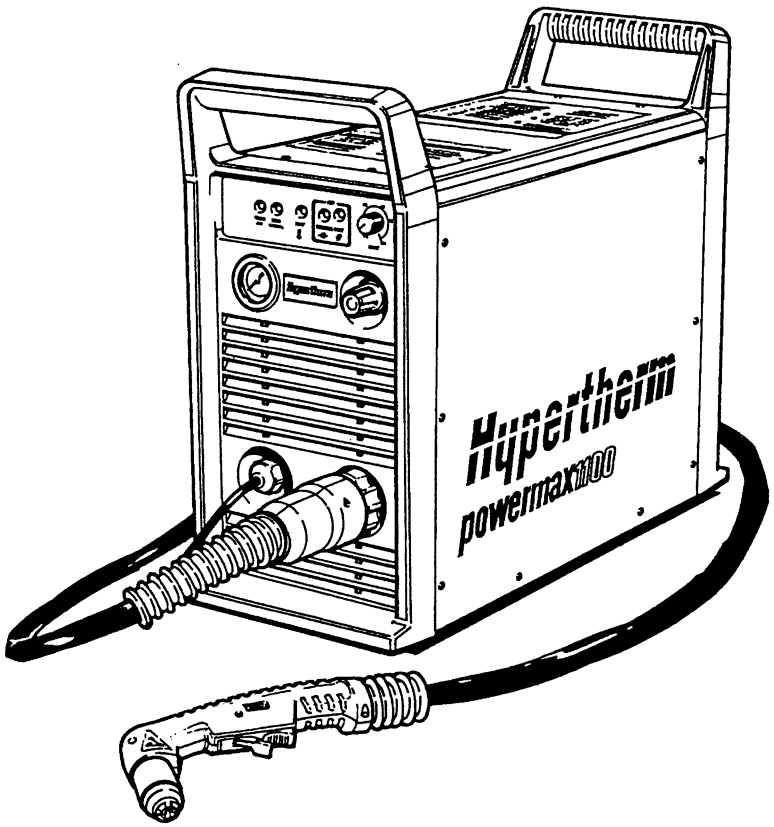
# powermax1100®

## *Plasma Arc Cutting System*

*Service Manual*
*802910 - Revision 1*




CE

*EN50199*
*EN50192*

# powermax1100

## Plasma Arc Cutting System

## Service Manual
## IM-291
## (P/N 802910)

**for systems beginning with serial number**
**1100-010000**

**Revision 1 July, 1999**

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## EMC INTRODUCTION

The 400V CE power supply has been built in compliance with standard EN50199. To ensure that the equipment works in a compatible manner with other radio and electronic systems, the equipment should be installed and used in accordance with the information below to achieve electromagnetic compatibility.

The limits required by EN50199 may not be adequate to completely eliminate interference when the affected equipment is in close proximity or has a high degree of sensitivity. In such cases it may be necessary to use other measures to further reduce interference.

This plasma equipment should be used only in an industrial environment. It may be difficult to ensure electromagnetic compatibility in a domestic environment.

## INSTALLATION AND USE

The user is responsible for installing and using the plasma equipment according to the manufacturer's instructions. If electromagnetic disturbances are detected then it shall be the responsibility of the user to resolve the situation with the technical assistance of the manufacturer. In some cases this remedial action may be as simple as earthing the cutting circuit, see *Earthing of Workpiece*. In other cases it could involve constructing an electromagnetic screen enclosing the power source and the work complete with associated input filters. In all cases electromagnetic disturbances must be reduced to the point where they are no longer troublesome.

## ASSESSMENT OF AREA

Before installing the equipment the user shall make an assessment of potential electromagnetic problems in the surrounding area. The following shall be taken into account:
a. Other supply cables, control cables, signalling and telephone cables; above, below and adjacent to the cutting equipment.
b. Radio and television transmitters and receivers.
c. Computer and other control equipment.
d. Safety critical equipment, for example guarding of industrial equipment.
e. Health of the people around, for example the use of pacemakers and hearing aids.
f. Equipment used for calibration or measurement.
g. Immunity of other equipment in the environment. User shall ensure that other equipment being used in the environment is compatible. This may require additional protection measures.
h. Time of day that cutting or other activities are to be carried out.

The size of the surrounding area to be considered will depend on the structure of the building and other activities that are taking place. The surrounding area may extend beyond the boundaries of the premises.

## METHODS OF REDUCING EMISSIONS

### Mains Supply

Cutting equipment should be connected to the mains supply according to the manufacturer's recommendations. If interference occurs, it may be necessary to take additional precautions such as filtering of the mains supply. Consideration should be given to shielding the supply cable of permanently installed cutting equipment, in metallic conduit or equivalent. Shielding should be electrically continuous throughout its length. The shielding should be connected to the cutting mains supply so that good electrical contact is maintained between the conduit and the cutting power source enclosure

### Maintenance of Cutting Equipment

The cutting equipment should be routinely maintained according to the manufacturer's recommendations. All access and service doors and covers should be closed and properly fastened when the cutting equipment is in operation. The cutting equipment should not be modified in any way except for those changes and adjustments covered in the manufacturer's instructions. In particular, the spark gaps of arc striking and stabilizing devices should be adjusted and maintained according to the manufacturer's recommendations.

### Cutting Cables

The cutting cables should be kept as short as possible and should be positioned close together, running at or close to the floor level.

### Equipotential Bonding

Bonding of all metallic components in the cutting installation and adjacent to it should be considered. However, metallic components bonded to the workpiece will increase the risk that the operator could receive a shock by touching these metallic components and the electrode at the same time. The operator should be insulated from all such bonded metallic components.

### Earthing of Workpiece

Where the workpiece is not bonded to earth for electrical safety, nor connected to earth because of its size and position, for example, ship's hull or building steelwork, a connection bonding the workpiece to earth may reduce emissions in some, but not all instances. Care should be taken to prevent the earthing of the workpiece increasing the risk of injury to users, or damage to other electrical equipment. Where necessary, the connection of the workpiece to earth should be made by a direct connection to the workpiece, but in some countries where direct connection is not permitted, the bonding should be achieved by suitable capacitances selected according to national regulations.

Note. The cutting circuit may or may not be earthed for safety reasons. Changing the earthing arrangements should only be authorized by a person who is competent to assess whether the changes will increase the risk of injury, for example, by allowing parallel cutting current return paths which may damage the earth circuits of other equipment. Further guidance is given in IEC TC26 (sec)94 and IEC TC26/108A/CD Arc Welding Equipment Installation and Use.

### Screening and Shielding

Selective screening and shielding of other cables and equipment in the surrounding area may alleviate problems of interference. Screening of the entire plasma cutting installation may be considered for special applications.

**WARNING**

**Genuine Hypertherm parts are the factory-recommended replacement parts for your Hypertherm system. Any damage caused by the use of other than genuine Hypertherm parts may not be covered by the Hypertherm warranty.**

## GENERAL

HYPERTHERM, Inc. warrants that Products shall be free from defects in materials and workmanship, under proper and normal use for which such Equipment is recommended, for a period of two (2) years, except only with respect to the Torch, for which the warranty period shall be one (1) year, from the date of its delivery to you.

HYPERTHERM, at its sole option, shall repair, replace, or adjust, free of charge, any Products covered by this warranty which shall be returned with HYPERTHERM's prior authorization (which shall not be unreasonably withheld), properly packed, to HYPERTHERM's place of business in Hanover, New Hampshire, all costs, insurance and freight prepaid, and which examination proves not to be free from defects in materials and workmanship. HYPERTHERM shall not be liable for any repairs, replacements, or adjustments of Products covered by this warranty, except those made pursuant to this paragraph or with HYPERTHERM's written consent. This warranty shall not apply to any Product which has been mishandled, incorrectly installed, modified or assembled by you or any other person. HYPERTHERM shall be liable for breach of this warranty only if it receives written notice of such breach within the applicable warranty period specified herein above. THE FOREGOING SHALL CONSTITUTE THE SOLE REMEDY TO DISTRIBUTORS OR THEIR CUSTOMERS FOR ANY BREACH BY HYPERTHERM OF ITS WARRANTY.

## PATENT INDEMNITY

Except only in cases of Products not manufactured by HYPERTHERM or manufactured by a person other than HYPERTHERM not in strict conformity with HYPERTHERM's specifications, and in cases of designs, processes, formulae or combinations not developed or purported to be developed by HYPERTHERM, HYPERTHERM agrees to indemnify, protect and hold harmless Distributors and their customers against any and all liability or claims in any manner imposed upon or accruing against Distributors and their customers because of the use in or about the construction or operation of Equipment or any design, system, formula, combination, article or material which infringes or alleges to infringe on any patent or other right. Distributors shall notify HYPERTHERM promptly upon learning of any action or threatened action in connection with any such alleged infringement, and each party may appoint its own counsel for any such action or threatened action.

## DISCLAIMER OF OTHER WARRANTIES

HYPERTHERM MAKES NO WARRANTIES REGARDING PRODUCTS MANUFACTURED BY IT OR OTHERS (INCLUDING WITHOUT IMPLIED LIMITATION WARRANTIES AS TO MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE), EITHER EXPRESS OR IMPLIED, EXCEPT AS PROVIDED HEREIN. This warranty is in lieu of any and all warranties, express or implied, by law or otherwise; and Distributors are not authorized to give any other warranty purporting to be binding upon HYPERTHERM upon resale of Products to their customers. IN NO EVENT shall HYPERTHERM be liable for incidental or consequential damages or injury to the person or property of anyone by reason of any defect in any Equipment sold hereunder.

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**ILLUSTRATIONS**

# Section 1 SAFETY

In this section:



***Before using this plasma arc system. . . .***

***Each person who will operate this equipment, perform service or maintenance, or supervise its use must read the safety instructions and warnings in this manual and the labels on the equipment.***

## About Notes, Cautions and Warnings

Notes: Throughout this manual, useful information for operating the plasma system is presented in "notes", such as shown in this paragraph.

**Cautions: Information in bold type and surrounded by a box describes a situation that may cause damage to the plasma system.**

**WARNINGS**

**Warnings describe situations that present a physical danger to the operator, and advice to avoid or correct the situation. Each type of warning includes applicable danger symbols, such as a hand burn, electrical shock, fire, explosion, etc.**

**WARNING — Instant-On Torches**

**Instant-on torches produce a plasma arc immediately after the torch switch is pushed.**

**Always hold a hand torch away from your body as a precaution against accidental torch firing. Be aware of this hazard, which has potential for serious bodily injury.**

**WARNING — Electric Shock**

- **Never touch the torch body, workpiece or the water in a water table when operating the plasma system.**
- **When using a water table, be sure that it is correctly connected to earth ground.**
- **Operating the plasma system completes an electrical circuit between the torch and the workpiece and anything touching the workpiece. The workpiece is part of the electrical circuit.**

## Eye Protection

- Wear dark safety glasses or goggles with side shields, or a welding helmet, in accordance with applicable national or local codes, to protect eyes against the plasma arc's ultraviolet and infrared rays.

| Arc Current | Lens Shade AWS (USA) | Lens Shade ISO 4850 |
|---|---|---|
| Up to 100 A | No. 8 | No. 11 |
| 100–200 A | No. 10 | No. 11-12 |
| 200–400 A | No. 12 | No. 13 |
| Over 400 A | No. 14 | No. 14 |

- Replace the glasses, goggles or helmet when the lens becomes pitted or broken.
- Warn other people in the area not to look directly at the arc unless they are wearing glasses, goggles or a 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 Protection

- Wear protective clothing to protect against burns caused by ultraviolet light, sparks and hot metal:
  - Gauntlet gloves, safety shoes and hat.
  - Flame-retardant clothing which covers all exposed areas.
  - Cuffless trousers to prevent entry of sparks and slag.

## Toxic Fume Prevention

- 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 and use proper ventilation when cutting galvanized metal.
- Do not cut containers with toxic materials inside. Clean containers that have held toxic materials thoroughly before cutting.

**WARNING — Toxic Fumes**

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

## Fire Prevention

- 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 m).
- 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. When cutting with oxygen as the plasma gas, an exhaust ventilation system is required.
- Never operate the plasma system in an atmosphere which contains heavy concentrations of dust, flammable gas or combustible liquid vapors unless properly vented.

## 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:

- Wear insulated gloves and boots, and keep body and clothing dry.
- Do not stand, sit or lie on—or touch—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.
- Provide a wall-mounted disconnect switch with properly sized 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 a system with a damaged power cord. Replace a damaged power cord immediately.
- Inspect the torch leads. Replace if frayed or damaged.
- 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 during the cutting process.

## Electric Shock Prevention (continued)

- Before changing the torch parts, disconnect the main power or unplug the power supply. After changing torch parts and replacing the retaining cap, plug in the power supply 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 exposure to severe electrical hazard, wait five minutes after disconnecting the main power to allow capacitors to discharge.
- Never operate the plasma system unless the power supply unit covers are in place. Exposed power supply connections present a severe electrical hazard.

## Explosion Prevention

**WARNING — Compressed Gas**

**The plasma system uses compressed gas. Observe proper precautions when handling and using compressed gas equipment and cylinders.**

- Do not use the plasma system if explosive dust or vapors may be present.
- Do not cut pressurized cylinders or any closed container.

**WARNING — Hydrogen Explosion Hazard**

**If your system uses hydrogen, remember that this is a flammable gas that presents an explosion hazard. Keep flames away from cylinders containing hydrogen mixtures and hoses that carry hydrogen mixtures. Also, keep flames and sparks away from the torch when using argon-hydrogen as the plasma gas.**

### Compressed Gas Cylinders

Handle and use compressed gas cylinders in accordance with safety standards published by the U.S. Compressed Gas Association (CGA), American Welding Society (AWS), Canadian Standards Association (CSA) or applicable national or local codes.

- 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 its 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.

### Pressure Regulators

- Be certain that all pressure regulators are in proper working condition.
- 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.

**WARNING — Hydrogen Detonation with Aluminum Cutting**

**When cutting aluminum underwater, or with the water touching the underside of the aluminum, free hydrogen gas may collect under the workpiece and detonate during plasma cutting operations.**

**Installing an aeration manifold on the floor of the water table is an effective way to eliminate the possibility of hydrogen detonation when cutting aluminum. Refer to the Appendix section of this manual for instructions on how to fabricate an aeration manifold.**

### 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.
- Examine hoses at regular intervals for leaks, wear, loose connections or other hazard.
- Replace hose that is damaged in any way.

### Hoses (continued)

- Keep hose lengths to a minimum to prevent damage, reduce pressure drop and to prevent possible flow restrictions.
- Prevent kinking by laying out hoses as straight as possible between termination points.
- Coil any excess hose and place it out of the way to prevent damage and to eliminate the danger of tripping.

## Noise Protection

The plasma cutting process can generate high levels of noise. Depending on the arc current, material being cut, acoustics and size of the cutting room, distance from the torch and other factors, acceptable noise levels as defined by national or local codes may be exceeded by your plasma system.

- Always wear proper ear protection when cutting or gouging with the plasma system.

## Grounding

### Input Power

- Be sure to connect the power cord ground wire to the ground in the disconnect box.
- If installation of the plasma system involves connecting the power cord to the power supply, be sure to properly connect the power cord ground wire. Conform to Canadian Standards Association (CSA) standards by placing the power cord ground wire on the stud first; then place any other ground wires on top of the power cord ground. Fasten the retaining nut tightly.
- Tighten all electrical connections to avoid excessive heating.

### Work Cable

- Attach the work cable securely to the workpiece or the work table by making good metal-to-metal contact.
  Do not connect it to the piece that will fall away when the cut is complete.

### Work Table

- Connect the work table to a high-quality earth ground, in accordance with the U.S. National Electrical Code, Article 250, Section H, Grounding Electrode System, or other appropriate national or local codes.

## Safety Reminders

- Never bypass or shortcut the safety interlocks on any of the plasma system units.
- Except in Hypertherm's largest mechanized systems, all Hypertherm torches are designed with a safety interlock that prevents firing of the plasma arc when the retaining cap is loosened.
- 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. Hypertherm's warranty does not cover problems caused by the use of torches not made by Hypertherm.
- Use only consumable parts and replacement parts made by Hypertherm. Hypertherm's warranty does not cover problems caused by the use of parts not made by Hypertherm.
- 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.

## Electronic Health Support Equipment

Plasma arc cutting and gouging systems create electric and magnetic fields that may interfere with the correct operation of electronic health support equipment, such as pacemakers or hearing aids. Any person who wears a pacemaker or hearing aid should consult a doctor before operating or being near any plasma system when it is in use. To minimize exposure to EMF:

- Keep both the work cable and the torch lead on one side of your body. Keep your body from coming in between the torch lead and the work cable.
- Route torch leads as close as possible to work cable.
- Do not wrap the torch lead or work cable around your body.
- Stay as far away from the power supply as possible.

# Section 1a SÉCURITÉ

Cette section comprend :



***Avant d'utiliser ce système de coupage plasma...***

***Chaque personne qui utilise, répare ou entretient l'appareil ou en surveille l'emploi, doit lire les consignes de sécurité et les avertissements donnés dans ce manuel et sur les étiquettes du matériel.***

## Au sujet des rubriques Notes, Attention et Avertissements

Notes : Sous cette rubrique, on donne des conseils pratiques pour utiliser le système plasma.

**Attention : Les informations en caractères gras et encadrées décrivent une situation qui risquerait d'endommager le système plasma.**

**AVERTISSEMENTS**

**Un avertissement décrit des situations qui présentent un danger physique pour l'opérateur, et donne des conseils pour éviter ou rectifier ce problème. Chaque type d'avertissement est accompagné d'un symbole de danger correspondant, comme une brûlure aux mains, un feu, une explosion, un choc électrique, etc.**

**AVERTISSEMENT — Torches à allumage instantané**

**Les torches à allumage instantané produisent un arc plasma immédiatement après avoir appuyé sur le bouton d'allumage de la torche.**

**Par précaution, maintenez toujours la torche éloignée de votre corps en cas d'un allumage accidentel. Prenez garde à ce danger qui risque de provoquer des blessures graves.**

**AVERTISSEMENT — Chocs électriques**

- **Ne jamais toucher le corps de la torche, la pièce à couper ou l'eau de la table à eau quand on utilise le système plasma.**
- **Quand on utilise une table à eau, s'assurer qu'elle est bien mise à la terre.**
- **Quand on utilise le système plasma, on établit un circuit électrique entre la torche et la pièce à couper et avec tout ce qui touche la pièce. La pièce à couper fait partie intégrante du circuit électrique.**

## Protection des yeux

- Porter des lunettes de sécurité à verres teintés ou des lunettes-masque munies d'écrans latéraux ou encore un masque à serre-tête, conformément aux codes nationaux ou locaux applicables, pour se protéger contre les rayons ultraviolets et infrarouges de l'arc.

| Courant de l'arc | Pouvoir obscurcissant des verres AWS (É-U.) | ISO 4850 |
|---|---|---|
| Jusqu'à 100 A | N° 8 | N° 11 |
| 100-200 A | N° 10 | N° 11-12 |
| 200-400 A | N° 12 | N° 13 |
| Plus de 400 A | N° 14 | N° 14 |

- Remplacer les lunettes, les lunettes-masque ou le masque à serre-tête quand les verres sont rayés ou cassés.
- Avertir les autres personnes se trouvant sur les lieux de travail de ne pas regarder directement l'arc, à moins qu'elles ne portent des lunettes, des lunettes-masque ou un masque à serre-tête.
- Préparer le poste de coupage de façon à réduire la réflexion et la transmission des rayons ultraviolets :
  - Peindre les murs et autres surfaces de couleur foncée pour réduire la réflexion.
  - Installer des écrans ou des rideaux protecteurs pour réduire la transmission des rayons ultraviolets.

## Protection de la peau

- Porter des vêtements de sécurité pour se protéger contre les brûlures que peuvent causer les rayons ultraviolets, les étincelles et le métal brûlant :
  - Gants à crispin, chaussures et casque de sécurité.
  - Vêtements ignifuges couvrant toutes les parties du corps exposées.
  - Pantalon sans revers pour éviter que des étincelles ou des scories puissent s'y loger.

## Prévention des vapeurs toxiques

- Tenir le poste de coupage bien aéré.
- Avant le coupage, enlever tous les solvants chlorés du poste de coupage. Certains solvants chlorés se décomposent sous l'effet des rayons ultraviolets et forment du phosgène.
- Porter un masque respiratoire approprié lors du coupage de métaux galvanisés, et s'assurer que la ventilation est efficace.
- Ne pas couper des réservoirs contenant des matières toxiques. Avant le coupage, nettoyer soigneusement les réservoirs qui ont contenu des matières toxiques.

**AVERTISSEMENT — Vapeurs toxiques**

**Ne pas couper des métaux (peints ou non) qui contiennent du zinc, du plomb, du cadmium ou du béryllium, à moins que l'utilisateur et toute personne exposée aux vapeurs ne portent un appareil respiratoire ou un masque à adduction d'air.**

## Prévention des incendies

- S'assurer qu'il y a des extincteurs au poste de coupage.
- Éloigner les matières inflammables d'au moins 10 m du poste de coupage.
- Tremper le métal que l'on vient de couper ou le laisser refroidir avant de le manipuler ou de le mettre en contact avec des matériaux inflammables.
- Ne jamais utiliser un système plasma pour couper des réservoirs contenant des matières potentiellement inflammables. De tels récipients doivent être soigneusement nettoyés avant le coupage.
- Aérer toute atmosphère potentiellement inflammable avant de couper avec un système plasma. Quand on utilise l'oxygène comme gaz plasma, il faut utiliser un système de ventilation par aspiration.
- Ne jamais faire fonctionner le système plasma dans une atmosphère qui contient une forte concentration de poussière, de gaz inflammable ou de vapeurs de liquides inflammables, à moins que l'on utilise une bonne ventilation.

## Prévention des chocs électriques

Tous les systèmes de coupage Hypertherm utilisent une haute tension (jusqu'à 280 V c.c.) pour amorcer l'arc plasma. On doit prendre les précautions suivantes quand on utilise le système plasma :

- Porter des gants et des bottes isolants et garder le corps et les vêtements au sec.
- Ne pas se tenir, s'asseoir, se coucher sur une surface mouillée, ni la toucher, quand on utilise le système plasma.
- Bien s'isoler contre les chocs électriques. Agir avec la plus grande prudence quand l'on doit travailler près ou à l'intérieur d'une zone humide.
- Installer un sectionneur mural avec fusibles appropriés, à proximité de la source de courant. Ce dispositif permet à l'opérateur d'arrêter rapidement la source de courant en cas d'urgence.
- Se conformer aux codes électriques de la région au point de vue des types et des grosseurs du câblage primaire.
- Inspecter fréquemment le cordon d'alimentation primaire pour s'assurer qu'il n'est ni endommagé ni fissuré. Un câble dénudé peut tuer. Ne pas utiliser le système si le cordon d'alimentation est endommagé. Si tel est le cas, remplacer immédiatement le cordon.
- Inspecter les câbles ou tuyaux de la torche. Les remplacer s'ils sont effilochés ou endommagés.
- Ne pas saisir la pièce à couper ni les chutes lors du coupage. Laisser la pièce à couper en place ou sur la table de travail, le câble de retour connecté lors du coupage.

## Prévention des chocs électriques (suite)

- Avant de remplacer les pièces de la torche, couper l'alimentation ou débrancher la source de courant. Après avoir remplacé les pièces de la torche et remis en place la buse de protection, rebrancher la source de courant.
- Ne jamais contourner ou court-circuiter les verrouillages de sécurité.
- Avant d'enlever le capot de la source de courant pour effectuer l'entretien, couper l'alimentation au sectionneur mural ou débrancher. Attendre cinq minutes pour que les condensateurs se déchargent ; sinon on s'expose à des chocs importants.
- Ne jamais faire fonctionner le système plasma sans que le capot de la source de courant soit en place. Les raccords exposés de la source de courant sont extrêmement dangereux.

## Prévention des explosions

**AVERTISSEMENT — Gaz comprimé**

**Le système plasma utilise du gaz comprimé. Prendre les précautions nécessaires quand on manutentionne et utilise des appareils et des bouteilles à gaz comprimé.**

- Ne pas couper en présence de poussière ou de vapeurs explosives.
- Ne pas couper des bouteilles sous pression ni des réservoirs fermés.

**AVERTISSEMENT — Risque d'explosion de l'hydrogène**

**Si le système utilise de l'hydrogène, se rappeler que c'est un gaz inflammable qui présente un danger d'explosion. Tenir toute flamme éloignée des bouteilles et des tuyaux contenant des mélanges d'hydrogène. Tenir également la torche plasma éloignée de toute flamme ou étincelle lorsque le gaz plasma est constitué d'un mélange argon-hydrogène.**

### Bouteilles de gaz comprimé

Manipuler et utiliser les bouteilles de gaz comprimé conformément aux normes de sécurité publiées par la Compressed Gas Association (CGA), l'American Welding Society (AWS), l'Association canadienne de normalisation (ACNOR/CSA) ou les codes nationaux ou locaux.

- Ne jamais utiliser une bouteille qui fuit ou est endommagée.
- Ne jamais utiliser une bouteille qui n'est pas placée à la verticale et bien assujettie.
- Ne jamais déplacer ou transporter une bouteille si son chapeau n'est pas en place.
- Ne jamais utiliser une bouteille de gaz ou son contenu à des fins autres que celles pour lesquelles elle est conçue.
- Ne jamais lubrifier le robinet des bouteilles avec de l'huile ou de la graisse.
- Éviter à tout prix le contact électrique entre l'arc plasma et une bouteille.
- Ne jamais exposer des bouteilles à une chaleur excessive, aux étincelles, aux scories ou aux flammes nues.
- Ne jamais utiliser des marteaux, des clés ou d'autres outils pour débloquer le robinet des bouteilles.

### Détendeurs

- S'assurer que tous les détendeurs sont en état de marche.
- Ne jamais utiliser un détendeur avec un gaz autre que celui pour lequel il a été conçu.
- Ne jamais utiliser un détendeur qui fuit, présente une dérive excessive ou est endommagé.
- Ne jamais lubrifier un détendeur en utilisant de l'huile ou de la graisse.

**AVERTISSEMENT — Détonation de l'hydrogène lors du coupage de l'aluminium**

**Quand on coupe l'aluminium sous l'eau, ou si l'eau touche la partie inférieure de la pièce d'aluminium, de l'hydrogène libre peut s'accumuler sous la pièce à couper et détoner lors du coupage plasma.**

**On peut éliminer la possibilité de détonation de l'hydrogène lors du coupage plasma de l'aluminium si l'on place un collecteur d'aération au fond de la table à eau. Voir l'annexe de ce manuel qui donne des directives pour fabriquer un collecteur d'aération.**

### Tuyaux

- Étiqueter et coder tous les tuyaux de gaz avec des couleurs différentes pour chaque type de gaz. Consulter les codes nationaux ou locaux applicables.
- Ne jamais utiliser un tuyau à oxygène pour un autre gaz.
- Examiner les tuyaux à intervalles réguliers pour vérifier s'ils présentent des fuites, s'ils sont usés ou si leurs raccords sont desserrés et s'ils présentent d'autres dangers.
- Remplacer un tuyau s'il est endommagé de quelque façon que ce soit.

**Tuyaux (suite)**

- N'utiliser que la longueur de tuyau nécessaire pour éviter les dégâts, réduire la chute de pression et éviter de réduire le débit.
- Empêcher la formation de coudes brusques en posant les tuyaux le plus possible en ligne droite entre les points de raccordement.
- Enrouler le tuyau en trop et le ranger pour ne pas l'endommager et pour éviter qu'il ne fasse trébucher.

## Protection contre le bruit

Le coupage plasma peut être très bruyant. Selon le courant de l'arc, le matériau coupé, l'acoustique et la grandeur de la salle de coupage, l'éloignement de la torche et autres facteurs, votre système plasma peut dépasser les niveaux de bruit fixés par les codes nationaux et locaux.

- Porter en permanence un protecteur anti-bruit convenable quand on coupe ou gouge avec le système plasma.

## Mise à la masse et à la terre

**Alimentation**

- S'assurer que le fil de terre du cordon d'alimentation est connecté à la terre dans le coffret du sectionneur.
- S'il faut brancher le cordon d'alimentation à la source de courant lors de l'installation du système, s'assurer que le fil de terre est correctement branché. Respecter les normes de l'Association canadienne de normalisation (ACNOR/CSA) en plaçant le fil de terre du cordon d'alimentation sur le plot de mise à la terre. Placer ensuite les autres fils de terre par-dessus. Bien serrer l'écrou de retenue.
- S'assurer que toutes les connexions sont bien serrées pour éviter la surchauffe.

**Câble de retour**

- Bien fixer le câble de retour (ou de masse) à la pièce à couper ou à la table de travail de façon à assurer un bon contact métal-métal.

Ne pas fixer le câble de retour à la partie de la pièce à couper qui doit se détacher.

**Table de travail**

- Raccorder la table de travail à une terre de bonne qualité, conformément au National Electrical Code (É.-U.), Article 250, Section H, «Grounding Electrode System», ou aux codes de sécurité nationaux ou locaux appropriés.

## Rappels de sécurité

- Ne jamais contourner ou court-circuiter les verrouillages de sécurité des systèmes plasma.
- Exception faite des plus gros systèmes mécanisés d'Hypertherm, toutes les torches Hypertherm sont conçues avec un verrouillage de sécurité qui empêche d'amorcer l'arc plasma quand la buse de protection est desserrée.
- Chaque système plasma Hypertherm n'est conçu que pour être utilisé avec les torches Hypertherm particulières. Ne pas les remplacer par d'autres torches qui pourraient surchauffer et présenter un danger pour l'opérateur et le personnel sur les lieux. La garantie d'Hypertherm ne couvre pas les dégâts causés par l'utilisation d'autres torches que celles d'Hypertherm.
- N'utiliser que les pièces consommables ou de rechange d'Hypertherm. La garantie d'Hypertherm ne couvre pas les problèmes causés par l'utilisation d'autres pièces que celles d'Hypertherm.
- Ne jamais faire fonctionner le système de coupage plasma si les capots ne sont pas en place, car cela mettrait en danger l'opérateur et les autres personnes présentes, en plus de compromettre le refroidissement des pièces.

## Prothèses électroniques

Les systèmes de coupage et de gougeage plasma produisent des champs électriques et magnétiques qui peuvent créer des problèmes de fonctionnement pour les prothèses électroniques, comme les stimulateurs cardiaques et les appareils auditifs. Les personnes qui portent de telles prothèses doivent consulter un médecin avant de faire fonctionner un système plasma ou de s'en approcher, quand celui-ci est en marche. Pour réduire l'exposition aux champs électromagnétiques :

- Garder le câble de retour et le faisceau de la torche d'un côté du corps. Ne pas se tenir entre le faisceau de la torche et le câble de retour.
- Faire passer le faisceau de la torche le plus près possible du câble de retour.
- Ne pas entourer le faisceau de la torche ou le câble de retour autour du corps.
- Se tenir le plus loin possible de la source de courant.

# Section 2

# SPECIFICATIONS

In this section:

# INTRODUCTION

The Powermax1100 service manual provides higher-level troubleshooting and a more complete parts list than the Powermax1100 operator manual. This manual also provides a detailed list of safety practices so that the system can be safely operated and maintained. **READ THE SAFETY SECTION (Section 1) FIRST!**

See also *Basic Troubleshooting* in the **Powermax100 Operator manual** for causes and solutions to common operating problems.

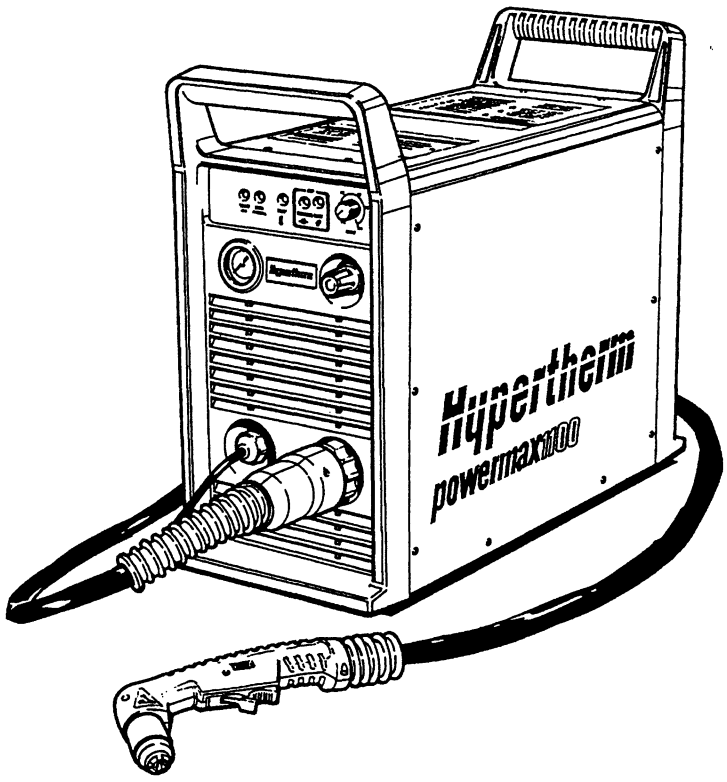



**Figure 2-1 Powermax1100 Hand Plasma Cutting System**

# SPECIFICATIONS

## Power Supply

| | |
|---|---|
| Rated Open Circuit Voltage (OCV) ($U_0$) | 280-320 VDC |
| Rated Output Current ($I_2$) | 30–80 amps |
| Rated Output Voltage ($U_2$) | 140 VDC |
| Duty Cycle (X) @ 104° F (40° C) | 50% ($I_2$=80A, $U_2$=140V)<br>100% ($I_2$=57A, $U_2$=140V) See data tag on power supply for more information on duty cycle |
| Ambient temperature | Power supplies will operate between +14° and 104° F (-10° and +40° C). |
| Apparent Input Power ($S_1$) | 19.2 kVA ($U_1I_1$) non CE power supplies<br>13.1 kVA ($U_1I_1$) CE power supplies |
| Input Voltage ($U_1$)/Input Current ($I_1$) @11.2 kw Output | 208V/92A; 240V/80A; 480V/40A - 1ϕ, 50/60 Hz<br>208V/53A; 240V/46A; 480V/23A - 3ϕ, 50/60 Hz<br>200V/96A; 230V/84A; 400V/48A - 1ϕ, 50/60 Hz<br>200V/56A; 230V/49A; 400V/28A - 3ϕ, 50/60 Hz<br>230V/33A; 400V/19A (CE) - 3ϕ, 50/60 Hz<br>600V/20A - 3ϕ, 60 Hz |
| Gas Type | Air or Nitrogen |
| Gas Quality, Air | Clean, dry, oil-free |
| Gas Quality, Nitrogen | 99.995% pure |
| Gas Inlet Pressure | 90 psi (6.2 bar) |
| Gas Flow | 400 scfh/6.7 scfm at 90 psi (189 l/min at 6.2 bar) supplied to power supply pressure regulator |
| Power Supply pressure regulator setting | 65 psi (4.5 bar) flowing |
| Dimensions and Weight: | |
| Depth | 25.1" (638 mm) |
| Width | 10.4" (264 mm) without wheels<br>15.8" (401 mm) with wheels |
| Height | 19.6" (498 mm) without wheels<br>23.7" (602 mm) with wheels |
| Weight, 208/240/480V and 200/230/400V without power cord | 77 pounds (35 kg) without wheels<br>89 pounds (40 kg) with wheels |
| Weight, 230/400V CE with power cord | 87 pounds (39 kg) without wheels<br>99 pounds (45 kg) with wheels |
| Weight, 600V with power cord | 160 pounds (73 kg) with wheels |

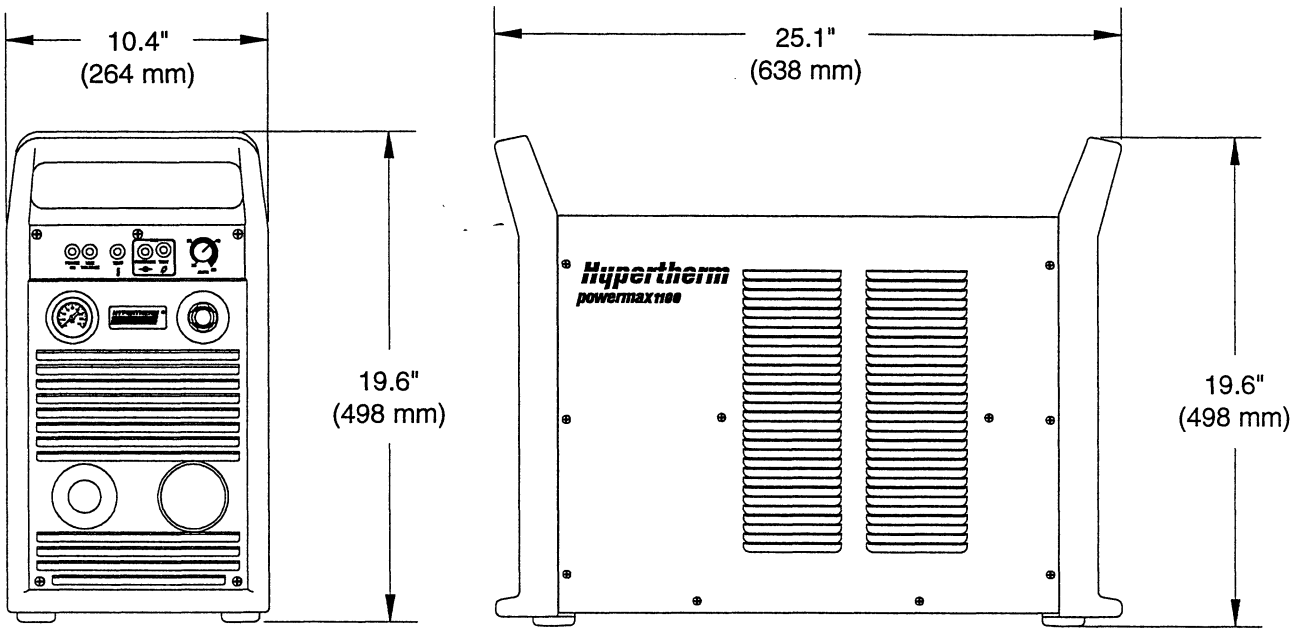



**Figure 2-2 Powermax1100 Power Supply Dimensions**

## PAC135 80A TORCHES

| | |
|---|---|
| Maximum 80A Cutting Capacity (PAC135T) | 1" (25 mm) @ 50% duty cycle |
| Recommended 80A Cutting Capacity (PAC135T) | 3/4" (20 mm) @ 100% duty cycle |
| Maximum 80A Cutting Capacity (PAC135M) | 1/2" (12 mm) @ 50% duty cycle |
| Recommended 80A Cutting Capacity (PAC135M) | 3/8" (9.5 mm) @ 100% duty cycle |
| Maximum current at 50% duty cycle | 80 amps |
| Gas Flow | 400 scfh/6.7 scfm at 65 psi (189 l/min at 4.5 bar) |
| Gouging Capability (metal removal rate) | 6.6 pounds (3.0 kg)/hr |
| Weight PAC135T | 9.3 pounds (4.2 kg) with 25 ft (7.6 m) lead<br>17.8 pounds (8.1 kg) with 50 ft (15 m) lead |
| Weight PAC135M | 9.6 pounds (4.4 kg) with 25 ft (7.6 m) lead<br>18 pounds (8.2 kg) with 50 ft (15 m) lead |

## PAC135T Hand Torch Assembly

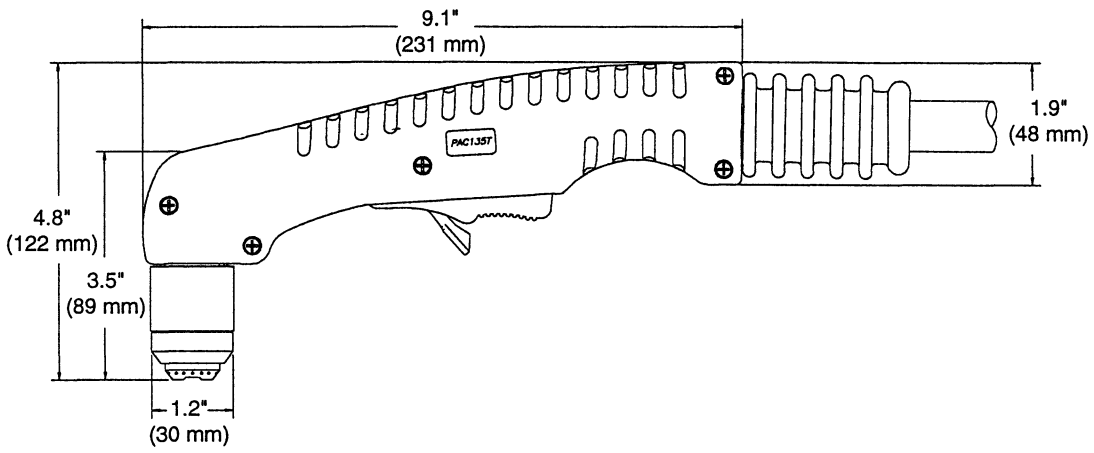



**Figure 2-3 PAC135T Torch with Dimensions**

## PAC135M Machine Torch Assembly

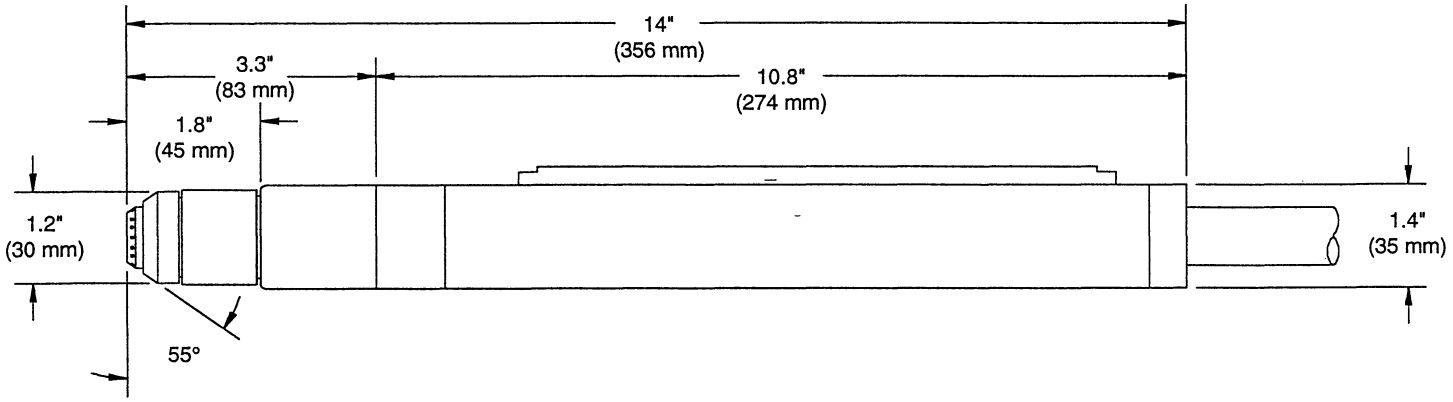
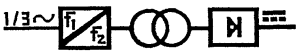
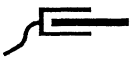



**Figure 2-4 PAC135M Torch with Dimensions**

## S MARK

The Powermax1100 conforms to CE standard EN50192. The S mark indicates that the power supply and torch are suitable for use in environments with increased hazard of electrical shock. The hand torches must have shielded consumable parts to maintain S mark compliance.

## IEC SYMBOLS USED

| | |
|---|---|
|  | Direct Current (DC) |
|  | Alternating current (AC) |
|  | Plasma cutting torch |
|  | AC input power connection |
|  | The terminal for the external protective (earth) conductor |
|  | An inverter-based power source |
|  | Anode (+) work clamp |
|  | Temperature switch |
|  | Pressure switch |
|  | Plasma torch in the TEST position (cooling and cutting gas exiting nozzle) |
| I | Power is on |
| O | Power is off |
|  | Volt/amp curve, "drooping" characteristic |

# Section 3 MAINTENANCE

In this section:

# INTRODUCTION

This section provides service technicians with routine maintenance procedures, a theory of operation, and resistance and voltage checks on the power supply. Also included in this section are the sequence of operation, control board test points, torch check procedure and the removal and replacement procedures for the PAC135T trigger torch and PAC135M machine torch parts.

# ROUTINE MAINTENANCE

## Bowl Draining/Filter Element Cleaning

Moisture in the torch can cause the torch to sputter and hiss. If moisture is present, purge the gas lines. If moisture builds up in the bowl of the filter, drain the bowl and clean the filter element:

1. **Shut off the gas supply and disconnect the gas supply hose** from the filter assembly before proceeding.

2. Remove the cap at the bottom of the filter bowl and turn the knurled drain valve to the right to release water from the bowl.

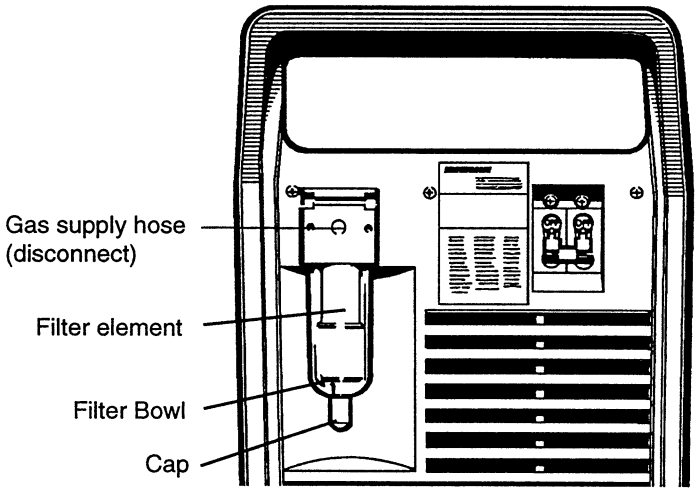



**Figure 3-1 Filter Assembly**

3. Unscrew the filter bowl.

4. Unscrew the filter element.

5. Clean the filter element with alcohol, then blow it out with air.
   Clean the bowl with household soap only.

6. Replace the filter element and filter bowl.

7. Reconnect the gas supply hose.

## Cooling Air Filter Removal, Cleaning and Replacement

Powermax1100 systems are normally shipped without an air filter. If your Powermax1100 has the air filter option, the filter will need cleaning periodically. Excessively dirty or dusty environments can block the filter (if installed) and cause the power supply to overheat and shut down.

**WARNING**

**SHOCK HAZARD: Always turn off the power, unplug the cord and wait 5 minutes before removing any power supply cover. If the power supply is directly connected to a line disconnect switch, place switch in the OFF position. In the U.S., use a "lock-out / tag-out" procedure until the service or maintenance work is complete. In other countries, follow appropriate local or national safety procedures.**

1. **Turn the Powermax1100 power switch to the OFF (0) position**, unplug the power cord, or turn off the wall receptacle, and disconnect the gas supply.
2. Remove the screws that secure the power supply cover to the chassis.
3. Remove the cover, and remove the cooling air filter from the clips by sliding the filter to the left and then up.

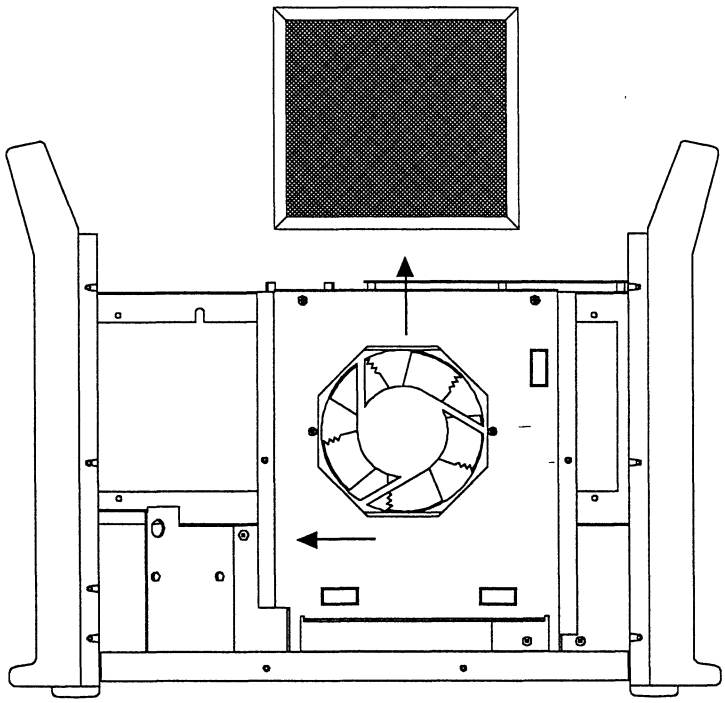


**Figure 3-2 Air Filter Removal**

4. Clean the air filter with either soap and water or with low-pressure compressed air.
5. Replace the dry filter in the power unit with the wire mesh facing the fan.

# THEORY OF OPERATION

## General

The Powermax1100 is a multi-voltage, multi-phase power supply. The two inverter inputs are linked in *series* for 480V on the 208/240/480V units, and also in series for 400V on the 200/230/400V and 230/400V CE units. When set up for 200, 208, 230 or 240 volts, the inverter inputs are linked in *parallel*. The inverter links are located behind the rear panel at TB3.


**Linked in Series for 400 or 480 Volts**

**Linked in Parallel for 200, 208,230 or 240 Volts**

**Figure 3-3 Inverter Links**

## Functional Description

Refer to block diagram 3-4, Figure 3-3 and the system wiring diagram. See **Section 4: Parts List** to identify system components referenced in this description.

AC power enters power switch S1 and contactor CR1. A "soft start" is implemented via filter board resistors R1 and R2 and relay K1. Once the capacitors on the power board are charged up and incoming power is within limits (≈ 3 seconds after S1 closure), the control board turns on the main contactor CR1. The input diode bridge rectifies the AC to DC. The DC voltage is then supplied to the inverters.

Each inverter consists of several components: an insulated gate bipolar transistor (IGBT - Left or Right), a coil of the power transformer (T2), a current sense transformer (CS1 or CS2), and a power board. The inverters operate as a pulse width modulator controlled half-bridge circuit. The inverters are capacitor fed and transformer coupled, switching at 20 KHZ. The inverter outputs are connected in series, and are rectified by the output diode bridge.

The output circuitry consists of a current sensor CS4 and transfer sensor CS3 located on the control board, pilot arc relay CR2, and output inductor L1.

Feedback loop operation: The current adjust pot P1 is set to the desired value. Current sensor CS4 measures the actual output current and compares it at the control board error amplifier with the user-set current setting. The error amplifier output is an analog indication of how wide the pulse width should be to maintain the current setting. The error amplifier output is then fed to the control board pulse width modulator chip. The pulse width modulator sends the signal to the gate drive board transformers, and the gate drive boards in turn drive the left and right inverter IGBTs.

For a description of the control board LEDs and test points, see *Control Board* later in this section.

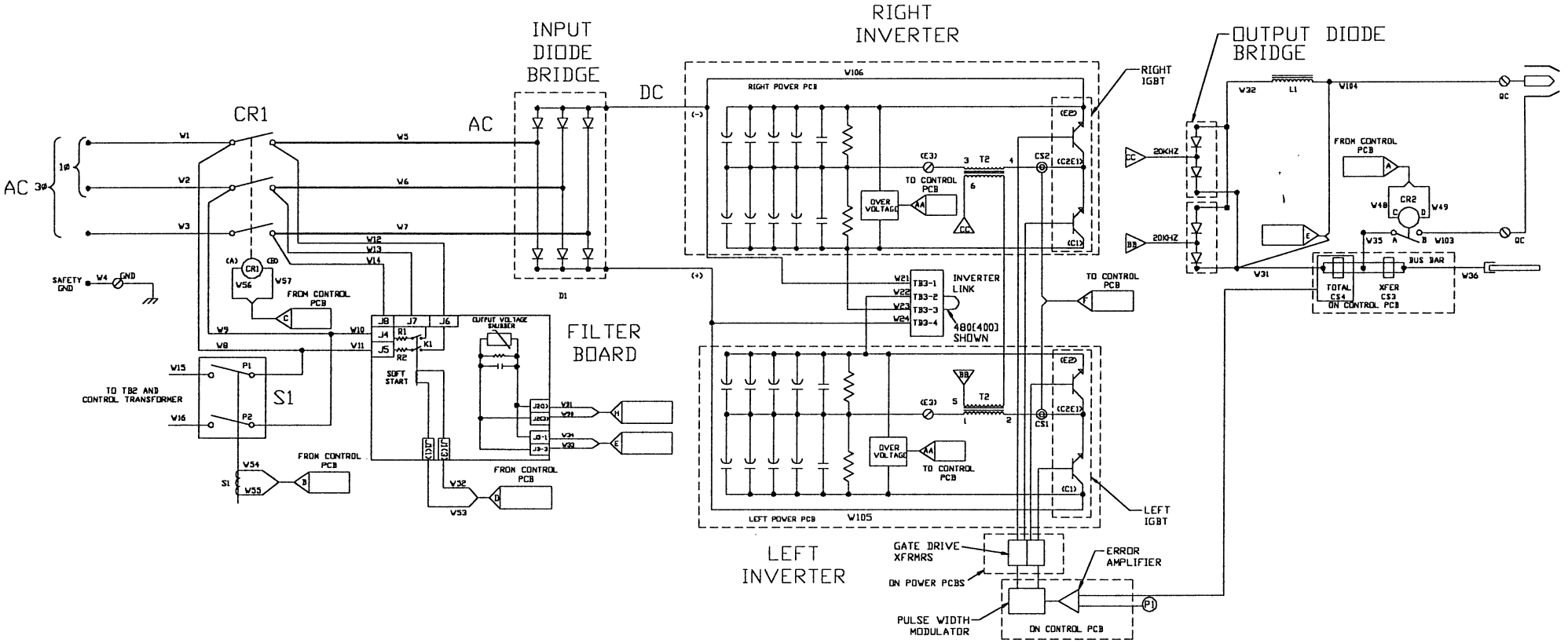



**Figure 3-4 Powermax1100 Block Diagram**

# CONTROL BOARD

## Control Board LEDs

There are 4 control board LEDs visible from the Powermax1100 front panel. There are 6 more LEDs that are visible only when the cover is removed. See Figure 3-5 for location of LEDs.

- **D8** POWER ON: Illuminates when power is applied.
- **D15** LINE VOLTAGE: Illuminates when the input voltage is out of limits. This LED will remain illuminated if the line voltage is too low, and illuminate briefly before the power supply shuts down if the line voltage is too high.

  Note: When operating at or near the lower limit (–15% of line voltage), the line voltage LED will illuminate, and the power supply will function, but with some performance degradation. When operating below the lower limit, the torch may become disabled.

  The upper and lower range for line voltages are as follows:

| Lower Limit (D15 illuminates) | **Line Voltage** | Upper Limit |
|---|---|---|
| 170VAC | **200VAC** | 235VAC |
| 178VAC | **208VAC** | 239VAC |
| 195VAC | **230VAC** | 270VAC |
| 204VAC | **240VAC** | 276VAC |
| 340VAC | **400VAC** | 470VAC |
| 408VAC | **480VAC** | 552VAC |
| 510VAC | **600VAC** | 690VAC |

Note: To avoid performance deterioration, input voltage should be within 10% of the listed line voltage.

- **D24** OVERCURRENT: Illuminates when CS1 or CS2 senses current above 120 amps.
- **D25** PILOT ARC RELAY: Illuminates when pilot arc relay PAR (CR2) is energized.
- **D26** GAS SOLENOID: Illuminates when gas solenoid is energized (when GAS TEST switch is pressed or when plasma start is pressed).
- **D27** MAIN CONTACTOR: Illuminates when contactor CR1 is energized (following "soft start").
- **D29** TEMP LED: Remains off when temperature is within operating limits. It illuminates when the thermostat in power transformer T2 opens (over 95° C (203° F) on non-CE power supplies or over 105°C (221° F) on CE power supplies) or if the heatsink becomes too hot (over 85°C (185° F)). Overheating can be caused by exceeding the duty cycle rate.
- **D35** GAS PRESSURE: Illuminates when incoming gas pressure sensed by PS1 is within operating limits (over 39 psi (2.7 bar)).
- **D38** ARC TRANSFER: Illuminates when arc transfers to the workpiece.
- **D42** PLASMA START: Illuminates when the torch start button is pushed or when start button is activated from the machine interface.

The control board also controls the sequence required to generate plasma:

- Turns on the inverter when the torch start button is pressed
- After a short delay, turns on the gas solenoid valve V1 to blow the nozzle forward
- Monitors the pilot arc for arc transfer
- Ramps the current control command from the pilot arc level (30 amps) to the cut current selected by the operator
- Turns the inverter off if the arc transfer does not occur within 5 seconds
- Turns the power supply off when the retaining cap is loose or when line voltage is too high

## Control Board Test Points

| Test Point | Description | Value |
|---|---|---|
| TP1* | Transfer signal. | A logic high (12V) indicates that the arc is transferred. |
| TP2 | Start signal. | A logic high (12V) indicates that the torch start switch is on. |
| TP3 | GND | |
| TP4 | | +12V |
| TP6 | | +18V |
| TP7 | INV-ON signal. | A logic high (12V) indicates that the inverter is on. |
| TP8 | Transfer latch signal. | A logic high (12V) indicates that unit is in transferred mode. |
| TP9 | Temp OK signal. | A logic high (12V) indicates that all temperatures are OK. |
| TP10 | Continuous PA threshold voltage. | Set to 3.55V by P3. |
| TP11 | | 7.0V |
| TP15 | Error amplifier reference voltage. | During inverter operation this signal is 1.915V at 80A current setting and .75V at 30A current setting. |
| TP16 | Error amplifier output voltage | |
| TP17 | Reference voltage | 2.50V |
| TP18 | Output current value signal | 38.3mv/amp |
| TP19 | Wiper voltage. | 2.5V at 80A current setting and 1.00V at 30A current setting. |
| TP20 | GND | |
| TP21 | Buffered, inverted, capacitor feed version of pulse width modulator B signal. | |
| TP22 | Buffered, inverted version of pulse width modulator A signal. | |
| TP23** | Special test point. Jumper to TP4 when testing power supply using a resistive load instead of a torch. | |
| **Fuses** | | |
| F1,F2 | Cap sensor circuit protection | .5A (see **Parts List** for part number and specifications) |
| F3,F4 | Start circuit protection | .5A (see **Parts List** for part number and specifications) |

* Located above TP2 on Rev A boards

** Not availabe on Rev A boards

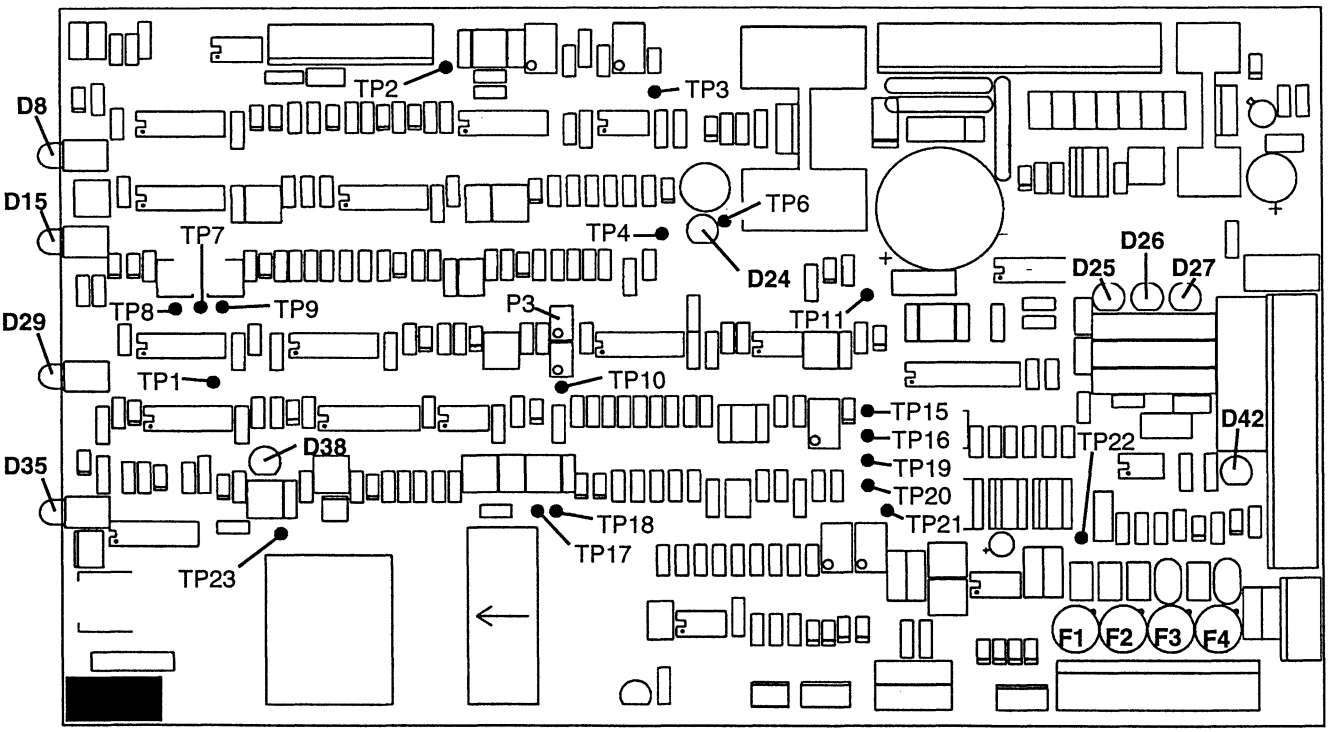
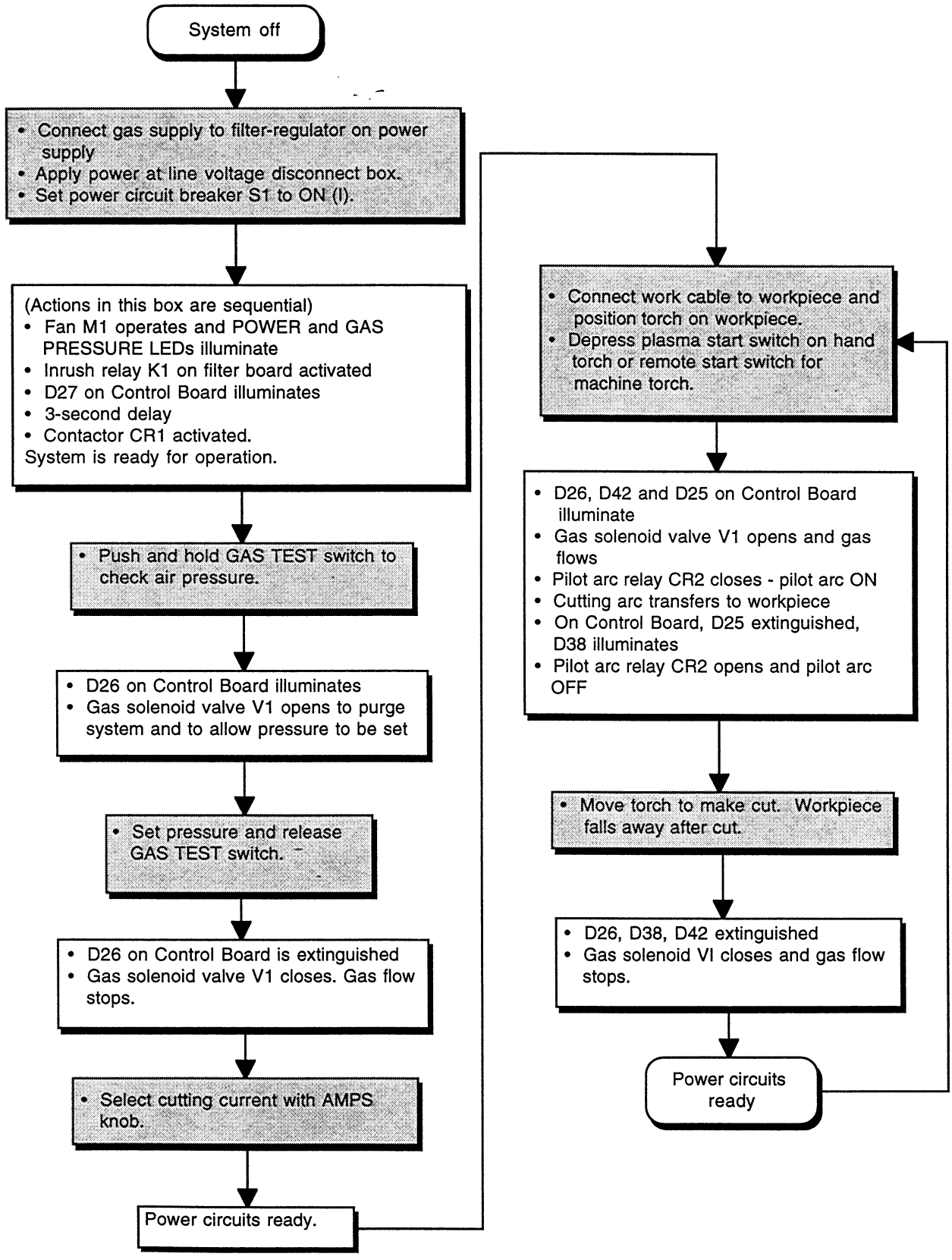



**Figure 3-5 Control Board Test Points and LED Locations**

## SEQUENCE OF OPERATION

Shaded boxes represent operator action. Clear boxes represent results from operator action.



# TROUBLESHOOTING

See *Basic Troubleshooting* in the **Powermax1100 Operator Manual** for causes and solutions to common operating problems. If the Powermax1100 still does not function properly after eliminating the possible causes outlined in *Basic Troubleshooting*, use the information in this section to isolate the problem

The complexity of the circuits require that service technicians have a working knowledge of inverter power supply theory. In addition to being technically qualified, technicians must perform all testing with safety in mind.

If questions or problems arise during servicing, call the Hypertherm Technical Services Department at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.

## Test Equipment

- Multimeter

## Troubleshooting Procedures

- Refer to the system wiring diagrams when performing the checkout procedures.
- To locate power supply and torch components refer to **Section 4**.
- After the problem has been located and repaired, refer to the *Sequence of Operation* flow diagram in this section to test the power unit for proper operation.

## Visual Inspection - External

1. Inspect the outside of the power supply for damage to the cover and external components.
2. Inspect the torch and the torch lead for damage.

Visual Inspection - Internal

## WARNING

SHOCK HAZARD: Always turn off the power, unplug the cord and wait 5 minutes before removing any power supply cover. If the power supply is directly connected to a line disconnect switch, place switch in the OFF position. In the U.S., use a "lock-out / tag-out" procedure until the service or maintenance work is complete. In other countries, follow appropriate local or national safety procedures.

Dangerous voltages in the power supply can cause serious injury or death. If questions or problems arise during servicing, call the Hypertherm Technical Services department at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.

## WARNING

The aluminum heatsink on the power PC board is electrically live when the plasma is on. In case of an electrical failure of the inverter circuit, the heatsink may be live when the power is off.

SHOCK HAZARD: The large electrolytic capacitors, (blue-cased cylinders) located on the power boards store large amounts of energy in the form of electrical voltage. Even if the power is off, dangerous voltages exist at the capacitor terminals, and on certain areas of the PC boards. Never discharge the capacitors with a screwdriver or other implement... explosion, property damage and/or personal injury will result.

Wait at least 5 minutes after turning the power supply off before touching the PC boards or capacitors. If questions or problems arise during servicing, call Hypertherm Technical Services at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.

## WARNING

**SHOCK HAZARD: Do not attempt repairs on the power boards or control board. Do not cut away or remove the protective conformal coating from the boards. To do so will risk a short between the AC input circuit to the output circuit and may cause serious injury or death.**

**The power supply and PC boards are subjected to dielectric and insulation resistance tests per applicable CSA and IEC standards for the safety of the operator and service technicians.**

**Removal of the protective conformal coatings and other unauthorized repairs to the PC boards will void the warranty.**

**If questions or problems arise during servicing, call the Hypertherm Technical Services department at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.**

1. Set the Powermax1100 power switch to O (off), unplug the power cord, disconnect the gas supply and disconnect the torch.

2. Remove the cover of the power supply by removing the securing screws.

3. Visually inspect the inside of the power supply, especially on the side with the power boards (see Fig. 3-7). Look for broken or loose wiring connections, burn and char marks, damaged components, etc. Repair or replace as necessary.

## Resistance Checks

**All resistance values in this section were taken with the power cord disconnected, all internal power supply wires attached, and with the torch unplugged. Perform *Visual Inspection - Internal* before continuing in this section.**

- If your resistance values are not close to the values given in this section, isolate the problem by removing wires attached to the resistance check points or component until the problem is found.
- After the problem has been located and repaired, refer to the *Sequence of Operation* flow diagram in this section to test the power unit for proper operation.

1. **Contactor to Chassis**
   All contactor points to the chassis are open (greater than 50MΩ).

2. **Across Input of Contactor**
   All input points to the contactor are open (greater than 50MΩ) between each other.

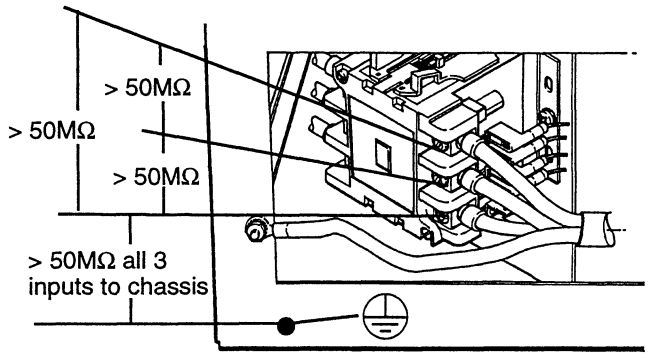



**Figure 3-6 Contactor Resistance Checks**

3. **Input to Chassis**
   Inputs to the chassis are open (greater than 50MΩ).

4. **Output to Chassis**
   Outputs to the chassis are open (greater than 50MΩ).

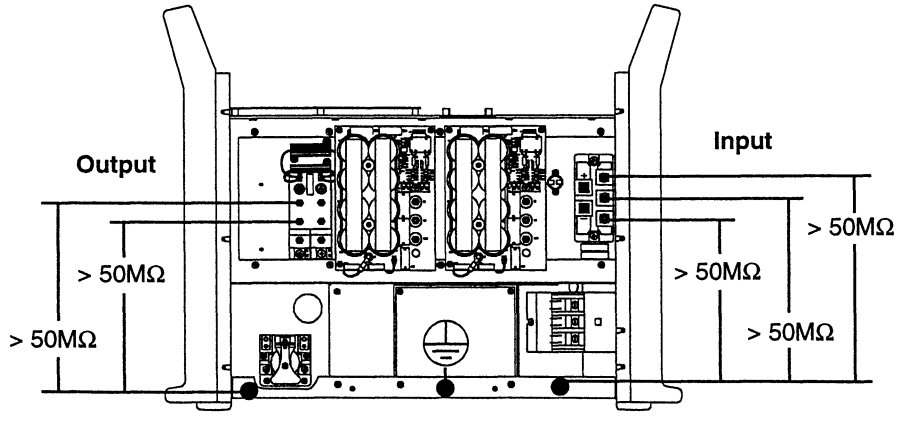



**Figure 3-7 Input and Output to Chassis Resistance Checks**

**5. Across Input Diode Bridge**

Take measurements matching the polarity of the multimeter probes with the diode bridge polarity.

Non-CE Power Supplies: Resistance across the input diode bridge is approximately 500KΩ from any of the diodes to the + or the – side of the bridge, and also 500KΩ between bridge diodes.

CE Power Supplies: Resistance across the input diode bridge is approximately 430KΩ from any of the diodes to the + or the – side of the bridge, and 250KΩ between bridge diodes.

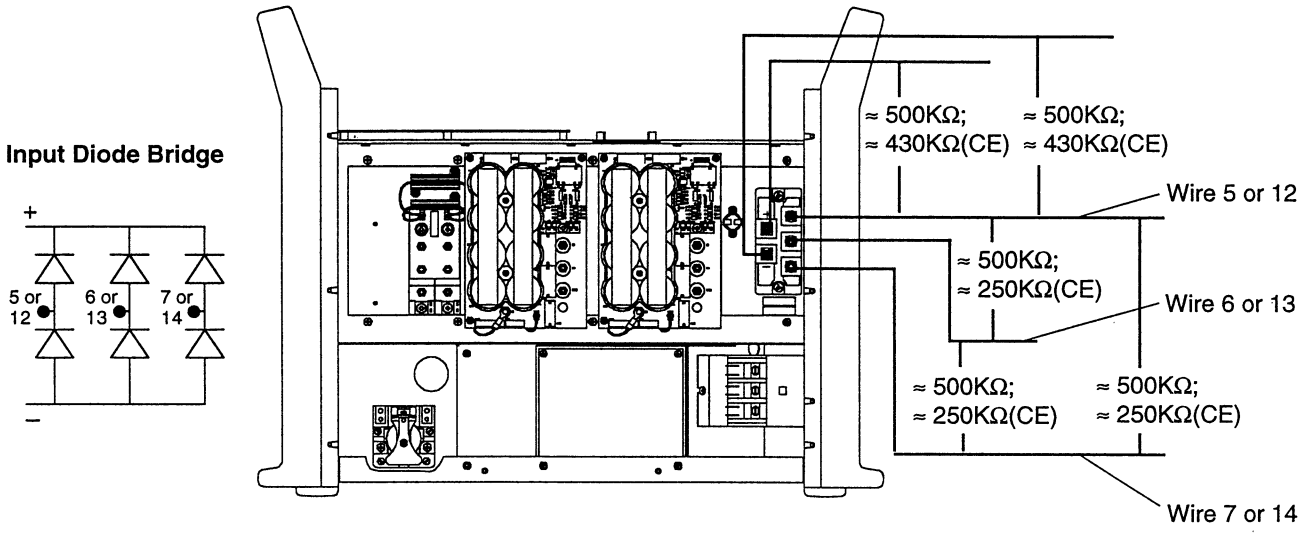



**Figure 3-8 Input Diode Bridge Resistance Checks**

**6. Across Output Diode Bridge**

Resistance across the output diode bridge is approximately 4.7KΩ when the + multimeter lead is placed on the + side of the bridge and the – multimeter lead is placed on the – side of the bridge.

When reversing the meter leads, the resistance is approximately 3KΩ.

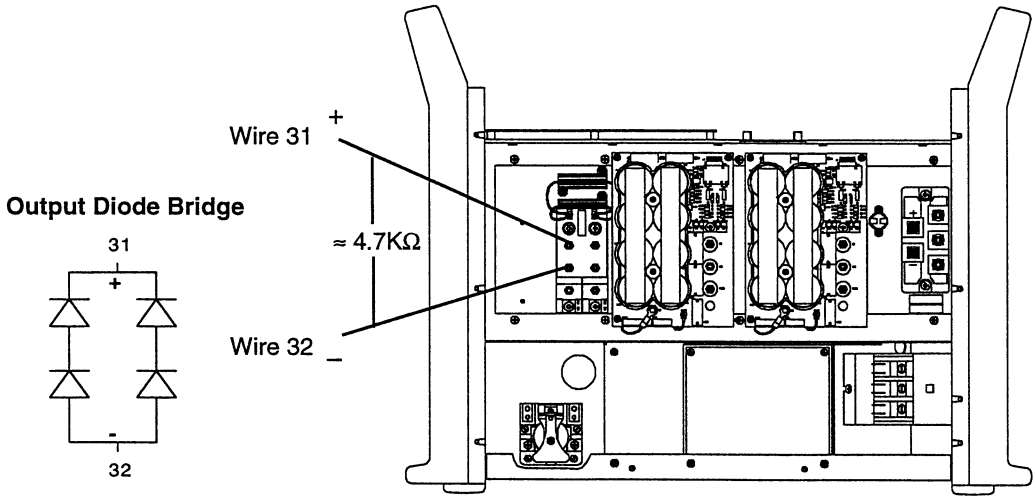



**Figure 3-9 Output Diode Bridge Resistance Checks**

## Voltage Checks

### WARNING

**SHOCK HAZARD: Always turn off the power, unplug the cord and wait 5 minutes before removing any power supply cover. If the power supply is directly connected to a line disconnect switch, place switch in the OFF position. In the U.S., use a "lock-out / tag-out" procedure until the service or maintenance work is complete. In other countries, follow appropriate local or national safety procedures.**

**When performing voltage checks, be aware that dangerous voltages exist within the power supply which can cause serious injury or death. If questions or problems arise during servicing, call the Hypertherm Technical Services department at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.**

### WARNING

**The aluminum heatsink on the power PC board is electrically live when the plasma is on. In case of an electrical failure of the inverter circuit, the heatsink may be live when the power is off.**

**SHOCK HAZARD: The large electrolytic capacitors, (blue-cased cylinders) located on the power boards store large amounts of energy in the form of electrical voltage. Even if the power is off, dangerous voltages exist at the capacitor terminals, and on certain areas of the PC boards. Never discharge the capacitors with a screwdriver or other implement... explosion, property damage and/or personal injury will result.**

**Wait at least 5 minutes after turning the power supply off before touching the PC boards or capacitors. If questions or problems arise during servicing, call Hypertherm Technical Services at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.**

## WARNING

**SHOCK HAZARD: Do not attempt repairs on the power board or control board. Do not cut away or remove the protective conformal coating from either board. To do so will risk a short between the AC input circuit to the output circuit and may cause serious injury or death.**

**The power supply and PC boards are subjected to dielectric and insulation resistance tests per applicable CSA and IEC standards for the safety of the operator and service technicians.**

**Removal of the protective conformal coatings and other unauthorized repairs to the PC boards will void the warranty.**

**If questions or problems arise during servicing, call the Hypertherm Technical Services department at 1 800 643 9878 or the nearest Hypertherm office listed in the front of this manual.**

If no problems were found during the resistance checks and the power supply still does not operate correctly, perform the following voltage checks.

Note: Study the system wiring diagrams and troubleshooting schematics in **Section 5** and understand the theory of operation before troubleshooting. Before purchasing a major replacement component, check with Hypertherm's Technical Service group at 1 800 643 9878 or the nearest Hypertherm repair facility.

1. Connect the torch to the power supply.
2. Connect the power cord to the line voltage disconnect switch box or plug into a properly grounded outlet.
3. Connect the gas supply to the pressure regulator at the rear of the power supply.
4. Perform the voltage checks starting on the following page.
5. After the problem has been located and repaired, refer to the *Sequence of Operation* in this section for the normal operation of the power supply.

## Voltage Checks (continued)

**Before switching on the power supply, perform *Visual Checks - Internal, Resistance Checks* and also review the warnings on pages 3-14 and 3-15.**

- Verify that the torch is plugged into the power supply
- Switch the power supply on

**1. Voltage at Input of Input Diode Bridge**

The AC voltage between any 2 input wires will equal the line voltage on 3ϕ systems.
On 1ϕ systems, the AC voltage between the top 2 input wires will equal the line voltage.

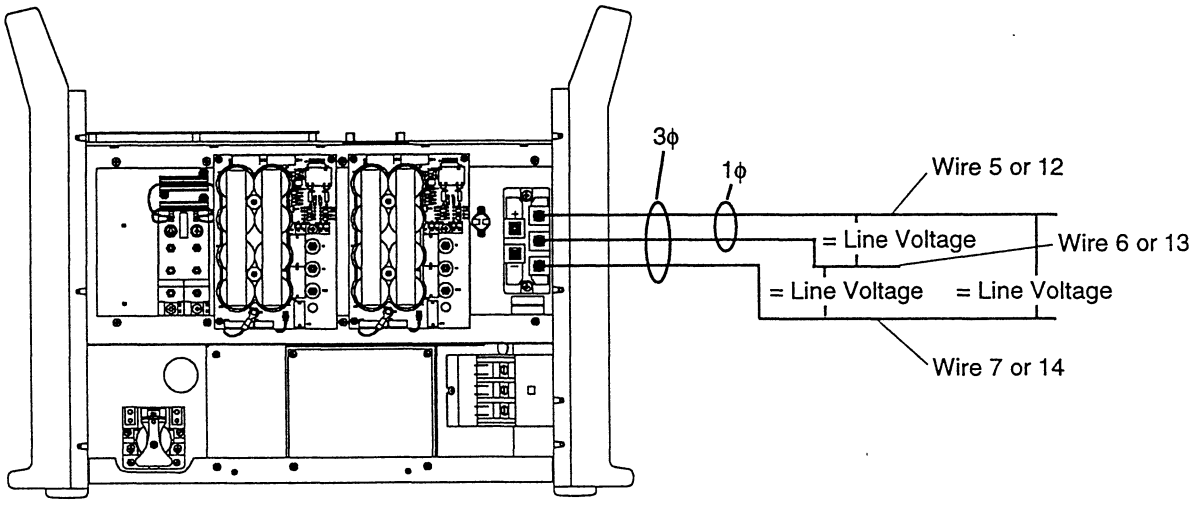



**Figure 3-10 Voltage at Input of Input Diode Bridge**

**2. Voltage at Output of Input Diode Bridge**

This DC voltage will approximately equal the line voltage X 1.414 - See table below.

| Line Voltage | Output at Bridge |
|---|---|
| 200VAC | ≈ 280VDC |
| 208VAC | ≈ 290VDC |
| 230VAC | ≈ 320VDC |
| 240VAC | ≈ 340VDC |
| 400VAC | ≈ 560VDC |
| 480VAC | ≈ 680VDC |

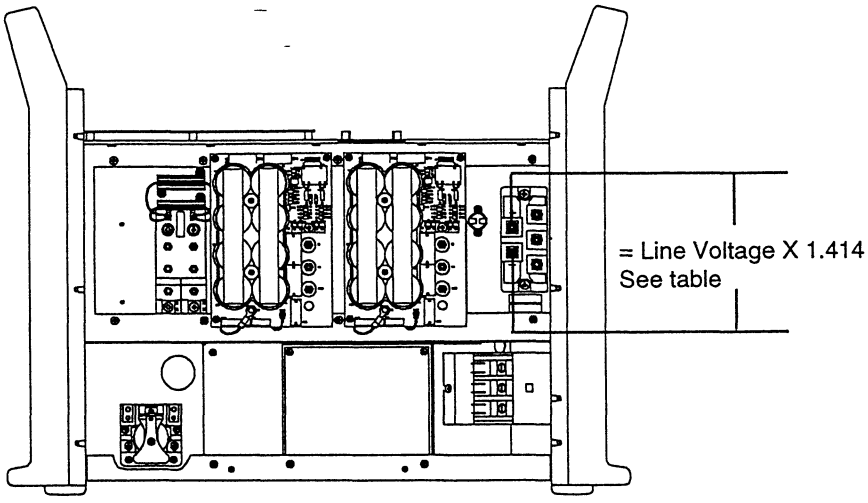
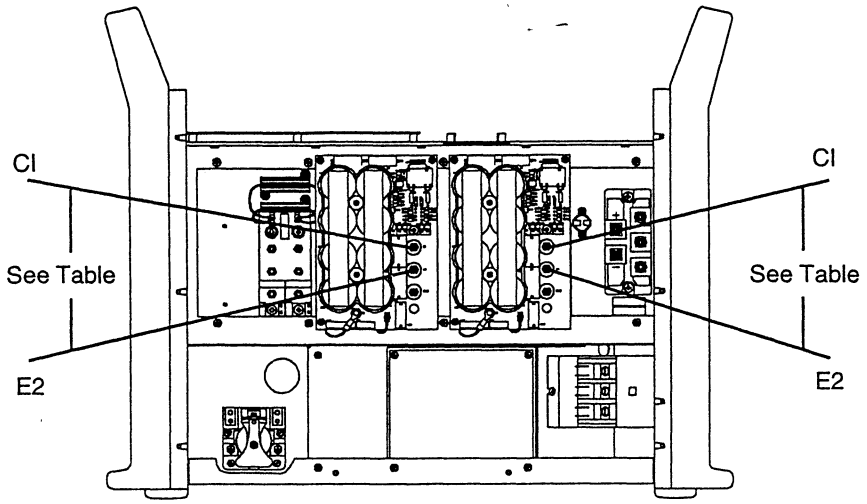



**Figure 3-11 Voltage at Output of Input Diode Bridge**

3. **Voltage Across Power Board Capacitors**
   See the table in Fig. 3-12 to find the correct voltage reading between C1 and E2 of the power boards.

   - If there is a voltage imbalance between the 2 power boards, replace the power board that has the lower voltage reading.




| Line Voltage | Voltage at C1 and E2 of Power Boards |
|---|---|
| 200VAC | ≈ 280VDC |
| 208VAC | ≈ 290VDC |
| 230VAC | ≈ 320VDC |
| 240VAC | ≈ 340VDC |
| 400VAC | ≈ 280VDC |
| 480VAC | ≈ 340VDC |

**Figure 3-12 Voltage Across Power Board Capacitors**

4. **Output Voltage With Transferred Arc**
   The voltage is approximately 140VDC at the output diode bridge when the torch arc is transferred to the workpiece.
   If the torch is not working, the voltage will be approximately 300VDC for 5 seconds and then drop to 0VDC.

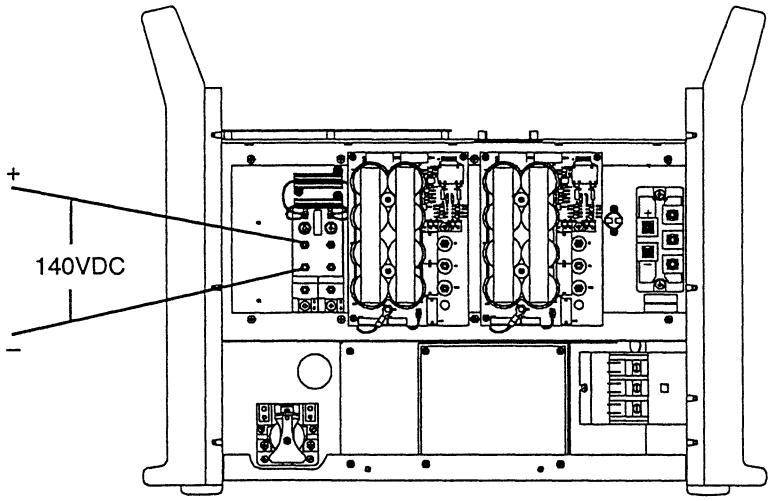



**Figure 3-13 Output Voltage With Transferred Arc**

# TORCH CHECK

A failure of the torch cap sensor circuit will cause the Powermax1100 power supply to shut down, and a failure of the torch start circuit will prevent the torch from firing. If your Powermax1100 has either of these problems, proceed with the following checks.

**WARNING**

**Set the Powermax1100 power switch to O (off), unplug the power cable, and disconnect the gas supply. Always wait 5 minutes before removing any cover of the power supply.**

## Cap Sensor Circuit Check

If the torch retaining cap is screwed down tightly and the ON/OFF power switch shuts off, there could be a problem with the torch cap sensor circuit.

1. Disconnect power and gas.
2. Remove the power supply cover.
3. Locate fuses F1 and F2 on the control board. See Fig. 3-5.
4. Check to see if the fuses are open.

   If the fuses are open, replace the torch, the torch leads and the control board fuse(s). See **Section 4: Parts List** to order new components.

   If the fuses are OK, the line voltage is OK, and the power supply continues to shut off, replace the control board.

## Start Circuit Check

If the torch start trigger is pressed and there is no pilot arc, there could be a problem with the torch start circuit.

1. Disconnect power and gas.
2. Remove the power supply cover.
3. Locate fuses F3 and F4 on the control board. See Fig. 3-5.
4. Check to see if the fuses are open.

   If the fuses are open, replace the torch, the torch leads and the control board fuse(s). See **Section 4: Parts List** to order new components.

   If the fuses are OK, the gas supply is OK, pressing the torch switch closes the connection between control board JP8 sockets 5 & 6, and the torch does not start, replace the control board.

   If the fuses are OK, the gas supply is OK, pressing the torch switch does not close the connection between control board JP8 sockets 5 & 6, and the torch does not start, replace the torch and the torch leads.

# PAC135T TORCH DISASSEMBLY AND MAIN BODY REMOVAL

1 **Set the Powermax1100 power switch to O (off), unplug the power cable, and disconnect the gas supply. Disconnect the torch lead quick disconnect from the power supply.**

2. Remove the 5 screws that secure the handle halves together and remove one handle half from the torch main body and leads, cap-on sensor and trigger switch.

3. Lift the boot end of the torch away from the remaining torch handle half and remove the torch main body and leads, cap-on sensor and trigger switch. Be careful not to damage the cap-on sensor assembly when removing it from the torch main body and handle half.

4. Slide back the PVC tubing from the plasma gas lead to expose the connections.

5. Cut the heatshrink away from the pilot arc lead to expose the connections.

6. Using 1/2" (13 mm) and 3/8" (10 mm) wrenches, disconnect the plasma gas lead from the torch main body.

7. Using 5/16" (8 mm) and 7/16" (11 mm) wrenches, disconnect the pilot arc lead from the torch main body.

8. Replace the torch main body.

9. Reassemble the torch by reversing the above directions and referring to Fig. 3-14. Be certain that the torch switch slides into position above the safety trigger, and that trigger movement activates the switch pushbutton. While positioning the handle halves together, be careful not to damage the cap-on sensor assembly or to pinch any wires.

10. When installing consumable parts, verify that the retaining cap makes contact with the cap-on sensor pins.

See Fig. 4-5 to order torch parts. See also *Changing Consumable Parts* in the Powermax1100 Operator manual.

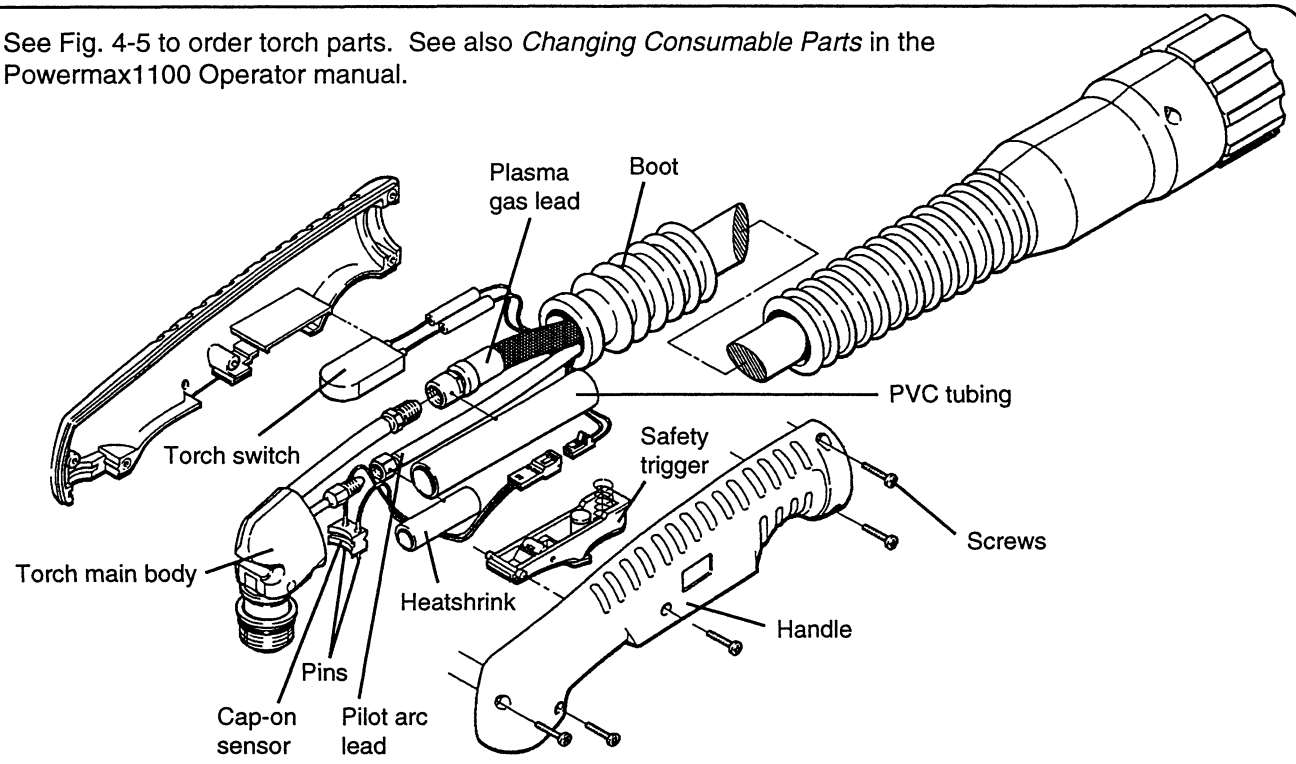



**Figure 3-14 PAC135T Torch Main Body Removal**

## PAC135M TORCH DISASSEMBLY AND MAIN BODY REMOVAL

1. **Set the Powermax1100 power switch to O (off), unplug the power cable, and disconnect the gas supply. Disconnect the torch lead quick disconnect from the power supply.**
2. Unscrew the torch sleeve from the torch main body and slide the sleeve back over the torch leads.
3. Disconnect the torch main body cap-on sensor lead from the mating connector on the torch leads.
4. Slide back the PVC tubing from the plasma gas lead to expose the connections.
5. Cut the heatshrink away from the pilot arc lead to expose the connections.
6. Using 1/2" (13 mm) and 3/8" (10 mm) wrenches, disconnect the plasma gas lead from the torch main body.
7. Using 5/16" (8 mm) and 7/16" (11 mm) wrenches, disconnect the pilot arc lead from the torch main body.
8. Replace the torch main body.

   Note: the cap-on sensor contacts are replaceable parts of the torch main body assembly. To remove a contact, grab it with protected pliers and pull it out of the main body.
9. Reassemble the torch by reversing the above directions and referring to Fig. 3-15.

See Fig. 4-6 to order torch parts. See also *Changing Consumable Parts* in the Powermax1100 Operator manual.

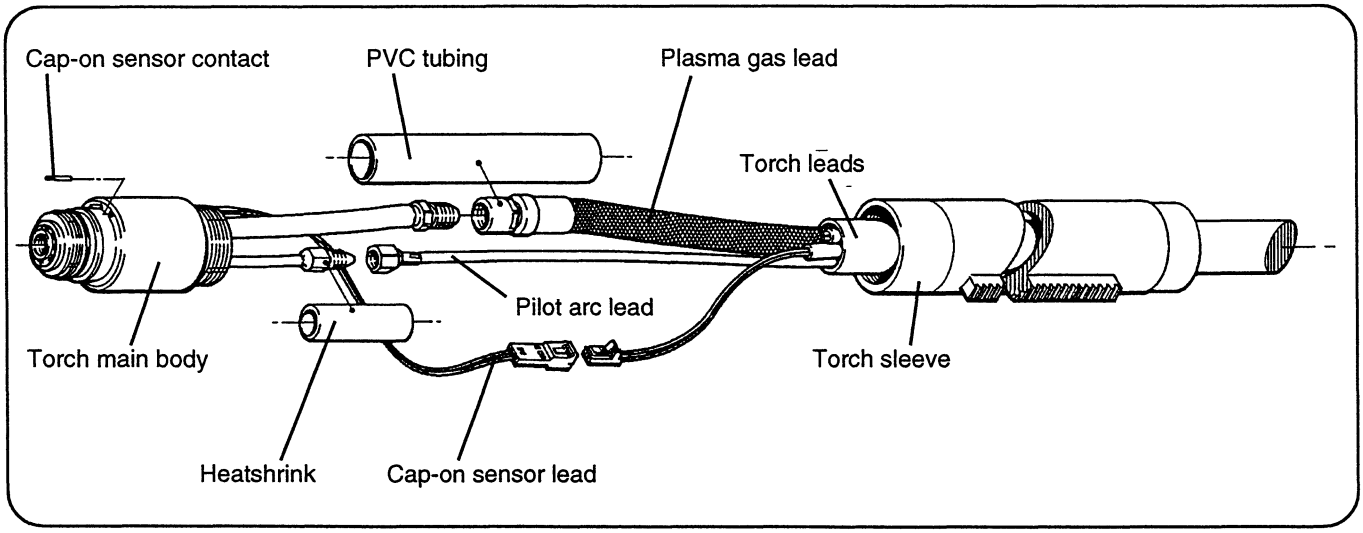



**Figure 3-15 PAC135M Torch Assembly**

# Section 4 PARTS LIST

In this section:

## POWER SUPPLY

### Front

| Index No. | Part No. | Description | Ref. Desig. | Quantity |
|---|---|---|---|---|
| 1 | 001606 | Panel:Pmx1100 Power Unit Plastic Front | | 1 |
| 2 | 001609 | Chassis:Pmx1100 Power Unit | | 1 |
| 3 | 004675 | Spacer:Pmx1100 Pressure Gauge | | 1 |
| 4 | 008965 | Knob:.850 Dia. 1/4 Black/Silver | | 1 |
| 4A | 075498 | Flatwasher: 0.257 .500 .062 Black Nylon | | 1 |
| 5 | 110123 | Label:Pmx1100 Power Unit Control Panel | | 1 |
| 6 | **123106†** | **Cable w/Clamp:Pmx1100 Work 20'** | | 1 |
| 7 | 008280 | Strain Relief:PG13 .270-.480 Nylon | | 1 |
| | **129139** | **Manifold SA:Pmx1100 Power Unit** | | 1 |
| 8 | 005112 | Pressure Switch:39 Psi .013 Orifice | **PS1** | 1 |
| 9 | 006101 | Solenoid Valve:1/4NPT - 24V | **V1** | 1 |
| 10 | 011060 | Regulator:0-125 Psig 1/4FPT | | 1 |
| 11 | 011074 | Nut:Regulator Panel Mounting | | 1 |
| 12 | 015304 | Male Elbow: 1/4NPTx3/8 Push in tube | | 2 |
| 13 | 015141 | Adapter:1/8NPTx1/8 Compression 90° Brass | | 1 |
| 14 | 015512 | Nipple:1/4x3" Long Brass | | 1 |
| 15 | 015590 | Nipple:1/4x1-1/2" Long Brass | | 1 |
| 16 | 015541 | Tee:1/4 Brass | | 1 |
| 17 | 004727 | Bracket:Pmx1100 Air Regulator Mounting | | 1 |
| 18 | 022027 | Pressure Gauge:160# 1.5" 1/8 Panel | | 1 |
| 19 | 015136 | Adapter:1/8FPTx1/8 Compression 90° Brass | | 1 |
| 20 | 015570 | Reducer Bushing:1/4x1/8 Brass | | 1 |
| 21 | 009480 | Pot:250-Ohm 1W 10% 1T | **P1** | 1 |
| 22 | **129142** | **Receptacle SA:Pmx1100 Power Unit Quick Disc.** | | 1 |
| 22 | **129221*** | **Receptacle SA:Pmx1100 CE Power Unit Quick Disc.** | | 1 |
| | 001610† | Cover:Pmx1100 Power Unit | | 1 |

* 230/400V CE power supplies only

† Not shown in Fig. 4-1.

Notes: **Bold** part numbers and descriptions are subassemblies.
Indented normal type items are components of subassemblies

All mounting hardware in power supply drawings shown for reference only.

## POWER SUPPLY

### Front

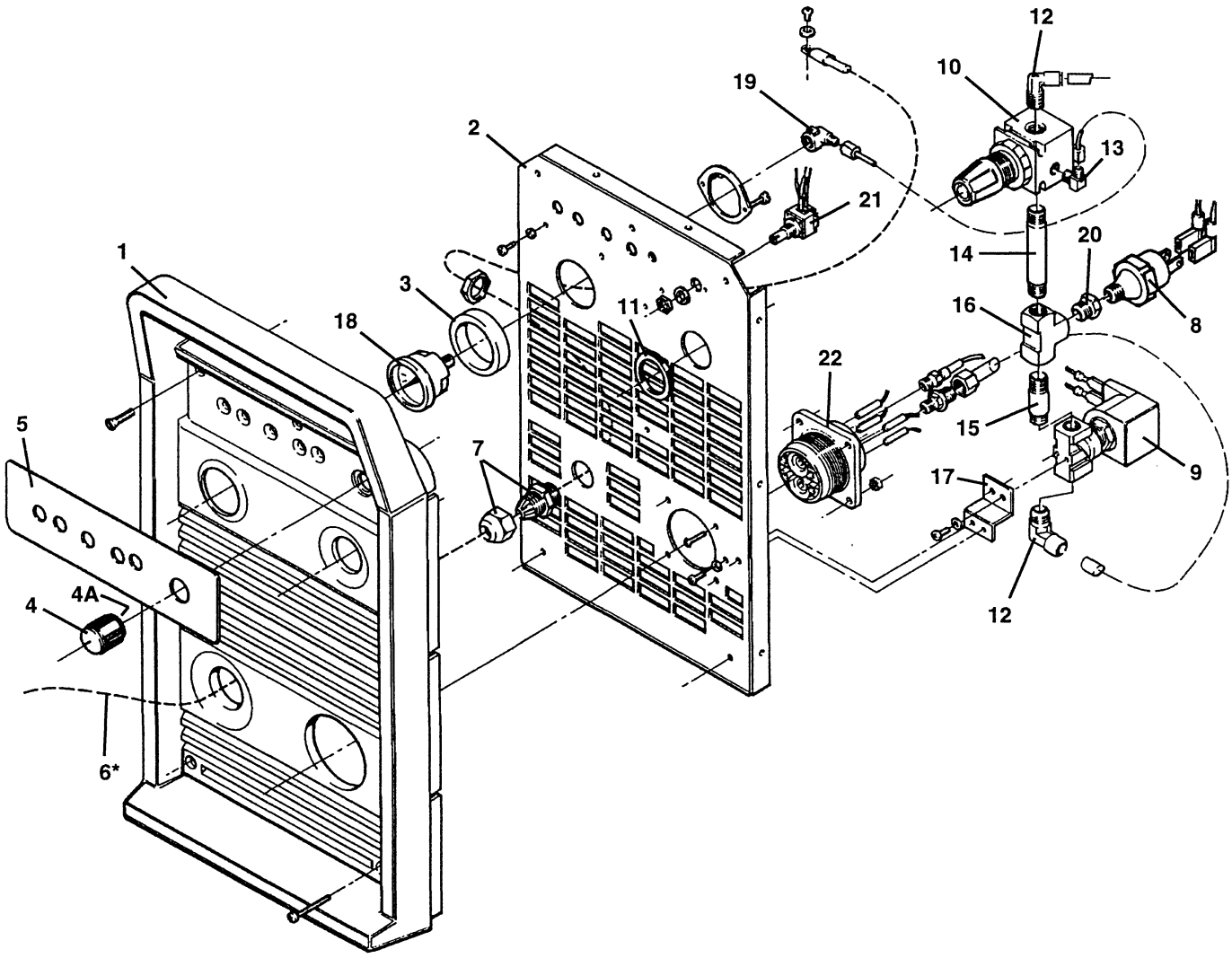



**Figure 4-1 Powermax1100 - Front**

# POWER SUPPLY

## Top and Right Side

| Index No. | Part No. | Description | Ref. Desig. | Quantity |
|---|---|---|---|---|
| 1 | 003078 | Relay:30A NO QDisc Terminal | **CR2** | |
| | **129141** | **Heatsink SA:Pmx1100 Power Unit** | | 1 |
| | **129194*** | **Heatsink SA:Pmx1100 CE Power Unit** | | 1 |
| 2 | 004724 | Heatsink:Pmx1100 Power Unit | | 1 |
| 3 | 008903 | Thermal Pad:AL-197-114 | | 4 |
| 4 | 009849 | Resistor:20-Ohm 50W 5% Non-Inductive | | 4 |
| 5 | 004731 | Mount:Pmx1100 Heatsink | | 1 |
| 6 | 005178† | Temperature Switch Opens 85°/Closes 75°C | **TS1** | 1 |
| 7 | 109060† | Diode:1600V 150A 3 Phase Module | | 1 |
| 8 | 109019*† | Diode:1600V 100A 3 Phase Module | | 1 |
| 8A | 129211* | MOV SA:Pmx1100 CE | | 1 |
| 9 | **041525** | **PCB Assy:Pmx1100 Power** | **Left Pwr Bd** | 1 |
| 10 | **041525** | **PCB Assy:Pmx1100 Power** | **Right Pwr Bd** | 1 |
| 11 | 109061† | IGBT:600V 150A Fast IGBT Module | **Left IGBT** | 1 |
| 12 | 109061† | IGBT:600V 150A Fast IGBT Module | **Right IGBT** | 1 |
| 13 | 109018† | Diode:600V 100A Ultra Fast Recovery, Dual | | 2 |
| 13 | 109071*† | Diode:600V 80A Ultra Fast Recovery, Dual | | 2 |
| 14 | **041549** | **PCB Assy:Pmx1100 Output Snubber** | | 1 |
| 15 | **041527** | **PCB Assy:Pmx1100 Filter/Soft Start** | | 1 |
| 16 | **041540*** | **PCB Assy:Pmx1100 CE Filter/Soft Start** | | 1 |
| 17 | **041538** | **PCB Assy:Pmx1100 Control** | | 1 |
| | 008989 | Fuse:630ma 250V IEC 127-3 Fast | **F1-F4** (pcb fuse) | 4 |
| | **128143***** | **Kit:Pmx1100 PA Control** | | |
| 18 | **041486***** | **PCB Assy:Pmx1100 PA Control** | | |
| 19 | **129233***** | **PA Control SA:Pmx1100** | | |
| | **128144******** | **Kit:Pmx1100 Machine Interface, 208/240/480V** | | |
| | **128168******** | **Kit:Pmx1100 Machine Interface, 200/230/400V** | | |
| | **128169******** | **Kit:Pmx1100 Machine Interface, 230/400V CE** | | |
| 20 | **041546******** | **PCB Assy:Pmx1100 Machine Interface** | | |
| 21 | 014137 | Current Sense Transformer, 40A | **CS1** | 1 |
| 21 | 014218** | Current Sense Transformer, 80A | **CS1** | 1 |
| 22 | 014137 | Current Sense Transformer, 40A | **CS2** | 1 |
| 22 | 014218** | Current Sense Transformer, 80A | **CS2** | 1 |
| 23 | 109070* | Toroid:Pmx1100 CE EMI Test | **L3-L5** | 3 |

* 230/400V CE power supplies only

** 200/230/400V and 230/400V CE power supplies only

*** Available only on power supplies with the pilot arc control option

**** Available only on power supplies with the machine interface option

† Apply a uniform coat of Dow Corning 340 thermal grease or equivalent to these items when mounting

Notes: **Bold** part numbers and descriptions are subassemblies.
Indented normal type items are components of subassemblies.

All mounting hardware in power supply drawings shown for reference only

## POWER SUPPLY

### Top and Right Side

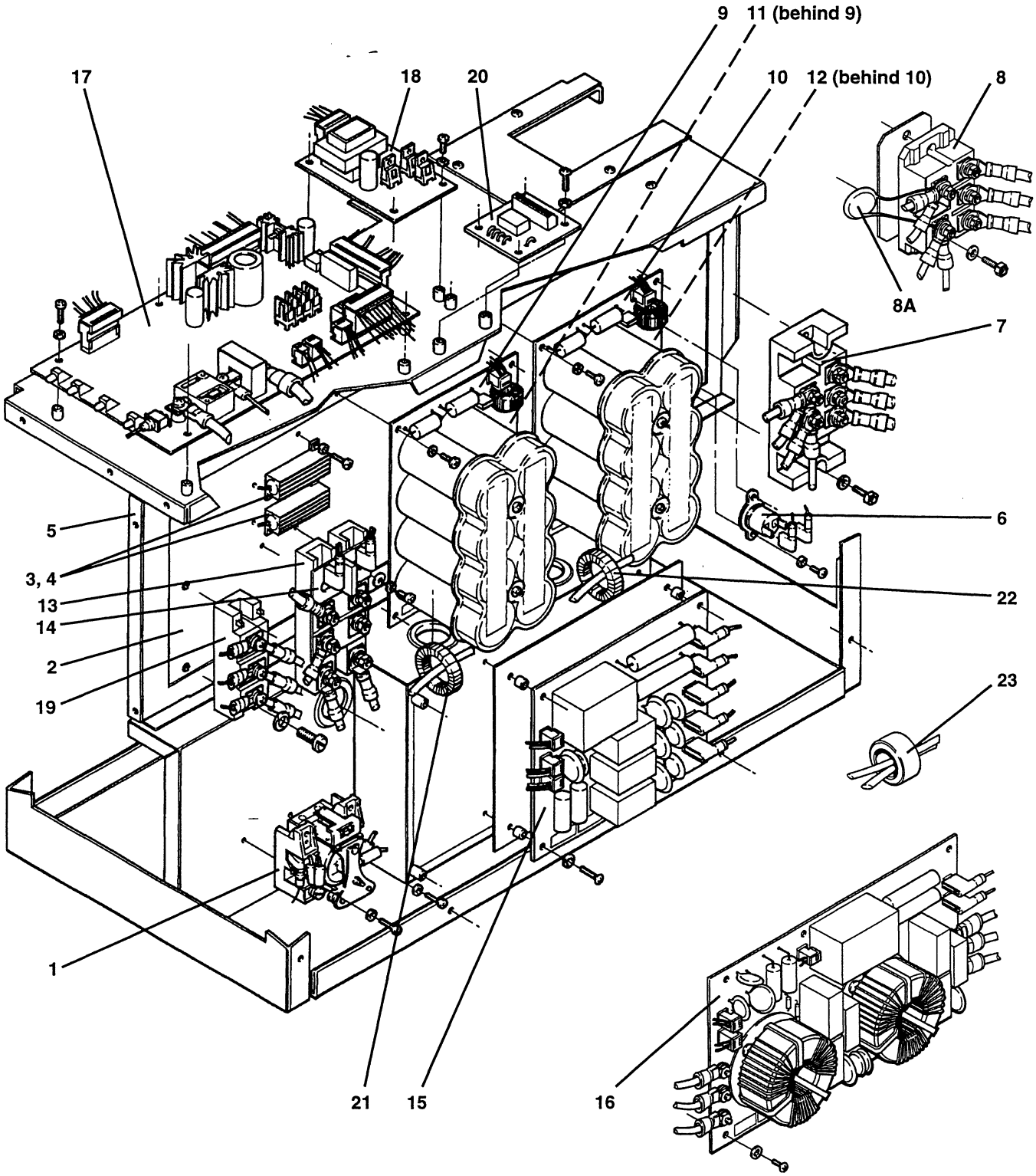



**Figure 4-2 Powermax1100 - Top and Right Side**

# POWER SUPPLY

## Floor and Left Side

| Index No. | Part No. | Description | Ref. Desig. | Quantity |
|---|---|---|---|---|
| 1 | 001609 | Chassis:Pmx1100 Power Unit | | 1 |
| 2 | 004722 | Bracket:Pmx1100 Power Unit Fan | | 1 |
| 3 | 014207*** | Xfmr:Pmx1100 208-240-480 Control | **T1** | 1 |
| 3 | 014208** | Xfmr:Pmx1100 200-230-400 Control | **T1** | 1 |
| 4 | 014199*** | Xfmr:Pmx1100 208-240-480 Power | **T2 (w/TS2)** | 1 |
| 4 | 014214** | Xfmr:Pmx1100 200-230-400 Power | **T2 (w/TS2)** | 1 |
| 5 | 014216 | Inductor:Pmx1100 .6MH 80A | **L1** | 1 |
| 6 | 014220*† | Inductor:Pmx1100 1.0MH 50A: | **L2** | 1 |
| 7 | 027443 | Fan:236CFM 120VAC 50-60HZ | **M1** | 1 |
| | **129141** | **Heatsink SA:Pmx1100 Power Unit** | | 1 |
| | **129194*** | **Heatsink SA:Pmx1100 CE Power Unit** | | 1 |
| 8 | 004724 | Heatsink:Pmx1100 Power Unit | | 1 |
| 9 | **129235** | **Contactor Assembly:Pmx1100 Power Unit** | **CR1** | 1 |
| 9 | **129236*** | **Contactor Assembly:Pmx1100 CE** | **CR1** | 1 |
| 10 | 008900 | Terminal Board:4-Terminal with protector | **TB3** | 1 |
| 11 | 008926 | Terminal Board:4-Terminal with protector | **TB2** | 1 |

* Used only on 230/400V CE power supplies

** Used on 200/230/400V and 230/400V CE power supplies

*** Used only on 208/240/480V power supplies

† Location of inductor indicated in Fig. 4-3

Notes: **Bold** part numbers and descriptions are subassemblies.
Indented normal type items are components of subassemblies

All mounting hardware in power supply drawings shown for reference only.

## POWER SUPPLY

### Floor and Left Side

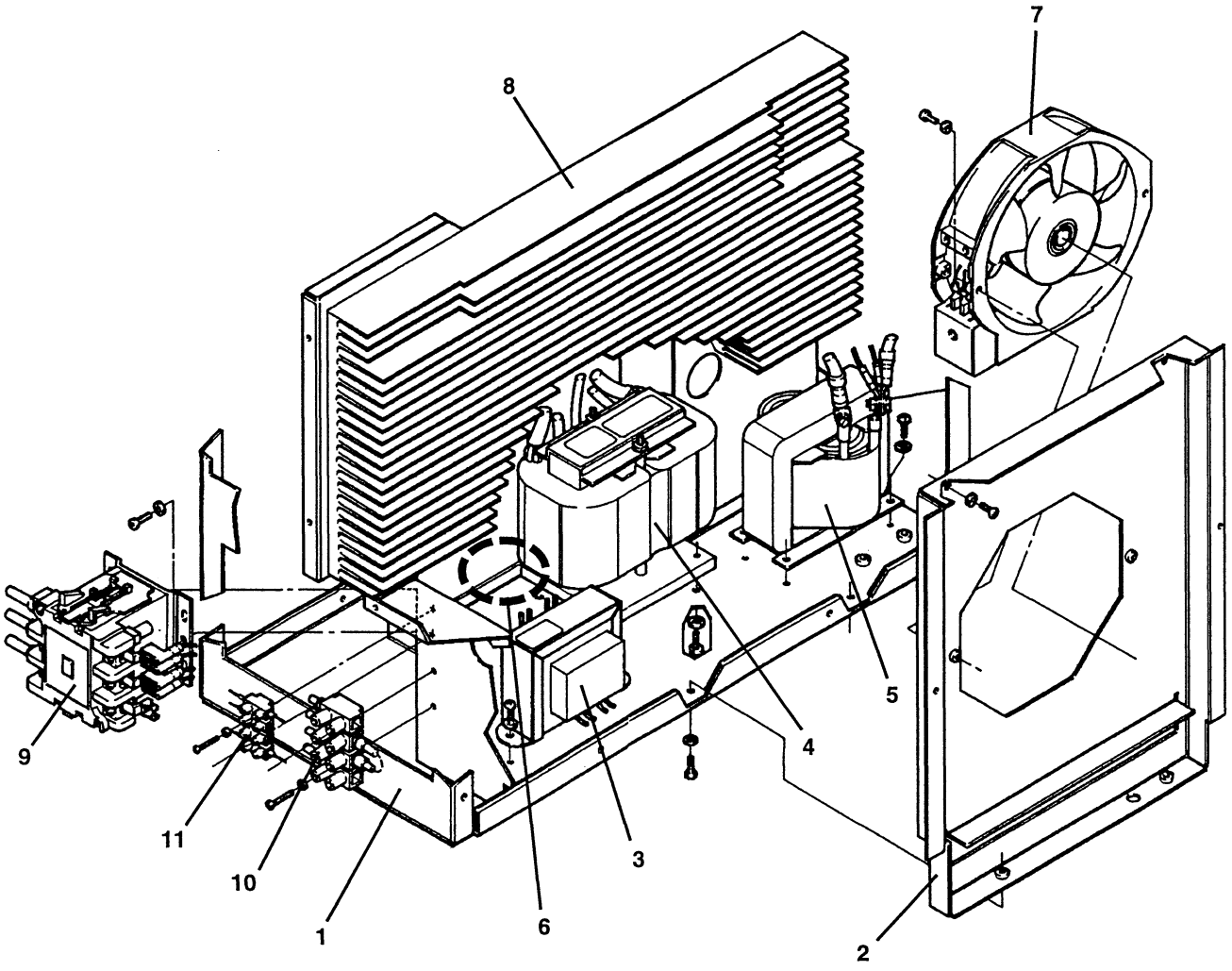



Figure 4-3 Powermax1100 - Floor and Left Side

## POWER SUPPLY

### Rear

| Index No. | Part No. | Description | Ref. Desig. | Quantity |
|---|---|---|---|---|
| 1 | 001503 | Panel:Pmx1100 Power Unit Plastic Rear | | 1 |
| 2 | 001609 | Chassis:Pmx1100 Pwr Unit | | 1 |
| 3 | 003184 | Circuit Breaker:3 Pole 1A | **S1** | 1 |
| 3 | 003189* | Circuit Breaker:3 Pole 1A | **S1** | 1 |
| | **129302** | **Regulator SA:Pmx1100 Pwr Unit** | | 1 |
| 4 | 011059 | Filter:5 Micron 1/4FPT | | 1 |
| 5 | 011079 | Filter Element for 011059 Filter | | 1 |
| 6 | **129143*** ** | **Linecord Panel 208/240/480V** | | 1 |
| 7 | 108030**** | Strain Relief with 0.86 - 1.26 Sleeve | | 1 |
| 8 | 108031 | Lock Nut | | 1 |
| 6 | **129230**** | **Linecord Panel 200/230/400V** | | 1 |
| 7 | 108030**** | Strain Relief with 0.86 - 1.26 Sleeve | | 1 |
| 8 | 108031 | Lock Nut | | 1 |
| 6 | **129229*** | **Linecord Panel 230/400V CE** | | 1 |
| 7 | 108030**** | Strain Relief with 0.625 Sleeve | | 1 |
| 8 | 108031 | Lock Nut | | 1 |
| 9 | **123195*** | **Cable:Pmx1100-CE Power Cord** | | 1 |
| 10 | **129232†** | **Linecord Cover Machine Interface 230/400V CE** | | |
| 10 | **129231††** | **Linecord Cover Machine Interface 200/230/400V** | | |
| 10 | **129212†††** | **Linecord Cover Machine Interface 208/240/480V** | | |
| 11 | **123099††††** | **Cable:Pmx Machine Interface** | | |
| 12 | 008279†††† | Strain Relief 0.187 - 0.312 | | |

* Used only on 230/400V CE power supplies

** Used only on 200/230/400V power supplies

*** Used only on 208/240/480V power supplies

**** See *Powermax1100 Field Upgrade Kits and Optional Parts* for strain relief sleeve part numbers

† Used only on 230/400V CE power supplies with the machine interface option

†† Used only on 200/230/400V power supplies with the machine interface option

††† Used only on 208/240/480V power supplies with the machine interface option

†††† Used in all power supplies with the machine interface option

See *Powermax1100 Field Upgrade Kits and Optional Parts* for machine interface kit part numbers

Notes: **Bold** part numbers and descriptions are subassemblies.
Indented normal type items are components of subassemblies

All mounting hardware in power supply drawings shown for reference only.

## POWER SUPPLY

### Rear

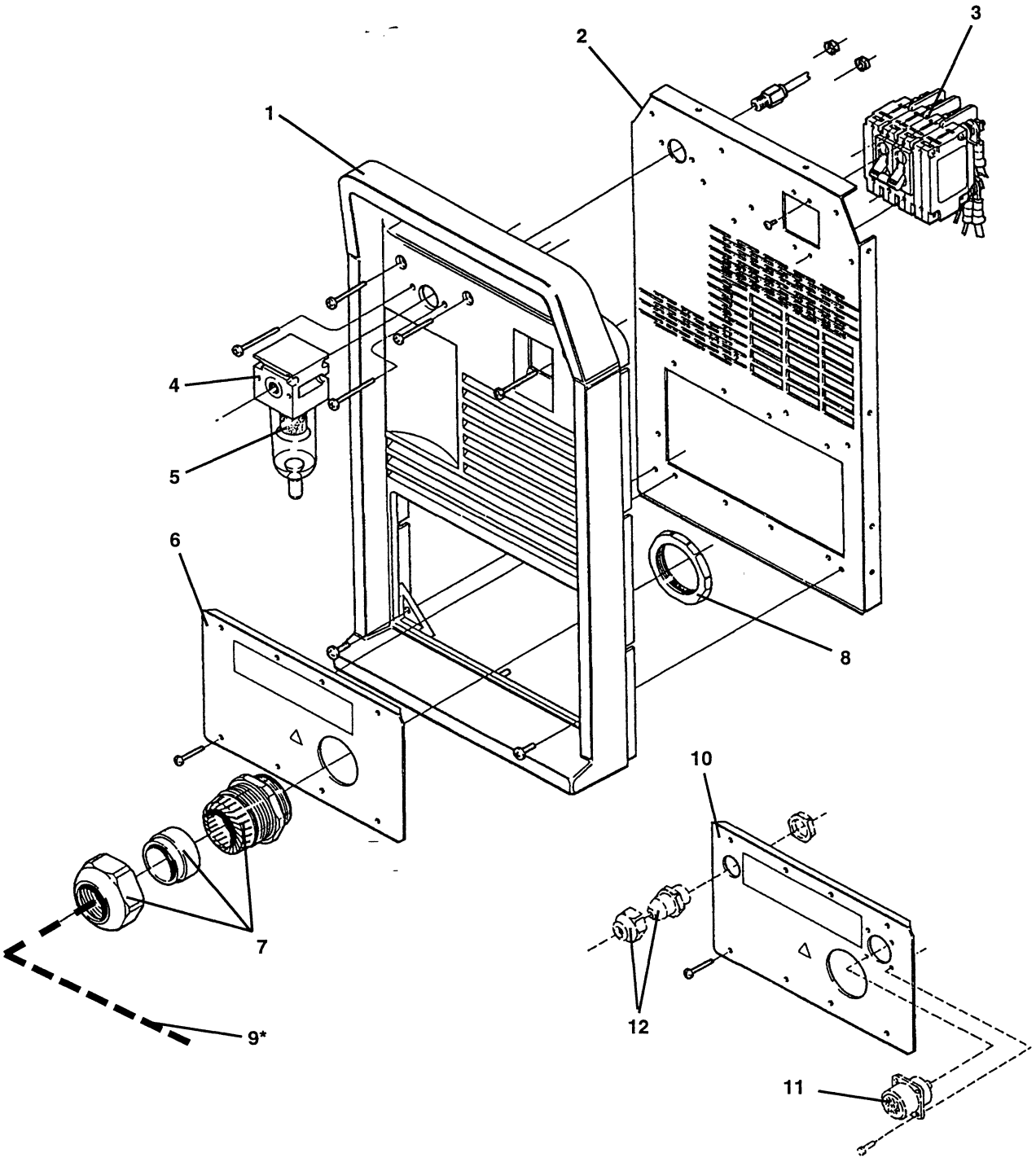



Figure 4-4 Powermax1100 - Rear

## PAC135T Torch Assembly and 25 ft (7.6 m) Lead - 085001
## PAC135T Torch Assembly and 50 ft (15.2 m) Lead - 085061

| Index No. | Part No. | Description | Qty. |
|---|---|---|---|
| | **002287** | **Handle Assembly: PAC135T w/screws** | |
| 1 | 001615 | Handle, PAC135T | 1 |
| 2 | 075497 | #6 X 5/8 Phillips Head, Pan Head | 5 |
| 3 | **002299** | **Safety Trigger Assembly, PAC135T** | 1 |
| 4 | **005212** | **Switch Assembly, Cap on Sensor** | 1 |
| | 120473 | Electrode, Air: PAC135 | 1 |
| | 120474 | Swirl Ring: PAC135 | 1 |
| | 120475 | Shield: PAC135 80A | 1 |
| | 120476 | Nozzle: PAC135 80A Shield | 1 |
| | 120483 | Retaining Cap: PAC135 | 1 |
| 5 | **120477** | **Torch Main Body, PAC135T** | 1 |
| 6 | 026020 | O-Ring: Silicon .864 X .070 | 1 |
| 7 | **129559*** | **Torch Lead, 25 ft (7.6 m)** | 1 |
| 7 | **129560**** | **Torch Lead, 50 ft (15.2 m)** | 1 |
| 8 | 005247 | Push Button Switch: Lo-Profile | 1 |
| 9 | 128122 | Plug Assembly: PAC135T Torch Quick Disconnect | 1 |
| 10 | 074069 | Splice:22-18 Butt | 2 |
| 11 | 046056 | Tubing:5/8" ID | 4" |
| 12 | 046072 | Heatshrink:1/2" ID | 2.5" |

* Used only in 085001, includes 002299
** Used only in 085061, includes 002299
Note: See page 4-12 for detail of consumable parts

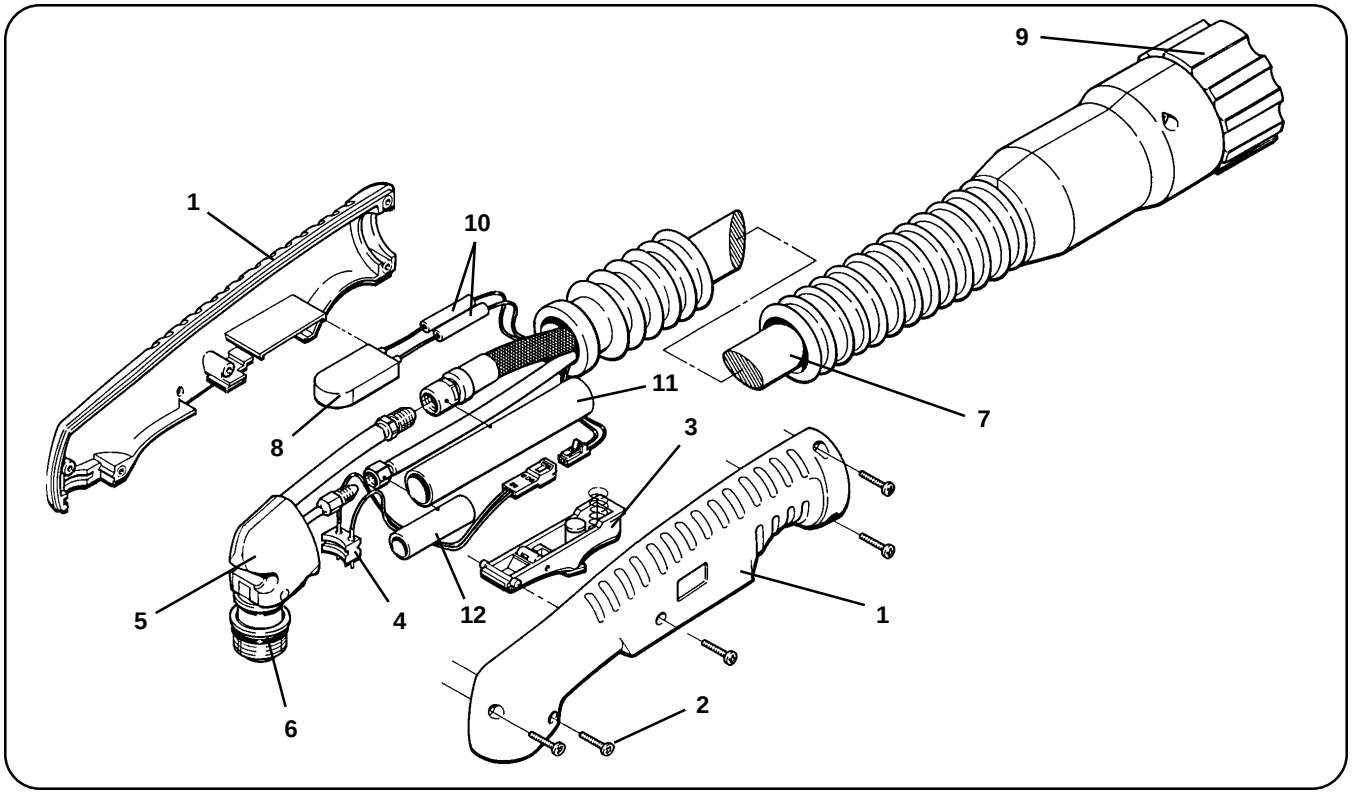



**Figure 4-5 PAC135T Torch Assembly and Leads**

## PAC135M Torch Assembly and Lead 14 ft (4.3 m) - 085062
## PAC135M Torch Assembly and Lead 25 Ft (7.6 m) - 085063
## PAC135M Torch Assembly and Lead 35 Ft (10.6 m) - 085064
## PAC135M Torch Assembly and Lead 50 Ft (15.2 m) - 085065

| Index No. | Part No. | Description | Qty. |
|---|---|---|---|
| 1 | 020243 | Sleeve, Torch Position | 1 |
| 2 | **129240*** | **Torch Lead, 14 ft (4.3 m)** | 1 |
| 2 | **129241**** | **Torch Lead, 25 ft (7.6 m)** | 1 |
| 2 | **129242***** | **Torch Lead, 35 ft (10.6 m)** | 1 |
| 2 | **129243******** | **Torch Lead, 50 ft (15.2 m)** | 1 |
| 3 | 128122 | Plug Assembly:PAC135 Torch Quick Disconnect | 1 |
| 4 | 008268 | Plug:3-Socket Female | 1 |
| 5 | 108034 | Receptacle Housing:2-Position 26-22AWG | 1 |
| | 120473 | Electrode | 1 |
| | 120474 | Ring, Swirl | 1 |
| | 120516 | Shield: PAC135M Machine Torch | 1 |
| | 120476 | Nozzle: PAC135 80A Shield | 1 |
| | 120483 | Cap, Retaining | 1 |
| 6 | **120508** | **Torch Main Body, PAC135M** | 1 |
| 7 | 026020 | O-Ring: Silicon .864 x .070 | 1 |
| 8 | 108035 | Pin Housing:2-Position 26-22AWG | 1 |
| 9 | 108040 | Contact:PAC135M Cap-On Sensor Switch | 1 |
| 10 | 046056 | Tubing:5/8" ID | 4" |
| 11 | 046072 | Heatshrink:1/2" ID | 2.5" |

* Used only in 085062 assembly
** Used only in 085063 assembly
*** Used only in 085064 assembly
**** Used only in 085065 assembly

Note: See page 4-12 for detail of consumable parts

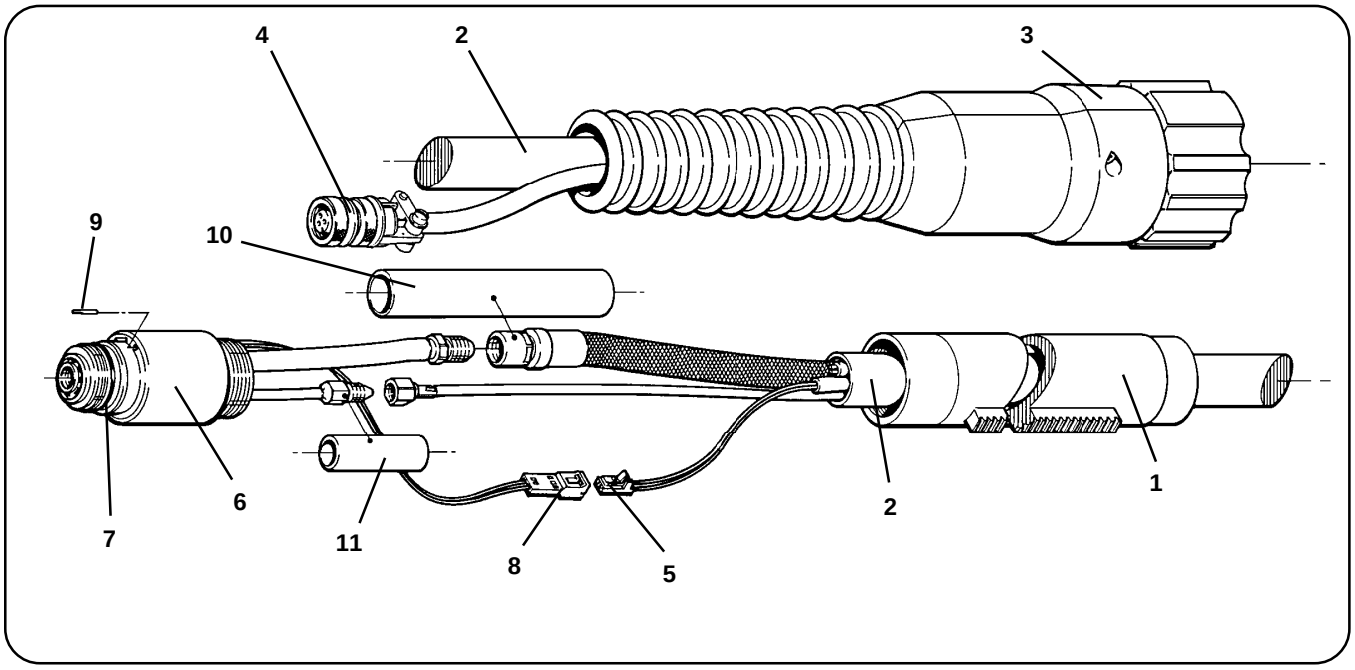



**Figure 4-6 PAC135M Torch Assembly and Leads**

## CONSUMABLE PARTS

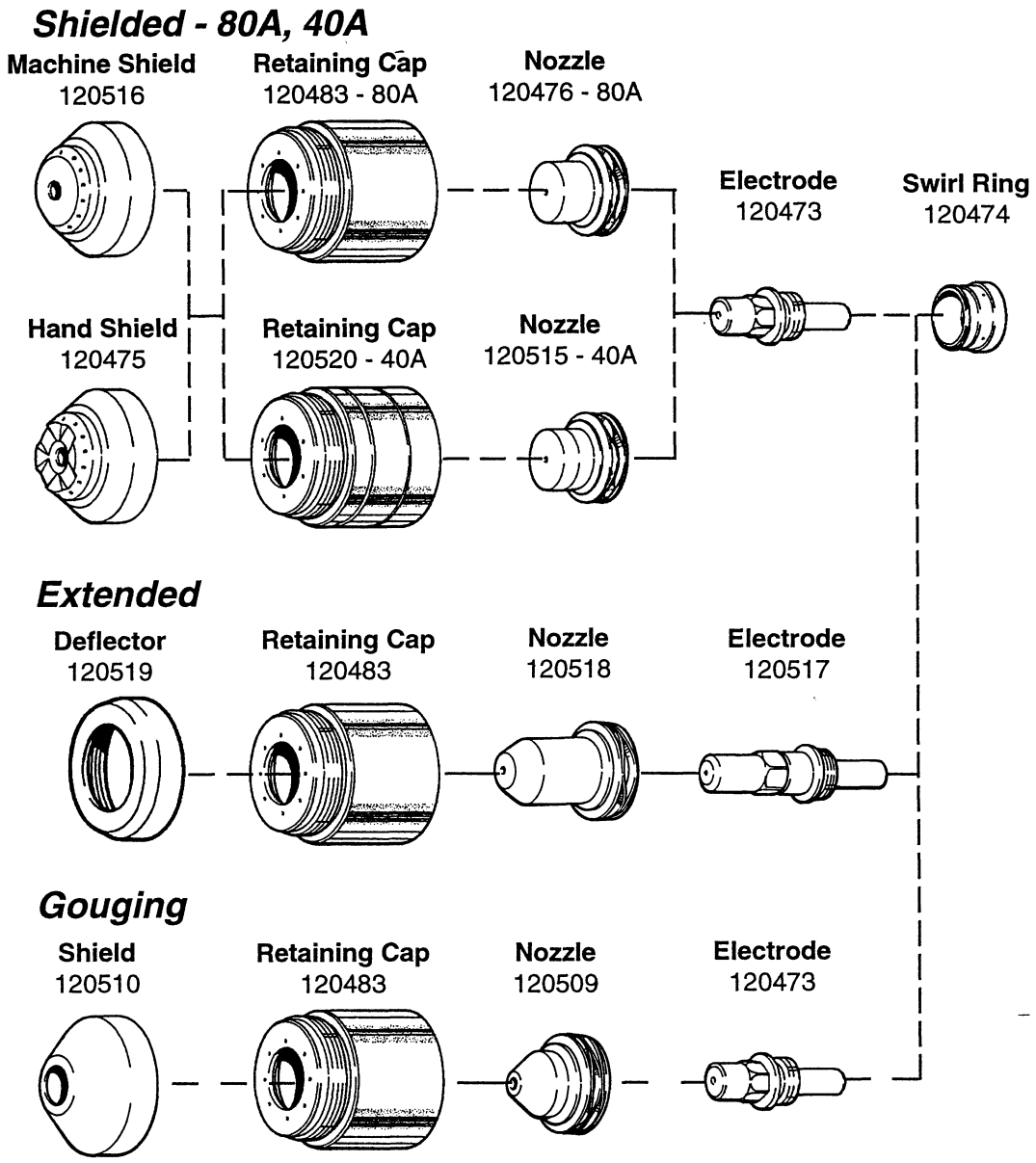



**Figure 4-7 PAC135 Consumable Parts**

## Consumable Parts Kits

### Hand Consumable Parts Kit (128148)

| Part Number | Description |
|---|---|
| 120473 | Electrode, PAC135 |
| 120517 | Electrode, PAC135 Extended |
| 120476 | Nozzle, PAC135, 80A |
| 120509 | Nozzle, PAC135 Gouging |
| 120518 | Nozzle, PAC135 Extended |
| 120475 | Shield, PAC135 Hand |
| 120510 | Shield, PAC135 Gouging |
| 120519 | Deflector, PAC135 |
| 026020 | O-Ring, .864 x .070 |
| 027055 | Lubricant, Silicone 1/4 Oz Tube |
| 027526 | Electrode Wrench, PAC135 |
| 015152 | Nipple, 1/8 NPT,QDisc, Steel |
| 015570 | Bushing, Reducer, 1/4 x 1/8, Brass |
| 001285 | Box, Consumable Parts |

### Machine Consumable Parts Kit (128149)

| Part Number | Description |
|---|---|
| 120473 | Electrode, PAC135 |
| 120516 | Shield, PAC135 Machine |
| 120476 | Nozzle, PAC135, 80A |
| 120515 | Nozzle, PAC135, 40A |
| 120520 | Cap, PAC135, 40A |
| 026020 | O-Ring, .864 x .070 |
| 027055 | Lubricant, Silicone 1/4 Oz Tube |
| 027526 | Electrode Wrench, PAC135 |
| 015152 | Nipple, 1/8 NPT, QDisc, Steel |
| 015570 | Bushing, Reducer, 1/4 x 1/8, Brass |
| 001285 | Box, Consumable Parts |

### Consumable Parts Kit - CE (128170)

| Part Number | Description |
|---|---|
| 120473 | Electrode, PAC135 |
| 120476 | Nozzle, PAC135, 80A |
| 120509 | Nozzle, PAC135 Gouging |
| 120475 | Shield, PAC135 Hand |
| 120510 | Shield, PAC135 Gouging |
| 026020 | O-Ring, .864 x .070 |
| 027055 | Lubricant, Silicone 1/4 Oz Tube |
| 027526 | Electrode Wrench, PAC135 |
| 015145 | Adapter, 1/4NPT x G 1/4 Hose |
| 001285 | Box, Consumable Parts |

## POWERMAX1100 FIELD UPGRADE KITS AND OPTIONAL PARTS

| Part Number | Description |
|---|---|
| 028714 | On/Off Pendant with Lead, 25 ft (7.6 m) (Also comes standard with most machine torch system configurations.) |
| 128061 | On/Off Pendant with Lead, 50 ft (15.2 m) |
| 128062 | On/Off Pendant with Lead, 75 ft (23 m) |
| 128142 | Kit: Wheels, Powermax1100 |
| 128143 | Kit: Pilot Arc Controller, Powermax1100 |
| 128144 | Kit: Machine Interface, Powermax1100, 208/240/480V |
| 128168 | Kit: Machine Interface, Powermax1100, 200/230/400V |
| 128169 | Kit: Machine Interface, Powermax1100, 230/400V CE |
| 128145 | Kit: Work Cable, 50 ft (15.2 m), Powermax1100 |
| 128146 | Kit: Cooling Air Filter, Powermax1100 |
| 128147 | Kit: 600V Conversion, Powermax1100 |
| 011079 | Filter Element: Gas Supply Filter |
| 129146 | Jumper: Powermax1100 Link Box |
| 023206 | Cable: Machine Interface, 25 ft (7.6 m) (Comes standard with machine torch system configurations and with machine interface kits.) |
| 109068 | Toroid for power cord ground, Powermax1100 (CE power supplies only) |
| 002282 | Strain Relief Sleeve: 0.875 |
| 002283 | Strain Relief Sleeve: 0.750 |
| 002286 | Strain Relief Sleeve: 0.625 - Shipped in CE power supply rear panels |

Note: Field upgrade kits must be installed by qualified service personnel.

## POWER SUPPLIES - 208/240/480V, 1ϕ/3ϕ, 50/60 HZ

| Part Number | For Torch Type | With Pilot Arc Control | With Machine Interface |
|---|---|---|---|
| 085000 | Hand | No | No |
| 085012 | Hand | Yes | No |
| 085013 | Machine | No | Yes |
| 085014 | Machine | Yes | Yes |

## POWER SUPPLIES - 200/230/400V, 1ϕ/3ϕ, 50/60 HZ

| Part Number | For Torch Type | With Pilot Arc Control | With Machine Interface |
|---|---|---|---|
| 085002 | Hand | No | No |
| 085034 | Hand | Yes | No |
| 085035 | Machine | No | Yes |
| 085036 | Machine | Yes | Yes |

## POWER SUPPLIES - 230/400V CE, 3ϕ, 50-60 HZ

| Part Number | For Torch Type | With Pilot Arc Control | With Machine Interface |
|---|---|---|---|
| 085003 | Hand | No | No |
| 085023 | Hand | Yes | No |
| 085025 | Machine | No | Yes |
| 085024 | Machine | Yes | Yes |

Note: Contact your distributor or call the nearest Hypertherm office for hand and machine torch system configurations.

## RECOMMENDED SPARE PARTS - POWERMAX1100- 208/240/480V

| Part Number | Description | Page Reference |
|---|---|---|
| 003078 | Relay:30A NO QDisc Terminal | 4-5 |
| 003184 | Circuit Breaker SA:3Pole 1A | 4-9 |
| 129235 | Contactor SA:Pmx1100 | 4-7 |
| 014207 | Xfmr:Pmx1100 208-240-480 Control | 4-7 |
| 014199 | Xfmr:Pmx1100 208-240-480 Power | 4-7 |
| 014216 | Inductor:Pmx1100 0.6MH 80A | 4-7 |
| 123106 | Cable w/Clamp:PMX1100 Work 20' | 4-3 |
| 027443 | Fan:236CFM 120VAC 50-60HZ | 4-7 |
| 005112 | Pressure Switch:39 Psi .013 Orifice | 4-3 |
| 006101 | Solenoid Valve:1/4 Nipple 24VAC | 4-3 |
| 011059 | Filter:5 Micron 1/4FPT | 4-9 |
| 011079 | Filter Element for 011059 Filter | 4-9 |
| 011060 | Regulator:0-125 Psig 1/4FPT | 4-3 |
| 022027 | Pressure Gauge:160# 1.5" 1/8 Panel | 4-3 |
| 129141 | Heatsink SA:Pmx1100 Power Unit | 4-5 |
| 109018 | Diode:600V 100A Ultra Fast Recovery Dual (2) | 4-5 |
| 109060 | Diode:1600V 150A 3PH Module | 4-5 |
| 005178 | Temperature Switch Opens 85°/Closes 75°C | 4-5 |
| 009849/008903 | Resistor:20-Ohm 50W 5% Non-Inductive (4)/Thermal Pad: AL 197-114 (4) | 4-5 |
| 109061 | IGBT 600V 150A Fast (2) | 4-5 |
| 041538 | PCB Assy:Pmx1100 Control | 4-5 |
| 041525 | PCB Assy:Pmx1100 Power (2) | 4-5 |
| 041549 | PCB Assy:Pmx1100 Output Snubber | 4-5 |
| 041527 | PCB Assy:Pmx1100 Filter/Soft Start | 4-5 |
| 128146 | Kit:Pmx1100 Cooling Fan Filter | |

## RECOMMENDED SPARE PARTS - POWERMAX1100- 200/230/400V

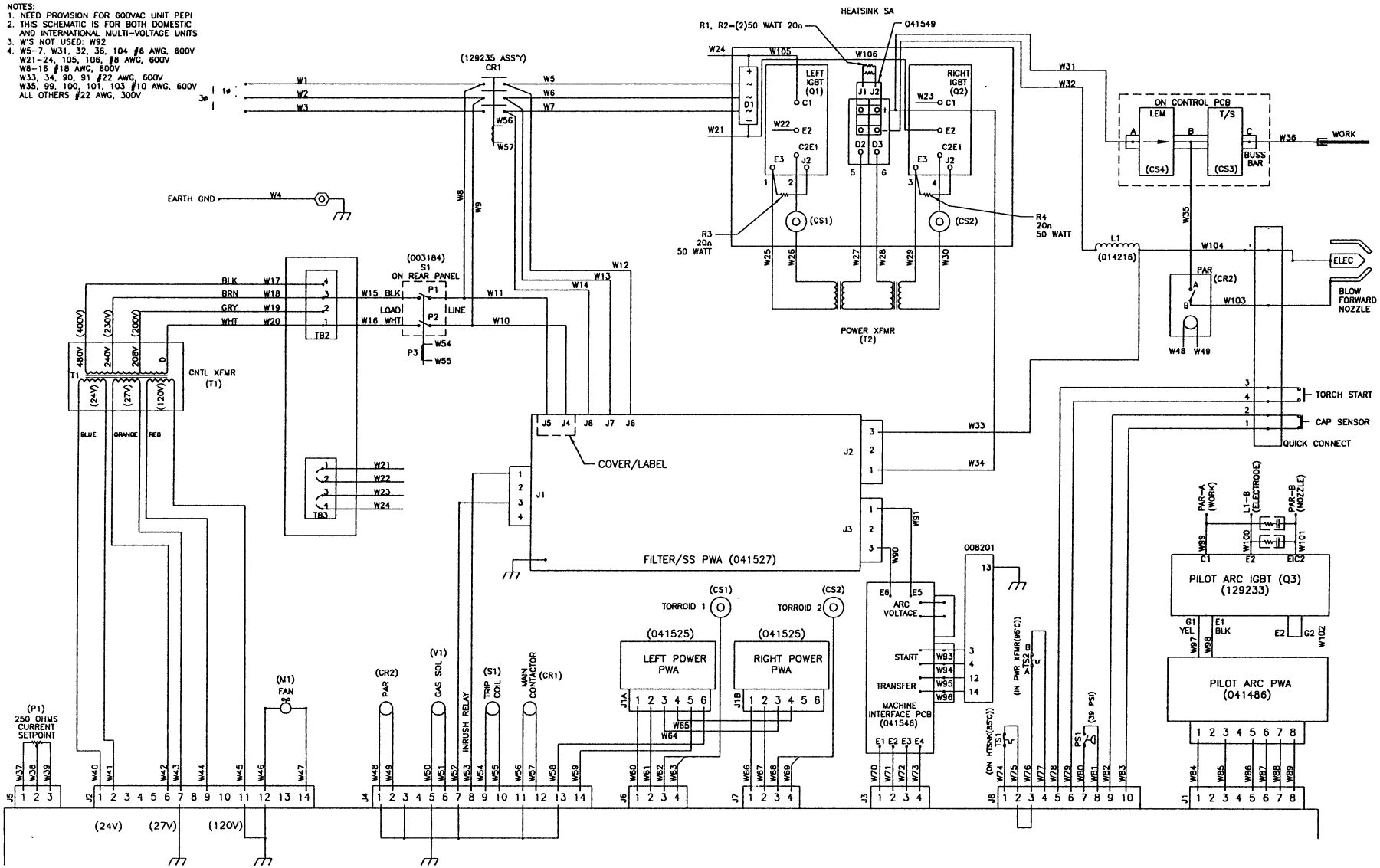
| Part Number | Description | Page Reference |
|---|---|---|
| 003078 | Relay:30A NO QDisc Terminal | 4-5 |
| 003184 | Circuit Breaker SA:3Pole 1A | 4-9 |
| 129235 | Contactor SA:Pmx1100 | 4-7 |
| 014208 | Xfmr:Pmx1100 200-230-400 Control | 4-7 |
| 014214 | Xfmr:Pmx1100 200-230-400 Power | 4-7 |
| 014216 | Inductor:Pmx1100 0.6MH 80A | 4-7 |
| 123106 | Cable w/Clamp:PMX1100 Work 20' | 4-3 |
| 027443 | Fan:236CFM 120VAC 50-60HZ | 4-7 |
| 005112 | Pressure Switch:39 Psi .013 Orifice | 4-3 |
| 006101 | Solenoid Valve:1/4 Nipple 24VAC | 4-3 |
| 011059 | Filter:5 Micron 1/4FPT | 4-9 |
| 011079 | Filter Element for 011059 Filter | 4-9 |
| 011060 | Regulator:0-125 Psig 1/4FPT | 4-3 |
| 022027 | Pressure Gauge:160# 1.5" 1/8 Panel | 4-3 |
| 129141 | Heatsink SA:Pmx1100 Power Unit | 4-5 |
| 109018 | Diode:600V 100A Ultra Fast Recovery Dual (2) | 4-5 |
| 109060 | Diode:1600V 150A 3PH Module | 4-5 |
| 005178 | Temp. Switch Opens 85°/Closes 75°C | 4-5 |
| 009849/008903 | Resistor:20-Ohm 50W 5% Non-Inductive (4)/Thermal Pad: AL 197-114 (4) | 4-5 |
| 109061 | IGBT 600V 150A Fast (2) | 4-5 |
| 041538 | PCB Assy:Pmx1100 Control | 4-5 |
| 041525 | PCB Assy:Pmx1100 Power (2) | 4-5 |
| 041549 | PCB Assy:Pmx1100 Output Snubber | 4-5 |
| 041527 | PCB Assy:Pmx1100 Filter/Soft Start | 4-5 |
| 128146 | Kit:Pmx1100 Cooling Fan Filter | |

## RECOMMENDED SPARE PARTS - POWERMAX1100- 230/400V CE

| Part Number | Description | Page Reference |
|---|---|---|
| 003078 | Relay:30A NO QDisc Terminal | 4-5 |
| 003189 | Circuit Breaker SA:3Pole 1A | 4-9 |
| 129236 | Contactor SA:Pmx1100 CE | 4-7 |
| 014208 | Xfmr:Pmx1100 290-230-400 Control | 4-7 |
| 014214 | Xfmr:Pmx1100 200-230-400 Power | 4-7 |
| 014216 | Inductor:Pmx1100 0.6MH 80A | 4-7 |
| 014220 | Inductor:Pmx1100 CE 1.0 MH 50A | 4-6 |
| 123106 | Cable w/Clamp:PMX1100 Work 20' | 4-3 |
| 027443 | Fan:236CFM 120VAC 50-60HZ | 4-7 |
| 005112 | Pressure Switch:39 Psi .013 Orifice | 4-3 |
| 006101 | Solenoid Valve:1/4 Nipple 24VAC | 4-3 |
| 011059 | Filter:5 Micron 1/4FPT | 4-9 |
| 011079 | Filter Element for 011059 Filter | 4-9 |
| 011060 | Regulator:0-125 Psig 1/4FPT | 4-3 |
| 022027 | Pressure Gauge:160# 1.5" 1/8CBM Panel | 4-3 |
| 129194 | Heatsink SA:Pmx1100 CE Power Unit | 4-5 |
| 109071 | Diode:600V 80A Ultra Fast Recovery Dual (2) | 4-5 |
| 109019 | Diode:1600V 100A 3PH Module | 4-5 |
| 005178 | Temperature Switch Opens 85°/Closes 75°C | 4-5 |
| 009849/008903 | Resistor:20-Ohm 50W 5% Non-Inductive (4)/Thermal Pad: AL 197-114 (4) | 4-5 |
| 109061 | IGBT 600V 150A Fast (2) | 4-5 |
| 041538 | PCB Assy:Pmx1100 Control | 4-5 |
| 041525 | PCB Assy:Pmx1100 Power (2) | 4-5 |
| 041549 | PCB Assy:Pmx1100 Output Snubber | 4-5 |
| 041540 | PCB Assy:Pmx1100 CE Filter/Soft Start | 4-5 |
| 128146 | Kit:Pmx1100 Cooling Fan Filter | |

# Section 5 WIRING DIAGRAMS

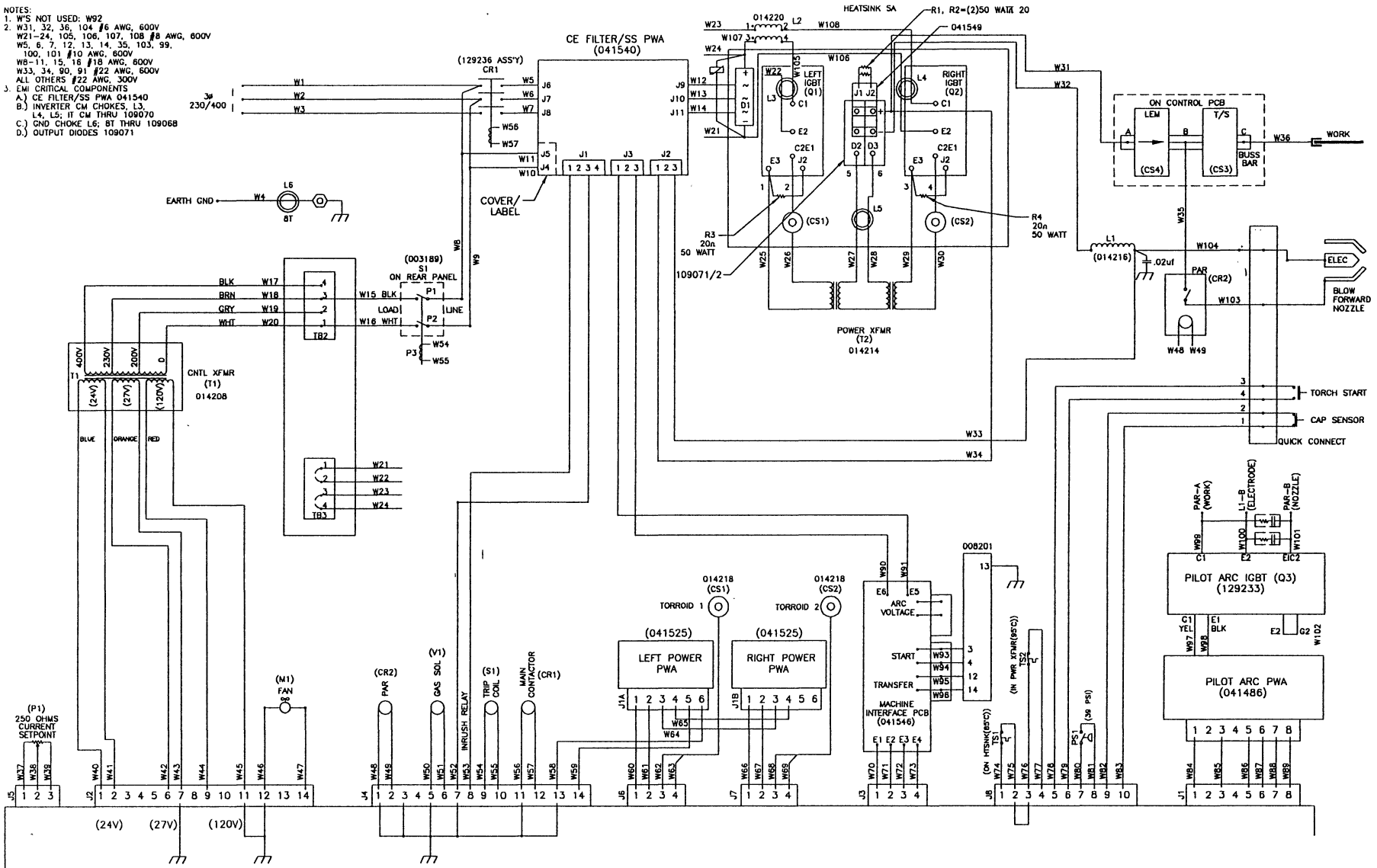
In this section:




| | T1 | T2 | CS1,CS2 |
|---|---|---|---|
| DOMESTIC | 014207 | 014199 | 014137 |
| INTERNATIONAL MULTI-VOLTAGE | 014208 | 014214 | 014218 |

CONTROL PWA (041538)

ELEC SCH: PMX1100 208-240-480
013-3-297
1 OF 1




5-3

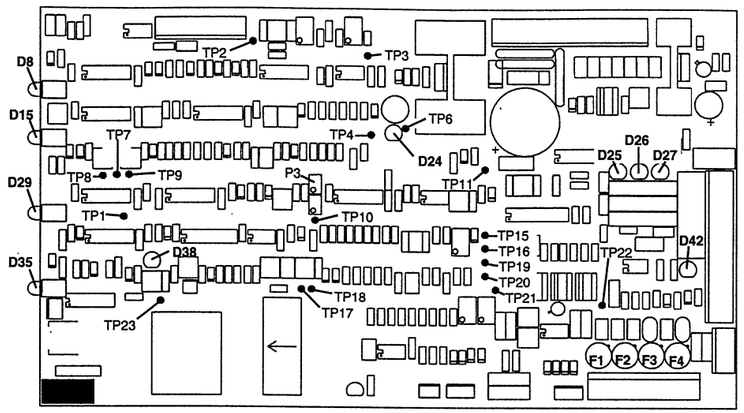
CONTROL PWA (041538)

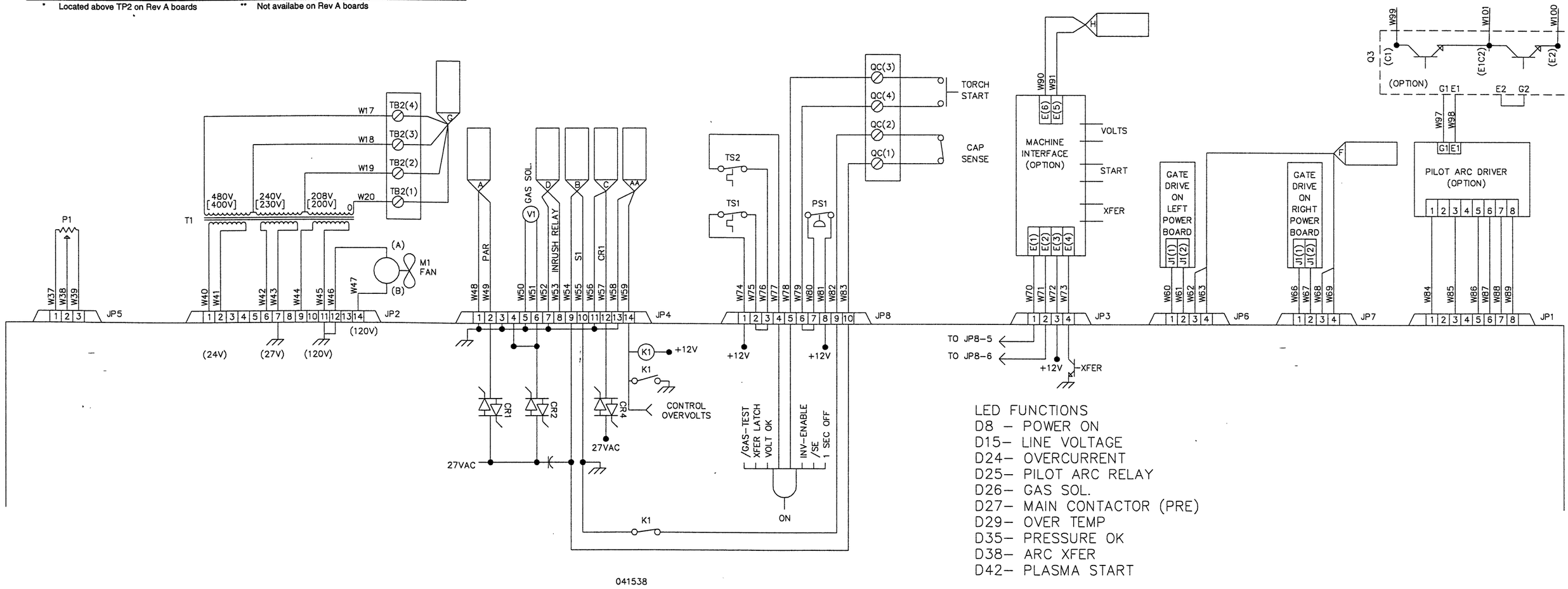
ELEC SCH: PMX1100-CE
013-3-303
1 OF 1

## Control Board Test Points

| Test Point | Description | Value |
|---|---|---|
| TP1* | Transfer signal. | A logic high (12V) indicates that the arc is transferred. |
| TP2 | Start signal. | A logic high (12V) indicates that the torch start switch is on. |
| TP3 | GND | |
| TP4 | | +12V |
| TP6 | | +18V |
| TP7 | INV-ON signal. | A logic high (12V) indicates that the inverter is on. |
| TP8 | Transfer latch signal. | A logic high (12V) indicates that unit is in transferred mode. |
| TP9 | Temp OK signal. | A logic high (12V) indicates that all temperatures are OK. |
| TP10 | Continuous PA threshold voltage. | Set to 3.55V by P3. |
| TP11 | | 7.0V |
| TP15 | Error amplifier reference voltage. | During inverter operation this signal is 1.915V at 80A current setting and .75V at 30A current setting. |
| TP16 | Error amplifier output voltage | |
| TP17 | Reference voltage | 2.50V |
| TP18 | Output current value signal | 38.3mv/amp |
| TP19 | Wiper voltage. | 2.5V at 80A current setting and 1.00V at 30A current setting. |
| TP20 | GND | |
| TP21 | Buffered, inverted, capacitor feed version of pulse width modulator B signal. | |
| TP22 | Buffered, inverted version of pulse width modulator A signal. | |
| TP23** | Special test point. Jumper to TP4 when testing power supply using a resistive load instead of a torch. | |
| **Fuses** | | |
| F1,F2 | Cap sensor circuit protection | .5A (see **Parts List** for part number and specifications) |
| F3,F4 | Start circuit protection | .5A (see **Parts List** for part number and specifications) |

* Located above TP2 on Rev A boards ** Not availabe on Rev A boards



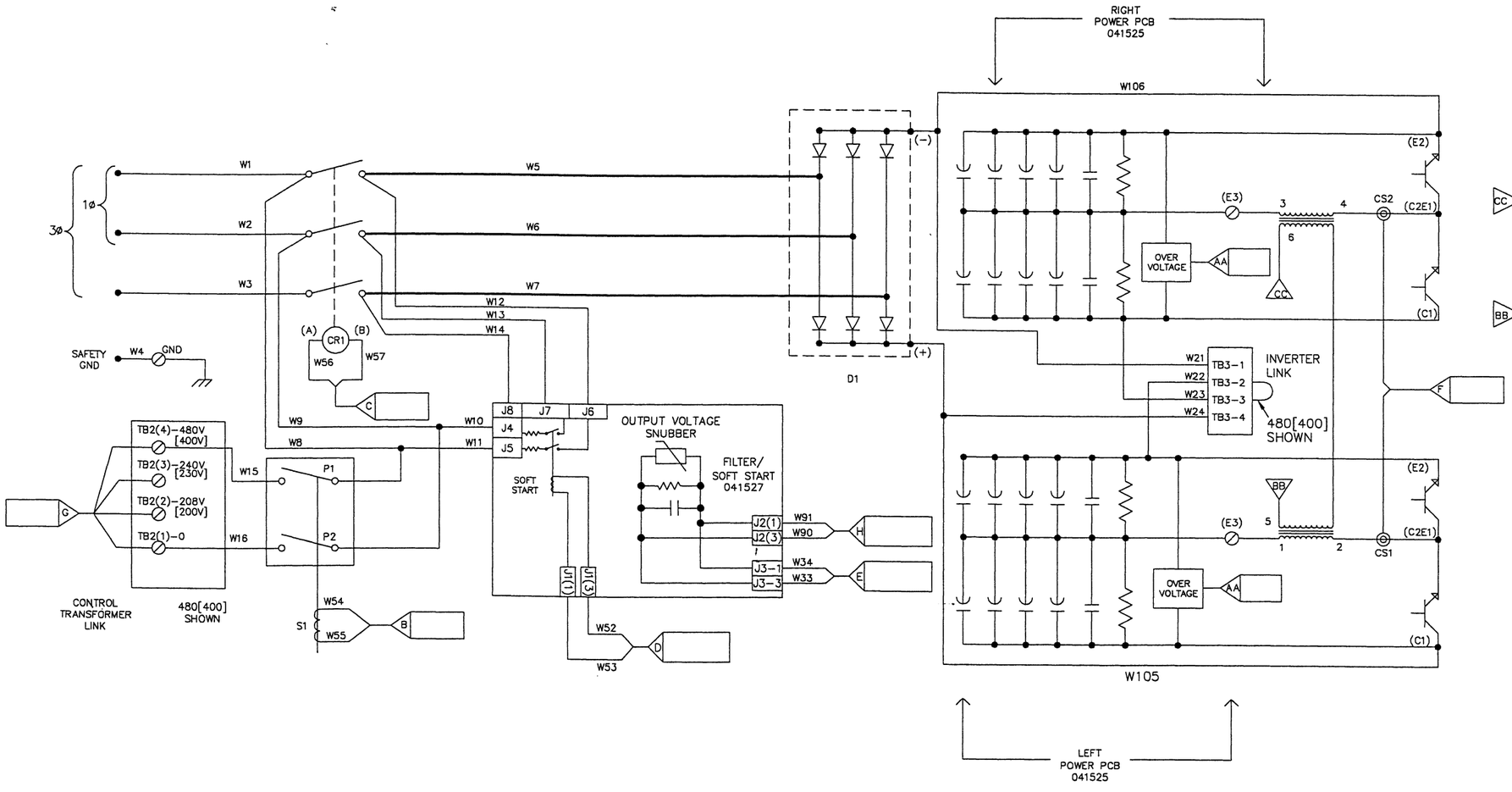

041538

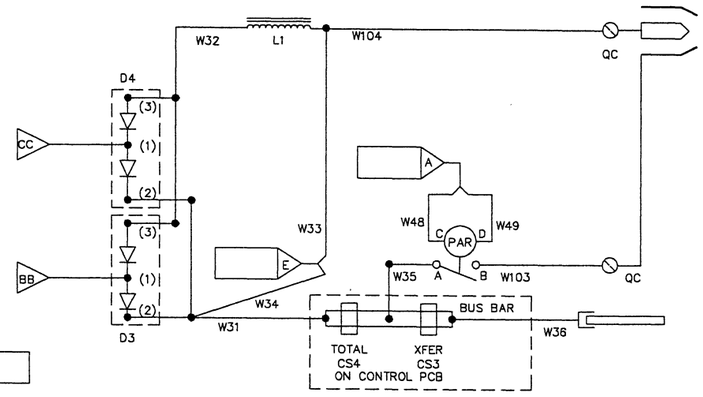
LED FUNCTIONS
D8 – POWER ON
D15– LINE VOLTAGE
D24– OVERCURRENT
D25– PILOT ARC RELAY
D26– GAS SOL.
D27– MAIN CONTACTOR (PRE)
D29– OVER TEMP
D35– PRESSURE OK
D38– ARC XFER
D42– PLASMA START

PMX1100 TROUBLE SHOOTING SCH
013-2-320
1 OF 2



A




NOTES:

1. THIS IS A TROUBLE SHOOTING REFERENCE SCHEMATIC, WHICH PERTAINS TO BOTH DOMESTIC AND MULTI–VOLT INT'L UNITS. DIFFERENCES IN MULTI–VOLT INT'L UNITS VOLTAGES ARE IN [SQUARE BRACKETS].

2. VOLTAGE LINKING

| LINE VOLTAGE | CONTROL VOLTAGE CONNECTION | JUMPER LINKS |
|---|---|---|
| 208[200] | 208[200] | TB3(1) TO TB3(2) AND TB3(3) TO TB3(4) |
| 240[230] | 240[230] | TB3(1) TO TB3(2) AND TB3(3) TO TB3(4) |
| 480[400] | 480[400] | TB3(2) TO TB3(3) |

3) TRANSFORMER T2 IS SINGLE CORE DUAL SECTION SHOWN SEPERATED FOR CLARITY

4) ALL TERMINALS PREFIXED WITH (E) ARE LOCATED ON POWER PCB'S

# PMX1100 TROUBLE SHOOTING SCH
# 013–2–320
# 2 OF 2

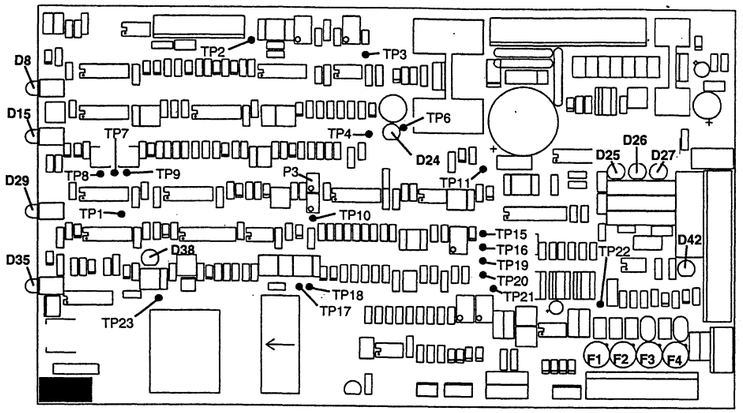


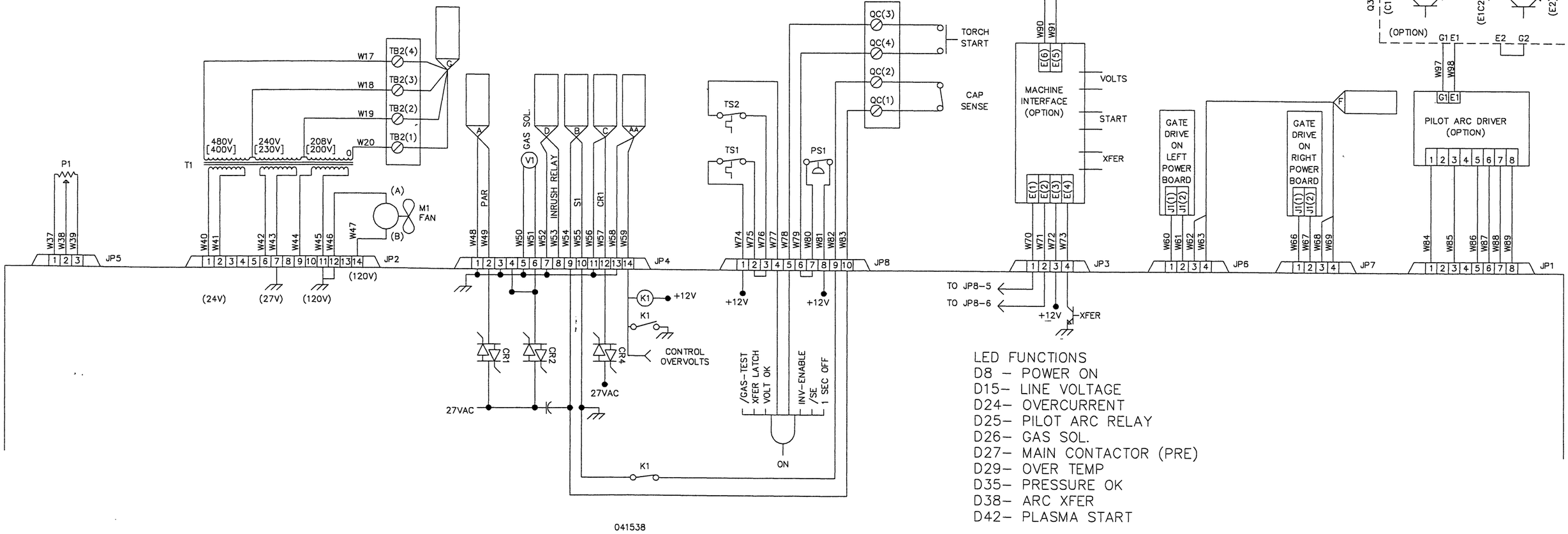
A

## Control Board Test Points

| Test Point | Description | Value |
|---|---|---|
| TP1* | Transfer signal. | A logic high (12V) indicates that the arc is transferred. |
| TP2 | Start signal. | A logic high (12V) indicates that the torch start switch is on. |
| TP3 | GND | |
| TP4 | | +12V |
| TP6 | | +18V |
| TP7 | INV-ON signal. | A logic high (12V) indicates that the inverter is on. |
| TP8 | Transfer latch signal. | A logic high (12V) indicates that unit is in transferred mode. |
| TP9 | Temp OK signal. | A logic high (12V) indicates that all temperatures are OK. |
| TP10 | Continuous PA threshold voltage. | Set to 3.55V by P3. |
| TP11 | | 7.0V |
| TP15 | Error amplifier reference voltage. | During inverter operation this signal is 1.915V at 80A current setting and .75V at 30A current setting. |
| TP16 | Error amplifier output voltage | |
| TP17 | Reference voltage | 2.50V |
| TP18 | Output current value signal | 38.3mv/amp |
| TP19 | Wiper voltage. | 2.5V at 80A current setting and 1.00V at 30A current setting. |
| TP20 | GND | |
| TP21 | Buffered, inverted, capacitor feed version of pulse width modulator B signal. | |
| TP22 | Buffered, inverted version of pulse width modulator A signal. | |
| TP23** | Special test point. Jumper to TP4 when testing power supply using a resistive load instead of a torch. | |
| **Fuses** | | |
| F1,F2 | Cap sensor circuit protection | .5A (see **Parts List** for part number and specifications) |
| F3,F4 | Start circuit protection | .5A (see **Parts List** for part number and specifications) |

* Located above TP2 on Rev A boards ** Not availabe on Rev A boards



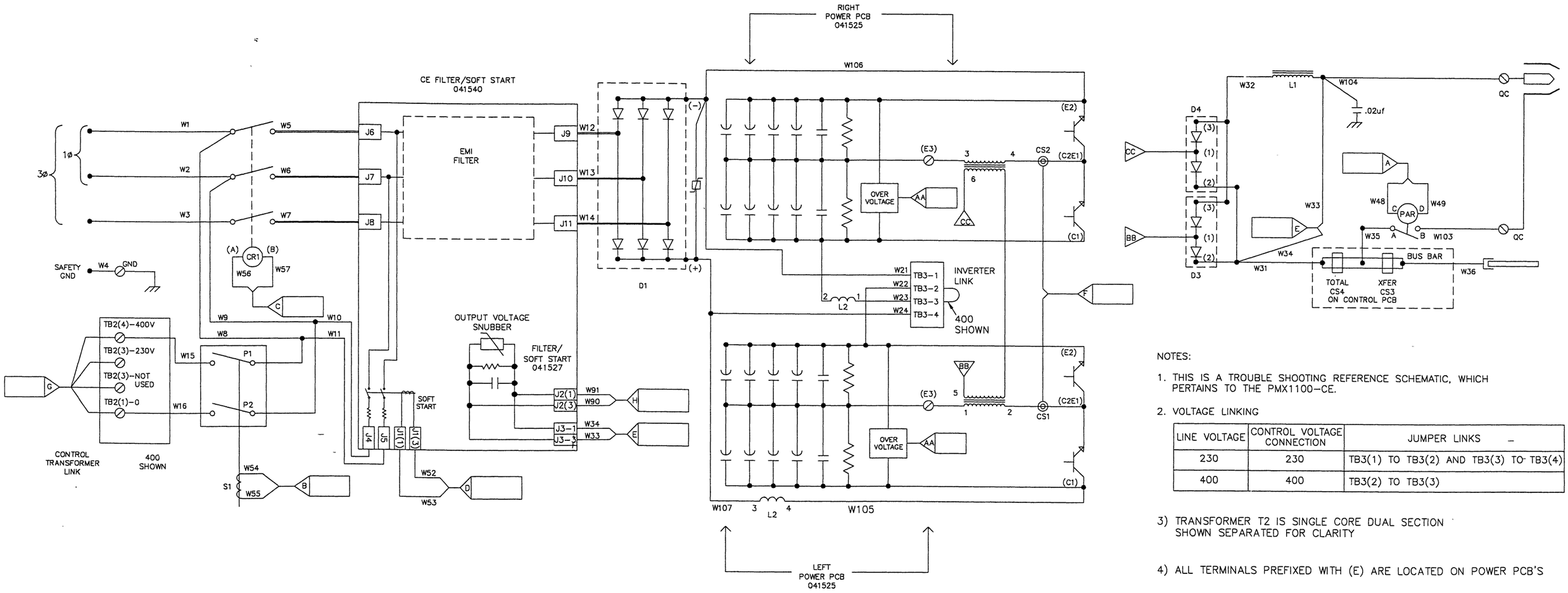

041538

LED FUNCTIONS
D8 – POWER ON
D15– LINE VOLTAGE
D24– OVERCURRENT
D25– PILOT ARC RELAY
D26– GAS SOL.
D27– MAIN CONTACTOR (PRE)
D29– OVER TEMP
D35– PRESSURE OK
D38– ARC XFER
D42– PLASMA START

PMX1100–CE TROUBLE SHOOTING SCH
013–2–321
1 OF 2



A




NOTES:

1. THIS IS A TROUBLE SHOOTING REFERENCE SCHEMATIC, WHICH PERTAINS TO THE PMX1100-CE.

2. VOLTAGE LINKING

| LINE VOLTAGE | CONTROL VOLTAGE CONNECTION | JUMPER LINKS |
|---|---|---|
| 230 | 230 | TB3(1) TO TB3(2) AND TB3(3) TO TB3(4) |
| 400 | 400 | TB3(2) TO TB3(3) |

3) TRANSFORMER T2 IS SINGLE CORE DUAL SECTION SHOWN SEPARATED FOR CLARITY

4) ALL TERMINALS PREFIXED WITH (E) ARE LOCATED ON POWER PCB'S

3) INDUCTOR L2 IS A SINGLE CORE DUAL SECTION SHOWN SEPARATED FOR CLARITY

# PMX1100-CE TROUBLE SHOOTING SCH
# 013-2-321
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# AERATION MANIFOLD FOR PLASMA CUTTING ALUMINUM

## Introduction

When plasma arc cutting aluminum at the water table surface or below water, free hydrogen gas may be generated by the cutting process. The high temperature of the plasma process causes disassociation of oxygen and hydrogen from the water in the water table. The hot aluminum, which has a high affinity for oxygen, then combines with the oxygen leaving free hydrogen.

An effective means of avoiding free hydrogen buildup is to install an aeration manifold on the floor of the water table to replenish the oxygen content of the water.

## Making an Aeration Manifold - Figure c-1

Make an aeration manifold with two-inch (50 mm) PVC tubing with one-inch (25 mm) distribution lines connected to it. Drill 1/8 inch (3 mm) holes every six inches (150 mm) in the distribution lines. Cap the ends of the distribution lines and install the lines so that air is delivered to all parts of the cutting area.

Connect the manifold to a shop air line. Set a pressure regulator to obtain a steady stream of bubbles.

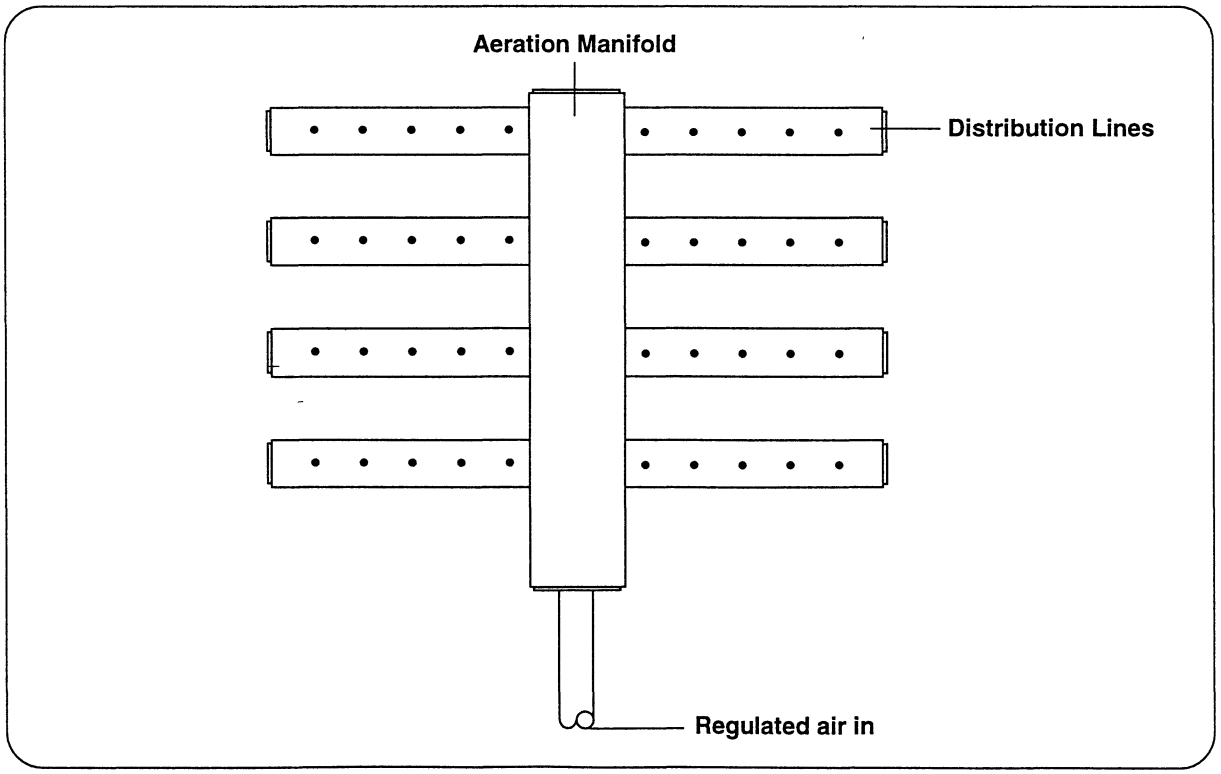


**Figure a-1 Aeration Manifold**

# APPENDIX B

## 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, *Standard 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.