Power Sources for Arc Welding

-Welding Equipments and control Methods-

By

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DAIHEN Corporation
1. General Description for welding equipment

(1) What is an arc welding equipment?

Fig 1.1 Arc welding equipment
(2) History of Welding Power Source

Fig 1.2 AC Power Source

Fig 1.3 DC Power Source
<table>
<thead>
<tr>
<th>Material</th>
<th>Process &amp; Polarity</th>
<th>Penetration</th>
<th>Welding width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel (M.S.)</td>
<td>MIG, TIG</td>
<td>Average</td>
<td>Average (wide)</td>
</tr>
<tr>
<td>DC, AC</td>
<td>DEEP</td>
<td>Shallow</td>
<td>Large (wide)</td>
</tr>
</tbody>
</table>

- **Material:** Mild Steel (M.S.), Aluminum (Al), Copper (Cu), Stainless Steel (Stainless), etc.

- **Process & Polarity:** MIG, TIG, DEEP

- **Penetration:** Average, Shallow

- **Welding width:** Average (wide), Large (wide)

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**Latest 350A CO2/MAG Machine**

- **Size:** Transformer, inside cart, integrated circuit (IC)
- **Weight:** 49.5 kg, wt: 41.1 kg
- **Frequency:** 50 Hz, 60 Hz
- **Output:** 50 Hz, 60 Hz
- **Watt:** 60 Hz
- **Design:** DEEP, wire electrode melts more

- **Tungsten electrode melts more when it has DC polarity.

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- **Extrude film is cleansed from all surface when electrode is 8 V Bar 15 Vener Rod electrode cleans itself when it has 8 V Bar.
Drooping/Constant Current Characteristic
- AC, DC, AC/DC Power Source

**Stick Electrode Welding**

- **Holder**
- **Stick**
  - **Metal**
  - **Flux**
- **Shielding**
  - **Gas**
  - **Arc**
  - **DC or AC**
- **Base Metal**

**Diagram Notes**
- SMAW < 20% in Japan
- 35% (USA, Europe, Australia)
- DC is used when stable arc is required (MIG concern), ex to weld steel, low-alloy steels (< 5% alloy elements) sheet metals, pipes.
Drooping/Constant Current Characteristic
AC, DC, AC/DC Power Source

Tungsten Inert Gas (TIG) Welding

- Drooping/Constant Current Characteristic
- AC, DC, AC/DC Power Source

![Diagram of TIG Welding](image)
Drooping/Constant Current Characteristic
AC, DC, AC/DC Power Source

Stick Electrode Welding (SMAW)

Holder
Stick
Metal
Flux

Shielding gas
Arc (gas generated)

DC or AC

Base Metal

SMAW < 10% in Japan
35% (USA, Europe, Australia)

DC is used when stable arc is required (MT concern), ex to weld
SS, CS steel, low-alloy steels (< 5% alloy elements), sheet metals, pipes.
(SMAW) steels, CS steels, alloy steels, non-ferrous metals when (Ni alloy, Cu-alloy)
CO₂/MAG gas shielded arc Welding

- (Ar + CO₂) = MAG
- CO₂ only = CO₂ welding (called in Japan)
- CO₂ + 100 Ar = MIG

DC power source is used (usually)
AC/DC is also available (expensive)
**Self-Shielded (Non-Gas Shielded) Arc Welding**

- Constant Potential Characteristic
- DC Power Source (is used)

Diagram:
- Wire feeder
- Nongas Wire
- Contact tip
- DC or AC
- Shielding gas
- Flux
- Arc
- Base Metal

Notes:
- Disadv: Arc sometimes unstable, spatter
- Adv: Effective than SMAW, weld speed than SMAW
- Drooping/Constant Current Characteristic
- AC, DC Power Source

Submerged Arc Welding (SAW)

- Wire feeder
- Contact tip
- Flux
- Arc
- Base Metal
- DC or AC

Detailed:
- Arc is not seen b/c is covered by flux.
- No shielding gas required, but flux is supplied while welding.

Briedly:
1) Needed vacuum system to collect left over flux.
2) Only used for flat position.
3) Used thick plates only b/c it is very high (not used for thin plates).
4) Weld speed
### Classification of welding power sources

<table>
<thead>
<tr>
<th>By Current</th>
<th>Welding Process</th>
</tr>
</thead>
</table>
| **AC** Arc Welding Power Source  
  (AC= Alternating Current) | * Stick Welding  
  * Tig  
  * SAW |
| **DC** Arc Welding Power Source  
  (DC= Direct Current) | * Stick Welding  
  * Tig  
  * SAW  
  * CO2  
  * MIG |
| **AC/DC** Arc Welding Power Source  
  (but supplied by 1 power source, machine) | * Stick Welding  
  * Tig |

<table>
<thead>
<tr>
<th>By Volt/Ampere Characteristics</th>
<th>Welding Process</th>
</tr>
</thead>
</table>
| **Drooping / Constant Current** (C.C.) Type Power Source | * Stick Welding  
  * Tig  
  * SAW |
| * Arc is Stable  
  (ΔV >> ΔI) | |
| b/c V drops | |
| **Constant Potential** (C.P.) Type Power Source | * CO2  
  * MIG  
  * FCAW |
| * Arc is Unstable  
  (ΔI >> ΔV) | |
| V = constant when I varies | |

**Fig 1.4 Classification of arc welding power source**
### (4) Structure of welding power sources

<table>
<thead>
<tr>
<th>Output control</th>
<th>Structure of power circuit</th>
<th>Output characteristic AC/DC/DC/DC</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving core</td>
<td></td>
<td>O       O               O</td>
<td>Simple</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Add to rectifier for DC</td>
</tr>
<tr>
<td>Tap changer</td>
<td></td>
<td>O       O               O</td>
<td>For CP characteristic</td>
</tr>
<tr>
<td>Slide transformer</td>
<td></td>
<td>O       O               O</td>
<td>For CP characteristic</td>
</tr>
<tr>
<td>Magnetic amplifier</td>
<td></td>
<td>O       O               O</td>
<td></td>
</tr>
<tr>
<td>Combination of leakage transformers</td>
<td></td>
<td>O       O               O</td>
<td>For High current</td>
</tr>
<tr>
<td>Thyristor</td>
<td></td>
<td>O       O               O</td>
<td>For DC in 3 phases</td>
</tr>
<tr>
<td>Transistor chopper</td>
<td></td>
<td>O       O               O</td>
<td>Applied for pulse</td>
</tr>
<tr>
<td>Transistor inverter</td>
<td></td>
<td>O       O               O</td>
<td>Lightweight small size transformer</td>
</tr>
<tr>
<td>Analog transistor</td>
<td></td>
<td>O       O               O</td>
<td>High speed response</td>
</tr>
<tr>
<td>Engine drive &amp; thyristor</td>
<td></td>
<td>O       O               O</td>
<td>Precision control</td>
</tr>
</tbody>
</table>

**Fig 1.5 Structure of welding power sources**

\[ V_o = 80 \sim 90 \text{V (no load V)} \]

- Transformer input 240 V
- Tap changer
- Use to \( \frac{1}{4} \) V from \( 1 \text{V (high)} \) to \( 2 \text{V (low)} \)
- Use insulated wire instead
- 3. \( \frac{1}{4} \text{top = } \frac{1}{4} \text{output (0 to 5 top)} \)
- \( \frac{1}{4} \text{gap = } \frac{1}{4} \text{V(low)} \)
- \( V_{\text{output}} \text{ (0 to 5 top)} \)
- \( V_{\text{input}} \text{ (0 to 5 top)} \)
- \( V_{\text{output}} \text{ (0 to 5 top)} \)
- \( V_{\text{input}} \text{ (0 to 5 top)} \)
- \( V_{\text{output}} \text{ (0 to 5 top)} \)
- \( V_{\text{input}} \text{ (0 to 5 top)} \)
(5) Changes of output control methods

(a) GMA Welding Power Source

(b) GTA Welding Power Source

Fig 1.6 Change and spread of control method for welding power source in Japan
2. AC Welding Power Sources

(1) Principle and structure of AC Welding Power Sources

**Fig 2.1 Principle of normal power transformer**
- When V is applied, I flows.
- Flux is generated in iron core.
- Induced emf in 2nd winding (coil)

\[ V_2 = \frac{V_1}{N_1/N_2} \]

**Fig 2.2 Principle of AC welding transformer**

- Leakage flux increases, welding current decreases.
- Leakage flux decreases, welding current increases.

**Fig 2.3 Structure of AC welding power source**
(2) Characteristics of Leakage Transformer

Equivalent circuit

\[ I_1 \quad I_2 \quad r \quad x \]

\[ E_{20} \quad Z_0 \quad E_{12} \quad R_L = R_L \]

\[ I_2 R_L = I_2 R_L \]

\[ I_2 X_L = I_2 x \]

Voltage diagram

Current diagram

(7)
a) Electrical diagram of the welding transformer

Even if the voltage fluctuation is small, the current fluctuation is large. Therefore, arc is unstable.

Even if the voltage fluctuation is large, the current fluctuation is small. Therefore, arc is stable.

Fig 2.4 Equivalent diagram of welding transformer

Characteristics of power supply

a) CP Type

b) Drooping Type

Fig 2.5 Why is the drooping type power source used to the manual welding?
Electric 3 factors
1) Resistor: $\frac{\text{V}}{\text{I}}$
2) Inductor: $\frac{\text{V}}{\text{L}(\text{core turning})}$ (core turning). If V applied to reactance, flux in core flows.
3) Capacitor: $\frac{\text{V}}{\text{C}}$

Variable Reactor

Variable Resistor

b) $i=0$ (No Load)

$V_0$

$V_0 = e_0$

(Vo is called “No Load Voltage” or “Open Circuit Voltage”)

c) Reactive Load

$V_0$

$e_0 = IR$

Resistive type power supply can not supply the reignition voltage $V_p$, therefore arc can not be kept stable.

c) Resistive Load

$V_0$

$e_0 = IR$

d) Arc Load

$V_0$ (No Load Voltage)

$i$ (Arc Current)

$V_p$ : Arc Welding Voltage

Arc Voltage

Fig 2.6 Why is the leakage transformer used?
3. DC Welding Power Sources

(1) Schematic Diagram for DC Welding Power Sources

(a) Composition of DC Arc Power Source

(b) Schematic Diagram of Rectifier Circuit

Fig 3.1 Principle of Transformer-rectifier

- Turn Over Switch (Tapping switch)
- Tapped Transformer
- Rectifier
- Inductor

(a) Tap Change Type
- carbon brush slides to gap

(b) Slide Turn Type

Fig 3.2 The simplest method of output control
**Fig 3.3 Thyristor type DC welding power source**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Diode</th>
<th>Thyristor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode</td>
<td>Cathode</td>
<td>Anode</td>
</tr>
</tbody>
</table>

- **Direction of current**: Only flows from anode to cathode.
- **Waveform of output voltage**:
  - Time: $0 = 0, \theta = \pi/2, \pi, \theta = 3\pi/2$.
  - Effective value: $E_{d} = 0.45 E$

- **Average voltage of output ($E_d$)**:
  - $E_{d} = \frac{1}{2\pi} \int_{0}^{\pi} E \sin(\theta) d\theta$
  - $E_{d} = \frac{1}{2\pi} \frac{1}{2} E$

**Fig 3.4 Fundamentals of thyristor**

- Thyristor: dc rectifier tapped (reactor/inductor).
- Thyristor: direct-fed tapped (reactor/inductor).
- Rectifies AC to DC X emfs output power.
- Diode rectifies: we use tap in transformer, diode cannot control output power.
(2) Principle of Thyristor type DC Welding Power Sources

The principle of Operation of an Interphase Reactor

Trigger pulse for system A
Trigger pulse for system B

Current 1: System A operating
Current 2: System B operating

Maximum output voltage
Reduced output voltage

The Thyristor controls the output current by changing the triggering time, we can control the output power.
(13)

Thyristor

A (Anode)

G (Gate)

K (Cathode)

apply V → \( V_{cc} \) on \( Tr_2 \) base

- when pulse is applied to gate (3) \( Tr_2 \) conducts to cathode (gate - \( Tr_2 \) base - cathode)

- Then \( I_2 \) flows from 1 to 2. And gate (3) volt is stopped on 1 to 2

\( Tr_1 \) and \( Tr_2 \) conduct simultaneously from 1 to 2 as follows:

\[ I_{anode} - Tr_1 - \left( I_a + I_g \right) \]

\[ Mn_{T} - Tr_2 - \text{cathode} \]
(a) Constant Current Characteristics

Brief goal: make $I_{\text{weld}}$ constant
- To make $I_{\text{output}}$ constant
  - $V_{\text{gap}}$ increases $I_{\text{weld}}$ is needed
  - Power, trigger signal moves to left, for power & vice versa

(a) Constant Potential Characteristics

**Fig 3.5 Feedback control**
4. Duty cycle

Duty Cycle = \( \frac{t_a}{t_a + t_b} = \frac{t_a}{T} \)

% Duty Cycle = \( \frac{(Rated\ Current)^2}{(Load\ Current)^2} \times (Rated\ Duty\ Cycle) \)

\[ T = 10 \text{ minutes} \]

\[ t_a, t_b \]

**CAUTION:** The current rating of some individual components may be limited. Do not expect a power supply to operate at low duty cycles and high current unless the current is within the capacity (rating) of all the individual components (diodes, fuses, contactors, etc.)

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**Example:**

Find: The output current of a 100 ampere 69% duty power source, when it is operated on a 100% duty cycle.

Answer: \( 100 \times \sqrt{0.6} = 77.5 \text{ amps} \)
5. Stability of arc welding

(1) Stability for CP Type Power Sources

Self Regulation of CP Power Supply

\[ L_1 > L_0 > L_2 \]
\[ V_m > V_m^0 > V_m^2 \]
\[ V_f : \text{Wire Feeding Speed} \] \hspace{1cm} (V_f = \text{const.})
\[ V_m : \text{Melting Speed} \]

Application: CO2 MIG Welding, Submerged Arc Welding

Fig 5.1 Constant wire feeding with CP type power source

Fig 5.2 Example DC motor control circuit
(Constant wire feed speed)
(2) Stability for CC Type Power Sources

\[ V_a : \text{Arc Voltage} \]
\[ V_f : \text{Wire Feeding Speed} \]
\[ V_m : \text{Melting Speed} \]

**Fig 5.3** Drooping or CC type power source and arc length control

**Fig 5.4** Example of variable feed speed control circuit
(3) Role of DC Reactor

**Welding power source**

- **L**
- **R**
- **E**

**Wire feed**

- **I**
- **V**

**Fig 5.5 The role of DC reactor**

1. **Short-circuiting mode**
   - Short-circuiting arc welding

2. **Current**
   - Average current graph showing points a, b, c, d, e, f, g, h, i, j.

3. **Voltage**
   - Average voltage graph showing points a, b, c, d, e, f, g, h, i, j.

- **Smooth TIG, Gauges high & leaders change**
- **Flux**
- **L**
- **a**, **b**, **c**, **d**, **e**, **f**, **g**, **h**, **l**
- **Current value**
- **Voltage source**
- **Arc current**
- **Voltage for arc start**

(18)
Fig 5.6 A - V Curve

Fig 5.7 Definition of time constant
(4) Pulse Current Control

Arc voltage waveform

Current waveform

Fig 5.8 Pulse waveform

<table>
<thead>
<tr>
<th>Change of extension</th>
<th>Pulse current control</th>
<th>Pulse width control</th>
<th>Pulse frequency control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lp</td>
<td>lp</td>
<td>lp</td>
</tr>
<tr>
<td></td>
<td>lp</td>
<td>lp</td>
<td>lp</td>
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<td></td>
<td>Tp</td>
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<td></td>
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<td>Tp</td>
<td>Tp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>l'</td>
<td>l'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 5.9 Principle of arc length control
6. Arc striking method in TIG welding

![Diagram of arc striking method]

**Fig 6.1 Touching start method**

**Fig 6.2 HF (high-frequency) arc striking method**

**Fig 6.3 DC high-voltage arc striking method**

Notes:
- To energize arc, we apply ~7V.
- Separation 2-3 mm.
- High voltage frequency causes spark.
- High-voltage frequency can flow on surface of body.
- If frequency is big, no damage to body.
- Once arc started, it continues.
- HF ~3kV may damage other components of machine if not well insulated.
- AC normally used (cheap, safe than DC for electric shock).
- DC is expensive, DC voltage.
7. Sequence control

Fig 7.1 Crater fill: OFF
Fig 7.2 Crater fill: ON

Fig 7.3 Crater fill: Repeat

Fig 7.4 Arc Spot

[Handwritten notes: Semi-automatic with wire feeder at end of weld we have to apply voltage to melt remaining last wire crater filling voltage to fill last weld crater whole.]

Within 2 seconds

Arc spot time
Fig 7.5 Up-slope, Down-slope control
8. Inverter controlled power sources for DC Arc Welding

(1) What is the Inverter?

- AC Converter → DC Inverter

Power Devices
- Thyristor
- Bipolar Power Transistor
- Power MOSFET
- IGBT

Fig 8.1 What is the inverter

(2) Application of Inverter

Fig 8.2 Tree of the inverter
(3) Basic operation of the Converter

Fig 8.3 Converter

(4) Basic operation of the Inverter

Fig 8.4 Inverter

Principle of Output control in Inverter power source

Fig 8.5 Pulse Width Modulation

Fig 8.6 Pulse Frequency Modulation

- Some adequate freq, shall be kept & regular.
- "DC current is converted to AC; the frequency becomes very high, but does remain constant."
(5) Structure and Operation of Inverter Controlled Welding Power Sources

**Fig 8.7 Structure of Inverter Power Source**

- Input 3 Phase 50/60Hz
- Prim. Rectifier
- Capacitor
- Inverter
- Transformer
- Sec. Rectifier
- DC Reactor
- Inverter

**Fig 8.8 Operation of Inverter Power Source**

- Primary Rectifiers
- Transistors (Inverter)
- Sec. Rectifiers
- DC reactor
- Transformer
- Output

---

Inverter (output control) + 2-pulse width → + J output

---

Block diagram, current input power

Rectangular waveform (AC)

Sine wave form (AC)

Rectangular waveform (AC)

Rectangular waveform (AC)

Output: 100 Hz

Pulse width modulation (PWM)

PWM: Pulse width modulation; width of signal (A) + J output

Pulse width modulation (PWM)

PWM: Pulse width modulation; width of output (A) + J output

Pulse width modulation (PWM)
## (6) Merits of Inverter Controlled Welding Power Sources

<table>
<thead>
<tr>
<th>No.</th>
<th>Merits</th>
<th>Control method</th>
<th>Number of the output in a second</th>
<th>Comparison of the response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fast Response</td>
<td>High frequency inverter operation achieves fast response.</td>
<td>Thyristor: 100 ~ 300; Inverter: 40,000</td>
<td>Thyristor: 1; Inverter: 130 ~ 400</td>
</tr>
<tr>
<td></td>
<td>At 20kHz Sw. Frequency</td>
<td>Thyristor: 100 ~ 300; Inverter: 40,000</td>
<td>Thyristor: 1; Inverter: 130 ~ 400</td>
<td></td>
</tr>
</tbody>
</table>

### 2 Small and Light Transformer
- Transformer size is in inverse proportion to operating frequency.
- HF operation achieves smaller size of transformer.

\[
E = B \times S \times N \times f \\
E = \text{Electric Capacity of Transformer} \\
B = \text{Magnetic flux density} \\
S = \text{Core area} \\
N = \text{Number of winding} \\
f = \text{Operating frequency}
\]

> ![Equation diagram]

### 3 Low Input Power
- Inverter control type converts the input voltage to DC directly, and achieves higher power factor.
- Stopping the inverter operation while welding pause, no-load loss is cut and electric power is saved.

---

- Advantages of transformer: environmentally friendly, low weight, small size, long durability, recover its cost plan, no moveable iron core, 1 year weld.
- Advantages of thyristor: high cost, 10 years power, cost is high (cost), durability 40 ~ 45 years, (durability).
(6)-1 Fast Response

Theory and Response of Welding Power Supplies with Thyristor Control

Double star connection with interphase reactor type

\[ V_o = 1.17E_0 \text{ as } \phi \]

Reference signal + Error Amplifier \rightarrow Gate pulse Generator \rightarrow Output Detector

Output

(28)
Theory and Response of Welding Power Source with Inverter Control

[Full - Bridge Type]

\[ V_{on} = \frac{1}{T} \frac{E_o}{E_s} \]

\[ T = 0.1 \text{ ms} \] (In the case of 10 kHz operation)

Nyquist's Theory: Frequency of System Response < + Operating frequency.
(6)-2 Small Size and light Weight

\[ e = \frac{E \sin(2\pi f \theta)}{\sqrt{2}} \quad \text{Magnetic Flux} : \Phi \]

Maximum Magnetic Flux
\[ \Phi_m = \frac{E}{4.44Nf} \]

Magnetic Flux Density
\[ B = \frac{\Phi}{S} \]

Maximum Magnetic Flux Density
\[ B_m = \frac{E}{4.44SNf} \]

Transformer size is in proportion to \(SN\)
\[ SN \propto \frac{1}{f} \]

---

**Result of the small size transformer**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Loss (Iron Loss)</td>
<td>(\downarrow)</td>
</tr>
<tr>
<td>Ohmic Loss (Copper Loss)</td>
<td>(\downarrow)</td>
</tr>
<tr>
<td>Power Saving</td>
<td>(\downarrow)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume</th>
<th>44%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>49%</td>
</tr>
<tr>
<td>Floor area</td>
<td>61%</td>
</tr>
</tbody>
</table>

( Volume and weight are less than half of previous machines )

* : Thyristor controlled type

(Unit: mm)

(30)
9. Control

![Diagram showing control processes and automatic settings]

**Fig 9.1** Conception of automatic output voltage adjustment by fuzzy control

**Fig 9.2** Welding current waveform by transistor inverter controlled power source
Fig 9.3  Block diagram of inverter controlled AC pulsed arc welding power source
Fig 9.4 Latest digital controlled inverter welding power source

Fig 9.5 Printed circuit board for Digital control circuit

*Surface mounted pc-board*
Fig 9.3  Block diagram of inverter controlled AC pulsed arc welding power source
10. Standard for Arc Welding Equipments

(1) Standards

International standard

IEC/TC26
- Safety requirements for arc welding equipment

IEC/TC77 CISPR/B
- EMC requirement

ISO/TC44/SC4
- Terms and symbols

IEC60974:
- 1: Welding power sources (published)
- 2: Liquid cooling systems
- 3: Arc striking and stabilizing devices
- 5: Wire feeders
- 6: Welding power sources for limited duty
- 7: Torches (published)
- 9: Graphical symbols for arc welding equipment
- 10: EMC requirements
- 11: Electrode holders (published)
- 12: Coupling devices for welding cables (published)
- 13: Terms for arc welding equipment

IEC62081: Arc welding equipment - Installation and use (published)

Japanese standard

JIS: Japanese Industrial Standard
WES: The Standard of The Japan Welding Engineering Society

JIS C9300: Arc welding power sources
JIS C9311: Voltage reducing devices for AC arc welding machines
WES 6105: Constant voltage characteristic type DC power sources for consumable electrode gas-shielded arc welding
### Identifications of Welding Power Sources

#### a) Identification

- Manufacturer
- Address

#### b) Welding output

<table>
<thead>
<tr>
<th>Type</th>
<th>Duty cycle</th>
<th>Current Range</th>
<th>Serial number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Hz</td>
<td>X</td>
<td>15 A / 20.6 V to 160 A / 27 V</td>
<td>ISO / IEC 60974-1</td>
</tr>
<tr>
<td>60 Hz</td>
<td></td>
<td>160 A / 130 A / 100 A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>26 V / 25 V / 24 V</td>
<td></td>
</tr>
</tbody>
</table>

#### c) Energy input

- Voltage: U₁ = 230 V
- Input: Imax = 37 A
- Output: I₀ = 22 A

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### Fig 10.1 Examples of rating plates

Three-phase rotating frequency converter

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Handwritten notes:
- Feeding: 380 V for 230 V doesn't work
- Voltage: 330 V for 230 V doesn't work
- Magnetism contactors may burn from high voltage, fan motor may burn transformer, fuse is used.
(3) Warning symbols for safe operation

- **Electrical (Shock)**
- **Fume**
- **Protection from Optical radiation**
- **Sharp wire**
- **Falling object**
- **Falling object**
- **Flammable or Explosion chemicals (fuel, oil, etc.)**
- **Entanglement**

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- **No load volt**
  - \( V_0 = 80-90 \text{V} \)
- **3 people/year may die**
- **3 people/year may die**
- **Device to \( V_0 \leq 25 \text{V} \) (using small transformer)
1. About shielded arc metal welding

Recently, the technology of arc welding has improved so much, and the shielded arc metal welding is widely used as an essential welding among various arc welds that are used in diverse sectors. The A.C. arc welding is mainly used in this shielded arc metal welding. In comparison with other arc welds (CO2, MAG and MIG welds, TIG weld), the shielded arc metal welding has features below.

<Advantages>
① Simple machine and low equipment expenses
② Easy welding and easy setting of weld
③ Sufficient portability and using feasibility in windy places
④ Easy maintenance because of simple structure of welder

<Disadvantages>
① Non-applicability for automation and mechanization
② Non-continuous welding and remainder of electrode
③ Time-consuming slag elimination after weld

2. Principles of shielded arc metal welding

The shielded arc metal welding is the one to melt an electrode and a base metal by utilizing the heat generated from the arc between the electrode with the coating flux and the base metal. The coating flux applied to the electrode enhances the stability of arc and produces the gas covering the arc periphery and becomes the slug to inhibit oxygen and nitrogen in the air from intruding into the molten metal and causing bad influence.

![Diagram of shielded arc electrode](image-url)
3. Principle and structure of A.C. arc welding machine

3.1 Output adjustment of A.C. arc welding machine

As a mean to adjust the welding current in the A.C. arc welding machine, the movable core is applied to the most A.C. arc welding machines currently used. In the A.C. arc welding machine of movable core type, the fixed core has an input winding and an output winding, and the movable core for the current adjustment is allocated between the input winding and output winding as shown below.

The change of the movable-core position alters the amount of leakage flux in the transformer and adjusts the output current.

The A.C. arc welding machine has the drooping characteristic in which the output voltage declines as the welding current increases because of this movable core and the transformer structure. This characteristic steadily produces the arc and maintains its stability in the A.C. arc welding machine.

Most of the flux produced from the input winding passes through the movable core and hardly passes through the output winding, which causes the output becoming small.

Most of the flux produced from the input winding passes through the output winding and hardly passes through the movable core, which causes the output becoming big.

Moving distance of movable core → (mm)
3.2 Structure and part arrangement of A.C. arc welding machine

Power switch (SW)
Weld is feasible with rotating the fun by turning it “ON”. It turns “OFF” with abnormal temperature of weld transformer.

Current indication
It displays the setting value of weld current.

Handle
It adjusts the weld current.

Output terminals
They supply the weld output.

<Front of welder>

Back-side of machine

Cooling fan (FAN)
They cool down the inside of the welder.

Input terminals
They apply the input voltage.

Ground terminal
It grounds the welder.

<Back of welder>
Thermostat (TP)
Its contact turns “ON” at the abnormal temperature.

Welder transformer (WT)

<Lateral view of welder inside>

INPUT
SW
TP
FAN
OUTPUT

<Schematic diagram> (AC-arc welder)
4. Voltage reducing device

High no-load voltage (voltage without welding) on the output causes the extreme danger of electrical shock in the A.C. arc welding machine. It is required by Japanese law to use the voltage reducing device for operations at high places above 2m and specific closed places.

There are two types of the voltage reducing devices, "external one" and "built-in one". The external one is used by attached to the welding machine as necessary, and the built-in one is originally incorporated in the welding machine.

4.1 Operation of Voltage reducing device

When there is not the voltage reducing device, no-load voltage (about 85V) always applies to output terminals with the power on (even when the weld is not carried out). If the operator touches electrodes as shown below, the operator may have strong impact from electrical shock and sometimes face the danger resulting in deadly wounds.

< Example of schematic diagram of A.C. arc welding machine without voltage reducing device>
When the voltage reducing device is used, the low voltage (about 20V) of a control transformer (TR1) applies to the output terminals with the power on because of the disconnection between the welding transformer (WT) and the output terminals by the magnetic switch (magnetic contactor). In this case, there is little danger of electrical shock due to the low output voltage even if the operator touches electrodes. The magnetic switch operates when the electrodes touch the base metal, and the resistance between the output terminals gets lower than the activating value (from 2 to 500Ω) of the voltage reducing device set in advance. Then, the continuity between the welding transformer (WT) and the output terminals is secured to enable the welding.

Circuit of voltage reducing device

Example of schematic diagram of A.C. arc welding machine with voltage reducing device>

<Operation sequence of voltage reducing device>
5. Maintenance

**Warning**
You must follow the items below to avoid electrical shock.

- Do not touch any conductive parts inside or outside of the welder.
- When you touch any parts inside of the welder, turn off the line disconnecting switch to disconnect all the input power.
- Carry out maintenance periodically and use the welder after fixing damaged parts.
- Qualified persons or someone knowing welders very well must carry out maintenance and repair to secure safety.

5.1 Regular check

**Daily attention**
- Are there any abnormal vibration, buzz and smell?
- Is there any abnormal heat occurring at cable connections?
- Does the switch have any malfunctions?
- Are any connections and insulations of cables perfect?
- Are there any parts nearly disconnected on cables?
- Before every-day operation, make sure that the voltage reducing device works properly by pushing the inspecting button of the voltage reducing device (for the built-in voltage reducing device).

**Checks in every 3 to 6 months**
- Check any loosened screws, bad contacts by rust and insulations at connections of input and output on the welding machine.
- Check if the enclosure of the welding machine is completely grounded.
- Check how abraded the magnetic contactor is. If the contact is worn out, smooth the contact surface with sand paper. If it is abraded severely, replace it to the new one (for the built-in voltage reducing device).
- Apply the grease with molybdenum disulfide to the sliding surfaces of the guide rails of movable core and feed screws.
- Piling dust between windings of transformer causes the insulation defection. Therefore, remove the enclosure of the welding machine once in every three month and clean the each winding by spraying compressed air with less humid.