SKEM4153
ROBOT TECHNOLOGY FOR AUTOMATION

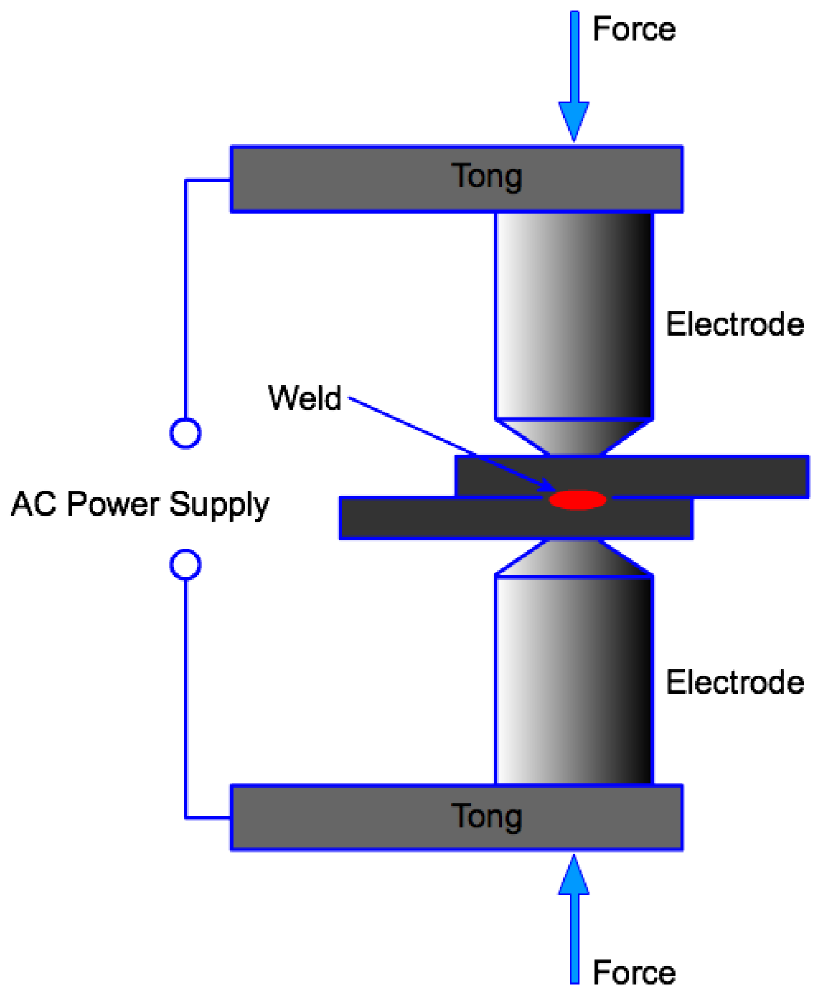
CHAPTER 3
WELDING APPLICATIONS

Prof. Dr. Shamsudin H.M. Amin
Ir. Dr. Mohd Ridzuan Ahmad
(mdridzuan@utm.my)

SPOT WELDING

- Spot welding is a process in which two sheet metal parts are fused together at localized points by passing a large electric current through the parts where the weld is to be made.
- The fusion is accomplished at relatively low voltage levels by using two copper (or copper alloy) electrodes to squeeze the parts together at the contact points and apply the current to the weld area.
- The electric current result in sufficient heat in the contact area to fuse the two metal parts, hence producing the weld.

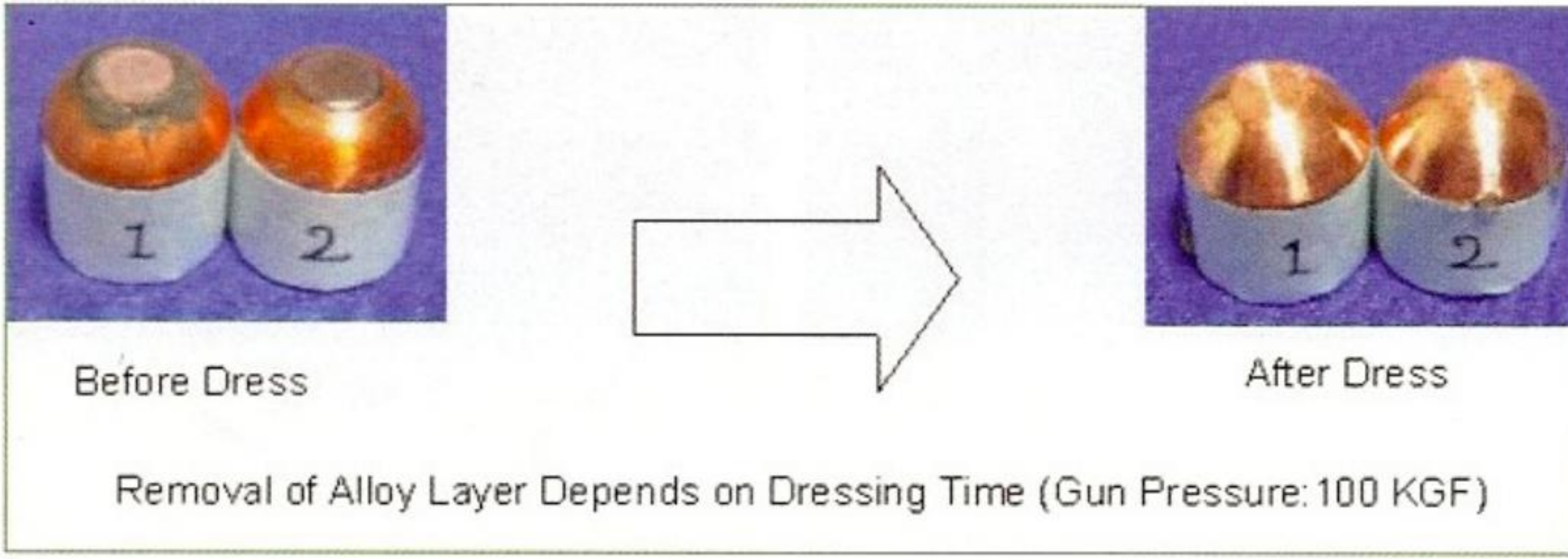
SPOT WELDING



SPOT WELDING

- The two electrodes are squeezed together against the mating parts, and the current is applied to cause heating and welding of the contacting surfaces
- The actual welding portion of sequence typically requires less than a second. Therefore, the rates of production in spot welding are largely dependent on the time required for positioning of the welding electrodes and the part relative to each other.
- Another factor that affects production rate is the wear of the electrodes. Because of the heat involved in the process, the tips of the electrodes gradually lose their shape and build up a carbon deposit which affects their electric resistance. Both of these effects reduce the quality of the welds made. Therefore, the electrodes must be periodically be dressed to remove the deposits and restore the desires shape.

SPOT WELDING



SPOT WELDING

Spot welding has traditionally been performed manually by either of two methods.

- The first method uses a spot-welding machine in which the parts are inserted between the pair of electrodes that are maintained in a fixed position. This method is normally used for relatively small parts that can be easily handled.
- The second method involves manipulating a portable spot-welding gun into position relative to the parts. The welding gun consists of the pair of electrodes and a frame to open and close the electrodes.
- In addition, large electrical cables are used to deliver the current to the electrodes from a control panel located near the workstation. The welding gun with cables attached is quite heavy and can easily exceed 100 lb in weight.

SPOT WELDING

SPOT WELDING

Requirements of Spot Welding Robots

- Relatively large robots: work volume, payload
- Positioning and orientation capability with sufficient DOF.
- Controller: memory capacity, storage of many programs

SPOT WELDING

Benefits of Using Spot Welding Robots

- **Improved product quality**

  Consistent welds, better repeatability compared to human operators

- **Improved operator safety**

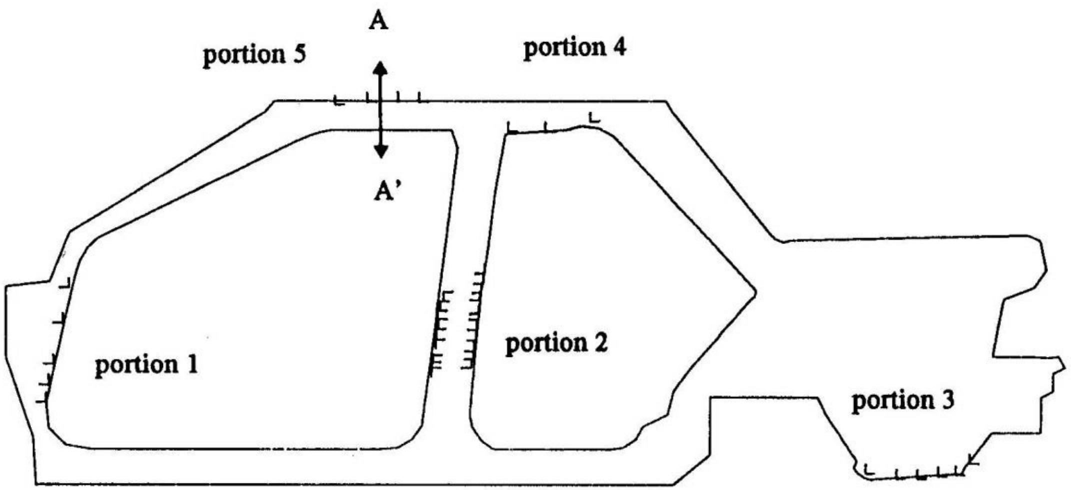
  Work hazards due to electrical shocks and burns

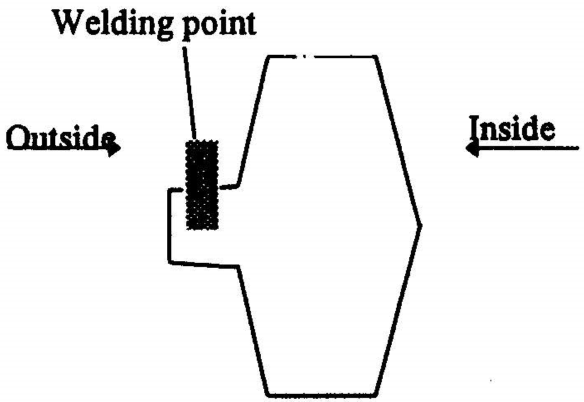
- **Better control over the production operation**

  Production scheduling and inventory control

Robotic Spot Welding Study 1

PROTON WIRA SIDE FRAME SPOT WELDING WORKCELL USING KUKA ROBOTS



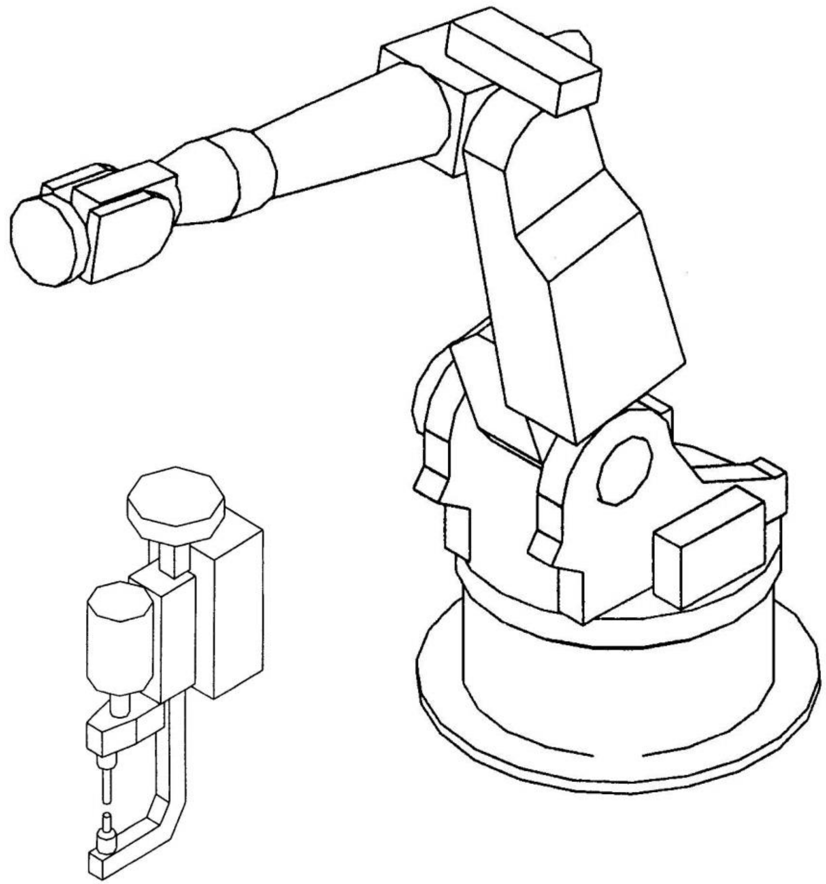


- Proton Wira side car frame
- 37 welding points

Robotic Spot Welding Study 1

PROTON WIRA SIDE FRAME SPOT WELDING WORKCELL USING KUKA ROBOTS

- KUKA IR761 robot: to study reachability of robot arm: 1350mm (normal) or 1550mm (extended) upper arm
- To study use of C-type or G-type welding gun

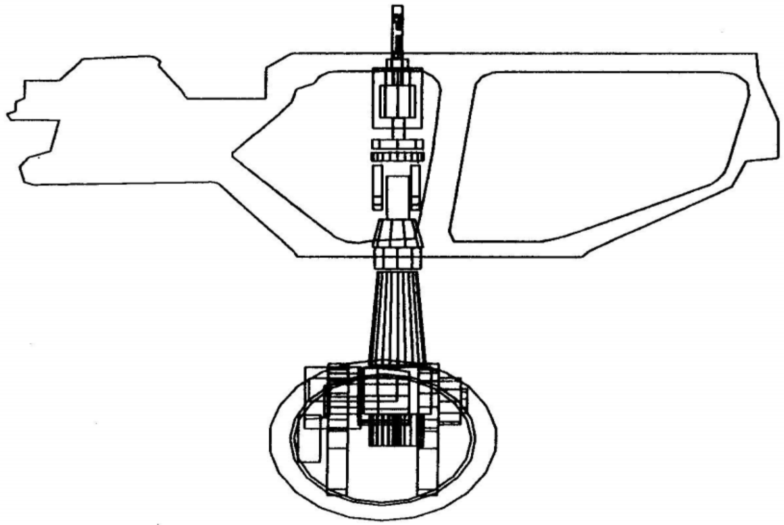


G-type welding gun

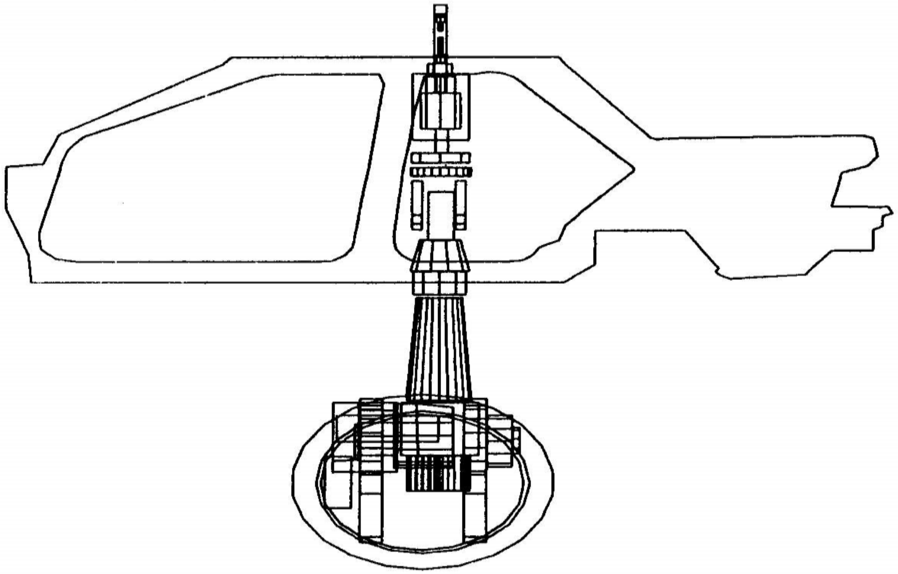

ceaweld.com
ceaweld.com

Robotic Spot Welding Study 1

PROTON WIRA SIDE FRAME SPOT WELDING WORKCELL USING KUKA ROBOTS



- Car frame orientation with bottom close to robot



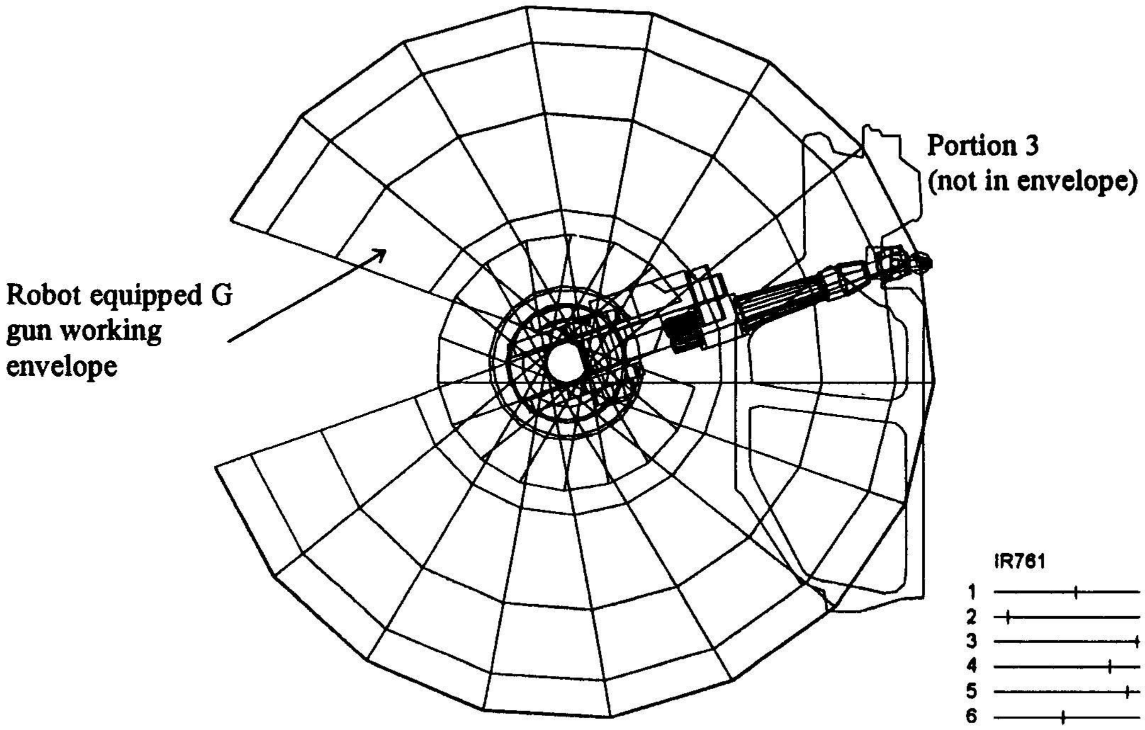
- Car frame orientation with roof close to robot

Robotic Spot Welding Study 1

PROTON WIRA SIDE FRAME SPOT WELDING WORKCELL USING KUKA ROBOTS

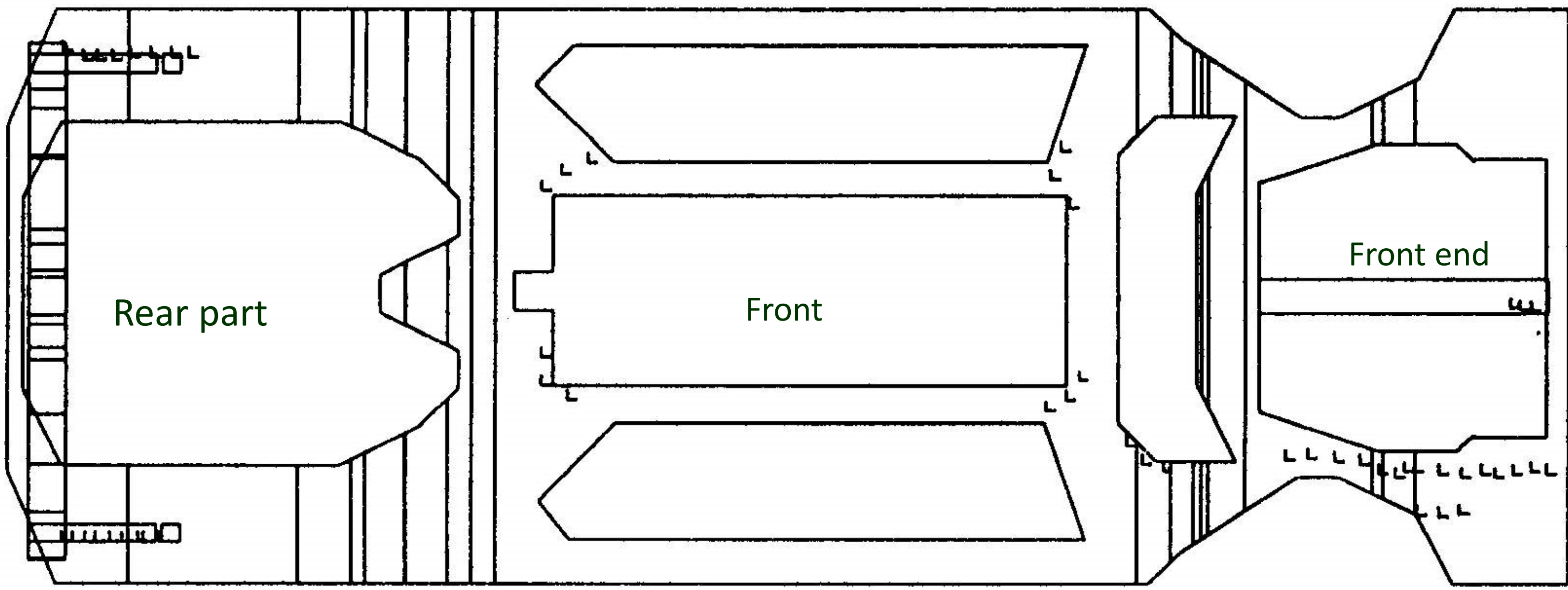
SUMMARY OF FINDINGS

- Cycle time of 64 secs was achieved (within specification of 69 secs)
- Use of KUKA IR761 with extended upper arm (1550mm)
- Use of G-type welding gun for accessibility
- Spot welds at 0.9 sec for each spot



Robotic Spot Welding Study 2

MULTI-ROBOTIC SPOT WELDING WORKCELL DESIGN AND CONTROL FOR PRODUCTION WIRA UNDER BODY ASSEMBLY



Objectives

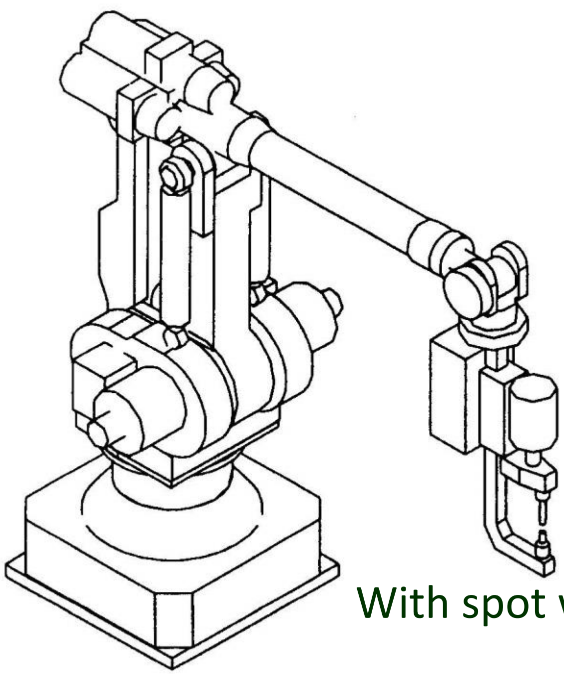
- Reduce cycle time from 100 seconds to 89 seconds.
- Propose robot path and teaching points.
- Reduce waiting time between robots

Robotic Spot Welding Study 2

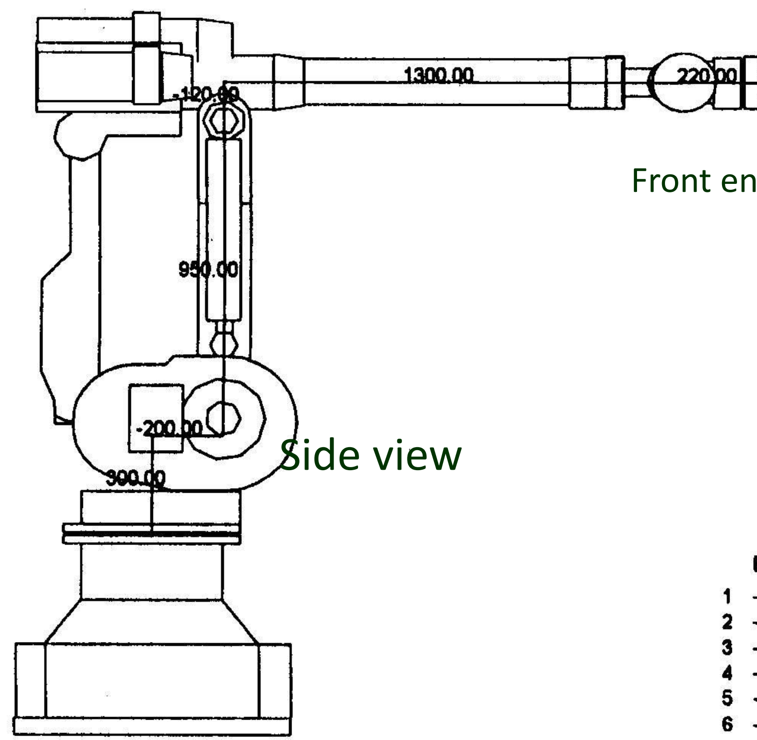
MULTI-ROBOTIC SPOT WELDING WORKCELL DESIGN AND CONTROL FOR PRODUCTION WIRA UNDER BODY ASSEMBLY

C:EX100.MOD

The Robots – Kawasaki EX100

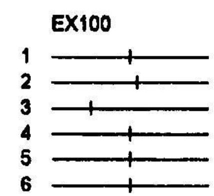


With spot welding gun



Front end

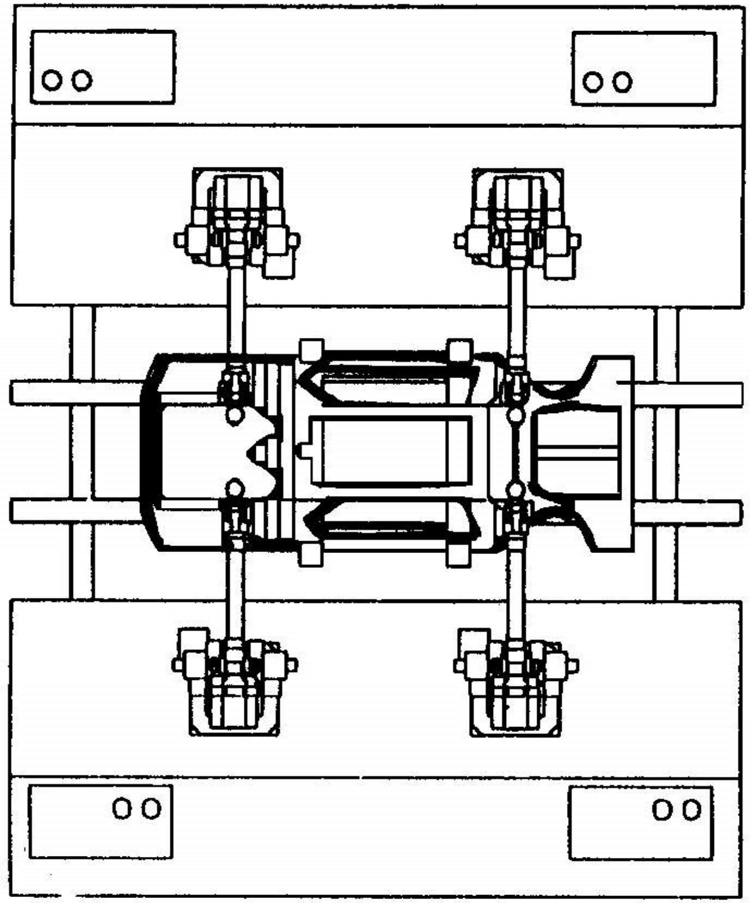
Side view



Robotic Spot Welding Study 2

MULTI-ROBOTIC SPOT WELDING WORKCELL DESIGN AND CONTROL FOR PRODUCTION WIRA UNDER BODY ASSEMBLY

Top view

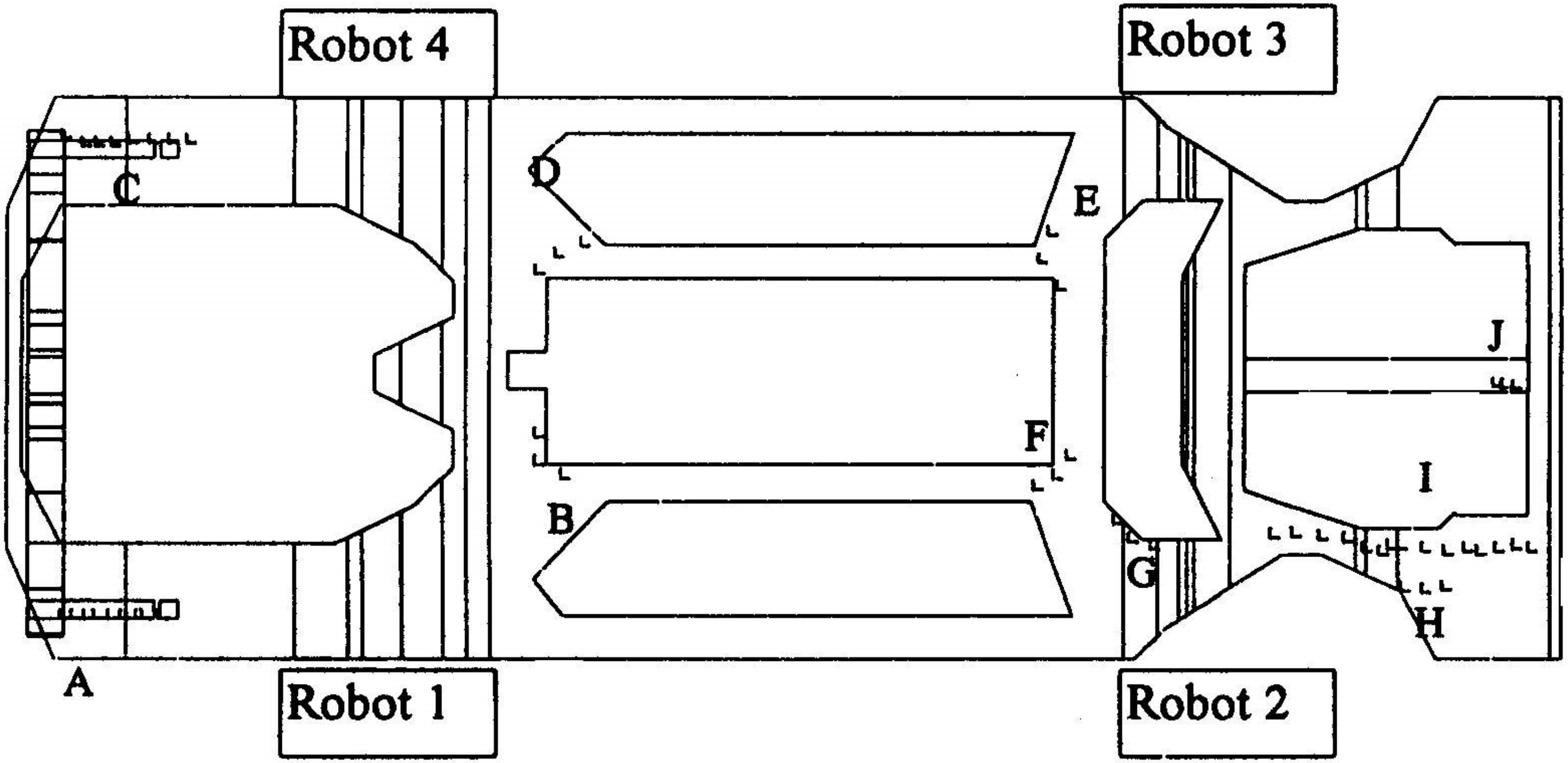


The Work Cell

Four-robot work cell

Robotic Spot Welding Study 2

MULTI-ROBOTIC SPOT WELDING WORKCELL DESIGN AND CONTROL FOR PRODUCTION WIRA UNDER BODY ASSEMBLY



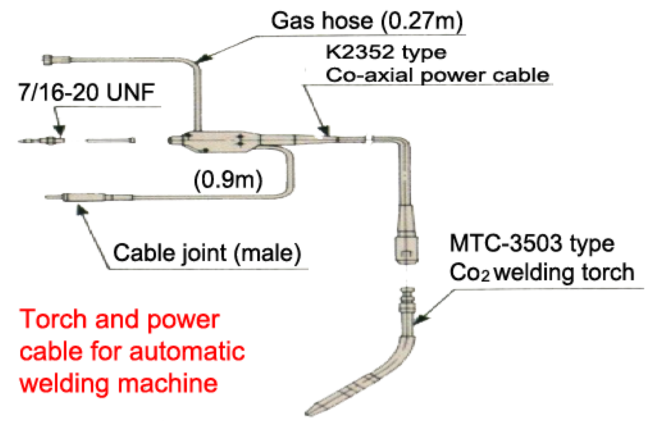
The Work Cell 87 welding spots Welding spots divided into portions A,B, … J

ARC WELDING

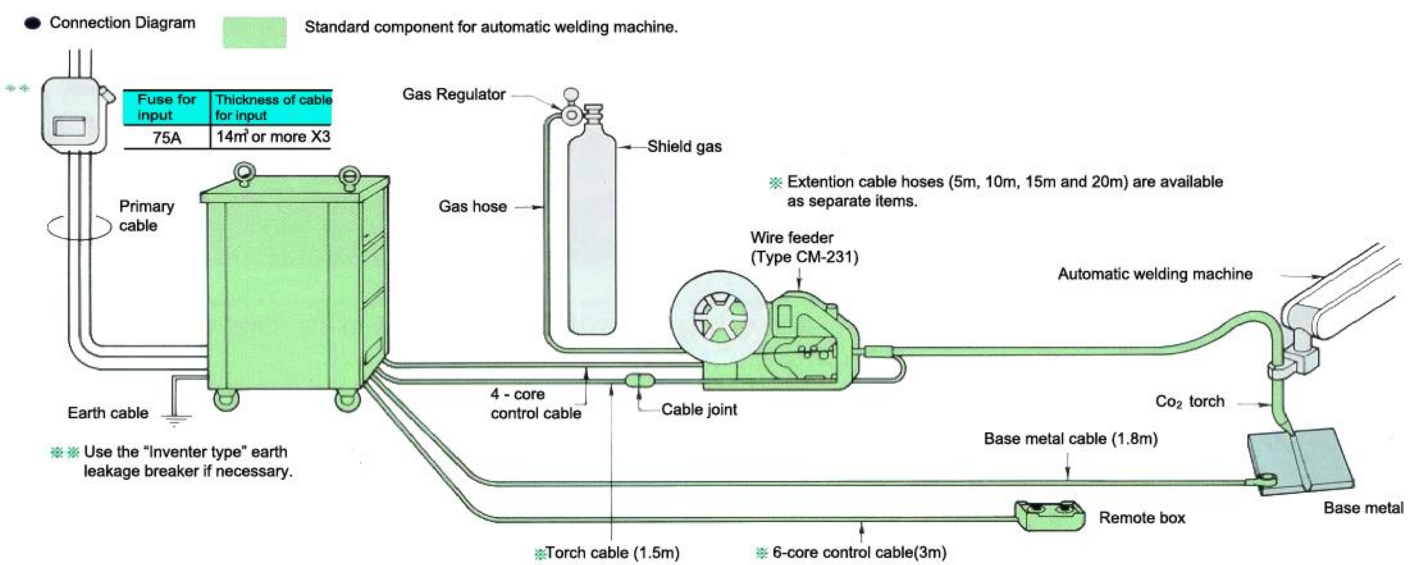
Arc Welding Processes

SYSTEM OVERVIEW OF WELDING SET-UP

The diagram below is a system overview of a typical welding set-up. The role of the robot arm is to provide mobility for the welding gun. The welding process is controlled by the welding transformer unit, gas supply unit and auto-wire feed unit. Details of the typical set-up for the different technologies involved welding applications are given later.



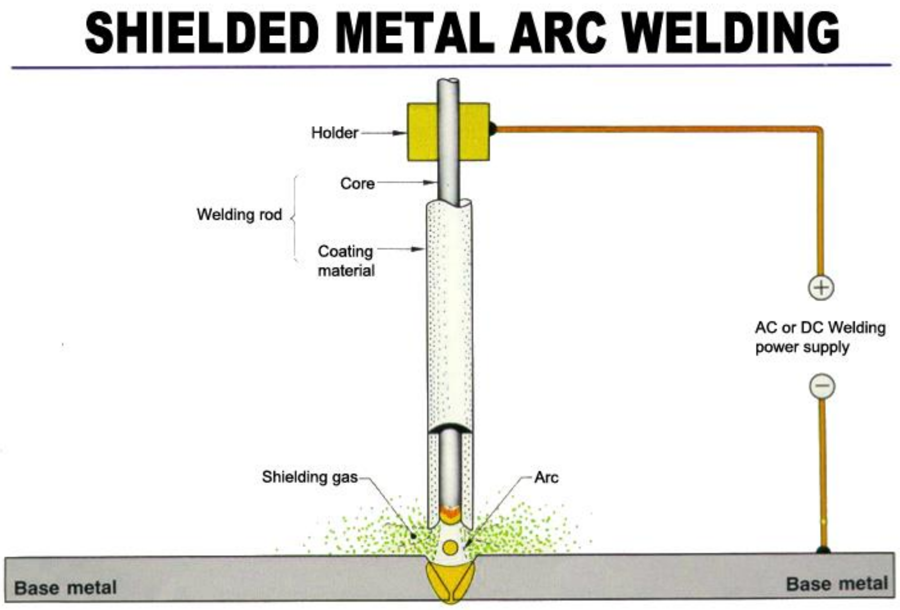
Torch and power cable for automatic welding machine



Inverter Auto 350TB can also be used as a manual semi-automatic welding unit for high quality and cost efficient welding

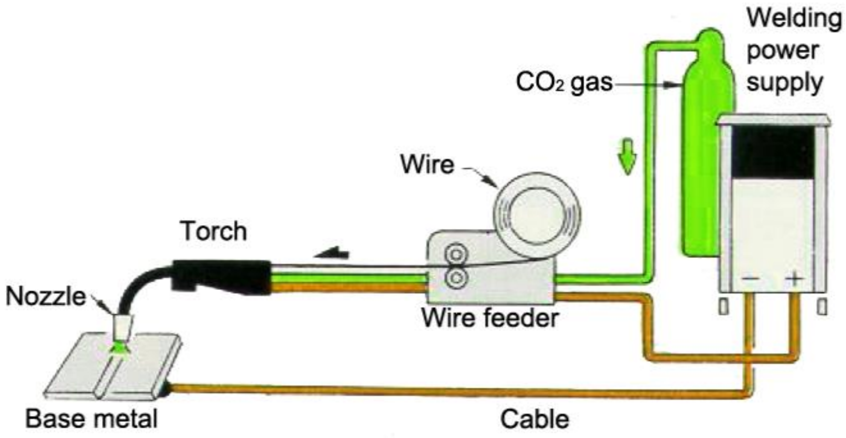
ARC WELDING

- With the shielded metal-arc welding, an arc welding electrode consisting of metal rod of about 1.6 to 8 mm (1/16 to 5/16 in) in diameter and coating material (organic or inorganic material or mixture) is held by holder.
- AC and DC voltage is impressed between the work (called base metal) and the covered electrode to strike arc for welding.



ARC WELDING

- Under the influence of high temperature of arc, the coating material is decomposed into gas or slag, thereby protecting the molten metal from the atmosphere and preventing oxidation, nitration and, in addition, serving to stabilize the arc.

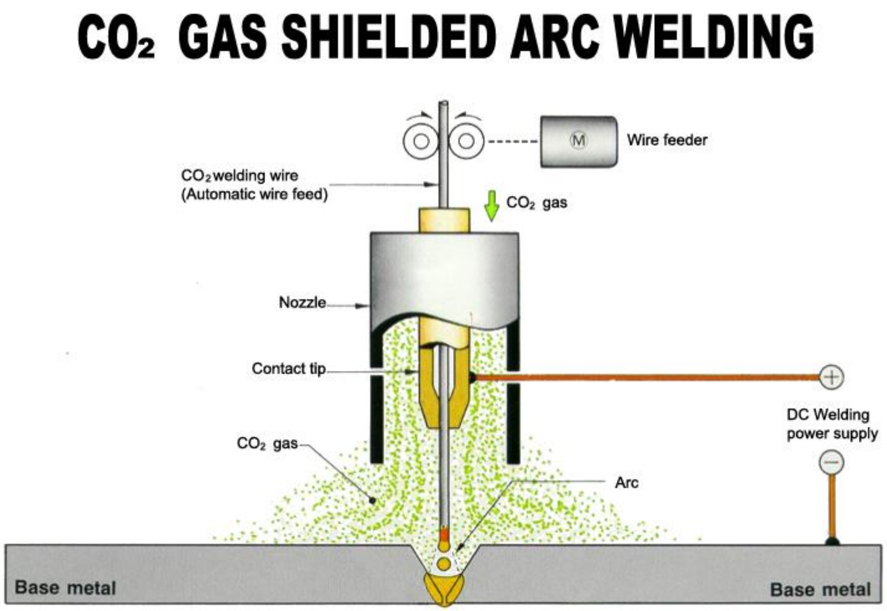


Bead shape

Material : Mild steel

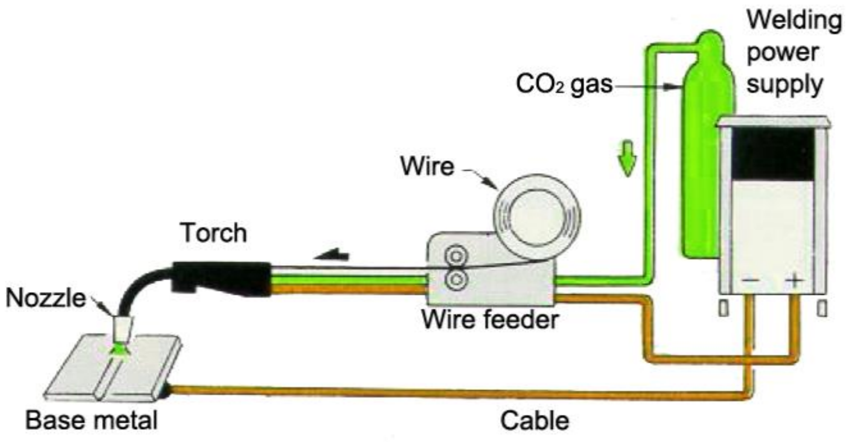
ARC WELDING

- In this welding, fine coiled welding wire (0.8-1.6 mmϕ (1/32-1/16 inϕ)) is used in place of manual welding rod.
- The welding wire is fed to the welding torch through the wire feed roll. This wire is electrified through the torch tip, due to which arc is struck between the base metal and the wire, and both the base metal and the wire are continuously molten by arc heat.
- Since CO2 gas is used to protect the arc part from air, this welding method is named CO2 gas-shielded are welding.



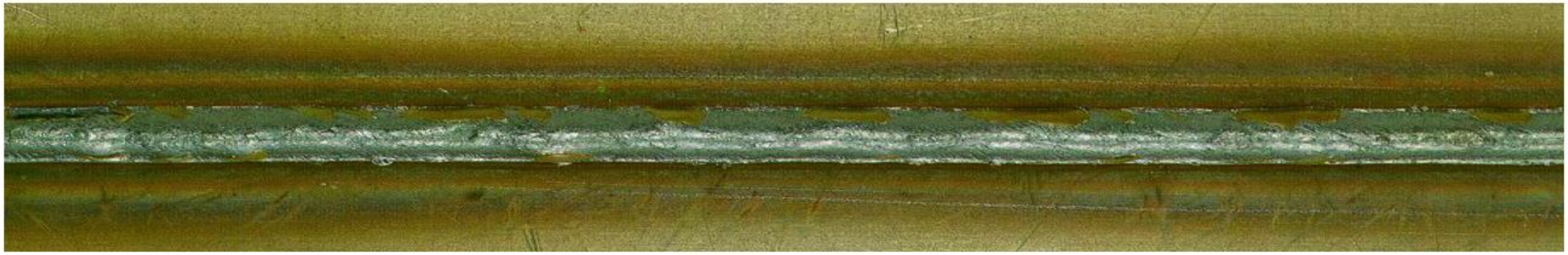
ARC WELDING

- Perfect arc start, almost spatter free CO2 welding.



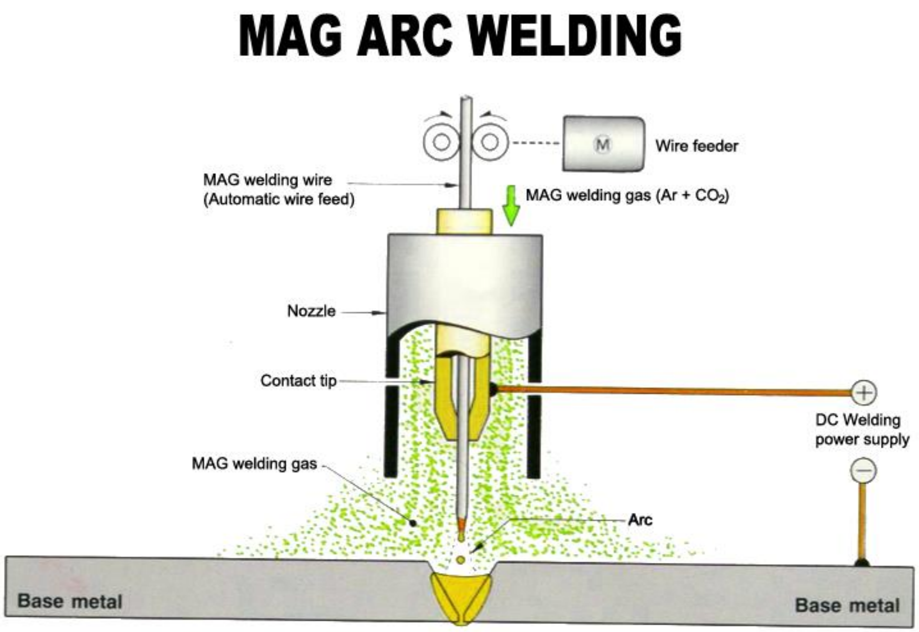
Bead shape

Material : Mild steel



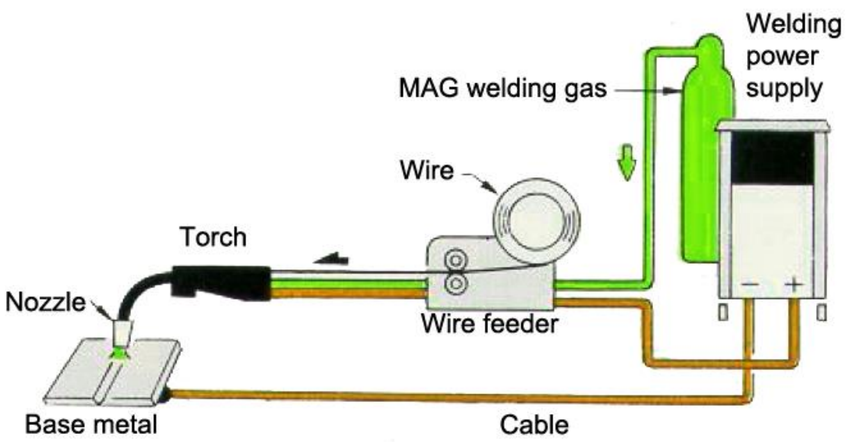
ARC WELDING

- The welding process using mixed gas of Argon and CO2 is called MAG (Metal Active Gas) arc welding.
- MAG arc welding is similar to CO2 gas shielded arc welding in terms of similar basic power supply.
- Difference between MAG and CO2 gas shielded arc welding is only using gas and wire.



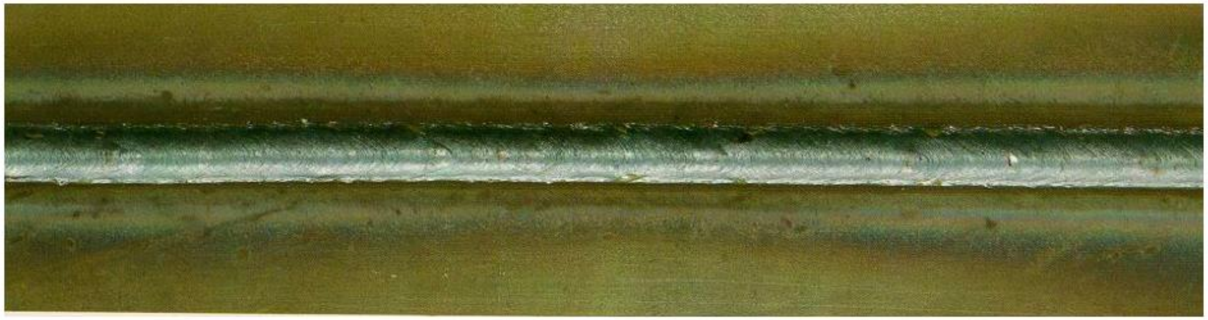
ARC WELDING

- Upgrading of quality without spatter and great reduction of post processes by MAG pulse high speed welding



Bead shape

Material : Mild steel



ARC WELDING

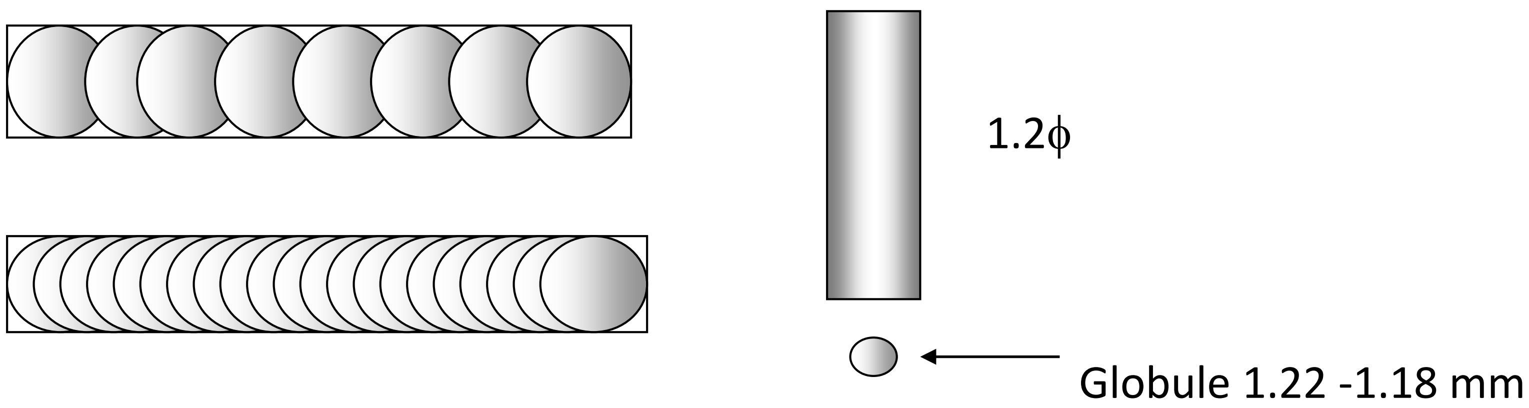
CO_2 / MAG gas mixtures :

Inert: Ar		CO_2 : active
0%	+	100% -------- Spatters appear
10%	+	90%
50%	+	50% -------- Normally
75%	+	25% -------- USA
80%	+	20% -------- Current practice in Japan
90%	+	10%
100%	+	0% --------- Arc not stable

Argon makes the bead sharp and narrow reduces globule size, less spatter

ARC WELDING

The argon forces the bead ball to be small. Hence, less spatter.

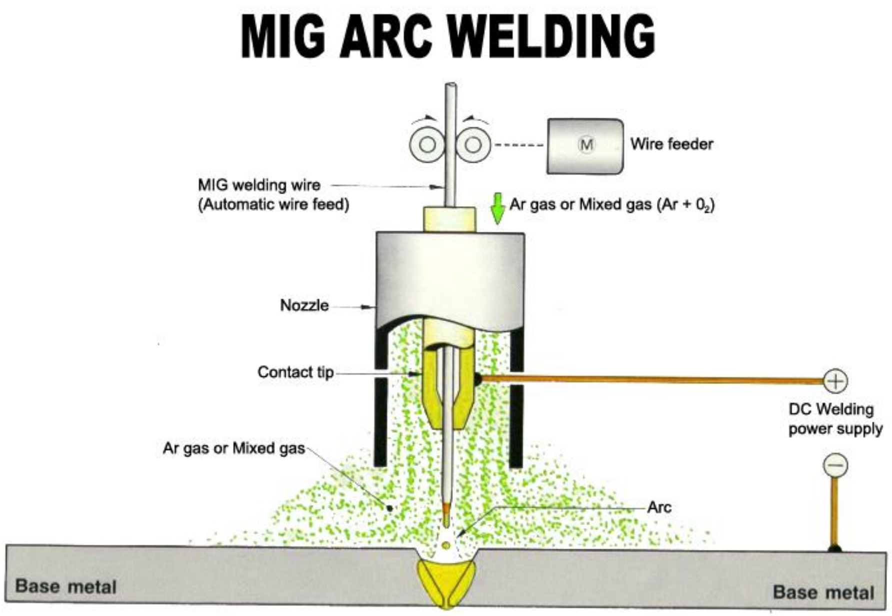


MAG/MIG spatter is easy to remix, CO2 is not.

ARC WELDING

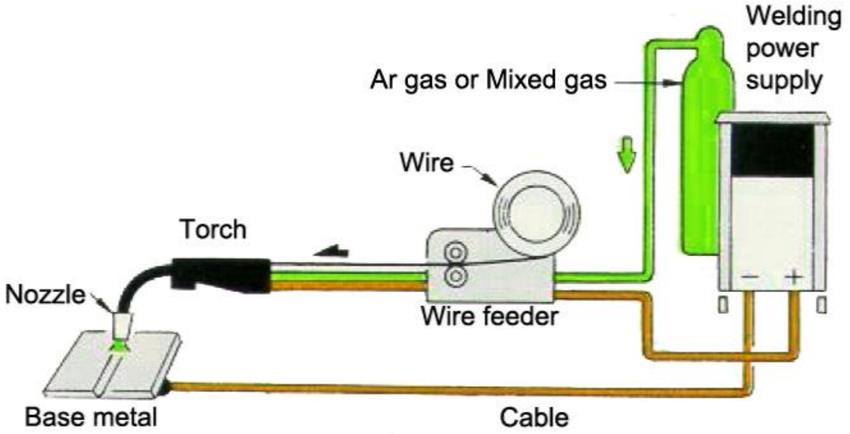
- MIG (Metal Inert Gas) welding process is similar to CO2 gas shielded arc welding and MAG arc welding in the principle.

- Usually Aluminum and Stainless steel welding is popular as MIG arc welding, although various metal, copper, high-tension steel, Monel, Inconel etc. can be welded by this method.



ARC WELDING

- Unique synchro-pulse and many other developments make this MIG-pulse welder superior



Bead shape

Material : Aluminum

ARC WELDING

Metal Inert Gas: MIG Welding

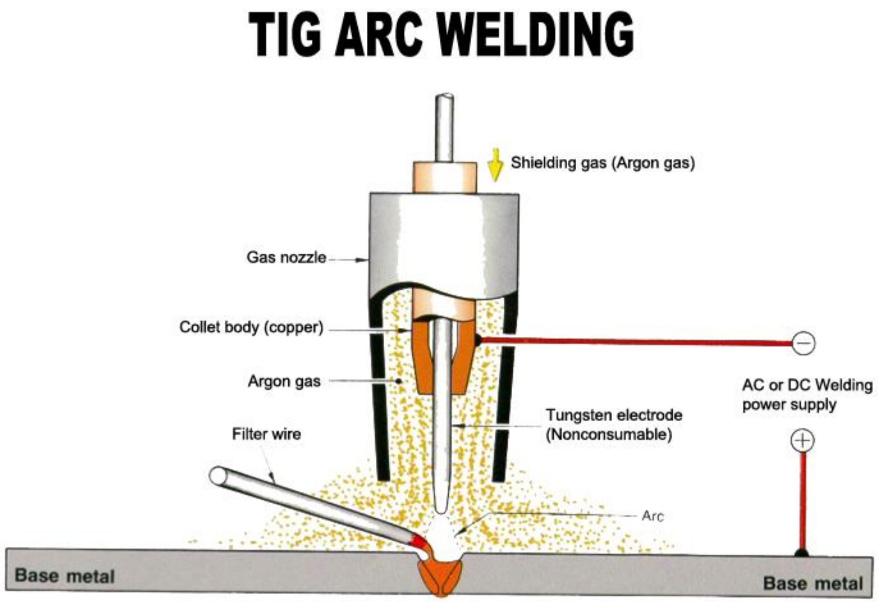
Argon: cheaper, widely used
Helium: previously popular

Xenon: expensive
Neon: expensive

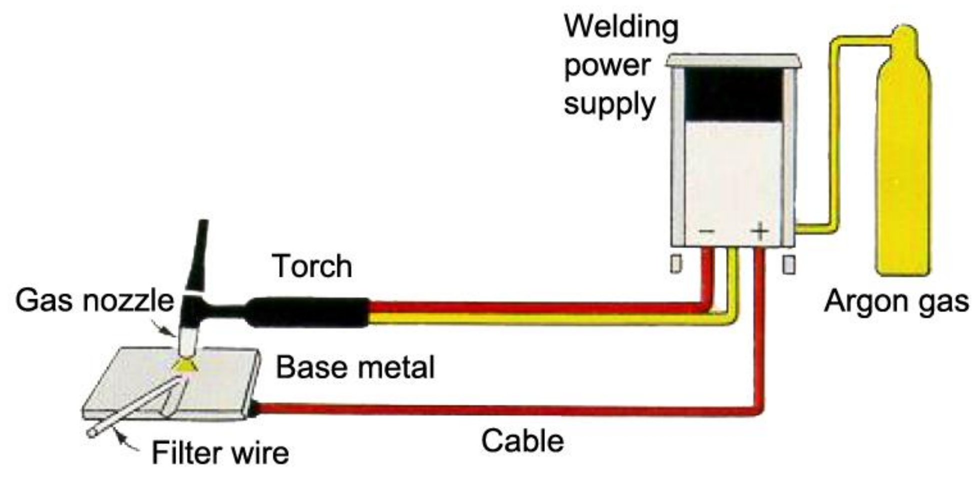
Used for aluminium, alloy, stainless steel, copper

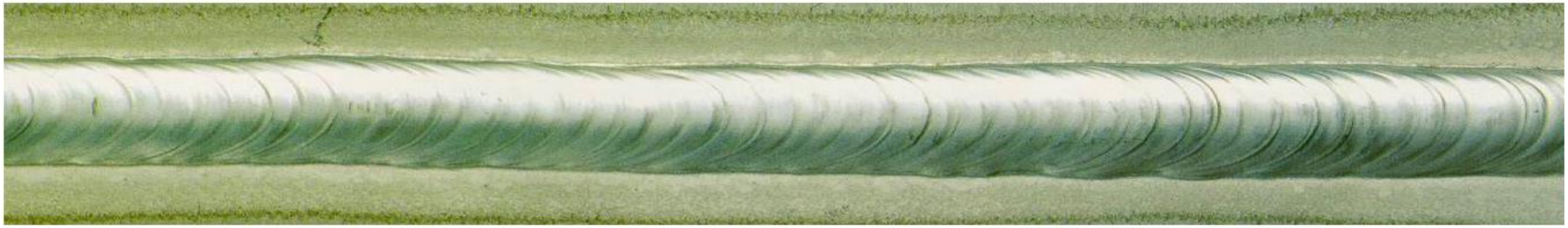
ARC WELDING

- The gas tungsten arc welding (GTAW) process is some times known as “TIG” (tungsten inert gas) welding.
- The inert gases (argon and helium) are mainly used for gas tungsten arc welding.
- Since argon gas is extensively used as shielding gas, this welding method is generally called argon arc (TIG) welding.
- In this welding tungsten electrode (nonconsumable) is used and filler wire may or may not be added.
- The electric arc is produced by passing current through the ionized inert shielding gas.



ARC WELDING


Welding
power
supply
Torch
Gas nozzle
Argon gas
Base metal
Cable
Filter wire


Bead shape
Material : Aluminium

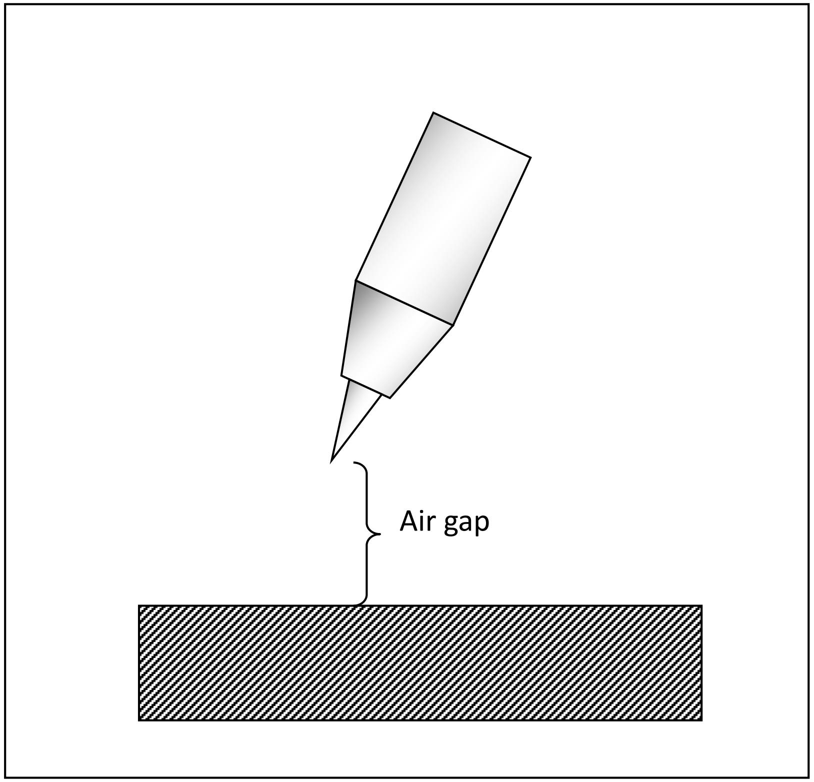
ARC WELDING

Tungsten Inert Gas: TIG, GTAW.

High Freq. = 2MHz (1.8 MHz)
Typical Voltage = 6KV.
1mm air gap needs 1KV

Practically, 3 - 4mm
Can weld any kind of metal.
High quality welding
- Air planes
- Satellites
- Chassis

* Very beautiful bead shape



ARC WELDING

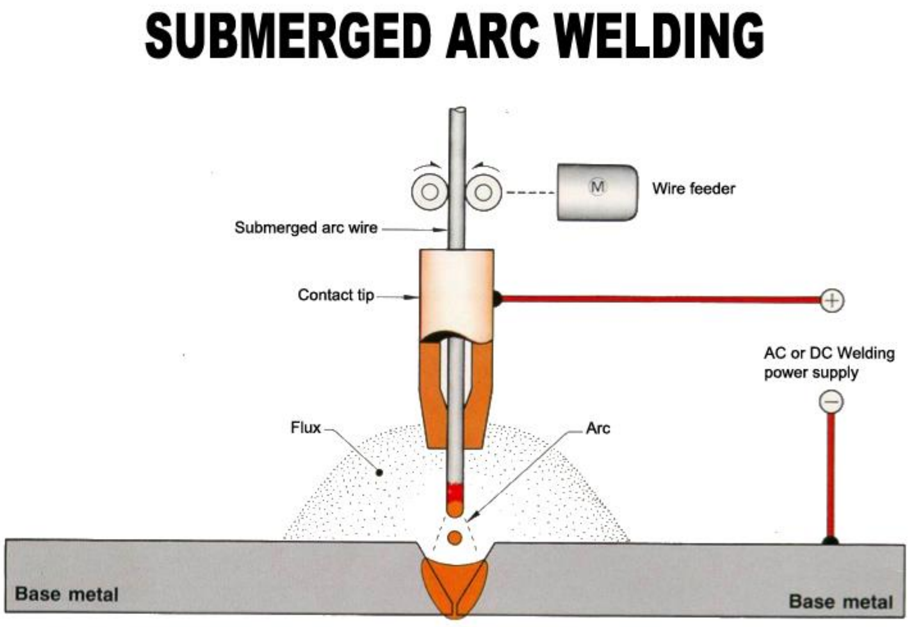
Drawback is slow speed for Tungsten Inert Gas TIG, GTAW.

Brief comparison of welding speeds

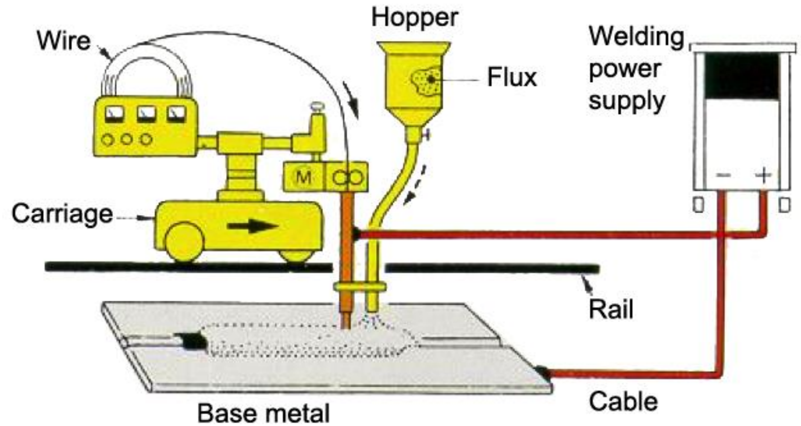
TIG: 10-15 cm/min
CO_2: 40-55 cm/min (semi-auto)
MIG: 50-65 cm/min (semi-auto)

ARC WELDING

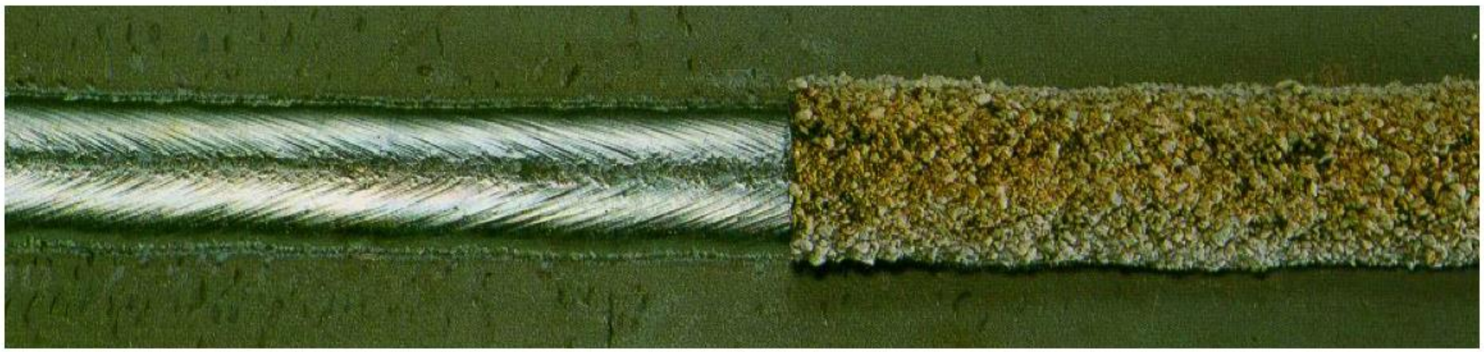
- With the submerged arc welding, flux is scattered on the base metal in advance, and a bare welding wire is fed into the flux layer to perform welding.
- The welding wire is fed automatically by the feed motor, and the wire and the base metal are fused by the heat of arc struck between them to form weld point.
- Being also fused by arc heat, the flux becomes slag which covers arc and molten metal to protect them from atmosphere and effect dioxidation refining due to chemical reaction with molten metal.



ARC WELDING



Bead shape **Material : Mild steel**



ARC WELDING

Wire sizes

CO2, MAG,others (mm)

0.4
0.6
0.8
0.9
1.0
1.2 Common
1.4
1.6 Common

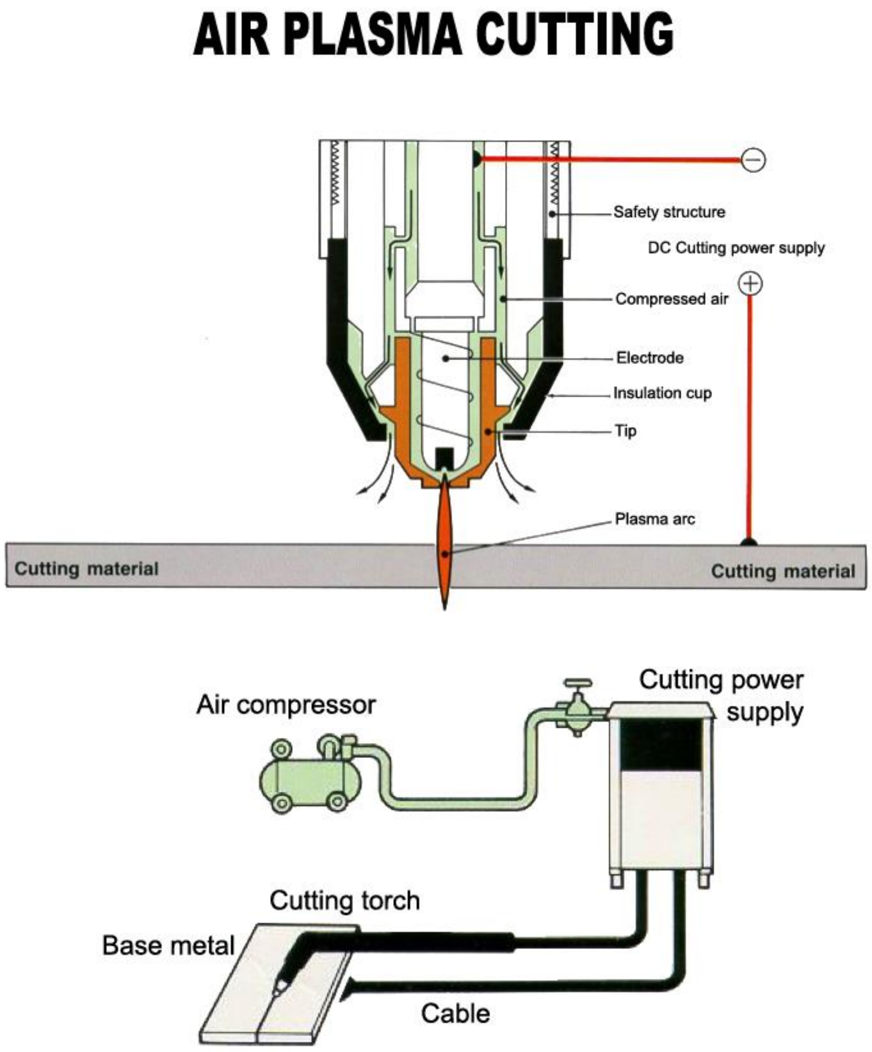
} 350 – 500 Amp machines

Submerged (mm)

2.0
2.3
3.2
4.0
4.8 Common
6.4 Common
8.0

} 1000-1500 Amp machines

ARC WELDING



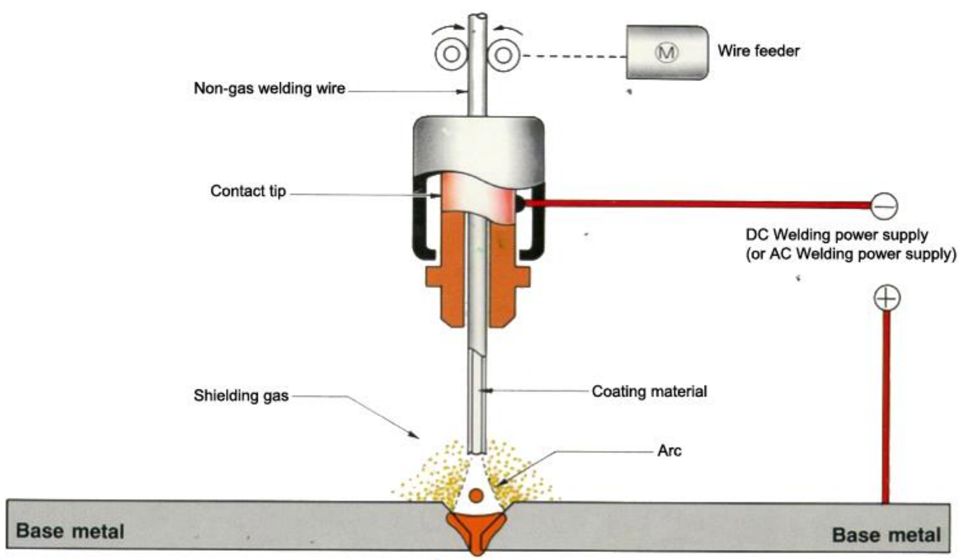
- Air plasma cutting is used compressed air and high velocity jet of compressed air gas emitted from the shielded gas cup blows away the molten metal to form a kerf.
- Various types of metal, including mild steel, galvanized sheet steel and painted steel as well as stainless steel, aluminium and copper can be cut. Since compressed air is extensively used as cutting gas and cooling gas, this method is called Air plasma cutting.

ARC WELDING

- Non-gas welding wire (self shielded wire) is automatically fed by wire feeding motor and wire itself is consisted of coating material inside the wire. Therefore this process sometimes called as self shielded arc welding.

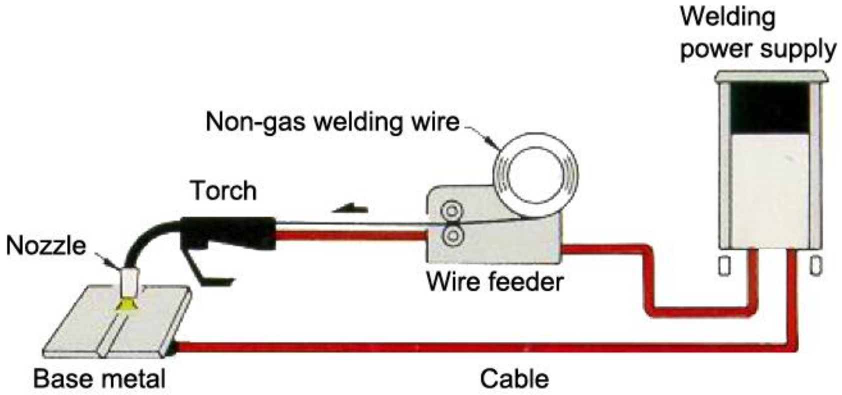
- Since it is unnecessary to use conventional shielding gas such as CO2 gas or MAG gas, this welding method is used especially for outdoor welding.

NON - GAS SHIELDING ARC WELDING



ARC WELDING

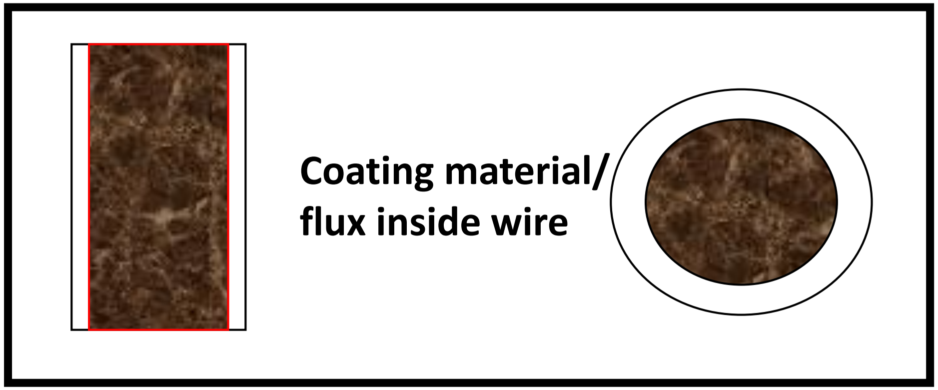
- Unnecessary to protect against the wind, therefore suitable for outdoor welding
- Beautiful finish and high quality welding using fine sized non gas welding wire.



ARC WELDING

Self-Shielded (Non-Gas)

Coating material/ flux inside wire



Why use this?

For CO_2, /MAG shield, if wind speed > 2m/s, need protection.

In some cases, can erect partition for protection of shielding.

Outdoors cannot put partition.

Therefore Use NON-GAS SHIELDING

Self-shield Arc for up to 15m/s wind (small typhoon)

ARC WELDING CONTROLLER

Controller Technologies:

Thyristor: (SCR)

50Hz, sampling

Shannon's Sampling Theory

1/50 = 0.02 second

Control Freq. : 50 x 6

Sampling: 1/300 sec

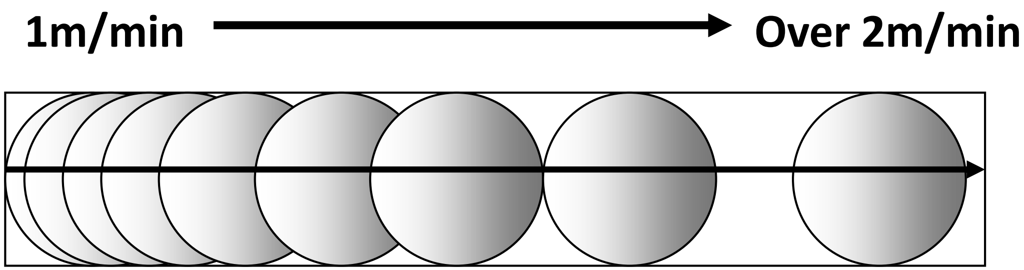
Inverter:

50 kHz.

Sampling, 1/50,000 sec = 0.00002 second

* Hence there is an Inverter **"War"** among manufacturer for high speed welding.

ARC WELDING CONTROLLER



Comparison between thyristor and inverter

Speed	Thyristor	Inverter
1m/min	OK	OK
2m/min	X	OK
5m/min	X	OK

Why is this significant ? Typical high speed applications e.g. in car manufacturing industry welding speed is 2-2.5m/min

THEREFORE CANNOT USE THYRISTORS

ARC WELDING CONTROLLER

Metal Transfer Mode

- Short arc metal transfer

  - thin plate

  - for vertical, horizontal, overhead weldings

  - CO_2, MAG < 200A

- Globule arc metal transfer

  - high current > 200A

  - Not for overhead welding

  - CO_2/MAG welding

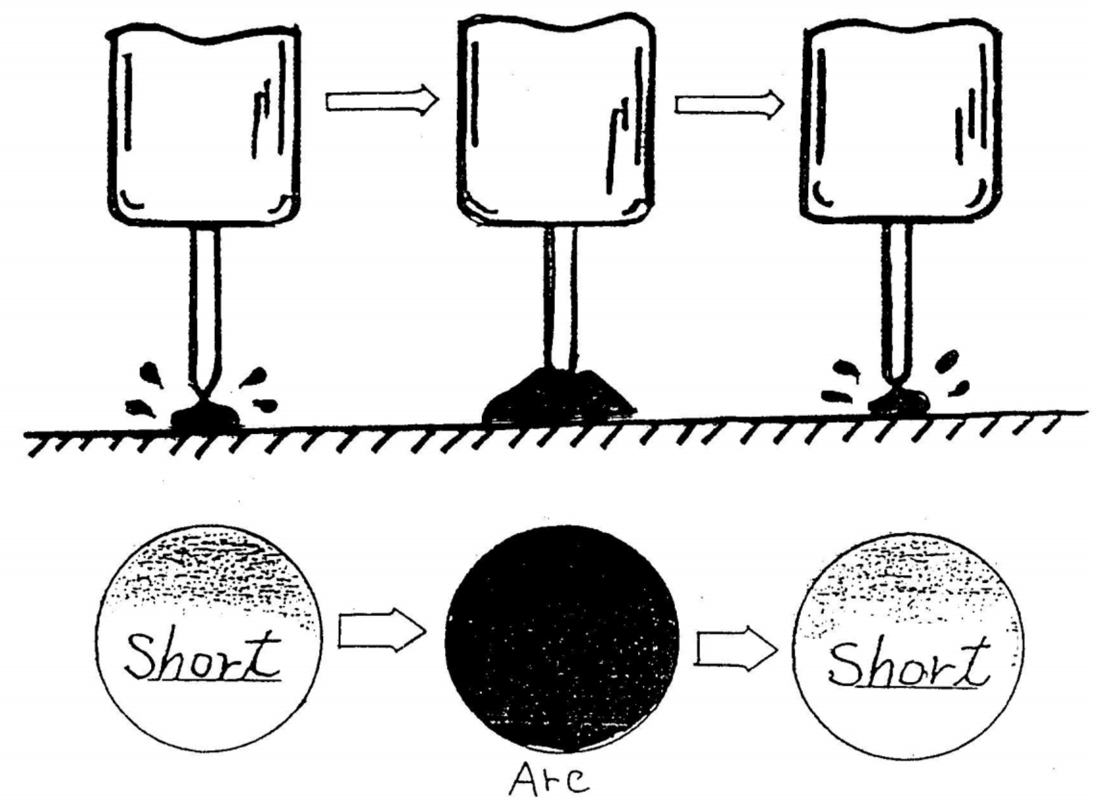
- Spray arc metal transfer

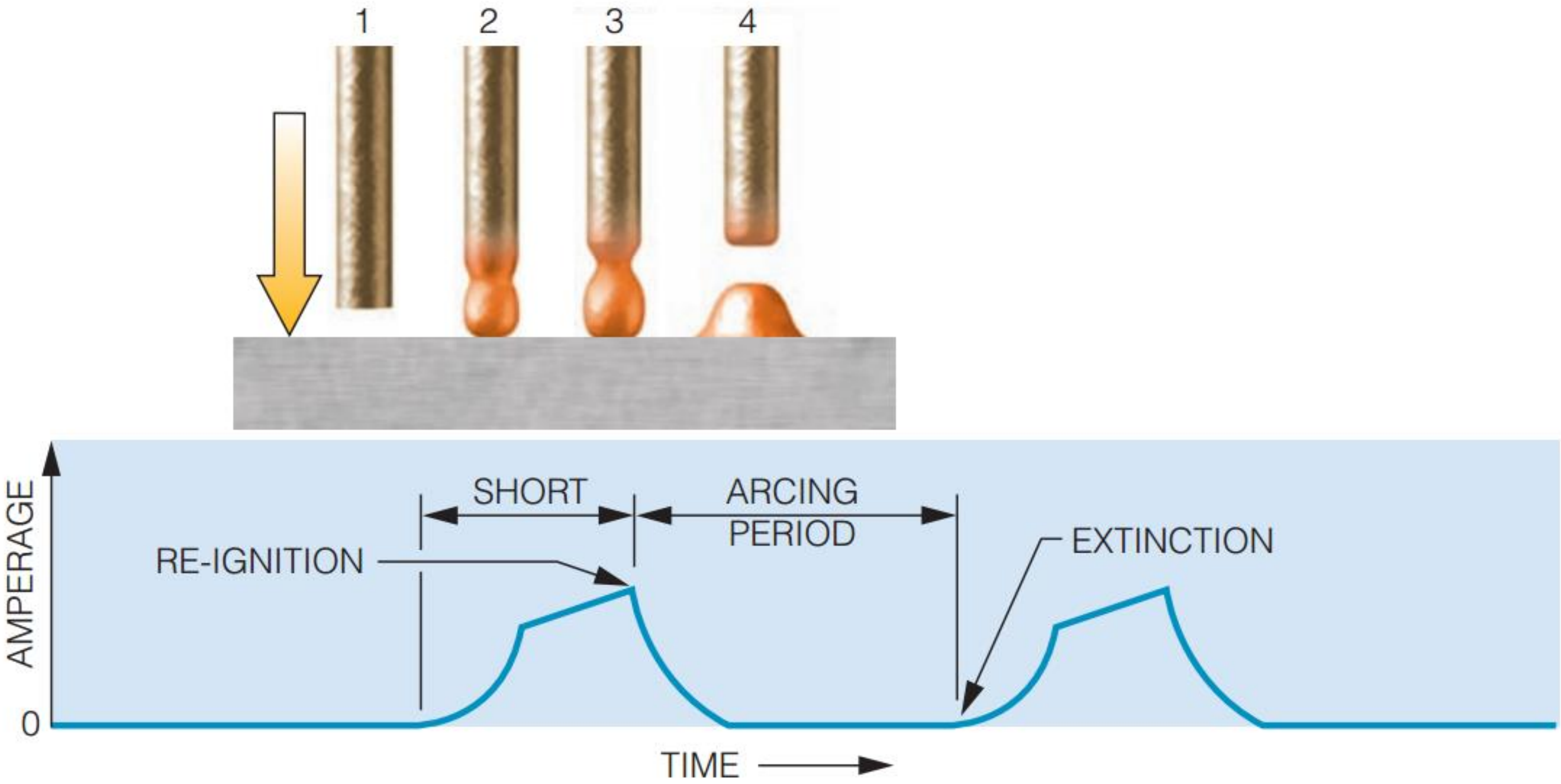
  - MAG (for deep welding penetration)

  - not for overhead welding

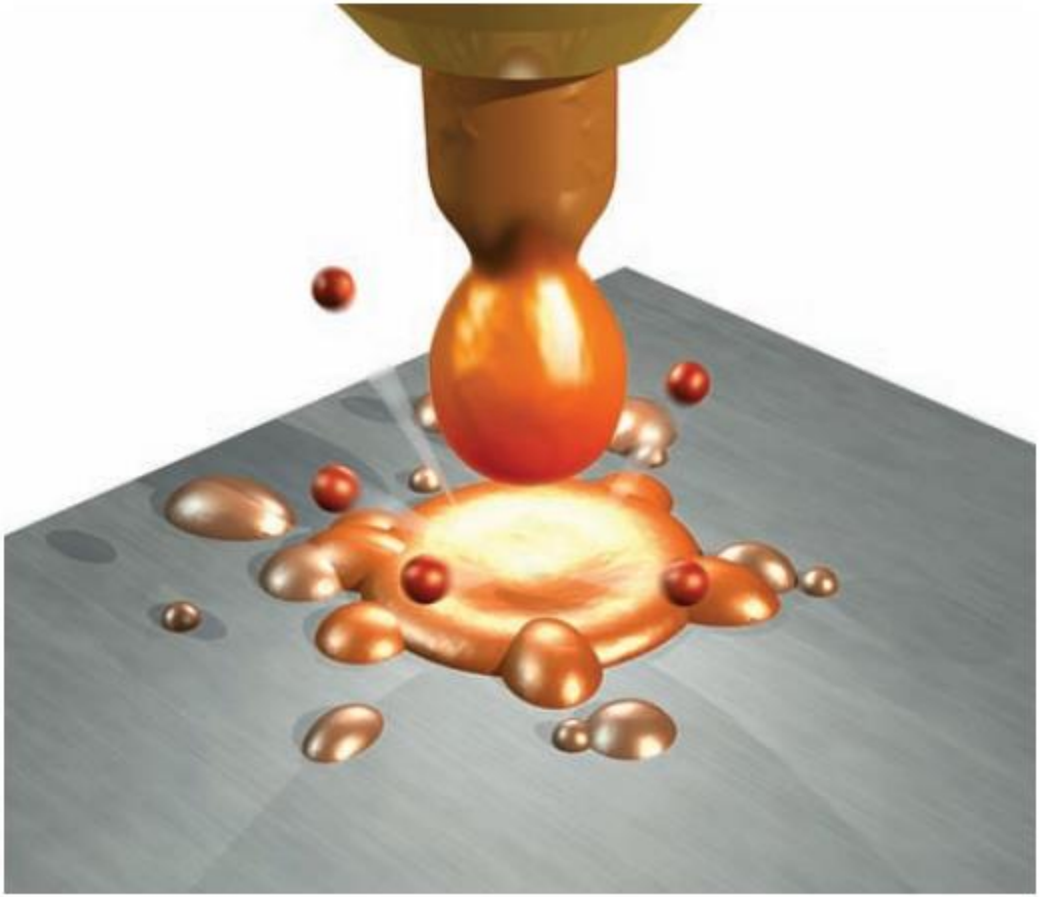
ARC WELDING CONTROLLER

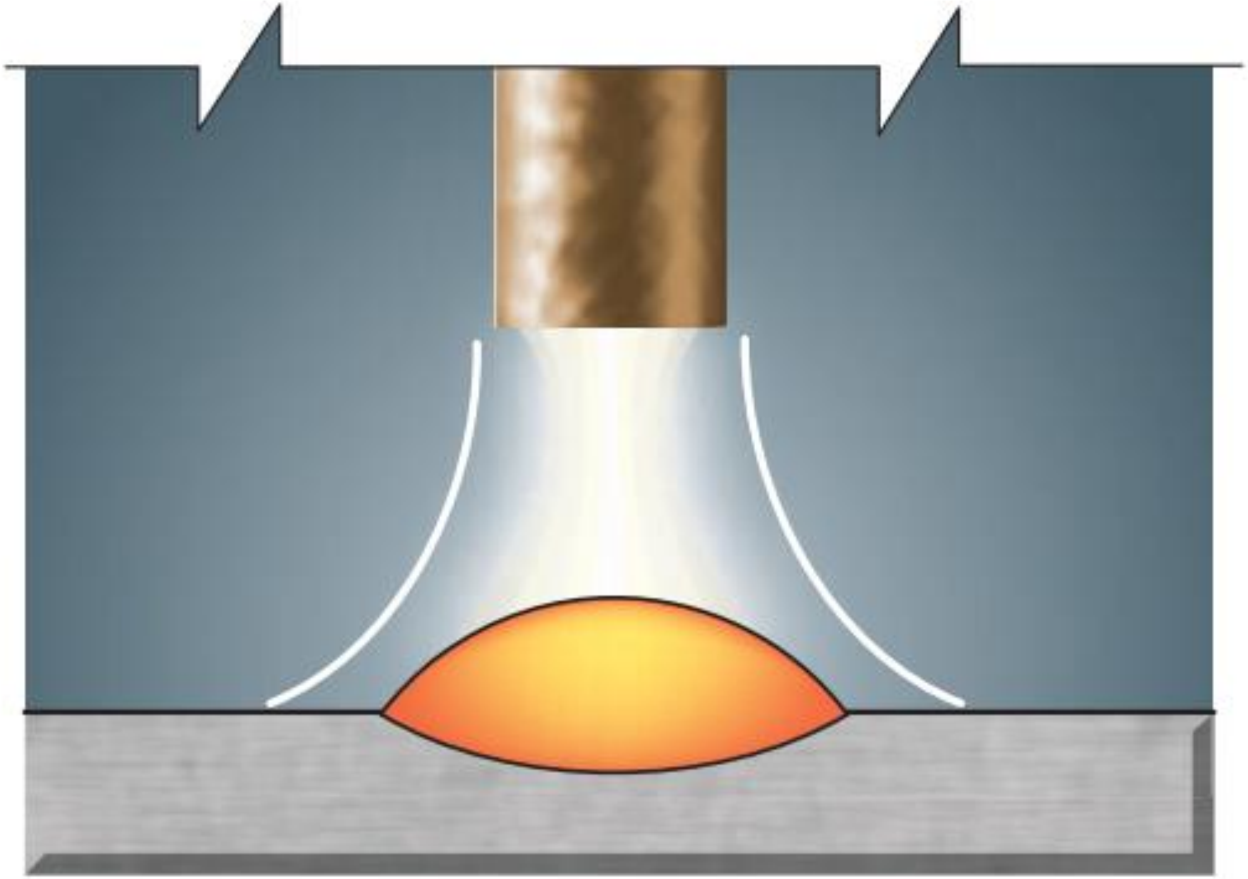
Arc Phenomena

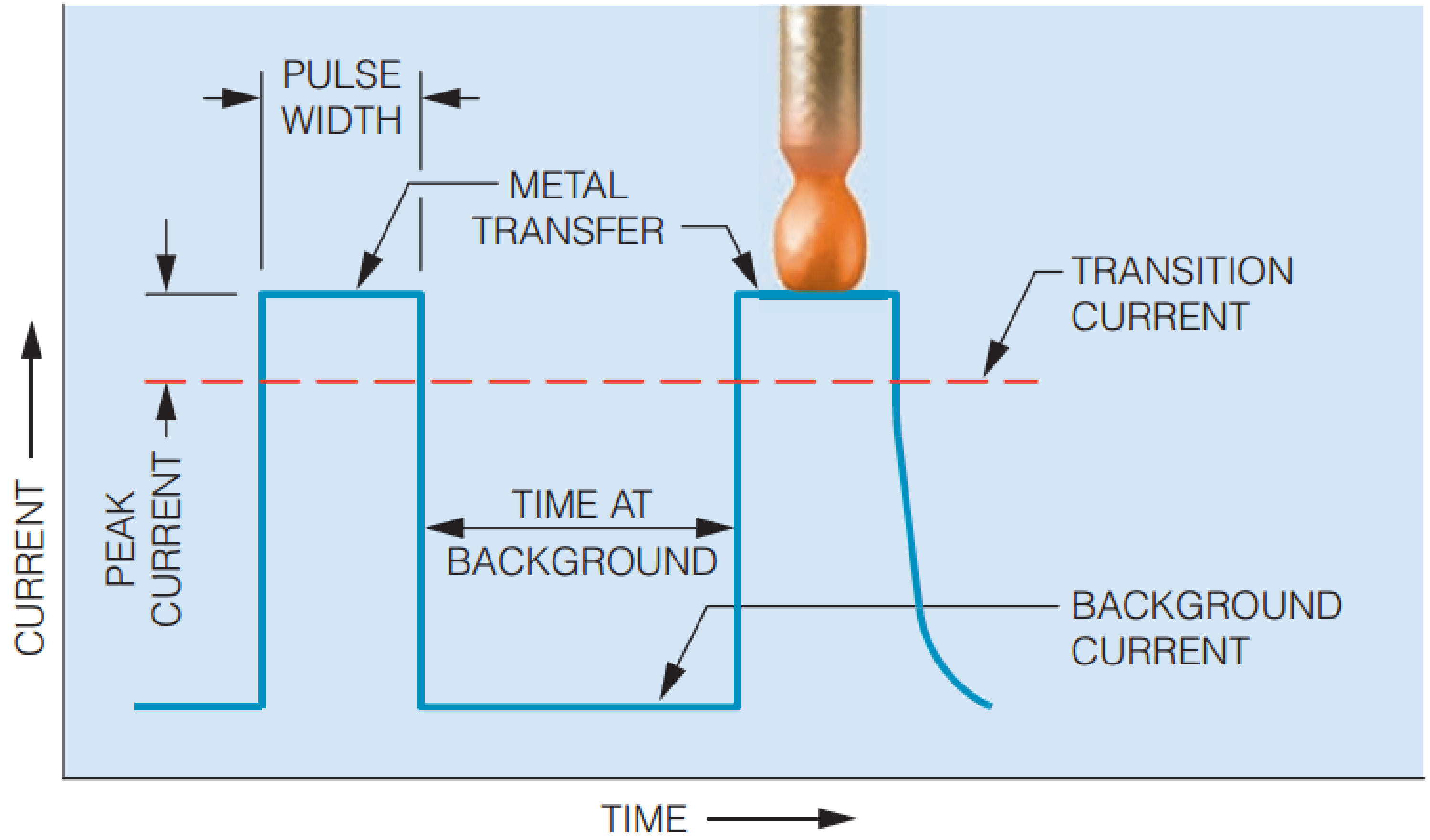


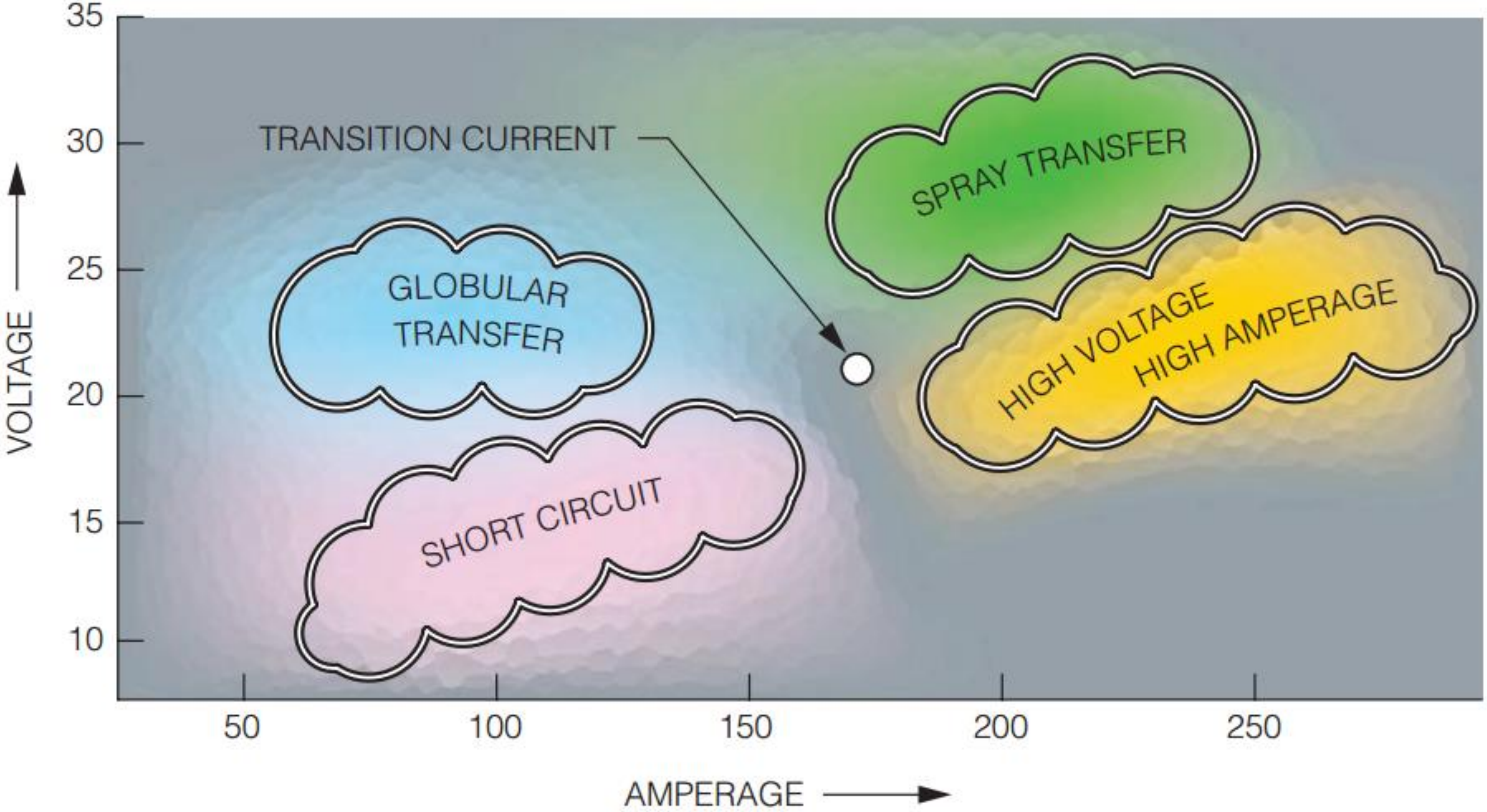

1
2
3
4
AMPERAGE
0
SHORT
ARCING
PERIOD
RE-IGNITION
EXTINCTION
TIME

1. At this step, the trigger is pressed on the welding gun, and the wire feeds.
2. The electrode contacts the work, voltage drops, and amperage increases.
3. Magnetic forces pinch the electrode while the amperage peaks and voltage increases.
4. The electrode melts off, and the arc opens. There is a separation of weld deposit from electrode, and the open arc period begins. The arc length increases, and the weld pool becomes more fluid and wets out to the base metal.





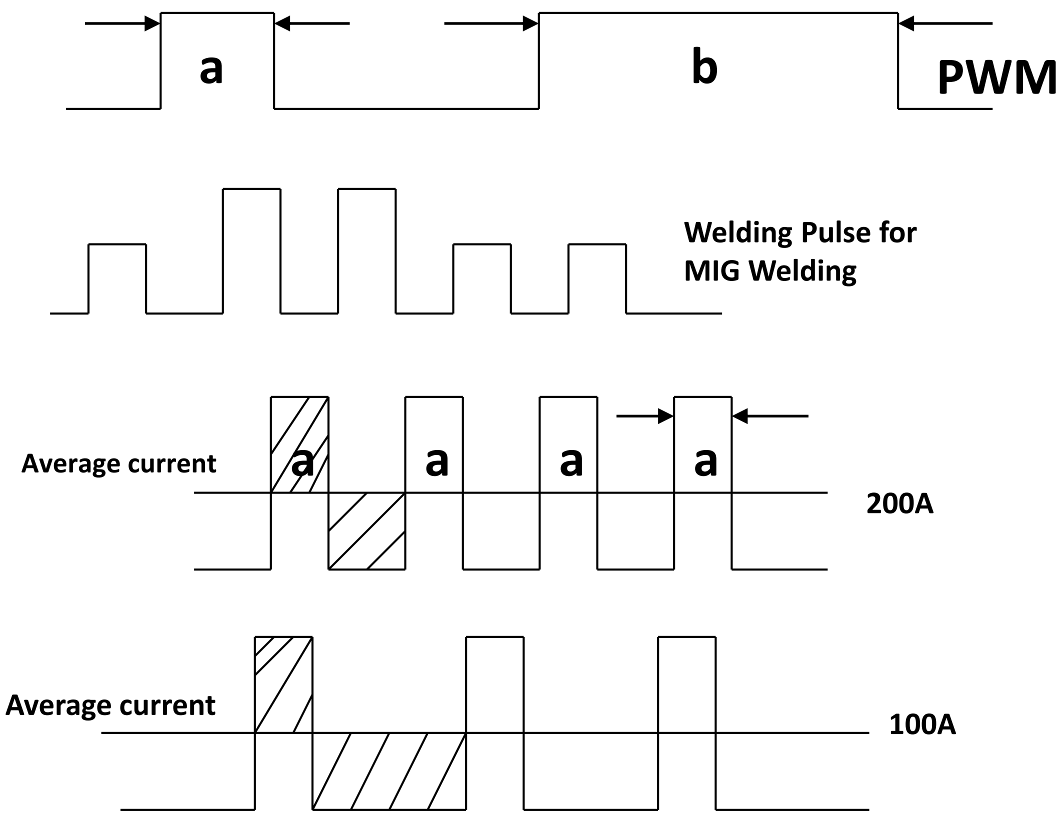

PULSE WIDTH
METAL TRANSFER
TRANSITION CURRENT
PEAK CURRENT
CURRENT
TIME AT BACKGROUND
BACKGROUND CURRENT
TIME


35
30
25
20
15
10
VOLTAGE
TRANSITION CURRENT
GLOBULAR TRANSFER
SHORT CIRCUIT
SPRAY TRANSFER
HIGH VOLTAGE
HIGH AMPERAGE
50
100
150
200
250
AMPERAGE

ARC WELDING CONTROLLER

Many engineers consider the welding controller (welding transformer) as the most important part of a welding system.

WHY ?



When welding current is high, arc noise is high

When welding current is low, arc noise is low

One unit pulse makes one globule

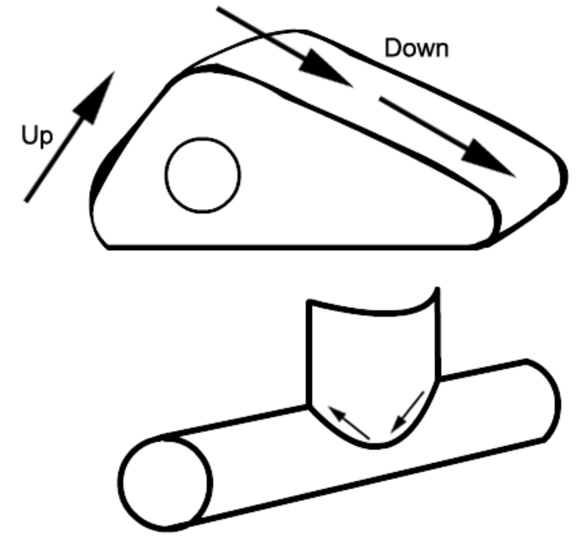
ARC WELDING CONTROLLER

Therefore the higher is the controller frequency, the faster is the welding speed.

Hence, inverter technology gives the faster speed.

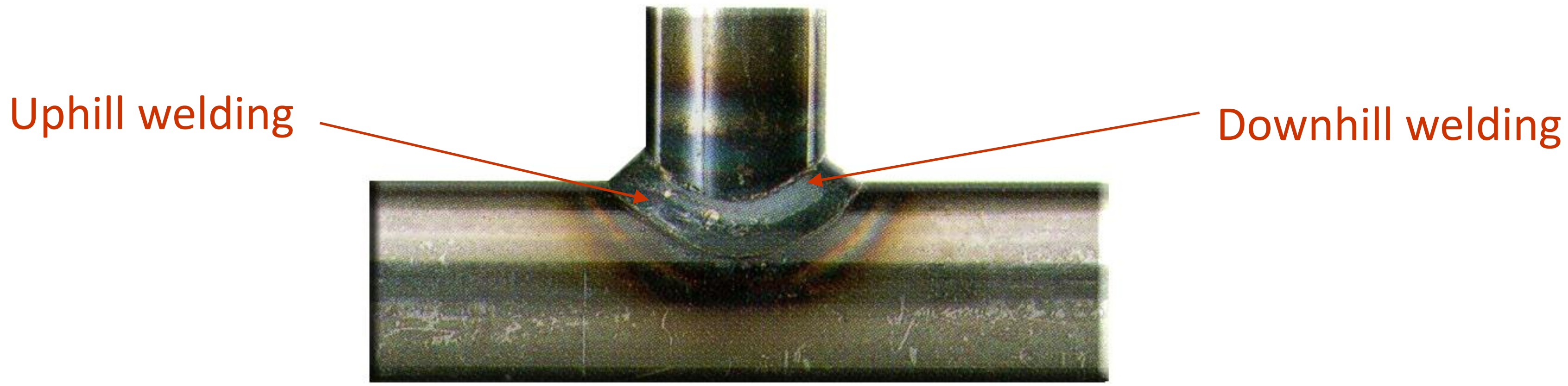
ARC WELDING CONTROLLER

Uphill Downhill Welding Problem



Uphill welding – deep penetration of arc
Downhill welding – shallow arc penetration
Therefore nonuniform welding occurs

Solution: Use Synchromotion



ARC WELDING CONTROLLER

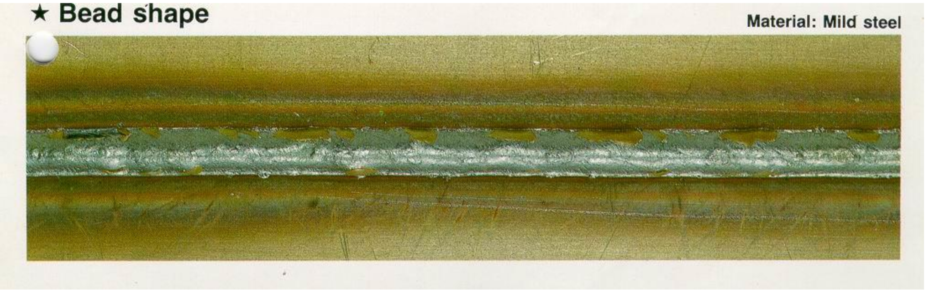
A Quick Review of Arc Welding Controllers Commercially Available

ARC WELDING CONTROLLER TECHNOLOGIES

- Current rating of 500A
- Thyristor controlled with built-in no-load voltage reducer and welding current remote control device
- Welding current can be adjusted at welding site without using control cable
- Easy reading by digital indicator

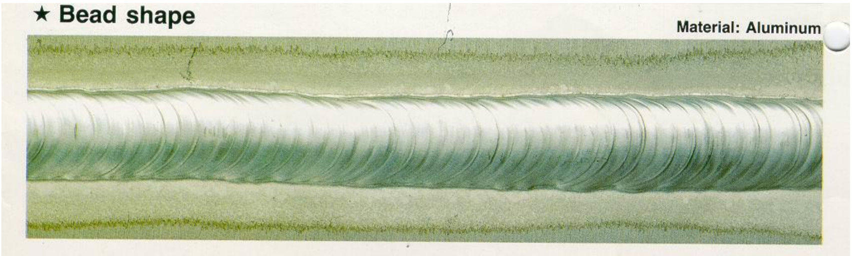
ARC WELDING CONTROLLER TECHNOLOGIES

- Inverter controlled high performance CO2/MAG welding machine
- 350/500 A current
- Weld spatter in CO2 welding is drastically reduced, almost spatter free welding
- Perfect/instantaneous arc start
- High speed characteristics improve efficiency



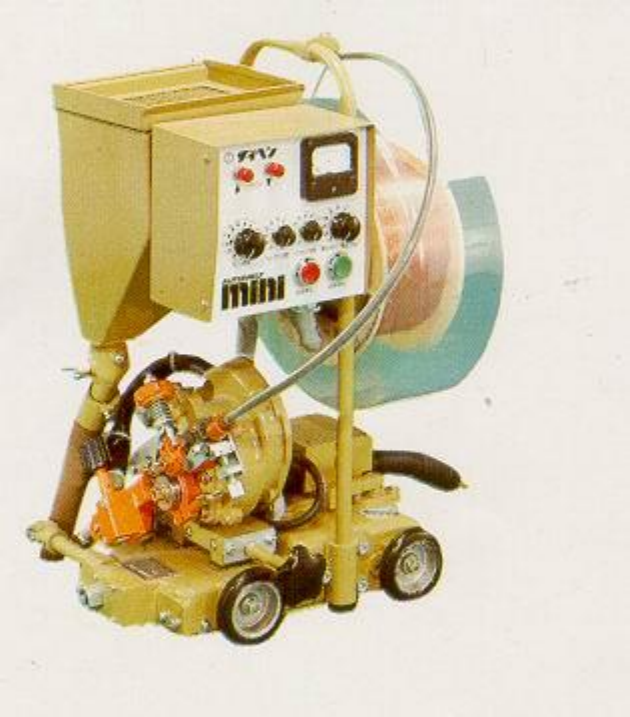
ARC WELDING CONTROLLER TECHNOLOGIES

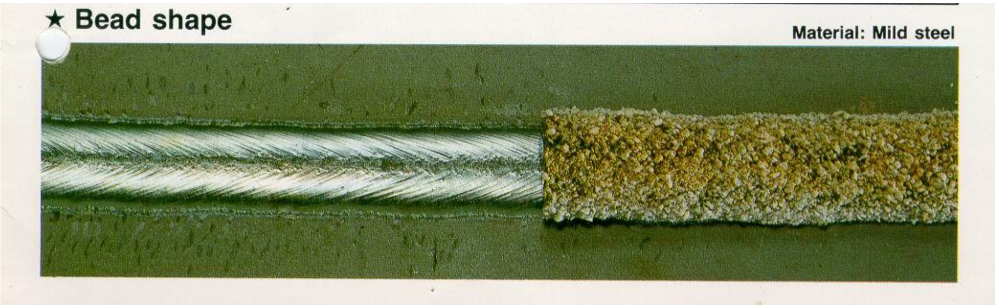
- Inverter Elecon
- Current ratings of 200/300/500 A
- Ultra compact high quality AC/DC TIG Pulse Welding Machine
- High quality TIG for stainless steel, copper, nickel alloy, titanum etc
- Middle frequency pulse function (10-500Hz)
- Low frequency pulse function (0.5-15Hz)



ARC WELDING CONTROLLER TECHNOLOGIES

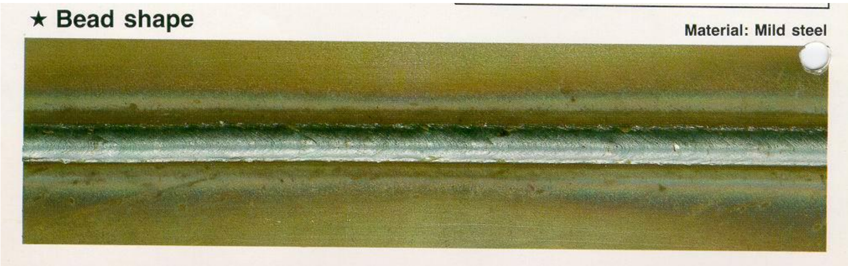
- Fillet-Butt Portable Submerged Arc Welding
- Can utilise AC or DC power supply
- Wide variety of applications
- Weight is only 19 Kg





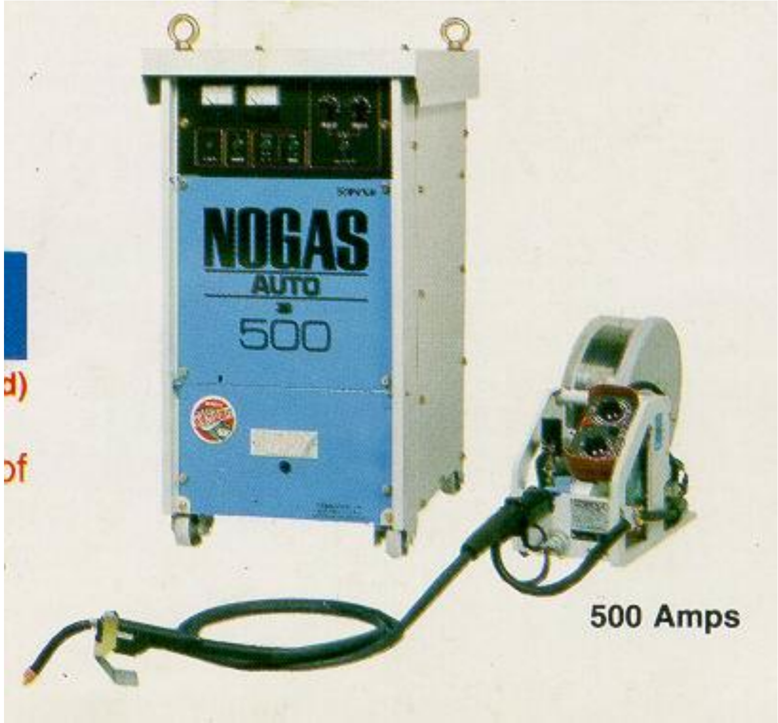
ARC WELDING CONTROLLER TECHNOLOGIES

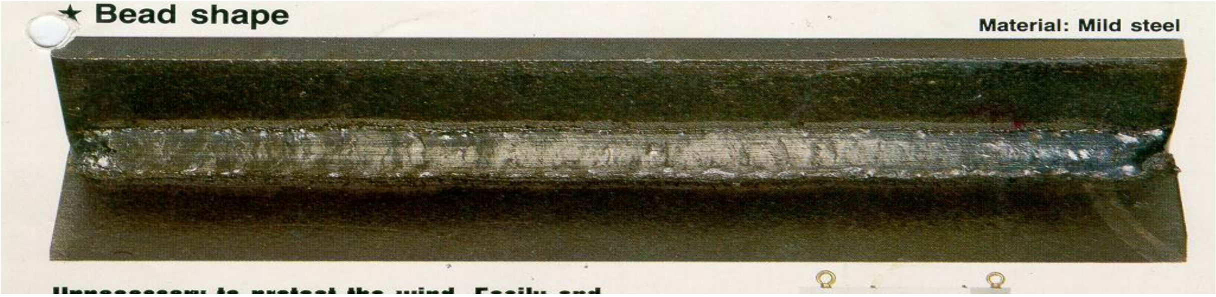
- Inverter controlled high quality MAG-MIG pulsed welding
- Current rating of 350 A
- Upgrading of welding quality by instantaneous arc start and spatterless welding
- Flat, beautiful bead appearance using MAG
- Optimum for welding of narrow parts and boxes, due to arc blow free.



ARC WELDING CONTROLLER TECHNOLOGIES

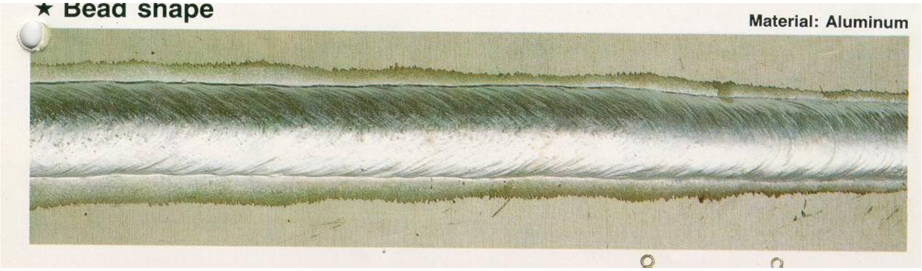
- IC-Thyristor controlled DC Nongas Shielded Arc Welding
- Current rating 500 A
- Beautiful finish and high quality welding using fine sized nongas welding wire
- Smooth arc start, excellent arc stability





ARC WELDING CONTROLLER TECHNOLOGIES

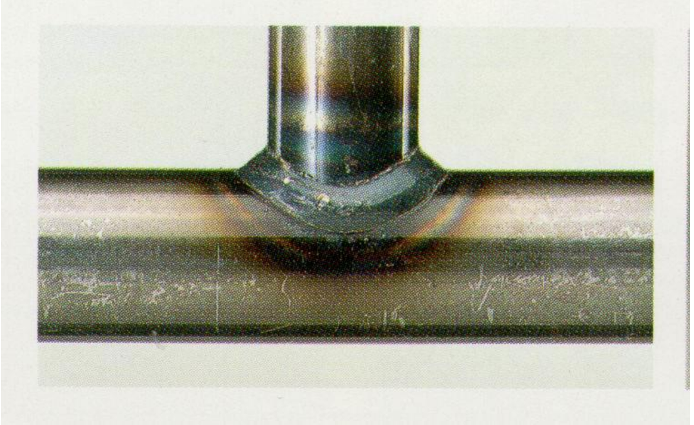
- Power transistor controlled pulsed MIG/MAG welder
- Current rating of 350/500A
- Applicable to all kinds of metals such as aluminium, stainless steel, mild steel etc
- Stable pulsed arc permits reduction of spatters and high quality welding
- Buckling and burn back associated with aluminium welding can be prevented

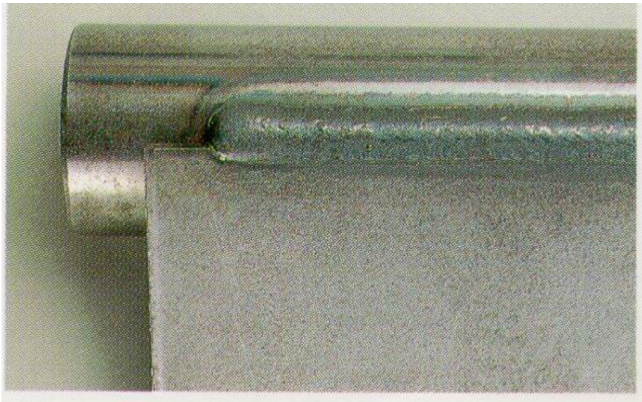


An In-Depth Study of an Arc Welding Controller with Advanced Inverter Technology

Professional arc welding standard covering all material gauge wire diameters, gas, welding speed and welding position

Shorter cycle time essential
In automatic and robot welding





- Microprocessor-aided Electronic Reactor is flexible enough to process variations required in automatic and manual welding
- Its fine control will allow to reach professional welding standards including the welding of stainless steel

An In-Depth Study of an Arc Welding Controller with Advanced Inverter Technology

Summary of Improvements

Improvement of productivity

A smooth and high-speed arc start will shorten cycle time remarkably, providing improved productivity

Reduction of man hours

A smooth and high-speed arc start will shorten cycle time remarkably, providing improved productivity

Reduction of down time

Inverter Auto reduces the time taken for maintenance of nozzle cleaning, wire deposition and intermittent arc

FEATURES OF ARC WELDING ROBOTS

- *Work volume and degrees of freedom*
- *Motion control system*
- *Precision motion*
- *Interface with other systems*
- *Programming – continuous path and weave*

* The reader is invited to explore the various weave patterns*

PROBLEMS FOR ROBOTS IN ARC WELDING

- Welding in confined spaces such as the insides of tanks, pressure vessels, ship hulls. Humans can position themselves into those areas more readily than robots.
- Welding in the presence of variations in the components to be welded. Variations in dimensions which involves slight changes from part to part.
- Variations in the edges and surfaces to be welded together.

One solution is to use sensors for robotic welding.

ARC WELDING SENSORS

Contact arc welding sensors

- Shock sensors on welding gun – stop upon detecting a threshold force
- Mechanical tactile probe

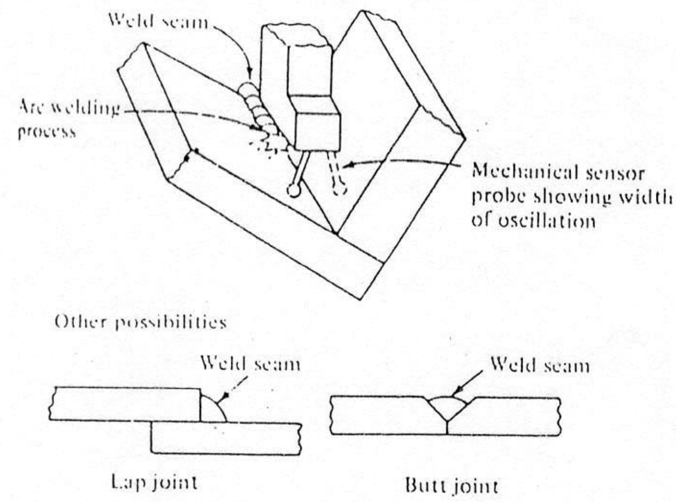
Noncontact arc welding sensors

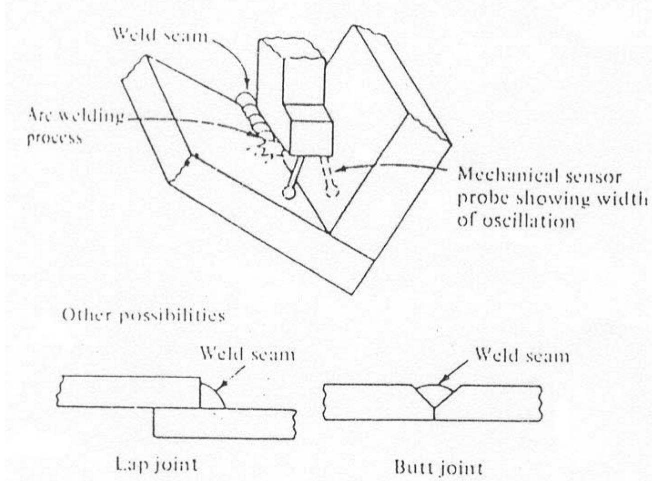
- Arc-sensing systems
- Vision-based systems

ARC WELDING SENSORS

Contact arc welding sensors

- Mechanical tactile probe
  Touch the groove ahead
  Oscillating probe
  For linear paths





ARC WELDING SENSORS

Noncontact arc welding sensors

- Arc-sensing systems

Also known as through-the-arc systems. Uses measurements of current (for constant-voltage welding) or voltage (in constant-current welding).

- The reader is invited to explore way the weaving works*

Fig. Robot welding with sensor guidance.

The welding robot workcell consists of a 6 DOF robot, a turning table so that the seam is accessible and welded in a flat position, the weld source with a fume extractor and the welding torch. Safety fences and light shields are not shown. The welding torch is attached to the robot flange. A service station (not shown) in the robot workcell is approached regularly to clean the gas nozzle.

ARC WELDING SENSORS

Noncontact arc welding sensors

- Arc-sensing systems - calculation of arc current:
- According to Murakami, the following relationship exist between wire feeding speed *vf* , wire extrusion length *Lw* and average current *Iav* :
- where *K0,K1,K2, a* and *b* are constants which are determined by the welding power source and welding conditions.

$$v_t - \frac{4L_w}{dt} = K_2 . \frac{d^2 I_{av}}{dt^2} + (K_1 + b.K_2.I_{av}^2)\frac{dI_{av}}{dt} + \{a + b(L_a - K_0 + K_1.I_{av}).I_{av}\}.I_{av}$$

- That is, it is possible to obtain wire extrusion length *Lw* by detecting dynamic changes in the average arc current *Iav* and to know the distance *Lx* between the contact chip and the work piece by computing the arc length *La* which is determined by the welding conditions.
- Hence, if the welding torch is weaved during an arc welding, it is possible to compute the correction in the torch direction of the welding torch.

ADVANTAGES AND BENEFITS OF ROBOTIC ARC WELDING

Higher Productivity

- Arc-on time: manual 10-30%
  robot 50-70%
- No fatigue for robots
- Use of positioners allows high utilisation of robots

Improved Safety and Quality-of-Life

- Human is taken away from uncomfortable, fatiguing, hazardous work place

Greater Quality of Product

- Robots are capable of producing consistent quality welding
- Better accuracy and repeatability

Process Rationalization

- Systematic organisation of work and material flow
- Use of Just in Time material delivery
- Design of fixtures
- Inventory control

ADVANTAGES AND BENEFITS OF ROBOTIC ARC WELDING

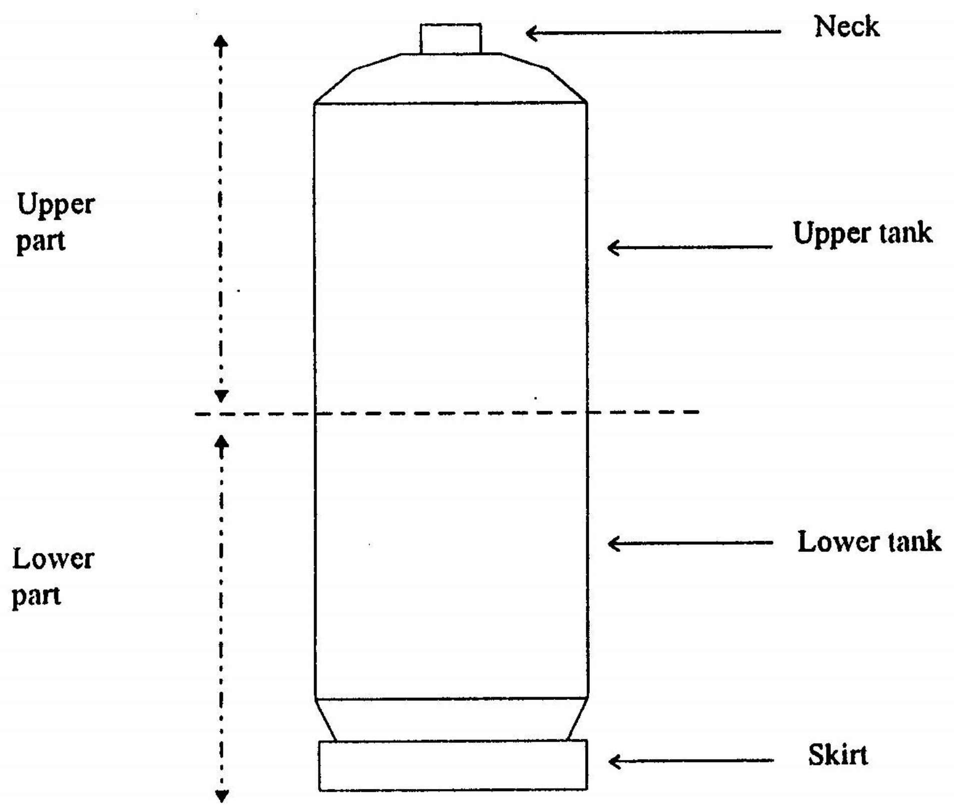
A Comparison Between Human and Robotic Welder

(A Small Case Study)

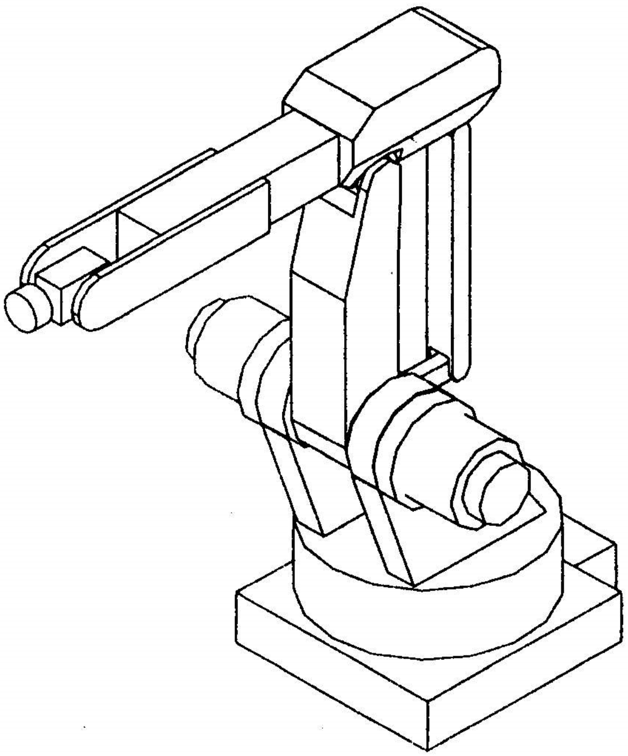
CASE STUDY 3
Robotized Fire Extinguisher Assembly

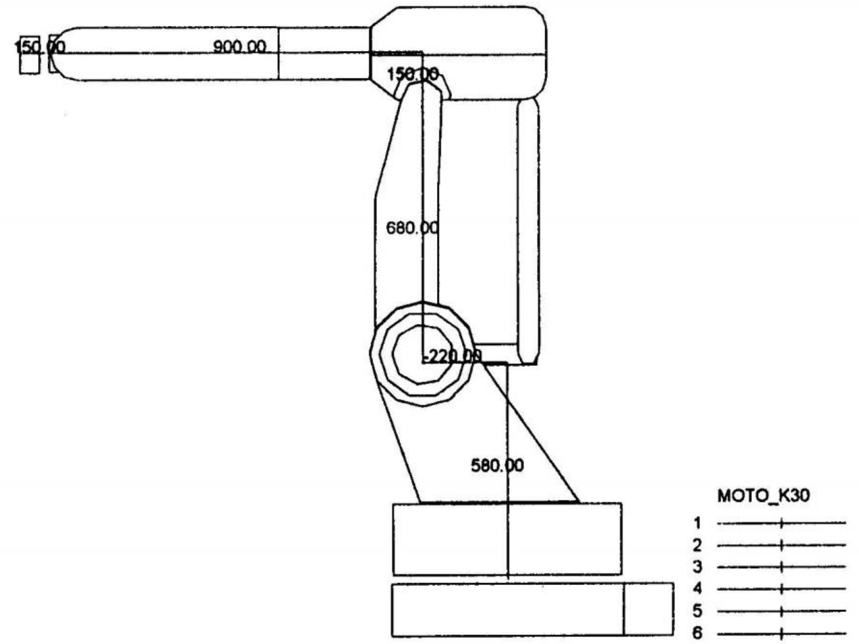
Features:

- Smooth flow
- Minimum process cycle time
- Safety features
- Human interface



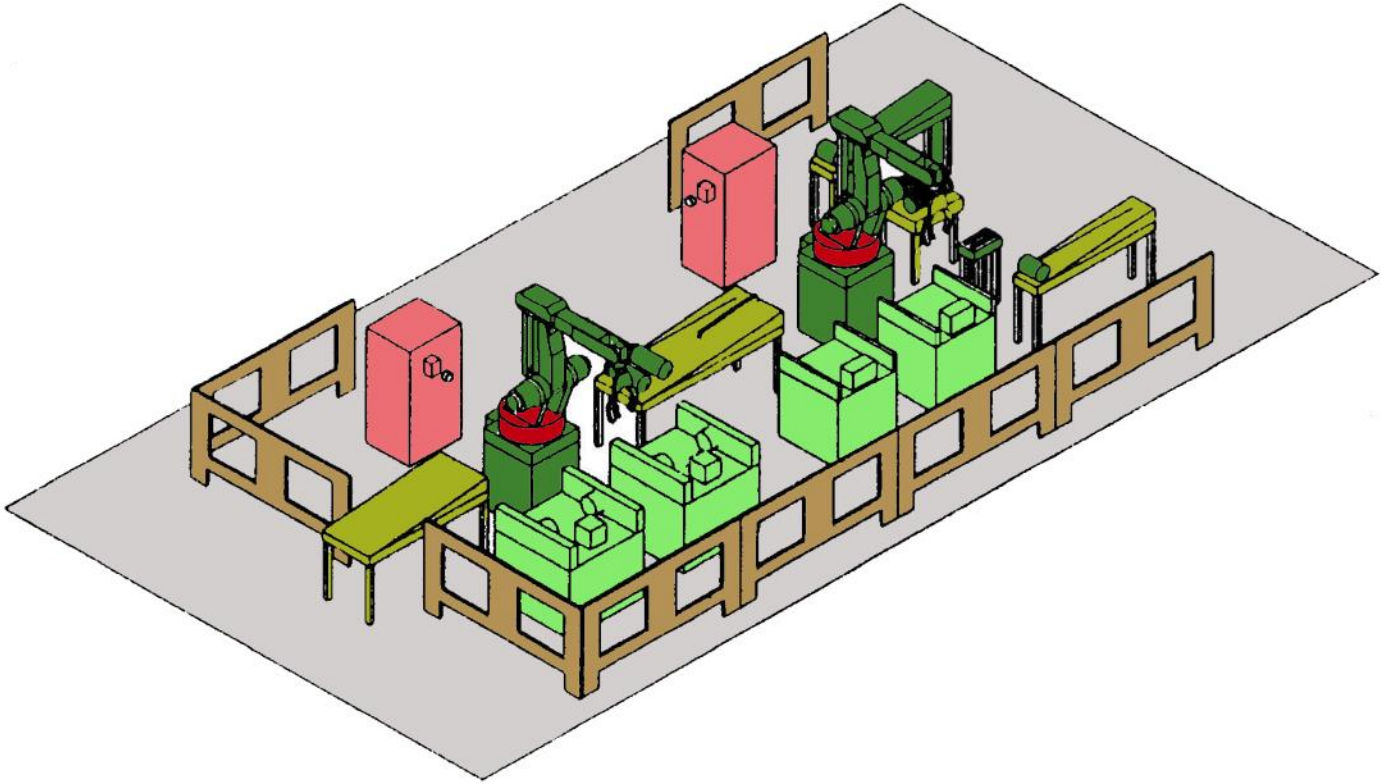
CASE STUDY 3
Robotized Fire Extinguisher Assembly





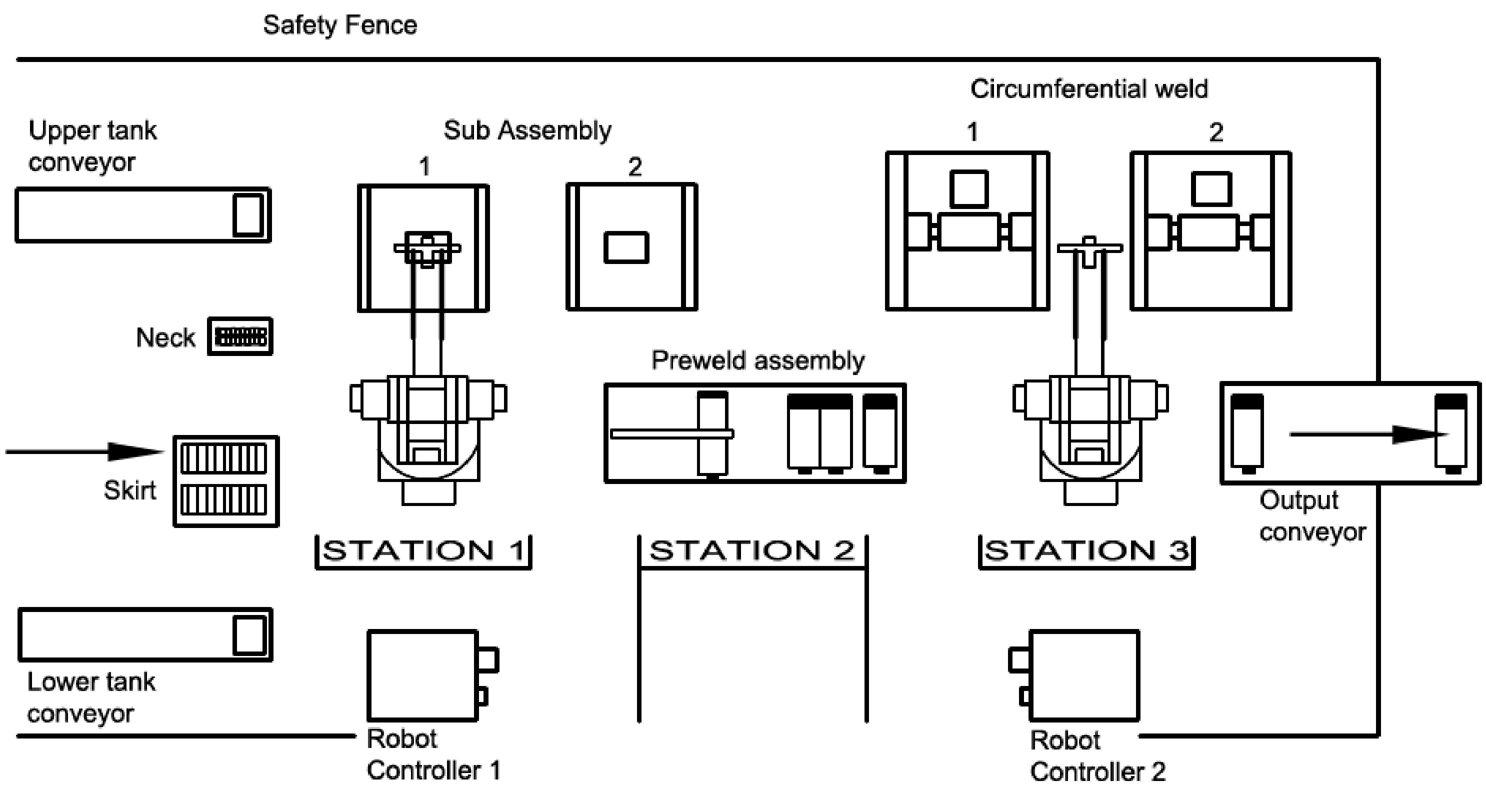
Motoman K30 Robot

CASE STUDY 3
Robotized Fire Extinguisher Assembly



Two Robot Fire Extinguisher Handling System

CASE STUDY 3
Robotized Fire Extinguisher Assembly



Layout of the work cell

CASE STUDY 3
Robotized Fire Extinguisher Assembly

Features of the work cell

Well Organised Elements (rationalised process)
- Welding machines are at front end of robots.
- Input components at the left end.
- Output components at the right end.
- Robots are in-line and centered at each station; no physical interference of each robot working envelope.
- Power sources and controllers are located at rear end.

Easy Maintenance
- Clearance between the machine allows access for technician to pass through

Smooth process flow
- All parts input are located at the left end.
- Products output are at the right end.
- Upper part and lower part preweld assembly is done between the Station 1 and Station 2.

Safety
- There are no interference of working envelope between two robots; collision between robots is avoided.
- Labor work at Station 2 is safe as the area is outside of robot working envelope.
- Safety fence is used to prevent workers entering the robot's working area.

CASE STUDY 3
Robotized Fire Extinguisher Assembly

Cycle Time and Production Rate

With the computed cycle time,
production rate of 1034 sets per day was obtained.

TEXT AND REFERENCE BOOKS

Textbook:

1. James A. Rehg: Introduction to Robotics in CIM Systems. Fifth Edition, Prentice-Hall. 2003.

Reference book:

1. Mikell P. Groover: Automation, Production Systems, and Computer Integrated Manufacturing, Second Edition. 2004.
2. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, Nicholas G. Odrey: Industrial Robotics: Technology, Programming, and Applications, McGraw-Hill. 1986.
3. Farid M. L. Amirouche: Computer-Aided Design and Manufacturing. Prentice-Hall.
4. Richard K. Miller, Industrial Robot Handbook. Van Nostrand Reinhold, N.Y. (1987).