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TONGZE ELECTRIC

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# Parallel high frequency manual

Sincerely congratulate and thank for you purchased products from Baoding Tongze Electric Technology Co., Ltd.. Please be sure carefully read this manual before using Baoding Tongze's products and according to the instructions provide in the instruction manual to install and operate equipment. It is possible for our company control method and structure for welder will upgrade at any time, all changes will be included in the new version manual.

## Solemnly statement

The equipment was invested and developed by Baoding Tongze Electric Technology Co., Ltd.. The technological achievements owned by Baoding Tongze Electric Technology Co., Ltd.. For any technology leaks, imitation and other infringing acts, our company will pursue its economic responsibilities according to law. Without permission, the user can not secretly copy and outward spread this manual. Otherwise will damage the good relationship between our company and users.

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## **I . Equipment installation**

### **1.1 Installation environment**

- 1) Indoor installation , grounding of equipment should be well. There is obvious difference for the color between the grounding line and the control line, earth resistance is not bigger than  $4\Omega$ .
- 2) Altitude height is not more than 1000m, otherwise should reduce the rated value to use.
- 3) Ambient temperature does not exceed  $+40^{\circ}\text{C}$ , not lower than  $-10^{\circ}\text{C}$ .
- 4) Air relative humidity is not bigger than 85%.
- 5) Non-fierce vibration, non-conductive dust, without a variety of corrosive gases and explosive gases.
- 6) Installation obliquity is not bigger than  $5^{\circ}$ .
- 7) Installed in a well-ventilated place.

### **1.2. Equipment pre-installation check**

After equipment unpacking, should inspect whether various components are vibrated during the transportation to cause damage and fall off and damp phenomena so on. If discover the above situation should renovate and removal defect before installation and use and please promptly inform this company in case of missing the claim time.

### **1.3 Equipment layout**

#### **1.3.1 Layout and installation**

Whatever the layout mode you use, please note: ① please ensure the length between rectifier cabinets and inverter cabinet is not more than 1.5m, the length between rectifier cabinet and transformer is not more than 0.5m. That would probably save a lot of expensive cables, but also effectively reduce transmission line losses and improve the efficiency for the whole machine. ②The standard cable with the welder is 3m, As for customer site limited cable is not long enough, please self-provided cable. ③ the distance between inductor and output legs of inverter cabinet should not be too long, otherwise it will affect the welder efficiency. Regarding to the detail contents please refer to the attached drawing.

### **1.4 Electrical circuit installation**

#### **1.4.1 Power supply**

- ① Power input wire use copper core cable, when connect to the load should use copper row.
- ② Power input wire hasn't the distinction request for the phase sequence, it is better to connect by the positive sequence so that when maintenance can check the synchronous correspondence relationship between trigger pulse and power input wire. Power input wire A,B,C should connect to the color Yellow, Green and Red and winding the clearly marked.
- ③ The connecting plug of power input wire should be fastness and make the rinse tin processing,

with screw fastening.

#### 1.4.1.1 Power cable selection

① Power input wire use copper core cable to connect, cable's rated voltage is greater than or equal to the rated voltage for power supply of electricity grid, the maximum withstand voltage shall not exceed 15% for the cable rated voltage.

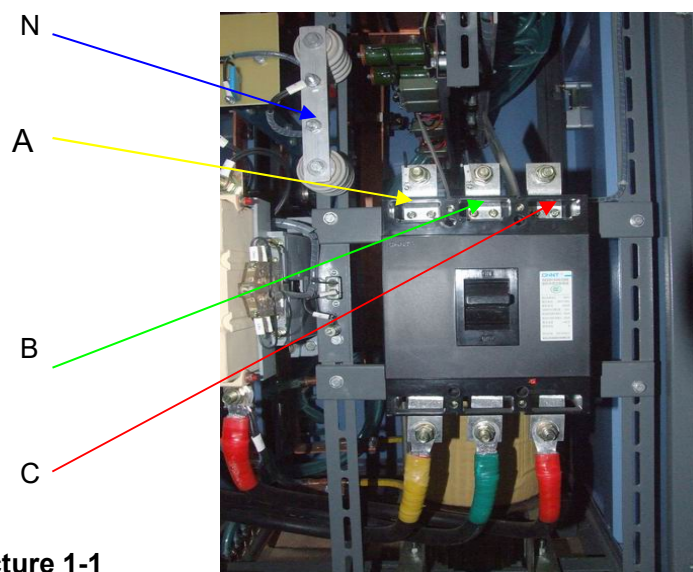
② Except in special conditions, generally use the ZR-RVV(anti flaming- PVC insulated single core or three core, four core)copper power cable or RVV(PVC insulated single core or three core, four core)copper power cable.

③ The diameter for input wire is not less than table1-1

**Table1-1 Selection list of cross sectional area for power input wire**

Rated power (KW)	Copper wire cross sectional area for three phase (mm <sup>2</sup> )			
	A phase(Y)	B phase(G)	C phase (R)	N
60	70	70	70	≥6
100	95	95	95	≥6
150	150	150	150	≥6
200	185	185	185	≥6
250	240	240	240	≥6
300	300	300	300	≥6
400	395	395	395	≥6
500	500	500	500	≥6
600	600	600	600	≥6
800	730	730	730	≥6
1000	910	910	910	≥6
1200	1090	1090	1090	≥6

#### 1.4.1.2 Power cable installation position as shown in picture 1-1



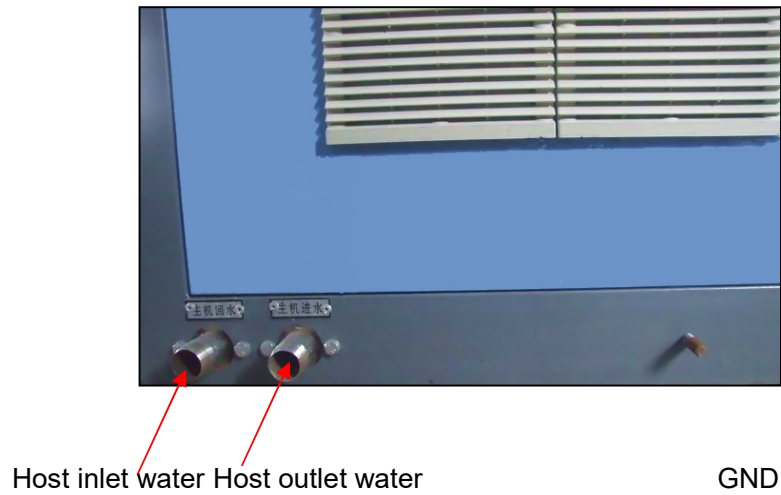
**Picture 1-1**

#### 1.4.1.3 N line installation position of power cable is shown in picture 1-1

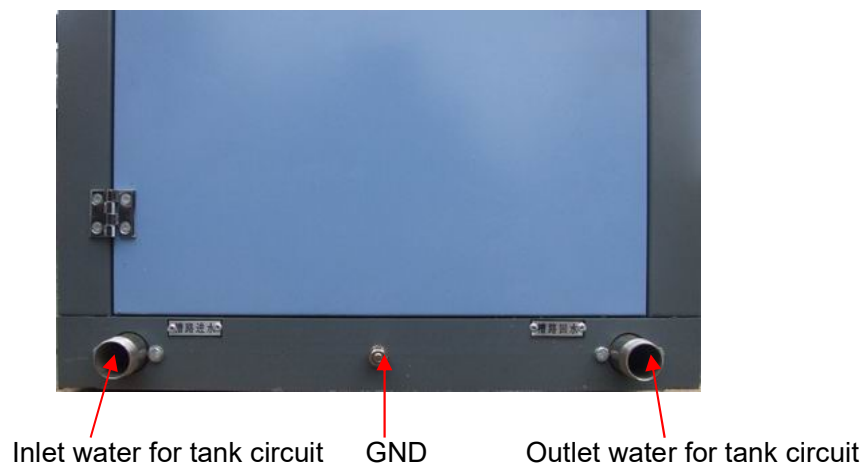
#### 1.4.1.4 GND installation position for power cable shown in picture 1-2, copper cable diameter

is not less than 95mm<sup>2</sup>

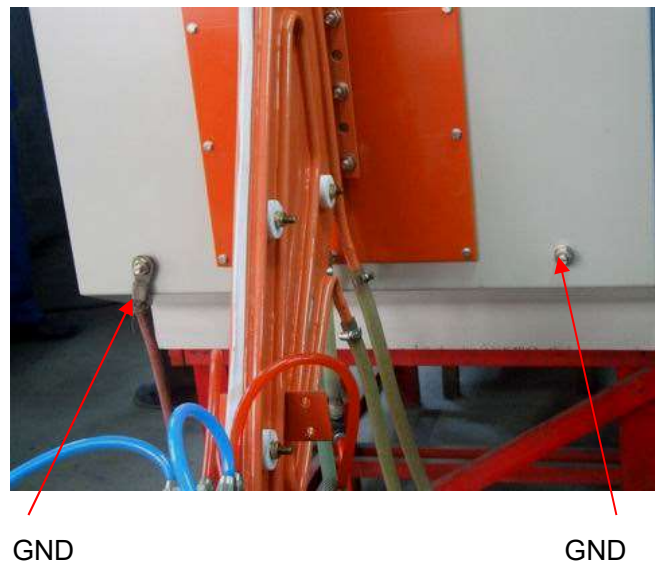
Picture 1-4 shows the grounding point should reliable connect to near squeeze roll of mill, the detail contents please refer to the chapter 8 is showing.



Picture 1-2



Picture 1-3

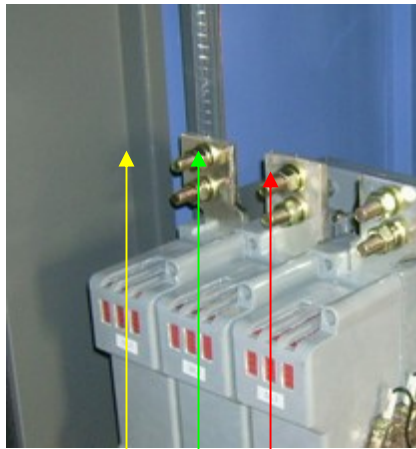


Picture 1-4



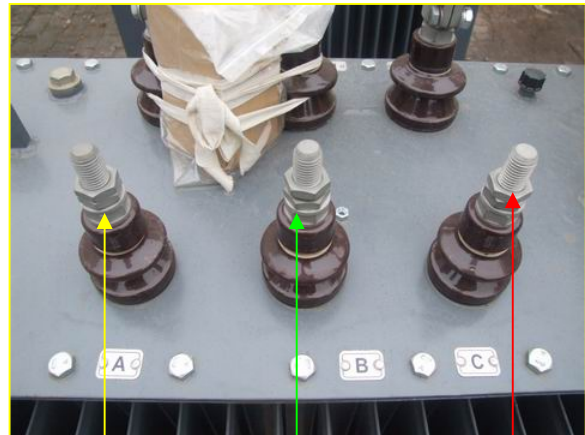
#### 1.4.2 Connection line between rectifier cabinet to transformer

Rectifier cabinet terminal installation position as shown in picture 1-5, picture1-9, picture 1-10, transformer terminal installation position as shown in picture 1-6.



A1 B1 C1

Picture 1-5



A1 B1 C1

Picture 1-6

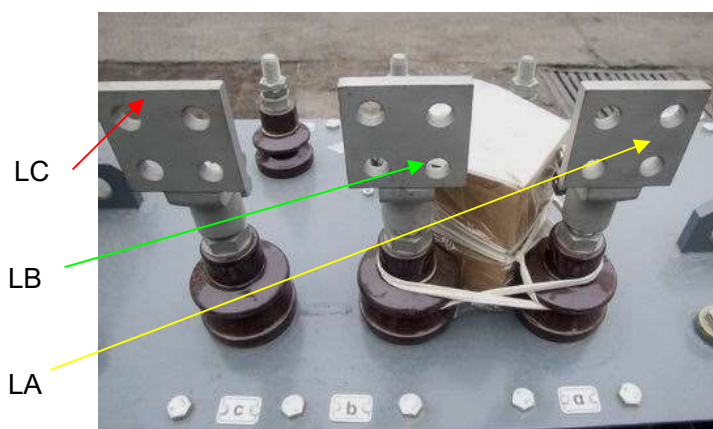
Standard configuration for the connection line between rectifier cabinet and transformer such as table 1-2, if you need to extend the length you should suitable increase the cross-sectional area.

Table 1-2

Rated power(KW)	Cross sectional area of copper wire between rectifier cabinet and transformer( mm <sup>2</sup> )			
	A phase(Yellow)	B phase(Green)	C phase(Yellow)	Length for each group(m)
60	70	70	70	3
100	95	95	95	3
150	150	150	150	3
200	185	185	185	3
250	240	240	240	3
300	300	300	300	3
400	395	395	395	4
500	500	500	500	4
600	600	600	600	4
800	730	730	730	5
1000	910	910	910	5
1200	1090	1090	1090	5

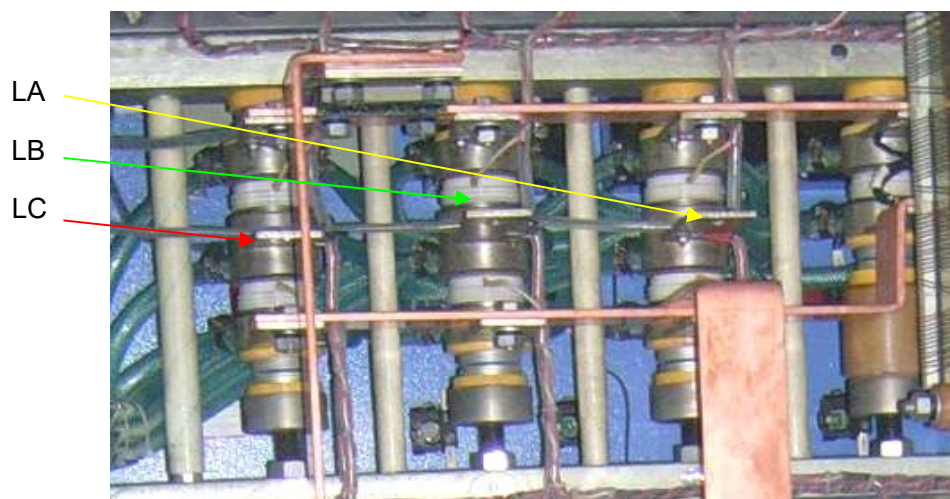
#### 1.4.3 Connection line between transformer and rectifier cabinet

The installation position of transformer is shown in Picture 1-7

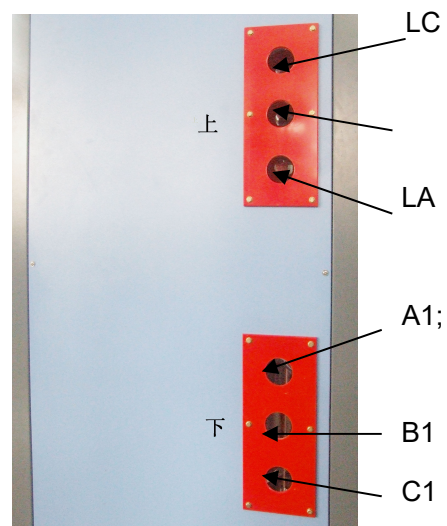
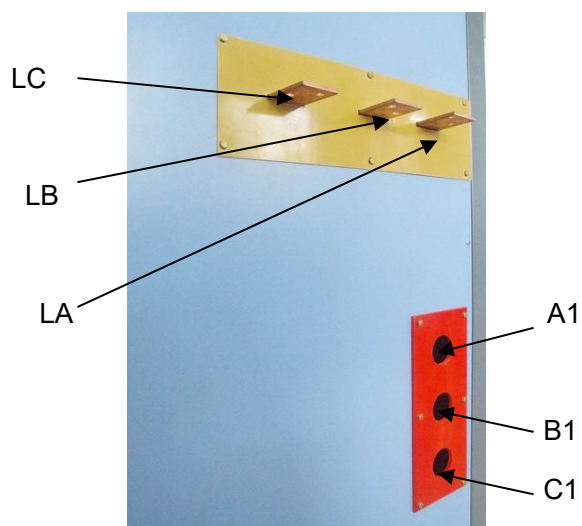


Picture1-7

The installation position of rectifier cabinet terminal is shown in picture 1-8, 1-9,1-10



Picture 1-8(60-200KW)



Picture 1-9(300KW)

Picture 1-10(60-200KW)

Rated power(KW)	Cross sectional area of copper wire between transformer and rectifier cabinet( mm <sup>2</sup> )			
	A phase(Yellow)	B phase(Green)	C phase(Red)	Length for each group(m)
60	95	95	95	3
100	190	190	190	3
150	250	250	250	3
200	380	380	380	3
250	480	480	480	3
300	500	500	500	3
400	700	700	700	4
500	900	900	900	4
600	1100	1100	1100	4
800	1300	1300	1300	5
1000	1700	1700	1700	5
1200	2000	2000	2000	5

Standard configuration for the connection line from transformer to rectifier cabinet such as table 1-3, if you need to extend the length you should suitable increase the cross-sectional area.

Table 1-3

#### 1.4.4 Connection line between rectifier cabinet and inverter cabinet

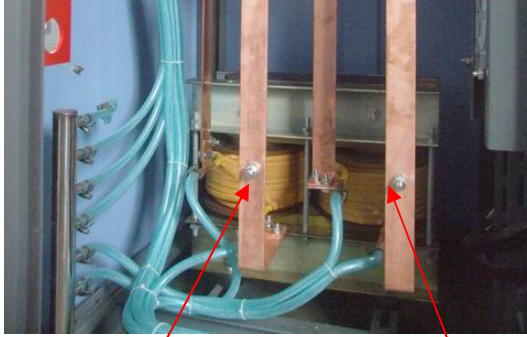
##### 1.4.4.1 Cable selection

- ① Using copper core cable to connect between equipments, cable's rated voltage is  $\geq 400V$
- ② Generally use the ZR-RVV(anti flaming-PVC insulation)copper power cable or RVV(PVC insulation) power cable.
- ③ Standard configuration for the connection line between rectifier cabinet and transformer such as table 1-4, if you need to extend the length you should suitable increase the cross-sectional area.

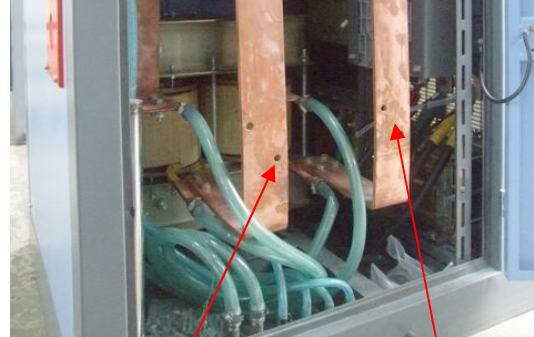
**Table 1-4: Cross sectional area of connection line between transformer and rectifier cabinet**

Rated power(KW)	Cross sectional area of copper wire between transformer and rectifier cabinet( mm <sup>2</sup> )		
	Positive(+)	Negative(-)	Length for each group(m)
60	95	95	3
100	190	190	3
150	300	300	3
200	450	450	3
250	600	600	3
300	600	600	3
400	900	900	5
500	1100	1100	5
600	1350	1350	5
800	1600	1600	7
1000	2000	2000	7
1200	2400	2400	7

1.4.4.2 Installation position(in rectifier cabinet) is shown as picture 1-11, 1-12

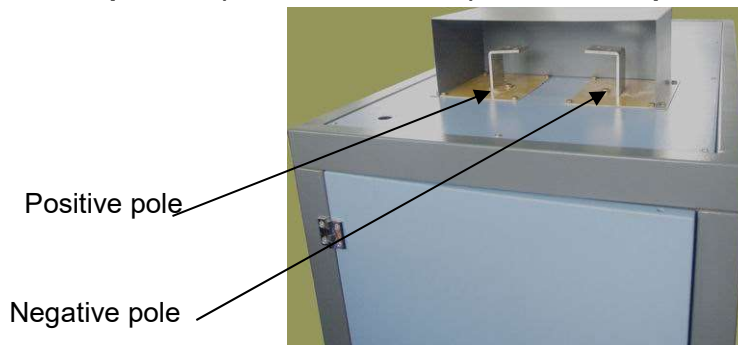


Positive pole  
Negative pole  
Picture 1-11 (60-200KW)



Negative pole  
Positive pole  
Picture 1-12(300KW)

1.4.4.3 Installation position(in inverter cabinet) is shown as picture 1-13

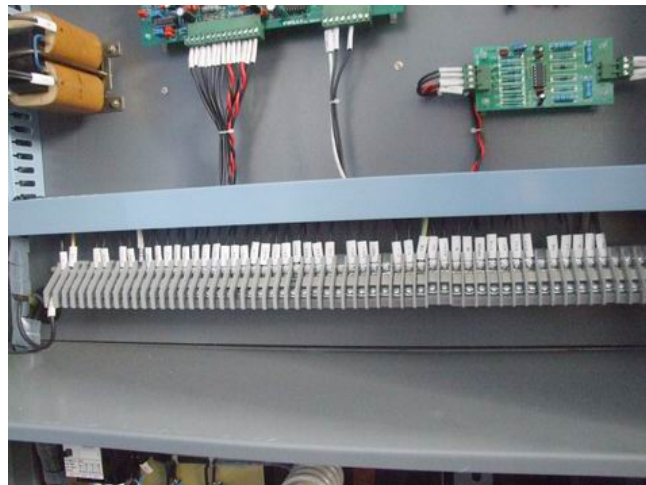


Picture 1-13

#### 1.4.5 Small line installation from rectifier cabinet to inverter cabinet

NOTE: Small line between rectifier cabinet and inverter cabinet should use shielding line of RVVP to shield the interference from the big line. Small line and big line should be respectively ligated in bundle, can not bundle together. If the distance is longer between rectifier cabinet and inverter cabinet, the small line must be weared in a suitable diameter iron tube alone to shield the interference from the big line.

1.4.5.1 Small line installation position from rectifier cabinet to inverter cabinet (in rectifier cabinet) is shown as picture 1-14





Picture 1-14

1.4.5.2 The installation position of rectifier cabinet and inverter cabinet (in inverter cabinet) is shown as picture 1-15



Picture 1-15

1.4.6 Installation of out plate(leg) : 60-200KW is shown as picture 1-16 , 300KW is shown as picture 1-17.



图 1-16



图 1-17

## 1.5 Waterway installation

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### 1.5.1 Water quality requirement

Equipment cooling water must use the industrial distilled water and meet the following requirements. In order to prevent when welder worked for a long time ,due to waterway pipe scale or corrosion affect components heat dissipation or to cause leakage, further damage to the equipment.

Using water cooling to power supply unit, load inductor and bus bar and so on, the quality of cooling water condition directly effect equipment movement's reliability, we would like to suggest that you can analyse and monitor to the cooling water, its result should be able to meet the following condition, if has the difference, should solve through the related purification method.

① Mechanical properties

Transparence, no turbid, no sediment(screen cloth size is 0.38mm), the total solid content does not surpass 250mg/L.

② Chemical properties

PH value is in 6~8

Chloride is not >100mg/L

NO<sub>2</sub> is not >0.04mg/L

Iron is not >0.3mg/L

Mn is not >0.05mg/L

Sulphur is not >250mg/L

③ Conductivity: is not >600μs/cm

④ Incoming water temperature: it is not lower than 5°C and not higher than 35°C, When water supply in hot days must avoid surface dewing for water cooling components

⑤ Incoming water pressure: 0.2~0.3Mpa

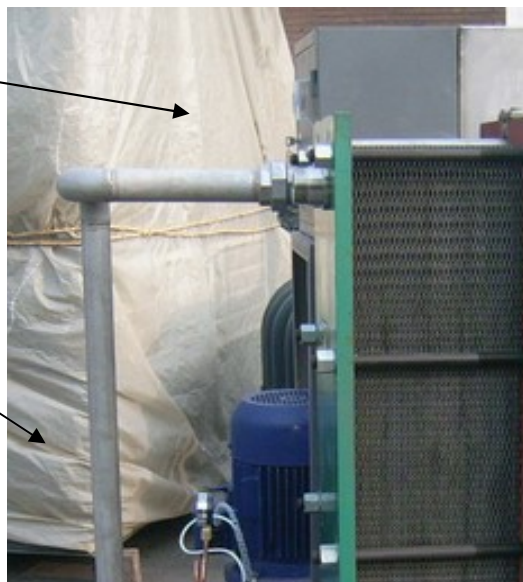
⑥ Flow rate: refer to Table 3-2

**Attention: If customer use the cooling water or water temperature and water pressure don't meet the above standard and specified value to cause equipment damage, even during the warranty period, the company may still require customers to pay maintenance costs.**

### 1.5.2 Water system is shown as picture 1-18,1-19:

External cooling water out  
to the cooling tower

Distilled water to high  
frequency

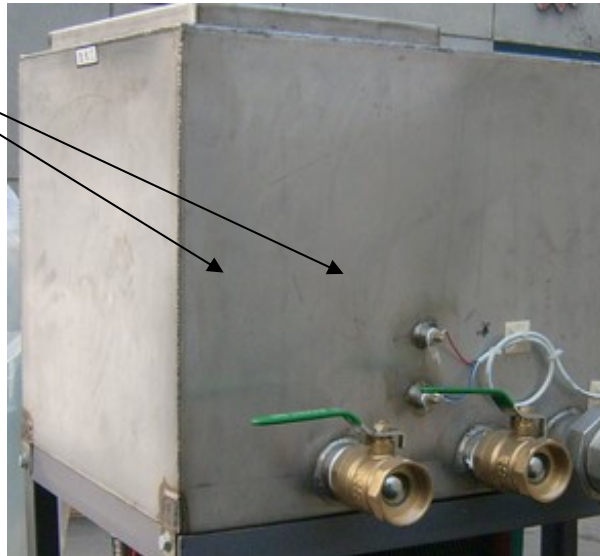


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External cooling water  
from the cooling tower

Picture 1-18

Distilled water from  
high frequency



Picture 1-19

**1.5.3 Equipment inlet water position is shown as picture 1-2 and 1-3.**

**1.5.4 Equipment backwater waterway position is shown as picture 1-2, 1-3.**

**1.5.5 Output plate and cooling water for inductor**

**Note:** in 1.4.6 output plate and cooling water for inductor are from the mill supply water at scene by the user.

#### **1.5.6 Waterway connection**

Due to water cooling electronic components of equipment have a higher water quality requirements, therefore they also have a higher requirements for water supply pipeline. It is required that the water supply pipeline has the following characteristics: the strength will meet equipment water pressure requirements, non-corrosive, does not rust, not easy to aging, and has a certain heat-resisting ability. General the waterway connection for various parts of equipment should use stainless steel pipe for the same pipe diameter for same equipment inlet and outlet or use other pipe material to meet above requirements, never use ordinary steel pipe to connect.

#### **1.6 The production of inductor**

Our company does not provide inductor used for welding pipe, inductor will be produced by users themselves. Inductor in the welder plays an important role, the quality of inductor direct affects the efficiency, status and stability for equipment. Therefore, we offered the following requirements to the production of inductor, please be sure to pay attention to it.

① According to the welded steel pipe diameter, to determine the copper pipe(or copper plate)diameter that most suitable for this equipment. For details, please refer to 7.3.1.

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② To cover a lay of PTFE that its thickness is 0.5mm at the outside wall of copper pipe for the multi-turn inductors; for the single-turn inductor can directly add a layer of PTFE between inductor and welded steel pipe. To prevent frequent spark between inductor and steel pipe to cause equipment stop work.

③ The winding of inductor must be standard, the ID and OD must have the higher roundness, the space between turns must be evenly, In general the width of inductor is same with the diameter of steel pipe which be covered by the inductor. Turn's quantity must be accurate, the output end shall have some transposition , that is to say that the three turns of inductor will be make a little more than three turns, not be made of two half-turn.

④ The distance from inductor center to the output plate will be determined by our debugging engineer, user can not be allowed to optional change it without our technical staff agree.

⑤ After the inductor deformation, please reshaping it in time, the inductor which is leakage, water shutoff should be timely replaced.

## **II .Equipment debugging**

### **2.1 Waterway debugging**

After waterway installation, use water debugging and observe if has the water leakage inside the equipment. If the water pressure indication lies between the maximum and minimum pointer for the water pressure gage in the rectifier cabinet and inverter cabinet. The inlet water pressure for rectifier cabinet and inverter cabinet is not lower than 0.2Mpa and no more than 0.3Mpa, Otherwise the device may be damaged.

### **2.2 Circuit debugging**

#### **2.2.1 Starting steps:**

①To determine all the connection have been completed well for the equipment's big line, small line.

②Power supply to the equipment incoming line, please observe if the “power supply voltmeter ” in the rectifier cabinet within the allowable range.

③Connect the cooling water system and the normally open contact of water pressure relay is closed. Check and confirm the outlet pipe should be smoothly and conform to above the requirements for cooling water pressure and quality.

④Check the tank circuit and inductor; check whether short-circuit exists between the heated work piece and inductor; check whether open circuit or short circuit exists at the inductor.

⑤Adjust anti-clockwise the power regulating potentiometer to the minimum position and press down start button for control power supply. The indicator of control power supply is on and the 1# board and 2 # board start self-check, during self-check process the comprehensive fault indicator is on. When finishing of self-check without fault , the comprehensive fault indicator off and 1# nixie tube flash display



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"1", if any fault is detected by the self-check, then the nixie tube will stop at the display position for fault code, corresponding fault indicator will turn on.

⑥ Please rotate the button "internal/external control" to "external" position, the indicator of "external control" is light.

⑦ Check the power regulating potentiometer has been adjusted with anti-clockwise to the minimum position, after the equipment reach the preheating time, to press the button "main circuit on" which is on console, after this step, the nixie tube of 1# board still flash display "1", the indicator of "main circuit" is light, main contactor pull in, transformer start to supply the power and send it to input terminal of SCR.

⑧ After press the button "main circuit on" for three seconds, then press the button of heating start" on the console, after this step, the "heating indicator" is light. SCR is triggered, rectifier - inverter start to work, then slowly adjust the button "power adjustment" to observe whether current and voltage have the certain proportion such as voltage 50V, current 200A-250A, that can illustrate the welder is basic normal and can normal operation. If the proportion deviation for current/voltage is larger, please check whether the inductor is suitable, whether have touch with iron wall. If unknown the reason, please inform us by email or telephone to seek state recognition. After confirmation from our technical staff, the welder can be normal opened.

### **2.2.2. Shutdown steps:**

The shutdown steps are inversed to the starting steps. Pay attention to the following two points:

① The main circuit can be just stopped after the heating button is pressed for three seconds.

② When shutting down the machine, must operate in the sequence of pressing heating stop → stop main circuit → stop control power supply → stop external power supply for switch cabinet. Because interlocking control exists between the operation of heating control, main circuit control and control power supply, it is prohibited to directly cut off the main external power supply for switch cabinet.

### **2.3 Main contactor start-up explanation:**

The first step: excitation contactor KM5 start, transformer through resistors AO, BO, CO, KM5-RA, RB, RC excitation, delay 1.5s, the main contactor KM2 pull in, delay 1.5s, KM5 disconnect, the starting process for main contactor will be end.

### **2.4 The disconnect process explanation for main contactor**

KM5 is not action, KM2 directly disconnect, the disconnection process for main contactor will be end.

### **2.5 Function and display for each control board**

① Function classification for control board and module

Equipment mainly include the following control PCB and power module, according to the difference for the welder rated power, the quantity of modules and power distribution board are different, as Table 2-1

Table 2-1

Name	Function	Quantity
1# board	Rectifier control, voltage and current adjustment, rectifier pulse control, fault protection	1
2# board	Inverter control, switching for separate excitation and self excitation, frequency tracking	1
<b>Power module</b>	Inverter、 MOSFET drive and protection	2/50KW
<b>Power distribution board</b>	DC power distribution for module board and the integrated failure for each module	2 (4)
<b>Signal feedback board</b>	Signal sampling of tank circuit, pre-treatment	2
<b>Voltage feedback board</b>	DC voltage sampling, processing, as the voltage feedback signal and power given signal	1

② Nixie tube and LED display state description

A. Rectifier board LED display description such as Table 2-2

Nixie tube name	State meaning
<b>DL11</b>	DL11 is the proportion regulator when it is on DL11is the proportion integral (PI) regulator when it is off
<b>DL12</b>	Self-excitation resonant state is light up
<b>DL13</b>	Separate excitation resonant state is light up

B. Nixie tube display description for rectifier board such as Table 2-3

Display content	Status meaning	Handling ways
"0"	Lack of phase Three phase is imbalance, input voltage is too low	<ul style="list-style-type: none"> <li>· Check whether the control power is lack of phase</li> <li>· Check whether the control power insurance is fusing.</li> <li>· Check whether the power grid voltage is imbalance</li> <li>· Check whether the power grid voltage is too low (line voltage is lower than 320V)</li> </ul>
"1"	Wait for heating	· Power on and self test and trouble free for welder, wait for heating start (normal state)
"2"	System reservation	
"3"	Reset signal has been connected when power on for welder	<ul style="list-style-type: none"> <li>Check whether the reset button has been pressed down.</li> <li>Check whether the reset button has been jammed</li> </ul>
"4"	Heating signal has been connected when power on for welder	<ul style="list-style-type: none"> <li>Check whether heating button has been pressed down</li> <li>Check whether heating button has been jammed.</li> <li>Check whether heating button has been closed</li> </ul>

Display content	Status meaning	Handling ways
"5"	Under water pressure fault	<ul style="list-style-type: none"> <li>· Check whether cooling water pressure consists with the request of 0.2~0.4MPa</li> <li>· Check whether the normally open contact of water pressure relay is closed.</li> </ul>
"6"	Over-current protection action	<ul style="list-style-type: none"> <li>· Check whether the DC current exceeds the value of equipment to allow</li> <li>· Check whether the rectifier SCR for DC side rectifier has been damaged</li> <li>· Check whether the inverter modules have damage.</li> <li>· Please tell us if you have any trouble</li> </ul>
"7"	System reservation	
"8"	Main contactor trip	<ul style="list-style-type: none"> <li>· Check whether the hardware trip circuit of control PCB has action.</li> <li>· Check whether there is disconnected for coil loop of main contactor according to the electrical schematic diagram.</li> </ul>
"9"	System reservation	
"A"	Power on and self test A/D initial value is too large	<ul style="list-style-type: none"> <li>· Replace ADC0804 chip, whether the fault is eliminated.</li> <li>· Replace DG212 chip, whether the fault is eliminated.</li> <li>· Please tell us if you have any trouble.</li> </ul>
"b"	Inverter control board fault	<ul style="list-style-type: none"> <li>· Check whether the middle of a row of red lights in inverter control board are light up, please troubleshooting according to the indicating meaning</li> <li>· Check whether each terminal connection is loose.</li> <li>· Please tell us if you have any trouble.</li> </ul>
"C"	System reservation	
"H"	Normal heating state	

**C LED indicating description for inverter control board such as Table2-4**

	Nixie tube name	Status meaning(when they are light)
<b>Status LED (close to the terminal)</b>	DC.ON	Control power normal
	DC.OK	System reservation
	SYNC	Starting success
	HFOK	The signal for HF board and module and power distribution board are normal
	START	Starting signal has been connected
	RESET	Reset signal has been connected
<b>Fault LED ( the middle row)</b>	H.P	Upper limit alarm for work frequency
	L.P	Lower limit alarm for work frequency
	O.F	Over limit alarm for frequency
	MOD	Fault alarm for module
	AUX	Power voltage low alarm for inverter control board
	O.V	Tank circuit over-voltage alarm for inverter cabinet

**D. LED indicating description for power module such as Table2-5**

Name of nixie tube	State meaning	Color
<b>PULSE</b>	It is light up without drive pulse	RED
<b>MOS</b>	It is light up when Mosfet is damage	RED
<b>SUPPLY</b>	It is light up for DC power fault	RED
<b>TEMP</b>	It is light up for temperature is over-high	RED
<b>OK</b>	It is light up when power module is normal	GREEN

### E. Potentiometer function description

a. Rectifier board potentiometer function shown as table 2-6

Potentiometer	Function	Description
<b>RW11</b>	Given integration time adjustment	When clockwise adjust it need time is long, generally counterclockwise adjust it to the end, from the end position starting, then clockwise adjust it for about 15 circles, please don't touch it by user.
<b>RW12</b>	Proportional coefficient adjustment For voltage regulator	When clockwise adjust it ,the proportion is large, when counterclockwise adjust it, the proportion is small, generally counterclockwise adjust it to the end, please don't touch it by user.
<b>RW13</b>	Attenuation adjustment of current given value	To adjust RW13 in cooperation with the button RW15, generally should counterclockwise adjust it to the end , please don't touch it by user.
<b>RW14</b>	Proportional coefficient adjustment for current regulator	Same with the regulation rule of RW12, please don't touch it by user.
<b>RW15</b>	Current feedback matching adjustment	When clockwise adjust it, the feedback value will increase, the limited current value will decrease. When counterclockwise adjust it , the feedback value will decrease, the limited current value will increase, please don't touch it by user.
<b>RW16</b>	Overcurrent protection value adjustment for AC input line side	When clockwise adjust it, the protection given value will decrease, when counterclockwise adjust it , the protection given value will increase.
<b>RW19</b>	Voltage feedback matching adjustment	When clockwise adjust it, the feedback value will increase, the limited voltage value will decrease. When counterclockwise adjust it, the feedback value will decrease, the limited voltage value will increase. Please don't touch it by user.
<b>RW21</b>	Symmetry adjustment for phase lock	Please don't touch it by user
<b>RW22</b>	The initial phase angle adjustment for	Please don't touch it by user

b. Potentiometer function for inverter board shows as table 2-7

Potentiometer	Function	Description
<b>RW1</b>	Signal delay time adjustment	Please don't touch it by user
<b>RW2</b>	Under testing state, testing frequency adjustment	Please don't touch it by user
<b>RW3</b>	Frequency calibration	System reserved, please don't touch it by user
<b>RW4</b>	Frequency beyond protecting Settings	Please don't touch it by user
<b>RW5</b>	Over-voltage protection adjustment	Please don't touch it by user.
<b>RW6</b>	Voltage signal calibration	System reserved, please don't touch it by user
<b>RW7</b>	Pulse overlapping time adjustment	Please don't touch it by user.
<b>RW8</b>	Starting oscillation frequency adjustment under working state.	Please don't touch it by user.

## 2.6 No-load debugging

The purpose is check whether equipment can normal working and whether to meet the design requirements, the working contents is check whether work flow according to design process work, check whether cooling system, circuit, waterway, air condition system and so on are all normal work. Whether water pressure and water current are in the rated scope. When debugging the given potentiometer should be placed on the zero position, start power on operation to control power supply, main loop and heating and observe whether HMI display normal and whether there is alarm.

## 2.7 Load debugging

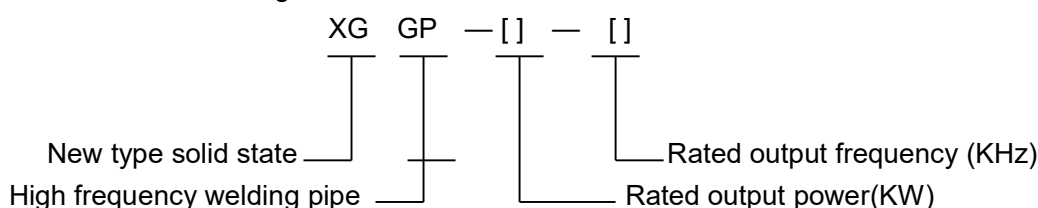
Load debugging contents including whether the equipment is in normal work condition after loading, whether frequency characteristics and load characteristics can meet the requirement, check the reliability of equipment protection. The specific procedure is use the difference inductor to test with loading, gradually testing from small power to full power, to test whether pipe welding quality can meet the technological requirements.

# III Operation instructions

## 3.1 Product introductions

### 3.1.1 Model explanation

Welded pipe power supply of all-solid-state high frequency induction heating for XGGP series, and its model meaning is as follows:



### 3.1.2. Application

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Welded pipe power supply of all-solid-state high frequency induction heating for XGGP series is mainly used for metal welding, heated, quenching and so on occasions.

### **3.1.3 New product explanation**

This product is the new type solid-state welding pipe power supply which is the latest product from our company.

Welding pipe power supply of all-solid-state high frequency induction heating for XGGP series uses modern electric power electronic component MOSFET (Power-MOSFET) as inverter's key component, use single-chip microcomputer system as the core composing the rectifier, inverter's intelligent control systems with some advantages such as the high efficiency, the circuit is simple and reliable, easy debugging etc that not only can improve the production technique and can improve the product quality for the production enterprise, and has the obviously energy conservation effect. The welder uses PLC as the external controller which used for the entire production line coordination control and alarm management etc., at the same time it equips with man-machine interface to display with multi-function, when the system occurs the breakdown can automatically detect and push out the alarm content with Chinese characters display.

In welding pipe industry of our country the production of high-frequency welder has been using tube oscillation power supply, but vacuum tube HF exist some shortcoming such as the high voltage, the low conversion efficiency, the big energy consumption and the short lifetime and need the regular replacement and so on. For this reason our company has developed the power supply of solid-state welding pipe with series resonance type so that the efficiency can be raised. Because tank circuit of series resonance is high, easily lead to the inductor strike fire so that the component damage. In addition, the adaptation scope of series resonance load is narrow, when replacement product specification must readjust the tank circuit matching. In view of many insufficiencies for vacuum tube power supply and series resonance solid state power supply, Our company latest promotes the all solid state welding pipe power supply which refers to the zero voltage and zero electric current of overseas newest soft switch technology and combine with the actual demand to develop. The power supply compare to our company's early GGP serial products of solid-state power supply of series resonance, not only technologically advanced, more reasonable structure, and further improve efficiency, at the same time simplifying the control circuit, thus more energy. The equipment has some features such as cover an area of small, the weight light, the working voltage low, the safety coefficient high, the high frequency radiation small and the noise low, the fault rate low and maintenance difficulty small and so on. Compared to the traditional power supply of vacuum tube, the power-saving and water-saving effect more obvious, especially the power efficiency reaches as high as above 85%, fully embodied the advantages of solid-state electronic devices. In the high frequency welding pipe process the electricity consumption is one of the main cost that is only inferior to the material cost, Today in the energy intensive, reducing electricity consumption not only can reducing costs, reducing investments and has

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more extensive social efficiency. The selection of the new type power supply switch component is the imported high quality MOSFET, The switch speed high, reliability well, anti-overload capacity is not easy to damage. The overall circuit is composed of the unit circuit, to take isolation measures so that reduce the related influence by mutually, regarding the heat dissipation of power supply fully consider technology characteristics, reasonable layout and the distribution for cooling water source. In order to ensure heat dissipation to be even, adaptation for long-term operation mode with continuously and uninterrupted. When replace different specification product, the circuit adjustment method is simple, only need as per DC voltmeter and DC ammeter adjust inductor and connection is ok.

Control circuit advantages are as follows: ①using compound resonance circuit with parallel type, adaptation load scope is wide, the interference is small to electrical network, many equipment will not interfere mutually. ②control circuit using the man-machine interface and PLC and it can interlock control to the power supply and production line and can monitor and control to the overall line. ③ rectifier circuit using phase control technical of SCM, integration level is high, anti-jamming capability is strong. ④inverter circuit using the new integrated circuit, the circuit structure is simple, the phase-lock control is precise to ensure that the circuit has a strong adaptability to the load. ⑤ environment adaptive capacity is strong , especially suitable for work in bad condition. ⑥the protection circuit is complete, each kind of protection circuit is designed in rectifier and inverter control circuit to ensure the component and the equipment security. Equipment pass through the testing of temperature protection for short circuit, open circuit and grounding and over-current and over-voltage and cooling system before the equipment deliver to ensure the equipment to be able the long-term stability safe operation.

### **3.2 Using condition**

#### **3.2.1 Using condition : same 1.1**

#### **3.2.2 Cooling water request: same 1.5.1**

#### **3.2.3 Electrical network request**

The network voltage should be the sine wave, the harmonic distortion is not bigger than 5% , electrical network input voltage is line voltage that is AC 380V. Continuous fluctuation range of electrical network voltage is not surpass  $\pm 10\%$ , the frequency change of electrical network does not surpass  $\pm 2\%$ (it should be between 49~51Hz), unbalance between three phase should be less  $\pm 5\%$ .

### **3.3 Technical index**

#### **3.3.1 Equipment composition**

① Control and rectifier cabinet	one
② Console	one
③ Rectifier transformer	one
④ Inverter cabinet	one
⑤ DC output bus	one



- 
- |                                    |   |
|------------------------------------|---|
| ⑥ Automatic control system and PLC | one(in control cabinet and rectifier cabinet) |
| ⑦ Water cooling system (option)    | one   |

### 3.3.2 Appearance and structure

(1) External dimension of power supply cabinet:(L×W×H)

- |                                 |                    |
|---------------------------------|--------------------|
| ① Rated power is 100KW~300KW:   | 1000×800×2000(mm)  |
| ② Rated power is 400KW~600KW:   | 1000×1200×2000(mm) |
| ③ Rated power is 800KW~1200KW : | 1400×1600×2000(mm) |

Above external dimension of power supply cabinet are our company standard size. If the user has the special request, we may make the non-standard design according to the user request, but the minimum size must be approved by both sides.

(2) External dimension of inverter cabinet(L×W×H)

- |                              |                    |
|------------------------------|--------------------|
| ① Rated power is 60-150KW:   | 1600×700×1050(mm)  |
| ② Rated power is 200KW:      | 1650×700×1150(mm)  |
| ③ Rated power is 250KW:      | 1720×800×1400(mm)  |
| ④ Rated power is 300KW :     | 2450×800×1440(mm)  |
| ⑤ Rated power is 400KW :     | 2650×900×1620(mm)  |
| ⑥ Rated power is 500KW:      | 2650×900×1750(mm)  |
| ⑦ Rated power is 600KW:      | 2650×900×1850(mm)  |
| ⑧ Rated power is 800~1200KW: | 2800×1000×2260(mm) |

(3) Panel switch settings

On equipment main door (it is called panel) set the following content:

#### **XGGP60-300**

- AC voltmeter of incoming line : indication the line voltage of equipment incoming line
- DC voltmeter: indication output DC voltage average value of rectifier bridge for three-phase full-controlled bridge
- DC ammeter: indication output DC current average value of rectifier bridge for three-phase full-controlled bridge
- ON/OFF button of control power supply and start-up indicator light
- ON/OFF button of AC contactor of main circuit and start-up indicator light
- ON/OFF button of heating control and start-up indicator light.
- Switcher of internal/external control: Main switch heating control and the given signal of power adjustment.
- Adjustable power potentiometer: when the adjustable power potentiometer clockwise rotation, the output power increase, otherwise the output power decreases.
- Fault reset button

#### **XGGP400-600**

- AC voltmeter of incoming line : indication the line voltage of equipment incoming line
- DC voltmeter: indication output DC voltage average value of rectifier bridge for three-phase full-controlled bridge
- DC ammeter: indication output DC current average value of rectifier bridge for three-phase full-controlled bridge
- General fault indicator light: When the equipment occurs any failure to cause the equipment not to be able the normal work ,general fault indicator lights are bright, fault type is indicated by the nixie tube and the corresponding indicator lights on equipment control board.
- Emergency stop button

### 3.3.3 Specifications and model

Rated input power supply of equipment

Three phase four wire system AC , frequency is 50Hz, line voltage is 380V.

Standard value of XGGP series all-solid-state induction heating power supply shown such as Table 3-1 , 3-2 and 3-3.

**Table 3-1: 60-200KW power supply date**

Model	XGGP-60	XGGP-100	XGGP-150	XGGP-200
Power distribution capacity	90KVA	150KVA	230KVA	300KVA
Output power	60KW	100KW	150KW	200KW
Input voltage	3Φ380V	3Φ380V	3Φ380V	3Φ380V
Maximum input current	140A	230A	350A	455A
DC voltage	0-250V	0-250V	0-250V	0-250V
DC current	0-300A	0-500A	750A	1000A
Frequency range	350-420KHZ	350-420KHZ	350-420KHZ	350-400KHZ
Efficiency	85%	85%	85%	85%
Power factor	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87
Cooling water pressure	0.35MPa	0.35MPa	0.35MPa	0.35MPa
Flow rate of cooling water	11.7m <sup>3</sup> /h	11.7m <sup>3</sup> /h	11.7m <sup>3</sup> /h	12.5m <sup>3</sup> /h
Incoming water temperature	<35℃	<35℃	<35℃	<35℃

**Table 3-2: 250-500KW power supply data**

Model	XGGP-250	XGGP-300	XGGP-400	XGGP-600
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Model	XGGP-250	XGGP-300	XGGP-400	XGGP-600
Power distribution capacity	375KVA	450KVA	600KVA	900KVA
Output power	250KW	300KW	400KW	600KW
Input voltage	3Φ380V	3Φ380V	3Φ380V	3Φ380V
Maximum input current	570A	685A	910A	1370A
DC voltage	0-250V	0-250V	0-250V	0-250V
DC current	1250A	1500A	2000A	3000A
Frequency range	350-420KHZ	300-380KHZ	250-330KHZ	200-280KHZ
Efficiency	85%	85%	85%	85%
Power factor	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87
Cooling water pressure	0.35MPa	0.35MPa	0.35MPa	0.35MPa
Flow rate of cooling water	23.5m <sup>3</sup> /h	23.5m <sup>3</sup> /h	23.5m <sup>3</sup> /h	47m <sup>3</sup> /h
Incoming water temperature	<35℃	<35℃	<35℃	<35℃

**Table 3-3: 600-1200KW power supply date**

Model	XGGP-600	XGGP-800	XGGP-1000	XGGP-1200
Power distribution capacity	900KVA	1200KVA	1450KVA	1680KVA
Output power	600KW	800KW	1000KW	1200KW
Input voltage	3Φ380V	3Φ380V	3Φ380V	3Φ380V
Maximum input current	1370A	1823A	2203A	2552A
DC voltage	0~250V	0~250V	0~235V	0~235V
DC current	3000A	4000A	5000A	6000A
Frequency range	200~250KHZ	200~250KHZ	150~200KHZ	150~200KHZ
Efficiency	85%	85%	85%	85%
Power factor	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87	full load $\geq$ 0.87
Cooling water pressure	0.2MPa	0.2MPa	0.2MPa	0.2MPa
Flow rate of cooling water	47m <sup>3</sup> /h	50~90m <sup>3</sup> /h	50~90m <sup>3</sup> /h	50~90m <sup>3</sup> /h

Model	XGGP-600	XGGP-800	XGGP-1000	XGGP-1200
Incoming water temperature	<35℃	<35℃	<35℃	<35℃

### 3.3.4 Connection request of power supply

- (1) The incoming line of equipment power supply using copper core cable to connect, the connection with load should use the copper bar or the cable line and should guarantee the junction is good and reliability, as far as possible to increase contact area, reducing the contact resistance.
- (2) Power input wire hasn't the distinction request for the phase sequence, it is better to connect by the positive sequence so that when maintenance can check the synchronous correspondence relationship between trigger pulse and power input wire. Power input wire A,B,C should connect to the color Yellow, Green and Red and winding the clearly marked.
- (3) The compression joint should be fastness for the connector lug of power supply and make the dip soldering treatment and using screw fastening, nominal current value of connector lug is not less than the maximum DC current value×0.816 for the corresponding power where is showed in the Table 1.
- (4) Incoming line of power supply and the connection line between cabinets please refer to 1.4.

### 3.4. Electric Principle

The main circuit configuration of the equipment is as shown in Diagram 1. The rectifier adopts fully-controlled three phase bridge type thyristor rectifying circuit; inverter adopts compound parallel resonance configuration; smoothing reactor is used at the DC side as a filter to meet the operation need of inverter (current type inverter). As over pressure protection of current type inverter is very important, our company has designed a unique over pressure protection circuit which is critical to ensure the safe and reliable operation of inverter.

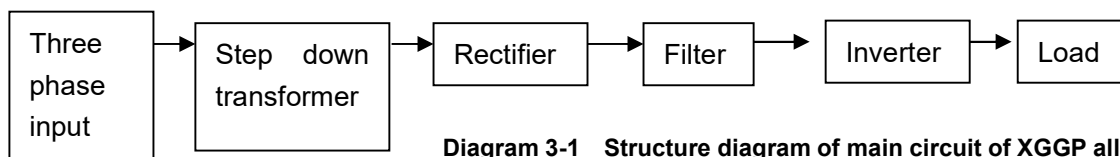


Diagram 3-1 Structure diagram of main circuit of XGGP all solid state induction heating power supply

#### 3.4.1 Introduction to fully-controlled three phase bridge type rectifying circuit.

Fully-controlled three phase bridge type rectifying circuit is a standard rectifying circuit which converts AC power supply to pulsating DC power.

When the inductance of the smoothing reactor at DC side is large enough, the output voltage of the fully-controlled three phase bridge type rectifying circuit is:

$$U_d = 1.35 U_a \cos \alpha \quad \text{Formula (1)}$$

Where,  $U_d$ ——mean value of output DC voltage

$U_a$ ——Input line voltage of rectifying bridge

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$\alpha$ —Trigger retardation angle of thyristor

At a given input line voltage of rectifying bridge  $U_a$ , the output DC voltage can be varied by varying the trigger retardation angle of thyristor  $\alpha$  to adjust the output power of the equipment. It can be observed that a cosine relationship exists between  $U_d$  and  $\alpha$  (non-linear relationship). Therefore in order to guarantee power adjustment linear, to add the no-linear correction link into the trigger program of computer control that has played a key role to the improvement for adjustment linearization. We can learn from (1) formula when  $\alpha > 90^\circ$ ,  $U_d$  value is zero or negative value, This time it is called inverter working status of rectification bridge, Its essence is the load to the electrical network feedback energy(rectifier bridge structure detail see the electrical schematic diagram).

### 3.4.2 Control principle of rectifier board

(1) Rectifier side control circuit using 89C51 SCM Of MCS-51 series as the control core to constitute all-digital trigger and make full use of the intelligentized function of SCM to constitute the protection measures with complete-function, and due to control program built-in for 89C51 SCM, the antijamming ability greatly improved.

(2) All digital trigger guaranteed pulse triggering with the equidistant, maximum limit reduced the non-characteristic harmonic, reduced the electrical network pollution.

(3) Using the DC voltage adjustment is the outer ring, the current adjustment for inner ring's double closed loop PI regulator, overcome the impact to the output power under the tradition proportional control method from electric network voltage fluctuation and the load change to ensure constant power output, It has the important meaning to enhances the heating effect and guaranteed the heating consistency. Moreover from the automatic control theory angle, what physical quantity as the feedback, then can automatically stabilize the physical quantity. Therefore the double closed loop PI regulator to realize the stable voltage, stable current function is the only effective method for the true and the accurate. Other issues, such as the proportion regulator add pressure limiting, current limiting measures should not be compared.

(4) Because the thyristor belongs to phase control technology, the synchronization question between electric network voltage phase sequence and trigger pulse is very important. Using SCM technology has successfully solved the function for automatic recognition phase , namely no need any adjustment to the input line of three phase power supply, the control circuit will automatically recognize phase and complete the rectification triggering function.

(5) The traditional circuit for tank circuit voltage and current take intersection-angle are all use two potentiometers to separately adjust tank circuit voltage and tank circuit current to transform amplitude angle size thus control the angle of lead size for inverter trigger pulse. This kind of electric circuit when replaces the load need two potentiometer coordination adjustment so that control the angle of lead size for inverter trigger pulse. The adjustment method need the experience and the adjustment is very cockamamie. Through the depth analysis and technical improvements to this

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circuit to simplify the regulation working of the angle of lead for the replaced load, greatly adapted to on-site adjustment.

(6) Using the big board structure, to concentrate the control power supply and the control circuit on a board, greatly simplify the external on-line, reducing fault points, more easy to maintain.

Rectifier side and inverter side are not in the same place, greatly improved. the antijamming ability.

(7) All the fault protection measures have two kind of ways which are the forced pull inverter control for microcomputer testing and the pull inverter control for regulator closed loop.

Guaranteed that all breakdown phenomenon can obtain the effective and the fast processing, not because one kind of protective measures invalidation cause the equipment damage.

(8) The self-checking function which SCM system has finished can test the circuit's abnormal phenomenon and through the nixietube display, in case of the control circuit work with fault lead to the protection circuit action is not accurate. SCM system at the same time can complete the functions which are protection of low water pressure, separate excitation/ self-excitation switching, automatic/manual switching, heating ON/OFF testing, power on testing of main circuit, fault reset state testing, overcurrent protection and overvoltage protection etc..

(9) The control circuit has the soft start function to prevent the rise rate of current and voltage to be too big during the startup procedure to cause overvoltage and overcurrent.

(10) After the output control signal for the voltage and current regulator pass the A/D converter, the interrupt signal will complete the read , start and switching process, so the biggest adjustment delay time is the switching time for A/D converter (or so  $80\mu\text{S}$ ) , This kind of fast response's capability is very close to the simulation adjustment's rapidity.

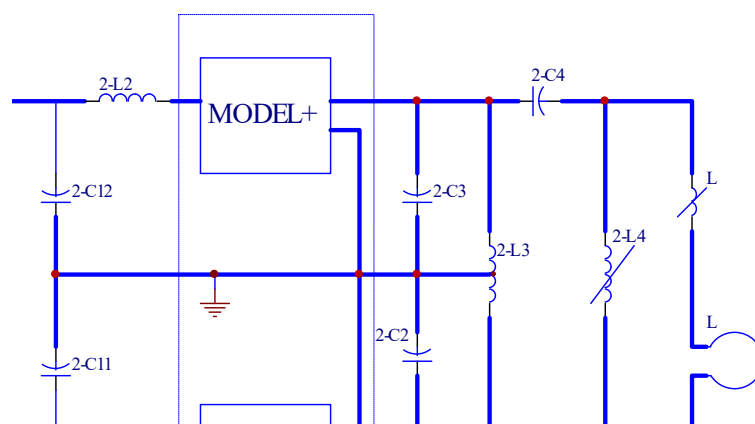
(11) Separate excitation/self-excitation switching by the inverter panel's onboard switch to complete , Not only reduce the interference caused by the external switch control resulted in weak signals external introduction for the traditional, but also can guarantee that the output frequency stability and over-voltage protection reliable action.

(12) Inverter control circuit using CMOS integrated circuits to complete the frequency control functions, the output amplitude of electricity level is big and anti-jamming capability is strong.

Coordinate circuit parameter which is designed carefully, has guaranteed the work sensitivity and reliability for the control panel.

### 3.4.3 Compound Parallel Bridge Type Inverter Circuit

The inverter adopts compound parallel resonance load configuration. The basic circuit (schematic) is as shown in Diagram 3-2.



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Diagram 3-2.

#### **3.4.4 Control Principle of Inverter Board**

The main functions of conversion control are to provide inverter power devices with reliable drive pulse for automatic tracking of load frequency and starting of inverter, as well as to collaborate with the control at rectifying side to control output voltage of rectifying bridge with the aim to ensure safety of the equipment when internal or external exception occurs. The functional block diagram of inverter control circuit is as indicated in Diagram 2.

The frequency signal obtained from load goes through zero-balancing circuit and self excitation square wave signal is obtained (timing principle of frequency automatic tracking) for control of sequence turn-on and turn-off of power device. Before the inverter works, as the voltage and current on the load are zero, the self excitation signal necessary for starting can not be obtained. This equipment adopts separate excitation frequency sweep starting. After the inverter starts, when the power output voltage reaches a certain value (threshold value), the output of level detection circuit inverses to convert the electronic output from separate excitation signal to self excitation signal, thus completes the starting process of inverter. The output impulse goes through phase slitting and drive circuit and forms correct drive impulse of inverter bridge.

#### **3.4.5 Power Supply Protection**

The protection function of power supply is designed addressing various exceptions and faults of power supply. In addition to normal protection such as control power supply fault and insufficient water pressure protection, over current protection and over voltage protection are provided.

As the impact resistance performance of the devices at inverter side is inferior to that of the devices at rectifier side, whether over current protection or over voltage protection requires the control circuit have characteristics of fast reaction and high reliability. Because the capacity of smoothing reactor at the DC side is relatively large and therefore the impact on the rectifier side is limited and sufficient time is gained for protection. The inversion work state in which energy is fed back to power grid is enabled by resorting to fully controlled three phase rectifier bridge  $\alpha > 90^\circ$ .

When output load of power supply inverter short-circuits or the inverter control drive circuit does not work properly, such as fire striking of inductor, individual connector not being securely inserted, or low voltage of any control power supply, power supply protection activities will be triggered and corresponding fault indication lamp will turn on. Over current protection circuit monitors three phase incoming current; when current exceeds setting value, the triggering phase shift angle of rectifier bridge

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will increase to over 90° and enters into the inversion work state, and the corresponding fault indication lamp will turn on at the same time to indicate fault reason.

When inverter bridge short circuits, the maximum short circuit current value  $I_{dm}$  during the pull inversion process of rectifier bridge is relative to the magnitude of rectified output inductance and the work state when the inverter bridge short circuits. Usually the  $I_{dm}$  is designed not exceeding three times of rated working current.

### **3.5 Operation and attentions**

#### **3.5.1 Operation procedure**

**Starting steps same with 2.2.1**

**Shutdown steps same with 2.2.2**

#### **3.5.2 Attentions**

①When changing the specification of the pipes, attention must be paid to the match between inductor and steel pipe in order to improve the efficiency and output capacity of the equipment.

②Regularly check the waterway of the equipment to confirm that there is no exceptions such as water leakage or water plugging.

③Check frequently whether the various indication lamps and meters on the panel are in normal condition, including the DC voltage meter, DC current meter, AC voltage meter, etc;

④Keep the various control circuits and devices inside the cabinet clean. Keep the passage of cooling water clear.

⑤The equipment adopts multiple protection measures. When any fault occurs, the protection circuit actuates and the fault indication lamp on the panel turns on. Please carefully observe the displayed instructions and analyze causes of fault. Power shall not be supplied until the fault is removed. It is prohibited to operate blindly otherwise the fault may deteriorate.

⑥ Equipment design has the change-over switch for internal/external control, when internal control to adjust power by the potentiometer on panel, internal heating controlled by ON/OFF button, when external control to adjust power by external voltage(0—10V), external heating controlled by ON/OFF button,

⑦The S201 short circuit module of 1# board(rectifier board) to choose the regulator type is for proportion/proportion —integral(P/P—I), under the proportion mode, DL11 indicator light is bright, the proportion status is for the experimental status, when normal work should switch the regulator for PI status so that equipment has the function which are the constant power output and the precise voltage limiting and current limiting.

### **3.6 Electrical schematic diagram (extra attached diagram)**

Because the company product constantly upgrade, when concrete maintain, must refer to the electrical schematic drawing and wiring drawing which attached with the welder, to prevent accidents.



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## **IV Maintenance of Solid State High Frequency Power Supply**

### **4.1 The importance for welder maintenance**

After a period use for electrical equipment, some electrical will have the aging phenomenon, its electrical parameters will change, and some action electrical components may be failure, the connection point between the various components are likely to loose, rusting , all these will affect the overall performance of welder even to occurs failure. Therefore, regular maintenance for welder plays an important role to guarantee long-term stable operation for equipment. So after starting the equipment, user must timely and regular maintenance it. Our company's solid state HF welder uses compound resonance method to produce low voltage and high current, though it is safer than vacuum tube high frequency, if improper use of maintenance is easy to cause accident for personal or equipment, if you use the proper maintenance, not only save a lot of energy, but also to greatly extend the long life for equipment. Therefore, the relevant workmen must learn how to operate and maintain the solid state high frequency equipment properly. The specific methods please refer to this manual to implement.

### **4.2 Statement**

During the equipment warranty, if due to the user improper use or maintenance to cause personal injury and welder fault should be responsible by user.

### **4.3 Routine Maintenance Contents**

①Prior each shift, the equipment shall be cleaned thoroughly, including wiping clean the external part of cabinet. Check whether each door of cabinet is properly sealed and whether water system is in normal condition. When necessary, use electric blower to remove dust inside the cabinet. The place where the cabinet is located shall also be cleaned.

Note: Power must be cut off before cleaning is conducted. To clean with the power cut off to ensure safety. When cleaning, take care to avoid water or oil to splash into the cabinet.

②For the check items of various parts, refer to the maintenance requirements that follows.

③After cleaning, firstly check whether anything is left inside the cabinet, then close the cabinet.

④Equipment operation log shall be filled after each shift.

### **4.4 Maintenance Requirements**

#### **4.4.1 Maintenance requirements for rectifier cabinet**

①The water pressure switch must be checked regularly. When it is damaged or deviated from the setting value, it shall be repaired and adjusted in time. If the water pressure switch fails and it is forgotten to supply water out of negligence, important water cooling devices such as SCR, MOSFET tube and fast recovery diode will be burned.

②The electric circuits shall be inspected regularly to ensure the contact is secure. Sufficient distance shall be maintained between the high voltage circuit and low voltage circuit; and high frequency circuit shall not be close to door plate or machine frame. Especially for important control circuit, it cannot be allowed to be close to heavy current high frequency lead though it is insulated, or else exception of

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the equipment may occur.

③The relay and contactor shall be checked regularly to confirm whether the leads are secure, whether the contact is burnt, whether the acts are reliable.

④The reliability of grounding system shall be checked regularly. If the grounding condition deteriorates, exception of the equipment or even personal injury may be incurred.

⑤The measuring system shall be adjusted regularly. Accurate measurement is significant to normal operation of the equipment.

The DC voltage meter, DC current meter and frequency meter directly reflect the work conditions of the equipment. Therefore, their accuracy is critical to the status of equipment and shall be adjusted frequently.

⑥The various components in rectifying cabinet should be often cleaned and keep its cleanness. If using wet cloth to wipe, make sure to start the welder after component dry.

#### **4.4.2. Maintenance for Inverter cabinet**

Inverter drive module is the core component of the equipment and is very expensive; it shall be maintained carefully. The structure of inverter bridge is compact and easy to accumulate dusts which may lead to fire striking and discharging, causing damage to the equipment. Therefore, the components in inverter cabinet shall be checked frequently to keep its cleanness.① Regularly check the water pressure switch, check whether water flow is unobstructed, whether the water temperature, water pressure is normal.

Regularly clean the components in inverter cabinet, especially the inverter bridge, usually it can be cleaned by hair brush and air blast; the oil which is hard to remove ,then can unload inverter module can be cleaned with cleaning agent for carburetor.

Except check, the door of equipment shall be closed properly; the door shall be repaired promptly if it is damaged in order to prevent dust from falling into inside of the equipment.

④ Regularly check whether the tank circuit, capacitor have discoloration and crack phenomena

⑤ Frequently check whether the insulation between the output plate is well. Whether output plate and inductor are connected tighten.

⑥ Moreover, no object shall be placed around the inverter bridge to avoid any unexpected accident.

#### **4.4.3. Maintenance for rectifier transformer**

Keep the porcelain bottle and body of transformer clean, free of oil stain or dust.

Inspect whether there is any oil leakage of transformer, whether the screws are loosen and whether there is any phenomenon or trace of local overheat.

#### **4.4.4. Water cooling system**

Many components of high frequency device need forced cooling. This equipment mainly adopts forced air cooling and forced water cooling. The water cooling system is an important constituent part of high frequency device.

Attention shall be paid to the following instructions for routine operation and maintenance of water cooling system.

①Abide by correct starting sequence. Open the water cooling system prior to starting the high frequency power supply; when shutting down, stop the high frequency power supply first and allow the water system continue to work for three minutes before shutting down the machine.

②Ensure the pressure at water inlet of the high frequency power supply is approximately 0.35MPa to provide the high frequency power supply with appropriate water supply pressure.

③Ensure the water inlet temperature is less than 35°C to provide the high frequency power supply with appropriate water supply temperature.

④Replenish the circulating water tank and dousing tank with water in time; the water for circulation water tank must be distilled water to prevent scaling which may lead to water clog.

⑤Following opening the water cooling system, firstly check whether there is any water leakage or clog in the whole water passage. Do not start the high frequency power supply until it is confirmed that the condition is normal.

⑥During normal operation, the water passage shall be checked frequently. If any problem is detected, the machine shall be stopped for repair to avoid any damage to the high frequency power supply.

⑦After the high frequency is shut down, 2-3 minutes shall be allowed before the water supply is stopped.

⑧The water cooling system shall also be maintained regularly. Seriously aged or rusty water pipe shall be replaced in time.

⑨The accuracy of water thermometer and water pressure gauge shall be adjusted on a regular basis.

⑩The cooling water passage for high tension device and power device shall be cleaned regularly. Because scaling in the water pipe may reduce insulation property and increase electric leakage.

#### 4.5 Maintenance Form

MAINTENANCE PERIOD	MAINTENANCE CONTENT				
	Rectifier cabinet	Inverter cabinet	Console	Transformer	Water passage
Daily maintenance	Cleaning; dust devices with electric blower; visual inspection	Cleaning; dust devices with electric blower; visual inspection	Cleaning; dust devices with electric blower; visual inspection	Cleaning; dust devices with electric blower; visual inspection	Cleaning, visual inspection for leakage or dripping
Weekly maintenance	In addition to above inspection, use multi-meter to check the	In addition to above inspection, use multi-meter to check the	As above	As above	As above

	performance of controllable silicon	performance of MOS tube			
Monthly maintenance	In addition to above, fasten connecting screws of connection terminals and copper bus-bar	In addition to above, fasten connecting screws of connection terminals and copper bus-bar	As above	As above	As above
Annual maintenance	In addition to above, conduct comprehensive inspection of the system; check electric insulation performance	In addition to above, conduct comprehensive inspection of the system; check electric insulation performance	As above	In addition to above, assay insulation oil and filter and replenish it if the insulation performance reduces	As above

## V Equipment maintenance

### 5.1 After sale service

This chapter is prepared for the operation and maintenance personnel for users, the main purpose is to enable users to confirm fault coverage and cause to the abnormal phenomena which occurred during the operation for equipment and take corresponding measures in time in prevention of expansion of fault coverage. If user is not able to understand the problem, please contact our company by email(1412971493@qq.com)

### 5.2 Tools and Instruments in common use

#### 5.2.1 Tools in common use

Besides the tools commonly used by electricians, 25W electric iron (e.g. TLN-25 model), solder sucker, tin wire, combination file, side cutting pliers, etc. shall be prepared.

#### 5.2.2 Multi-meter

Mainly used for circuit metering. Usually pointer type multi-meter is used for measuring semiconductor devices and digital multi-meter for measuring electric signals. As capacitors and inductors are massively used in the induction heating equipment, the digital meter would better have the capacity to measure them.

#### 5.2.3 Clamp type current meter

Large clamp type current meter which can measure current above 1000A and have multiple gears

Small clamp type current meter whose measurement range is below 40A; multifunctional for both AC and DC current and is able to measure mono-tube current of MOSFET tube.

#### 5.2.4 Signal generator

Signal generator of sine wave, square wave and triangle wave which can be used as signal source for idle debugging. The digital display shall be at least 5-digit to meet the need of 400KHZ.

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### 5.2.5 Dual-trace oscilloscope

It is a necessary tool for debugging and repair. It is mainly for inspection of waveform of grid and drain electrodes of MOSFET tube, waveform of grid and source electrodes of MOSFET tube, and voltage feedback waveform. It is also used to observe the tube voltage drop of drain and source electrodes as well as detect if there are burs on the waveforms. It is recommended to select oscilloscope larger than 20MHZ. Two points need to be given attention when using oscilloscope ①The dual-trace measuring probes shall be grounded, or else short circuit will be caused. ②Must observe the stipulation in oscilloscope for maximum measuring voltage.

## 5.3 Measuring Methods for Common Devices

### 5.3.1 Diode

Use pointer type multi-meter; red pen is positive and black pen is negative. Use red pen to connect to the negative pole of diode and black pen the positive pole; at this moment the resistance shall be around 20 ohm (using x1 step). Measure in the opposite way and the resistance shall be infinite. This tube is normal.

### 5.3.2 Triode

Triode can be equivalently regarded as two connected diodes. Refer to the measurement of diode, but the PNP type and NPN type have opposite polarity.

### 5.3.3 Resistor, Capacitor

The resistance of resistor can be directly measured with digital multi-meter; others are inspected visually.

Use multi-meter to check if there is any short-circuit in capacitor; others are inspected visually.

### 5.3.4 Controllable Silicon

Controllable silicon is a very common electric device. Six pieces of controllable silicon are used in this equipment to form rectifier voltage regulation for power regulation. Use the resistance gear of multi-meter to measure the resistance of cathode and gate electrode to check its integrity; usually the resistance is dozens of ohm. Measure with the diode gear of digital multi-meter; both the anode and cathode shall not be connected. Measure the resistance between the cathode and anode with the resistance gear of pointer type multi-meter; the resistance usually is several hundred thousands ohm.

### 5.3.5 MOSFET Tube

Viewing the IRFP460 MOS tube from front, the three pins from left to right are gate, drain, source respectively. The integrity of MOS tube can be inspected with DT9205A digital multi-meter. Do not touch the three pins of tube with finger and short circuit the three pins on a well-grounded metal platform. Then use multi-meter to measure the source and drain electrodes; it shall be of the characteristic of diode (gear resistance is 20 MΩ). Then hold the gate and drain electrodes with thumb and index finger and at the same time measure the drain and source electrodes; the resistance shall be around 4MΩ (200MΩ gear). This method can also be used to roughly measure the consistency of the parameters of MOS

tube.

#### 5.4 Common faults and trouble shooting

When the equipment is exceptional and shutdown is caused, general treatment measures are : do not immediately cut off power supply or press down reset button so as to store the fault display.

Firstly, the alarm content and fault position shall be confirmed from the man-machine interface. If the fault is located at rectifier control board or inverter control board, then check the fault indication from rectifier board and inverter board , After confirm the fault contents, should immediately cut off power supply. Several typical faults and countermeasures are introduced as follows:

##### 5.4.1 Failure phenomenon : after power on for the welder, operation panel comprehensive fault indicator are light

Analyze cause	Solution
It is due to the self-test failure to cause self-test can not normal end	First check the alarm information from HMI display, then according to the prompt to further check the reasons, 1# board fault continue to check nixie tube display digit, 2# board and Power module check the related LED signal , and check the related circuit.

##### 5.4.2 Fault phenomenon: after heat starting, power adjust potentiometer does not work

Possible cause	Solution
<b>Possible cause 1:</b> the adjustment switch internal/external mode for welder doesn't correspond the power adjust potentiometer	Please turn the adjustment switch on welder control panel to the position which is consistent with power adjust potentiometer.
<b>Possible cause 2:</b> 1 # board DL11 indicator is light, that indicated according to the proportion method operation or the welder has fault. As this moment the regulator magnification times is too small, the power adjust potentiometer maybe doesn't play a big role.	Check whether the welder has fault; check whether the short circuit insert block S201 is in the correct position. When it is in integral state, two inserting pins on right side are short-circuit, when it is proportion position state, two inserting pins on left side are short-circuit, when welder works should be as integral state.
<b>Possible cause 3:</b> power adjust potentiometer wrong line or broken line or + 10V voltage is wrong	The corrected connection method for power adjust potentiometer should be: +10(middle),0V(at the rotating end), Sliding contact head connect the given signal of power adjustment. To connect well the broken line. If +10 V voltage is incorrect, please check +10 V power supply from 1# board.
<b>Possible cause 4:</b> the center tapped for power adjust potentiometer is not correspond to the line of 151# from 1# board	According to the electrical schematic to check whether 151 from 1# board connect to the corresponding center tapped of potentiometer. Whether the middle contact point has not been connected.

Possible cause	Solution
<b>Possible cause 5:</b> the heat signal has not given to 1# control board that is to say the line of 120 has not connected to GND.	If nixie tube to show “H” is always light, 151 has the input, if 1# board is bad, please contact with our company in time.
	If nixie tube does not show “H”, then check whether the line of 120 disconnect with GND, check whether KA2 is damage and make the corresponding processing.

#### 5.4.3 Fault phenomenon: heat starting doesn't work

Possible cause	Solution
<b>Possible cause 1:</b> When welder heat is internal/external mode, doesn't correspond with the heat button. When it is the external mode, only the external heat start work. When it is the internal mode, only the internal heat start work, while heat stop, whatever internal/external control all start work. (Above 400KW welder without the function setting)	Please turn the heat conversion switch of console panel to the position which is consistent with the heat button
<b>Possible cause 2:</b> press down the emergency stop button	Please check whether each emergency stop button is pressed down; please according to electrical schematic check whether the corresponding emergency stop signal is in the right state.
<b>Possible cause 3:</b> the wire is broken for heating control circuit or interlock and fault action.	Refer to electrical schematic, to connect well the broken wire, interlock and troubleshooting.

#### 5.4.4 Fault phenomenon: main circuit and control circuit is off and failure

Analyze cause	Solution
Refer to electrical schematic, to add the interlock to the control for welder on and off, the starting step is control power on, main circuit on, heating on, the normal shutdown order is inverse process, should be heating off, main circuit off, control power off, any other operations are not conform to the rules that maybe lead to malfunction. When the welder is detected a fault, it will automatically cut off the heating circuit, or main circuit main contactor directly trip.	To connect well the broken wire, interlock and troubleshooting

**5.4.5 Fault phenomenon: after failure , press down the reset button, fault indication doesn't disappear**

Possible cause:	Solution
<b>Possible cause 1:</b> Refer to electrical schematic, check whether the connection for reset button is correct.	After troubleshooting, press the reset button, fault indication is disappear naturally.
<b>Possible cause 2:</b> Distinguish fault type, maybe fault is still exist, so when press the reset button, the fault is disappear.	

## 5.5 Faults of Power Module and Repair

If the power module is faulty, firstly check whether there is any alarm display. The alarm contents include four items, which are: damaged MOSFET tube, no drive pulse, over temperature and fault of DC power supply. Apart from these, if there is any damage to components, check the components one by one with multi-meter. Replace the faulty component when the fault is identified.

### 5.5.1 Fault distinguish of power module

There are five indication lamps at each side of each power module. In normal condition, only one green indication lamp at each side is on. In fault condition, the green indication lamp will turn off and corresponding red fault lamp will turn on. Each indicator specific meaning as follows:

#### ① Lamp of “power supply fault” is light **SUPPLY**

It indicates that the power supply voltage of module is less than 15V, and the supply voltage of corresponding power distribution board shall be checked.

#### ② Lamp of “over temperature” is light **TEMP**

It indicates that the temperature of water cooling aluminum rod which used to heat output for MOS tube is too high; should check whether the water passage is smooth. If temperature switch was damaged, instead of a new temperature switch, as shown in Picture 6-2

#### ③ Lamp of “pulse lost” is light **PULSE**

It indicates that there is no pulse input into the module; should check whether the ox horn cable at output side of AC bus-bar is correctly plugged. Or it is possible that the output pulse wire of the inverter board is not plugged securely. Should find out the fault and remove it.

#### ④ Lamp of “damaged MOS tube” is light **MOS**

It indicates that possibly one or more MOS tubes were damaged. In this situation, carefully observe the appearance of power components of module. In general damaged power components will accompany the external characteristic such as shell burst and so on. Check with multi-meter the other power components on the module, especially the fast diode and high power absorbing resistor shall be inspected one by one and any damaged one shall be replaced. The power module shall be removed for repair when necessary; specific operation steps as follows:

1. Working stop for welder fault
2. Check the information display window of HMI, it can display “inverter alarm”. Note: at this time,



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please don't press the reset button, to reserve the fault information of welder.

3.To observe the fault indication red LED on inverter control board is in the back door of inverter cabinet, you will find "Mod", the fault indication LED is light(as shown in picture 5-1) .

4. To observe the fault indication LED on both sides(internal and external )of power module,(as shown picture 5-2) if power module is normal, then two green LED are light. If power module has fault, then the corresponding red indicator is light.

Note: due to each green LED to equip with each module baseboard's inside and outside, in general it is easy to directly see the outside one, it is difficult to see the inside one. General you can observe it at the opposite side or with a little mirror reflector to observe and determine whether the module is damaged. If one of the LED is not light or both LED are not light, that can ascertain that the module was damaged, and further observe the corresponding Red LED on module, and refer to "Inverter Troubleshooting Flow Chart" to determine the causes of damage. If the two green LED are all light , normally the module is not damage.

5. Another way to determine whether the module damage that is directly observe MOSFET on power module, if the MOSFET damage, usually can be seen it's package case has been exploded and or cracked, indicating that the module be sure has damaged .

6.To check all modules, it is possible for other modules have the similar damage to occur

7.Once confirmed the module is damage, other modules even if the two green LED are light, it's fast recovery diodes may also be damaged, need to check. With a digital multimeter check the following:

(1) Positive module's examination

① There are  $25\Omega$  resistor between DC input bus bar corresponding to water cooling bar, if the resistance value becomes larger, and showed diode characteristics, indicating the first water-cooled resistor of  $25\Omega$  is damage that near the outlet of the water cooling bar. If the resistance value change to 0, then illustrate the fast recovery diodes on water cooling bar are damaged, due to fast recovery diodes appears the parallel relation that need to check the water cooling bar be removed one by one, as shown picture 5-3.

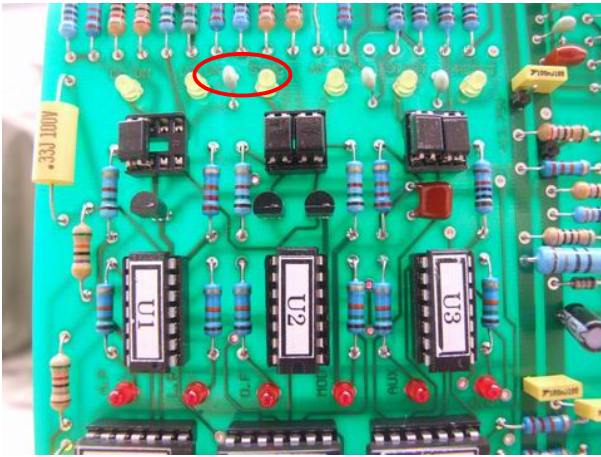
② It is the diode characteristic between water cooling bar corresponding to AC output bus bar that is nearest to the water cooling bar. AC bus bar terminal is the diode anode terminal. If no diode characteristics, indicates that water cooling bar has the damaged MOSFET, then removed and check one by one. as shown picture 5-4 and picture 5-5.

(2) Negative module's examination

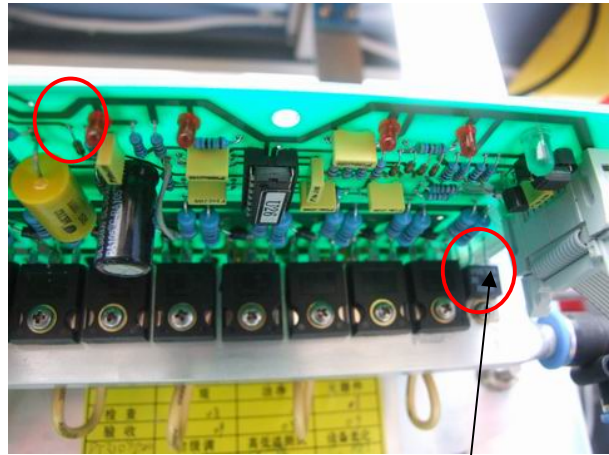
①It is the diode characteristic between DC input bus bar corresponding to water cooling bar. AC bus bar terminal is the diode anode terminal. If no diode characteristics, indicates that water cooling bar has the damaged MOSFET, then removed and check one by one. as shown picture 5-6 and picture 5-7.

②There are  $25\Omega$  resistor between water cooling bar corresponding to AC output bus bar that is nearest to the water cooling bar, if the resistance value becomes larger, and showed diode

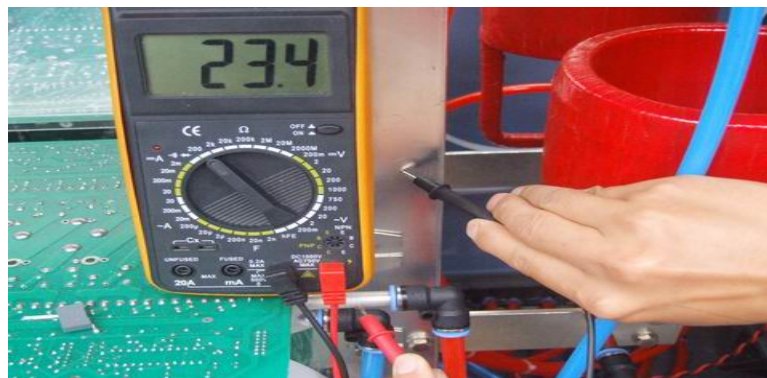
characteristics, indicating the first water-cooled resistor of  $25\Omega$  is damage that near the outlet of the water cooling bar. If the resistance value change to 0, then illustrate the fast recovery diodes on water cooling bar are damaged, due to fast recovery diodes appears the parallel relation that need to remove the water cooling bar and check one by one, as shown picture 5-8.



Picture 5-1



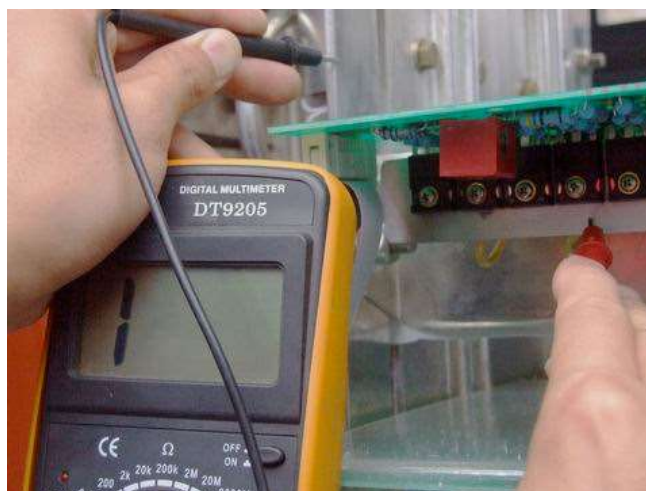
Picture 5-2 Temperature switch



Picture 5-3 (The normal resistance value is  $25\ \Omega$  for DC input positive bus bar of positive module corresponding to the water cooling bar)



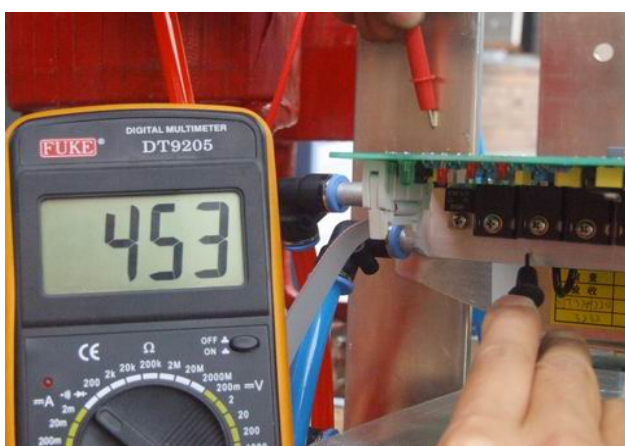
Picture 5-4



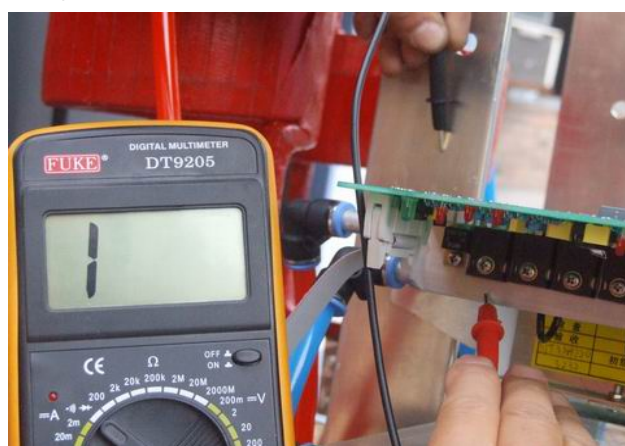
Picture 5-5

Picture 5-4 (It is the diode characteristic for water cooling bar of positive module corresponding to AC output bus bar that is nearest to the water cooling bar.)

Picture 5-5 (It is the diode characteristic for water cooling bar of positive module corresponding to AC output bus bar that is nearest to the water cooling bar.)



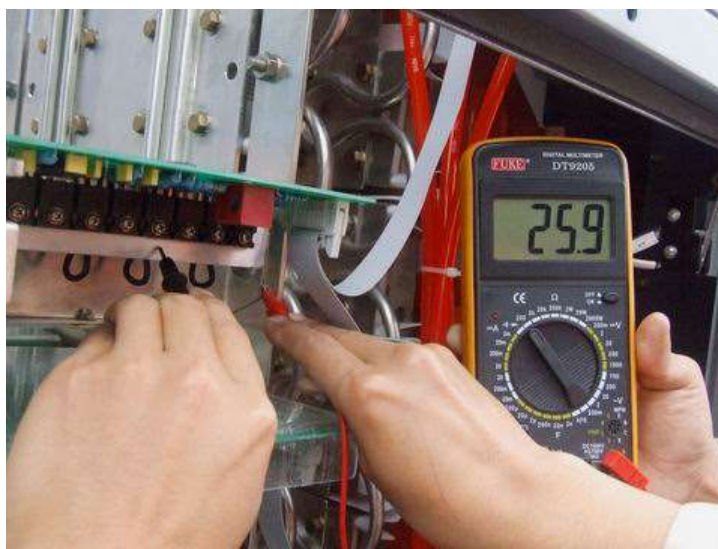
Picture 5-6



Picture 5-7

Picture 5-6 (It is the diode characteristic for DC input negative bus bar of negative module corresponding to water cooling bar.)

Picture 5-7 (It is the diode characteristic for DC input negative bus bar of negative module corresponding to water cooling bar.)



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Picture 5-8 (The normal resistance value is  $25\Omega$  for the water cooling bar of negative module corresponding to AC output bus bar that is near the water cooling bar)

**Note:** Above measure result 's premise is don't dismantle modules, and can accurately reflect the short-circuit damage for Mosfet and fast restore diode, but it can not reflect its open circuit situation. Regarding to the change of resistance value ( $25\Omega$ resistor) that parallel with fast restore diode and open circuit can be all accurately reflected. The inspection of MOS tube need an oscillograph to measure the driver waveform. It is inconvenient to take photos for inside, so only show to measure the module's outside. Inside measuring method same with the outside, please understand.

### 5.5.2 Power module's repair

According to the above section method, once to determine module has damaged, you must repair it according to the following sequence.

① View and replace all damaged MOS tube and fast recovery diode. MOS tube is evenly coated conductive paste, fast recovery diode is evenly coated heat conductive silicon grease, welding firmly, and tighten the screw. If the attached copper burnout, after clear the carbide then use wire connection instead of the burned-out copper.

② Measure all resistors for  $10\Omega/2W$ , value should be  $10\pm0.2\Omega$ , otherwise it should be replaced.

③ Measure all  $25\Omega$  water cooling resistors.

④ Check whether the appearance for all  $1.5nF/1600V$  capacitors are damage. If so, please replace.

⑤ Check whether the drive tubes, such as 30P05、60NF06、2219、2905 are damage. If so, please replace.

⑥ Measure whether the temperature switch of water cooling is damage. Whether the breakover is normal, whether the open circuit has damage. If so, please replace.

⑦ Feel no problem, then testing the module on console or welder. After power on to the welder, the green pulse indicator is light. To use an oscilloscope check whether all Mosfet's drive waveform is normal and overlap, if there are problems, please repeat the above steps.

### 5.5.3 Replacement for power module

A Needed tools for dismantle module

1. The open end wrench both  $12mm$  and  $14mm$  or socket wrench both  $12mm$  and  $14mm$ .
2. A clean cloth to wipe the water.

B. To dismantle a power module



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Once confirm the power module has damaged, the module must be dismantled down. The wrong removal method may cause the damage for other modules. Please properly dismantle them according to the following methods.

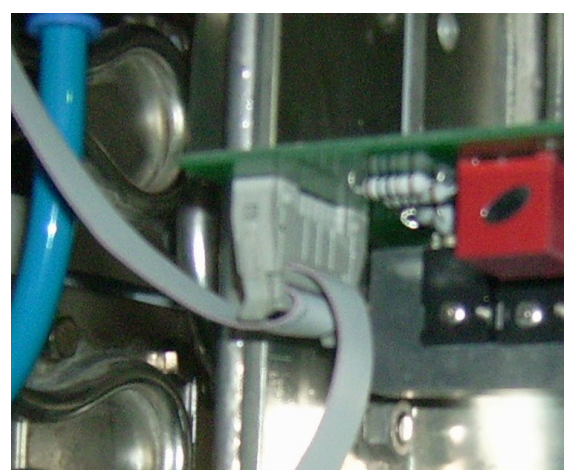
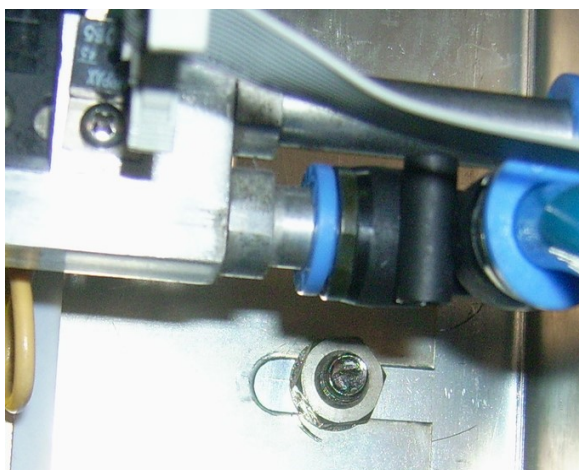
**Warning: Please reconfirm the power supply for the welder has been cut off, to confirm the water pump has stopped working.**

1. To remove the flat cable plug from two ends of power module

2. Loosen three pieces of hex bolts that fixed module : during the assembly process, use socket wrench tighten bolt, only need to use open end wrench of 12mm, 14mm or socket wrench of 12mm, 14mm to loosen it , one of which is installed in the DC busbar (as shown in picture 5-9), The other two pieces are installed in the AC busbar (tank capacitor side as shown in picture 5-10), first remove the bolt outside the AC busbar, and to raise the pressed copper strip so that expose a bolt of inside that can remove the inside bolt, otherwise the bolt installed inside of AC bus bar is invisible. Bolts and washers will be well collected in order to replace new module to use.

3. Gently pull the module out , at the same time rotating one end of module to be out which close to the AC side. If like this the quick connector which the module connect to one side of the hose can be exposed.

4.To remove the quick connector of water hose, note that to block the hose mouth with hand to prevent water leakage. Please do not try to pull the hose to outside or pry the connector with a screwdriver under the situation for the quick connector hasn't loosen that it is easy to cause damage to the water mouth so that the water connector leak and beyond repair in future.



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Picture 5-9

Picture 5-10

C: Installation for new module:

1. First confirm the positive and negative before install new power module, in other words, should ensure that the positive module is installed in the positive module side and the negative module is installed in the negative module side, the installation can not be wrong. Usually recognized by the two markers together: first, at the lateral side of both positive module and negative module are labeled and indicated that the module is positive or negative module, also indicated the module models or the No. of spare parts. Should ensure the model and spare parts No. is consistent with the module which has been replaced. Secondly, the positive module is visible red or yellow wire rings in them. And the negative module is visible black or blue wire ring in them.

2. First to insert the quick connector in the water hose and connect it well.

3. Gently push the module to the original installation location. Ensure that the spacers of insulation PTFE at the ends of module AC side pass through from the gap in the middle of AC busbar to arrive the other side of the busbar that is the capacitance side.

4. To install three bolts, pay attention not to tighten them first

5. First tighten the bolts on AC side, then tighten the bolts on DC side.

6. The flat cable plugs of both sides of module have been inserted well to ensure that the locking ring at the two ends of socket can firmly lock the plug.

7. Carefully wipe leakage water or splashing water when remove modules.

8. When power on to the welder, start the heat exchanger pump, check whether it leaks, after supply water for 20 minutes, check again whether it leaks.

9. Module replacement success.

#### **5.6. Tank circuit failure and maintenance**

1. Cooling water failure would cause the plate red-hot and damage or capacitor damage.

2. Capacitor damage may cause the tank circuit can not afford to vibration, or welder frequently shut down. Capacitor should be removed and check one by one.

3. If the insulation of output plate damage may lead to tank circuit can not afford to vibration, or welder frequently shut down. Should remove the output plates and check PTFE plate between the two output plates, replace and wipe clean them.

#### **5.7 Driving power failure and maintenance**

DC power supply use the switch power which has the best protection, not easily damaged, and only added high voltage it will be damage. If damage, the normal working indicator does not light, then replace it. Overcurrent protection can lead to stop working, find out the reasons and troubleshooting, re-power on can resume normal work.

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## 5.8 Cooling waterway maintenance

Cooling waterway often occurs a problem is water hose blocked, cause reason is the water quality from the user is poor or has debris, or PVC pipe deformation cause water currents are not smooth, even breaking stream. Therefore shall regularly check when necessary replace them.

## 5.9 Troubleshooting record

No.	Date	Fault phenomenon	Fault cause	Measure
1				
2				
3				
4				
5				
6				
7				

## VI. High Frequency Induction Welding Process

### 6.1 Skin Effect and Proximity Effect of High Frequency Current

High frequency welding is performed by utilizing the “skin effect” and “proximity effect” of high frequency current. In order to analyze the high frequency welding process of steel pipe, we need firstly understand the “skin effect” and “proximity effect” of high frequency current. When AC current goes through conductor, the current density at the cross section of conductor is not uniformly distributed. The maximum current density is at the surface of conductor whereas the current density at the axis is minimal or even zero. This phenomenon of current concentration is called as “skin effect”. The conception of current penetration “ $\Delta$ ” is introduced thereof, by electromagnetic induction theory the

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following can be derived

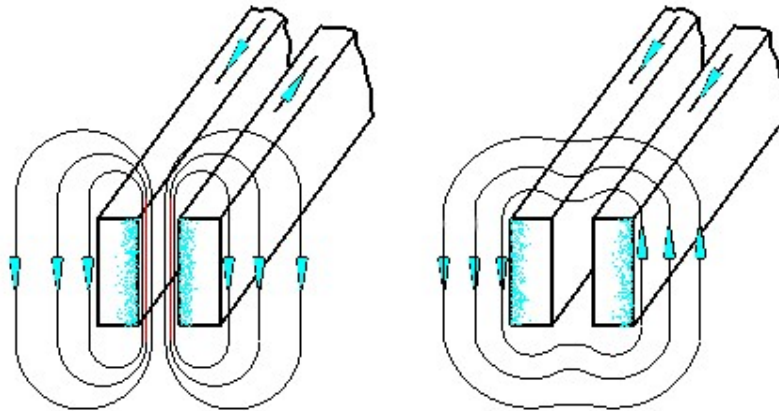
$$\Delta = 5030 \sqrt{\frac{\rho}{\mu_r f}} \quad (\text{centimeter})$$

Where,  $\rho$  —resistivity of conductor, ohm·centimeter

$\mu_r$  —relative permeability of conductor

$f$  —current frequency, hertz

It is known from the electromagnetic induction principle that: when AC current goes through conductor, the current is always concentrated at the location where the flux interlinkage is minimal. Therefore, when AC current is applied to two adjacent conductors, if the directions of currents in these two conductors are opposite, the current will go through the conductor while concentrating at the inner sides of conductors; if the currents are in same direction at the same moment, then the currents will be repulsed to the outer sides of conductors. This is called “proximity effect”. The “skin effect” and “proximity effect” can be illustrated by the following diagrams:



When currents flow in opposite directions  
in two parallel conductors

When currents flow in opposite directions  
in two parallel conductors

## 6.2 Brief Introduction to the Principle of High Frequency Welding Pipe

Band-shaped metal strip is squeezed by forming machine into open pipe blank. The edges of strip butt at the position of squeeze roll and form an angular aperture of “V” shape. High frequency current is applied to inductor. According to electromagnetic induction law, there are two current loops in the pipe blank. One loop is in circumferential direction of the pipe blank and corresponds to the inductor; another is in the direction from the inductor to squeeze roll and flows along the V-shaped angular aperture which is at the edge of strip. This current is that high frequency current which applies in welding. Obviously, we wish that the current flowing along the V-shaped angular aperture could be as large as possible. The placement of impeder (bar magnet) enlarges the impedance of the current loop which flows along the circumference of pipe blank so as to force most current flow along the angular aperture. Under the influence of skin effect and proximity effect, the edges of metal strip are quickly heated. These two effects are particularly obvious at the bottom butt of the V-shaped angular aperture. The edges of metal



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strip are quickly heated to the temperature required by welding process. Under proper squeezing pressure of squeeze roll, oxide impurity inclusions of the molten metal are squeezed out of welding joint and pure base metal is well welded together. It can be observed that how high the work frequency of high frequency power supply is directly affects how strong the skin effect and proximity effect are. Appropriate frequency must be selected in order to ensure welding quality of steel pipes of different thickness.

### **6.3 Process Parameters of High Frequency Welding and Principle of Adjustment**

The third generation solid state high frequency power supply has remarkable energy saving performance and is able to produce high quality welded pipes. In order to enable the equipment to operate in its best condition to play to the multiple excellent performance of the third generation solid state power supply to the maximum, the following shall be given attention to:

- Technological parameter for winding of inductor

- Selection and placement of bar magnet

- Length and magnitude of angular aperture

The welding process of steel pipe is a very complicated physical and chemical process in which many factors have their influences. Such as the magnitude of welding frequency, speed of rolling machine, material of metal strip, adjustment of machine set, and even the water cooling in welding process will affect the quality and energy consumption of welded pipes. Some specific process parameters and principle of adjustment are expounded as follows.

#### **6.3.1 Inductor**

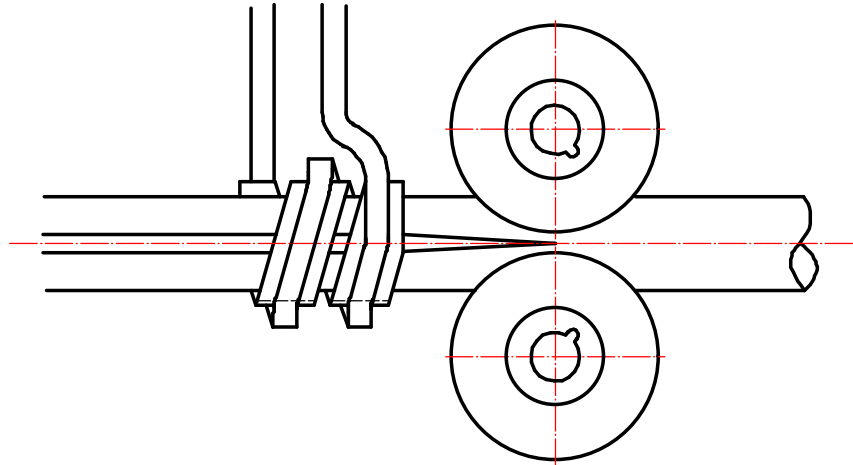
The inductor is usually made from copper tube or copper band and is of single-turn coil or multiple-turn coil. High frequency current is applied to it. It is easy to understand that skin effect and proximity effect also exist in the inductor. Therefore, the cross section area of the copper tube or copper band of inductor is not equal to effective conduction area. The actual conduction area is much smaller. Therefore, there is certain loss incurred by the inductor itself and this is an efficiency issue. Selecting proper material to wind the inductor will effectively reduce loss of the inductor itself and improve the overall efficiency of the equipment. Besides, the number of turns and inner diameter of inductor as well as the handling of leading-out end will have effect on whether energy can be conveyed to the welding zone at a high efficiency. The third generation all solid state high frequency power supply adopts compound resonance circuit without transformer output. The inductor and pipe blank system is at the same time both the load of the whole set of power supply and resonance device of the circuit. Fabricating and installing proper inductor will enable good performance of the power supply. Theoretically the smaller the gap between inner diameter of inductor and outer diameter of steel pipe is, the better. However, if the gap is too small, frequent contact and fire-striking between the inductor and steel strip will be caused and even the inductor might be pulled away. In practice, this gap is controlled within the range of 3-10mm; relatively smaller gap is adopted for small caliber and larger gap for large

caliber. The total width of inductor is controlled at 1-1.2 times of the diameter of welded pipe as a rule. It could be smaller than the diameter of steel pipe for large caliber pipe. As the space of squeeze roll allows, the inductor shall be close to the squeeze roll as possible. The table below includes practice-proven parameters for fabrication of inductor, which is suitable for application of the third generation all solid state high frequency.

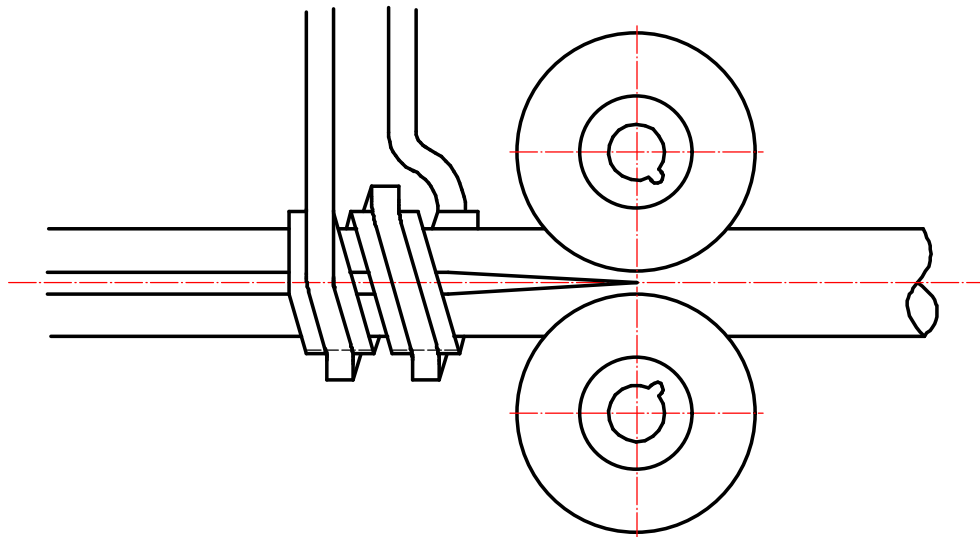
O.D of steel pipe(mm)	I.D. of inductor (mm)	Copper tube	Coil turn
10	17	Φ8	3
12.7	19	Φ8	3
16	24	Φ8	3
19	27	Φ8	3
22	32	Φ8	3
25	36	Φ8	3
29	40	Φ8	3
32	45	Φ8	3
38	50	Φ10	3
44	60	Φ10	3
51	65	Φ10	3
57	70	Φ10	3
60	75	Φ10	3
64	80	Φ10	3

O.D of steel pipe(mm)	I.D. of inductor (mm)	Copper tube	Coil turn
76	95	Φ10 Copper band	2
79	95	Φ10 Copper band	2
89	105	Φ10 Copper band	2
100	120	Φ10 Copper band	2
114	140	Φ10 Copper band	2
127	150	Φ10 Copper band	2
140	165	Φ10 Copper band	2
155	181	Φ10 Copper band	1
168	195	Φ10 Copper band	1
190	217	Φ10 Copper band	1

Proper and correct installation of inductor also directly affects the efficiency of coupling efficiency. The diagram below illustrates the winding direction of inductor relative to the angular aperture of steel pipe.



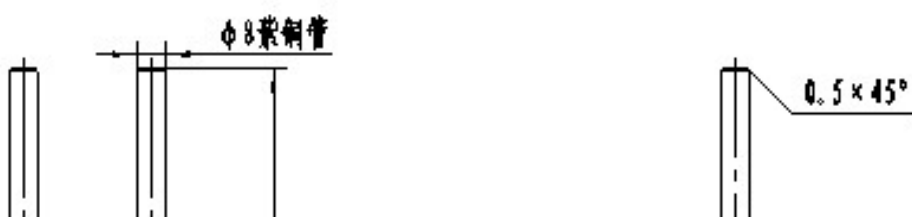
Correct winding direction of inductor



Wrong winding direction of inductor

### 6.3.2 Reference sketch for producing inductor

Φ8 copper tube



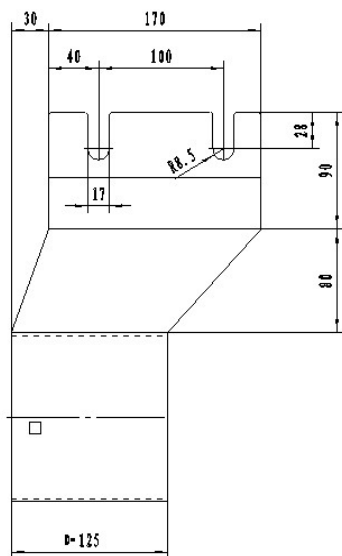
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**PTFE tube position**

**Technical requirement**

- 1. Ensure the size for every parts**
- 2. To wear the PTFE tube before winding the inductor(  $\delta 0.5$ )**

**Producing sketch for multiturn inductor**



D取值一般为钢管直径的1.1倍

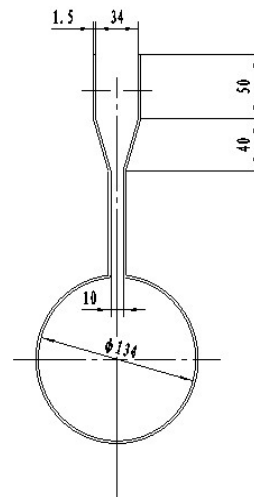
D value usually is the 1.1 times of steel pipe Dia.

114钢管为例感应器制作示意图

意图

Take 114 steel pipe as the example

Producing sketch for inductor



技术要求: 1. 保证各尺寸。

2. 尖端倒角R2, 边缘倒角R0.5, 钻孔后去毛刺。

3. 酸洗。

Technical requirement:

1. To ensure the size for each parts

2. Rounding chamfer R2 for top point, rounding chamfer R0.5 for edge, debur after drilling

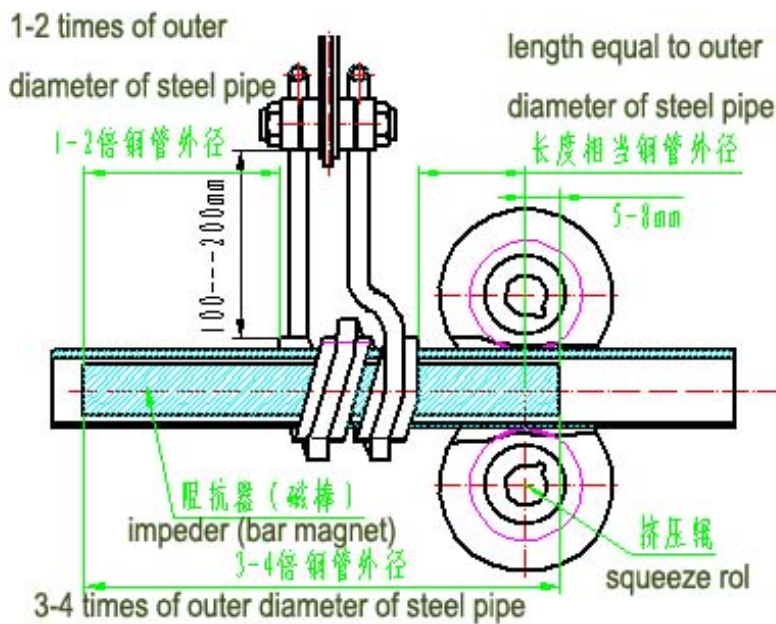
3. Pickling

## Producing sketch for single-turn inductor

### 6.3.3 Impeder (bar magnet)

Installation of impeder reduces the high frequency current flowing along the circumference of pipe blank and consequently increases the high frequency current at the edges of welding joints. The heating efficiency is remarkably improved. Usually, the cross section area of bar magnet shall be 70%-75% of the cross section area of inner diameter of pipe blank. When it is less than 70%, efficiency drops obviously. The bar magnet used for high frequency pipe welding shall have a high initial permeability  $\mu_i \geq 800$ , a value of saturation flux density  $B_s$  larger than 3000GS, high curie temperature as possible and low loss. In use, care shall be taken to adequately cool down the bar magnet in prevention of crack of bar magnet or failure due to the temperature exceeding the Curie point. Both the length and location of impeder will affect the welding efficiency. The diagram below shows the specific dimensions of impeder relative to those of squeeze roll and inductor when welding steel pipe of medium or small caliber. It needs to point out that the gross cross section area and length of the bar magnet shall be adjusted in accordance with the steel pipe to be welded. As a rule, when welding steel pipe of large caliber, the total length of bar magnet might be shorter, but the bar magnet at that side where angular aperture is formed shall still exceed the central line of squeeze roll.

(clockwise from upper left)



## VII Zero connection and ground connection requirement for solid state welded pipe power supply

### 7.1 Zero connection for welder(N)

Welder power supply is three-phase four-wire, where zero line (N) use the copper wire is not less than 16mm<sup>2</sup> and connect to "N" of welder terminal strip, primarily to meet the requirement that single phase 220V for welder operation power supply.

**Note:** Zero connection and ground connection for welder can not be connected together.

### 7.2 Ground connection for welder( $\frac{\perp}{=}$ )

To ensure that equipment is working properly and operator is safety, and from equipment shielding requires to be considered, the equipment should use a separate grounding system that is consists of grounding body and grounding wire. the total resistance of ground loops should be less than 4  $\Omega$ .

**Note:** The equipment grounding system is absolutely avoid to share the same grounding system with electric welding machine, motive power machine and other large electrical devices. The grounding wiring should be away from large power equipment power line, Welder should be regularly checked and maintained in good condition.

#### 1. Grounding body requirement

Grounding body can be made by galvanized angle steel, the specific requirements as following:

①The length of grounding body is 2.5m(45×45), at least the quantity for galvanized angle steel is three roots

②It is vertical that can be made the horizontal and the triangular then laying them.

③ Angle steel space is 2.5m-3m

④ Laying depth  $\geq 0.6\text{m}$

⑤ Vertical grounding body connection

A. The galvanized flat steel can be used to weld and connect as a whole body.

B. If the output wire for grounding body and grounding wire net use the screw to connect, need firm and reliable. Contact point need to do anti-corrosion processing.

⑥ In order to increase the conductivity for the grounding body, the soil environment of the grounding body can be made a treatment for reducing resistance. Lime, salt, water, charcoal acid and other materials can be watered with a certain proportional allocation.

## 2. Grounding wire

The grounding wire connection use the galvanized round steel which not less than  $\phi 8$ . The connection with the grounding body should use lap welding method. At the bottom of equipment back to equip the grounding bolt, A3 steel lug be welded to the galvanized round steel and be fixed on the grounding bolt.

## 3. The construction reference drawing for equipment grounding system.

