# TODAY'S WELDING EQUIPMENTS - FROM MAINTENANCE ENGINEER'S EYE

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## INTRODUCTION

Sir Humphry Davi Struck a first welding arc in 1809 with a battery of voltaic cells signifying the use of a first D.C. power source. As production, transmission and distribution of alternating current became economical, A.C.welding power sources came into existance. A.C. welding power sources found wide applications in industries because these are least expensive, light weight and small in size. However, instability of the welding arc due to pulsating nature of the current has prevented the use of these power sources in all types of welding processes. Thus a necessity was felt to design a D.C. power source to weld specific material with special electrodes. This led to the development of motor generator set (either run electrically or diesel engine driven) and D.C. rectifier. Although motor generator sets provide almost constant welding current, these are increasingly being replaced by the D.C. rectifier due to higher initial cost, higher maintenance cost, noisy operation and least efficient (Figure 1). Further development in electronics has led to replacement of the D.C. rectifier having silicon diodes with thyristorised and transistorised power sources.

All these welding equipments have been designed and manufactured keeping in view of requirement of quality and nature of welding. In the process, easy maintainability of the welding equipments has been given less importance. This has created various difficulties before the maintenance engineer in the maintenance of welding equipments. Although now-a-days, many equipments, to suit various arc welding processes such as GTAW, GMAW, and Plasma arc welding etc. have found applications. In industries, this paper limits the study to welding transformers and welding rectifiers only.

## Welding Equipments used in Bhilai Steel Plant

For an integrated steel plant, importance of maintaining the technological and structural parts in good working condition, to sup-

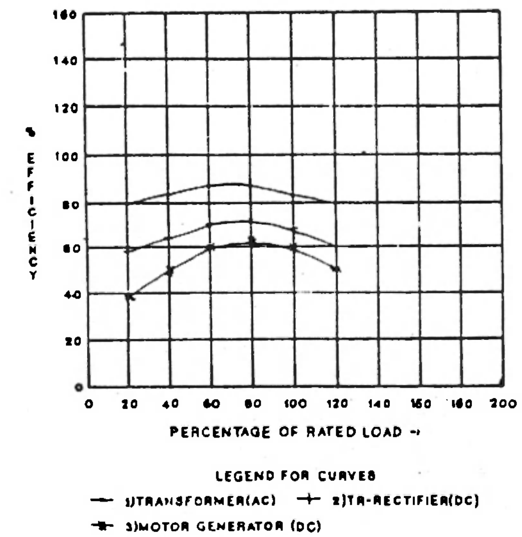



*Fig 1 : Effect of operating load (As a percentage of rated load) on efficiency of three types of power supplies* port production activities need not be overemphasised. This involves welding activities on a large scale. To cater to this need Bhilai Steel Plant has a fleet of about 212 numbers of welding transformers and 62 numbers of welding rectifiers. At one million tonne stage, the plant had mostly the USSR make welding transformers and welding generators. With the fast progress made in the manufacture of welding equipments in India, USSR make equipments are being phased out, primarily due to non-availability of spares.

In Bhilai Steel Plant, we are using both welding rectifiers with silicon diode and thyristorised welding rectifier both are being used.

## National and International Standards on Welding Equipments.
## National Standards

***Indian standards***

These cover the requirements for :

* Portable single operator type arc welding rectifier, transformer for manual metal arc welding rectifier, transformer for manual metal arc welding and is generally based on IS : 4559-1968 "Specification for single operator rectifier type D.C. arc welding power source".

* Portable single operator type welding transformer for manual metal arc welding and is generally based on IS:1851-1975 "Specification for single operator type arc welding transformers (second revision)".

* Portable single operator type drip proof metal arc welding motor generator set and is generally based on IS : 2635-1975 "Specification for D.C. electric welding generators (Second revision)".

### Inter plant standard steel industry

Inter plant standardisation of steel industry has been initiated under the aegis of the Bureau of Indian Standards (BIS) and Steel Authority of India Limited (SAIL). This has standardised various aspects of welding equipments under following IPSS :-

* Specifications for Arc welding transformer set is covered under IPSS " 1-07-001-88.

* Specification for Arc Welding rectifier set is covered under IPSS : 1-07-003-88.

* Specification for Motor generator welding set is covered under IPSS : 1-07-003-88.

***International Standards***

There are a number of foreign standards for arc welding equipments of which following deserve special mention.

* British Standard Institution.

* Arc welding plant and equipment : BS-638-1954.

* American Standard Association

* Transformer type arc welding machine : ASA/c 33.2.1956.

* Canadian Standard Association.
Constitution and test of arc welding equipment, transformer type CS A/c 222 No. 60-1959.

* Association of German Electrical Engineers :
Rules for D.C. arc welding generators and convertors - VDD 0540/5.54

## Welding Equipment as seen by a Maintenance Engineer

A maintenance engineer has to integrate his maintenance activities to the larger objective of obtaining quality in welding. This requires proper upkeep of the welding equipment to improve its availability and reliability.

Following are some of the common faults and design requirements as seen by a maintenance engineer in the course of maintaining the welding transformers and welding rectifiers.

### In-turn short circuit

Welding transformer/rectifier may develop in-turn short circuit in the primary on secondary windings due to failure of insulation. This can happen on account of improper cooling of the windings. In turn short circuit in secondary winding foes not cause much con-

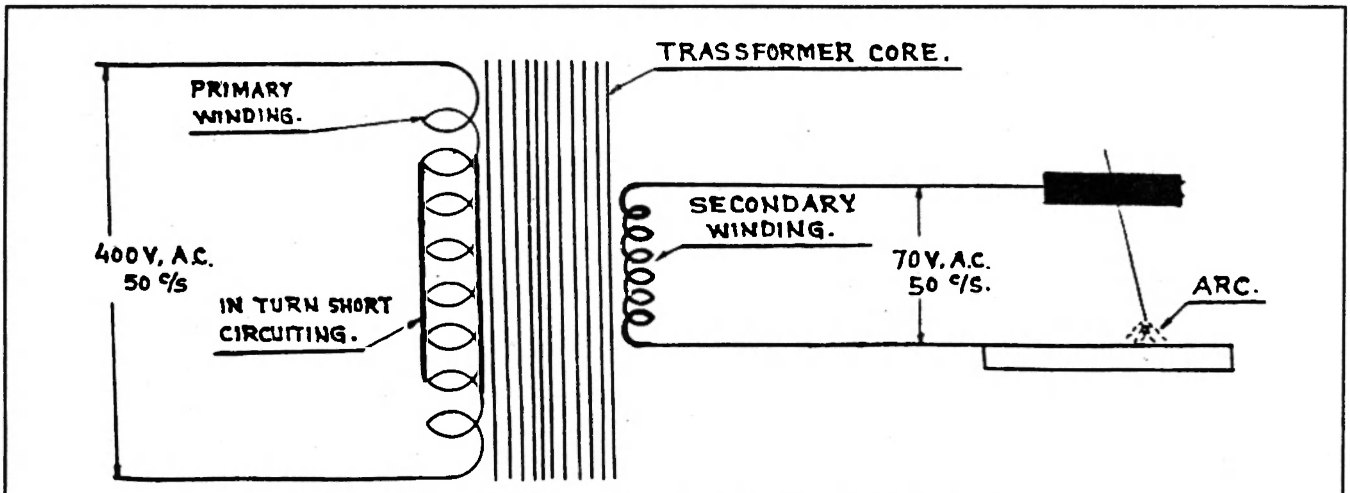



*Fig 2 : In-turn short circuit in primary winding of welding transformer*

cern as the welding will not be possible with the reduced open circuit voltage due to decrease in number of turns in secondary winding. But the short-circuiting of a few turns in a primary winding may convert step down transformer into a 'step up' transformer. This situation is dangerous from the safety point of view (Figure 2).

In order to prevent such remote occurance, we invariably connect welding machine to a 100 amperes M.C.C.B. In the event of partial short circuit in the primary winding, the primary current of the machine will exceed the rated primary current of 100 amperes, the M.C.C.B. will trip as per its "Time Inverse" characteristics.

**Polarity in Welding Rectifier**

When welding with rectifier, it is often required to change the polarity depending on the thickness, kind of metal to be welded and type of electrode. No such provision of changing the polarity from straight to reverse or vice versa is given on the presently available welding rectifiers. Since it requires a trained electrician to change over the polarity, the welder often avoids the trouble of calling the electrician and does the welding with the polarity available irrespective of demand of quality in welding. To make easier for the welder to meet the demand of good quality, manufacturer may design and incorporate a changeover switch to function as a polarity changeover switch. This will not only avoid, the disturbing of well tightended secondary terminals but at the same time, make the equipment ready for quality welding. Figure 3 shows tentative scheme for such type of polarity changeover switch.

**Secondary Terminals**

In any welding equipment, specially the welding transformers and welding rectifiers, the most common and frequent cause of breakdown is the burning of secondary terminals. Normal practice followed by manufacturer as well

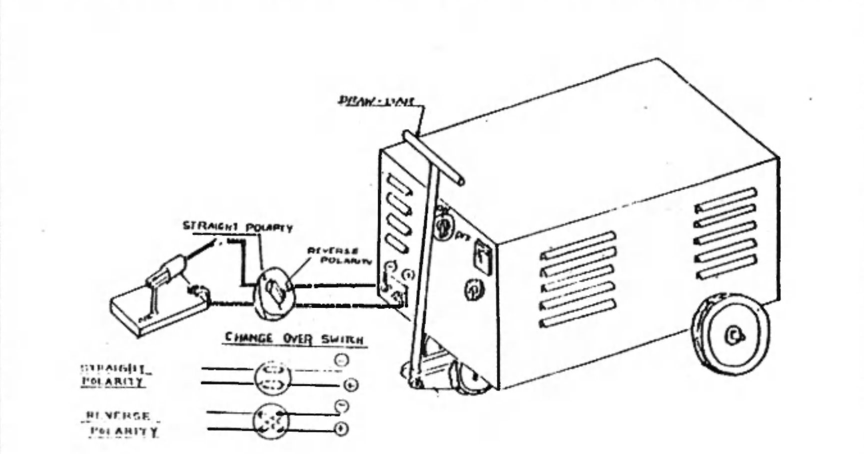



*Fig 3 : WELDING RECTIFIER*
*With polarity change over switch and DRAW BAR*

as user is to bring out the leads of secondary winding on the fabric based textolite plates. They are connected with mild steel nuts and bolts on both sides (inside and outside of the machine). This forms the weakest link in the secondary circuit. Such joints are bound to loosen primarily due to the vibration in the machine. It also happens due to the gap between nut and bolt threads, however small it may be. Once the joints become loose, the heating starts. This further loosens the joints. It again increases the heating. Thus a self destructing process sets in. Ultimately the heat is so severe that it starts melting the lugs, burning of fibre based textolite plate and cable insulation. To minimise such type of breakdown, we have used asbestos plate in place of an ordinary fibre based textolite plate. The results are quite encouraging. Whereas with fibre based textolite plate, the welding equipment underwent breakdown once in fifteen to thirty days, with asbestos plate the breakdown has not occured even after three months. At the same time cost of asbestos plates is much less than the ordinary fibre based textolite plate, reducing maintenance cost and improving welding equipment availability. Asbestos being hygroscopic in nature, may absorb moisture during rainy season and lead to short-circuiting of secondary terminals. This condition can be prevented by giving a coating of epoxy resin based compund "Red gel" on the secondary lead plate of asbestos. Asbestos plate can withstand a temperature upto 250°C.

## Cable Colour Coding and Numbering

Any fault in electrical circuit can be quickly located if the electrical circuit diagram also indicates the cable lay-out. Although electrical fault in a welding transformer with its simple circuit can be rectified quickly, it takes more time in welding rectifier which has comparatively a complicated circuit. In the absence of proper numbering of colour coding of wire, the fault finding becomes all the more difficult. Present day rectifiers of many makes do not provide the colour coding or numbering, thus compounding the problem of fault finding.

To overcome this difficulty, we have numbered the wires at the time of locating the faults.

## Overloading of Welding Equipments

Under IPSS, welding equipments have been given two current ratings, one at 60% duty cycle and other at 100% duty cycle. The welding equipments with drooping characteristics (Figure 4) are mostly employed in MMAW and seldom used for semiautomatic or automatic welding process. Thus, most of the equipments work at 60% duty cycle only. In actual practice however welding equipment is always subjected to more than 60% duty cycle. For a 60% duty cycle with a normal cycle time of five minutes the welder should take two minutes to change the electrode and scrapping of the slag. However, in order to complete his job early he takes less than thirty seconds, some time even less. Thus the machine is subjected to 90% duty cycle.

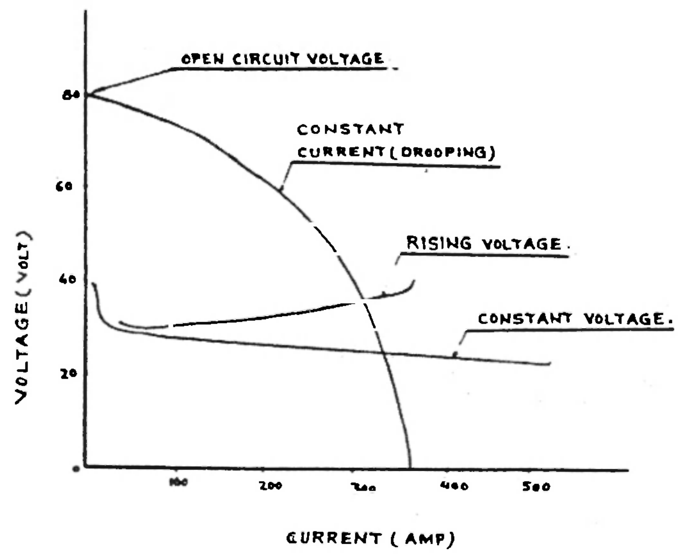



*Fig 4 : Volt - Ampere charecteristics of a welding power source*

It is our common observation that a four gauge (6.3 mm) electrode is preferred by the welders, who stress on faster production. A four gauge electrode approximately requires a current of 230-250 Amps. Voltage drop in the secondary circuit due to various reasons such as long secondary cable, loose connections and longer arc length requires the setting of current higher than what is actually required i.e. higher than 230-250 Amps. In actual practice, it is more than 300 Amps. rated current of a smaller machine at 100% duty cycle. Thus welding machine is overloaded. If a power supply is operated at its rated capacity but beyond its rated duty cycle, overheating will occur possibly resulting in the failure of windings. Overheating will also occur if a power supply is operated beyond its rated capacity unless the duty cycle is reduced. This is one of the reasons why a maintenance engineer has to advise for welding transformer/welding rectifier with a current rating of 400 Amps. at a duty cycle of 100%. Other reason for selection of higher capacity machine is to use it for gouging.

Actual duty cycle of the welding machine can be calculated with following formula if a machine is required to supply current beyond its rated capacity.

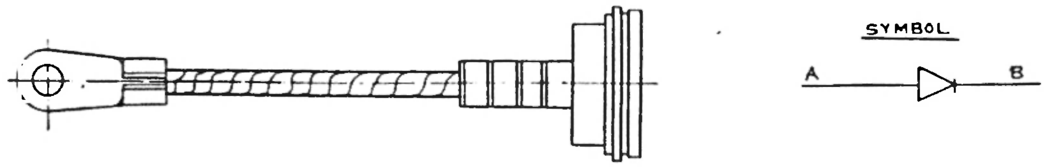
$$\text{Desired duty cycle in \%} = \frac{(\text{Rated Current})^2}{(\text{Desired current})^2} \times \text{Rated duty cycle in \%}$$

**Failure of Silicon Diodes in Welding Rectifier**

Although the selection of proper silicon diode, matching the rating of the machine and proper cooling reduces its chances of failure significantly, but still silicon diodes do fall. Silicon diodes fall due to its overheating. In a welding rectifier, the overheating of silicon diodes may occur due to the failure of cooling fan or deposition of dust over their sinks. Normally, in presently available welding rectifiers, a thermostat is fitted on the sinks. It senses the overheating of silicon diodes and trips the auxiliary rectifier unit of the machine thus decreasing the welding current to safer limits. In this condition welding will not be possible due to reduction in current, reducing the chances of overheating of winding. But some times the thermostat itself becomes non-functional. Non-functional condition of the thermostat due to its often failure or failure of the circuit in which it is connected may overheat the silicon diodes. This may cause the failure of the silicon diodes. In this condition, phase to phase short circuiting of the secondary A.C. voltage will take place. If this goes unnotice, it may result into overheating of the secondary winding and its subsequent burning. Once this happens, it forces the welding machine out of use for a couple of weeks.

To prevent such occurence, a maintenance engineer has to check the proper working of the entire cooling system. For this, regular cleaning of welding machine (specially the sinks) with compressed air, has to be carried out every fifteen days. The fre-

*Fig 5 : Silicon Diode*




FOR A HEALTHY DIODE : WHEN 'A' IS POSITIVE WITH RESPECT TO 'B'. THE DIODE CONDUCTS. WHEN 'A' IS NEGATIVE, IT DOESN'T

FOR DEFECTIVE DIODE : THE DIODE CONDUCTS IRRESPECTIVE OF WHETHER 'A' IS POSITIVE OR NEGATIVE WITH RESPECT TO 'B' quency of cleaning may be decided according to the more dusty or less dusty environment. Secondly, it must be ensured that cooling fan always works during the operation of the machine. Thirdly, a periodic check up of silicon diodes for its proper functioning (one way closed, other way open) will ensure against overheating of the secondary windings (Figure 5).

## Spatter in Welding Equipments

Spatter is one of the problems. In the welding equipments, a maintenence engineer is confronted with A.C. welding equipments give less spattering than D.C. welding equipments due to the pulsating nature of the current in the former. The biggest contributor to the spattering in a welding equipment is the phenomenon of arc blow. Arc blow is more prominent in D.C. welding machine than in A.C. welding machine, hence more spattering. During welding with rectifier, a magnetic field is set up around and perpendicular to the electrode. This magnetic field becomes unbalanced at the start and finish of the welding thereby contributing to the maximum spattering. Spattering is observed less in the centre of the base metal being welded. Secondly, longer arc length also causes spattering. Whenever the arc length is more than or equal to the diameter of the core of the electrode the arc becomes unstable and the metal transfer from the electrode to the weld pool takes place in bigger droplets which scatter in the form of weld spatter. This spatter will coarse in appearance. Thirdly, the nature of electrode is also responsible for the spattering if the electrode covering has improper composition and non-uninform consistency. Fourthly, if the welding current is too high in comparison to normal current of speific electrode, spatter occurs. This spatter will be fine in appearance. These are mostly the factors which are beyond the control of a maintenance engineer. The role of a maintenance engineer in preventing the spattering in a weld-

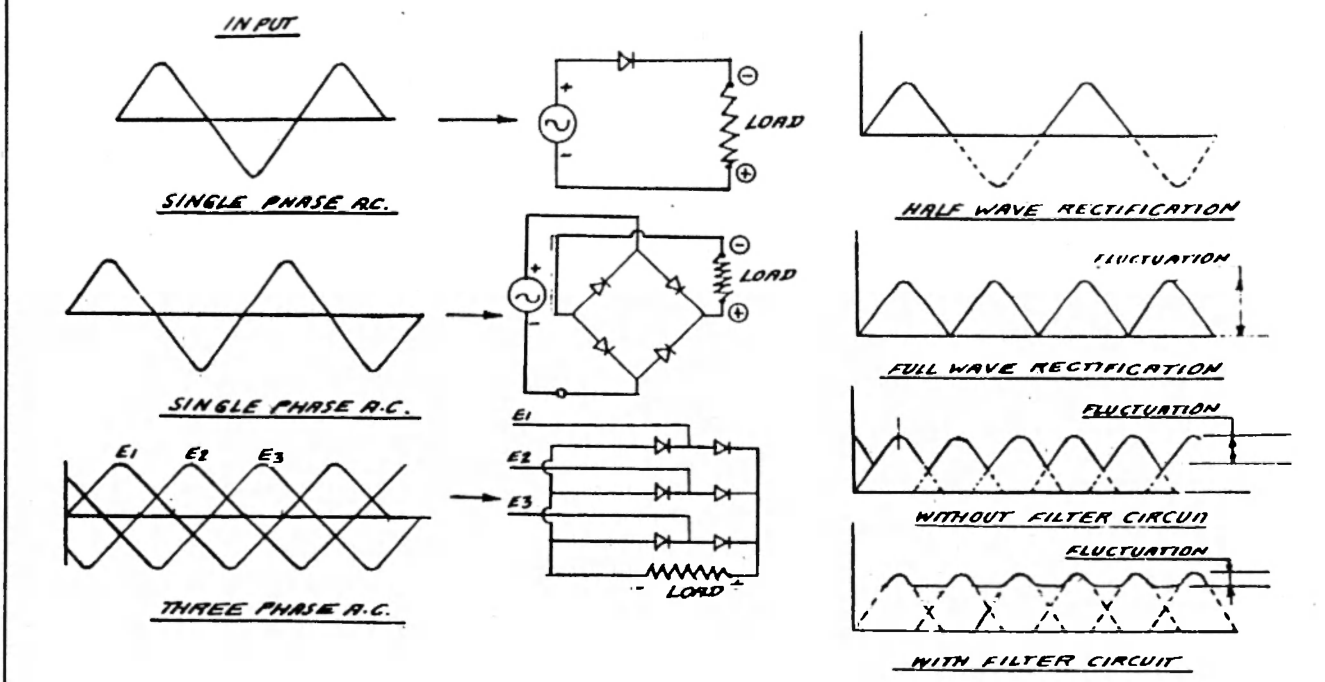



*Fig 6 : Conversion from A. C. to D. C. with Silicon Diodes* ing equipment is limited to the extent that the equipment should not give a fluctuation in the output current. In other words, fluctuation should be as minimum as possible. If there is wide fluctuation of the welding current, the arc will be unstable and hence prone to produce spattering. In some electro chemical application, such as charging of storage batteries and electroplating unidirectional pulsating current may be satisfactory but in welding rectifier, a smooth output current with zero pulsation is required to obtain stable arc. It is because of this reason filter circuits are employed for smoothing out the pulsations in the output current. Pulsation in the output current of a rectifier is indicated by ripple factor, Higher the ripple factor more will be fluctuation in the output current (Figure 6).

It has been observed that spattering in a welding rectifier with all other conditions remaining constant, increases with increase in the ripple factor due to failure of the filter circuit. Hence, a maintenance engineer has to periodically check up for the failure of a filter circuit.

It has also been observed over a period, a thin film of oxide of silver-irridium and dust accumulates between the sink and the diode base. This causes high resistance to current through that particular diode, increasing voltage drop across it. This will unbalance the output current. Hence, the ripple factor will increase. This will lead spatter to occur. In order to reduce the spatter, a maintenance engineer should periodically clean this film to obtain spatter free welding.

### Provision of Draw Bar

it is observed that many of the standard make welding transformers and rectifiers have no provision of draw bar. This makes the transportation of the equipment difficult (Figure 3).

### Dimension

Overall dimensions of welding transformer and welding rectifier with same type of cooling differ from make to make. One make welding equipment may require more space in comparison to other. Such variation not only affects the house keeping but also creates difficulty in transportation. Now-a-days floor utilisation is increasingly being given more importance in the design of fabrication shops. If machines are designed with limitation of overall dimensions, it improves house keeping. Figure 7 shows the dimensions of welding equipments as per American Society for Metals.

## CONCLUSIONS

Common faults observed as above can be rectified by maintenance engineer collectively. If a manufacturer supplies a machine, designing it without keeping the provision of easy maintenance, the cost of maintenance will increase. If user deviates from using the machine with technological discipline, it will again increase the cost of maintenance. Similarly, a maintenance engineer should constantly inspect and periodically do maintenance of machine to increase its reliability and availability. The cause of quality weld can be best served if there is constant and periodic interaction between manufacturer, user and maintenance engineer.

SOURCE : (HANDBOOK OF AMERICAN SOCIETY FOR METALS)

| Typical floor space required in mm. | Typical output ranges in Amps |
|---|---|
| LIGHT DUTY TRANSFORMER (AC) | |
| 355.6 x 355.6 | 30 TO 180 |
| | 35 TO 295 |
| HEAVY DUTY TRANSFORMER (AC) | |
| 558.8 x 736.6 | 50 TO 375 |
| | 50 x 625 |
| 711.2 x 1143 | 100 TO 1300 |
| LIGHT DUTY MOTOR GENERATOR (DC) | |
| 457.2 x 660.4 | 40 x 260 |
| HEAVY DUTY MOTOR GENERATOR (DC) | |
| 482.6 x 914.4 | 30 TO 450 |
| 482.6 x 999.8 | 40 TO 600 |
| 482.6 x 1066.8 | 50 TO 800 |
| LIGHT DUTY TRANSFORMER RECTIFIER (DC) | |
| 457.2 x 990.6 | 25 TO 425 |
| 609.6 x 1117.6 | 25 TO 525 |
| HEAVY DUTY TRANSFORMER-RECTIFIER(DC) | |
| 558.8 x 990.8 | 40 TO 375 |

*Fig 7 : Space requirement and out put range of A.C. and D.C. power supplies for Shielded Metal Arc Welding*

## REFERENCES


(1) Metals Handbook, Eight Edition Volume - 6. American Society for Metals.

(2) Andrew D Althouse, Calt H. Turnquest, William A Bowditch - Modern Welding.

(3) Boniface C Rossi, Welding Engineering