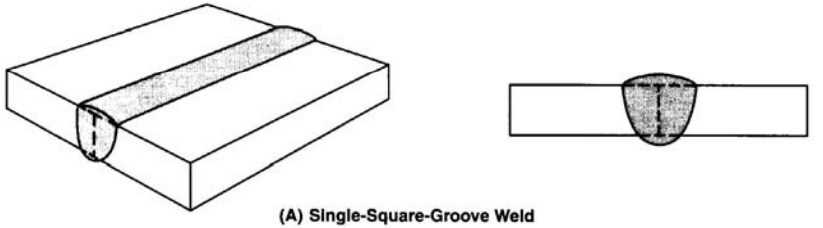
Welding in Shipbuilding

Week 2

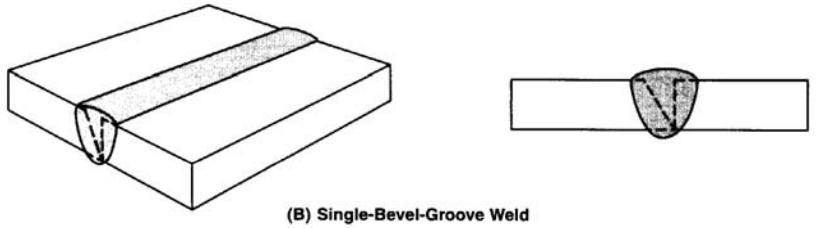
ARC WELDING BASICS

- When the atoms at the edge of one piece of metal come close enough to the atoms at the edge of another piece of metal for inter-atomic interaction to develop, the two pieces become one. This is known as welding process.
- Most welding processes apply significant heat to the base material. This heat is a means to bring the atoms at the edge of one piece of material close enough to the atoms of another piece for inter-atomic interaction.
- As hot metal tends to oxidize, sufficient protection from oxidation must be provided by the welding process to prevent this detrimental reaction with ambient oxygen.
- The welding process to be applied varies with the material and thicknesses.
- The term “arc welding” applies to a large group of welding processes that use an electric arc as the source of heat. The arc is struck between the work piece and the tip of electrode. Filler metal may be used.
- The welding current is conducted through consumable electrodes which take the form of wire or rod, or non-consumable electrodes, consisting of carbon or tungsten rods.

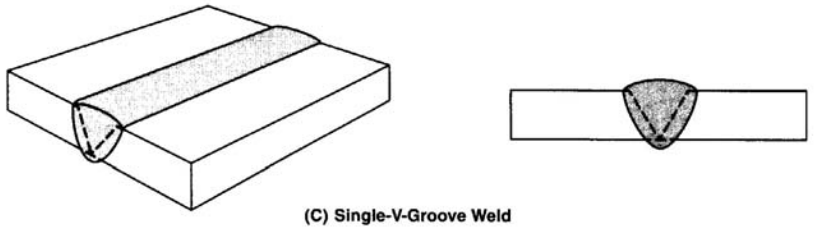
WELDING POSITIONS



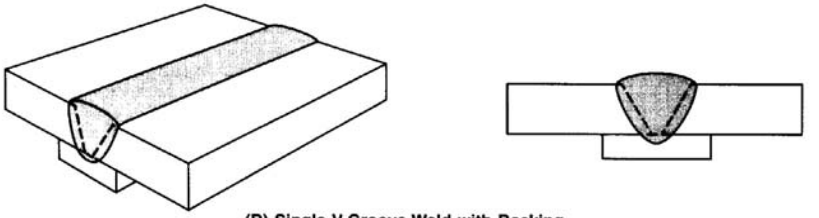
(A) Single-Square-Groove Weld



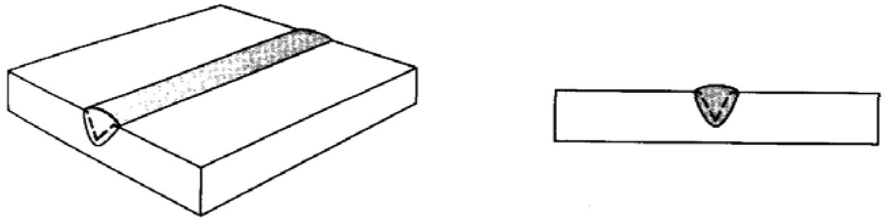
(B) Single-Bevel-Groove Weld



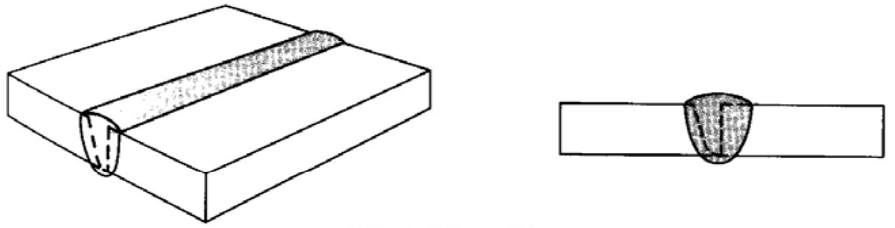
(C) Single-V-Groove Weld



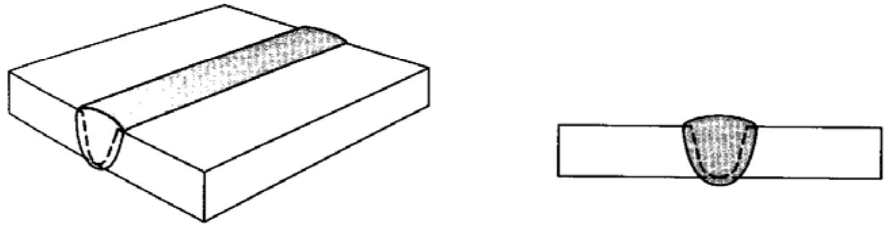
(D) Single-V-Groove Weld with Backing



(E) Single-V-Groove Weld on a Surface



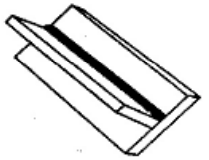
(F) Single-J-Groove Weld



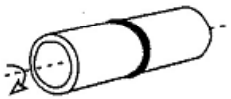
(G) Single-U-Groove Weld

WELDING POSITIONS

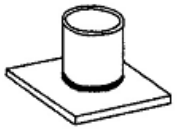
ASME :1G
EN :PA



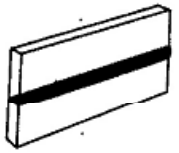
ASME :1F
EN :PA



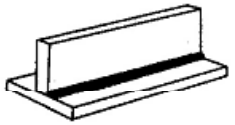
ASME :1G
EN :PA



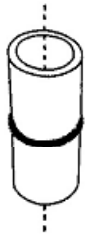
ASME :2F
EN :PB



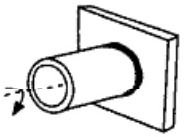
ASME :2G
EN :PC



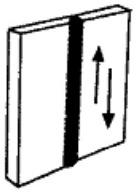
ASME :2F
EN :PB



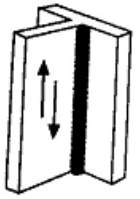
ASME :2G
EN :PC



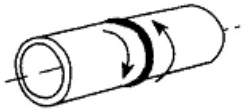
ASME :2F
EN :PB



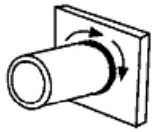
ASME :3G
EN :PG (down)
PF (up)



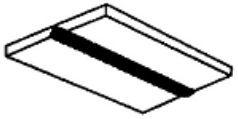
ASME :3F
EN :PG (down)
PF (up)



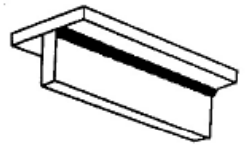
ASME :5G
EN :PG (down)
PF (up)



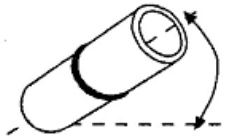
ASME :5F
EN :PG (down)
PF (up)



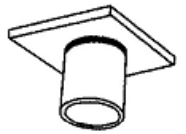
ASME :4G
EN :PE



ASME :4F
EN :PD

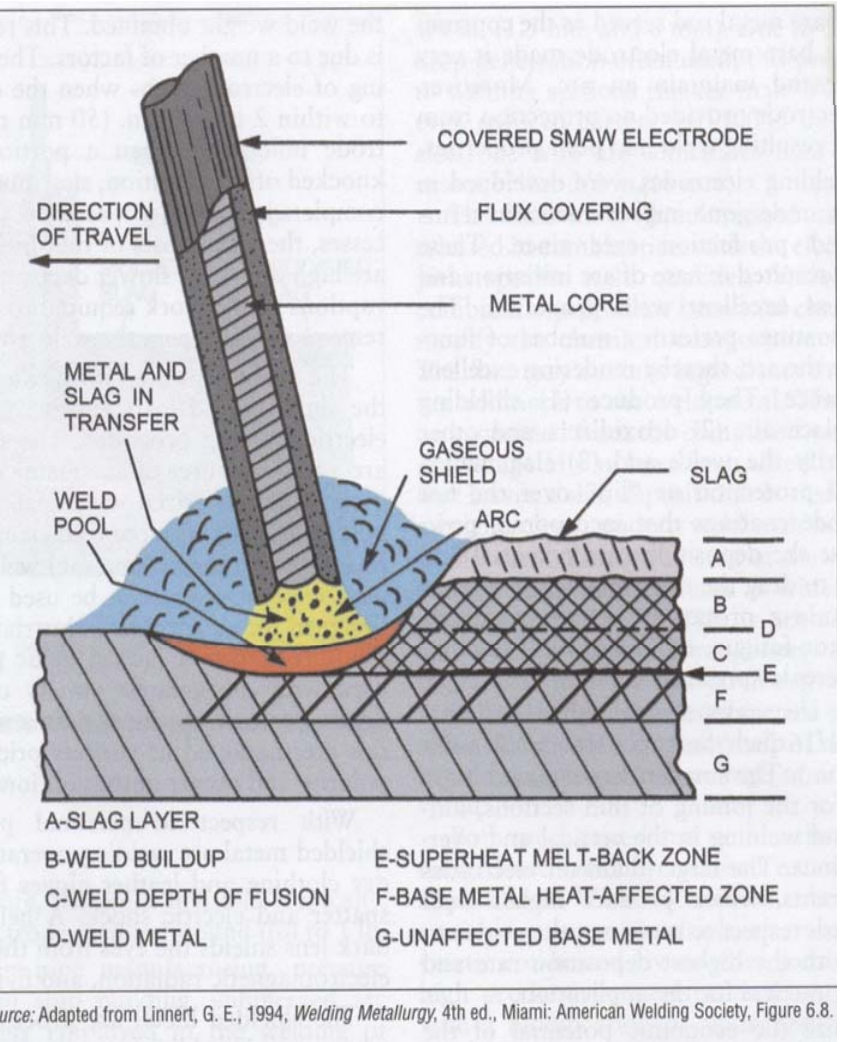


ASME :6G
EN :J-L045 (down)
H-L045 (up)



ASME :4F
EN :PD

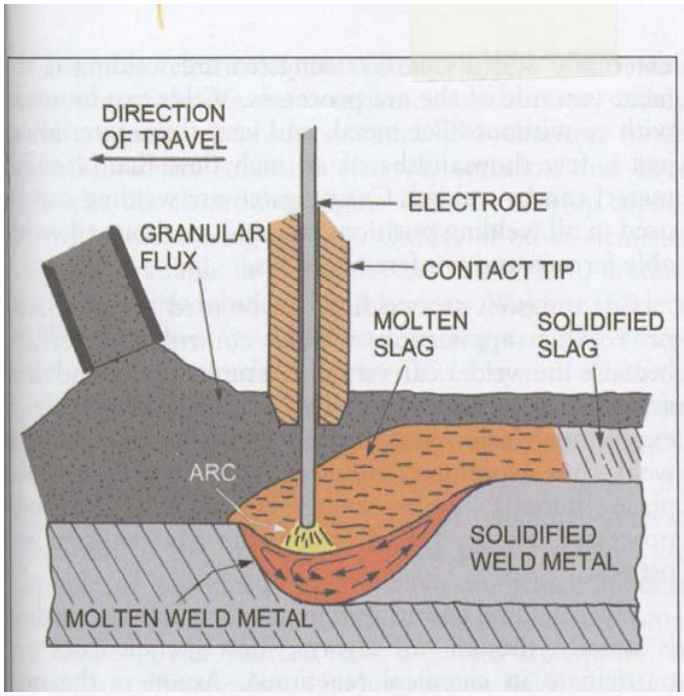
Shielded Metal Arc Welding (SMAW)

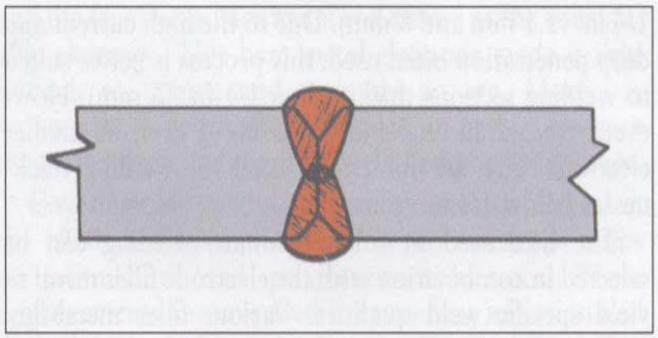


urce: Adapted from Linnert, G. E., 1994, *Welding Metallurgy*, 4th ed., Miami: American Welding Society, Figure 6.8.

- SMAW is performed by a consumable electrode covered by flux which provides shielding of the welded area. It is also known as "stick welding."
- The electrode consists of a wire core surrounded by silicate binders and powdered material such as fluorides, carbonates, metal alloys and cellulose.
- The covering serves as a source of arc stabilizers and vapors to displace air as well as metal and slug to protect, support and insulate the hot weld metal.
- Electrodes are available in diameter from 2 mm. to 8mm. The smaller diameter are used with low currents for joining thin sections, limited access work and welding in vertical and overhead welding positions.
- The amperage per mm^2 of the electrode cross sectional area, is termed "current density" and must be optimized.
- SMAW process yields a deposition efficiency of less than 60 per cent. Splatter is relatively high.

Submerged Arc Welding (SAW)





Source: Adapted from Kielhorn, W. H., 1978, *Welding Guidelines with Aircraft Supplement*, Englewood, Colorado: Jepperson Sanderson, Figure 5.44.

▪SAW effects the joining of metal by an arc formed between a ba metal electrode and the work piece. The process involves submergi the welding arc beneath granular flux particles.

▪The flow protects the arc and molten weld metal from ambie atmosphere. A part of the flux is melted in the process. The rest cleaned and re-used.

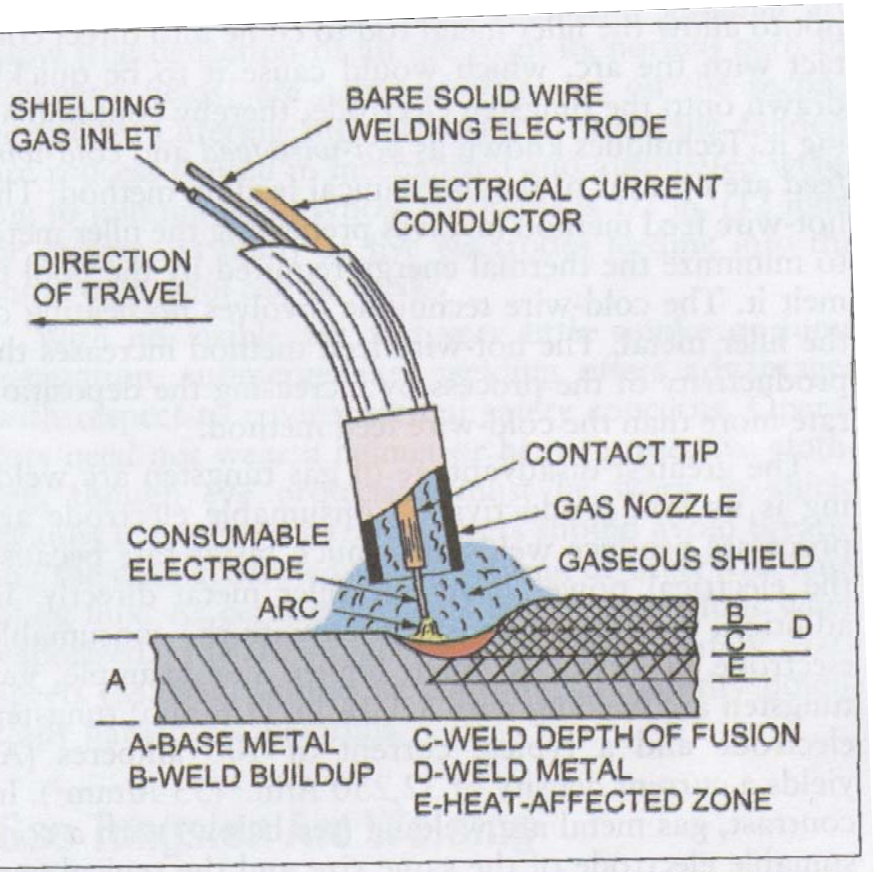
▪The welding positions best suited to SAW are the flat positions f fillet and grove welds. It can be also used in horizontal butt welds.

▪The electrode diameters range between 1.5 to 6 mm. Due to the hi current and deep penetrations it is better suited to welding sectio thicker than 6 mm. Electrodes are in the form of coiled wire that fee into the arc.

▪High current densities are used to obtain high yield deposition rat and deep penetration. It can also be used with low current densiti with relatively low deposition rates and penetrations.

▪SAW can be performed mostly with single electrodes, but it can al be used with two arcs known as “tandem arc process”. Tandem a process is used in mechanized and automated welding to jo materials, thicker than 12 mm as many as five electrodes feeding in the same weld pool is need.

Gas Metal Arc Welding (GMAW)



Source: Adapted from Linnert, G. E., 1994, *Welding Metallurgy*, 4th ed., Miami: American Welding Society, Figure 6.12.

•GMAW involves the use of a metal arc and consumable electrode with internally added shielding gas. It is also known as MIG or wire feed welding.

•It is a very versatile process with a wide selection of arc modes, electrode sizes and shielding gas mixtures, and can be use welding meta with thickness 0.5 mm and above.

•With the proper procedure, welding can be performed in all positions.

•The shielding gas is often CO_2 mixed with argon or several added gass Small quantities of O_2 (up to 5%) are sometimes mixed with argon.

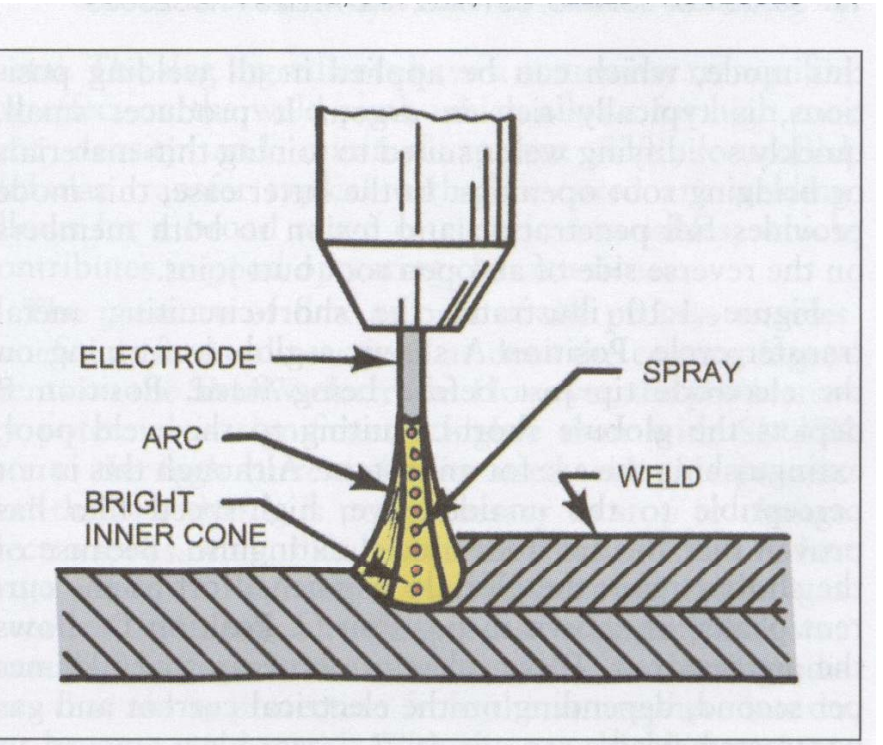
•GMAW employs either a solid electrode wire or an electrode with a co of powdered metal. Electrode sizes range from 0.5 mm to 3.2 mm. Spoo weights vary from 0.5 to 27 kg.

•The basic equipment consists of a welding gun (air or water cooled), electrode, an electrode feed unit, welding control, a power supply, shielding gas, cables and hoses, and in case of water cooled torches, a water circulation system.

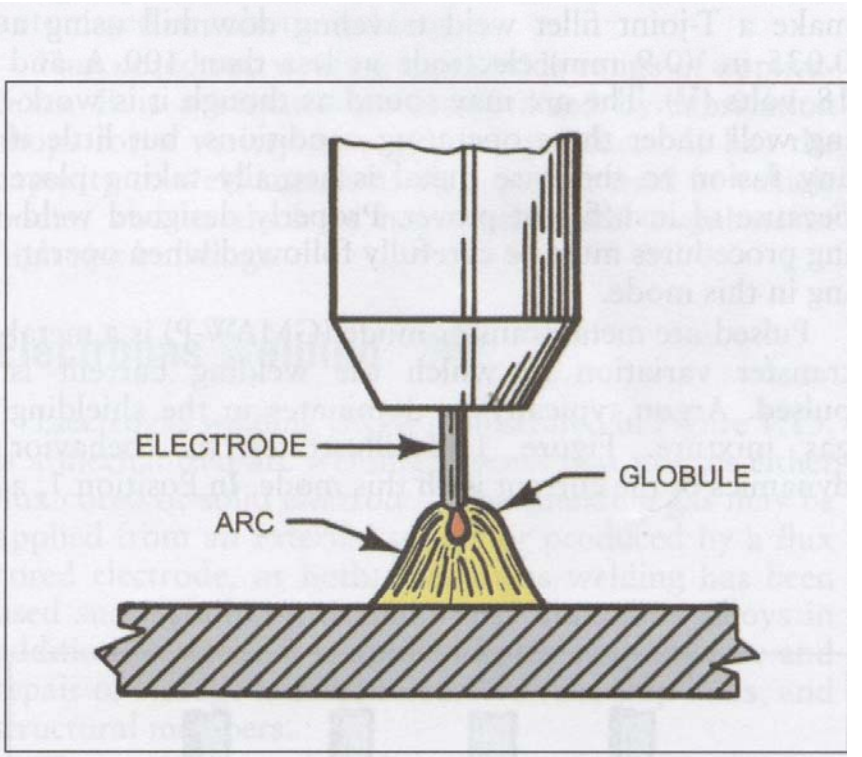
•GMAW can be used as semi-mechanised, mechanised, automatic and robotic applications.

•Several types of metal transfer variations can be used. These include spray, globular, short circuiting, pulsed arc, and high deposition and buried arc metal transfer modes.

Gas Metal Arc Welding: Spray Metal vs Granular Metal Transfer Mode

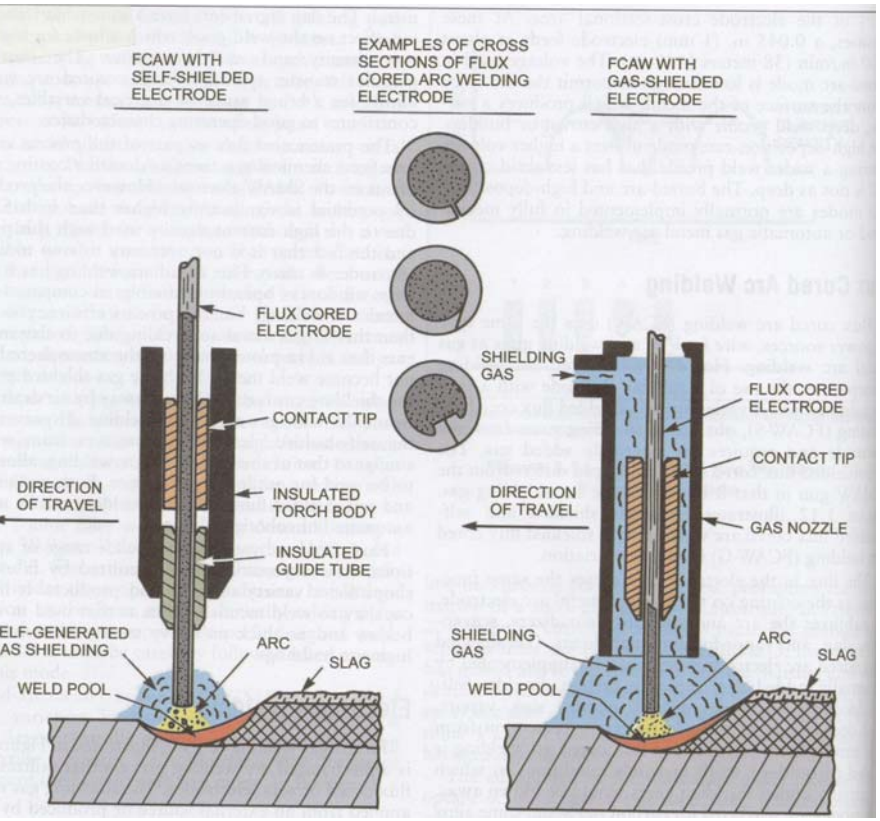


Source: Adapted from Kielhorn, W. H., 1978, *Welding Guidelines with Aircraft Supplement*, Englewood, Colorado: Jepperson Sanderson, Figure 5.26.



Source: Adapted from Kielhorn, W. H., 1978, *Welding Guidelines with Aircraft Supplement*, Englewood, Colorado: Jepperson Sanderson, Figure 5.28.

Flux Cored Arc Welding (FCAW)



•FCAW uses the same type of power sources, with feeders and welding guns as GMAW. However, FCAW uses a tubular electrode with a core containing flux. A variation, self-shielde flux cored arc welding (FCAW-S) obtains its shielding gas from the electrode.

•The flux in the core stabilised the arc, and contains deoxidisers, scavengers, slag and vapour-forming ingridents. Gas shielded FCAW electrodes must be supplemented with shielding gas supply (Typically CO_2).

•Electrode sizes range from 0.5 to 4 mm.

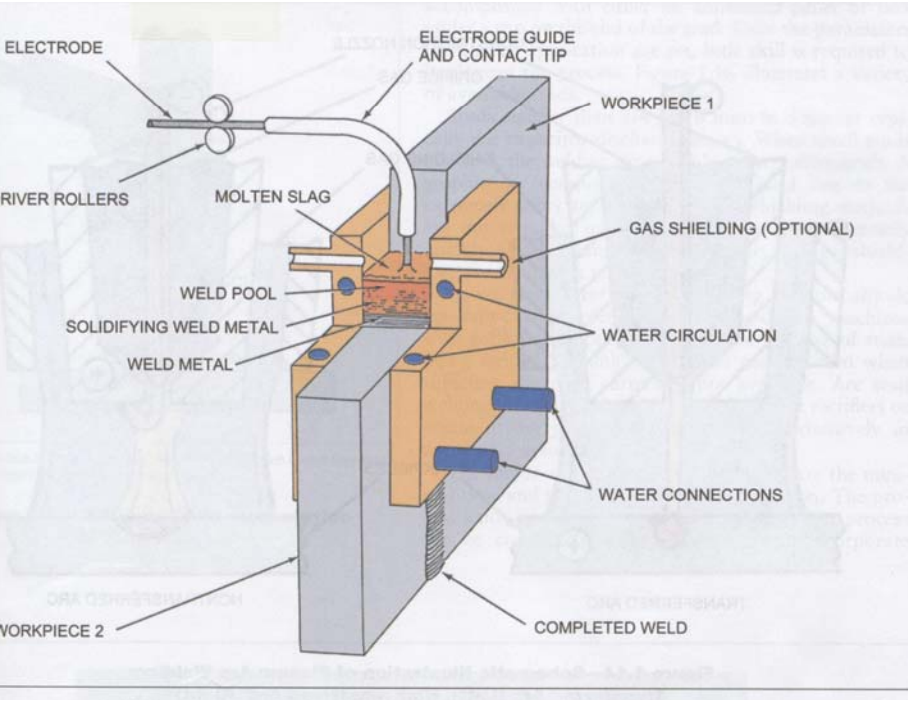
•FCAW require more electrod extention than GMAW due to the higher current density requirement. If the extention is not sufficient it can create porosity in the weld.

•Due to the higher current density deposition rates in FCAW is higher than GMAW.

•The presence of flux and consequential slug provide further protection. FCAW can be used outdoors.

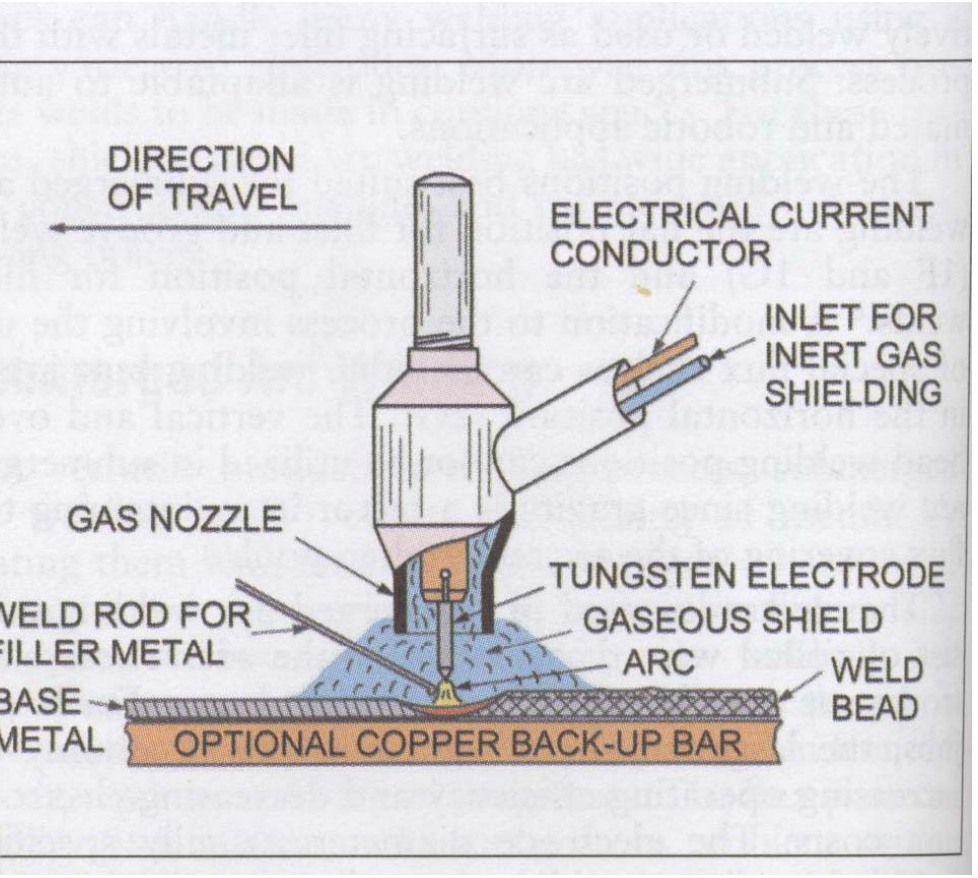
•FCAW is suitable for mechanisation and automation.

Electrogas Welding (EG or EGW)



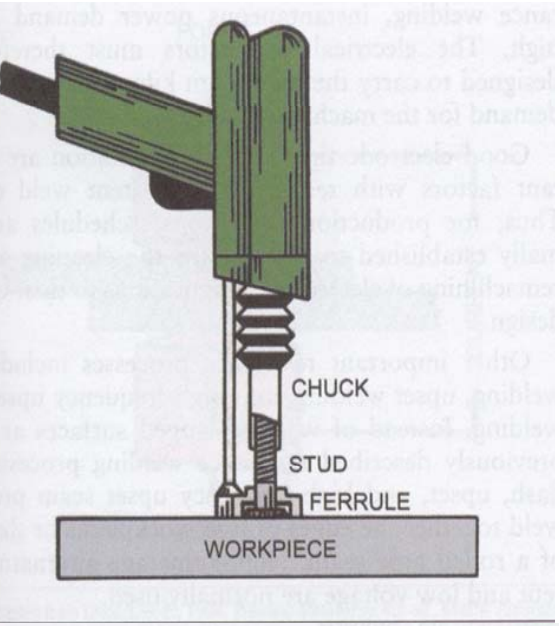
- EGW is a mechanized arc welding process that utilizes either flux cored or solid electrodes. The shielding gas may be applied from external source or produced by flux or both.
- EGW is used to hold thick sections in vertical position.
- EG machines are usually automatic to maintain constant arc and vertical movement of welding head, and can be used to weld sections up to 76mm. thick, using single electrode.
- EGW machines create as high as 400A with solid electrode and 750A with flux cored electrodes. Deposition rates are typically in the range of 7 to 13 kg/hr.
- EGW has the capacity to produce square grove and single–V butt joints. Single edge preparation minimizes the joint preparation costs. Weld transverse shrinkage is uniform, hence the joints are essentially free of angular distortion.
- Due to high current density EGW has high deposition rates.

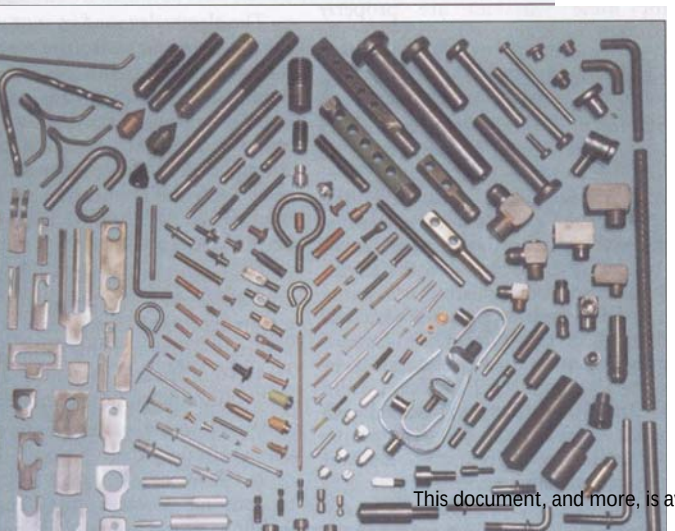
Gas Tungsten Arc Welding (GTAW)



- GTAW incorporates the use of a non-consumable tungsten electrode which is shielded from atmosphere by externally added gas. Welds can be made with or without the filler metal. It is also known as .“TIG welding”
- GTAW can be used in all welding positions and can be used for very thin materials (less than 1mm.). It is suitable for automated and robotic applications.
- The shielding gas in GTAW is usually inert (i.e. it does not participate in the chemical reaction). Argon or Argon–Helium mixtures are usually used. Since some chemical reactions are desirable sometimes hydrogen or nitrogen is added.
- The greatest disadvantage of GTAW is its low productivity.

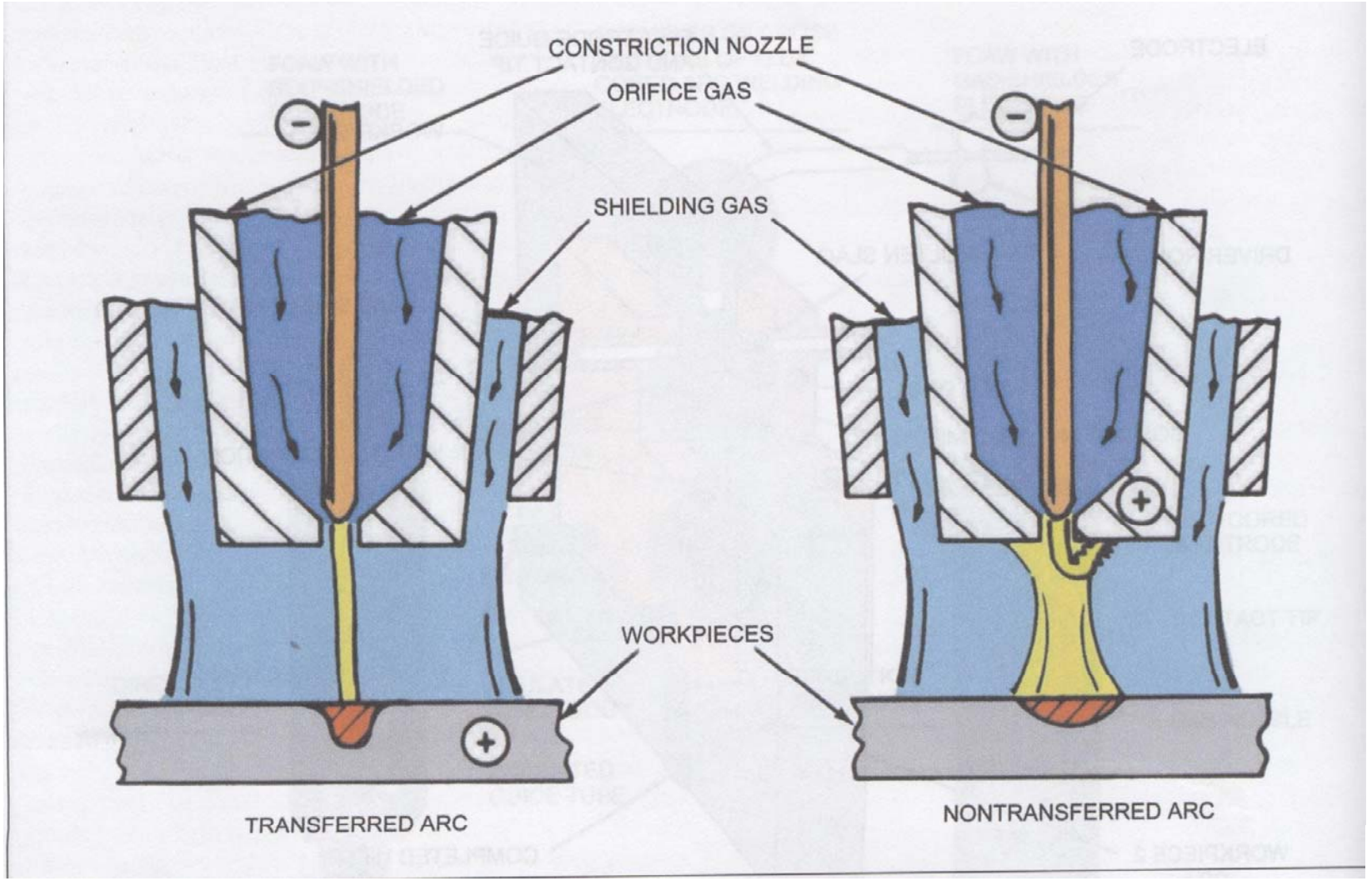
Stud Welding (SW)





- SW is used to join innumerable devices (usually fasteners) to the base metal. This process utilizes an arc struck between a metal stud and the work piece and is applied without filler material, and with or without shielding gas. Pressure is applied when the faying surfaces are adequately heated.
- Studs are usually surrounded by graphite or ceramic ferrules for partial shielding.
- The arc created by SW creates molten metal and application of pressure creates a uniform cross section. For a stud of 9.5 mm. typical arc time is 1/3 second.
- SW skill requirement is minimal and the process lends itself to robotic welding.
- A limitation of the process involves the use of brittle base metal such as cast iron, in which metal shrinkage can not be tolerated and heat affected zone cracking occurs.

Plasma Arc Welding: Transferred or non-transferred Arc



Capabilities of Joining Processes

Material	Thickness†	Processes*																							
		SMAW	SAW	GMAW	FCAW	GTAW	PAW	ESW	EGW	RW	FW	OFW	DFW	FRW	EBW	LBW	TB	FB	RB	IB	DB	IRB	DFB	S
Carbon steel	S	x‡	x	x		x				x	x	x			x	x	x	x	x	x	x	x	x	x
	I	x	x	x	x	x				x	x	x		x	x	x	x	x	x	x	x	x	x	x
	M	x	x	x	x					x	x	x		x	x	x	x	x	x				x	
	T	x	x	x	x			x	x		x	x		x	x			x					x	
Low-alloy steel	S	x	x	x		x				x	x	x	x		x	x	x	x	x	x	x	x	x	x
	I	x	x	x	x	x				x	x		x	x	x	x	x	x	x				x	x
	M	x	x	x	x					x	x		x	x	x	x	x	x	x				x	
	T	x	x	x	x			x			x		x	x	x		x					x		
Stainless steel	S	x	x	x		x	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x
	I	x	x	x	x	x	x			x	x		x	x	x	x	x	x	x				x	x
	M	x	x	x	x		x				x		x	x	x	x	x	x	x				x	
	T	x	x	x	x			x			x		x	x	x			x					x	
Cast iron	I	x										x					x	x	x				x	x
	M	x	x	x	x							x					x	x	x				x	x
	T	x	x	x	x							x						x					x	
Nickel and alloys	S	x		x		x	x			x	x	x			x	x	x	x	x	x	x	x	x	x
	I	x	x	x		x	x			x	x			x	x	x	x	x	x				x	x
	M	x	x	x			x				x			x	x	x	x	x					x	
	T	x		x				x			x			x	x			x					x	
Aluminum and alloys	S	x		x		x	x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	I	x		x		x				x	x		x	x	x	x	x	x			x		x	x
	M	x		x		x					x			x	x		x	x			x		x	
	T	x		x				x	x		x			x	x			x			x		x	
Titanium and alloys	S			x		x	x			x	x		x		x	x		x	x			x	x	
	I			x		x	x				x		x	x		x		x					x	
	M			x		x	x				x		x	x		x							x	
	T			x			x				x		x		x	x							x	
Copper and alloys	S			x		x	x			x§	x				x		x	x	x	x			x	x
	I			x						x				x				x		x			x	x
	M			x						x				x				x					x	
	T			x										x				x					x	
Magnesium and alloys	S			x		x				x					x	x	x	x			x		x	
	I			x		x				x				x	x	x	x	x			x		x	
	M			x										x	x	x		x					x	
	T			x										x	x								x	
Refractory alloys	S			x		x	x			x	x				x		x	x	x	x		x	x	
	I			x			x			x	x				x		x	x					x	
	M										x													
	T																							

* SMAW = shielded metal arc welding; SAW = submerged arc welding; GMAW = gas metal arc welding; FCAW = flux cored arc welding; GTAW = gas tungsten arc welding; PAW = plasma arc welding; ESW = electroslag welding; EGW = electrogas welding; RW = resistance welding; FW = flash welding; OFW = oxyfuel gas welding; DFW = diffusion welding; FRW = friction welding; EBW = electron beam welding; LBW = laser beam welding; TB = torch brazing; FB = furnace brazing; RB = resistance brazing; IB = induction brazing; DB = dip brazing; IRB = infrared brazing; DB = diffusion brazing; and S = soldering.

† S = sheet (up to 1/8 inch [in.] 3 millimeters [mm]); I = intermediate (1/8 in. to 1/4 in. [3 mm to 6 mm]); M = medium (1/4 in. to 3/4 in. [6 mm to 19 mm]); T = thick (3/4 in. [19 mm] and up).

‡ Commercial process.

§ Copper resistance welding requires special techniques.

Table 1 : Arc Welding Cost Definitions

Cost Definitions	
Variable	Definition
Deposition rate, D	Rate of weld metal deposited, lb/h (kg/h) (from data for 1 hour of continuous welding without arc stoppage)
Deposition efficiency, E	Ratio of weld metal deposited to total weight of electrode used, %
Operator factor, K	Ratio of arc hours to clock hours for a welder, %
Labor rate, L	Welder wages, $/h
Overhead rate, O	Cost of other business expenses, $/h
Power cost, P	Electricity, $/kWh
Amperes, A Volts, V	Vary according to specific welding procedure as well as electrode type and diameter
Material cost, M	Electrodes, $/lb ($/kg); wire, $/lb ($/kg); and gas, $/ft^3 ($/m^3);

Table 2 : Manual Arc Welding Values for Steel

Manual Arc Welding Values for Steel*		
Process	Deposition Efficiency (E)	Operator Factor (K) Average
SMAW	65%	25%
GTAW	90%	25%
GMAW	95%	35%
FCAW	85%	35%
SAW	98%	50%

* Users are advised to use in-house time studies for actual values.

Table 3 : Equations

EQUATIONS USED TO ESTIMATE the DIRECT COSTS of ARC WELDING		
COST	**EQUATION**	
Gas cost per unit weight of deposited metal, $/lb ($/kg)	$Cost_{Gas} = \frac{G \times F}{D}$	(1)
Power cost per unit weight of deposited metal, $/lb ($/kg)	$Cost_{power} = \frac{P \times V \times A}{1000 \times D}$	(2)
Cost of materials per unit weight of deposited metal, $/lb ($/kg)	$Cost_{Materials} = \frac{M}{E}$	(3)
Labor rate per unit weight of deposited metal, $/lb ($/kg)	$Cost_{Labor} = \frac{L \times K}{D \times 100}$	(4)
Overhead cost per unit weight of deposited metal, $/lb ($/kg)	$Cost_{Overhead} = \frac{O}{D \times \left(\frac{K}{100}\right)}$	(5)
Total cost of weld per unit weight of deposited metal, $/lb ($/kg)	$Cost_{\text{Weld per unit length of deposited metal}}$ = Sum of Eqs. (1) through (5)	(6)
Total cost of weld per unit length of joint, $/ft ($/m)	$Cost_{\text{Weld per unit length of joint}} = Cost_{\text{Weld per unit length of deposited metal}} \times S$	(7)
Total cost of weld, $	Total $Cost_{Weld} = Cost_{\text{Weld per unit length of deposited metal}} \times W$ or (7)x N	(8)

Total welding time, T (h)	$T = \frac{W}{D \times K}$
Total weight of weld metal, W (lb [kg])	$W = S \times N \times C$
Welding time per unit length for a specific joint, T_{Joint}	$T_{Joint} = W + (D \times K)$
Total consumables required	Electrode or wire (lb [kg]) = $W + E$
	SAW flux (lb [kg]) = $\frac{1.5W}{E}$
	Gas (ft^3 [m^3]) = $\frac{(F \times T)}{E}$

Key:
A = Amperes
C = Specific gravity of metal, lb/in.^{3}
D = Deposition rate, lb/h (kg/h)
F = Flow rate, cubic feet per hour
G = Unit cost of gas or flux by volume, $/ft^3
E = Deposition efficiency. %
P = Power cost, ($/kWh)
W= Total weight of weld metal, *lb/ft (kg/m)
S = Cross-sectional area of weld joint, in.2
T= Total welding time,h
V= Volts+
K = Operator factor, %
L = Labor rate, dollars (or other currency) per
M = Cost of materials, $/lb
N = Length of specified weld, in. (mm)
O = Overhead rate, $/h

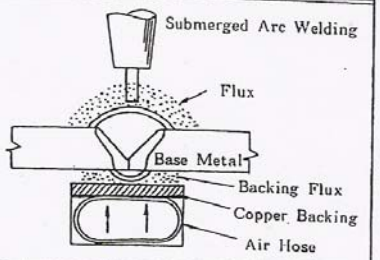
*Steel weighs0.283lb/in.^{3}(7.8x10^{-6}kg/mm^3)

Flux and Copper Backing (FCB)

Classification	Name	Welding Process
Process / Equipment	FCB (Flux and Copper Backing) Welding Process	Submerged Arc Welding Process

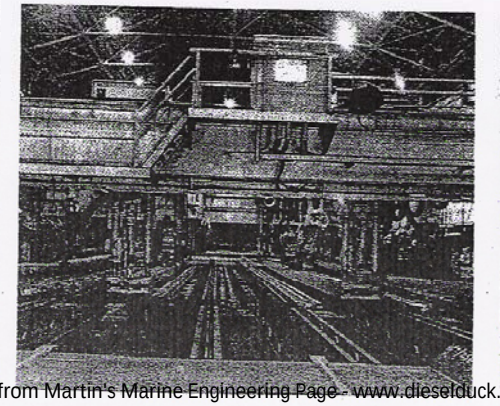
Outline of Process

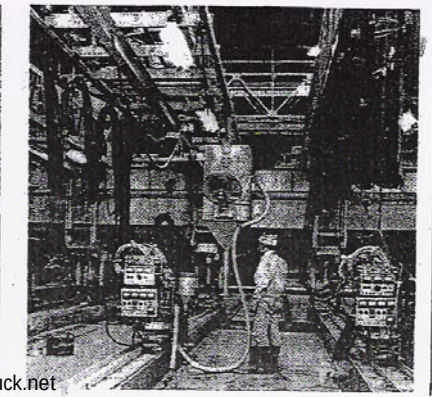
Automatic one-side submerged arc welding method in which uniform reverse bead can be obtained simultaneously with surface bead by welding only from the surface side after spreading backing flux on copper backing and pressing copper backing to the reverse side.



Application		Quantity
Panel Joint of	Upper Deck Inner Bottom Bottom Plating Side Plating Inner Bulkhead	

Construction	Welding Power Source, Welding Torch (2 or 3 Torches), Carriage, Backing Equipment
Main Function	1. Welding Current : 800~1,500A 2. Welding Wire : 4.8mm ϕ, 6.4mm ϕ 3. Applied Steel Plate : Mild Steel, 50kgf/㎟ High Strength Steel up to Grade II 4. Applied Thickness : 6~45mm
Merit	Low running cost in spite of high equipment investment High welding efficiency by using roller conveyor together



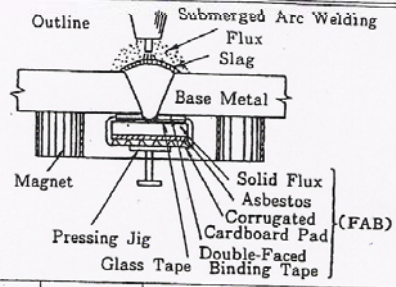


Flux and Asbestos Backing (FAB)

Classification		Name	Welding Process
Process	Equipment	FAB (Flux and Asbestos Backing) One Side Submerged Arc Welding Process	Submerged Arc Welding Process

Outline of Process

One-side submerged arc welding process using flexible backing material which consists of glass tape, flux, asbestos wrapped in a thermo-shrinkage film. The backing material is usually supported by magnetic clamp.



Application

Stage	Joint	Structure	Quantity
Assembly Erection	Butt Joint	◦ Curved Outside Plating ◦ Upper Deck ◦ Inner Bottom Plating ◦ Bottom Plating	

Construction

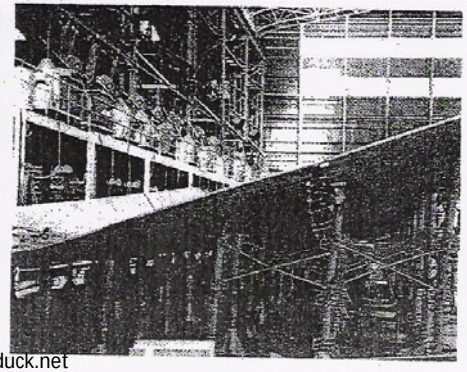
① Welding Power Source (1,500A Drooping Characteristics AC)
② Welding Machine ③ Rail ④ Control Box ⑤ Operation Box

Main Function

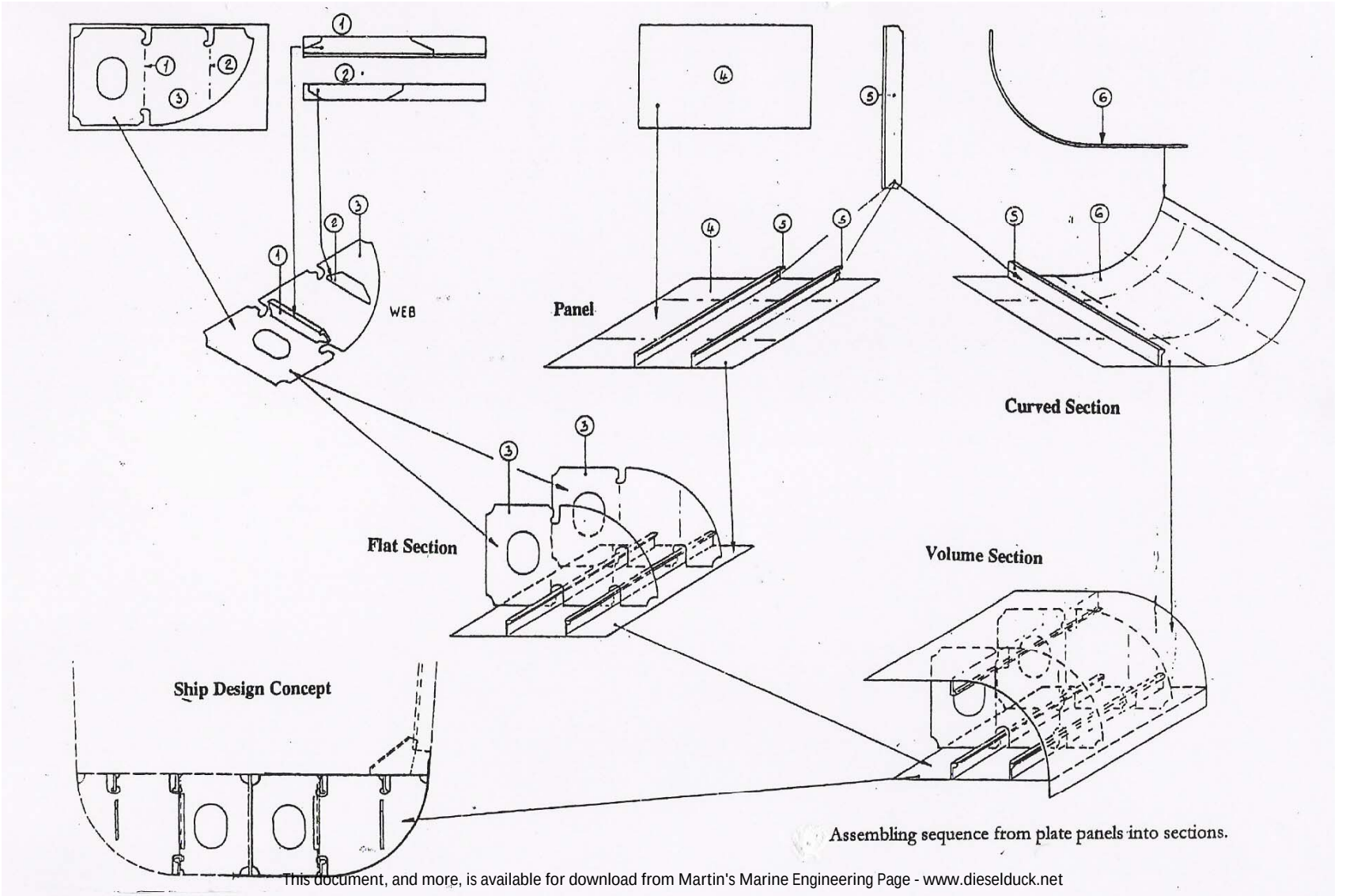
1. Welding Current : 800~1,100A
2. Welding Wire : 4.8mm ϕ, 6.4mm ϕ
3. Wire Feeder Speed Control : Arc Voltage Control
4. Applied Plate Thickness : 11~35mm

Merit

1. Stable welding quality of curved joint because of flexible backing
2. Insensitive to bevel accuracy and stable welding quality
3. Easy to weld from one side and useful to improve working environment

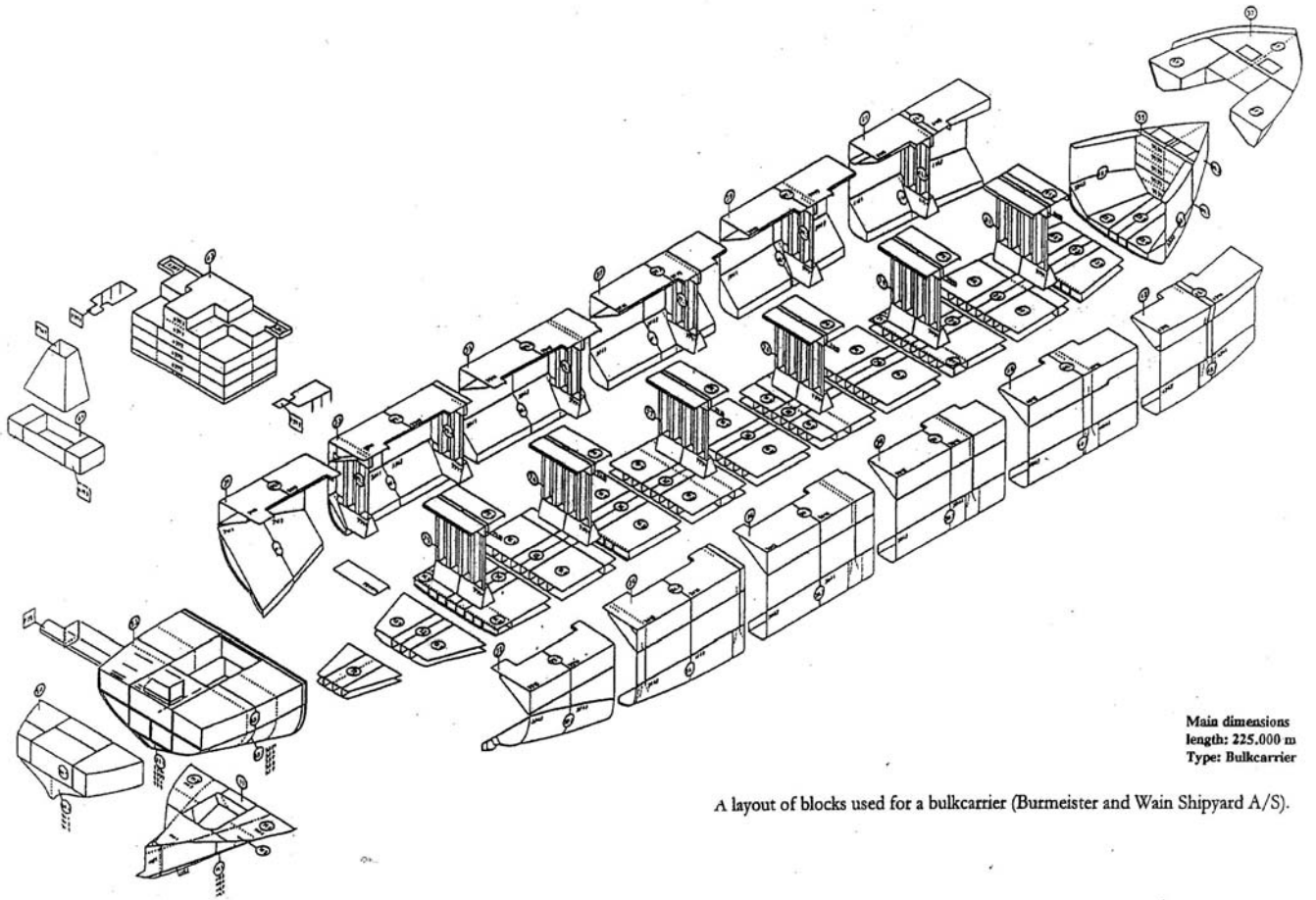


Assembling Sequence from Plate Panels into Sections



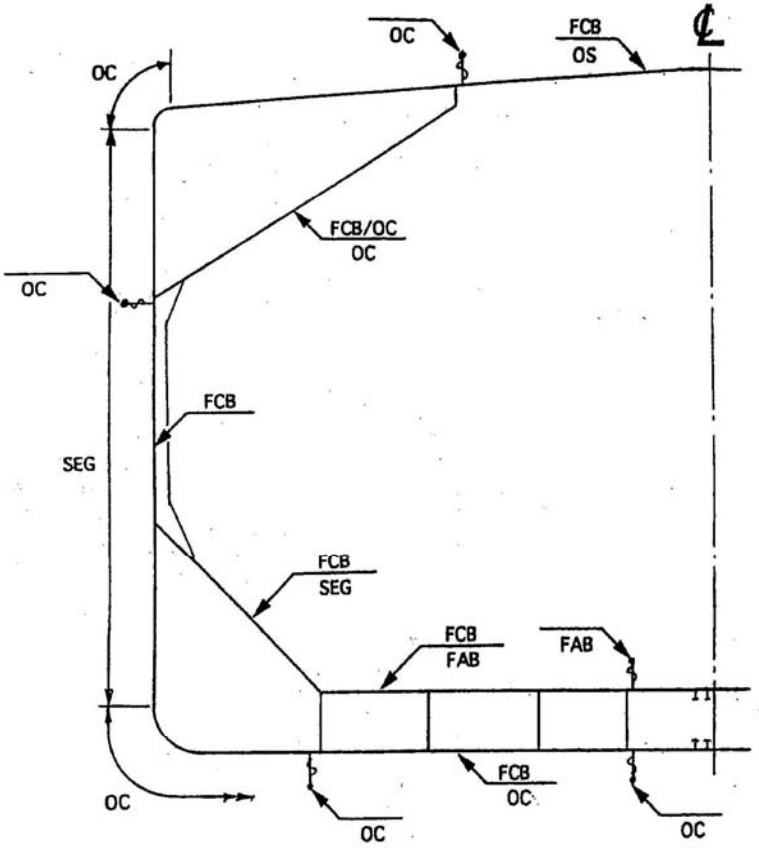
Assembling sequence from plate panels into sections.

Blocks Layout for a Bulkcarrier



A layout of blocks used for a bulkcarrier (Burmeister and Wain Shipyard A/S).

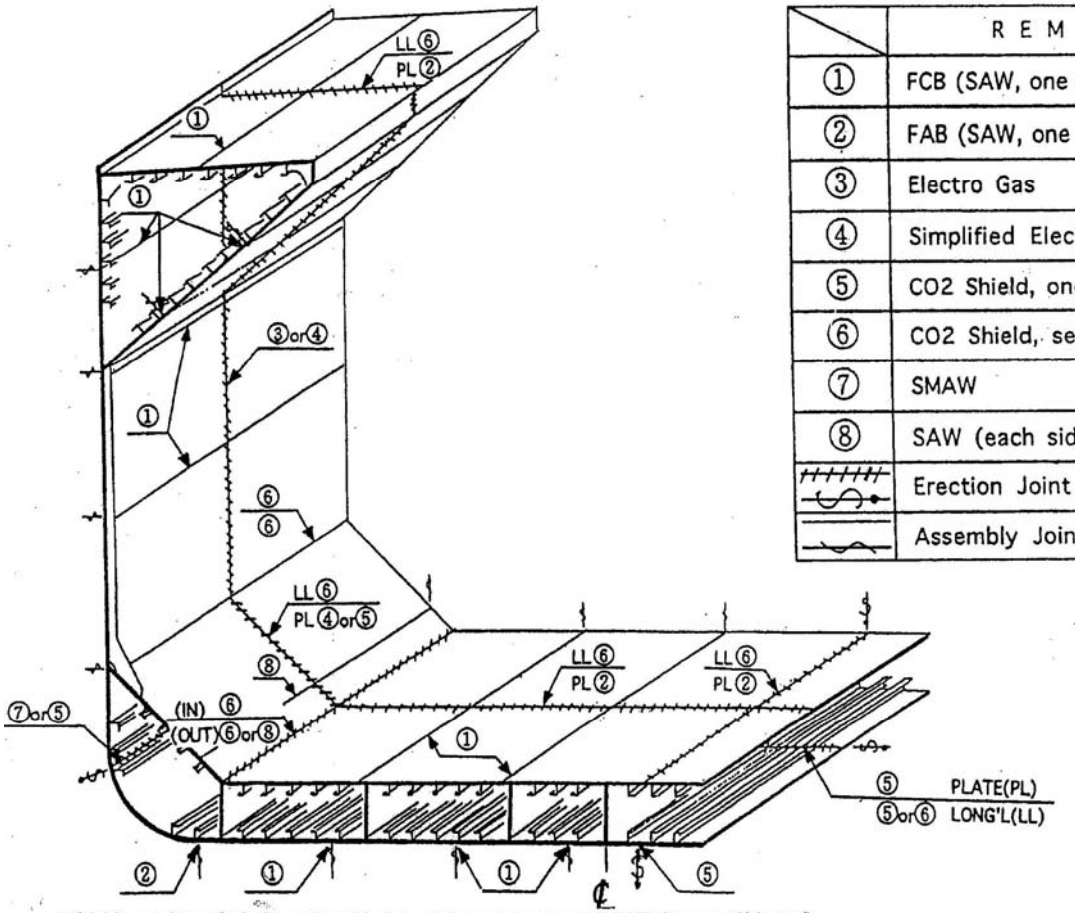
Welding Processes for a Midship Section



Midship section of a bulk carrier and welding processes used in the assembly and erection stage (NKK Corporation – TSU Works, Japan).

OO / OO	Assembly Stage / Erection Stage
FCB	SAW, one side
FAB	SAW, one side
OC	CO2, one side, semi-auto
OS	OC + SAW
SEG	Simplified EG
SES	Simplified ES
	Block Joint

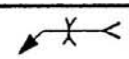
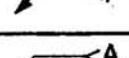
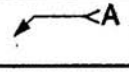
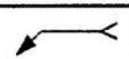
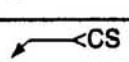
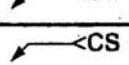
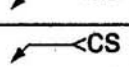
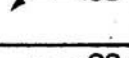
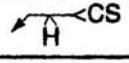
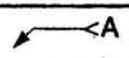
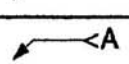
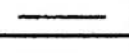
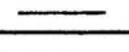
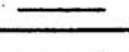
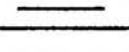
Welding Processes for a Midship Section



	REMARKS
①	FCB (SAW, one side)
②	FAB (SAW, one side)
③	Electro Gas
④	Simplified Electro Gas
⑤	CO2 Shield, one side, semi-auto
⑥	CO2 Shield, semi-auto
⑦	SMAW
⑧	SAW (each side, including fillet)
	Erection Joint
	Assembly Joint

Midship section of a bulkcarrier with the welding processes used (SHI Oppama Shipyard).

Welding Processes for a Midship Section

No.	Welding Process	Abbre-viation	Symbols	Joint Position	Joint Dezin	Bass Metal Grade	mm	Shield Gas	Welding Materials	Backing Material	WPS No.	Remarks
01	Both side Submerged Arc Welding (AUTO)	SAW		Flat Groove	X Groove	DH40	30	Non	US-36 PFH-55E	Non	LR-40-01-R	
02	One side Submerged Arc Welding (FCB)	FCB		Flat Groove	40Y Groove	DH40 EH36	30 25.4	Non	US-36 PFI-55E	MF-1R Cu-Back.	LR-40-02-R LR-36-05-R	
03	One side Submerged Arc Welding (FAB)	FAB		Flat Groove	50V Groove	DH40 EH36	30 25.4	Non	US-36 PFI-52E RR-2	FAB-1	LR-40-03-R LR-36-06-R	
04	Both side CO_2 Semi Automatic Arc Welding	FCAW		All Groove	40V Groove	DH40	30	CO_2 100%	SF-1 DW-100	Non		
05	One side CO_2 Semi Automatic Arc Welding	FCAW		F, Vr, Ho. Groove	40V Groove	DH40 EH36	30 25.4	CO_2 100%	SF-1, DW-100 SF-3	ABH-5	LR-40-05~07-R LR36-07~09-R	
06	One side CO_2 Semi Automatic Arc Welding	FCAW		F, Vr Groove	40V Groove	DH40 EH40	50 50	CO_2 100%	SF-3 SF-36E	ABH-5	LR-93-C-D40-01,2 LR-93-C-E40-05,6	
07	One side CO_2 Automatic Arc Welding	FCAW		Vert. up Groove	40V Groove	EH36 DH40 EH40	25.4 50 50	CO_2 100%	SF-3 SF-3 SF-36E	SB-41	LR-36-04-R LR-93-C-D40-04 LR-93-C-E40-08	
08	One side CO_2 Automatic Arc Welding	FCAW		Horis. Groove	30.15 Groove	DH40 EH-36	30 25.4	CO_2 100%	SF-1, DW-100 SF-3	SB-41	LR-40-07-R LR-36-02-R	
09	One side CO_2 Automatic Arc Welding (Singl)	GMAW		Flat Groove	50V Groove	EH40	50	CO_2 100%	YM-55H YK-CM	SB-41	LR-93-C-E40-09	
10	One side CO_2 Automatic Arc Welding (Tandem)	GMAW		Flat Groove	50V Groove	EH36	25.4	CO_2 100%	YM-55H YK-CM	SB-41	LR-36-01-R	
11	One side CO_2 Automatic Arc Welding (Singl) (15° X 20)	GMAW		Flat Groove	50V Groove	EH36	25.4	CO_2 100%	YM-55H YK-CM	SB-41	LR-36-03-R	
12	CO_2 Semi Automatic Arc Welding	FCAW		All Fillet	Fillet	DH40	30	CO_2 100%	SF-1 DW-100	Non		
13	CO_2 Automatic Arc Welding	FCAW		Horis. Fillet	Fillet	DH36	25.4	CO_2 100%	SF-1 DW-100	Non		
14	CO_2 Automatic Arc Welding	FCAW		Vert. up Fillet	Fillet	DH36	25.4	CO_2 100%	SF-1 DW-100	Non		
15	CO_2 Tandem Twin Auto Arc Welding	FCAW		Horis. Fillet	Fillet	DH36	25.4	CO_2 100%	SM-1F	Non	LR-36-07-R	
16	Gravity Arc Welding	SMAW		Horis. Fillet	Fillet	EH36	25.4	Non	LBA-50 EX-50F	Non	LR-36-09-R	
17	Easy Electrogas Welding (AUTO)	SEG		Vert. up Groove	Groove	DH40	30	CO_2 100%	DW-43G	KL-43G	LR-40-09-R	
18	Robotic Arc Welding	GMAW		Vert. Horis. Fillet	Fillet	DH40	30	Ar 90% + CO_2 10%	YM-28	Non		

Selection of Welding Processes in the Erection Stage: Horizontal and Flat Position

The notation of welding process is the same as before. Some new notation has been added.

SAW	One-sided submerged-arc welding
EG	Electrogas arc welding with copper slide shoe backing
SEG	Simplified electrogas arc welding with fixed ceramic backing
G	Gas metal arcwelding (semi-automatic)
GSM	Gas metal arc welding (simple mechanized)
GMAW	(Automatic with highly advanced functions)
	-Joint tracking
GHA	-Sequence controlled multipass welding system
	-Adaptive controlled welding system
GOS	GMAW One-sided (semi-automatic) + submerged-arc welding

Welding Procedures in the Horizontal Position

G	Widely applied.
GSM	Many cases for joints with thickness over 15 mm and length over 2 metres.
GHA	Few applications.

Few cases for joints with medium thickness and long length

Selection of welding procedures in the flat position

1. Plate thickness limitations:

There is no technical limitation for plate thickness to apply G, GSM, or GHA.

Application. of SAW to plate under 10 mm is limited to prevent severe deformation. Application to thicknesses over 35 mm is limited to prevent hot cracking in the root pass.

To apply GOS, same passes of GMAW are required to prevent burn through by SAW. Therefore, applicatian to thin plate is limited.

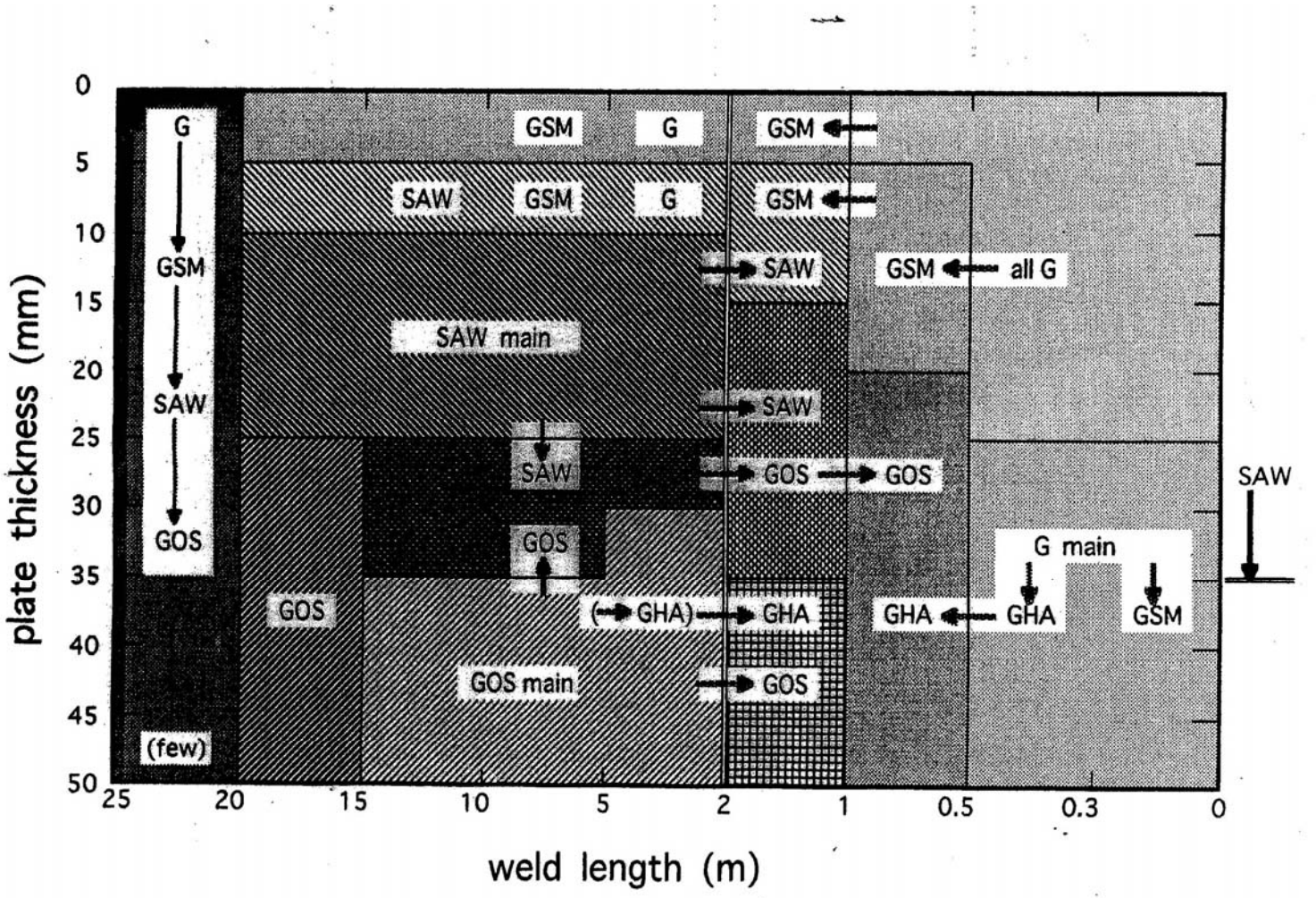
2. Economical limitations and/or manpower limitations:

SAW has a high deposition rate, but it takes time and manpower to fit-up joints with high groove accuracy and to set-up heavy welding equipment in the erection stage. Therefore, economical limitation to the weld length exists for each plate thickness.

3. Technical limitations:

GHA is applied in few cases. The accuracy of the weld joint in the erection stage is not good and the development of a sensing system for irregular joints, and a database which corresponds to irregular weld joints is expected.

Selection of Welding Procedures

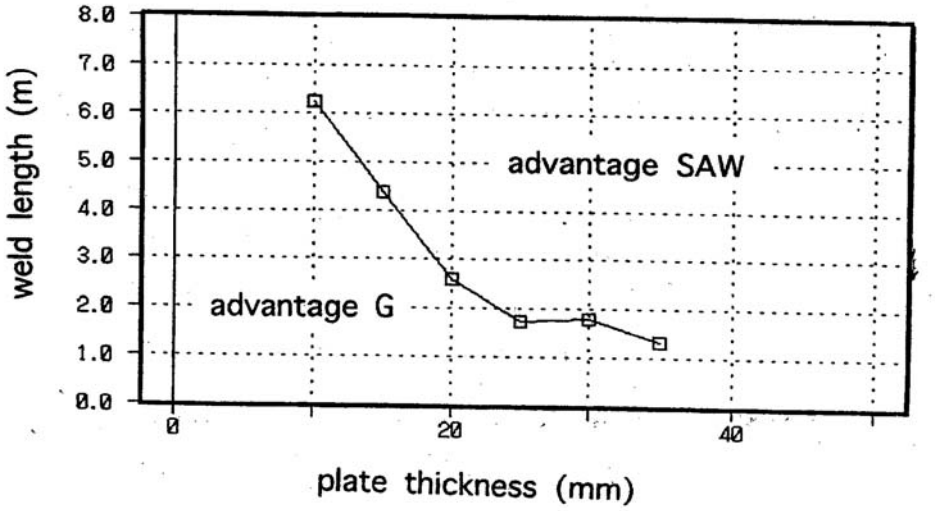


Selection of welding procedures (flat position).

Welding Time (Hours)

Table 3.10 A comparison of total welding hours (flat position)

GMAW semiauto							SAW oneside						
t (mm)	10	15	20	25	30	35	t (mm)	10	15	20	25	30	35
operator	1	1	1	1	1	1	operator	2	2	2	2	2	2
groove	40	40	40	40	40	40	electrode	1	1	2	2	2	2
root gap	5	5	5	5	5	5	Pass	1	1	1	1	2	2
depo. ratio	80	100	120	120	120	120	speed(cpm)	35	30	35	30	30	25
preparation	0.5hr X 1 welder						preparation	1hr X 2 operators					
arc time %	35 %						arc time %	25 %					
Area x Length x 7.85 x operator / depo. ratio x 6 0 x arc time % + prepa-ration							Length x pass x 100 x operator / speed x 6 0 x arc time % + prepa-ration						
length (m)	weld time						length (m)	weld time					
0.3	0.7	0.7	0.8	0.9	1.0	1.2	0.3	2.1	2.1	2.1	2.1	2.3	2.3
0.5	0.8	0.9	1.0	1.2	1.4	1.6	0.5	2.2	2.2	2.2	2.2	2.4	2.5
1.0	1.1	1.3	1.5	1.8	2.2	2.7	1.0	2.4	2.4	2.4	2.4	2.9	3.1
2.0	1.7	2.1	2.4	3.1	3.9	4.9	2.0	2.8	2.9	2.8	2.9	3.8	4.1
5.0	3.6	4.4	5.3	7.1	9.1	11.5	5.0	3.9	4.2	3.9	4.2	6.4	7.3



Weld length with same welding hours (flat position).

Welding Procedures in the Vertical Position

1. Plate thickness limitations:
There is no technical limitation regarding plate thickness for the application of G; GSM, or GHA.

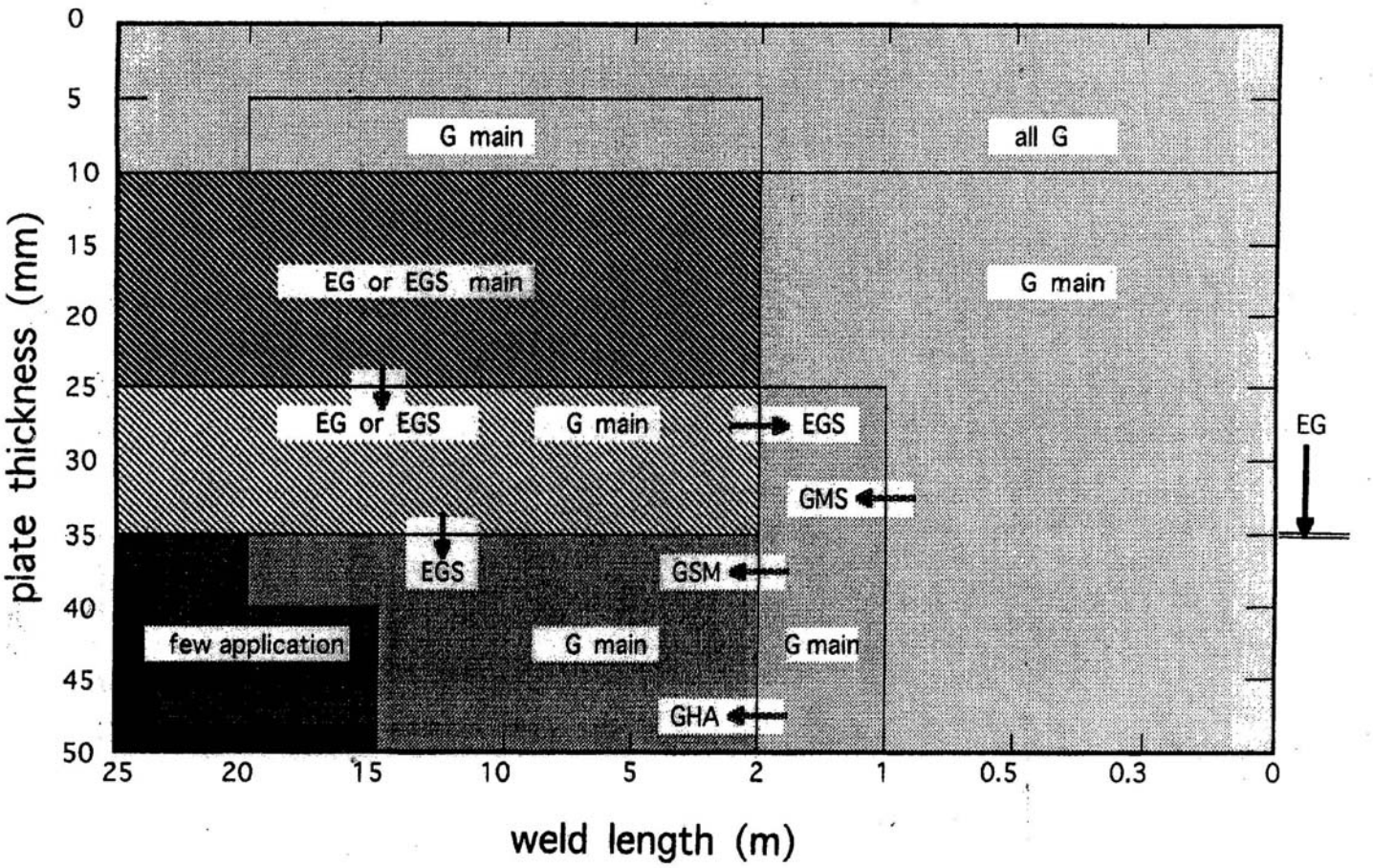
Application of EG to plate of under 10 mm in thickness is limited by controlling the position of the wire during welding.

Since EG is carried out with fixed backing, SEG is applied for a wider range than EG. Same shipyards apply a two pass technique.

2. Economical limitations and/or manpower limitations:
EG or SEG is a high deposition rate process with a long joint preparation time to achieve high groove accuracy. Heavy welding equipment is required in the erection stage, and economical limitations to weld lengths therefore exist for each plate thickness.

3. Technical limitations:
GHA is applied in a few cases. As the accuracy of the weld joint in the erection stage is not good, development is expected of a sensing system and a database which corresponds to irregular weld joints.

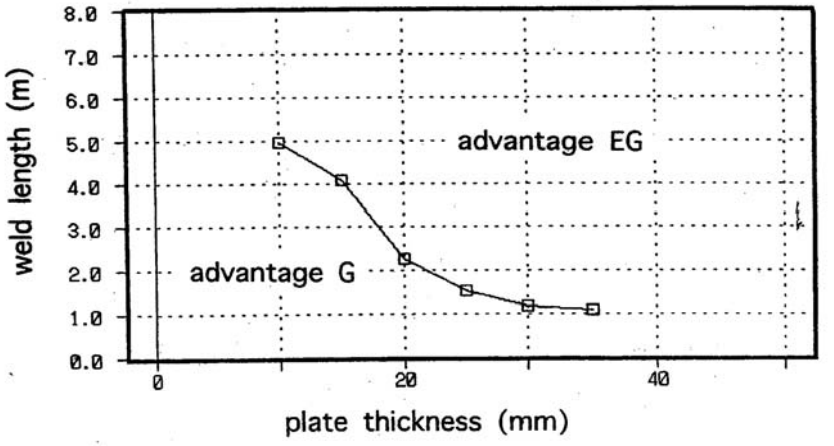
Selection of Welding Procedures



Welding Time (Hours)

Table 3.11 A comparison of total welding hours (vertical position)

GMAW semiauto							Electro Gas Welding						
t (mm)	10	15	20	25	30	35	t (mm)	10	15	20	25	30	35
operator	1	1	1	1	1	1	operator	2	2	2	2	2	2
groove	40	40	40	40	40	40							
root gap	5	5	5	5	5	5	Pass	1	1	1	1	1	1
depo. ratio	30	40	40	40	40	40	speed(cpm)	14	12	10	8	6	4
preparation	0.5hr X 1 welder						preparation	2hr X 2 operators					
arc time %	35 %						arc time %	25 %					
Area x Length x 7.85 x operator / depo. ratio x 6 0 x arc time %						+prepa-ration	Length x pass x 100 x operator / speed x 6 0 x arc time %						+prepa-ration
length (m)	weld time						length (m)	weld time					
0.3	1.0	1.1	1.4	1.7	2.1	2.5	0.3	4.3	4.3	4.4	4.5	4.7	5.0
0.5	1.3	1.5	1.9	2.5	3.1	3.8	0.5	4.5	4.6	4.7	4.8	5.1	5.7
1.0	2.2	2.5	3.4	4.4	5.7	7.1	1.0	5.0	5.1	5.3	5.7	6.2	7.3
2.0	3.8	4.4	6.2	8.4	10.8	13.7	2.0	5.9	6.2	6.7	7.3	8.4	10.7
5.0	8.8	10.3	14.8	20.2	26.4	33.4	5.0	8.8	9.6	10.7	12.3	15.1	20.7



Weld length with same welding hours (vertical position).

Welding Procedures in the Horizontal Position

Figure shows a summary of applications.

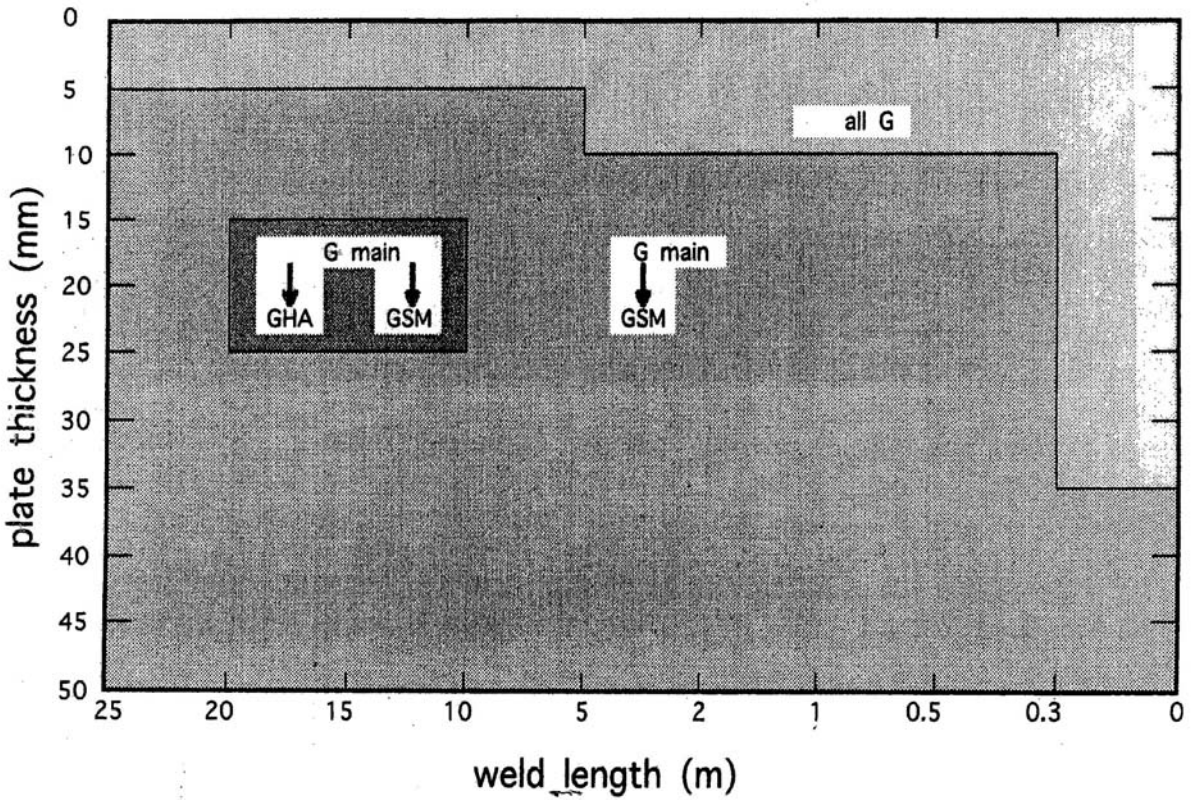
1. Plate thickness limitations:

There are no technical limitations to plate thickness in applying G, GSM or GHA.

2. Economical limitations and/or manpower limitations:

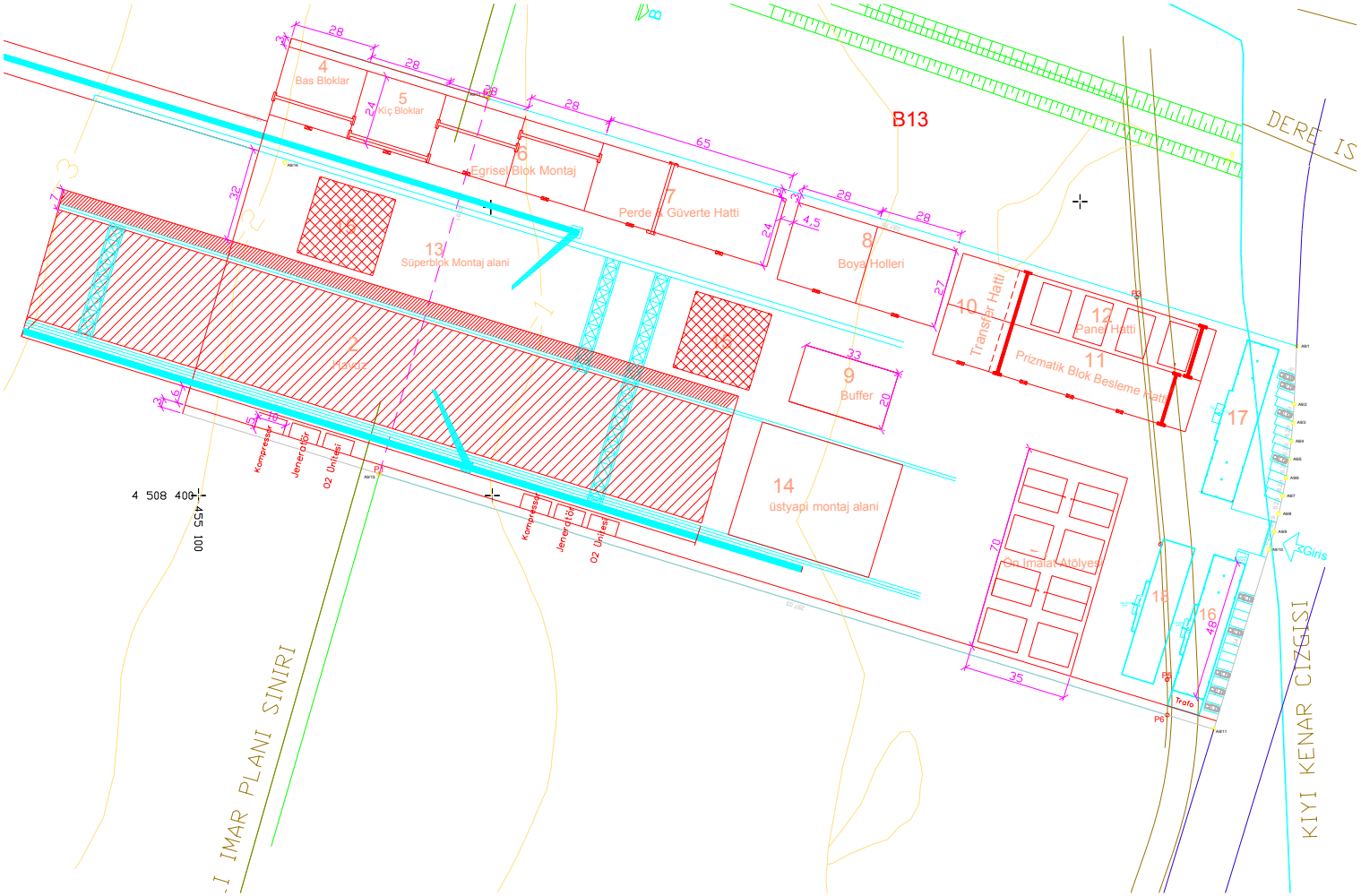
As there is no practical high deposition rate process for horizontal welding, only GMAW is applied at present. The cost of welding facilities increases in the order of G, GSM and GHA.

Selection of Welding Procedures



Selection of welding procedures (horizontal position).

Shipyard Layout



Stock Area

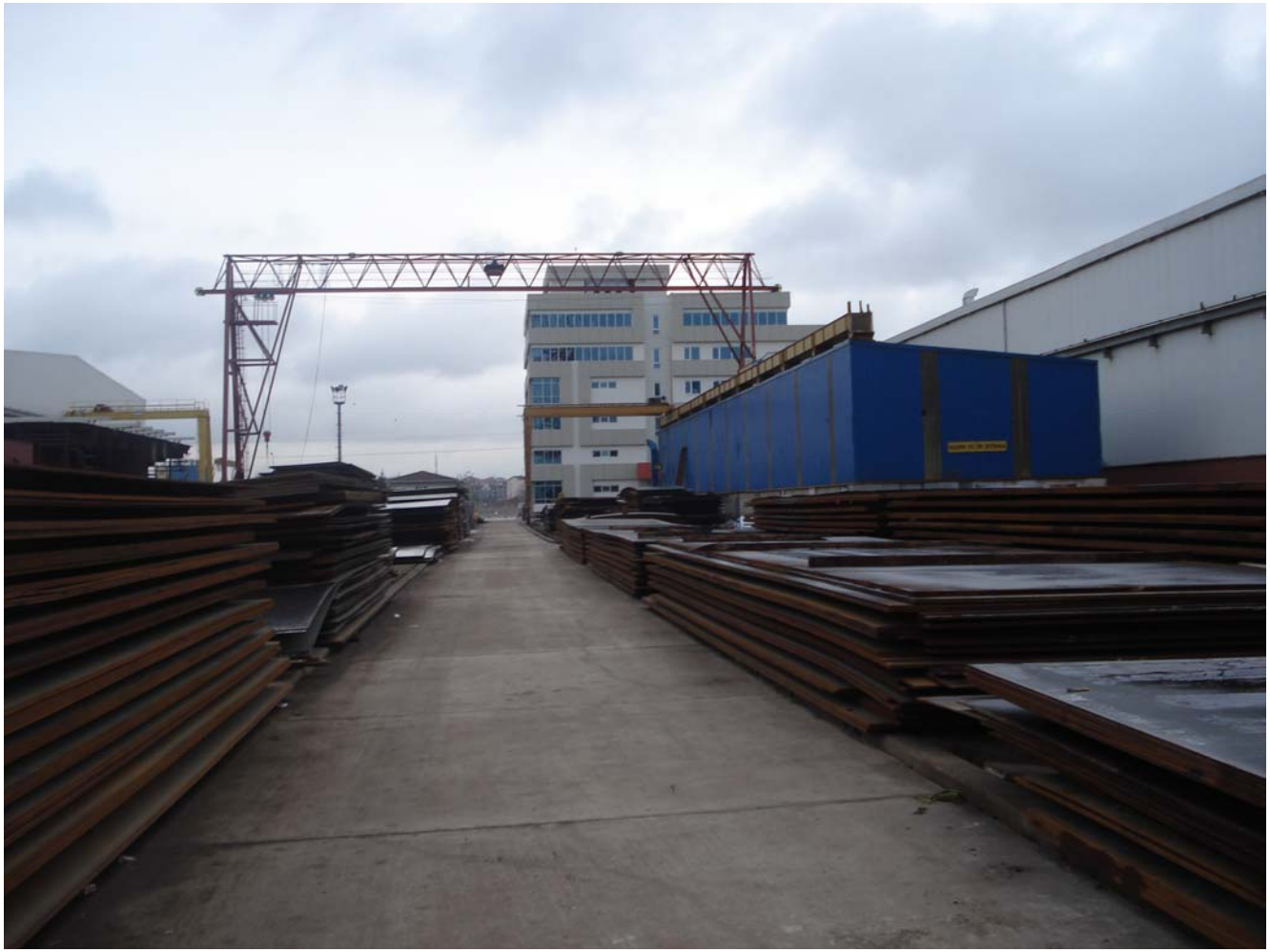
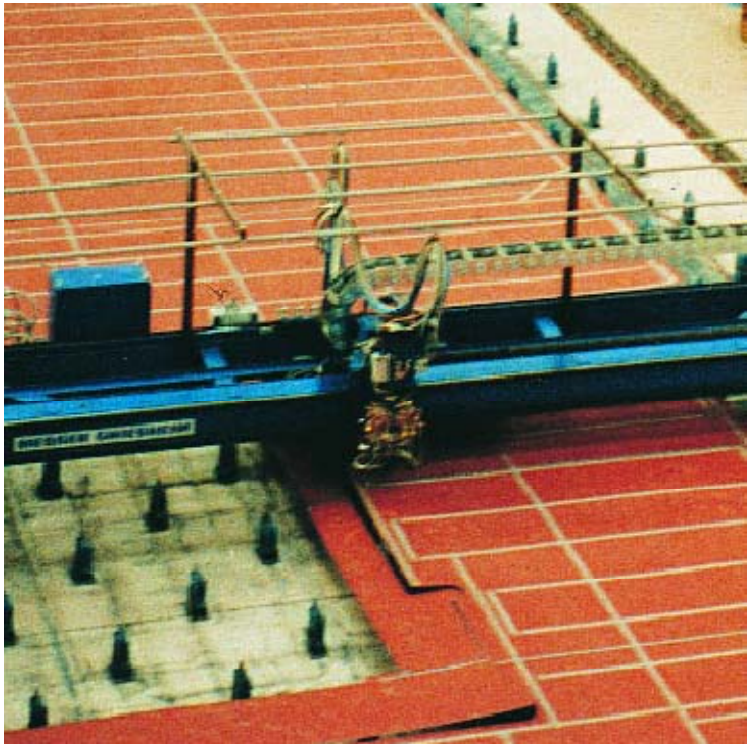
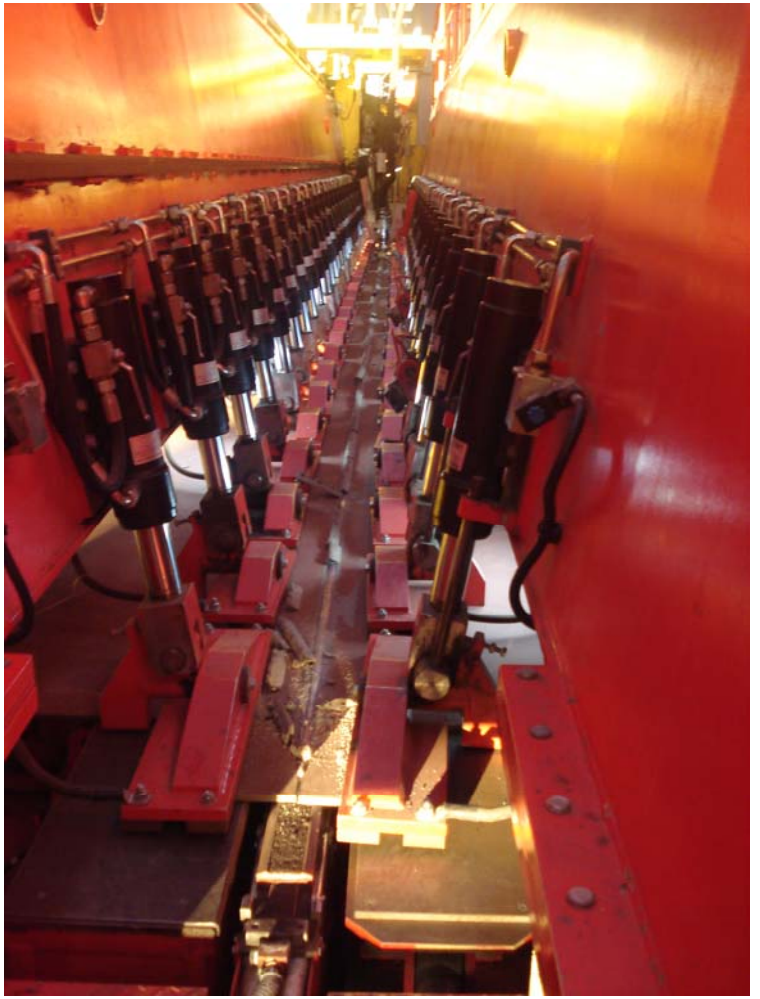


Plate Lifting and Plasma Cutting

Marking

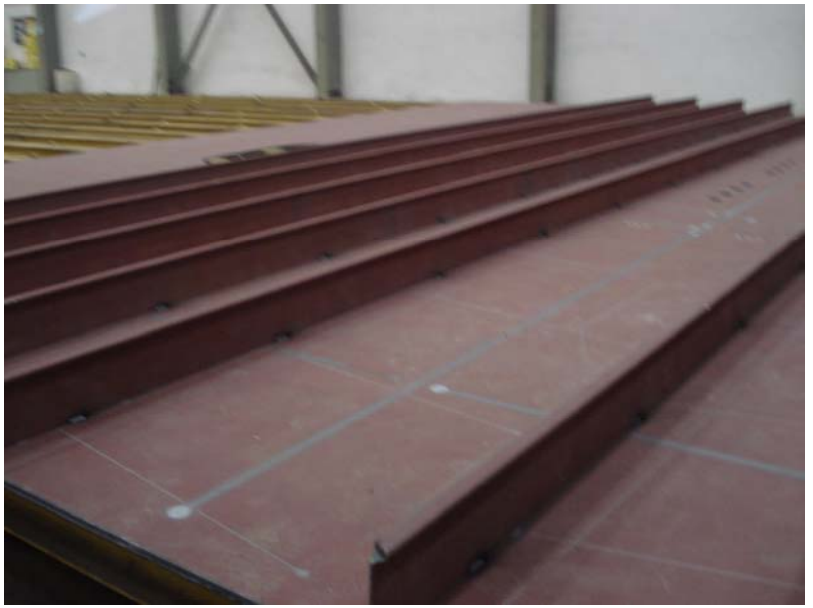


Submerged Arc Welding of Plates

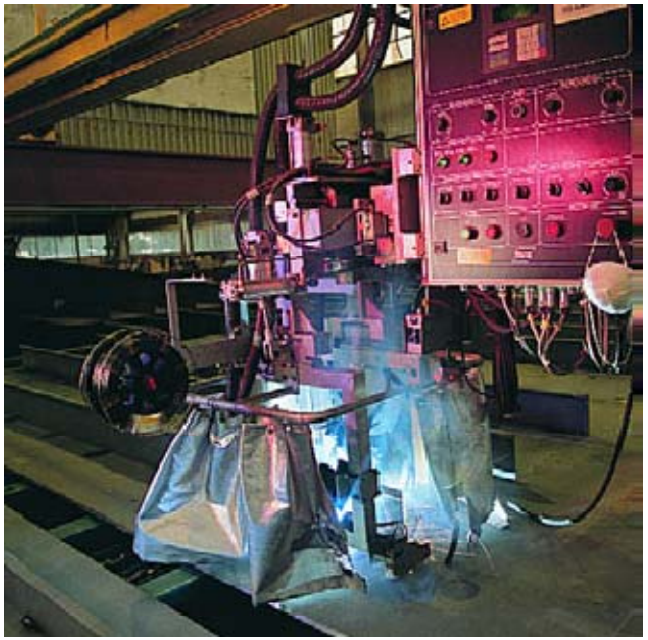


Palet System for Stiffeners

Temporary Welding

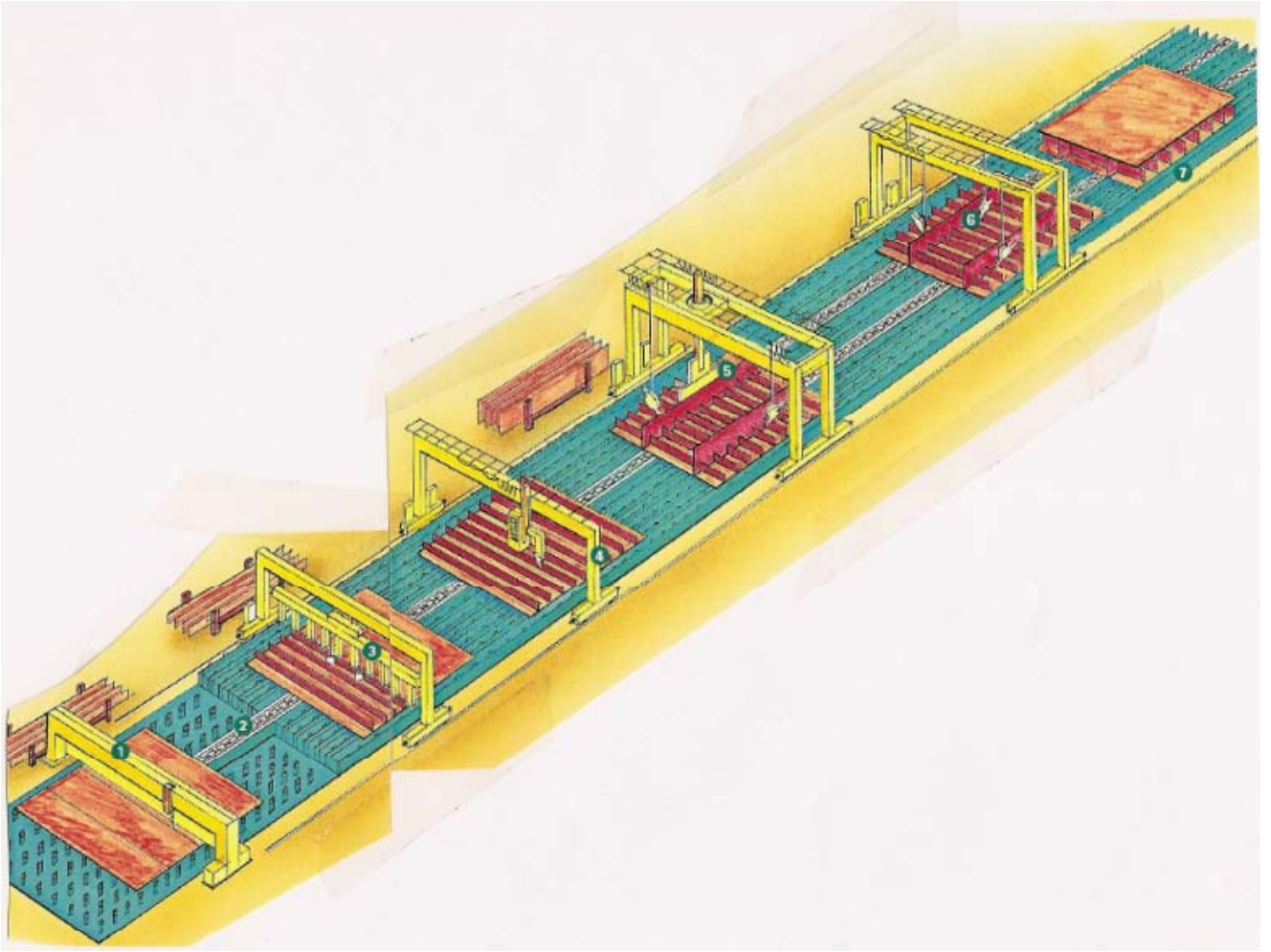


Stiffeners Final Welding

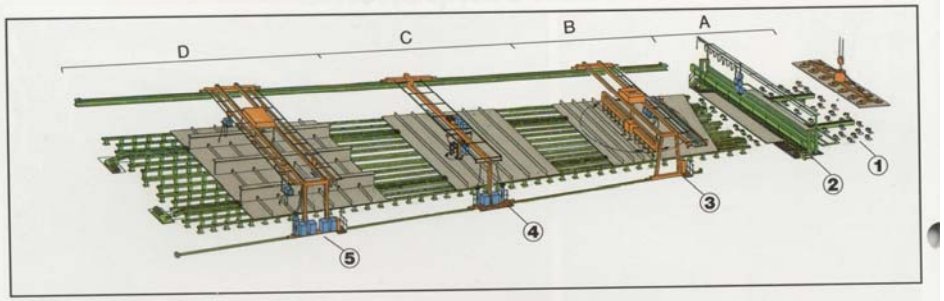


Sub Assembly Examples

Panel Line



Panel and Bulkhead Line



PRODUCTIVITY

No. of panels per 8 Hrs. shift: .. 1,5-2,0
No. of workers: 8
No. of plate joints per Hr.: ..... ca. 1,2
No. of stiffeners per 8 Hrs. shift: 24
(multidirectional stiffener mounting).

EQUIPMENT

1. *Roller bed and plate alignment frame.*
2. *One side Buttwelding Station.*
3. *Stiffener Mounting Gantry.*
4. *Automatic Filletwelding Gantry.*
5. *Web Mounting and Welding Service Gantry.*

DESCRIPTION

The TTS Small Panel and Bulkhead line will produce small panels and bulkheads with 7-12 meters width and with the stiffener mounted in any selected horizontal direction.

In an 8 hours shift 8 workers will produce 1½-2 panels with 12-16 stiffeners and additional webs and brackets.

The Panel and Bulkhead line has a specialized mobile gantry with a swivel mounted clamping yoke for alignment and mounting of stiffeners in any selected horizontal direction.

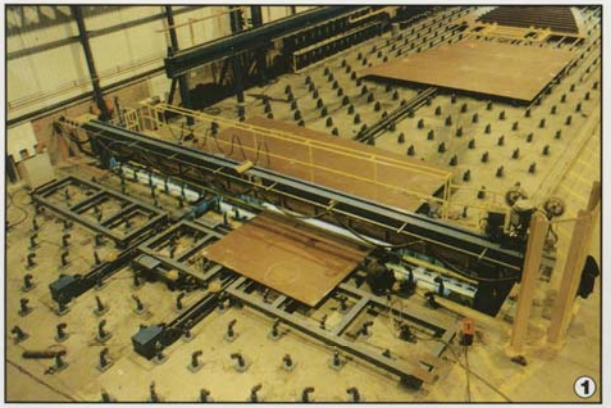
A. PLATE JOINTING.
Plate alignment and tacking. One side, single pass automatic buttwelding.

B. STIFFENER MOUNTING.
Stiffener alignment, clamping and tacking by Stiffener Mounting Gantry.

C. STIFFENER WELDING.
Automatic filletwelding of stiffeners by Autowelding Gantry.

D. WEB MOUNTING AND WELDING.
Alignment and clamping by hydraulic handling and fairing unit on the Web Mounting and Welding Service Gantry.
Tacking and final welding by semiautomatic MIG welding suspended on the gantry.

Panel and Bulkhead Line: Main Components



ONE SIDE WELDING STATION
Single pass 5-15 mm plate (see separate documentation).

1. *Plate alignment manipulators, clamping beams and welding machine.*

2. *Backing arrangement.*

STIFFENER MOUNTING

3. *TTS Stiffener Gantry with magnet beam and rotation for mounting and tackwelding in all directions. Also shown stiffener supply pallet.*

STIFFENER WELDING

4. *TTS Autowelding Gantry for programmable continuous and intermittent fillet welding.*

5. *Two side fillet welding and fume extraction arrangement.*

Curved Panel Assembly

Sub Blocks

Blocks

Paint Hall

Paint Hall

Questions ?