600	No provision	F, H-Fil	AC or DC

Remarks:

1. Symbols used for the position of weld are as follows:

   F : Flat, V : Vertical, OH : Overhead, H : Horizontal, H-Fil: Horizontal fillet. Positions of weld shown in Table i above apply to the welding rod less than 5 mm in diameter.

2. Abbreviations used for the type of current to be used are as follows :

   AC: Alternating current,
   DC: Direct current double polarity
   DC (S): Direct current straight polarity,
   DC (R): Direct current reversed polarity

No.	Subject	Description
1.	Outline	1. Arc welding rod (electrode) has a combined (dual) function of electrode and weld metal for the weld. Since it has a close relation with the convenience in the welding operation and the quality of weld, a careful attention should be paid to its selection and handling. 2. Arc welding rod commonly in use is a coated electrode. Coatings heop promote generation, stability and durability of arc, provide protection for molten metal (prevention of oxidization and nitriding), supply useful elements and promote the improvement of mechanical properties of weld metal.
2.	Type of coated arc electrode for mild steel	1. Coated arc electrode for mild steel is classified as shown in Table 1, depending on the mechanical property of molten metal, position of weld, type of coatings and type of current. 2. Characteristics comparison of these electrodes is shown in Table 2.
3.	Optimum current for electrode	1. Each electrode has its own optimum current. Use of optimum current in welding result in the maximum performance of the electrode. 2. Optimum current has a certain range and the use of current higher than its upper (maximum) limit will result : (1) Excessive heating of electrode, thus causing a change in the quality of flux and degrading its function. (2) Deterioration of the condition of protector (guard) tube at the tip of electrode, thus causing weld bead to become larger and rendering inefficiency of the work. (3) Increase of spatter and unsatisfactory covering of slag. As a result, appearance of bead is not satisfactory either. 3. When the welding is done with the current lower than the optimum current, it will result in slow weld speed and roll-in of slag, thus making the work more difficult. Appearance of bead is not satisfactory either.
4.	Handling of electrode	(1) Care should be exercised so that coatings do not get moisted. Moisted coatings cause an increase of hydrogen in the weld metal, thus creating defects such as fish eye, linear composition and cracks. It also degrades the efficiency of electrode. (2) Electrode should be dry prior to its use. Do not apply intense fire in an attempt to dry it quickly. Drying for about two hours at about 150°C is most desirable. (About one hour at 355–400°C for low hydrogen type). (3) Electrode should be free of oil and grease or dirt and other impurities. (4) Electrode should never be left indicriminately but should be placed in a container.

Subject Manual arc welding (Thin steel plate) Work No. No.4

Shape and welding requirements of weld joint is governed by (1) -- (6) (JIS Z 3601-1961) in principle.

(1) Butt joint (Square groove welding)

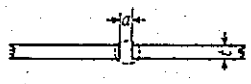


Table 1 Standard requirements for butt joint welding

Plate thickness (mm)	Position of weld	Diameter of electrode (mm)	Welding durrent (A)	Type of electrode coatings	Root opening	Remarks
0.8	Flat, vertical, horizontal	2.0	25–35	Illuminite type, lime titamium type, high titan oxode type, high cellulose type	0–1/2 t	Single weld
1.2	Flat, vertical, horizontal	2.6	40–55	Illuminate type, lime titamium type, high titan oxode type, high cellulose type	0–1/2 t	
1.6	Flat, vertical, horizontal	2.6	55–70 (50–65)	Illuminate type, lime titamium type, high titan oxode type, high cellulose type	0–1/2 t	Single or double welding
2.3	Flat, vertical, Horizontal	2.3	65–90 (65–85)	Illuminite type, lime titamium type, high titan oxode type, high cellulose type	0–1/2 t	

Remarks: Figures in parenthesis show the current for internal welding.

(2) T jointing (Fillet weld)

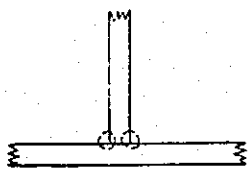


Table 2 Standard welding requirements for T jointing

Plate thickness (mm)	Position of weld	Diameter of electrode(mm)	Welding current (A)	Type of electrode coatings
1.6	Flat, vertical	2.6	60–80	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
2.3	Flat, vertical	3.2	85–100	Illuminite type, lime titenium type, high titan oxide type, high cellulose type

(3) Lap joint

(A) Fillet weld

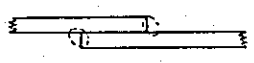


Table 3 Standard welding requirements for lap joint

Plate thickness (mm)	Position of weld weld	Diameter of electrode (mm)	Welding current (A)	Type of electrode coatings
0.8	Flat, vertical horizontal	2.0	30–40	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
1.2	Flat, vertical, horizontal	2.6	55–65	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
1.6	Flat, vertical horizontal	2.6	65–80	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
2.3	Flat, vertical horizontal	3.2	90–100	Illuminite type, lime titanium type, high titan oxide type, high cellulose type

(B) Plug weld

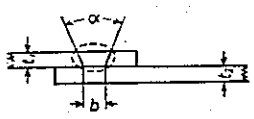


Table 4 Standard welding requirements for lap joint (for plug weld)

Thickness of drilled plate (mm) t'	Thickness of undrilled plate (mm)	Position of weld	Diameter of electrode (mm)	Welding current	Type of electrode coatings	Bore side	Included angle
0.8	More than 1.2	Flat	2.0	45–60	Illuminite type, lime titanium type, high cellulose type	0–4	0
1.2	More than 1.2	Flat	2.6	80–100	Illuminite type, lime titanium type, high cellulose type	6	0
1.6	More than 1.2	Flat	3.2	105–125	Illuminite type, lime titanium type, high cellulose type	8	0
2.3	More than 1.2	Flat	3.2	105–125	Illuminite type, lime titanium type, high cellulose type	10	0

3.2	1.2 – 2.3	Flat	3.2	110–130	Illuminite type, lime titanium type, high cellulose type	10	0
4.5	1.2 – 2.3	Flat	3.2	110–130	Illuminite type, lime titanium type, high cellulose type	10	0
6.0	1.2 – 2.3	Flat	3.2	115–135	Illuminite type, lime titanium type, high cellulose type	12	0
						10	60

(4) Joggled lap joint (Fillet weld)

Table 5 Standard welding requirements for joggled lap joint

Plate thickness (mm)	Position of weld	Diameter of electrode (mm)	Welding current (A)	Type of electrode coatings
0.8	Flat, vertical, horizontal	2.0	30–40	Illuminite type, limetitamium type, high titan oxide type, high cellulose type
1.2	Flat, vertical horizontal	2.6	55–65	Illuminite type, limetitamium type, high titan oxide type, high cellulose type
1.6	Flat, vertical, horizontal	2.6	65–80	Illuminite type, limetitamium type, high titan oxide type, high cellulose type
2.3	Flat, vertical, horizontal	3.2	90–100	Illuminite type, limetitamium type, high titan oxide type, high cellulose type

(5) Corner joint

Table 6 *Standard welding requirements for corner joint*

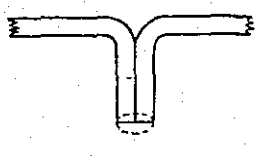


Plate thickness (mm)	Position of weld	Diameter of electrode (mm)	Welding current (A)	Type of electrode coatings
0.8	Flat, vertical, horizontal	2.0	20–35	Illuminite type lime titanium type, high titan oxide type, high cellulose type.
1.2	Flat, vertical, horizontal	2.6	40–50	Illuminite type lime titanium type, high titan oxide type, high cellulose type
1.6	Flat, vertical horizontal	2.6	50–70	Illuminite type, lime titanium type, high titan oxide type, high cellulose type.
2.3	Flat, vertical horizontal	3.2	70–90	Illuminite type lime titanium type, high titan oxide type, high cellulose type.

(6) Edge joint

Table 7 Standard welding requirements for edge joint

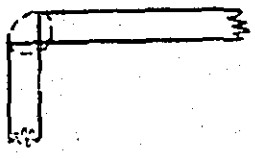
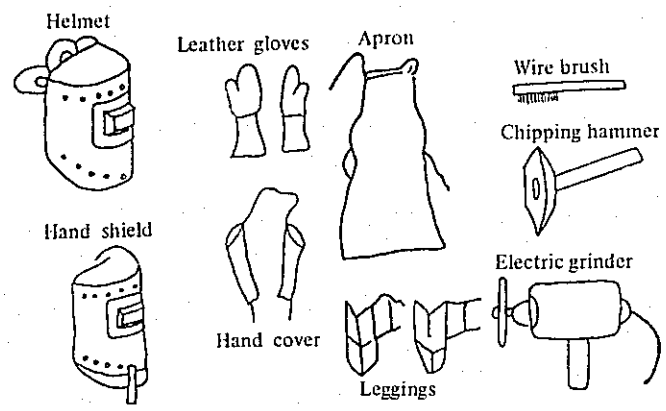


Plate thickness (mm)	Position of weld	Diameter of electrode (mm)	Welding current (A)	Type of electrode coatings
0.8	Flat, vertical, horizontal	2.0	20–35	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
1.2	Flat, vertical horizontal	2,6	35–50	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
1.6	Flat, vertical, horizontal	2.6	45–60	Illuminite type, lime titanium type, high titan oxide type, high cellulose type
2.3	Flat, vertical, horizontal	3.2	55–80	Illuminite type lime titanium type, high titan oxide type, high cellulose type

Part 1	Basic Knowledge	(Electric welding)
Subject	Protective equipment and other equipment	WORK No. No.5

Operator wearing protective equipment



No.	Subject	Description
1.	Requirement for protective equipment	Hazards of arc welding are electric shock, harmful rays (ultraviolet rays, infra-red rays), poisonous gases and spatterings. In order to protect the body from these hazards, welders must wear protective equipment shown in the picture above during the work.
2.	Helmet and hand shield	1. This provide protection for head and face and at the same time it can be used for observing the weld by installing a light shield glass in the lens box. Material to be used should be non-conductor of electricity and light in weight. 2. Helmet is suitable for the work being performed on unstable footings such as scaffolding or for vertical and overhead welding. Hand shield is suitable for the work on the ground level where wide range of vision is required.
3.	Light shield glass	1. It must be able to absorb and shield harmful rays completely and moreover it must have the transparency which provides sistinct observation of the weld. It is used along transparent glasses in its front and back to protect from the spattering. 2. Transparent glass should be replaced before they become extremely dirty.
4.	Other protective equipment	1. Other protective equipment are leather gloves, apron, hand covers, and leggings. All of these equipment should have heat resistancy and should contain less moisture. They should also be of soft materials so that the operation may not be hampered. 2. Gas masks should be worn for the work which may involve poisonous gases. 3. Screen and light shield curtains are also needed as a protection against harmful rays.
5.	Cleaning tools and others	1. Rust or other foreign matters in the weld degrade mechanical strength of the deposite metal and cause blowhole or cracks. Therefore, weld joint should be thoroughly cleaned prior to the welding operation. 2. For cleaning of weld joint and removal of slag, chipping hammer, wire brush, chisel and single hand hammer are required. Portable electric grinder is also helpful for edge preparation, grinding of excess metal or surface finishing. 3. Other tools required are pliers, electrode containers and holder hanger.

Table 1 Plate thickness and diameter of electrode

Thickness of base material (mm)	Diameter of electrode (mm)
Less than 2	1.5–2
2	2–2.6
3	2.6–3.2
4	3.2–4
5–6	4
7–10	4–5
More than 11	5–8

Table 2 Diameter of electrode and welding current

Diameter of electrode (mm)	Welding current (A)
Less than 2	20–50
2	40–80
2.6	50–100
3.2	80–120
4	120–180
5	150–230
6	200–300

Work No.	*No.1*
Type of work	Preparation of welding equipment
Main points	Installation of welding machine, establishment of welding circuit and other preparations
Materials	Insulating tape
Tools	Cleaning tools Protective equipment

No.	Sequence of work	Description	Related Information
1.	Connect welding machine to power source	1. Welding machine having the primary voltage of 100V should be connected to 100V power source and that having the primary voltage of 200 V should be connected to 200V power source. 2. Welding machine having three taps, 220V, 200V and 180V on primary side should be connected to its 220V tap when the voltage at power source is 220V and should be shifted to 180V tap when the voltage at power source dropped to 180V. However, when the voltage at power source returned to normalcy, it must be shifted to corresponding tap. 3. Check primary line (Poorly insulated portion should be repaired with insulating tape). 4. Outer container (outside box) of welding machine should be grounded.	
2.	Establish welding circuit (secondary circuit)	1. Connect holder line and grounding wire to the secondary terminal of the welding machine. 2. Check cable and repair frayed portion. 3. Make sure that the earth plate is attached to the weldment or to the work bench securely. 4. All connections should be clamped securely. 5. Check and ascertain that the connection of the cable and holder is complete (generally connection is soldered).	
3.	Prepare cleaning tools	Prepare wire brush, chipping hammer, single hand hammer, shisel and pliers.	
4.	Prepare protective equipment	1. Put on gloves, apron, hand covers, leggings and head gear and ascertain their dependability against the hazard of welding. 2. Check to see that the light shield glass of hand shield or helmet is not soiled and dirty.	
5.	Select electrode and determine welding current	1. Selection of electrode and welding current should be made by taking into account the type of material, plate thickness and welding requirements. 2. For replationship between plate thickness and diameter of electrode, see Table 1. 3. For relationship between the diameter of electrode and wleding current see Table 2.	

(1)	Tape shifting handle
(2)	Moval iron core operating handle
(3)	Secondary terminal
(4)	Switch

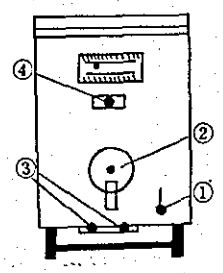


Fig. 1 Moval iron core type welding machine

(1)	Control handle
(2)	Current indicator
(3)	Secondary terminal

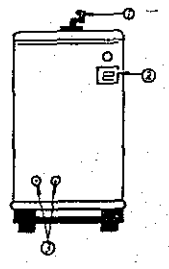


Fig. 2 Moval coil type welding machine

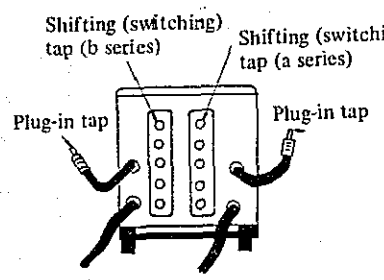


Fig. 3 Separate leg coil coil winding type (tap type) welding machine

Work No.	No. 2
Type of work	Handling of welding machine
Main points	Handling of welding machine and control of current
Materials	
Tools	One ammeter (400A) One voltmeter (50 V)

No.	Sequence of work	Description	Related information
1.	Prepare welding equipment	1. Connect welding machine to power source Refer to No. 2. Establish (mark) welding circuit.	
2.	Connect ammeter and voltmeter	1. Measurement of welding current: Measurement is taken by connecting ammeter in series to the welding circuit. 2. Measurement of arc voltage: Measurement is taken by connecting the voltmeter to the point between the both terminals of circuit to produce arc and pressing the switch on the voltmeter.	
3.	Control current	1. Control of current for moval iron core type welding machine. See Fig. 1 (1) Throw in switch on power source (side) after checking the internals of welding machine and ascertain that there is no possibility of short circuit or burning of the line. (2) Throw in switch on the welding machine, turn handle (2) and shift moval iron core to control current. (3) Then, throw in switch on the welding machine, turn handle (2) to shift moval iron core for a precise control of current. (4) Shifting of tap should be made only after disconnecting the switch. 2. Control of current for moval coil type welding machine. See Fig. 2. (1) Throw in switch after checking the internals of the welding machine. (2) Turn handle (1) in Fig. 2 and shift moval cokl to control current. 3. Control of current for separate leg coil winding type (tap type) welding machine. (1) Throw in switch after checking the internals of welding machine. (2) Plug the plug tap into the shifting tap to control current. For the type having the change (shifting) taps in two rows as shown in Fig. 3, control of current is made by plugging the tap (a) into the line (a) and the tap (b) into the line (b) and also by the combination of plug-in position of (a) and (b). (3) Tap should be plugged in completely.	Make certain that shifting of switch has been made. This welding machine provides only fragmental control of current.
4.	Other precautions	1. Switches on power source and welding machine should always be disconnected after work or at time of breaks. 2. Welding machine should not be installed at the location where leakage of rain water or sumersion in the water may be encountered or at the location of high humidity. 3. Internals of the welding machine should be inspected periodically and all connections should be tightened securely. Moving parts should be lubricated. 4. Welding machine should never be used without its cover placed in right location. 5. When the machine is to be used for a prolonged duration, attention should be paid to the rise of temperature in the coil or other parts. When there is a sign of burning out, disconnect switch immediately and let the internals cool down.	
Remarks			

Part 2	Demonstration

Fig. 1

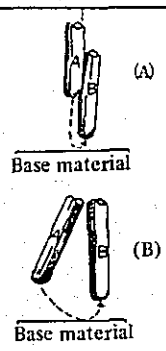


Fig. 2

Work No.	No.3
Type of work	Generation of arc
Main points	Generation of arc
Materials	One mild steel plate (6–8) x 100 x 150 mm Electrode 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Prepare welding equipment. Refer to No. 2. Place steel plan horizontally and brush off the surface with wire brush to remove rust and foreign matters. 3. Welding current should be 140–160 A.	Work under No.1 is common to all processes. Therefore, this procedure will not be repeated for the subsequent demonstrations.
2.	Posture	1. Bend the upper half, of the body forward slightly, stand with both feet spread a half step apart, weaken the strength in the shoulder and spread elblows out horizontally. 2. Grip holder lightly. 3. Handle holder cable in such a manner haht will not hamper operation. (1) Care should be taken so that the cable will not twist. (2) When the weight of the cable hampers operation, wind the cable around the wrist or lay it over the lap or put it on the shoulder.	Position of weld should be natural and stable. Fig. 1 shows an example of positions of weld (welding posture) for flat welding.
3.	Generate (produce) arc	1. Insert electrode in the holder at a right angle. 2. Hold electrode vertically to the surface of steel plate and bring the tip close to the point of arc generation. 3. Put on handshield or helmet to protect face. 4. (1) Hit the steel plate lightly with the tip of electrode, reaction of which will provide a clearance of 2–3 mm between the tip of electrode and base material and produce arc. (Refer to Fig. 2 (A).) (2) Rub the tip of electrode against the base materaial in the manner similar to striking a match by maintaining a clearance of 2–3 mm between the tip of electrode and base material and produce arc (Refer to Fig. 2 (B).) 5. When the electrode stuck to the base material and would not move, disconnect switch immediately.	(1) When using a handshield, put on the shield first and then produce arc. (2) When using a helmet, pull down the shield first and then produce arc.

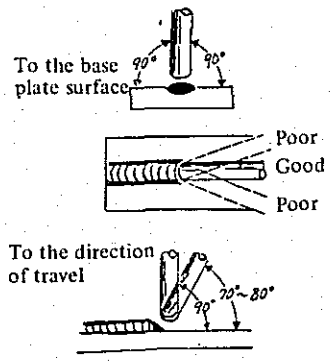


Fig. 1 Angle of electrode

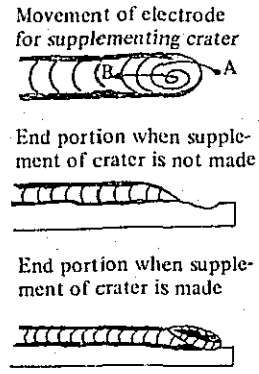
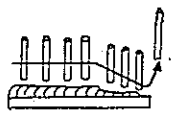


Fig. 2

Work No.	No. 4 – 1
Type of work	Placement of bead
Main points	Placement of string bead
Materials	One mild steel sheet (8–10)x100x250 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to No. 3–1. 2. Welding current should be 140–160 A.	
2.	Posture	Refer to No. 3–2 position of weld for flat welding.	
3.	Produce arc	Arc should be produced at the starting point of welding. Refer to No.3–3	
4.	Place bead	1. Maintain the angle of electrode vertically to the surface of base material but the electrode may be held at an inclination of 70°–80° in the direction of movement depending on the type of electrode. Refer to Fig. 1. 2. Electrode should be moved from left to right in a straight line. 3. Lower electrode slowly and move it in the designated direction while maintaining the arc length at 2–3 mm 4. Maintain uniform bead width (6–8 mm).	Base material – weldment (1) If the speed of movement is too slow, it will result in wider bead and cause roll-in of slag. (2) If the movement is too fast, it will result in a discontinued bead and involve (rolls in) slag. If the speed is not cons-constant, width of the bead will not be uniform.
5.	Cut off arc	*Shorten the arc a little before dis-*continuing the bead and promptly pull it apart immediately before a short-circuit occurs . 	
6.	Join bead	1. Remove slag from the suspended portion and clean it up. 2. Produce arc at point A shown in the figure at right, and join the bead by turning back in the order of A→B→C. 	
7.	Supplement the bead	1. Crater at the end of bead should always be supplemented by deposited metal. 2. Remove slag from crater, produce arc at the point A shown in Fig. 2 had supplement crater by moving electrode as shown in the figure. Repeat this movement until the concaved portion of crater is supplemented to the height of the bead.	When supplementing the crater, care should be exercised so that the portion will not be over-heated, which may result in a flow out of deposite metal or enlargement of crater. Arc should be maintained as short as possible.

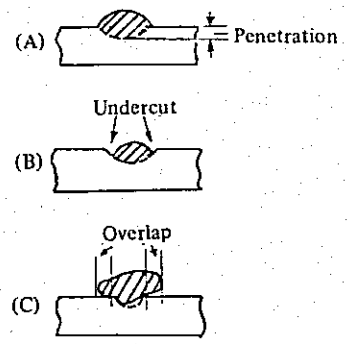


Fig. 3


200A 150A 90A 50A
Fig. 4


(A) (B) (C)
200A 150A 50A
Fig. 5

Work No.	No. 4 — 2
Type of work	Placement of bead
Main points	Placement of string bead
Materials	One mild steel plate (8—10)x100x250 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Inspect (check) bead	1. Satisfactory bead should have a proper penetration as shown in Fig. 3 (a) without undercut or overlap and should have uniform wave pattern with less irregularities. 2. Bead should be straight and in uniform width. 3. Bead having undercut or overlap as shown in Fig.3 (b) and (c), disproportioned wave pattern and extreme irregularities and uneven penetration is not desirable. 4. Welding current and penetration: Fig 4 shows the relationship between the welding current and penetration. An electrode 4 mm in diameter was used on the mild steel plate 9 mm in thickness and the bead was placed by changing the welding current from 50 A to 90 A, 150 A and 200 A. With 50 A and 90 A, penetration was insufficient and the bead had many irregularities. With 150 A, penetration was sufficient and the wave pattern of bead was fine and uniform. With 200 A, penetration was sufficient but the wave pattern of bead showed rough and discontinued string. 5. Welding current and appearance of bead: Fig. 5 shows the appearance of each of the above mentioned beads. (a) Bead made with excessive current. (b) Bead made with appropriate current. (c) Bead made with weakened current. Description in 4 and 5 above may be summarized that the optimum current for flat string bead on the mild steel plate 9 mm in thickness with an electrode 4 mm in diameter would be 140–160A. It should be kept in mind, however, that the welding current varies with the type of electrode and the thickness of the plate.	Undercut Fine groove created along the weld line on the boundary between bead and base materials. Overlap Boundary of bead and base material has not been fused and only overlapping each other. Cause of undercut (1) Excessive electric current. (2) Improper handling of electrode. (3) Excessively long arc as a result of excessive current. Cause of overlap (1) Current is too weak. (2) Improper movement of electrode. (3) Arc is too long as a result of weak current.

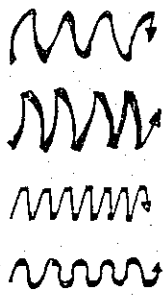


Fig. 1 Movement of electrode for weaving bead.
Move electrode slowly where it is shown by thick line and move it fast where it is shown by thin line.

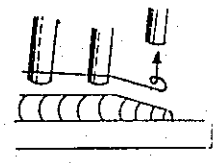


Fig. 2 Separation of arc

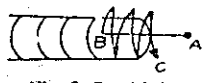
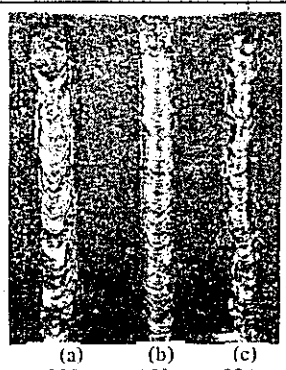


Fig. 3 Bead joint



(a) 200A (b) 150A (c) 50A

Fig. 4

Work No.	No. 5
Type of work	Placement of bead
Main points	Placement of weaving bead
Materials	One mild steel plate (8–10)x100x250 mm Electrode 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to No.3–1 2. Welding current should be 150–170 A.	
2.	Posture	Refer to No 3–2.	
3.	Produce arc	Refer to No. 3–3.	
4.	Place bead	Refer to No.4–4, angle of electrode. For the movement of electrode, see Fig. 1. 1. Maintain constant arc length and proceed by moving the electrode as shown in Fig. 1. 2. Move electrode fast when it passes the center of bead and stop it a little at both ends in the movement of electrode from side to side. 3. Weaving pitch should not be of rough or irregular intervals. 4. Movement of electrode should be made in such a manner that it would not cause irregularities in the condition of molten pool.	Molten pool (1) Movement of electrode for weaving bead should not be done by the wrist alone (angle of electrode to the base material changes). Try to use the whole arm for its operation. (2) Care should be exercised so that the width of bead will not become greater than three times the diameter of electrode being used.
5.	Cut off arc	Shorten arc while making the weaving and quickly cut off it by turning the tip in a small circle as shown in Fig.2.	
6.	Join the bead	1. Remove slag and clean the supended portion. 2. Produce arc at point A shown in Fig. 3, proceed to point B, and return to join the bead by maintaining weaving movement of electrode.	(1) A-B is for preheating. (2) The turn at point B should be made promptly, otherwise satisfactory joint of bead can not be expected. (3) B–C is for deposition of metal.
7.	Supplement crater	Refer to Demonstration No. 4–7.	
8.	Check welds	1. Wave pattern of bead should be uniform and without irregularities. 2. Bead should not have undercut or overlap. 3. Relations of welding current to the penetration and appearance are similar to those for straight bead. Refer to Demonstration No. 4–2. 4. Fig. 4 shows the appearnce of weaving bead (a) Bead made with excessively high current. (b) Bead made with appropriate current. (c) Bead made with too low current.	

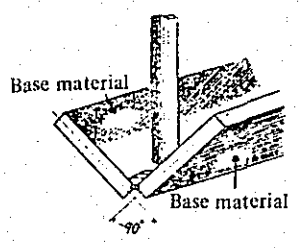


Fig. 1

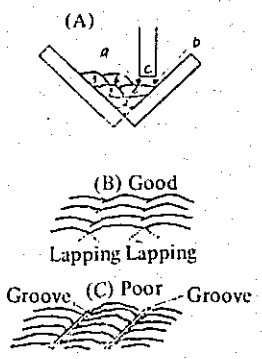


Fig. 2

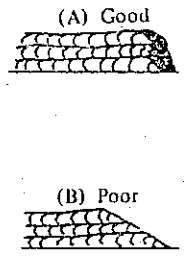
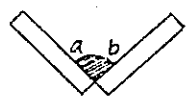
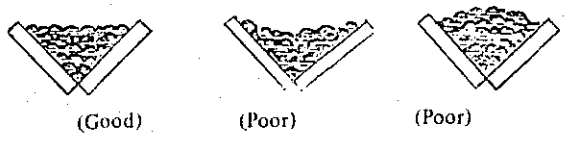


Fig. 3

Work No.	No. 6
Type of work	Placement of bead
Main points	Lapping of bead
Materials	Two mild steel plates (8–10)x80x200 mm Electrode 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Clean weld surface. 2. Welding current (For string bead – 140–160 A For weaving bead – 150–170 A)	Current for tack weld should be slightly stronger than that required for final welding to provide easy production of arc and sufficient penetration and also to prevent piling of bead.
2.	Make tack weld	1. Join both steel plates at an angle of 90 as shown in Fig. 1 and make tack weld at both ends. 2. Produce arc on other steel plate and bring the tip close to the weldment while the tip is still red in color to make tack weld. 3. After tack weld has been made, place the plate horizontally with the top of angle facing down.	If arc is produced directly over the weldment in making tack weld, the shock of arc may upset the joint of base material.
3.	Place bead	1. Practice string bead and weaving bead movement alternately. 2. For the angle and movement of electrode, refer to No. 4 and 5. Refer to Fig. 2 (A) 3. For bead lapping, refer to Fig. 2 (A). 4. First and second layers should be welded by single bead. The third layer and thereafter should be made by several passes after determining appropriate bead width. 5. Remove slag and clean at each pass. 6. When making a final pass for each layer, try to make the opening (clearance) between the previous bead (a) and base material (b) a little wider than electrode as shown in Fig. 2 (A). 7. Lap of each pass should be welded by providing complete joint as shown in Fig. 2 (B) and care should be taken not to make deep groove in the surface as shown in Fig. 2 (C).	Single bead: Bead in single line. (Pass) : Bead made with a single movement of electrode. Shape of single bead layer. When the single bead layer has a pile like the one shown in the figure below, point (a) and (b) often accumulate slag. Try to make a flat bead. 
4.	Supplement crater	Supplement of crater should be made accurately and care should be taken not to make the final portion of bead layer inclined. Refer to Fig. 3.	
5.	Check the bead	1. Check to see that the deposite metal has any cavities because of blowhole or slag. 2. Check to see that finished surface is flat 	

Part 2	Demonstration

(Electric welding)

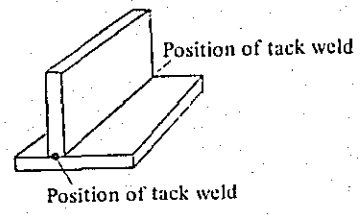


Fig. 1

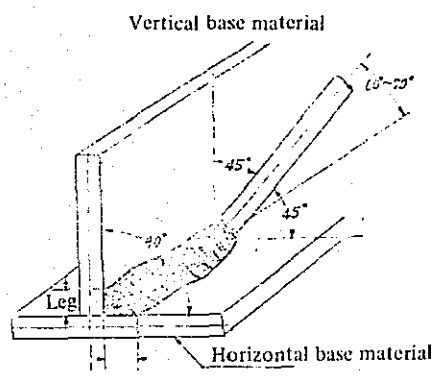
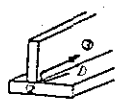
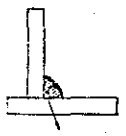


Fig. 2

Work No.	No. 7 – 1
Type of work	Horizontal fillet welding
Main points	Placement of string beam for T Joint
Materials	Two mild steel plates (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Finish cross-section and surface plane so that butt portion (joint) will not have a gap and then clean weld joint. 2. Welding current should be 150–170 A.	
2.	Make tack weld	1. Set up base materials in T shape and make tack weld at both ends avoiding weld line. See Fig. 1. 2. For tack weld procedure, refer to No.6–2. 3. After completing tack weld, place weld line horizontally.	
3.	Produce arc 	1. Maintain the angle of electrode at 45° to both base materials and produce arc in the manner described in No.3. 2. Produce arc at the point 10 mm inside from the end of weld line. While preheating the weld joint with arc, move toward the end and turn back to start welding. See figure at left.	
4.	Place bead	1. Maintain electrode at 45° to both base materials. Incline (tilt) it at 50°–70° to the direction of movement. However, inclination as close to 90° as possible will result in better penetration. Refer to Fig. 2. 2. Movement of electrode. Straight line (from left to right). 3. Movement from the point where arc is produced to the starting point of welding is aimed at providing preheating. Use long arc and shift to weld point before molten metal starts dripping. 4. While giving both base materials uniform penetration, move over the weld line so as to make the length of both legs equal. 5. Care should be taken so that it will not result in an insufficient penetration in the root of bead. 6. Electrode should always travel before slag. If slag travels before the electrode, it results in roll-up of slag.	Angle to the direction of movement should not be less than 60°:  Insufficient penetration
5.	Cut off arc	Maintain electrode at 45° to both base material and cut off arc in the manner described in No. 4–5.	

Part 2	Demonstration

(Electric welding)

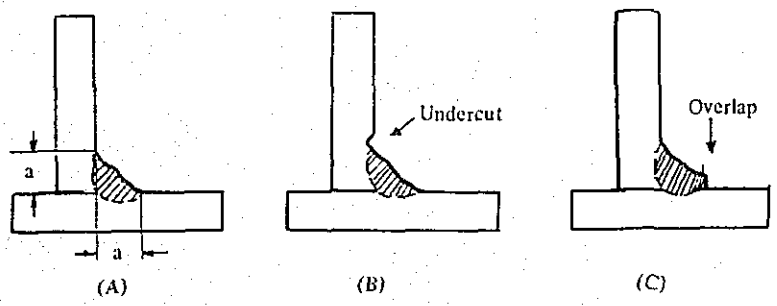


Fig. 3

Work No.	No. 7 – 2
Type of work	Horizontal fillet welding
Main points	Placement of string bead for T-piece
Materials	Two mild steel plates (8–10)x70x200 mm Electrode 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
6.	Join bead	Maintain electrode at 45°to both base materials and follow procedures described in No. 4–6.	
7.	Supplement crater	Maintain electrode at 45°to both base materials and follow procedures described in No. 4–7.	
8.	Check (inspect) welds	1. There should be complete penetration at the starting point of welding. 2. Surface of bead should be smooth and should have uniform wave pattern. The width of bead should be uniform and the length of vertical leg and horizontal leg should be even. 3. Cross section of desirable bead should have equal leg length as shown in Fig. 3 (A) and should have no faults such as overlap and undercut. It should also have sufficient penetration to its root. 4. Weld having undercuts or overlaps at the toe of bead weld or that having insufficient penetration at the bead root, as shown in Fig. 3 (b), (C) are not desirable.	Toe of weld: The boundary line of bead and base material. Undercut tends to occur in vertical base material and overlap is frequent with horizontal base material. When current is too weak or when the weld rate is too fast, it often results in an insufficent penetration.

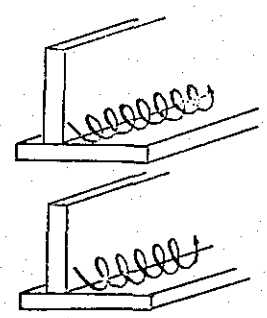


Fig. 1

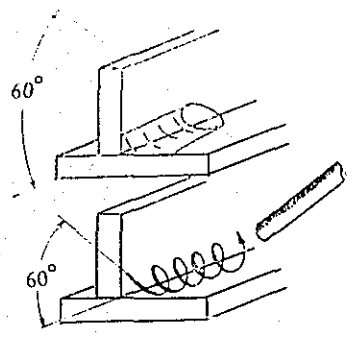


Fig. 2

Work No.	No.8
Type of work	Horizontal fillet welding
Main points	Placement of weaving bead for T joint
Materials	*Two mild steel plates* (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	Refer to No.7 – 1. Welding current should be 150–170 A.	
2.	Make tack weld	Refer to No. 7 – 2.	
3.	Produce arc	Refer to No. 7 – 3.	
4.	Place bead	1. Angle of electrode – Same as for string bead. 2. Movement of electrode – Refer to Fig. 1. 3. Weaving operation should be made at an incline of about 60 against the weld line (as a result, surface of molten pool has a similar inclination). Refer to Fig. 2. 4. In weaving operation, movement of electrode from bottom to top should be made as if to only maintain arc and the movement from top to bottom should be made as if to supply molten metal. 5. Care should be exercised since this process involves more deposite metal than string bead and tends to make overlapped bead. 6. For other information, refer to No. 7 – 4.	
5.	Cut off arc	Maintain electrode at 45° to both base materials and follow procedures described in No. 5 – 5.	
6.	Join bead	Maintain electrode at 45° to both base materials and follow procedures described in No. 5 – 6.	
7.	Supplement crater	Maintain electrode at 45° to both base material and follow procedures described in No. 4 – 7.	
8.	Check welds	Refer to No. 7 – 8.	

Part 2	Demonstration

(Electric welding)

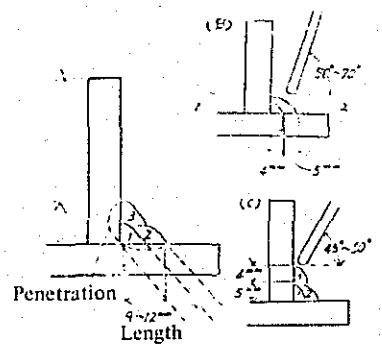


Fig. 1

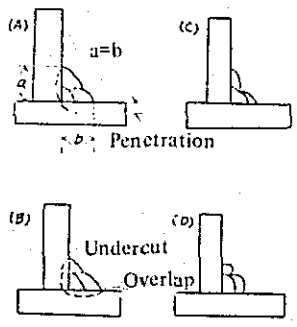


Fig. 2

Work No.	No. 9
Type of work	Horizontal fillet welding
Main points	Placement of multi-layer bead for T joint
Materials	Two mile steel plates (8–10) x 70 x 200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	Refer to No. 7 – 1.	
2.	Make tack weld	Refer to No. 7 – 2.	
3.	Welding sequence and size of fillet	1. When finishing in two layers, place bead in the sequence shown in Fig. 1 (A). 2. Finish bead of the second layer with the pass 2 and 3. Refer to Fig. 1 (C) 3. Leg length should be 9–12 mm.	
4.	Produce arc	Refer to No. 7 – 3.	
5.	Place bead of the first layer	1. Place string bead or narrow weaving bead. Refer to No. 7–4 and No. 8–4. 2. Since the leg length should be finished to 9–12 mm in the second layer, make the leg length of bead 4–6 mm.	Welding current slightly stronger (higher) than that described in the Demonstration No.7 and 8 will provide sufficient penetration and make the work easier.
6.	Place bead of the second layer	1. Remove slag and clean the weld joint for each layer. 2. For making the pass shown in Fig.B-2, refer to Fig. 1 (B). (1) Maintain electrode at 50°–70°to the horizontal base material. (2) Welding should be made by using the toe of weld of the first head on the side of horizontal base material as a basis with a particular attention paid to overlap. 3. For making the pass No.3, refer to Fig. 1 (C). (1) Maintain electrode at 45°–50°to the horizontal base material. (2) Welding should be made by maintaining the arc short and using the toe of weld at the side of the vertical base material as a basis, paying a particular attention to undercut. 4. For other information, refer to No.8.	Undercut often occurs in the vertical base material and the overlap is frequent with the horizontal base material. Refer to Fig.2 (B).
7.	Check (inspect) welds	1. Cross-section of desirable bead is shown in Fig. 2 (A). 2. Lap of bead should not be like the ones shown in Fig. 2 (C) and (D). 3. For other information, refer to No. 7 – 8.	

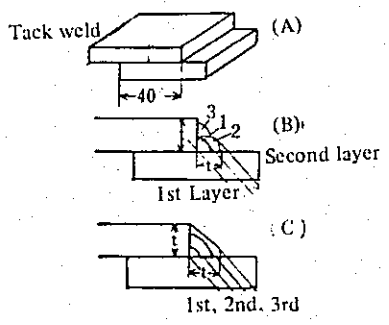


Fig. 1

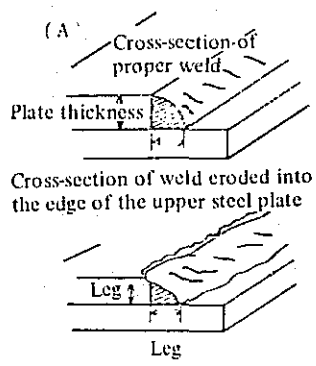


Fig. 2

Work No.	No. 10
Type of work	Horizontal fillet welding
Main points	Placement of multi-layer for lap joint
Materials	Two mild steel plates (8–10)x80x200 mm Electrode 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Finish surface in such a manner that no gap is made at the lap portion of base material. 2. Welding current should be 150 – 160 A.	
2.	Make tack weld	1. Maintain the lap length of base material at 40 mm and make tack weld at the both ends of the plate avoiding weld line. Refer to Fig. 1 (A). 2. For tack weld procedure, refer to No. 6 – 2. 3. Clean weld joint and lay weld line horizontally.	
3.	Produce arc	Refer to No. 7–3.	
4.	Place the first bead layer	Make straight bead or narrow weaving bead. Refer to No. 7 and 8.	
5.	Place the second and third layers	1. When finishing is made by the second layer : (1) Welding sequence is shown in Fig. 1 (B) (2) Make each pass to place weaving. Refer to Demonstration and No.9. (3) Since the edge of upper base material tends to melt easily, move electrode promptly on that portion to avoid undercut. 2. When finishing is made with the second and third layer : (1) Welding sequence is shown in Fig. 1 (C) (2) Place weaving bead. Refer to No. 8 (3) Try not to leave undercut on the edge of upper base material.	Size of fillet: Since the vertical leg length is equal to the plate thickness, make the horizontal leg length also equal to the plate thickness.
6.	Check welds	1. Weld joint should be in proper shape as shown in Fig. 2 (A). 2. The one shown in Fig. 2 (B), which has eroded the edge of upper base material, appears to have proper bead. Its cross-section, however, shows uneven leg length and penetration. 3. For further information, refer to No. 9–7.	

Part 2	Demonstration

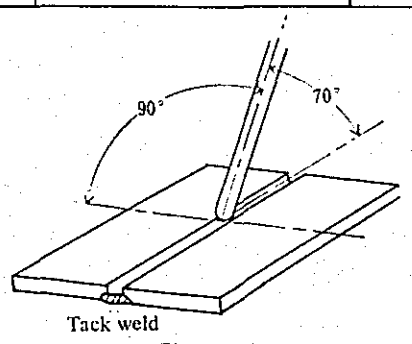


Fig. 1

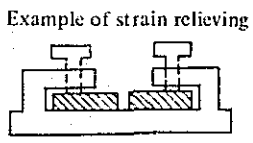


Fig. 2

Work No.	No. 11
Type of work	Flat butt welding
Main points	Square groove welding
Materials	Two mild steel plates (3–6)x80x250 mm Welding rod 4 mm in diameter
Tools	

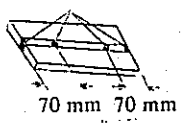
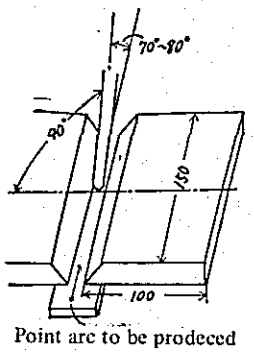
No.	Sequence of work	Description	Related information
1.	Make preparation	1. Cut base material to the desired dimension, relieve strain and finish butt portion (surface of joint) with a grinder. 2. Welding current should be 80–120 A.	(1) In butt welding, thin plate less than 6 mm in thickness are normally welded without beveling. For the plate 6 mm in thickness, however, make a root running after making back-chipping. (2) Plate thickness and root opening.
2.	Make tack weld 	1. Butt (join) steel plate and make tack weld by maintaining a proper root opening. 2. For position of tack weld, see figure at left. 3. After finishing tack weld, finish the surface of bead with a grinder to make the surface equal to the thickness of the plate. Place the plate horizontally with the surface facing down.	
3.	Produce arc	Refer to No. 3–3.	
4.	Place the first bead layer	1. Maintain electrode at 90° to the plane of base material and incline it to 70°–80° against the direction of movement. Refer to Fig. 1. 2. Movement of electrode – String bead. 3. Proceed by maintaining the arc short and giving both base materials even penetration.	
5.	Place the second bead layer	1. Welding current should be 120–150 A. 2. Angle of electrode – Same as for the first layer. 3. Movement of electrode – String bead or narrow weaving bead. 4. Give sufficient melting to the point where holes of the first bead layer was filled up. 5. Move electrode in such a manner as to correct irregularities in the surface of the first bead layer and maintain the width of bead a little greater than that of the first bead layer. 6. For other information, refer to No.4 and 5.	
6.	Check welds	1. Weld should have sufficient penetration to the bottom. 2. Bead surface should be smooth and wave pattern should be uniform. 3. Weld should not have suchdefects as undercut or overlap. 4. Excess metal of bead should not lean toward one side or crooked. 5. Brooping bead in the back in not desirable.	(3) Welding of thin plate often causes strain. Provide appropriate clamp to prevent strain. Refer to Fig. 2. (4) When welding current is too strong (hight) or when movement of electrode is too slow, weld point get overheated causing the flow out of molten metal and making blow holes in the base material. (5) When blowholes have been made, clean the portion thoroughly and fill up the hole by supplementing with deposit metal by using intermittent arc. (This process is similar to that for supplementing craters).

Plate thickness mm	Root opening mm
2.3	0– 1
3.2	2
4.5	3

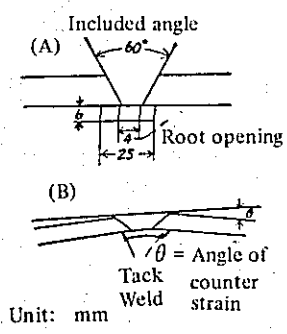
Part 2	Demonstration

(Electric welding)



Point arc to be prodeced

Fig. 1



Unit: mm

Fig. 2

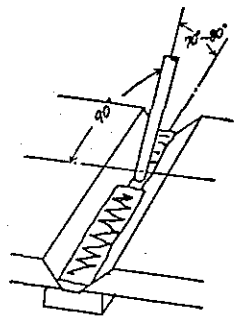


Fig. 3

Work No.	No. 12 – 1
Type of work	Flat butt welding
Main points	Single V-groove welding *with a strap*
Materials	Two mile steel plates (9–12)x100x150 mm One strap 6x25x160 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Cut the steel plate to the dimension shown in Fig.1 and bevel the corner (Included angle is 60). 2. Finish the surface of the strap with a grinder. 3. Welding current should be 160–180 A.	Counter strain When two steel plates are joined by butt welding, strain occurs by horizontal contraction as shown below. Provide an appropriate strain in opposite direction prior to the welding to make the base material return to proper position by the strain *which occurs at time of welding.*
2.	Make tack weld	1. Tack weld is generally made with both base materials placed like the one shown in Fig. 2 (A). However, because of the strain which is expected after welding, make tack weld by providing counter strain as shown in Fig. 2 (B). 2. Care should be taken so that there will be no gap between the bevel tip and the strap. 3. Keep one end of the strap protruding from base material. See Fig. 1.	
3.	Produce arc	Produce arc over the protruding strap and proceed to the groove after full penetration is obtained.	
4.	Place the first bead layer	1. Maintain the angle of welding rod at 90°against the plane of both base materials and incline it 70°–80° against the direction of movement. Refer to Fig. 1. 2. Movement of welding rod – string bead. 3. Move forward while giving full penetration to the bevel end of base materials and the strap. 4. Make the bead as thin as possible. 5. Move welding rod in such a manner as to prevent molten slag from turning to the tip of welding rod. When it is likely that the slag turns round in front of the rod, further incline the rod against the direction of movement and at the same time, make the arc a little longer. This will help expel the slag. 6. For other details, refer to Demonstation No. 4.	Though the standard angle of welding rod to the direction of *movement* is tentatively set at 70–80, keep practicing so that the welding may be obtained with the angle as close to 70 as possible.
5.	Place the second bead layer	1. Angle of welding rod should be the same as for the first bead. 2. Movement of welding rod – weaving bead. See Fig. 3. 3. Place the bead while keeping in mind the instructions described in paragraphs 3, 4 and 5 for the first bead layer. 4. For other details, refer to Demonstration No.5	

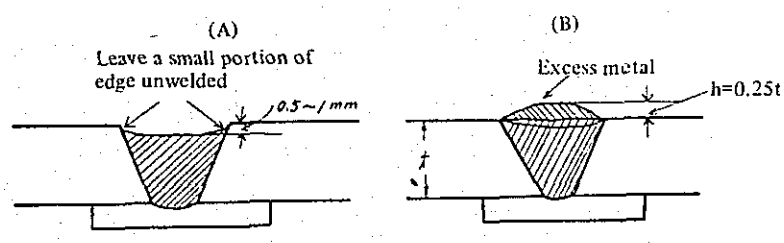


Fig. 4

Work No.	No. 12 – 2
Type of work	Flat butt welding
Main points	Single V-groove welding with a strap
Materials	Two mild steel plates (9–12)x100x150 mm One strap 6 x 25 x 160 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
6.	Place the third and subsequent bead layers	Placement of the third bead layer 1. Welding current – 160–170 A (Use current slightly lower than that for the second layer). 2. Angle of welding rod is the same as for the first bead alayer. 3. Movement of welding rod is the same as for the third bead layer (weaving bead). 4. Width for the movement of welding rod should be slightly greater than that for the second layer. 5. For other details, refer to Demonstration No.5. Placement of the fourth and subsequent layers 1. Welding should be made by lowering the welding current by 5–10 A for each layer but it should not be lowered below 150 A. 2. Make the width of weaving bead greater as the groove becomes wider. 3. For other details, refer to Demonstration No.5	Since the temperature in the weld has been increased by the welding heat of the first and second layer, welding should be made by lowering the welding current by 5–10 A. Number of layers 1. Make excess metal by Single V-groove with the plate thickness of 9–10 mm and place the bead so as to make the finishing by the 6th or subsequent layer. 2. If the bead prior to the excess metal is lower than the base material by 0.5–1 mm as shown in Fig. 4 (A), the dedge of base material remains intact as a line, thus making the weaving operation for excess metal easy and resulting in a straight bead. It also provides fine and uniform wave pattern.
7.	Excess metal (Place finishing bead)	1. Welding current should be 150 A. 2. Maintain the angle of welding rod at 70°to the horizontal plane. It may be inclined slightly to the direction of movement of but should be maintained at 90°as much as possible. 3. Make the width of weaving bead so as to make the deposit metal penetrate into the edge of base material by 0.5–1 mm and move welding rod carefully and precisely.	
8.	Check the welds	1. Height of excess metal should be equal to 25% of the plate thickness. 2. Bead for excess metal having undercut or overlap at its set end is not desirable. 3. Bead wave pattern should be fine and uniform. Bead having many irrefularities is not desirable. 4. Bead should be made straight. It should not be too wide.	Excess metal Bead piled up higher than the plate surface as shown in Fig. 4 (B).

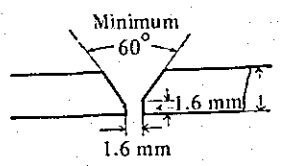


Fig. 1

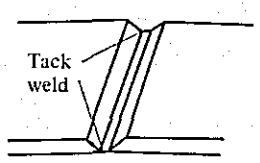


Fig. 2

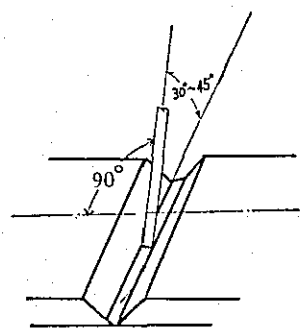


Fig. 3

Work No.	No. 13
Type of work	Flat butt welding
Main points	Single V-groove welding with a strap
Materials	Two mild steel plates (8–12)x100x150 mm Welding rods 3.2 mm and 4 mm in diameter respectively.
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Cut the steel plate to the desired dimension and bevel the edge as shown in Fig. 1. 2. Use welding rod having a diameter of 3.2 mm. Welding current should be 100–120 A.	
2.	Make tack weld	1. Provide root opening of 1.6 mm and tack weld by providing counter strain. 2. Make tack weld at the end of base material. See Fig.2. 3. For procedures of tack weld, refer to Demonstration No. 6–2.	
3.	Produce arc	1. Produce arc in such a manner as to bring the arc to the tip of bevel of both base materials evenly. 2. For generation of arc, refer to Demonstration No. 3–3.	
4.	Place the first bead layer	1. Maintain the angle of welding rod at 90°against the plane of base material and at 30–45°against the direction of movement. See Fig. 3. 2. Movement of welding rod – straight bead. 3. Operation for the first bead is similar to that for I shape Joint (square groove) joint. Maintain arc short so as not to cause drooping of deposit metal, make a fast movement of rod as if to spread molten metal and make a shin layer and provide a thin an fine bead. 4. Try to give sufficient penetration to the tip of bevel of both base materials so that the penetration reaches to the back of the metal. 5. Care should be exercised not to make blowhole by flowing molten metal. When a hole is made, fill it up by following the procedure described in Demonstration No. 11, related information.	
5.	Place the second and subsequent bead	1. Welding for the second and subsequent bead should be made in the same manner as for the welding with a strap described in Demonstration No.12 –5 and 6 (Use welding rod having a diameter of 4 mm).	
6.	Check the welds	1. There must be a complete penetration to the root. However, there should not be drooping of molten metal. 2. For other details, refer to Demonstration No. 12–8.	

Part 2	Demonstration

(Electric welding)

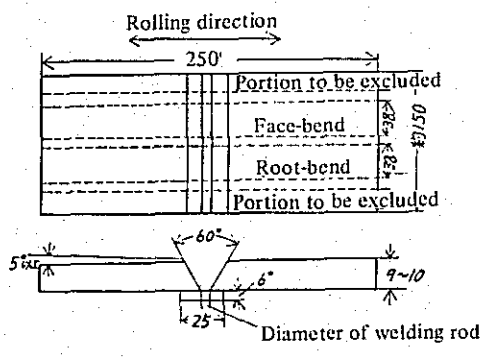


Fig. 1

Work No.	No. 14 – 1
Type of work	Bending test
Main points	Making test piece and bending test
Materials	Two mild steel plates (9–10)x100x150 mm One strap 6x25x160 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Test piece to be used should be either SS41 approved under JIS G3101, SM41 approved under JIS G3106 or SB42 approved under JIS G3103. 2. Cut steel plate and strap to the dimension shown in Fig. 1. 3. Beveling should be finished at 60°with a shaper, Other portions may be left as they are after gas cutting. 4. Use welding rod having a diameter of 3.2–5 mm which has been approved under JIS Z3211. 5. Welding rod must be completely dry prior to the test. 6. Welding machine may be either AC welding machine or DC welding machine.	This test is conducted following welders performance test (JIS Z3801 (A-2F)). JIS G 3101. Rolled steel for general structures. JIS G 3106. Rolled steel for weld structures. JIS G 3103. Rolled steel for boilers.
2.	Tack weld the test piece	1. Make the tack weld as shown in Fig. 1. 2. Counter strain of 3°–4°should be appropriate. 3. For tack weld procedures, refer to Demonstration No. 12–2.	
3.	Conduct a test	1. Test piece should not be treated (heat treatment or peening before and after welding operation. 2. For welding procedures, refer to Demonstration No.12 3. Welding should be made so as not to make the strain after welding exceed 5°. To prevent excess strain, base materials may be clamped in an appropriate manner.	Quality of the first bead decides the success of bending test. Slag carrying and insufficient penetration in the first bead layer cause cracks and breakage. Undercut, overlap or slag carrying in the finishing bead result in the failure of banding test. They also cause cracks and breakage.
4.	Check the appearance of welds	1. Check the appearance of welds in the following manner. (1) Surface wave pattern (desirable wave pattern should be uniform and without irregularities). (2) Condition of starting point and finishing point of welding. Starting point should have complete penetration and moderate rise of metal. Ending point should have craters completely supplemented and moderate rise of metal. (3) Condition of bead joint Bead should have been joined completely and should have moderate rise of metal. 2. For other details, refer to Demonstration No.12–8.	

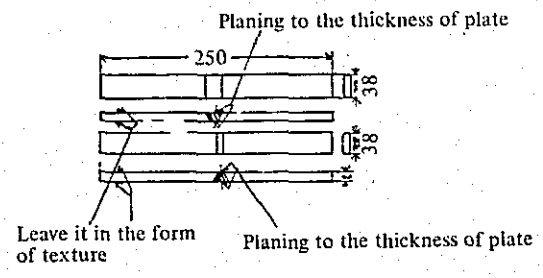


Fig. 2

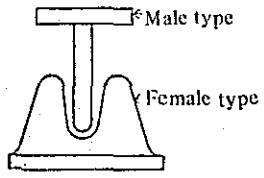


Fig. 3

Work No.	No. 14 – 2
Type of work	Bending test
Main points	Making test piece and bending test
Materials	Two mild steel plates (9–10)x100x150 mm One strap 6x25x160 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
5.	Take test piece samples	1. Strap and excess metal should be shaved off with a shaper. 2. Shaved test piece should be cut along the cutting line as shown in Fig. 1. When gas cutting is used, cut surface should be finished by machine for 3 mm or more. 3. Test piece taken should be finished to the dimension shown in Fig. 2. 4. Surface at both front and back should be finished to flush with the plate thickness with file and emery paper. A medium finishing should be given and trace (grain) of cutting tool, file and grinder should be at a right angle to the weld line. 5. Provide radius $R = \frac{t}{6}$ (maximum) at the four corners of test piece.	
6.	Condust a bending test	1. Condust a bending test by using a jig shown in Fig.3. 2. When making a face-bend, direct the front side of test piece toward female type (mold). When making a root– bend, direct the back side of test piece toward female type (mold) and place the piece so as to bring the weld exactly to the center of female type (mold). 3. Press down male type (mold) until the test piece becomes a complete U shape and keep bending until the gap between the test piece and the curved portion of female type (mold) will not allow a wire of 1 mm in diameter.	
7.	Determine the test result	1. After bending test, any portion of weld surface should not have cracks of 3.2 mm or more or other defects (insufficient penetration or blowhole). 2. Cracks of less than 3.2 mm in size or other defects could be the factor for disapproval if they are found many.	

Fig. 1

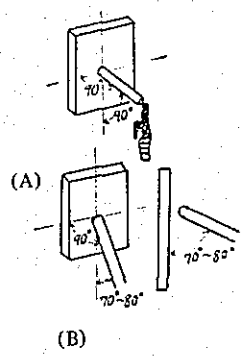


Fig. 2

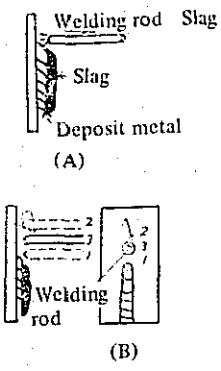


Fig. 3

Work No.	No. 15–1
Type of work	Placement of vertical bead
Main points	Upward method
Materials	One mild steel plate (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	Clean up the surface of steel plate and hold the plate vertically by appropriate support.	
2.	Posture	1. Take a position in front of weld line. 2. Stand with both feet spread apart a half step and keep a balance of the body. 3. Keep the arm in a raised position lightly and do not keep elbow close to the body 4. Fig.1 shown an example of welding posture.	
3.	Produce arc	Produce arc in a manner described in Demonstration No. 3-3 by maintaining the welding rod vertically against the plane of base metal.	
4.	Place the bead	1. Placement of string bead (1) Welding current should be 90–100A. (2) Maintain the angle of welding rod vertically against the plane of base metal as shown in Fig. 2 (A) but it may be inclined at 70°–80°against the weld line as shown in Fig. 2 (B). (3) Movement of welding rod – straight (from bottom to top). (4) Do not start moving immediately after producing arc. Maintain arc long and preheat base material at the starting point and start moving only after obtaining full penetration by maintaining arc short. (5) Maintain constant length of arc during movement. The tip of welding rod should always precedes slag and movement of welding rod should be made so as to make slag collect under the welding rod. See Fig. 3 (A) (6) When it is likely that the deposit metal droops, move the rod as shown in Fig. 3 (B), take arc away to let the metal cool down and return to the original position to resume welding operation.	

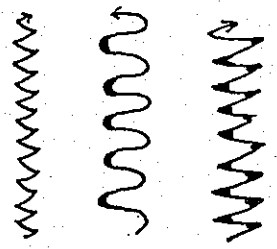
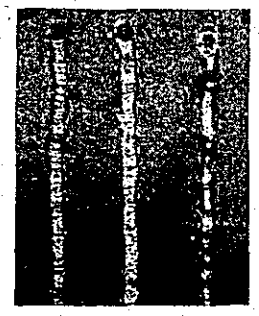
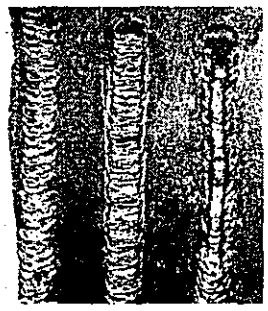


Fig. 4



(A) (B) (C)
50A 100A 150A

Fig. 5



(A) (B) (C)
50A 100A 150A

Fig. 6

Work No.	No. 15 – 2
Type of work	Placement of veritcal bead
Main points	Upward method
Materials	One mild steel plate (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
		2. Placement of weaving bead. (1) Welding current should be 100– 120 A. (2) Angle of welding rod should be the same as for string bead. (3) For movement of welding rod, refer to Fig. 4. (4) Maintain arc short and constant length and move upward while moving the rod both ways as if to spread the molten metal and make a thin layer with the tip of welding rod. Move welding rod fast when crossing the center line and hold it a little at the both ends. (5) If the upward movement lags behind the movement in both sides, molten metal start droopping. In this case, take arc away temporarily and then return to original position to resume welding as described in the preceeding paragraph. (6) For other details, refer to Demonstration No.15–4.	
5.	Cut off arc	1. In the case of string bead, shorten arc gradually and cut off it by pulling it apart upward immediately before a short-circuit occurs. 2. In the case of weaving bead, cut off arc at the center of the breadth of bead.	
6.	Join the bead	1. Remove slag and clean the portion to be joined. 2. (1) In the case of string bead, maintain the arc long to preheat the crater and then shorten arc to start welding. (2) In the case of weaving bead, produce arc in the center of the breadth of bead and start welding from the edge of the breadth of bead while preheating the metal.	
7.	Supplement crater	Supplement crater by adding a small quantity of molten metal at a time and using intermittent arc.	
8.	Check the welds	1. There should not be such defects as undercut, overlap, slag carrying or drooping of deposit metal. Crooked bead or many irregularities are not desirable either. 2. Relationship between welding current and appearance of bead. (1) For string bead, see Fig. 5. (A) 50A Because of inadequate welding current, arc is not stable, thus causing difficulty in the work and resulting in an excessive irregularity and slag carrying. (B) 100 A Because of appropriate welding current, arc is stable and work is easily accomplished with even and uniform bead. (C) 150 A Because of excessive welding current, bead has drooping metal, thus causing the work very difficult and making undercut. (2) For weaving bead, see Fig. 6. (A) 50 A – Welding current is too weak. (B) 100 A – Welding current is appropriate. (C) 150 A – Welding current is too strong. For all of the above three cases, appearance and other descriptions are the same as for the string bead.	Fig. 5 and 6 show a bead placed on the mild steel plate having a thickness of 9 mm with the use of welding rod 4 mm in diameter.

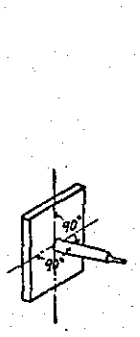


Fig. 1

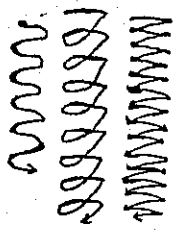


Fig. 2

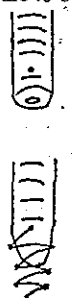


Fig. 3

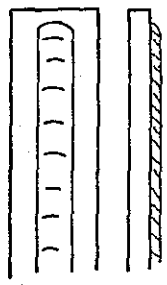


Fig. 4

Work No.	No. 16
Type of work	Placement of vertical bead
Main points	Downward method
Materials	One mild steel plate (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No. 15–1. 2. Welding current should be 100–130 A.	Select welding rod for downward welding. (D 4313)
2.	Produce arc	Refer to Demonstration No. 15–3.	
3.	Place the bead	1. Placement of string bead (1) Maintain the welding rod vertically against the plane of base material. However, it may be inclined slightly against the weld line depending the type of welding rod. See Fig. 1. (2) Movement of welding rod – straight (from top to bottom). (3) Maintain arc long at the starting point. After pre-heating base material, shorten arc and maintain it at constant length and then proceed. When the molten slag collects under the rod, touch the slag lightly with the tip of welding rod and push the slag in the direction of movement while coming down. (4) When the accoumulation of slag turns around in front of the tip of welding rod, make the arc long to give a shock to the slag and let it down. Return to the original position immediately to resume welding. 2. Placement of weaving bead (1) Angle of wedling rod should be the same as for the string bead. (2) For movement of welding rod, see Fig. 2. (3) After preheating base material by keeping the arc long, start moving downward to make bead by maintaining arc short and constant length. (4) While moving make a weaving operation by touching the slag with the tip of welding rod in the same manner as for the string bead. (5) When it is likely that the slag moves over the welding rod, make the arc long to give a shock and let it down and return to the upper portion a little ot resume welding. Arc may be cut off temporarily to remove slag and bead may be joined afterward.	
4.	Cut off arc	Shorten the arc and cut it off by pulling it downward immediately before a short-circuit occurs.	
5.	Join the bead	Produce arc at the point slightly above the crater, preheat the crater by maintaining the arc long and then shorten the arc to start welding. See Fig. 3.	
6.	Supplement crater	Supplement of crater at the ending point should be made by upward method to add deposit metal to the concaved portion.	
7.	Check the welds	1. Satisfactory bead should have uniform wave pattern as shown in Fig. 4 and should not have irregulatities over the surface. It should be a thin bead without having such defects as slag carrying, undercut or over-lap. 2. If welding current or operation of welding rod is not appropriate, bead making becomes impossible because of slag carrying and drooping of molten metal.	

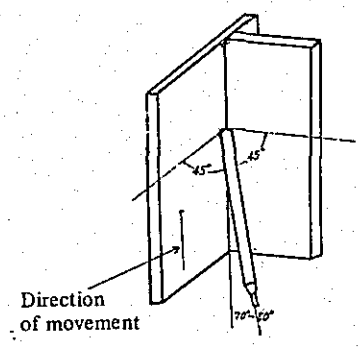


Fig. 1

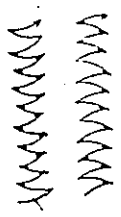


Fig. 2

Work No.	No. 17 – 1
Type of work	Vertical fillet welding
Main points	Welding of T-piece by upward method
Materials	Two mild steel plates (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1	Make preparation	1. Refer to Demonstration No.7–1. 2. Welding current should be 90 – 120 A	
2.	Make tack weld	1. Refer to Demonstration No.7–2. 2. After tack weld, place the steel plate with the weld line in vertical position. See Fig. 1.	
3.	Produce arc	1. Produce arc at the bottom end of weld line. 2. Hold welding rod at 45°against both base materials and produce arc in the manner described in Demonstration No.3.	
4.	Place the first bead layer	1. Placement of string bead. (1) Welding current – 90–120 A. (2) Maintain the angle of welding rod at 45 against both base materials. Angle against the weld line should be 90°in principle but it may be inclined to 70°–80°as shown in Fig. 1. (3) Movement of welding rod – straight (upward). (4) Move upward while giving sufficient penetration to both base materials and their edges. (5) Take caution not to cause undercut. (6) Bead in the shape of high convex is not desirable because it hampers the operation for the second layer. (7) Weld to the cross-section of base material at the upper end so as not to leave crater. (8) For other details, refer to Demonstration No.15, "Placement of string bead". 2. *Placement of weaving bead* (1) Welding current should be 90–130 A. (2) Angle of welding rod should be the same as for the string bead. (3) Movement of welding rod – see Fig. 2. (4) Placement of weaving bead for the first layer is shown in Fig. 3. Make a bead by maintaining the breadth of rod movement narrow and slide arc upward sometimes (without changing arc length) to prevent flow of deposit metal. (5) Give sufficient penetration to both base materials and to the corner. (6) For other details, refer to Demonstration No.15, "Placement of weaving bead".	 Configuration of slag With correct welding current and appropriate angle of welding rod, slag shows a vertical shape and collect at the center of bead as shown above.

Part 2	Demonstration

(Electric welding)

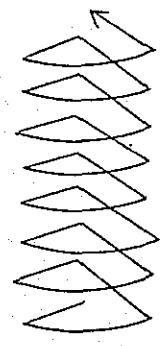


Fig. 3

Work No.	No. 17 – 2
Type of work	Vertical fillet welding
Main points	Welding of T-piece by upward method
Materials	Two mild steel plates (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
5.	Place the second bead layer	1. Place a weaving bead. 2. Place the bead after giving a full penteration to the set end of the first bead. 3. For other details, refer to Demonstration No.15, "Placement of weaving bead".	
6.	Check the welds	1. Standard width of bead is 12–14 mm. 2. For other details, refer to Demonstration No.15–8.	

Remarks

(1) Triangular movement of welding rod

1. When making the first and second layers with one pass, move welding rod as shown in Fig. 3 and advance upward while adding much molten metal.
2. A particular causion should be taken not to make any drooping of deposit metal.

(2) Appearance of bead and welding rod

Drooping of bead, undercut or overlap is caused by improper movement of welding rod and welding current. In vertical welding, in particular, quality of welding rod has an important bearing on the success of welding operation. Use of improper welding rod for vertical welding would not prevent drooping of bead or undercut even though it may be used skillfully.

Part 2	Demonstration

(Electric welding)

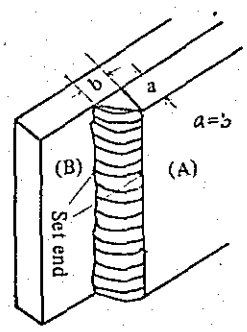


Fig. 1

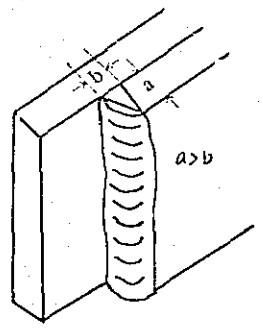


Fig. 2

Work No.	No. 18
Type of work	Vertical fillet welding
Main points	Welding of lap joint by upward method
Materials	Two mild steel plates (8–10)x80x200 mm Welding rod 3.2–1 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No. 10–1 2. Use welding rod 3.2 mm in diameter. 3. Welding current should be 70–100 A.	
2.	Make tack weld	1. Refer to Demonstration No. 10–2. 2. After making tack weld, hold weld line in vertical position and secure it in that position with an appropriate support.	
3.	Produce arc	Refer to Demonstration No. 7–3.	
4.	Place (Make) the first bead layer	Vertical fillet welding for lap joint is done in the same manner as for the T joint shown in No.17, demonstration, except for finishing bead. Refer to Demonstration No. 17–4.	
5.	Place the second bead layer	1. Use welding rod 4 mm in diameter. Welding current should be 70–120 A. 2. For other information (details), refer to Demonstration No. 17–4, "Weaving".	
6.	Place the third bead layer (Finishing bead)	1. Since the set end of the front base material (A) shown in Fig. 1 tends to melt faster, move welding rod a little faster on that portion so that under cut would not be made. Set end of the rear base material (B) should be welded after giving a sufficient penetration. Care should be taken, however, so that no defects such as undercut or overlap would be caused. 2. For other information (details), refer to Demonstration No. 17–4A, "Weaving". 3. When making the second and third layers with one pass, place the bead in triangular rod movement. Refer to Demonstration No.17–5.	
7.	Check the welds	1. Place (make) the bead in such a manner that the leg length of the rear base material (B) is made equal to the plate thickness of the front base material (A). See Fig. 1. 2. Uniform penetration must be provided for both base materials. 3. For other details, refer to Demonstration No. 15–8 "Inspection".	

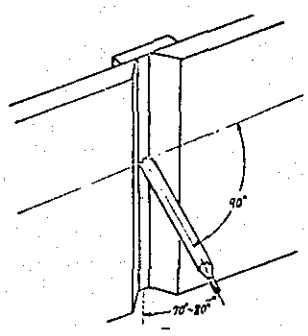


Fig. 1

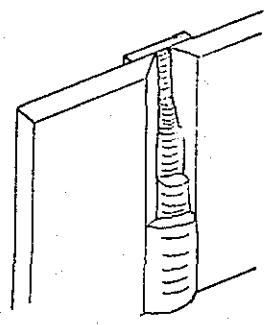
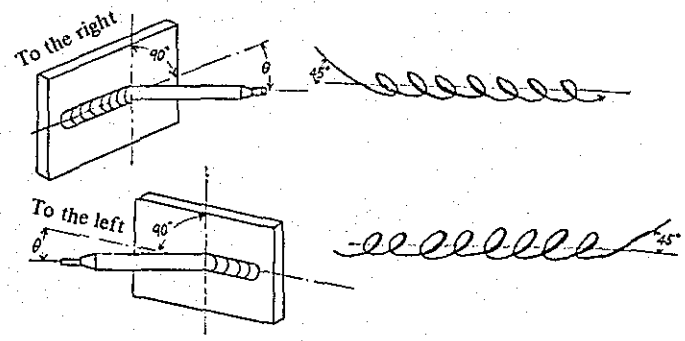


Fig. 2

Work No.	No. 19
Type of work	Vertical butt welding
Main points	Single V-groove welding with a root strap
Materials	Two mild steel plates (9—12)x100x150mm Strap 6 x 15 x 160 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1 Refer to Demonstration No. 12-1. 2. Welding current should be 100—140 A.	
2.	Make tack weld	1. Refer to Demonstration No. 12-2. 2. After making tack weld, hold weld line in vertical position and maintain it in that position with an appropriate support.	
3.	Produce arc	1. Produce arc at the lower end of strap. 2. For procedures of arc generation, refer to Demonstration No. 15-3.	
4.	Produce arc	1. Place (Make) string bead (Upward method). 2. Give sufficient penetration to the root and bevel ends of both base materials. 3. Make the bead as thin as possible so as not to make any drooping of molten metal. 4. For other details, refer to Demonstration No.15-4.	
5.	Place the second bead layer	1. Place weaving bead. 2. Make the bead in the rod movement for small weaving bead as described in Demonstration No. 15-4. 3. Make the bead as thin as possible so as not to make any drooping of molten metal. 4. For other details, refer to Demonstration No.15-4, "Placement of weaving bead".	
6.	Place the third bead layer and subsequent layer	1. Make weaving bead for the second and subsequent layers. Each layer should be made with one or two passes. 2. The number of layers in the case of plate more than 9 mm in thickness should be more than three including the finishing bead. 3. As with the flat single V-groove welding, welding current should be lowered slightly for each layer but it should never be lowered below 90 A. 4. Make bead as thin as possible so as not to make any drooping of molten metal. 5. Finishing bead should be made by providing penetration to the edge of base material by 0.5—1mm but care should be exercised not to cause undercut. Also try not to make excess metal. 6. For other details, refer to Demonstration No.15-4 "Placement of weaving bead".	Keep in mind that the height of bead before making excess metal should be about 0.5—1 mm lower than the face of base material.
7.	Others	Refer to Demonstration No. 15-5-7.	
8.	Check the welds	Refer to Demonstration No. 15-8, "Inspection".	

Part 2	Demonstration

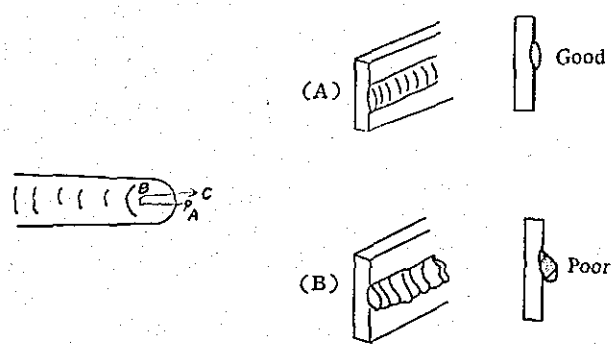


Work No.	No. 20 - 1.
Type of work	Placement of horizontal bead
Main points	Right direction method and left direction wor method
Materials	One mild steel plate (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Clean the surface of steel plate and support it in vertical position by an appropriate method. 2. Welding current should be 100 – 130 A.	
2.	Produce arc	Maintain welding rod in vertical position against the plane of base material and produce arc in the manner described in Demonstration No. 3-3.	
3.	Place bead Right direction method	1. Placement of string bead (1) Angle of welding rod: Hold welding rod veritcal against the surface of base material but it may be inclined at 70°–80°against the direction of rod movement. See Fig. 1. (2) Movement of rod is straight (Fron left to right). (3) Make a thin layer of bead while maintaining the arc short. (4) Slag should accumulate below the end of welding rod and the tip of welding rod must proceed slag. (5) When there is a possibility that the accumulation of slag proceed the tip of welding rod, knock the slag lightly with the tip of welding rod to let slag down. This operation, however, should be brief, otherwise it may disturb molten metal and cause drooping of the metal. 2. Placement of weaving bead (1) Angle of welding rod: Hold welding rod at 90° against base material and incline it at 40°–60°against the direction of movement. See Fig. 1. (2) Movement of welding rod" See Fig. 2. (3) Movement of welding rod shown in Fig. 2 should be made by holding the rod at 45°inclination against weld line. Maintain arc short and in constant length, paying attention so that the arc length would not change during the movement of rod. (4) Make the bead as thin as possible so as not to cause any drooping of molten metal. (5) The tip of welding rod must always proceed slag. Treat slag in the same manner as for the string bead.	If proper movement speed, welding current and rod angle are maintained, slag would not precede the rod movement.
	Left direction method	Left direction method is opposite to the right direction method.	

Part 2	Demonstration

(Electric welding)



Work No.	No. 20 – 2
Type of work	Placement of horizontal bead
Main points	Right direction method and left direction method
Materials	One mild steel plate (8–10)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
4.	Cut off arc	Make the arc shorter gradually and cut it by pulling it apart in the direction opposite to the direction of movement immediately before a short-circuit occurs.	
5.	Join bead	1. Remove slag and clean the joint portion of bead. 2. Produce arc in front of crater (Point A in Fig. 3), proceed to Point B while maintaing the arc long and preheating the crater, then shorten the arc and turn back to join the bead. See Fig. 3.	
6.	Supplement crater	Supplement crater by adding a small quantity of molten metal to it while maintaining intermittent arc at the final point.	
7.	Check the welds	1. Check and see if the bead is made like the one shown in Fig. 4 (A). Drooping bead shown in Fig. 4 (B) is not desirable. 2. Defects such as undercut, overlap and slag carrying are not desirable. 3. Bead should have been made in a straight line.	

Part 2	Demonstration

(Electric welding)

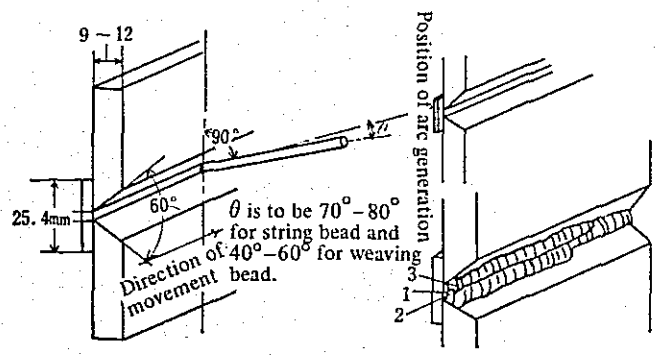


Fig. 1

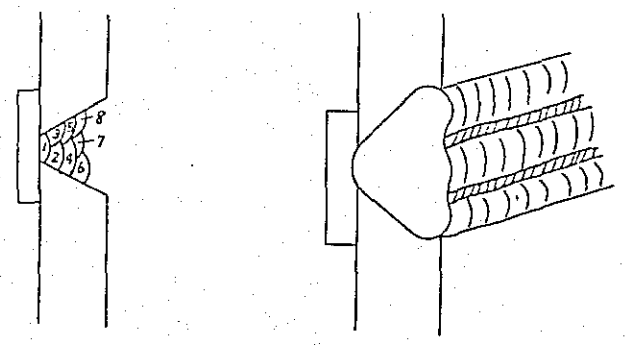
Fig. 2

Work No.	No. 21 – 1
Type of work	Horizontal butt welding
Main points	Single V-groove welding with a strap
Materials	Two mild steel plates (8–12)x 80 x 200 mm Strap 6x25.4x210 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No. 12-1. 2. Welding current should be 120–140 A.	
2.	Make tack weld	1. Refer to Demonstration No. 12-2. 2. After making tack weld, hold the plate so that the plane of base material is vertical and the weld line is horizontal and maintain the plate in that position by an appropriate support.	
3.	Produce arc	1. Produce arc on the protruding strap and move arc into the groove after it became sufficiently capable for penetration. 2. For arc generation, refer to Demonstration No. 20-2.	
4.	Place the first bead layer	1. Place string bead (Right direction method) 2. Maintain the arc short and constant length, make a thin layer of bead by giving sufficient penetration to the bevel end of both base materials and the strap. 3. Unlike the bead on the vertical base material, slag in this case can not be removed by being pushed down. Therefore, the tip of welding rod should always preceeds slag. When it is likely that the slag preceeds the welding rod, incline the rod further against the direction of movement, keep the arc longer in length and push back slag backward. When there is no possibility of slag preceeds the rod, return to normal process and continue welding. 4. For other details, refer to Demonstration No. 20-3 "Straight".	Care should be exercised so as not to make extreme irregularities, the second bead making becomes difficult.
5.	Place the second bead layer	1. Place weaving bead (Right direction method). 2. The second bead layer is made by two passes and the bead is started from bottom as shown in Fig.2. 3. Movement of welding rod for weaving bead should be in small motion. Make a narrow bead and make it as thin as possible. Movement of welding rod in large motion causes drooping or flowing out of bead, making it impossible to make the next pass. 4. For other details, refer to Demonstration No.20-3 "Weaving".	Sequence of pass is reversed sometimes.

Part 2	Demonstration

(Electric welding)



Work No.	No. 21 – 2
Type of work	Horizontal butt welding
Main points	Single V-groove welding with a strap
Materials	Two mild steel plates (8–12)x80x200 mm Strap 6x25.4x210 mm Welding rod 4 mm in diameter
Tools	

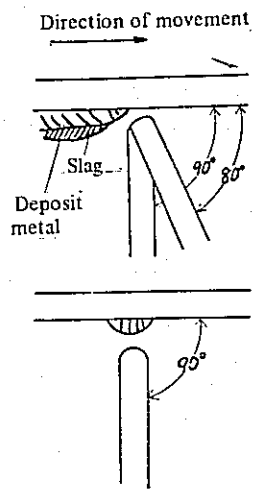
No.	Sequence of work	Description	Related information
6.	Place the second and subsequent bead layers	1. After the second layer, the number of passes should be determined depending on the width of bead. 2. Make the pass from bottom to top. See Fig.3. 3. For other details, refer to Demonstration No. 20-3, "Weaving".	Narrow bead made in small motion and with increased number of passes results in less frequency of defects than the wide bead made in large motion.
7.	Make finishing bead	1. Make bead by penetration in the edge of both base materials by 0.5–1 mm. 2. Pay attention to undercut, overlap, drooping of bead and slag carrying.	
8.	Cut off arc Joint bead Supplement crater	Refer to Demonstration No. 20-4, 5 and 6.	
9.	Check the welds	1. Each bead should be fully lapped (Bead having grooves on the surface as shown in Fig. 4 is not desirable). 2. For other details, refer to Demonstration No.20-7, "Inspection".	

Part 2	Demonstration

Fig. 1

Fig. 2

Work No.	No. 22 – 1
Type of work	Placement of overhead bead
Main points	Placement of string and weaving bead
Materials	Two mild steel plates (8–10)x100x200 Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Clean the surface of the steel plate and hold it at an appropriate height in horizontal position by using a jig. 2. Wear helmet for overhead welding operation. 3. Welding current should be determined depending on the type of wleding rod. (An example of welding current – 120–130 A)	Welding current Though the welding current (value) for overhead welding varies considerably depending on the type of welding rod, the point between the current for vertical welding and that for flat welding may be acceptable.
2	Posture	1. Take a position so as to easily observe the weld joint by looking up. 2. Stand with both best spread by a half step and keep the upper half of the body stable. 3. For the method of holding of holder and of pinching the rod, refer to Fig. 2. 4. Make a slack of holder cable at the right side of the body and put it over the right shoulder. (Preferable if appropriate support is available to hang it).	
3.	Produce arc	Produce arc by overhead method (while looking up) in the manner described in Demonstration No.3–3.	
4.	Place bead	Placement of string bead (1) Hold welding rod vertically to the plane of base material and incline it slightly against the direction of movement (See figure at right). (2) Movement of rod-straight (From left to right). (3) Move the rod in such a manner as to make the tip of rod preceeds slag while maintaining the arc short and constant length. (4) When it is likely that the slag preceeds the tip of rod, incline the rod further against the direction of movement and proceed by maintaining the arc a little longer in length. When there is no possibility of slag preceeding the tip of rod, return to original process. (5) Make a thin layer of deposit metal.	Direction of movement 

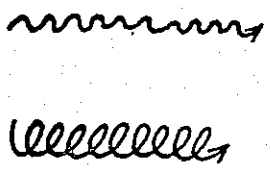


Fig. 3 Upward weaving movement

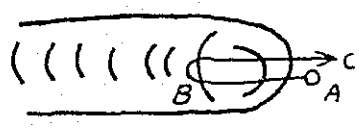


Fig. 4

Work No.	No. 22 – 2
Type of work	Placement of overhead bead
Main points	Placement of string and weaving beads
Materials	Two mild steel plates (8–10)x100x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
		2. Placement of weaving bead (1) Welding current should be the same as for string bead (2) Angle of welding rod should be the same as for string bead. (3) For movement of welding rod, see Fig.3. (4) Movement of welding rod should be made while maintaining the arc short and constant length and care should be taken so that the arc length and the angle of welding rod will not change during the movement of welding rod. (5) In overhead weaving operation the movement of welding rod is limited compared with flat and vertical weaving operation. Movement of welding rod should be in small motion as shown in Fig. 4. (6) Other details are the same as for the string bead.	Overhead welding operation involves very delicate elements and it should be kept in mind that the process varies depending on the type of welding rod, welding current and other requirements.
5.	Cut of arc	Shorten arc gradually and cut off arc by pulling it apart in the direction opposite to the direction of movement immediately before a short-circuit occurs.	
6.	Join bead	1. Remove slag and clean the portion to be joined. 2. Produce arc in front of crater (Point A in Fig. 4), proceed to Point B while maintaining the arc long and preheating the crater, then shorten the arc and turn back to join the bead.	
7.	Supplement crater	Supplement crater by adding a small quantity of deposit metal to it while maintaining an intermittent arc at the final point.	

Part 2	Demonstration

(Electric welding)

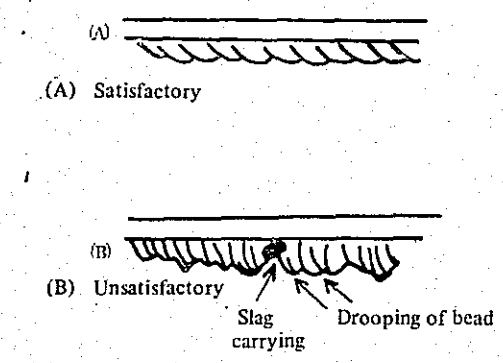


Fig. 5

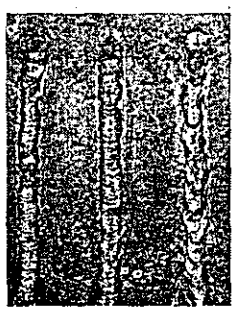


Fig. 6

Work No.	No. 22 – 3
Type of work	Placement of overhead bead
Main points	Placement of string and weaving beads
Materials	Two mild steel plates (8–10)x100x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
8.	Check the welds	1. Satisfactory bead is the one shown in Fig. 5(A) which is flat and has no drooping of deposit metal. 2. The one shown in Fig. 5 (B) with drooping metal or having slag or such defects as undercut, overlap is not desirable. 3. Welding current and appearance of bead – See Fig. 6. (A) 90 A Because of weak welding current, bead is not uniform and has drooping deposit metal. Welding operation with this current is very difficult. (B) 110 A Because of proper welding current, bead is uniform and shows a fine appearance. The bead is also flat without drooping deposit. Welding operation with this current is relatively easy. (C) 150 A Because of excessive welding current, bead is not uniform and the wave pattern is also irregular. The bead has drooping deposit at some portions. Welding operation with this current is very difficult.	

Part 2	Demonstration

(Electric welding)

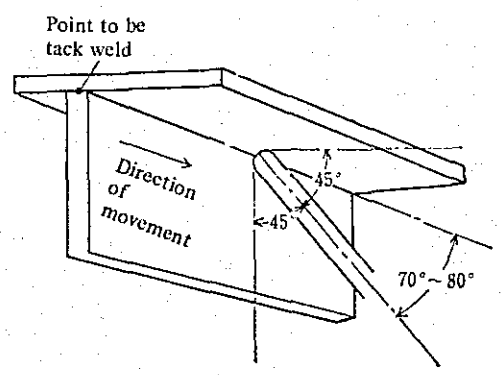


Fig. 1

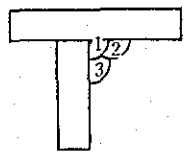
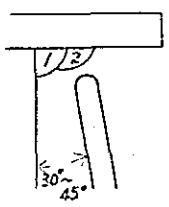
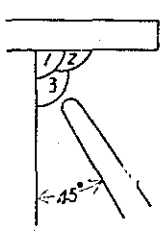


Fig. 2

Work No.	No. 23 – 1
Type of work	Overhead fillet welding
Main points	Welding of T-piece (Joint)
Materials	Two mild steel plates (9–12)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No. 7–1. 2. For wleding current, refer to Demonstration No.22–1.	
2.	Make tack weld	1. Refer to Demonstration No. 7–2. 2. After tack weld has been made, place the plates horizontally with the weld line facing downward.	
3.	Produce arc	1. Hold the welding rod at 45 against the base material and produce arc by overhead method (while looking up) in the manner described in Demonstration No.3-3. 2. Produce arc at the point closer to the center of weld line in the similar manner described in Demonstration No. 7-3 and start welding after making a turn at the edge of the base material.	
4.	Place the first bead layer	Place string bead (1) Hold welding rod at 45 against both base materials and incline it at 70°–80°against the direction of movement. See Fig. 1. (2) Movement of welding rod – straight (From left to right). (3) First heat both base materials sufficiently at the starting point and proceed after obtaining complete penetration. (4) Give uniform penetration to both base materials. Movement of welding rod should be made in such a manner as to prevent insufficient penetration at the bead root. The tip of welding rod should always preceeds slag. (5) For other details, refer to Demonstration No.22–4.	Leg length of the first bead layer should be determined appropriately by taking into consideration the finishing leg length.
5.	Place the second bead layer	The second layer should be finished in two passes as shown in Fig. 2. (Numbers in the figure indicate the sequence of pass). 1. For string bead (1) Welding current should be the same as for the first layer. (2) Movement of welding rod should be the same as for the first layer. (3) Angle of welding rod against the vertical base material : 30°–45° when the second pass is made : See figure at right 45°when the third pass is made : Incline the welding rod at 70°–80°against the direction of movement in each case. (4) Movement of welding rod is the same as for the first layer. Since the bead position of the second pass is similar to that of the overhead bead for flat plate, make the bead by referring to Demonstration No.22-4. Make the third pass by referring to Demonstration No. 20-3 as its position is similar to that of horizontal bead for the vertical plate. (5) Each bead should be lapped sufficiently so as not to leave any grooves.	 

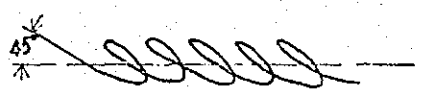


Fig. 3

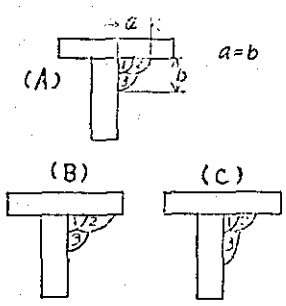


Fig. 4

Work No.	No. 23 – 2
Type of work	Overhead fillet welding
Main points	Welding of T-piece (Joint)
Materials	Two mild steel plates (9–12)x70x200 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
		2. For weaving bead (1) For welding current, refer to Demonstration No.22-1. (2) Angle of the welding rod is the same as for the first bead layer. (3) For the movement of welding rod, refer to Fig. 3. (4) The movement of welding rod shown in Fig. 3 should be made by inclining the rod at 45°against the weld line while maintaining arc short and constant length. (5) Move the rod in small motion, make a narrow weaving bead and finish it in the second and third passes. (6) Make the bead of the second pass by referring to Demonstration No. 22-4, "Weaving bead". Make the third pass also by referring to Demonstration No.20-3, "Weaving bead". (7) Each bead should be lapped sufficiently so as not to leave any grooves.	
6.	Cut off arc	Refer to Demonstration No. 22-5.	
7.	Join the bead	Refer to Demonstration No. 22-6.	
8.	Supplement crater	Refer to Demonstration No. 22-7.	
9.	Check the beads	1. Penetration at the starting point of weld should be sufficient. 2. Cross-section of satisfactory bead should be as shown in Fig. 4 (A). 3. Lapping of bead as shown in Fig. 4 (B) and (C) is not desirable. 4. Surface of bead should be smooth and the wave pattern should be uniform. Width should also be uniform and the vertical leg length should be equal to the horizontal leg length. 5. Bead having undercut, overlap or slag carrying or that having insufficient penetration at its root is not desirable.	

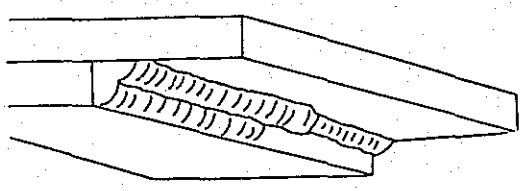


Fig. 1

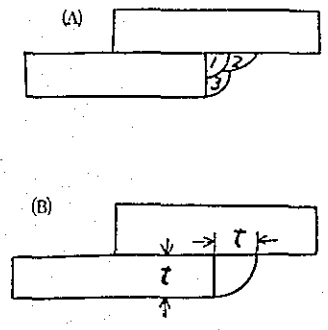


Fig. 2

Work No.	No. 24
Type of work	Overhead fillet welding
Main points	Welding of lap joint
Materials	Two mild steel plates (8–10)x80x200 mm Welding rod 4 mm in *diameter*
Tools	

No.	Sequence of work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No. 10-1. 2. For welding current, refer to Demonstration No. 22-1.	
2.	Make tack weld	1. Refer to Demonstration No. 10-2. 2. After tack weld, place the plate horizontally with the weld line facing down (See Figure 1).	
3.	Produce arc	Refer to Demonstration No. 23-3.	
4.	Place the first bead layer	Refer to Demonstration No. 23-4.	
5.	Place the second bead layer	1. Follow the sequence shown in Fig. 2 (A) for making the pass. 2. When making the third pass shown in Fig. 2 (A), the edge of the lower base material tends to melt out easily. Move the rod a little faster over this portion. 3. For other details, refer to Demonstration No.23-5.	
6.	Cut of arc Join the bead Supplement crater	Refer to Demonstration No. 22-5, 6 and 7.	
7.	Check the bead	1. Make the leg length of upper base material equal to the thickness of lower base material (Refer to Fig. 2 (A)). 2. The edge of lower base material having undercut is not desirable. 3. For other details, refer to Demonstration No. 23-9.	

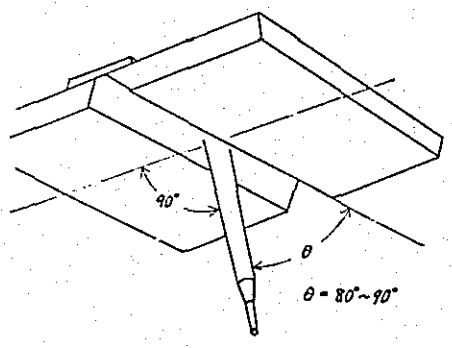


Fig. 1

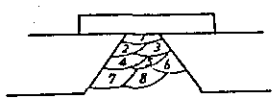


Fig. 2

Work No.	No. 25
Type of work	Overhead butt welding
Main points	Single V-groove welding with a strap
Materials	Two mild steel plates (9–12)x100x150 mm One strap 6x25x160 mm Welding rod 4 mm in *diameter*
Tools	

No.	Sequence of Work	Description	Related information
1.	Make preparation	1. Refer to Demonstration No.12-1. 2. For welding current, refer to Demonstration No. 22-1.	
2.	Make tack weld	1. Refer to Demonstration No. 12-2. 2. After tack weld, place the plate horizontally with the weld line facing down.	
3.	Produce arc	1. Produce arc over the protruding strap and proceed to the groove after obtaining sufficient penetration. 2. Produce arc by overhead method in the manner described in Demonstration No.3-3.	
4.	Place the first bead layer	1. Place string bead. 2. Give sufficient penetration to the bevel end of both base materials and the strap. 3. Make the bead as thin as possible so as not to leave any drooping of molten metal. 4. For other details, refer to Demonstration No.22-4.	
5.	Place the second and subsequent layers	1. Make string bead in two passes in the sequence shown in Fig. 2 (Numbers shown in the figure indicate the sequence of pass). 2. Bead should be made in the same manner as for the first bead layer. 3. Second and subsequent layers. (1) The second and subsequent passes may be either string or weaving. When making a weaving bead, move welding rod in such a manner as to make the molten pool as small as possible. (2) Finishing bead should be made by the fourth or subsequent layers. (3) Finishing bead should be made by providing penetration to the edge of base material by 0.5–1 mm but care should be taken not to cause undercut. 4. *For other details, refer to Demonstration* No.22-5	
6.	Cut off arc Join the bead Supplement crater	Refer to Demonstration No. 22-5, 6 and 7.	
7.	Check the welds	1. Bead should be flat with uniform wave pattern and without drooping of metal. 2. Bead should be free of such defects as undercut, overlap or slag carrying. 3. For other details, refer to Demonstration No.22-8.	

Part 2	Demonstration

(Electric welding)

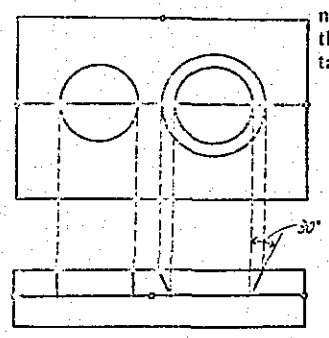


Fig. 1

Fig. 2

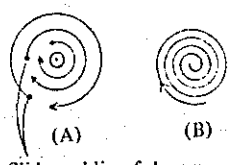
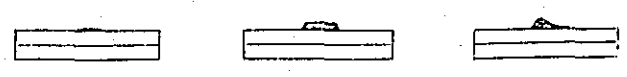


Fig. 3

Work No.	No. 26
Type of work	Plug welding
Main points	Plug welding
Materials	Two mild steel plates (9–12)x70x110 mm Welding rod 4 mm in diameter
Tools	

No.	Sequence of work	Description	Related information
1.	*Make preparation*	*Bore size D=2.5 t.* "*t*" *is the plate thickness* 1. Drill holes of the above bore size in one of the plate and make one hole countersunk. See Fig. 1. 2. Clean the hole and the bottom. Welding current should be 150–170 A.	
2.	Make tack weld	1. Lay one sheet on another and make tack weld. 2. Positions of tack weld are shown in Fig. 1. After tack weld, place the base plate horizontally.	
3.	Produce arc	Produce arc on other steel plate and bring the rod quickly to the point in the hole to be welded while the tip of welding rod is still red hot and produce arc.	
4.	Place the bead	1. Hold welding rod at 60–70 against the plane of base material.. See Fig. 2. 2. For movement of welding rod, see Fig. 3. 3. Welding should be made while providing sufficient penetration to the fillet. 4. For the bore size of 15 mm or more, movement of rod shown in Fig. 3 (A) is most appropriate. For the bore size of less than 15 mm, movement of welding rod shown in Fig. 3 (B) is most appropriate. 5. When the accumulation of slag hampers welding operation, cut off arc, remove slag and resume we welding operation. 6. Repeat the above process and fill up the hole.	For plug welding, use welding rod which causes less slag. *Movement of rod shown in* Fig. 3 should be made from outside to inside.
5	Check the welds	1. Surface should be finished flat and rather high as shown in Fig. (a) below. 2 Deposit metal should be free of defects made by slag carrying. 3. Beads having undercut or overlap at the end are not desirable.  (a) (b) (c) Satisfactory Not satisfactory Not satisfactory