HT4100®

Plasma Arc Cutting System - Operation -

Instruction Manual
801660 - Rev. 4

HYPERTHERM®

HT4100

Plasma Arc Cutting System
- Operation -

Instruction Manual
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(P/N 801660)

for Serial Numbers
beginning with
4100-000001

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ATTENTION

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National and local codes governing plumbing and electrical installation shall take precedent over any instructions contained in this manual. IN NO EVENT shall Hypertherm be liable for incidental or consequential injury to persons or property damage by reason of any code violation or poor work practices.

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Section 1 SAFETY

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SAFETY

INTRODUCTION

Abbreviated safety precautions are printed on the power supply.

Before using the plasma arc cutting equipment (including compressed gas), each person operating, maintaining or supervising the use of this equipment must read the following safety instructions.

NOTES, CAUTIONS & WARNINGS

Throughout this manual, notes, cautions, and warnings are used to describe situations that require additional information. The following formats are used for each:

Notes: A note offers additional information, such as an operating tip, that aids the user in operating the plasma system.

Caution: A caution describes a situation that may cause damage to the plasma system and offers advice to avoid or rectify the situation.

WARNING

A warning describes a situation that presents a physical danger to the operator, and offers advice to avoid or rectify the situation. Each type of warning displays an applicable danger symbol, ie. fire, explosion, electrical shock, etc.

WARNING

ELECTRIC SHOCK CAN KILL.
- Do not touch live electrical parts.
- Keep all panels and covers in place when the machine is connected to a power source.
- Insulate yourself from work and ground: wear insulating gloves, shoes and clothing.
- Keep gloves, shoes, clothing, work area, torch, and this machinery dry.

EXPLOSION WILL RESULT IF PRESSURIZED CONTAINERS ARE CUT.

ARC RAYS CAN INJURE EYES AND BURN SKIN.
- Wear correct eye and body protection.

NOISE CAN DAMAGE HEARING.
- Wear correct ear protection.

FUMES AND GASES CAN INJURE YOUR HEALTH.
- Keep your head out of the fumes.
- Provide ventilation, exhaust at the arc, or both to keep the fumes and gases from your breathing zone and the general area.
- If ventilation is inadequate, use an approved respirator.

HEAT, SPLATTER AND SPARKS CAUSE FIRE AND BURNS.
- Do not cut near combustible material.
- Do not cut containers that have held combustibles.
- Do not have on your person any combustibles such as a butane lighter or matches.
- Pilot arc can cause burns. Keep the torch nozzle away from yourself and others when the switch is depressed.
- Wear correct eye and body protection.

SAFETY

SAFETY INSTRUCTIONS

Burn Prevention

Eye Safety

To protect eyes against burns caused by high-intensity ultraviolet light, sparks and hot metal:

- Wear dark safety glasses/goggles with side shields or a welding helmet. Refer to the chart below for recommended lens shades:

Arc Current		Shield Shade
Up to 100 Amps		Shade No. 8
100 - 200 Amps		Shade No. 10
200 - 400 Amps		Shade No. 12
Over 400 Amps		Shade No. 14

- Replace the glasses/goggles or helmet when the shield becomes pitted or broken.
- Warn other people in the area not to look directly at the arc unless they wear a glasses/goggles or helmet.
- Prepare the cutting area in a manner that reduces the reflection and transmission of ultraviolet light:
  - Paint walls and other surfaces with dark colors to reduce reflection.
  - Install protective screens or curtains to reduce ultraviolet transmission.

Skin Safety

To protect skin against burns caused by high-intensity ultraviolet light, sparks and hot metal:

- Wear protective clothing:
  - Gauntlet gloves, safety shoes and hat.
  - Flame-retardant clothing which covers all exposed areas.
  - Cuffless trousers to prevent entry of sparks and slag.
- Hold any hand torch away from your body when pressing the start button because the pilot arc may come on immediately.

- Do not touch the front of the torch when starting it. After cutting, allow time for the front of the torch to cool.

Toxic Fume Prevention

To protect against the danger of toxic fumes which may be produced during cutting:

- Keep the cutting area well-ventilated.
- Remove all chlorinated solvents from the cutting area before cutting. Certain chlorinated solvents decompose when exposed to ultraviolet radiation to form phosgene gas.
- Wear proper breathing mask when cutting galvanized metal and use proper ventilation.
- Do not cut containers with toxic materials inside or containers that have held toxic materials. Clean such containers thoroughly before cutting.

WARNING

Do not cut metal or painted metals containing zinc, lead, cadmium or beryllium unless the operator, or anyone else subjected to the fumes, is wearing respiratory equipment or an air-supplied helmet.

Fire Prevention

Cutting with a plasma system produces hot metal, sparks and slag. Take the following precautions against fire:

- Make fire extinguishers available in the cutting area.
- Remove combustible material from the immediate cutting area to a distance of at least 35 feet (10 meters).
- Quench freshly cut metal or allow metal to cool before handling it or bringing it into contact with combustible materials.
- Never use a plasma system to cut containers with potentially flammable materials inside. Such containers must be thoroughly cleaned prior to cutting.

- Ventilate potentially flammable atmospheres before cutting with a plasma system. Never operate the plasma system in an atmosphere which contains heavy concentrations of dust, flammable gas or combustible liquid vapors.

Electric Shock Prevention

All Hypertherm plasma systems use high voltage (up to 280 VDC) to initiate the plasma arc. Take the following precautions when operating the plasma system:

- Keep your body and clothing dry.
- Do not stand in, sit on or lie on any wet surface when using the plasma system.
- Maintain proper insulation against electrical shock. If you must work in or near a damp area, use extreme caution. Wear insulated gloves and boots.
- Provide a wall-mounted disconnect switch with proper size fuses close to the power supply. This switch allows the operator to turn the power supply off quickly in an emergency situation.
- Conform to all local electrical codes for primary wiring sizes and types.
- Inspect the primary power cord frequently for damage or cracking of the cover. **Bare wiring can kill**. Do not use the system with a damaged power cord. If a power cord is damaged, replace it immediately.
- Inspect the torch leads. Replace if frayed or damaged.
- Never operate the plasma system unless the power supply unit covers are in place. Exposed power supply connections present a severe electrical hazard.
- Do not pick up the workpiece, including the waste cutoff, while you cut. Leave the workpiece in place or on the workbench with the work cable attached at all times.
- Before changing the torch parts, disconnect the main power or unplug the power supply. After changing the torch parts and returning the retaining cap to its operating position, plug the power supply in again.
- Never bypass or shortcut the safety interlocks.
- Before removing a power supply cover for maintenance, disconnect the main power at the wall disconnect switch or unplug the power supply. To avoid exposer to severe electrical hazard, wait five minutes after disconnecting the main power to allow capacitor discharge to occur.

Explosion Prevention

WARNING

The plasma system uses compressed gas. Proper precautions must be observed when handling and using compressed gas equipment and cylinders. Refer to the Standards Index in this manual.

When cutting with the plasma system:

- Do not cut in atmospheres containing explosive dust or vapors.
- Do not cut pressurized cylinders or any closed container.

Pressure Regulators

- Maintain all pressure regulators in proper working condition. Faulty regulators can cause damage or operator injury and must be serviced by trained repair technicians.
- Never use a regulator for any gas other than that for which it is intended.
- Never use a regulator that leaks, creeps excessively or is physically damaged in any way.
- Never attempt to lubricate a regulator with oil or grease.

Compressed Gas Cylinders

- Handle and use compressed gas cylinders in accordance with safety standards published by the Compressed Gas Association (CGA), American Welding Society (AWS) and Canadian Standards Association (CSA).
- Never use a cylinder that leaks or is physically damaged.
- Never use a cylinder that is not upright and secured in place.
- Never move or transport a cylinder without the protective valve cover in place.
- Never use a gas cylinder or its contents for any purpose other than that for which it is intended.
- Never lubricate cylinder valves with oil or grease.

- Never allow electrical contact between the plasma arc and a cylinder.
- Never expose cylinders to excessive heat, sparks, slag or open flame.
- Never use hammers, wrenches or other tools to open stuck cylinder valves.

Hoses

Label and color-code all gas hoses in order to clearly identify the type of gas in each hose. Consult applicable national or local codes.

- Never use the oxygen hose for any gas other than oxygen.
- Replace hose that is damaged by physical abuse or by sparks, heat or open flame.
- Lay hose out straight to prevent kinks.
- Coil excess hose and place it out of the way to prevent damage and to eliminate tripping danger.
- Examine hoses at regular intervals for leaks, wear, loose connections or other hazard.
- Keep hose lengths to a minimum to prevent damage, reduce pressure drop and to prevent possible volume flow restriction.

Grounding

Before operating the plasma system:

Input Power

- Be sure the power cord is plugged into a properly grounded outlet or that the power cord ground wire is properly connected to the ground in the disconnect box.
- If installation of the plasma system involves connecting the power cord to the power supply, ensure that the power cord ground wire is properly connected. Conform to CSA standards by placing the power cord ground wire on the stud first; then place the other wires on top of the power cord ground. Fasten the retaining nut tightly.
- Make sure that all electrical connections are tight to avoid excessive heating.

Work Table

- Clamp the work cable with good metal-to-metal contact to the workpiece (not the portion that will fall away) or to the work table.

Work Table

- Connect the work table to a good earth ground. Consult the U.S. National Electrical Code, Article 250, Section H *Grounding Electrode System*, or other appropriate national or local codes.

For additional information, refer to the *Standards Index* in this manual.

SAFETY REMINDERS

- All Hypertherm torches are designed with a safety interlock, which turns off the power supply when the retaining cap is loosened.
- Never bypass or shortcut the safety interlocks on any of the plasma system units.
- Never operate the plasma system with any of its covers not in place. This would be hazardous to the operator and other people in the area, and prevents the proper cooling of the equipment.
- Each Hypertherm plasma system is designed to be used only with specific Hypertherm torches. Do not substitute other torches which could overheat and present a potentially dangerous situation to the operator and any personnel in the area.

STANDARDS INDEX

The *Standards Index* contains a list of publications dealing with plasma arc cutting equipment safety practices. For additional information, refer to this *Standards Index*.

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INTRODUCTION & SPECIFICATIONS

INTRODUCTION

The instructions to install, operate and maintain the HT4100 system have been separated into three manuals. The following is a list of the manual titles, part numbers, and contents:

HT4100 Instruction Manual: Installation (#801650)

This manual gives pertinent information for the pre-installation supply requirements, installation, and post-installation requirements for the HT4100 system.

Also included in this manual are specifications of the components of the HT4100 system, system interconnect diagrams, and accompanying drawings.

HT4100 Instruction Manual: Operation (#801660)

This manual describes the controls and indicators for the system units, explains how to start-up and operate the HT4100 system, contains cut chart tables, gives instructions to remove and replace consumable parts, and provides routine inspection and cleaning information.

HT4100 Instruction Manual: Maintenance (#801670)

This manual contains basic troubleshooting tips, and a parts list.

It is our hope that this manual set will aid and answer most questions on installing, operating, and ordering parts for your HT4100 system.

If any questions do arise, please call our Customer Service at 1-800-643-0030 or Field Service group at 1-800-643-9878.
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General

Hypertherm's HT4100 is designed as a machine-mounted plasma cutting system for cutting mild steel from gauge to one and one-half inch (38 mm) thick using oxygen as the plasma gas. A micro-controller on the Master power supply control board helps to provide extended life for the torch consumable parts. To achieve consumable long life, **all cuts must begin and end on the plate surface**; this allows for the proper ramping of gases and DC current to extend the life of the torch nozzle and electrode.

The HT4100 system provides the user with capability of locating the power supply and the torch apart by a maximum of 300 feet (91 m). This is accomplished by adding a remote High Frequency (HF) Console.

Maximum DC output for clean, dross-free cuts using oxygen with the HT4100 system, is 300 amps (See *Cut Charts* in the **Operation** section of IM166). The following descriptions briefly describe the purpose and configuration of the major units which comprise the HT4100 System.

HT4100 Master Power Supply

This unit houses two 100-amp, 15kHz chopper power supplies to produce constant current DC output. Also located in this unit is the Torch Height Control (THC). The power supply interconnects with the HF console, IHS, computer interface, remote V/C, gas console, the HT4100 Slave power supply, and the workpiece.

HT4100 Slave Power Supply

This unit also houses two 100-amp, 15kHz chopper power supplies. When interconnected with the HT4100 Master power supply, up to 400 amps is made available to the cutting system. The Slave interfaces with the Master supply, and the Timer/Counter unit.

High Frequency (HF) Console

This unit houses the high frequency starting circuit which permits more effective RF shielding and allows the power supplies to be installed at a distance of up to 300 feet (91 m) from the torch. Also located in the console are two door interlock switches, and a cooling water flow switch.

Remote Voltage/Current (V/C) Control

This unit provides accurate operator control of the arc voltage and current. It includes high intensity LED displays which indicate the setpoints for volts and amperes prior to starting the arc. After the arc is initiated, the displays automatically switch to show the actual values of the voltage and current reached. This unit interfaces with the Master power supply. Three different types of remote V/C controls are available:

Switch Remote - Includes the voltage and current displays and two potentiometers used to select the desired values. Also included are start and stop switches for the power supply, switches for activating the torch height control (THC), and initial height sensing (IHS) circuits. This unit is for use on guidance machinery that does not include switches to control the initial height sensing and torch height functions.

Digital Remote - Includes the voltage and current displays and two potentiometers used to select the desired values. It is used with guidance machinery that already includes plasma control switches.

Programmable Remote - Includes the voltage and current displays. No switches or potentiometers are included. All functions are controlled by the guidance machinery computer. This unit also interconnects with the computer interface.

Gas Console

This unit houses solenoid valves for plasma and shield gas flow control as well as flowmeters for plasma and shield gas flow, metering valves for plasma and shield gas preflow, metering valves for shield gas operating flow, and three switches: one to choose between oxygen or nitrogen, another to select either test preflow, test operate flow, or run modes, and a third to adjust plasma operate flows during operate mode. The gas console interfaces with the gas supplies, the motor valve console and the Master power supply.

Motor Valve Console

This unit houses a motor-driven plasma gas metering valve as well as solenoid valves to switch the plasma gas and shield gas from preflow to operate modes. Plasma preflow and operate gas lines as well as shield preflow and operate lines and interface cable connect the motor valve console to the gas console. The motor valve console also interfaces with the torch via a lead set consisting of a plasma gas hose, shield gas hose and a plasma-off valve control cable.
Note: The motor valve console must be mounted 10 feet (3 m) from the torch.

Timer/Counter

The timer/counter is provided so that the number of arc starts and arc-on time can be monitored. This unit is interfaced to the HT4100 Slave power supply.

Water Chiller

The water chiller for the HT4100 system is a refrigeration unit that is capable of reducing the water coolant temperature well below ambient air and water supply temperature. Having this capabililty greatly increases the life of the nozzle and electrode. The water chiller is a three-phase power system that directly interfaces with the HF console. See *Water Supply Requirements* in the **Pre-Installation** section of this manual.

Initial Height Sensing (IHS) - Optional

This unit, used with two inductive probes, is designed to automatically detect the workpiece surface and index the torch to the pierce position. This system can be used for underwater, at the water line, or above-water applications. This unit interconnects with the Master power supply and the inductive probes, and requires an air supply to operate.

INTRODUCTION & SPECIFICATIONS

SPECIFICATIONS

System Requirements

Power Requirements:
Refer to HT4100 power supply specifications below:

Gas Requirements:

Plasma Gas Type	Oxygen (O_2), *Nitrogen (N_2)
Shield Gas Types	Oxygen (O_2), and Nitrogen (N_2) mixture
Gas Quality	
Oxygen	99.5% pure (liquid gas recommended)
Nitrogen	99.995% pure (liquid gas recommended)
Oxygen Gas Inlet Pressure	120 psi (8.3 bar)
Nitrogen Gas Inlet Pressure	120 psi (8.3 bar)
Oxygen Gas Inlet Flowrate	127 scfh (60 l/min) at fullscale
Nitrogen Gas Inlet Flowrate	338 scfh (160 l/min) at fullscale

* Nitrogen is used for plasma gas preflow

HT4100 Power Supplies (Master & Slave)

Maximum OCV (U_0)	275 VDC
Maximum Output Current (I_2)	400 amps
Output Voltage (U_2)	150 VDC
Duty Cycle Rating (X)	100%
Ambient Temperatures/Duty Cycle	Power supplies will operate between +14° and 104°F (-10° and +40°C). Power supplies operated in an ambient temperature above 86°F (30C) may show some decrease in duty cycle.
Cooling	Forced Air (Class F)

Input Power: (U_1 - Input Voltage ; I_1 - Input Current):

#073086 (Master)/ **#073087** (Slave)	200 VAC (U_1), 3PH, 50 Hz @ 108A (I_1)
#073089 (Master)/ **#073090** (Slave)	240 VAC (U_1), 3PH, 60 Hz @ 90A (I_1)
	480 VAC (U_1), 3PH, 60 Hz @ 45A (I_1)
#073095 (Master)/ **#073096** (Slave)	220 VAC (U_1), 3PH, 50 Hz @ 101 A (I_1)
	380 VAC (U_1), 3PH, 50 Hz @ 58A (I_1)
	415 VAC (U_1), 3PH, 50 Hz @ 54A (I_1)
#073070 (Master)/ **#073071** (Slave)	440 VAC (U_1), 3PH, 60 Hz @ 49A (I_1)
	460 VAC (U_1), 3PH, 60 Hz @ 47A (I_1)
#073100 (Master)/ **#073101** (Slave)	600 VAC (U_1), 3PH, 60 Hz @ 36A (I_1)

Dimensions and Weight:

Width	28-1/4" (71 cm)
Height	35-1/2" (90 cm)
Depth	41-1/4" (104 cm)
Weight	760 pounds (345 kg)

PAC610 Machine Torch #028601

Maximum cutting thickness	1-1/2 inch (38 mm)
Maximum current at 100% duty cycle	260 amps for O_2 cutting
Plasma and Shield Gas Flow	Refer to the *Cut Charts* in the **Operation** section of the HT4100 Instruction Manual: Operation (IM166) for specific gas requirements.
Electrode coolant flow rate	1.4 gpm (5.3 l/min)
Weight	3-1/2 pounds (1.59 kg)

High Frequency Console #073077

Dimensions and Weight:

Width	16" (41 cm)
Height	16-3/4" (42 cm)
Depth	13-3/4" (35 cm)
Weight	75 pounds (34 kg)

Switch Remote (SR) V/C Control (073053)

Controls .....

Start button:
Activates IHS (if on) and initializes pilot arc.

Stop button:
Deactivates main contactor in power supplies.

IHS On/Off switch:
Turns IHS system on or off.

Auto Height On/Off switch:
Activates THC in Master power supply.

Voltage adjust pot:
Adjusts arc cutting voltage and displays value on LEDs.

Current adjust pot:
Adjusts arc cutting current and displays value on LEDs.

Control Range ..... Current: 100 to 400 Amps
Voltage: 100 to 200 Volts
Control Resolution ..... Current: 20 Amps
Voltage: 5 Volts

Dimensions and Weight:
Width ..... 11-1/2" (29 cm)
Height ..... 5" (13 cm)
Depth ..... 13-1/4" (34 cm)
Weight ..... 6 pounds (2.7 kg)

Digital Remote (DR) V/C Control #055003

Controls ..... Voltage adjust pot:
Adjusts arc cutting voltage and displays value on LEDs.
Current adjust pot:
Adjusts arc cutting current and displays value on LEDs.

Control Range ..... Current: 100 to 400 Amps
Voltage: 100 to 200 Volts
Control Resolution ..... Current: 10 Amps
Voltage: 5 Volts

Dimensions and Weight:
Width ..... 11-1/2" (29 cm)
Height ..... 3" (7.6 cm)
Depth ..... 13-3/8" (34 cm)
Weight ..... 5 pounds-5 oz. (2.4 kg)

Programmable Remote (PR) V/C Control #055004

Controls ..... None. Controlled through guidance machinery computer.

Control Range ..... Current: 100 to 400 Amps
Voltage: 100 to 200 Volts
Control Resolution ..... Current: 10 Amps
Voltage: 5 Volts

Dimensions and Weight:
Width ..... 11-1/2" (29 cm)
Height ..... 3" (7.6 cm)
Depth ..... 12-1/2" (31.8 cm)
Weight ..... 5 pounds-5 oz. (2.4 kg)

Gas Console #073078

Dimensions and Weight:

Width ..... 11-1/2 " (29 cm)
Height ..... 14-5/8 " (37 cm)
Depth ..... 4 " (10 cm)
Weight ..... 23 pounds (10.4 kg)

Water Chiller

Refer to Water Chiller Model C Instruction Manual (#802410).

Motor Valve Console #073079

Dimensions and Weight:

Width ..... 11-1/2 " (29 cm)
Height ..... 6" (15.8 cm)
Depth ..... 8" (20 cm)
Weight ..... 18 pounds (8.2 kg)

Initial Height Sensing #053016

Input Power ..... 120 VAC from power supply
Air Pressure ..... 20 psi (1.4 bar) regulated shop air input to solenoid.

Dimensions and Weight:

Width ..... 9" (23 cm)
Height ..... 4.5" (11 cm)
Depth ..... 11-1/2" (29 cm)
Weight ..... 13 pounds (6 kg)

Timer/Counter #073057

Dimensions and Weight:

Width ..... 6-1/2" (16.5 cm)
Height ..... 2-1/2" (6.4 cm)
Depth ..... 8-5/8" (22 cm)
Weight ..... 3 lbs (1 kg)

Section 3 OPERATION

In this section:

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- HT4100 Master Power Supply 3-2
- HT4100 Slave Power Supply 3-2
- Gas Console 3-4
- Digital Remote (DR) V/C Module 3-6
- Programmable Remote (PR) V/C Module 3-6
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OPERATION

FRONT PANEL CONTROLS AND INDICATORS

HT4100 Master Power Supply (Fig. 3-1)

POWER

- **ON (1)** Pushbutton/indicator switch (PB1/LT1)
  Activates the power supply and its control circuits. Indicator lights when power up is complete.

- **OFF (0)** Pushbutton switch (PB2)
  Shuts the power supply down.

- **DC POWER ON** Indicator (LT2)
  Lights when main contactor closes, indicating DC power is being supplied to the torch.

STATUS

- **Slave Transformer** LED
  When off, indicates that the slave power supply main transformer has overheated.

- **Master Transformer** LED
  When off, indicates that the master power supply main transformer has overheated.

- **RHF Interlock** LED
  When off, indicates that either or both remote HF console door interlock(s) is disengaged.

- **Slave Interlock** LED
  When off, indicates that the slave power supply microprocessor has malfunctioned.

- **Plasma Gas** LED
  When off, indicates that the plasma gas pressure is too low.

- **Spare** LED
  Spare indicator.

- **Coolant Flow** LED
  When off, indicates that the coolant flow to the electrode is inadequate.

HT4100 Slave Power Supply (Fig. 3-2)

- **AC ON** Indicator (LT1)
  Lights when the power supply and control circuits are activated.

- **DC POWER ON** Indicator (LT2)
  Lights when main contactor closes, indicating DC power is being supplied to the torch.

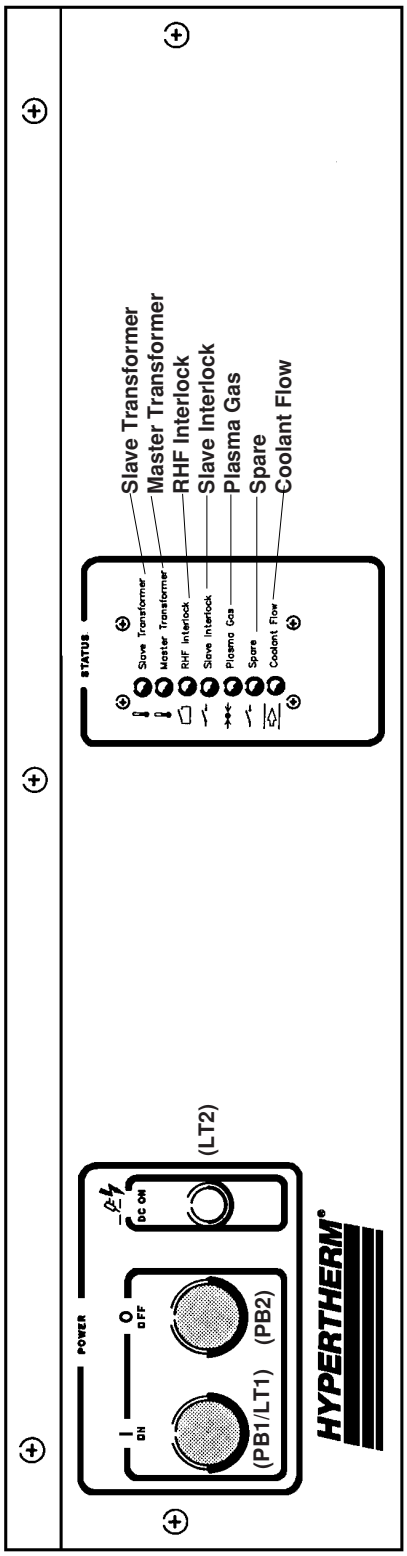


Figure 3-1 Master Power Supply Front Panel Controls and Indicators

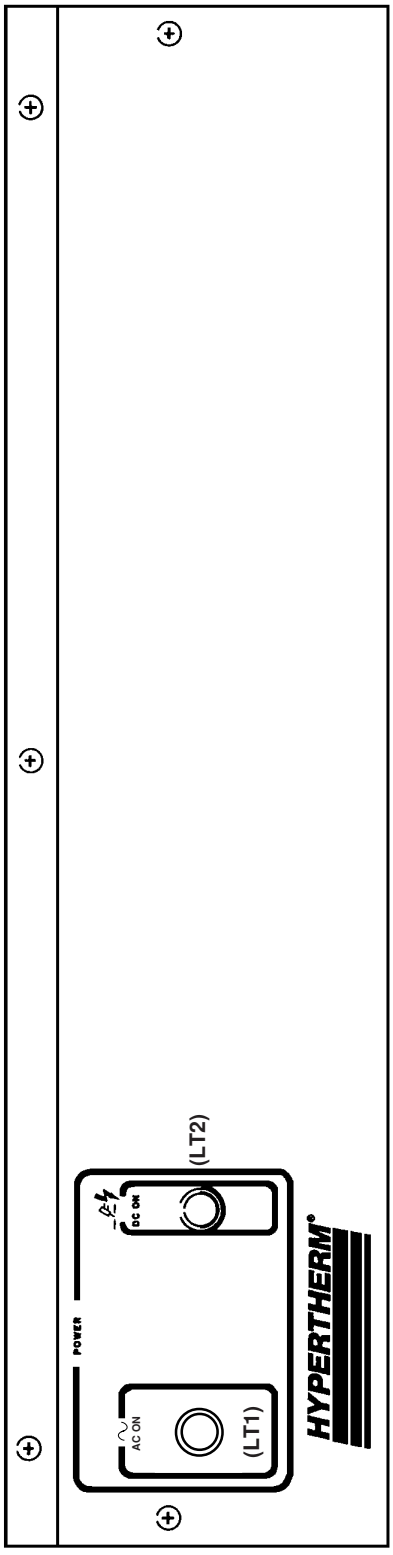


Figure 3-2 Slave Power Supply Front Panel Indicators

FRONT PANEL CONTROLS AND INDICATORS (Cont.)

Gas Console (Fig. 3-3)

- **PLASMA N_2/O_2** Toggle Switch (S1)
  The **O_2** position selects oxygen as the plasma cutting gas. The **N_2** position is for the future availability of nitrogen as the plasma cutting gas.

- **Test Preflow/Run/Test Cut Flow** Toggle Switch (S2)

  Test Preflow - This test position is used when setting the plasma and shield gas preflow flow rates on the flowmeters for plasma oxygen cutting as specified in the *Cut Charts* on pages 3-12 to 3-13. A nitrogen and oxygen mixture is used as the preflow gas in order to promote easier starts and longer electrode life when using oxygen. In this position the contactor is disabled, so that current is not delivered to the electrode and the arc cannot be fired.

- **PLASMA O_2** (FM1) and **N_2** (FM3) flowmeters - In test preflow, indicate the percentage of nitrogen and oxygen required for the preflow gas mixture for oxygen cutting.

- **PLASMA Preflow O_2** (MV1) and **N_2** (MV4) metering valves - Adjusts plasma gas preflow.

- **SHIELD O_2** (FM2) and **N_2** (FM4) flowmeters - In test preflow, indicate the percentage of nitrogen and oxygen required for the shield preflow gas mixture.

- **SHIELD Preflow O_2** (MV3) and **N_2** (MV6) metering valves - Adjusts shield gas preflow.

  Test Cut Flow - This test position is used when setting the plasma and shield gas flow rates on the flowmeters for cutting conditions as specified in the *Cut Charts* on pages 3-12 to 3-13. In this position the contactor is disabled, so that current is not delivered to the electrode and the arc cannot be fired.

- **PLASMA O_2** flowmeter (FM1) - In test cut flow, indicates the percentage of plasma (oxygen) gas flow required for cutting conditions.

- **PLASMA Cut Flow** Toggle switch (S3) - This switch controls a motor-driven metering valve in the motor valve console which adjusts the plasma gas (oxygen) in test cut flow.

- **SHIELD O_2** (FM2) and **N_2** (FM4) flowmeters - In test operate, indicate the percentage of nitrogen and oxygen required for cutting conditions.

- **SHIELD Cut Flow O_2** (MV2) and **N_2** (MV5) metering valves - Adjusts shield gas test cut flow.

  Run - This position enables the contactor and the subsequent firing of the arc after the gas flow rates have been set in the **Test Preflow** and **Test Cut Flow** positions.

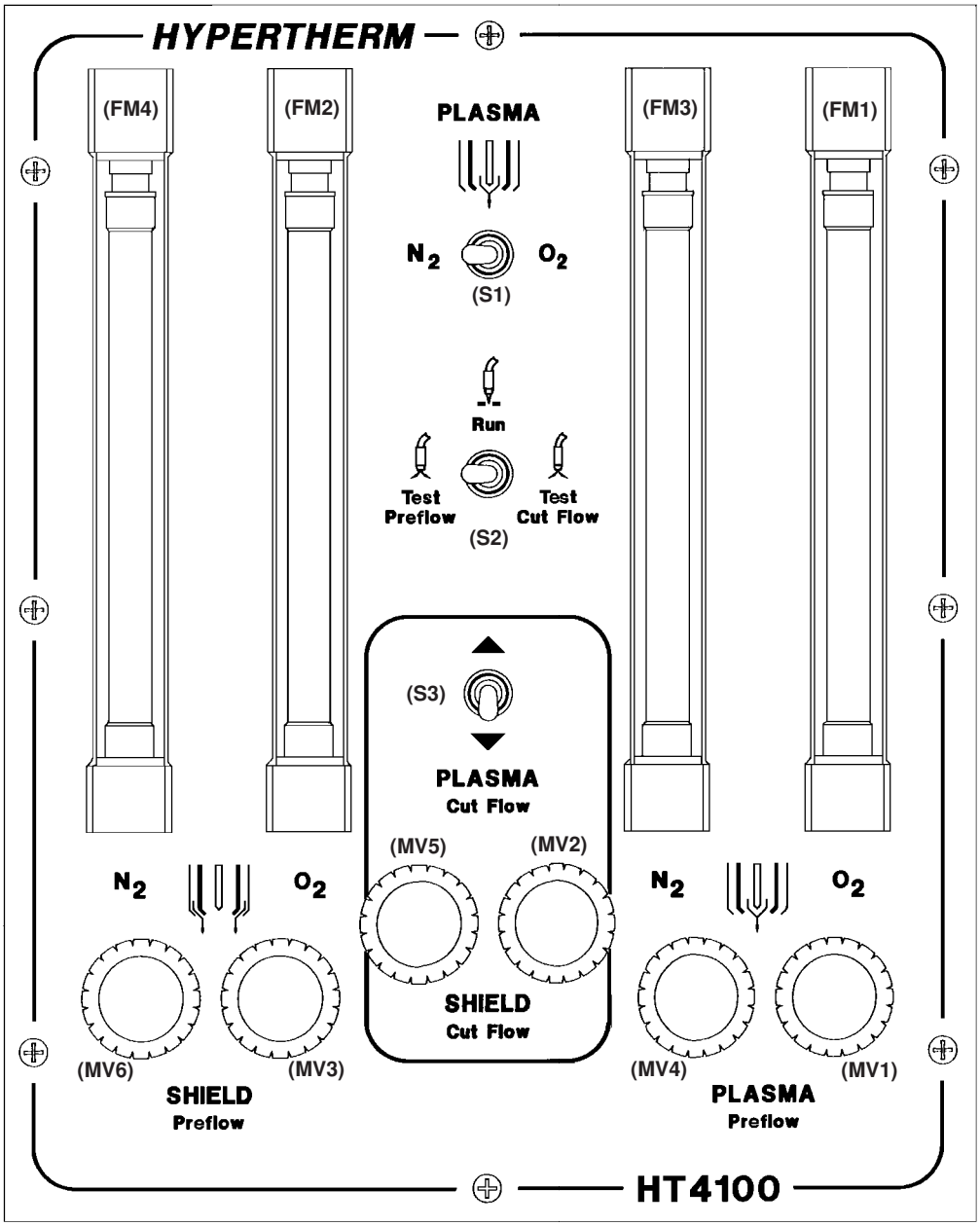


Figure 3-3 Gas Console Front Panel Controls and Indicators

FRONT PANEL CONTROLS and INDICATORS (Cont.)

Digital Remote (DR) V/C Module (Fig. 3-4)

- **VOLTAGE Adjust Pot**
  Adjusts the cutting arc voltage from 100 to 200 volts. Values are chosen from the *Cut Charts* and depend on the type of metal to cut, and metal thickness.

- **VOLTAGE LEDs**
  Displays cutting voltage.

- **CURRENT Adjust Pot**
  Adjusts the cutting arc current from 100 amps to 400 amps. Values are chosen from the *Cut Charts* and depend on the type of metal to cut, and metal thickness.

- **CURRENT LEDs**
  Displays cutting current during cut sequence.

- **UP/DOWN LEDs**
  Indicates that torch height is being adjusted up or down.

Programmable Remote (PR) V/C Module (Fig. 3-5)

- **VOLTAGE LEDs**
  Displays cutting voltage during cut sequence.

- **CURRENT LEDs**
  Displays cutting current during cut sequence.

- **UP/DOWN LEDs**
  Indicates that torch height is being adjusted up or down.

FRONT PANEL CONTROLS AND INDICATORS (Cont.)

Switch Remote (SR) V/C Module (Fig. 3-5A)

- **INITIAL HEIGHT ON/OFF Toggle Switch**
  Activates the IHS system when **ON**. When **START** button is pushed, the IHS system moves the torch down to the preset starting position above the workpiece.

- **AUTO HEIGHT ON/OFF Toggle Switch**
  When in **ON** position, automatically maintains torch height at preset distance from workpiece as cut is being made.

- **UP/DOWN LEDs**
  Indicates that torch height is being adjusted up or down. Works when Auto Height switch is in **ON** position.

- **START Button**
  Activates the IHS system (if on) and after a five-second delay, initializes the pilot arc, followed by cutting arc transfer.

- **STOP Button**
  Deactivates the main contactor, shutting off DC power to the torch which shuts off the cutting arc.

- **VOLTAGE Adjust Pot**
  Adjusts the cutting arc voltage from 100 to 200 volts. Values are chosen from the *Cut Charts*, and depend on the type of metal to cut, and metal thickness. The Torch Height Control constantly monitors the set voltage with the actual cutting voltage and adjusts torch up or down to maintain the set voltage.

- **VOLTAGE LEDs**
  Displays cutting voltage.

- **CURRENT Adjust Pot**
  Adjusts the cutting arc current from 100 amps to 400 amps. Values are chosen from the *Cut Charts* and depend on the type of metal to cut, and metal thickness.

- **CURRENT LEDs**
  Displays cutting current.

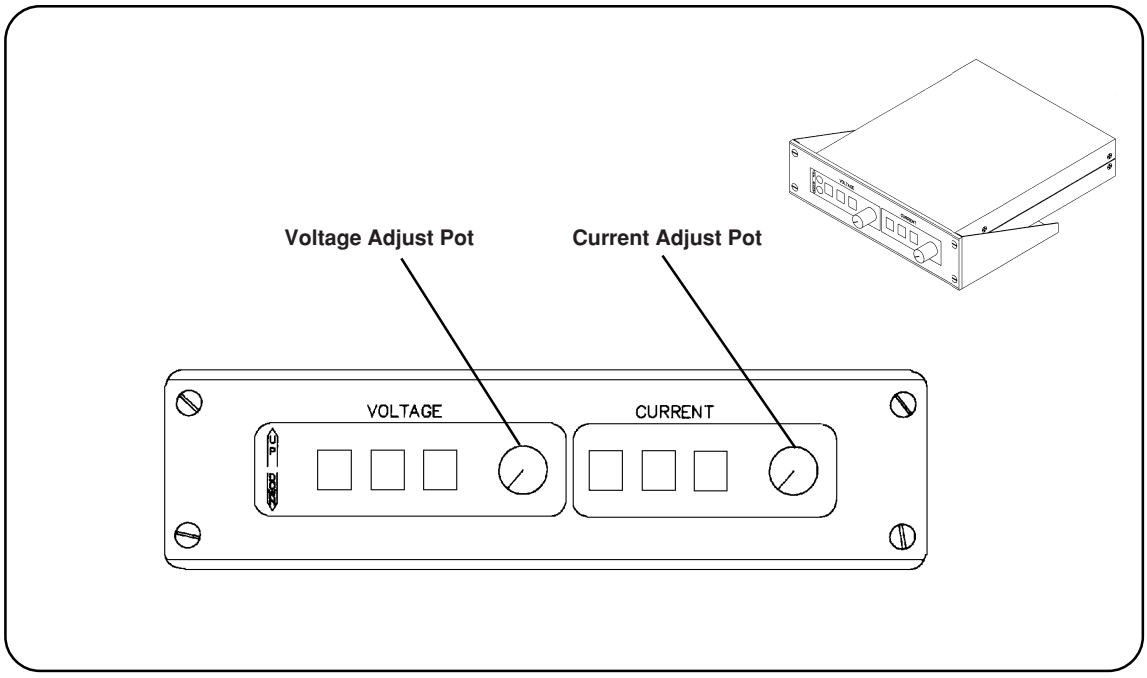


Figure 3-4 Digital Remote (DR) V/C Front Panel Controls and Indicators

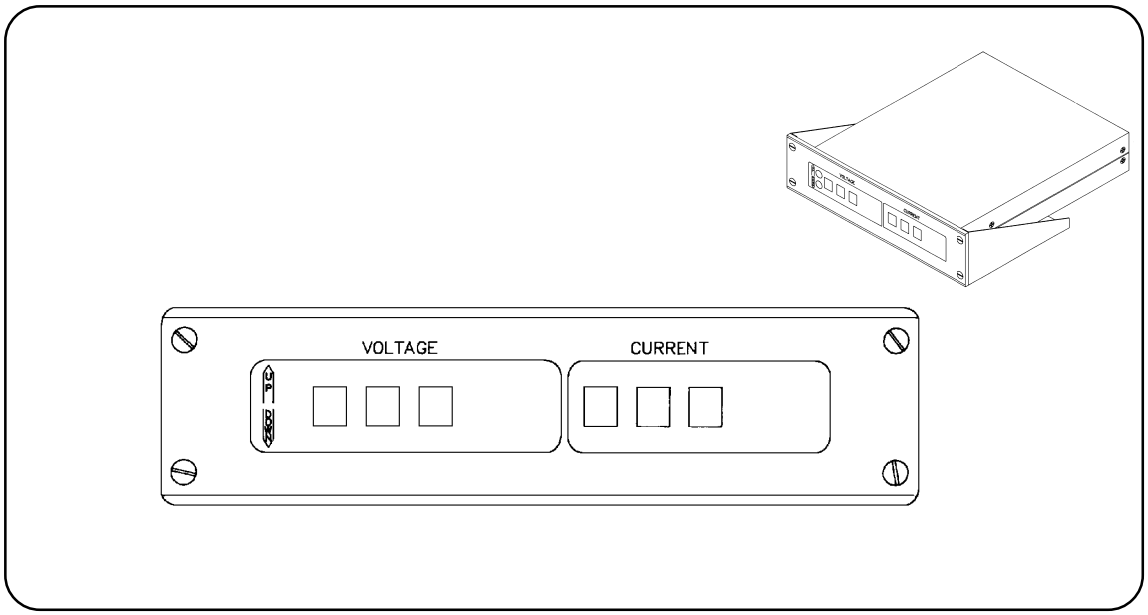


Figure 3-5 Programmable Remote (PR) V/C Front Panel Indicators

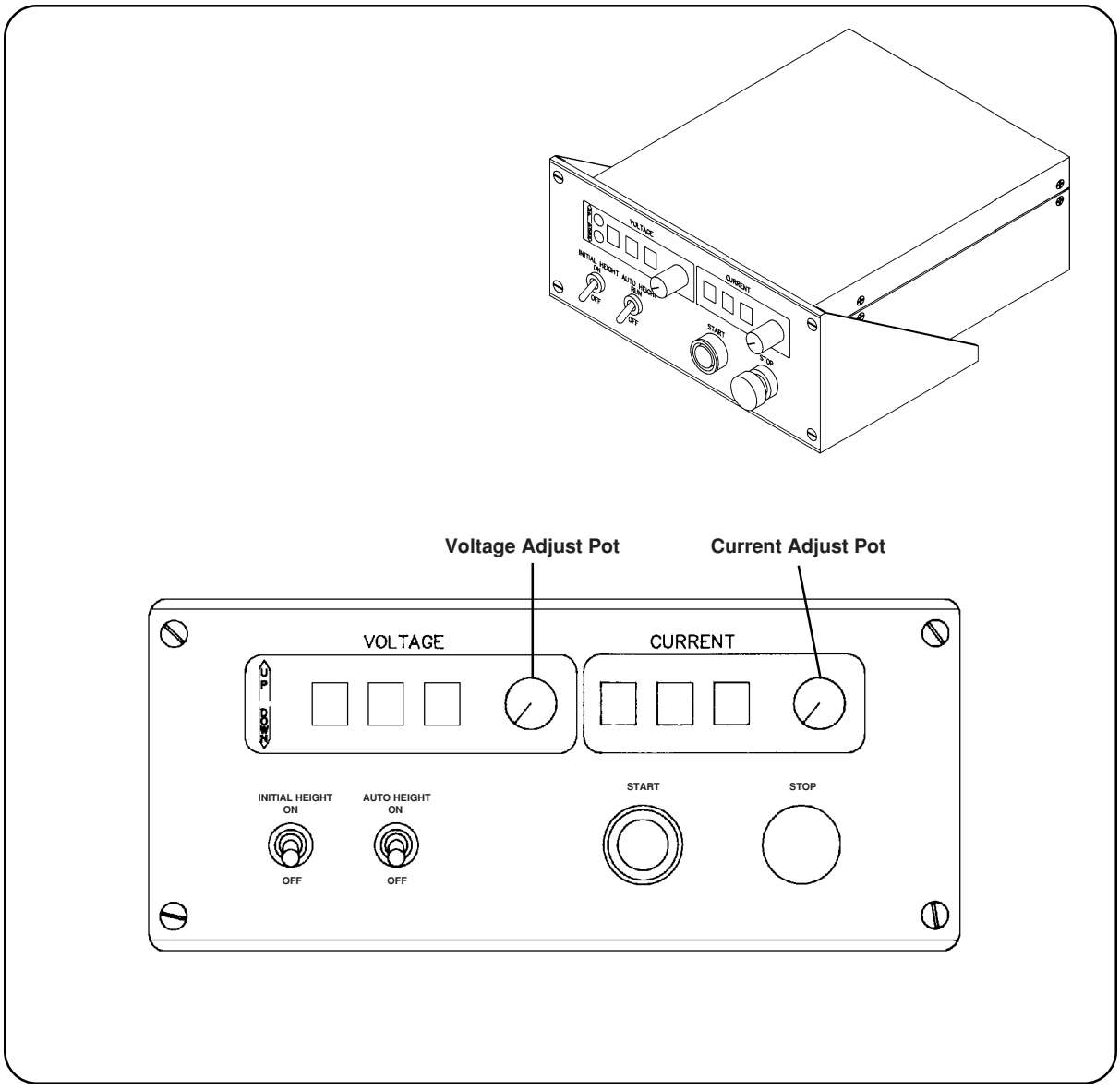


Figure 3-5A Switch Remote (SR) V/C Front Panel Controls and Indicators

FRONT PANEL CONTROLS and INDICATORS (Cont.)

Timer/Counter (Fig. 3-6)

Each LCD counter is self-powered by a three-volt lithium battery.

- **STARTS** LCD Counter (w/Reset)
  Indicates the number of arc starts.

- **ARC TIME** LCD Counter
  Indicates the cumulative time that the arc is on in hours.

- **ERRORS** LCD Counter (w/Reset)
  Indicates the number of times that the arc cut cycle ended before the programmed current ramp down time had elapsed. This reading provides a direct correlation to the long-life operation of the electrode; the higher the reading, the shorter the electrode life.

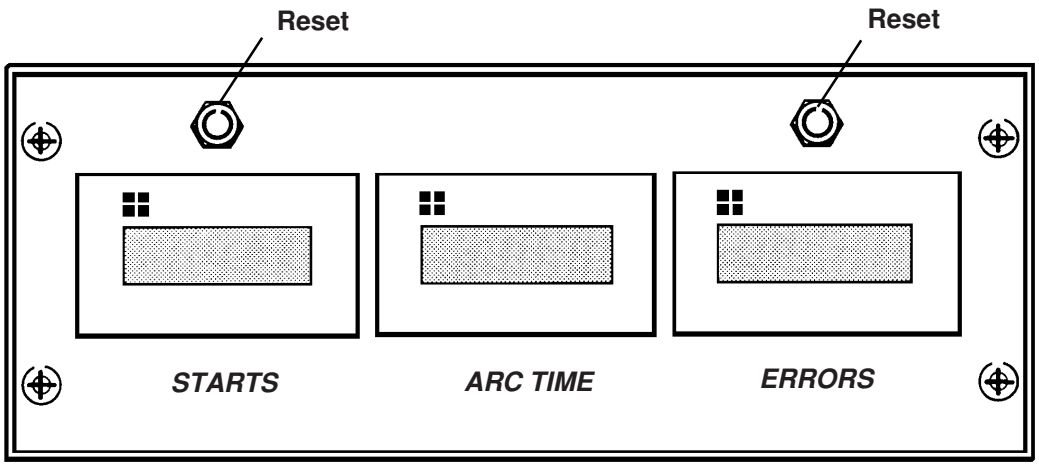


Figure 3-6 Timer/Counter Front Panel Indicators

DAILY START-UP

Prior to start-up, ensure that your cutting environment and that your clothing meet the safety requirements outlined in the *Safety* section of this manual. If problems occur during start-up, refer to the HT4100 Instruction Manual: Installation (#801650) for the post-installation system checkout requirements.

1. Remove the consumables from the torch and check for worn or damaged parts. **Always place the consumables on a clean, dry, oil free surface after removing. Dirty consumables can cause the torch to malfunction.**

   - Check the pit depth of the electrode using the electrode gauge assembly. The electrode should be replaced when the depth exceeds .050 inch (1.3mm).
   - Wipe the current ring in the torch with a clean paper towel or Q-tip (see Figure 3-7).
   - Refer to the *Cut Chart* on page 3-12 to choose the correct consumables for your cutting needs.

2. Replace consumable parts. Refer to the *Changing Consumable Parts* section later in this manual for detailed information on replacing consumables.

3. Ensure that the torch is squared to the material. Refer to the HT4100 Instruction Manual: Installation (P/N 801650) for the torch alignment procedure.

4. Set **Test Preflow/Run/Test Cut Flow** toggle switch (S2) on the gas console to **Run.**

5. Set the main disconnect switches for the master and slave power supplies and the water chiller to **On**.

6. Turn the required oxygen and nitrogen gas supplies gases **On.** Both gases should be supplied to the gas console at pressures of 120 psi (8.3 bar).

7. Check the water level in the water chiller.

8. Turn on the water chiller by depressing the **START** switch.

9. Set the **PLASMA N_2/O_2** toggle switch (S1) on the gas console to **O_2**.

10. Turn on the power supplies by depressing the **POWER ON (1)** button (PB1) on the master power supply and holding down for five seconds. Ensure the green **POWER ON** indicator (LT1) and all seven green LEDs on the master power supply and the white **AC ON** indicator (LT1) on the slave power supply are lit. If the seven green LEDs do not light, see *STATUS LED Troubleshooting* in **Section 3** of the Maintenance manual IM167 (#801670).

11. Set the **VOLTAGE** and **CURRENT** on the Digital Remote V/C module if installed. The Programmable Remote V/C module, if installed, is computer controlled and does not

require manual control by the operator. Select the arc current, arc voltage and pierce delay time from the *Cut Chart* on pages 3-12 for the type and thickness of metal to be cut.

12. Set the switch (S2) on the gas console to **Test Preflow**. Test preflow uses a nitrogen and oxygen mixture as the preflow gas. The plasma and shield preflow rates are set on the **PLASMA** (FM1 and FM3) and **SHIELD** (FM2 and FM4) flowmeters using the **PLASMA** (MV1 and MV4) and **SHIELD** (MV3 and MV6) metering valves and are specified in the *Cut Chart* on page 3-12.

13. Set the switch to **Test Cut Flow**. This position allows the plasma and shield test cut flow rates to be set on the **PLASMA O_2** flowmeter (FM1) using **PLASMA Cut Flow** switch (S3) and on the **SHIELD O_2** and **N_2** flowmeters using the **SHIELD Cut Flow** metering valves (MV2 and MV5). Test cut flow rates are specified in the *Cut Chart* on page 3-12.

14. Set switch (S2) to **Run** after the test preflow and test cut flow rates have been set.

15. The system is now ready for operation.

COMMON CUTTING FAULTS

- Torch pilot arc will initiate, but will not transfer. Cause can be:

  1. Work cable connection on cutting table not making good contact.

  2. Malfunction in HT4100 system. See HT4100 Instruction Manual: Maintenance (#801670).

  3. The torch initial height is set too high.

- The workpiece is not totally penetrated, and there is excessive sparking on top of the workpiece. Causes can be:

  1. Current is set too low (check *Cut Chart* information).

  2. Cut speed is too high (check *Cut Chart* information).

  3. Torch parts are worn (see *Changing Consumable Parts*).

  4. Metal being cut is too thick.

- Dross forms on the bottom of the cut. Causes can be:

  1. Cutting speed is too slow or too fast (check *Cut Chart* information).

  2. Arc current set too low (check *Cut Chart* information).

  3. Torch parts are worn (see *Changing Consumable Parts*).

- Cut angle not square. Causes can be:

  1. Wrong direction of machine travel.
     High quality side is on the right with respect to the forward motion of the torch.

  2. Torch standoff (torch-to-work distance) is not correct (check *Cut Chart* information).

  3. Cutting speed is not correct (check *Cut Chart* information).

  4. Arc current is not correct (check *Cut Chart* information).

  5. Damaged consumable parts (see *Changing Consumable Parts*).

- Short consumable life. Causes can be:

  1. Arc current, arc voltage, travel speed, pierce delay time, gas flow rates, or initial torch height not set as specified in *Cut Charts*.

  2. Attempting to cut highly magnetic metal plate (some metals such as armor plate with a high nickel content) will shorten consumable life. Long consumable life is difficult to achieve when cutting plate that is magnetized or becomes magnetized easily. Call Hypertherm's Technical Service department (1-800-643-9878) if you suspect the type of metal you are cutting is causing shortened consumable life.

TECHNICAL QUESTIONS

Claims for defective merchandise -- All units shipped from Hypertherm undergo rigorous quality control testing. However, if your system does not function correctly:

1. Recheck all pre-installation and installation requirements and connections in HT4100 Instruction Manual: Installation (P/N 801650).

2. If you are unable to solve the problem, call your distributor. They will be able to help you, or refer you to an authorized Hypertherm repair facility.

3. If you need assistance, call our Customer Service or Field Service group at 1-800-643-9878.

CUT CHART

The *Cut Chart* on the following page provides the necessary information for the operator using the HT4100 system to be successful in plasma arc cutting. The HT4100 provides a wide travel speed operating window: usually ± 10 ipm (± 254mm/min) on most materials. The *Cut Chart* data are for making drop cuts with minimal dross.

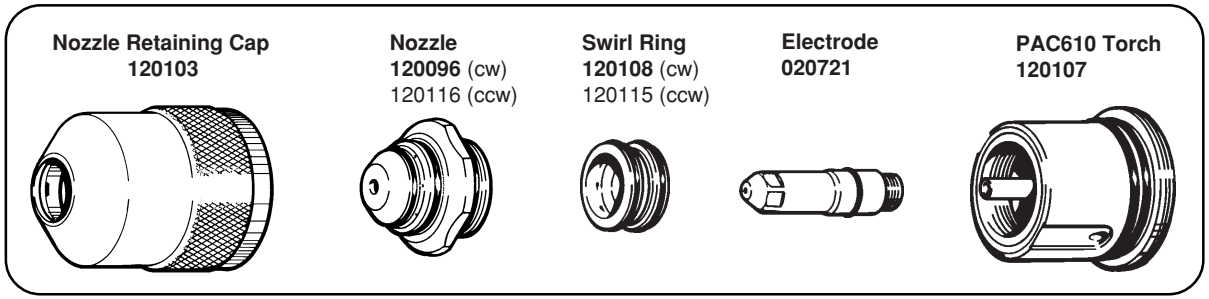
Caution: Before cutting, check all settings and adjustments and check for damaged torch parts and worn consumable parts.

Note: Plasma arc may extinguish if material intended to be cut is thinner than the minimum plate thickness listed in the cut chart tables.

HT4100 Operating Data (Cut) Charts

Mild Steel - 300 Amp Cutting

O_2 Plasma / O_2 & N_2 Shield



Material Thickness (in)	(mm)	Preflow Shield % Full Scale N_2 & O_2		Preflow Plasma % Full Scale N_2 & O_2		Cut Flow Shield % Full Scale N_2 & O_2		Cut Flow Plasma % Full Scale N_2 or O_2		Arc Current (amps)	Arc Voltage (volts)	Torch Standoff (in)	(mm)	Travel Speed (ipm)	(mm/min)	Pierce Delay Time (sec)	Initial Pierce Height (in)	(mm)
1/4	6	30	0	28	7	14	9	0	70	200	125	.06	1.5	160	4065	0.3	3/16	4.7
3/8	10	30	0	28	7	14	9	0	60	260	130	1/8	3	145	3680	0.5	3/16	4.7
1/2	12.5	30	0	28	7	14	9	0	60	260	135	1/8	3	105	2650	0.7	3/16	4.7
5/8	16	30	0	28	7	14	11	0	60	280	145	3/16	5	90	2280	0.9	1/4	6.3
3/4	19	30	0	28	7	14	11	0	60	300	150	3/16	5	80	2030	1.1	1/4	6.3
7/8	22	30	0	28	7	14	11	0	60	300	150	3/16	5	70	1780	1.3	3/8	9.5
1	25	30	0	28	7	14	11	0	60	300	155	3/16	5	55	1400	1.5	3/8	9.5
1-1/8	28.5	30	0	28	7	14	11	0	60	300	155	3/16	5	50	1270	*	*	
1-1/4	32	30	0	28	7	14	11	0	60	300	155	3/16	5	45	1145	*	*	
1-3/8	35	30	0	28	7	14	11	0	60	300	155	3/16	5	40	1015	*	*	
1-1/2	38	30	0	28	7	14	11	0	60	300	155	3/16	5	35	890	*	*	

Notes: O_2 and N_2 gas inlet pressures remain at one setting of 120 psi (8.3 bar) for all material thickness.
O_2 flowrate at full scale is 127 scfh (60 l/min) @ 120 psi (8.3 bar) inlet pressure.
Shield N_2 flowrate at full scale is 338 scfh (160 l/min) @ 120 psi (8.3 bar) inlet pressure.
Plasma N_2 flowrate at full scale is 135 scfh (64 l/min) @ 120 psi (8.3 bar) inlet pressure.
Torch standoff tolerances are ± 0.020 inch /± 0.5mm. When using a THC, the tolerances are ± 2.5 volt.
* Piercing is not recommended.

OPERATION

CHANGING CONSUMABLE PARTS

WARNING

Always disconnect the power supply from the main power source before inspecting or changing the torch parts.

Inspect the consumable parts before cutting for wear, and replaced when needed. Follow t the instructions below to inspect and replace the consumables and refer to Figure 3-7.

Removal and Inspection

1. Unscrew the retaining cap.

2. Remove the nozzle from the torch using the 1-1/4" (32 mm) tool (004574) in the Spare Parts Kit (028554). Check the orifices of the nozzle for signs of wear and arcing.

3. Remove the electrode by unscrewing it from the torch head using the 7/16" (11mm) socket wrench (027001) supplied in the Spare Parts Kit. Inspect and replace the electrode if the crater in the center of the insert exceeds .050 inch (1.3 mm).

4. Remove the swirl ring from the electrode and inspect it for plugged holes or other damage.

Replacement

Before replacing the consumable parts, clean the current ring in the torch. Use a clean paper towel or cotton swab to remove any dirt, grease, etc., from the current ring. If the water tube appears damaged or loose, see *Changing the Water Tube* on page 3-15.

1. Replace the electrode by screwing it back into the torch head. Use the electrode socket wrench to tighten down the electrode. **Do not overtighten.**

2. Prior to installing the swirl ring, apply a light coating of silicone grease to both outside O-rings. As a guideline, you should be able to feel the grease on your fingers, but not see it. **Do not use an excessive amount of grease.** The swirl ring ports can easily be plugged by grease, causing improper gas flow during operation. When installing the swirl ring, make sure to place the smaller diameter end into the torch.

3. When replacing the nozzle, apply a light coat of silicone grease to the O-ring on the O.D. of the copper portion of the nozzle (as a guideline for amount of silicone, see step 2 above). Insert the nozzle into the torch and tighten by hand. Use the nozzle wrench to tighten the nozzle snugly. **Do not overtighten.**

4. Replace the retaining cap by **tightening it snugly by hand to insure there are no water or gas leaks between the nozzle and the cap.**

If the cap does not go on easily, clean the threads on the torch body and the retaining cap and apply a small amount (see step 2 above) of silicone grease to both O-rings located just below the threads of the torch body.

Note: Failure to tighten the retaining cap snugly (or to keep the threads and current ring clean) will result in coolant water and gas leaks around the upper nozzle O-ring, impairing cut quality. However, the **retaining cap should be tightened by hand only.**

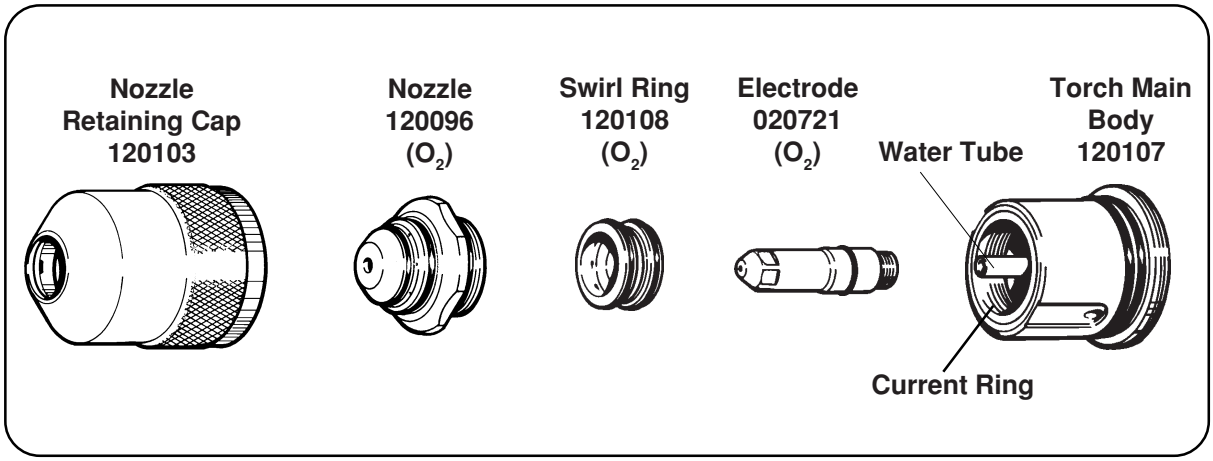


Figure 3-7 Changing Consumable Parts

Changing the Water Tube

Problems and causes you may find with a defective or improperly installed water tube:

- Short electrode life: Water tube not screwed in tightly
- Flow switch interlock shutting down the system: Water flow restricted due to loose water tube
- Humming or rattling sound coming from the torch: Water tube bent or loose

If you suspect a problem with the water tube, you may need to replace it.

1. Disconnect power supply from power source.
2. Remove all consumables from torch (see *Changing Consumable Parts* - pg. 3-14).

3. Look for any damage or bends in the water tube.

4. Remove and replace the water tube by using the water tube wrench (027347) supplied by Hypertherm - Fig. 3-8. **When installing water tube, do not over tighten!** Snug down by hand only.

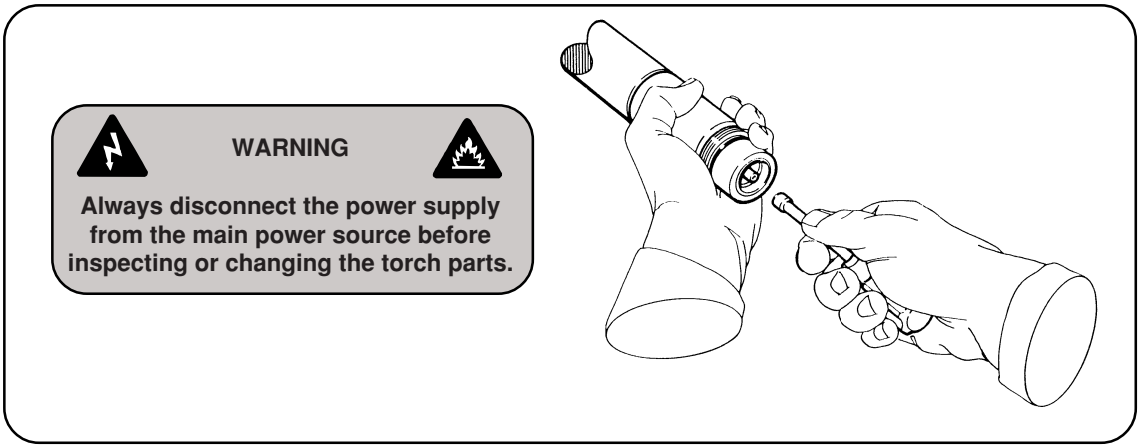


Figure 3-8 Changing the Water Tube

ROUTINE INSPECTION AND CLEANING

Power Supplies

The only routine inspection and cleaning necessary on the master and slave power supplies is to keep dust and foreign matter from inside the units. This can be done by removing the covers and blowing out the units with compressed air. Periodically, inspect the units for cleanliness and clean as required. In an excessively dirty environment, perform this procedure on a weekly basis.

Water Chiller

Refer to the Water Chiller instruction manual IM-88 (P/N 802410), *Maintenance* for weekly and monthly inspection and cleaning procedures.

Interconnections

Check for plumbing leaks. Repair any leaks in the water recirculation plumbing.

Section 4 STANDARDS INDEX

In this section:

Standards Index 4-2

STANDARDS INDEX

For further information concerning safety practices to be exercised with plasma arc cutting equipment, please refer to the following publications:

1. ANSI Standard Z49.1, *Safety in Welding and Cutting*, obtainable from the American Welding Society, 550 LeJeune Road, P.O. Box 351020, Miami, FL 33135.

2. NIOSH, *Safety and Health in Arc Welding and Gas Welding and Cutting*, obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

3. OSHA, *Safety and Health Standards*, 29FR 1910, obtainable from the U.S. Government Printing Office, Washington, D.C. 20402.

4. ANSI Standard Z87.1, *Safe Practices for Occupation and Educational Eye and Face Protection*, obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

5. ANSI Standard Z41.1, S*tandard for Men's Safety-Toe Footwear*, obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

6. ANSI Standard Z49.2, *Fire Prevention in the Use of Cutting and Welding Processes*, obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

7. AWS Standard A6.0, *Welding and Cutting Containers Which Have Held Combustibles*, obtainable from the American Welding Society, 550 LeJeune Road, P.O. Box 351040, Miami, FL 33135.

8. NFPA Standard 51, *Oxygen — Fuel Gas Systems for Welding and Cutting*, obtainable from the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.

9. NFPA Standard 70-1978, *National Electrical Code*, obtainable from the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.

10. NFPA Standard 51B, *Cutting and Welding Processes*, obtainable from the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.

11. CGA Pamphlet P-1, *Safe Handling of Compressed Gases in Cylinders*, obtainable from the Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

12. CSA Standard W117.2, *Code for Safety in Welding and Cutting*, obtainable from the Canadian Standards Association Standard Sales, 178 Rexdale Boulevard, Rexdale, Ontario M9W 1R3, Canada.

13. NWSA booklet, *Welding Safety Bibliography*, obtainable from the National Welding Supply Association, 1900 Arch Street, Philadelphia, PA 19103.

14. American Welding Society Standard AWS F4.1, *Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping That Have Held Hazardous Substances*, obtainable from the American Welding Society, 550 LeJeune Road, P.O. Box 351040, Miami, FL 33135.

15. ANSI Standard Z88.2, *Practices for Respiratory Protection*, obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

16. Canadian Electrical Code Part 1, *Safety Standards for Electrical Installations*, obtainable from the Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W1R3.

IEC SYMBOLS USED

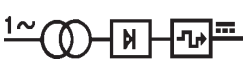
Direct Current (DC).

Alternating current (AC).

Plasma cutting torch.

AC input power connection.

The terminal for the external protective (earthed) conductor.



A chopper-based power source.

Anode (+) work clamp.

Temperature switch.

Pressure switch.

Plasma torch in the TEST position (cooling and cutting gas exiting nozzle).

I

The power is on.

O

The power is off.

Volt/amp curve.

GLOSSARY

AC — **A**lternating **C**urrent. Motion of current alternately in one direction, then the other. The number of times per second the direction changes (the "frequency") is measured in hertz.

amp — **Amp**eres. Measurement of the electron flow (the number of electrons per second) in an electrical circuit.

anode — The "positive" (+) side of a DC power source. Electrons leave the cathode and move toward the anode; ions move in the opposite direction. Plasma cutting requires the work and the nozzle to be the anode, and the electrode to be the cathode.

arc — Motion of electricity in a gas.

AWG — **A**merican **W**ire **G**auge. Defines the diameter of wires.

bar — A unit of pressure equal to one million dynes per square centimeter.

breaker — A device which interrupts an electrical current if the current exceeds a preset amperage setting. Breakers can be returned to their conducting (non-interrupting) state by some mechanical action, such as flipping a switch.

cap — Nozzle retaining cap. Holds the swirl ring, electrode and nozzle inside the torch.

capacitor — A device that stores electric energy in the form of voltage.

cathode — The "negative" (-) side of a DC power source. (See anode)

consumable — Electrode, nozzle, swirl ring and retaining cap.

CSA — **C**anadian **S**tandards **A**ssociation. A product standards and testing agency.

current — Movement of electricity, measured in amperes. Current is said to move in a direction opposite that of electron flow.

DC — **D**irect **C**urrent. Motion of current in one direction only, from anode (+) to cathode (-).

dross — Globs of metal hanging around the kerf, usually on the bottom side.

duty cycle — Percentage of on-time (measured in minutes) in a 10 minute period in which a device can be operated.

electricity — Fundamental property of atoms that atoms can have their electrons pulled away ("ionized") and then the electrons can move about in metals or gases. An atom missing one or more electrons is called an ion. Both electrons and ions can move about in gases.

GLOSSARY

electrode A part inside the torch connected to the cathode (-) of the power supply. Electrons come out of the electrode.

ferrule A ring of metal surrounding the end of a cable or wire to strengthen a connection**.**

fuse A protective device which melts when the current running through it exceeds the usage rating.

ground An electrical connection buried in the earth to establish a voltage of zero (0) volts.

Hertz (Hz) Measurement of "frequency" of an AC voltage or current in cycles per second.

IEC International Electrotechnical Commission. An international standards organization.

interlock A safety device which must be activated before another device can be activated.

ion An atom which has an excess or shortage of electrons.

IP International Protection. An IEC designator, describing the degree of protection an enclosure offers against entry of objects and water.

I_1 Rated supply current. The supply current to the power source at a rated cutting condition (given U_1, U_2 and I_2).

I_2 Rated output cutting current.

kerf Slit made in a workpiece by a cutting torch.

kilowatt Thousand (kilo) watts. Measurement of electrical power.

LED **L**ight **E**mitting **D**iode. An electronic indicator lamp.

line As in "line voltage." Utility voltage from a branch circuit (wall outlet).

liters/minute A measure of gas flow.

nozzle Tip of the plasma torch, made from copper, out of which the plasma arc comes. The nozzle pinches the plasma arc. It is usually an anode (+).

OCV **O**pen **C**ircuit **V**oltage. U_0. The highest voltage from a electrical power supply. It occurs when the power supply is on and active but not producing a plasma arc.

pilot arc A plasma arc that attaches to the torch nozzle rather than the work.

plasma An electrically charged gas is said to be "ionized". A cloud of ionized gas together with its electrons is called "plasma."

plasma arc	Movement of electric current in a plasma (ionized gas). An intensely hot and bright arc which exists between the cathode (-) (electrode) and the anode (+) (either the nozzle or the work).
pressure	Force per unit area.
psi	**P**ounds per **S**quare **I**nch. Measurement of gas pressure.
quench	Put in water to cool.
regulator	A mechanical device to control the outlet pressure of a gas supply.
ripple	Unwanted variations in current or voltage from an electrical power supply.
scfm	**S**tandard **c**ubic **f**eet per **m**inute. A measurement of gas flow.
single phase	An alternating current carried by only two wires. In the U.S. the "hot" carries the AC voltage and the "neutral" is at approximately "ground" voltage. The "ground" wire carries current only in fault conditions.
swirl ring	An insulating ring that separates the electrode from the nozzle and causes the air inside the plasma torch to swirl and aid in squeezing the arc.
transfer	A pilot arc *transfers* to the work when the plasma arc leaves the surface of the nozzle and attaches to the work.
U_0	Rated Open Circuit Voltage occuring at the rated input voltage (U_1).
U_1	Rated Supply Voltage. The supply voltage for which the power source is constructed.
U_2	Conventional load voltage. The output load voltage at which rated input current (I_1), rated output current (I_2) and duty cycle (X) are measured.
VAC	**V**olts **A**lternating **C**urrent.
VDC	**V**olts **D**irect **C**urrent.
volt	Measurement of electrical force required to move an electric current through an electrical circuit.
watt	Measurement of electrical power. The ability to heat the work equivalent to a current of one ampere times an electrical force of one volt.
work(piece)	The object to be cut.
X	Duty cycle at a given U_1, U_2 and I_2.