Keith Hartley Memorial Lecture

WELDING EQUIPMENTS & PROCESSES – JOURNEY SO FAR

BY

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1.0 HISTORICAL DEVELOPMENT

Welding plays an important role in the development of our society and mankind as a whole. One of the indexes used for measuring the prosperity of a country is the par capita steel consumption. Higher the production of steel, the greater is the role of welding.

Historically the welding was developed in the ancient times and can be traced during the Bronze Age when the lap joints were made by heating and hammering the two metal pieces. During excavation, parts and tools have been found, which were welded by pressure welding during the time as back as 1000 B.C.

The present welding processes and equipments as we see today, took time to come to this stage. Let us have a look to find out how this happened:

1800

Sir Humphrey Davy in 1800 produced an arc between two carbon electrodes. In 1836 Edmund Davy of England invented acetylene. In the mid-19th century, gas welding & cutting were developed. Welding using the carbon arc and resistance welding came into existence sometime in 1885. Nikolai N. Benardos and Stanislaus Olszewski developed an electrode holder and got it patented, which marked the beginning of carbon arc welding.

1890

In 1890, C.L. Coffin of Detroit was awarded the first U.S. patent for an arc welding process using a metal electrode. About the same time, N.G. Slavianoff, a Russian, presented the same idea of transferring metal across an arc, but to cast metal in a mould.

1900

Oscar Kjellberg of Sweden invented a covered or coated electrode during the period of 1907 to 1914. Stick electrodes were produced by dipping short lengths of bare iron wire in thick mixtures of carbonates and silicates, and allowing the coating to dry. This marked the beginning of modern welding.

1919

Around 1919, American Welding Society was formed as a non profit organization dedicated to the advancement of welding and allied processes.

1920

In 1920, automatic welding using bare wire was invented by P. O. Nobel. Initially it was used for re-building the worn out parts. The arc voltage was fed to the wirefeed motor to regulate the arc

length. During the 1920s there was considerable research in shielding the arc and weld area by externally applied gases.

1930

Stud welding was developed in 1930 at the New York Navy Yard. Stud welding became popular in the shipbuilding and construction industries.

Around the same time, automatic submerged arc welding was developed and became very popular for manufacturing pipes.

1940

Gas tungsten arc welding (GTAW) was developed during this time and it took nearly one year to perfect the process. During this time, the GTAW welding became very important tool for joining the metal as it gave good quality, defect free weld. The popularity of GTAW initiated the work on GMAW.

Initially, the GTAW came to perfection due to the effort of C. L. Coffin, H. M. Hobart and P. K. Devers.

The gas shielded metal arc welding (GMAW) process was successfully developed at Battelle Memorial Institute in 1948. The initial introduction of GMAW was for welding nonferrous metals. The high deposition rate led users to try the process on steel. The cost of inert gas was relatively high and the cost savings were not immediately available.

1950

In 1953, Lyubavskii and Novoshilov announced the use of welding with consumable electrodes in an atmosphere of CO2 gas.

Robert F. Gage invented plasma arc welding in 1957. This process uses a constricted arc or an arc through an orifice, which creates an arc plasma that has a higher temperature than the tungsten arc. It is also used for metal spraying and for cutting.

The electron beam welding process, which uses a focused beam of electrons as a heat source in a vacuum chamber, was developed in France. J.A. Stohr of the French Atomic Energy Commission made the first public disclosure of the process on November 1957.

The Electroslag welding process was announced by the Soviets at the Brussels World Fair in Belgium in 1958. It had been used in the Soviet Union since 1951, but was based on work done in the United States by R.K. Hopkins, who was granted patents in 1940. The Hopkins process was never used to a very great degree for joining. The process was perfected and equipment was developed at the Paton Institute Laboratory in Kiev, Ukraine, and also at the Welding Research Laboratory in Bratislava, Czechoslovakia.

1960

Prior to 1960, most of the welding was done using one particular gas. Soon it was realized that each gas has some advantages and disadvantages. For example, CO2 gas has advantage of giving better penetration, bus has disadvantage of spatter and poor bead appearance. Argon gas has the advantage of good bead appearance and practically no spatter but has the disadvantage of poor penetration. Scientists started experimenting with gas mixtures to maximize the advantages and minimize the disadvantages. Gas mixtures were developed to ensure homogeneous mixing of the gases.

The Arcos Corporation introduced another vertical welding method, called Electrogas, in 1961. It utilized equipment developed for Electroslag welding, but employed a flux-cored electrode wire and an externally supplied gas shield.

Most Recent

Friction welding, which uses rotational speed and upset pressure to provide friction heat, was developed in the Soviet Union. It is a specialized process and has applications only where a sufficient volume of similar parts is to be welded because of the initial expense for equipment and tooling. This process is called inertia welding.

Laser welding is one of the newest processes. The laser was originally developed at the Bell Telephone Laboratories as a communications device. Because of the tremendous concentration of energy in a small space, it proved to be a powerful heat source.

Friction-stir welding (FSW) is a solid-state joining process (meaning the metal is not melted during the process) and is used for applications where the original metal characteristics must remain unchanged as far as possible. It was invented and experimentally proven by Wayne Thomas and a team of his colleagues at The Welding Institute UK in December 1991.

2.0 MARKET SCENARIO:

Even during the recession, the production of steel and the market of welding equipment and consumable has been able to sustain its growth, may be at a little lower pace than expected. But certainly there was a better market demand compared to other industrial goods.

The rate of growth will reduce a bit in the years to come because the market is already matured. In order to sustain the growth in such a mature market, the manufacturers should continue to actively pursue new opportunities in different segments where at present the welding is not used and continue to add value to their existing welding techniques.

We have to find out ways to replace more designs to steel. We should look around and find out the items which can be changed to steel and items which are not fabricated at present but can be of fabricated design in future. The good example for this is the bridges & flyovers which were earlier made by concrete are now mostly fabricated structures.

Seeing the trend of steel production and the market demand, it is expected that the requirement of welding equipment and consumable in the world during the year 2009-10 will be approximately 775 billion rupees, i.e. 16.5 billion USD approx. With the globalization of the market, everyone is free to sale anywhere in the world. Also, India being a developing country, the growth rate for welding equipment and consumable market will be higher compared to the other section of the world. Hence there should not be any reason for worry as far as the market is concerned. The pressure on the price is expected to be very high hence the manufacturers will have to streamline their production process and come out with innovative design concepts.

3.0 EXPECTATION OF THE MARKET:

In order to maintain the growth rate the manufacturer will have to tune themselves as per the requirement of the market. The market requirement in the coming years will be as follow:

3.1 **ELIMINATION OF PRE & POST HEATING**: During the recent seminar at Jamshedpur, a paper was presented by Dr. T. K. Paul, a well-known metallurgist, wherein he discussed on an electrode which will eliminate pre & post heating. The idea looked strange to many audiences but any innovative idea when heard for the first time, it is found to be difficult to accept.

Here, emphasize is on innovative ideas for production-cost reduction making fabrication more viable.

3.2 **CONSUMABLE QUALITY:** Fabrication will shift from MMAW to Semi Automatic Welding. It will be necessary to have continuous solid or tubular consumable having perfect cast and helix with uniform diameter to have minimum hassle in feeding. This will eliminate interruption and will result in higher arc on time, thereby increasing the productivity.

3.3 **INNOVATION IN STEEL**: The steel manufacturers should work in close association with welding equipment and consumable manufacturers. Unfortunately, in India, at present the importance of the same is not fully realized. The basic idea is that the steel manufacturers should be able to produce steels which will give the same or better properties at a lower thickness, reducing the weight of steel thereby the weight of the fabricated structure. Whenever a new steel is produced, the challenge is thrown to the consumable manufacturers to come out with suitable consumable and it is passed on to the equipment manufacturers to produce welding machines which will give perfect result after using such consumable.

3.4 **AUTOMATION**: The demand for automation has been increasing in the last few years and will keep on increasing to improve the productivity and to reduce the requirement of skilled labourer. The degree of automation depends on the quantum of production and investment.

3.5 **MATERIAL FOR FABRICATION**: The growth of use of steel will reduce and that of aluminium and stainless steel will increase. We have satisfactory consumables and machineries for fabrication of steel but the same is not true for aluminium and stainless steel. Both equipment and consumable manufacturers should look into this.

3.6 **PRODUCTIVITY**: Requirement of improvement of productivity shall be considerably high in the years to come.

Cost of following inputs in fabrication has to be reduced:

a) Machines and automation cost.
b) Labour cost.
c) Consumable cost.
d) Energy cost.

3.7 **SOFTWARE**: The use of micro controller, micro processor with good quality software can reduce the set up time. The proper record of the weld parameter for a particular job can be stored and reused in future. The software should be able to calculate on-line fabrication cost.

3.8 **INTERNATIONALLY ACCEPTED EDUCATION & CERTIFICATION SYSTEM:**

Demand for above will increase every year. For better communication, it is essential that the welders and the welding technocrats including inspection personnel should have uniform internationally accepted education and qualification duly certified.

I am pleased to inform that Indian Institute of Welding, a member of International Institute of Welding, is Authorized National Body, which is imparting such education and training.

The fabricators can also be certified as per ISO 3848 for quality production and export of their items.

4. IMPROVEMENT REQUIRED OF EXISTING WELDING EQUIPMENTS AND PROCESSES IN INDIA:

India being a developing country, considerable investment is expected in the next few years in infrastructure development. In order to popularize the welding, let us look at what is the current status and what improvements are required:

PROCESS	CURRENT STATUS	IMPROVEMENT REQUIRED
GTAW	Mostly manual	- Semi automatic or Automatic
	Semi automated system	- To achieve perfection
	Manual root pass	- High amperage hot/cold wire system
	Simple GTAW	- High penetration GTAW
	Automatic voltage control system	- To be made more sophisticated but to be available at cheaper cost
SMAW	Electrode needs re-drying	- Vacuum packed electrode to eliminate /reduce re-drying
	All position electrodes	- Should be user friendly
	Pipe welding electrode	- Easily weldable
	Low moisture pickup & low-hydrogen	- Welder friendly consumables
GMAW	Semi automatic welding	- More automatic welding
	Mostly CO_2 gas used	- Use of more mixed gasses
	Mixed gasses in cylinder	- Gas mixture both portable and High volume for mixing of the gas at site.
	Limited range of consumables	- More varieties with different gas mix
FCAW	High cost	- Low cost
	Mostly semi automatic	- More automation
	Low hydrogen and low fume generating wires	- To be developed at cheaper cost
	Uniform filling of flux	- To be perfected
SAW	Single wire	- Use of multi wire
	Low speed welding	- High speed welding using tandem Wire
	Process limitation of down-hand Welding.	- Use of Manipulator and welding aids to bring the weld in down hand position.
	Narrow gap welding	- To be perfected
	Reclamation with round wire.	- Use of strip electrode for better deposition.
	Advanced wire-flux combination	- To be perfected for higher deposition
OTHERS	High cost of friction stir welding	- Cost reduction
	Guiding systems	- To be developed indigenously.
	Oscillation system	- At cheaper cost
	Accessories for welding automation Such as magnetic rail with special trolley.	- To be developed indigenously at lower cost
	Welding of large vessels/pen-stock pipes	- Innovative design of welding aids to reduce the cost.

5. WELDING INDUSTRY IN TOTALITY:

The industry consists of three parts:

i) The direct labour, i.e. the welder, who perform the actual welding operation.
ii) The manufacturer of welding equipments and consumables, who provide service & facility needed by the welder.
iii) The client, who depends on welding and joining process to get manufactured their end products.

The manufacturing of welding equipments and consumables depends both on the welders and the end users, to pursue their goal of higher growth and better market.

5.1 **THE WELDER:** There is a big shortage of trained welder in the national and international market. The shortage of trained welders can also affect the growth of other industrial products since the welding is an important tool for final assembly. The welding is a specialized skill and needs training for perfection. In India, there are number of training institutes for training welders such as The Indian Institute of Welding and some of the other agencies. But the entire training program is still not very systematic and professional. This needs a very serious attention because the growth of fabrication industry depends on easy availability of skilled welders.

The Indian Institute of Welding is doing lot of work in this direction by visiting different workshops & training institutes, providing training to the welders even in remote areas, helping them to improve their skill and finally examining their skill for issuance of certificate. Number of Authorized Training Bodies have been appointed and few more are in the process of appointment for giving training to the welders as per the international standard laid down by the International Institute of Welding.

Another way to solve the problem of shortage of trained welder is to depend more on automation and robotic welding.

5.2 **THE MANUFACTURER:** The manufacturers depend on distributors for the sale of their products. The problem is that though the most of the distributors are able to sale in volumes and pay in time but very few of them have technical staff trained to help customers select the best processes for their needs or to solve their technical problems quickly. Recently, some suppliers have realized that lack of technical expertise makes them look like commodity suppliers to their customers, and they are moving to improve their service.

The welding is hi-tech engineering hence it is necessary that both the manufacturers and the distributors have the full knowledge of the product, process and application to give full value of the money spent by the client.

The manufacturers will have to keep on introducing new products having increased performance and still better quality. At the same time the product must be affordable both for the initial investment and the overall life cycle cost.

5.3 **THE CLIENT:** The expectations of the end users or the clients which a manufacturer has to satisfy are:

i) Better innovative design
ii) Lower cost
iii) Technical back up on application
iv) Efficient after-sales service
v) Increased product life

The above are the present requirements. The future requirement can be following:

i) Sensing the welding profile in terms of curvature and fit-up and giving signals to the welding machine for correction.
ii) Joining of coated steels
iii) Joining of dissimilar metals
iv) Better welded design and process management
v) Recording and evaluating the weld cost.

6. WELDING SETUP: It consists of following:

i) Welding Consumables
ii) Power Sources
iii) Welding Equipments
iv) Aids for Automation.

6.1 **WELDING CONSUMABLES:** Welding consumables are the materials which are used up during welding, for example – consumable electrodes, filler wires, fluxes and externally applied shielding gasses. They influence the welding operation, heat input, solidification, bead shape and weld metallurgy. This is being a complete subject by itself; we will not discuss it further. A metallurgist can do the justice to this topic.

6.2 **POWER SOURCE:** All welding processes require electrical power which depends on the thickness of the job. The supply of current together with proper voltage for maintaining the arc is necessary. The current can be Alternating (AC) or Direct (DC) depending on the process. But it must have the means for controlling the same for obtaining the desired Volt-Amps Characteristic for maximum weld efficiency. The device which gives required Volt-Amps characteristic with precise control is called the POWER SOURCE.

6.2.1 **CLASSIFICATION OF POWER SOURCE depending on OUTPUT:**

i) AC or DC
ii) AC – DC
iii) Constant Current (CC)
iv) Constant Voltage (CV)
v) Variable Volt-Amp Characteristic

6.2.2 **CLASSIFICATION OF POWER SOURCE depending on DESIGN:**

i) Magnetic Leakage type
ii) Magnetic Amplifier type
iii) Thyristor Based
iv) Chopper Based
v) Inverter Based

6.2.3 **SELECTION OF POWER SOURCE**:

The most important factors to be considered in selecting the power source are the performance, the type of power source which will do the job easily and enable better welding at lower cost. The power source should be able to withstand rough input supply condition with surges and should be easily maintainable and repairable in case of accidental failure.

6.2.3.1 **DEPENDING ON THE EASE OF MAINTENANCE:**

Depending on the ease of maintenance, the power sources can be classified in following order, from simple to difficult:

i) **Magnetic Leakage type** – needs very less maintenance but output Volt-Amps characteristic is not accurate and is not immune to supply voltage fluctuation, has low efficiency & power factor.

ii) **Magnetic Amplifier type** – easy to maintain and immune to supply voltage fluctuation but has low efficiency and power factor.

iii) **Thyristor based** – most popular, is immune to supply voltage fluctuation, has booster circuit for higher OCV, hot start for easy arc striking, anti freeze avoiding sticking of the electrode with the job and also has arc force control. Has good power factor and efficiency. It is the cheapest DC welding power source.

iv) **Chopper based** – Advanced power source, higher efficiency and power factor, has very good tolerance to supply surges, not difficult to maintain, bigger in size compared to Inverter based power sources.

v) **Inverter based** – Advanced power source, has high efficiency & power factor and is light in weight and compact in size. Bad input supply condition with surges can create problem. A good machine is costlier compared to Thyristor based or Chopper based power source.

6.2.3.2 **DEPENDING ON THE OUTPUT VOLT-AMPS CHARACTERISTIC:**

Depending on the Output Volt-Amps Characteristic, the power sources can be classified as following:

i) **Constant Current (CC)** for Manual Metal Arc (MMA) & TIG Welding.

ii) **Constant Voltage (CV)** for Semi Automatic & Automatic Welding.

6.2.3.3 **DEPENDING ON THE PROCESS:**

Depending on the Process, the following may be used as guide for selection of Alternating or Direct Current Power Source:

Direct Current (DC) only:

- Gas Metal Arc Welding
- Flux Core Arc Welding
- TIG Welding of Stainless Steel
- Exx10 type Electrode
- Exx15 type Electrode

Direct Current (DC) preferred:

- The out of position welding
- Welding of Stainless Steel
- Low Hydrogen Electrode
- Non-Ferrous Electrode

Alternating Current (AC) only:

- TIG Welding of Aluminium.

Alternating Current (AC) preferred:

- Iron Powder Electrode for down hand welding
- To counter Arc Blow

Alternating Current (AC) & Direct Current (DC):

- High speed welding

6.2.4 **POWER SOURCES USED IN INDIA:**

- **A.C. POWER SOURCE:** Almost all the power sources used are Moving Core type, suitable for connection to two phase of three phase supply. The design is simple and output can be varied even when the welding is in operation unlike tap choke design.

- **D. C. POWER SOURCE:** Since majority of the welding is done using D.C. Power Sources, we will examine this in little more detail. Three types of D.C. Power Sources are used namely:

  i) Thyristor type
  ii) Chopper based
  iii) Inverter based

6.2.4.1 **THYRISTOR TYPE:** The input supply is connected to a step-down transformer, output of which is connected to a Thyristor Bridge.

The rectifier in a conventional welding power unit is essentially a static component. It simply accepts the alternating current from the transformer and converts it to DC without exercising any control. If a Thyristor is used in place of the conventional rectifier, however, the current flow can be altered in response to a remotely controlled command signal.

A Thyristor is a solid-state device which allows current to flow in one direction, i.e., it behaves as a normal rectifier. However, in the appropriate half cycle it will conduct only after being 'fired' by a voltage pulse applied to the control terminal. Current will then flow for the remainder of that half cycle, until its direction reverses and the Thyristor ceases to conduct. In a typical AC waveform, the mean current depends on the time, during which current is flowing.

Being a machine whose output is controlled electronically; its functions can be enhanced to various requirements. The rectified output passes through a choke and a free-wheeling diode circuit to give smooth DC.

6.2.4.2 **CHOPPER BASED:** Chopper based power source is the simplest form of high frequency power conversion. In case of Chopper based power source, a 3-phase mains is connected to a step-down transformer working at 50 Hz. the output of which is fed to a 3-phase rectifier bridge. Then the output is chopped to a lower output voltage, and a choke is placed in the path of the output to smooth current variation.

A capacitor and a free-wheeling diode are used to improve the flow of current.

DC voltage is applied through a solid state switch, which controls the welding arc by opening and closing, regulating the amount of current that is applied to the arc. When the switch is closed, current is applied through the inductor to the arc. When

the transistor switch is open, current stored in the inductor sustains current in the arc. The reception of this cycle of switch closure is at least 20 KHz, which allows fast control of the arc.

The Chopper based power source has excellent tolerance to surge voltage as the 3-phase mains is connected to a normal transformer. It is very useful where the input power is supplied through a Diesel Generator Set or where the input voltage keeps fluctuating heavily in a badly networked industrial site.

The cost of Chopper based power source is cheaper and has almost all the practical advantages of an Inverter based power source except that it is bulky.

6.2.4.3 **INVERTER BASED POWER SOURCE:** In this case, the input supply is applied directly to a bridge circuit where it is rectified and filtered to produce a pure DC voltage. Solid state switches then chop the DC to provide a high frequency more than 50 Hz. This high frequency voltage is then applied to the primary of a transformer. The secondary output of the transformer is then rectified and filtered to supply a DC welding voltage and current.

Because of the high frequency, the required magnetic components like transformer and choke become small. Higher the frequency, lower will be the size of transformer and choke. As a result of this, the Inverter base power sources are light in weight and compact in size. Because of the high frequency, the response to changed arc condition is very fast. It is a machine with full of electronics and most of the times has a micro controller/micro processor to give the desired output under various conditions of the welding.

Efforts should be made to manufacture this machine totally indigenous. At present, most of the Inverter based power sources available either imported or assembled, making the availability of spare parts difficult and costly.

6.2.5 **COMPARISON BETWEEN DIFFERENT POWER SOURCES:**

CRITERIA	DIODE TYPE	THYRISTOR TYPE	CHOPPER BASED	INVERTER BASED	
				Non-Resonance	Resonance
Volt-Amps characteristic	Not accurate but acceptable	Accurate	Accurate	Accurate	Accurate
Immunity to voltage fluctuation	Not available	Good	Good	Good	Good
Arc striking	Moderate	Good	Good	Good	Good
Range of output	Generally Multi Range	Single Range	Single Range	Single Range	Single Range
Weldability of different electrodes	Poor, specially low hydrogen	Good	Good	Good	Good
When used as Power Source for GTAW	Moderate	Good	Good	Very good	Very good
Cost of spare parts	Cheap	Cheap	Moderate	Costly	Costly

Size	Bulky	Moderate	Moderate	Compact	Compact
Weight	Heavy	Moderate	Moderate	Not so Light	Light
Power consumption in KW of 400 Amps. machine :-					
At 200A at 28V-	10.40	8.15	6.80	6.80	6.30
At 300A at 32V-	16.50	13.60	12.50	11.30	11.20
At 350A at 34V-	20.50	16.87	15.27	14.80	13.78

From the above, it is clear that while going for a sophisticated power source, one should be looking to the following aspects:

- Country of origin.
- Technology used.
- Initial cost involvement.
- Availability of after sales service.
- Cost of spare parts.

All the above problems with Inverter based machine will be eliminated when the machine is manufactured indigenously, which we are quite capable of doing.

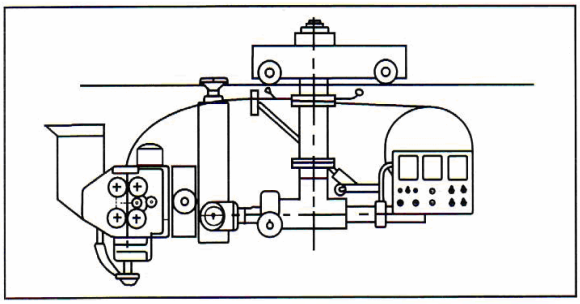
6.3 **EQUIPMENT**: Equipments are the means for feeding consumable electrode. These can be divided in three categories:

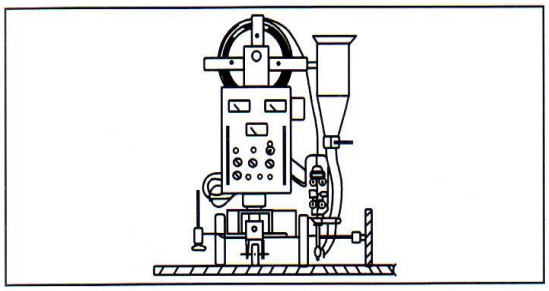
6.3.1 **MANUAL WELDING:** For Manual Metal Arc Welding where the maintenance of the arc voltage and the positioning of the arc both are manual, an Electrode Holder is the only equipment besides standard accessories.

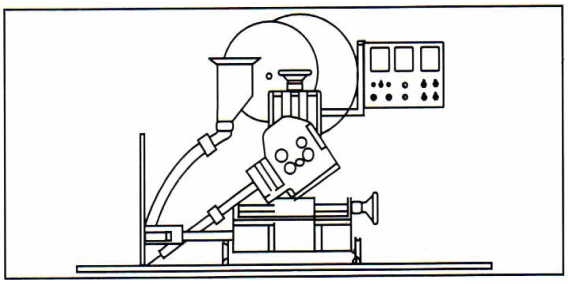
6.3.2 **SEMI AUTOMATIC WELDING:** In case of Semi Automatic Welding, the arc voltage is maintained constant automatically by the flat characteristic of the power source and the positioning of the arc is manual. The equipment required here is a Wirefeeder with a Welding Torch fitted in it besides other standard accessories.

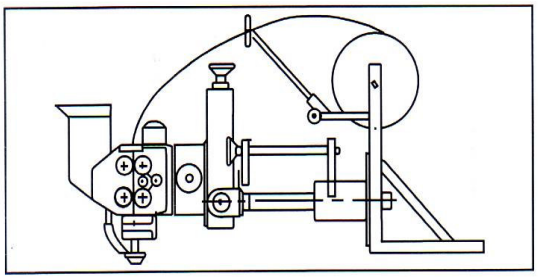
6.3.3 **AUTOMATIC WELDING:** In this case, both the maintenance of arc voltage and the positioning of the arc are automatic. The Wirefeeder is mounted on a trolley and it moves over the job. Alternatively, the wirefeeder is kept stationary and the job moves below it.

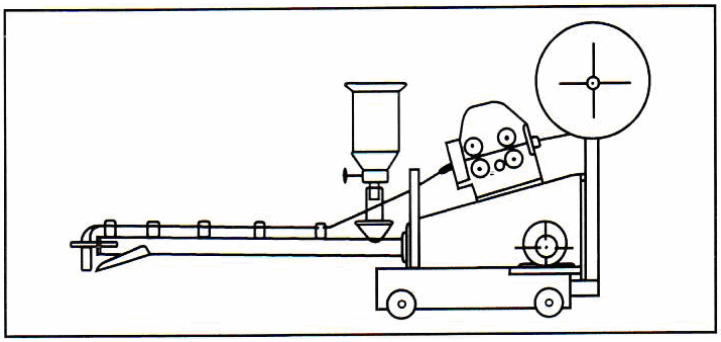
In case of automatic welding, lot of variation is possible as shown in the figure. The figure shows variation in submerged arc welding equipment. The same is true for other processes also.







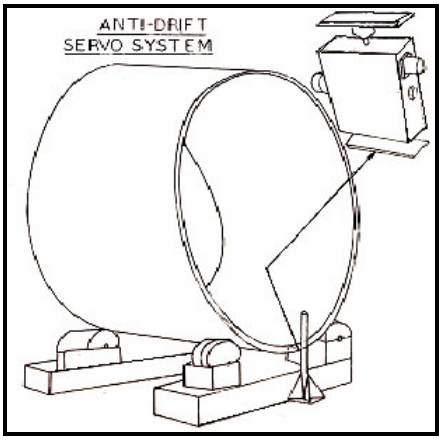




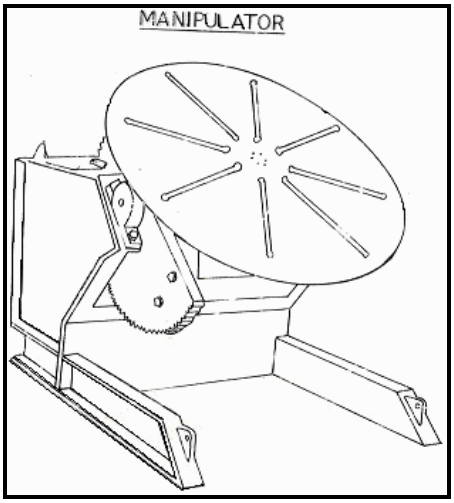
6.4 **AIDS FOR AUTOMATION:**

These are required to ensure good quality weld with minimum of skill and are tools for automation for better productivity. Examples of some of them are given below:

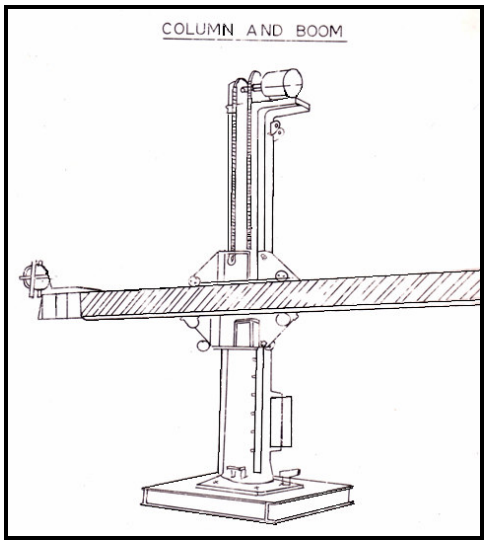
6.4.1 **ROTATOR:** For rotating a circular job for automatic circular seam. Advanced rotators are fitted with sensor to avoid drifting of job.



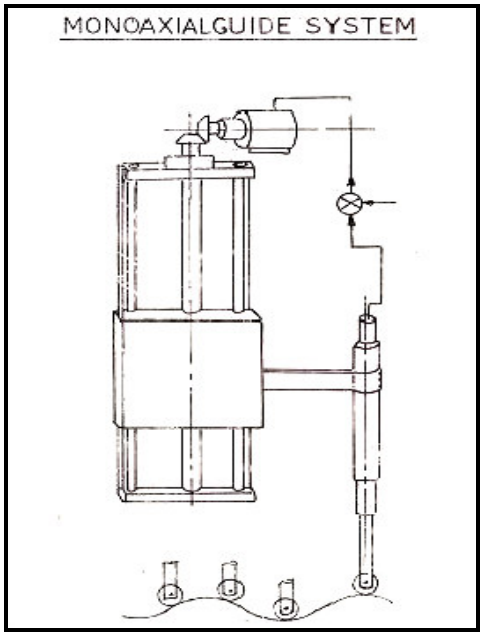
6.4.2 **MANIPULATOR:** For positioning the job for down-hand welding. C. G. & eccentricity of the job should be considered while ordering the manipulator.



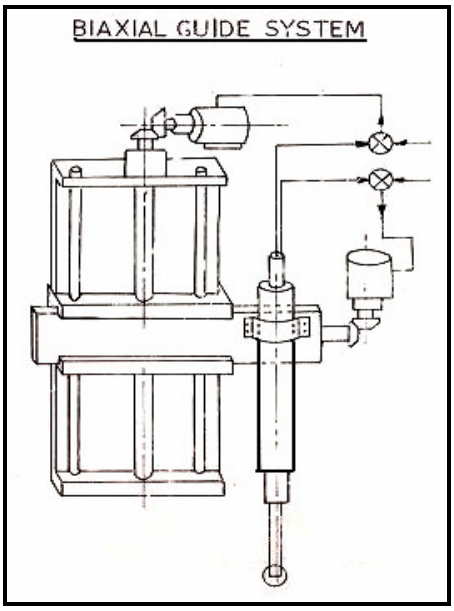
6.4.3 **COLUMN & BOOM:** When a welding head is fitted on a Column & Boom, it is capable of moving up & down and is able to travel to & fro, making it ideally suitable for pressure vessel industries. The Column of some of the machines are also capable of rotating along its axis, making the machine more useful.



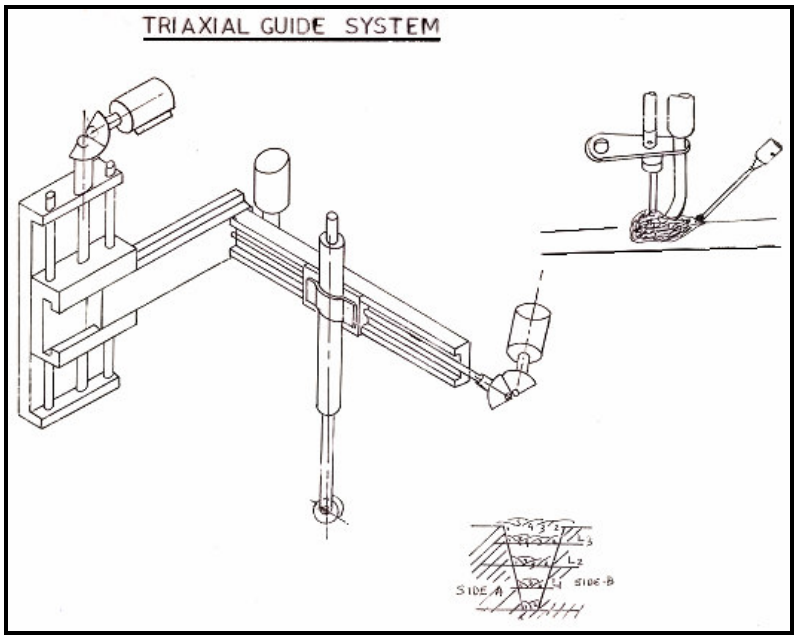
6.4.4 **MONO-AXIAL GUIDE SYSTEM:** The electronic probe positioned in front of the welding arc explores the joint to be welded and converts proportionally any vertical deviation from a neutral central position ('zero') into an electrical signal, which suitably amplified, controls the servo-meter of the axis Y, so as to maintain the distance of Torch from the welding surface constant.



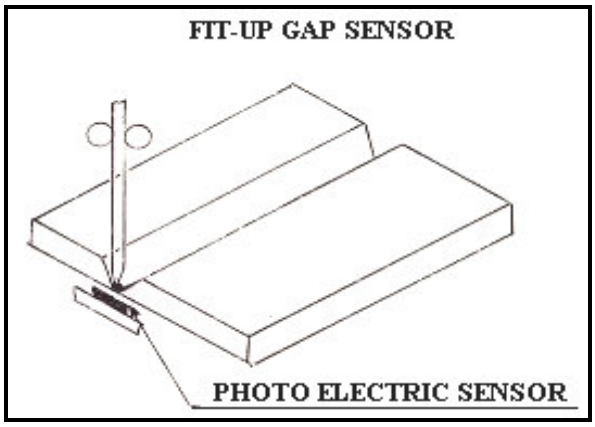
6.4.5 **BI-AXIAL GUIDE SYSTEM**: The system is normally used for welding circumferential and longitudinal joints of vessels or more in general, for the welding of joints with bi-dimensional copying.



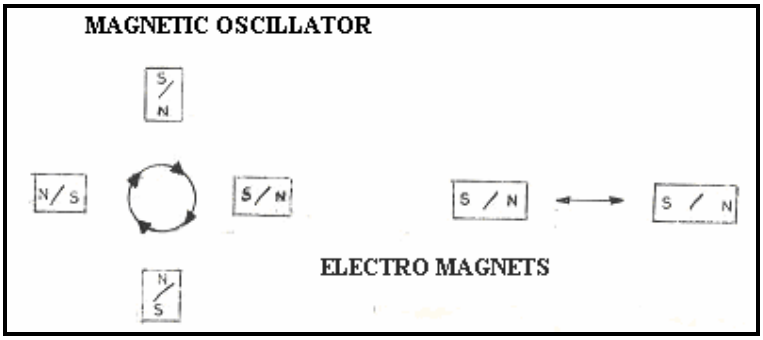
6.4.6 **TRI-AXIAL GUIDE SYSTEM:** The system carries out the complete welding of circumferential (or longitudinal) joints of vessels with continuous automatic evolution of welding, in a groove of many forms, from the bottom to top.



6.4.7 **FIT-UP GAP SENSOR:** In Fit-up Gap Sensor, a photo-electric device is kept below the joint which measures the light coming out from the joint which is proportional to the gap. It gives signal to an Oscillation unit and Power Source for manipulation of the weld parameter for satisfactory weld.



6.4.8 **MAGNETIC OSCILLATOR:** Magnetic oscillation is useful for oscillating the arc either in X-axis or in Y-axis and in some instances it can even rotate the arc to get desired weld bead.



The above are some of the common welding aids. The list is long. Anything that increases the weld-on time & helps in doing the welding in down-hand position or increase the automation of welding can be termed as Weld Aid.

7. CONCLUSION: The past of welding technology was good, the present is encouraging and the future is excellent. The expectations of clients shall be high and the pressure on price will be heavy in future. The welding manufacturers shall have to be innovative to accept the challenge. The expected requirement for qualified welders and welding personnel shall be very high. The revolution in design of power sources and improvement is processes will be the call of the day. The market of weld automation will be increasingly demanding to achieve high quality defect free weld with minimum skill requirement.