MEDRAD®
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Mark V ProVis®

Service Manual

KMP 870

CE 0086

98411-T-205 Rev. D

MEDRAD Interventional™

MEDRAD Interventional™

Mark v ProVis®

Injection System Service Manual

KMP 870

98411-T-205 Rev.D

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Copyright Notice

Trademarks

FluiDot, MEDRAD, and Quality for Life, are registered trademarks of MEDRAD Incorporated.

Patents

The *Mark V ProVis* Injection System is the subject of the following U.S. patent numbers: 4,677,980; 4,854,324; 5,383,858.

Restricted Sale

Federal (U.S.A.) law restricts the sale of this device to, or by the order of a physician.

Applicability

This manual applies to *Mark V ProVis* Injection Systems in the following configurations:

PPD 100 60 XXX	PRM 100 60 XXX
PPD 110 60 XXX	PRM 110 60 XXX
PPD 200 50 XXX	PRM 200 50 XXX
PPD 220 50/60 XXX	PRM 220 50/60 XXX
PPD 240 50 XXX	PRM 240 50 XXX

CE 0086

All *Mark V ProVis* models are designed to be in compliance with EN 60601-1 (Safety) and EN 60601-1-2 (EMC/Emissions).

CE 0086 Represents compliance to the European Council Directive concerning medical devices - 94/42/EEC.

Purpose

This manual is intended to provide instructions for servicing the *Mark V ProVis* Injection System (herein referred to as “the injection system” safely and accurately. It is intended for those qualified to service the injection system, whether they be MEDRAD Service Personnel, Laboratory Service Technicians, or MEDRAD Authorized Dealers.

Important Safety Notice

The information in this manual is intended for people with adequate backgrounds and experience in electronics and electromechanical devices. Any attempt to repair a sophisticated medical device such as the injector may result in personal injury, property damage, or patient injury.

Disclaimers

MEDRAD makes no warranties on the contents of this manual, and specifically disclaims any implied warranties of merchantability or fitness for any purpose.

MEDRAD reserves the right to change specifications and the contents of this manual without obligation.

MEDRAD reserves the right to modify the specifications and features described herein, or discontinue manufacture of the product described at any time, without prior notice or obligation. Please contact your authorized MEDRAD representative for the most current information.

External Wiring and Modification: MEDRAD disclaims liability for any modifications or interfaces with other equipment which are not in conformity with the specifications and information contained within this manual. Such unauthorized action could jeopardize injector operation, safety, or reliability.

Accessory equipment connected to the system interfaces must be certified according the IEC 601-1 standards. Furthermore, all configurations with attached accessory equipment shall comply with the system standard IEC 601-1-1. Anyone who connects additional equipment to the signal input or output configures a medical system, and is therefore responsible that the system complies with the requirements of the system standard IEC 601-1-1. To obtain on-site consulting or consulting references, contact MEDRAD Factory Service.

All drawings in this manual are for reference purposes only, and may not reflect the construction of units produced prior to the publication of this manual. Reproduction quality of these drawings may have been affected by the level of reduction required. Call MEDRAD Factory Service if assistance in drawing interpretation is required.

The injection system is not intended for portable use.

Problems or Questions

If you experience problems with any MEDRAD Injection System, contact:

MEDRAD Factory Service
MEDRAD, INC.
One MEDRAD Drive
Indianola, PA 15051-0780
Phone: (412) 767-2400
1-800-MEDRAD-S
1-800-633-7237
FAX: (412) 767-4126

MEDRAD EUROPE, B.V.
Postbus 205
6190 AE Beek
The Netherlands
Phone: (31) (0) 43 3585601
FAX: (31) (0) 43 3656598

Nihon MEDRAD K.K.
2-4-9, Umeda, Kita-ku,
Osaka, 530-0001
Japan
Phone: +81(0)66-133-6250
FAX: +81(0)66-344-2395

INTRODUCTION TO
WARNINGS / CAUTIONS

This manual contains important information about safe servicing of the injection system.

MEDRAD urges the service technician to read this manual carefully, become familiar with the procedures and system functions that it describes, and follow its recommendations to assure proper servicing of the system.

Warning labels on the injection system or Warning statements in this manual preceeded by any of the following words and/or symbols are of special significance:

WARNING: Indicates a potentially hazardous situation. If not avoided, this could result in death or serious injury.

CAUTION: Indicates potential hazards or unsafe practices which could cause product, system, or property damage.

NOTE: Indicates helpful information is being offered.

Intended Use

This device is intended to be used specifically for the purpose of injecting intravenous contrast medium into humans, for the purpose of diagnostic studies. DO NOT attempt to use the injector for any other purpose.

Contraindications

This device is not to be used for drug infusion, chemotherapy, or any other use for which the device is not indicated.

⚠ WARNINGS ⚠

Dangerous voltages exist within the injection system that can shock, burn, or cause death. To avoid injury, the system should be opened and serviced by qualified service personnel only. Disconnect the system from line power before cleaning or attempting to perform any maintenance or repairs.

Mains Voltage Hazard. To avoid dangerous voltages, do not remove connector J130 while power is applied to the system. Always disconnect the system from line power before removing connector J130

Live Voltage Hazard. Avoid contact with J40 pins. Ensure that the connector cover is in place or cable is connected.

Possible explosion hazard in the presence of flammable anesthetic gases. The injection system is not designed for use in association with anesthetic gases and equipment.

Electronic assemblies contain potentially hazardous materials. Dispose of system components or accessories properly. Follow all local regulations for the recycling or disposal of electronic assemblies, or contact MEDRAD Service for assistance.

Worn power cords or control cables may shock, injure, or cause death. Examine power cords and cables for cuts, frays, or any other visible damage. Do not use the system if any of the cords or cables show signs of damage. Any damaged or worn connection cables or power cords should be replaced.

Check for proper voltage and frequency before connecting the injector to an electrical outlet. Failure to do so may result in personal injury or equipment damage/malfunction. Check the voltage and frequency marked on the back of the unit. Ensure that the outlet providing power to the injector supplies a voltage, frequency, and volt-ampere rating within the range specified.

Do not use an extension cord or power cord adaptor. Connect the injector directly into a properly grounded AC outlet. Since the power cord supplies a safety ground to the unit, using an extension cord will compromise ground quality and the injector could become unsafe.

Do not immerse any injector components in water or any type of cleaning solution. Fluid entry may result in a shock hazard.

Ensure that FluiDot labels are clearly visible on all pressure jackets. FluiDot labels are intended to help in the avoidance of air embolization, which could result in patient injury or death.

Injury may result from springing action when injector head is removed from the arm. Move the arm to the maximum upright position before removing the injector head. When re-mounting the injector head, ensure that the retention knob is secured to prevent the injector head from falling from the arm.

Injury may result if excessive weight is applied to the device. Do not place heavy objects or lean on the arm, injector head, or handles.

Injury may result during the transport of the injection system. Care should be taken when transporting the injector. Ensure that the articulating arm is secured by inserting the locking pin.

Pinch Hazard. Do not grasp any pivot points. Position the injector head by grasping the arm or extension.

⚠ CAUTIONS ⚠

Electrostatic Discharge (ESD). Failure to follow ESD protection practices may result in equipment damage. To avoid damage, ESD protection practices must be followed when servicing any component of this system. If electronic components are to be shipped, place the components in conductive carriers (as supplied at MEDRAD).

Disconnect the power cord before removing or replacing PC boards. Sensitive circuits on the boards can be damaged by abrupt interruption or application of supplies.

Remove power when disconnecting or reconnecting head cables. Disconnecting the head cable from the injector pedestal, or head extension cable from the rack or table mounts, when power is applied, may result in equipment damage.

Allow system temperature to stabilize before use. When the system is exposed to an extreme temperature change (heat or cold), allow it to stabilize to room temperature before servicing.

Use only accessories and options designed specifically for the *Mark V ProVis* injection system. To ensure compatibility and proper operation, do not use an accessory or option designed for another system.

Perform regular preventive maintenance. To ensure that your injection system remains properly calibrated, and that all primary and backup circuits are functioning properly, regular preventive maintenance is recommended. An annual preventive maintenance package (offered in the U.S.A., Canada, and Europe) is available at an additional cost. Contact your local MEDRAD Factory Service Representative for details.

Do not soak or immerse any part of the injection system in water. Improper or careless cleaning methods may result in equipment damage. While cleaning any outside portion of the system, avoid allowing any water to seep inside system components.

Do not short the PPI Card Batteries. Do not place the card or the batteries on any conductive surface. When checking or replacing the PPI card batteries, discharge can occur with even a momentary short.

Do not apply voltage to ISI connector J40 pins 5,6,7,8 or 9. Equipment damage or malfunction may result.

Do not move the injector or pedestal by pulling on the syringe heater cable. Equipment damage or malfunction may result.**Do not connect injector head extension cables in parallel.** Connecting the extension cables in parallel, or extending the total extension length beyond 100 feet (30.5 m), can adversely effect injector performance and specifications.

NOTE: All relevant institutional, local, or national safety regulations related to cable routing and installation should be followed.

Do not apply voltage to external start lines if the injector is being started by an external start connection. Provide only a switch closure. If the external circuit contains excessive line frequency noise or voltage transients, injector damage or malfunction may result.

The Remote Start Signal from the film changer programmer (at pins 7 and 9 of J40), must never contain voltage or AC noise. Any voltage applied to these pins can damage the injector and void the warranty. Excess noise on these lines may cause intermittent problems of premature, or no injections.

The Remote Start Signal from the film changer programmer must remain closed throughout the duration of the injection. If the start signal is removed before the injection volume limits when armed in the SINGLE mode, the injection will stop, the unit will disarm, and display “PREMATURE TERMINATION” on the Control Panel. If the start signal is removed before the injection volume limits when armed in the MULTIple mode, the injection will stop, the Mechanical Stop will reposition at the selected volume, and the unit will remain armed. If a start signal is received at this time, an additional injection will result at the selected Flow Rate and Volume.

When starting the injection process from a remote location by the use of a relay closure in the film changer programmer, always install a “panic button” in series with the start signal. This function must be provided in the event that the operator must immediately terminate the injection. This button should be installed in a convenient location, properly labeled, and instructions for use provided to all users of the injection system.

3 Operating Guide

FLOW RATE

Press **Delta 2** to initiate change of Flow Rate for the injection or the indicated level of a Multi-Level injection currently displayed on the Control Panel. The *Set* indicate will flash. Use the keypad to select a new value. Minimum and maximum Flow Rate values depend on syringe size. Press **Delta 2** again to lock the value in. The *Set* indicator will stop flashing and remain lit when the ML value displayed in the *Flow Rate w*indow is locked in. The Flow Scale indicators to the right of the *Flow Rate w*indow show the current selected Flow Scale.

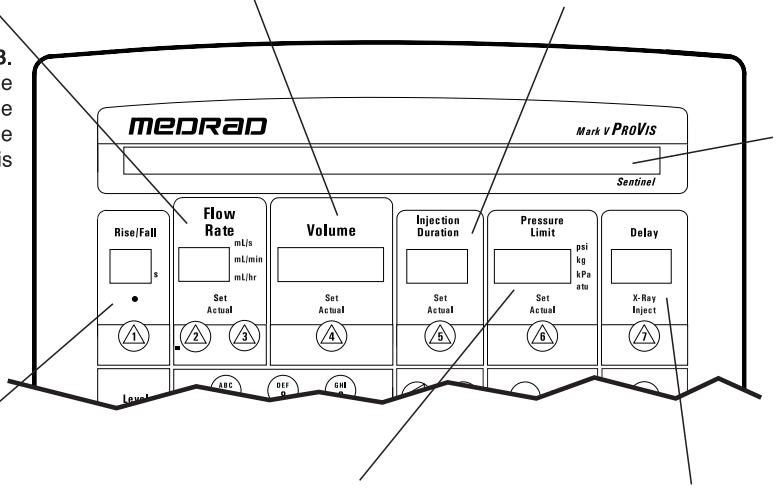
To select a new Flow Scale, press **Delta 3**. Press the **Yes** button in response to the Sentinel prompt. A new Flow Scale indicator will light. If necessary, repeat the process until the desired Flow Scale is illuminated.

VOLUME

Press **Delta 4** to initiate a program change for the Volume parameter. The *Set* indicator will begin to flash. Use the keypad to select a new value. Press **Delta 4** a second time to lock in the new parameter. The *Set* indicator will stop flashing and remain lit when the value displayed in the *Volume* window is locked in. The range of acceptable values is limited by syringe size. Volume can be entered in tenths of a ml (one decimal place).

INJECTION DURATION

Press **Delta 5** to change the Injection Duration. The *Set* indicator will flash. Use the keypad to select a new value. Injection Duration time values can be set in tenth of a second increments (one decimal digit). The new value will be displayed in the *Injection Duration* window. Press **Delta 5** again to lock in the new value. The *Set* indicator will remain lit when the value displayed is locked in. Changing Injection Duration automatically changes the volume to be delivered for the injection or level. Normally, Injection Duration is automatically calculated when other dependent injection parameters are programmed.



SENTINEL
Displays system messages.

RISE / FALL

Press **Delta 1** to change Rise/Fall time. The indicator light above **Delta 1** button will flash to indicate a change to the Rise/Fall time value. Use the keypad to select a new value from 0 to 9.9 seconds in tenth of a second increments (one decimal digit only). Press **Delta 1** again to lock in the new value. The indicator light stops flashing and remains lit when the value displayed in the *Rise/Fall* window is locked in.

PRESSURE LIMIT

Press **Delta 6** to change the pressure value displayed in the *Pressure w*indow. The *Set* indicator will begin to flash. Use the keypad to enter a new pressure value. Press **Delta 6** a second time to lock in the change. The *Set* indicator will stop flashing and remain lit when the value displayed in the *Pressure w*indow is locked in. Minimum and maximum pressure values depend on syringe size and selected Flow Scale.

X-RAY or INJECT DELAY TIME

Press **Delta 7** to change the delay time and/or type of delay being set. The delay value, displayed in the *Delay w*indow, will reset to 0. Whichever indicator light is flashing, *X-Ray* or *Inject*, is the type of delay being programmed. To change the type of delay, press **Delta 7** again before entering any delay value. Use the keypad to select a new delay value. Press **Delta 7** to lock in the delay time. The Indicator will stop flashing and remain lit when the value displayed in the *Delay w*indow is locked in. Minimum and maximum delay values are from 0 - 99.9 seconds in tenth of second increments (one decimal digit only).

LEVEL

Level Windows - Displays the currently displayed level number, and total number of levels programmed.

Level UP and DOWN Arrows - Use these keys to advance up or down one level of a multiple-level injection.

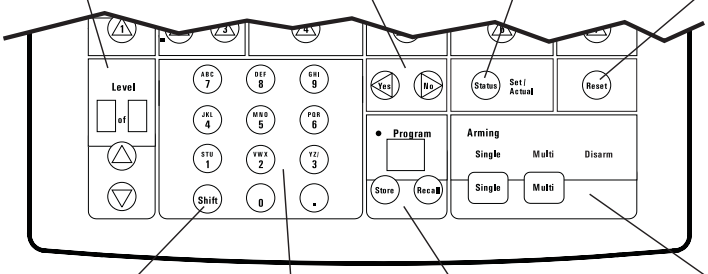
STATUS

The **Status** button is a "toggle" that allows a user to compare actual values to programmed values. Press after an injection to have actual injection parameters displayed. The *Actual* indicators will illuminate (the *Set* indicators will extinguish). Values displayed in the various windows are actual values. Press **Status** again. The *Set* indicators will light and the values displayed in the various windows are programmed values. The Sentinel will display CUMULATIVE PATIENT VOL XX.X ML. This number represents the total volume delivered since the control panel was last reset with the **Reset** button.

RESET

Press **Reset** to clear Cumulative Patient Volume, set the Control Panel display values to zero, or recover from a fault condition. Sentinel will prompt to confirm resetting of Cumulative Patient Volume and Control Panel values. Press **Reset** immediately after power up to display software version number of currently installed system software.

Yes/**No Arrows** - These buttons serve a dual purpose. Their primary purpose is to serve as a means to respond to Sentinel prompts. These keys are also used when entering the title of a stored program. Use the **No**/**Arrow** key after entering each character or space in the title. Use the **Yes**/**Arrow** key to delete characters and spaces.



ARMING MODE SELECTION

Single Arm - After entering all injection parameters, press **Single** to begin the arming sequence for a Single Injection. The *Disarm* indicator will remain lit until the Sentinel prompts are confirmed. After proper responses to Sentinel, the unit will be armed. The *Disarm* indicator will extinguish and the *Single* indicator flashes. The injector is now armed and ready to inject.

Multi Arm - After entering all injection parameters, press **Multi** to begin the arming sequence for Multiple injections. The *Disarm* indicator will remain lit until the Sentinel prompts are confirmed. When *Multi* indicator on panel begins to flash, the injector is armed for Multiple Injections. During a Multiple Injection the unit does not disarm after the injection. Instead, the injector automatically re-arms after each injection as long as a sufficient volume remains in the syringe.

SHIFT- The Shift button is used to select between letters or numbers on the alpha-numeric keypad during the program storage procedure. Press this key if the title is to contain letters.

Alpha-Numeric Keypad - This keypad is the operator input device. It is used to select new values for injection parameters, select a program number to be stored or recalled, enter a title for a stored injection, or respond to Sentinel prompts.

PROGRAMMED INJECTION STORE / RECALL

Program Window - Displays the program number of a recalled injection program. The number will be displayed as long as no modifications to the program recalled from memory are made.

Press **Recall** to recall a previously stored injection program or a system utility program. Injection programs are stored in locations 1 through 49. Storage location numbers 50 - 65 are reserved for system utility programs. The procedure for recalling any stored program is to first press **Recall**, then enter the number of the program to be recalled. Press **Recall** a second time to bring the program into active memory. The number of the program is displayed in the Program window. If any modifications are made to the recalled program, the program number will extinguish to show that the program displayed on the Control Panel is not the same as the one stored in memory.

Press **Store** to store injection parameters in permanent memory. The Sentinel will prompt with next available storage location number. Use the keypad to enter the number, then press the **Store** button a second time. The Sentinel will prompt for a title. Use the keypad to enter a title if desired. Press the **Store** button after entering the title. All currently displayed injection parameters are stored in permanent memory.

4 Preventive Maintenance

This section contains recommended procedures for preventive maintenance of injection systems. Routine maintenance and inspection will:

- Ensure the continued performance of your injector.
- Reduce the possibility of equipment malfunction.

Recommended Procedures

Preventive maintenance of the injection system should consist of four procedures: Inspection, cleaning, leakage, and performance checks. This section contains guidelines, recommended methods, and expected results for each of these procedures:

1. *Inspection:* This first step should encompass inspection of the entire system, looking for obvious signs of damage, such as; cracks in the housing, frayed or worn cables, missing or damaged labels, and contrast spills that may have leaked into the injector.

2. *Cleaning:* This cleaning procedure involves thorough cleaning of the console and head to remove any deposits of contrast medium. If any substances have leaked into any part of the unit, the subassembly should be disassembled and thoroughly cleaned.

3. *Electrical Leakage / Ground Continuity Checks:* To ensure the safety of the patient and hospital personnel in injector operations.

4. *Operational Checkout:* A complete functional performance checkout of the injection system.

Recommended Schedule

The injection system must be properly maintained to ensure that it is in peak operating condition. Your individual maintenance schedule depends upon how your injector is used; the type of procedures performed, and frequency of use. The following guidelines represent a suggested maintenance schedule:

Daily:
Before use each day, the system should be inspected, and the injector head piston rod thoroughly cleaned.

Monthly:
Once a month, the entire system should be thoroughly inspected and cleaned, and an operational checkout should be performed.

Annually:
Once per year, Electrical Leakage and Ground Continuity checks should be performed.

NOTE: Local regulations or hospital protocol may require electrical leakage checks at more frequent intervals. If this applies, local regulations for leakage must be followed.

MEDRAD also recommends that a complete system calibration and performance checkout, by a qualified MEDRAD Service Representative, be performed once a year. Contact MEDRAD Factory Service, or your local MEDRAD office for details.

In the United States, Canada, Europe, and other select areas of the world, the MEDRAD Service Department offers Preventive Maintenance Programs. These annual programs greatly assist in maintaining accuracy and reliability, and can extend the life of the injection system. Contact MEDRAD for details. In Europe, contact MEDRAD Europe B.V., or your local authorized dealer, for further information. Refer to Section 2 of this manual for address and telephone numbers.

NOTE: Failures which occur due to lack of proper maintenance, or abuse, will not be covered under warranty.

Inspection Procedures

The following procedures are recommended for all the components of the injection system. If defects are detected, either repair the system, or call MEDRAD for service. *Do not use the unit until the problem has been corrected.*

Injector Head

1. Inspect the housing for any cracks that could allow fluid to leak inside, or weaken the structural integrity of the unit.
2. Inspect the head cable for cuts, cracks, or worn areas.
3. Inspect the head connector for cracks, loose pins, or a loose strain relief.
4. Inspect the injector head control panel for cuts or cracks that could allow fluid to leak inside.

Syringe Heat Maintainer

1. Ensure that the device is warm to the touch.
2. Ensure that the LED indicator is not illuminated or flashing when installed on the pressure jacket/syringe. The lamp may illuminate if the syringe heat maintainer is not installed on the pressure jacket/syringe.

   If the lamp is illuminated while installed on the pressure jacket/syringe, the heater is too hot and should be replaced.
3. Inspect the cable and connector for cracks, worn areas, loose pins, or a loose strain relief.

Control Panel

1. Inspect the control panel case for cracks that could allow fluid to leak inside, or weaken the assembly.
2. Inspect the interconnect cable for cuts, cracks, or worn spots. Inspect the plug for cracks, loose prongs, loose wires, or a loose strain relief.
3. Inspect the handswitch and cord: Look for cuts, cracks, or worn spots in the cable; look for cracks and loose parts in the switch and housing.
4. Inspect any other cables connected to the control unit: Look for cuts, cracks, or worn spots in the cables; look for cracks, loose pins, or loose strain reliefs on the connectors.

Pedestal Mount

1. Inspect the case and legs for cracks and other defects that could weaken the structure.
2. Ensure that all mounting bolts and screws are secure.
3. Inspect the connectors on the pedestal for cracks or loose pins.
4. Ensure that the wheels roll smoothly, with no binding and scraping.
5. Ensure that the locking mechanism on all locking wheels is functional.

Injector Head Articulating Arm

The injector head support arm is typically associated with pedestal type injection systems and free standing injector head stands. Carefully inspect the areas shown below for any signs of damage.

1. Inspect all parts of the mounting system for cracks and other defects that would weaken the assembly.
2. Ensure that the mounting system is securely assembled, with no loose parts. The system should be stable with the head installed.
3. Ensure that the system moves smoothly in all directions, with no binding, scraping, or drifting.
4. Verify that all cabling is tied back and does not interfere with the movement of the supporting parts or the injector head.

NOTE: The injector head pivot knuckle should rest flat and rotate smoothly on the support arm.

NOTE: The head cable can wrap around the support arm, causing damage to the head cable, and possibly lifting the injector head from the support arm. Contact MEDRAD Factory Service for support arm replacement information.

Counterpoise Systems

1. Inspect all parts of the mounting system for cracks and other defects that would weaken the assembly.
2. Ensure that the mounting system is securely assembled, with no loose parts. The system should be stable with the head installed.
3. Ensure that the system moves smoothly in all directions, with no binding, scraping, or drifting.
4. Verify that all cabling is tied back and does not interfere with the movement of the supporting parts or the injector head.

NOTE: All relevant guidelines for institutional, local, or national safety recommendations related to cable routing and installation should be followed.

NOTE: Rotating the counterpoise consistently in one direction can cause the head extension cable to wrap around the counterpoise, causing possible equipment damage.

NOTE: The head cable can wrap around the support arm, causing damage to the head cable, and possibly lifting the injector head from the support arm. Contact MEDRAD Factory Service for support arm replacement information.

Cleaning Procedure

Deposits of contrast media can interfere with proper operation of the injection system. The following guidelines should be followed when removing deposits, or cleaning any portion of the system.

WARNING: **Shock Hazard**. Remove the power cord from the power source before cleaning any part of the system. Failure to do this could result in the exposure of lethal voltages, causing injury or death.

- Using warm water and soft cloths, clean the injector console and head thoroughly to remove contrast medium or other deposits.

- The injector head requires particular attention. Remove the turret, then: Clean the front casting where the piston moves in and out; Clean the turret and its pivot point; Remove any contrast from the entire length of the piston rod.

CAUTION: **Do not soak or immerse any parts of the injector in water**. Improper or careless cleaning methods may result in equipment damage. While cleaning the outside of the unit, avoid letting any liquids seep inside injector components.

- If contrast medium has leaked inside the head or console, the affected subassembly should be disassembled and cleaned. This cleaning procedure can be done in the field by trained MEDRAD Service personnel, or returned to MEDRAD Factory Service. If the cleaning will be performed in the field by a properly trained individual, ensure that any internal wiring or components are not disturbed, and that the system is completely dry before applying power.

- Check all of the System Safety and Warning Labels for legibility. Ensure that the labels are not damaged or missing.

WARNING: **Ensure that the system is completely dry before connecting to a power source and applying power.**

Leakage Check

To insure safe operation of the injection system, an electrical leakage check must be part of regular maintenance.

Use a commercial leakage tester such as one of the following:

Manufacturer	*Model*
Bio-Tek Instruments, Inc. Electrical Safety Analyzer	Model 601 PRO
Bender	Unimet 1000 ST
Bapco	IEC601L

1. With the AC ground open, power applied, and the line at normal, leakage should be less than 100 micro amps at 110V, or 300 micro amps at 220V.

2. With the AC ground open, power applied and the line reversed, leakage should be less than 100 micro amps at 110V, or 300 micro amps at 220V

3. Disconnect the leakage test device.

Ground Continuity Check

A ground continuity check must also be a part of regular maintenance of the injection system.

1. Disconnect the injector from the power source.

2. Using an ohm meter, measure the resistance between the ground terminal on the power cord and any exposed grounded metal surface of the system. The resistance measured must be less than 0.2 ohms.

5 CPU Card

The CPU Card contains the main injector operating program. Refer to Figure 5.1 for a block diagram of the CPU Card. The CPU Card contains the following circuits:

CPU

The Z-80 CPU U10 is supported by 512 Kbytes of EPROM, and 8 Kbytes of RAM. This processor provides a 16-bit address bus, an 8-bit data bus, and several control lines for Read/Write, Interrupts, etc..

Clock

Crystal Y2 (8 MHz) and clock generator chip U2, produce the 4 MHz clock system for the CPU, and provide a Reset pulse when power is first applied. This pulse resets the CPU, and ensures that the program starts at the beginning.

Memory

CPU memory is comprised of one EPROM / PROM chip (U24), and one RAM chip (U16). These chips connect the address and data buses, and are controlled by both the enable lines from the memory / I/O decoder, and the Read/Write lines from the CPU. EPROM chip U24 is only accessed when switch SP2-2 is set to the “U24” position. If this chip must be replaced, contact MEDRAD Service for a current version EPROM.

Memory / Input/Output Decoder

The Memory / Input/Output Decoder, comprised of U23 and U26, provides:

- Control of the memory chips during read/write cycles
- Two major decode lines (MEMIO1 and MEMIO2: Pins 16 and 17) that are buffered and sent to the Input/Output Card
- Direction control for the data buffer

Bus Buffers

The control lines from the CPU are buffered by U17, then sent to the motherboard bus. The address bus is buffered by U18 and U19, then sent to the motherboard bus. The flow of data is controlled by bidirectional buffer U20, which is controlled by the Memory / I/O Decoder. Control and addressing lines flow away from the CPU, while the buffered data bus, can flow in either direction.

Watchdog 1

The CPU watchdog (U3) must receive pulses from the I/O Card on the WATCHDOG 1 line, or CPU operations will be interrupted. The pulses are generated on the I/O Card, by decoding a CPU address. A loss of these pulses is most likely the result of a problem with the CPU or the EPROMs.

Test Section

The circuit surrounding U7 is used for in-house testing, and the enabling of Utility programs.

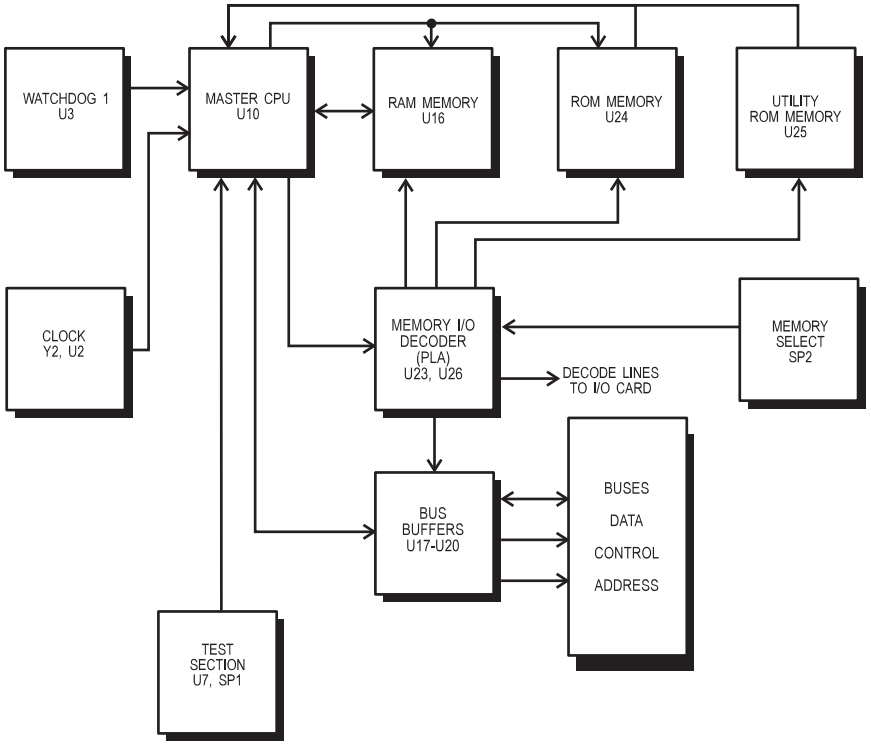


Figure 5.1: Block Diagram: CPU Card

6 Input / Output Card

Through the I/O Card, the CPU:

- reads external switches and system event status
- operates external connections
- synchronizes and times the injection.

Refer to Figure 6.1 for a block diagram of the I/O Card.

Bus Buffers

The control bus is buffered by U14, and the address bus is buffered by U15. The bidirectional data bus is buffered and controlled by U22, with direction control from I/O decoder U8.

Display Buffers

Two address lines, and eight data lines, are buffered for the Display Card by U16 and U19.

I/O Decoder

Decoder U8, controlled by address and control lines, provides an enable to programmable I/O (PIO) chips U5 and U6, counter/timer chip (CTC) U4, and, provides data direction control for data buffer U22.

Parallel Input/Output Chip

Parallel I/O chips permit the CPU to access external inputs, and to control outputs.

- PIO1 -- The inputs to U6 are the hand start switch, remote start switch, and remote disarm input. Through the data buses, the CPU can check the status of these inputs. Outputs from U6 include: The film changer relay enables two injecting signals; the Armed signal, and Head Indicator signals. Through the I/O chip, the CPU can turn these outputs on and off.

Counter / Timer Chip (CTC)

The CTC (U4) generates interrupt signals for the CPU. The interrupts are prioritized and asynchronous with the system clock.

- Trigger 1: PPI memory error interrupt request. PPI primary and backup memories are compared each time primary memory is read. If primary and backup data values are not equal, an interrupt request is generated.

- Trigger 2: Timed Interrupt. This provides a real-time clock and delay timer function. During an injection, this interrupt program performs Flow Rate and Volume Limit calculations. This interrupt is not externally triggered, but driven from the time divided clock generator.

Test Decoder This 4-16 channel decoder (U2) provides Reset pulses for Watchdog 1, and controls timing of the buzzer.

Test Section The circuit surrounding U17 and U18 is for in-house testing.

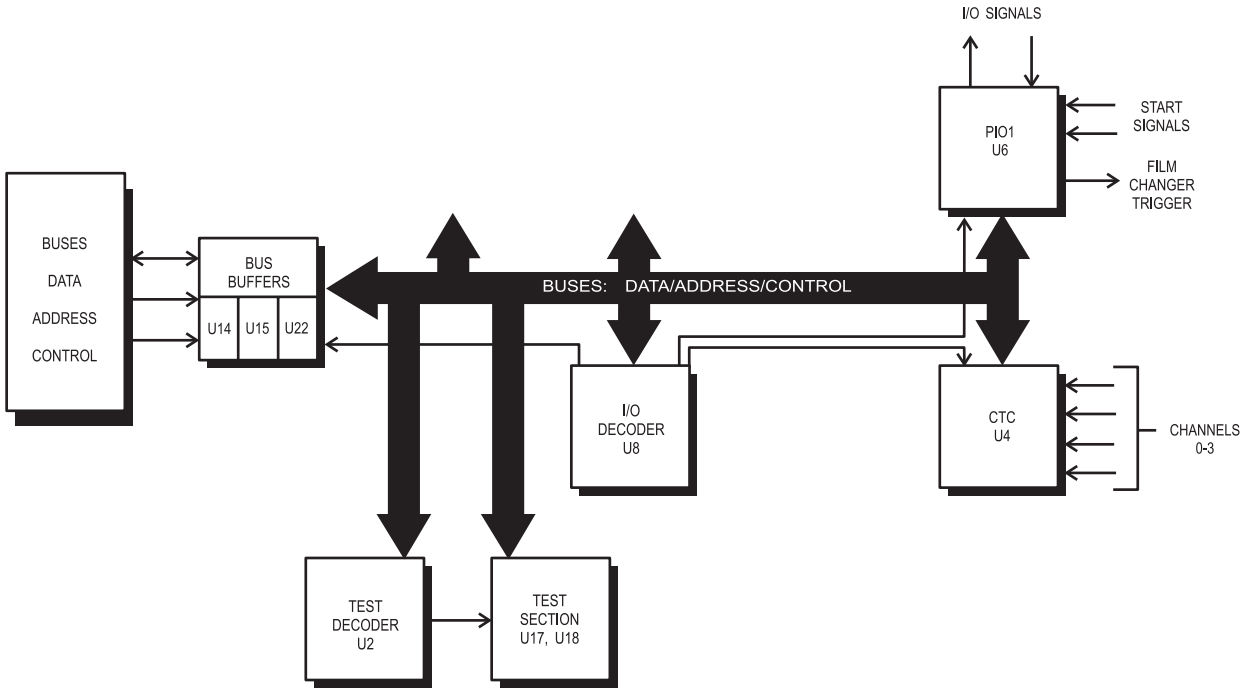


Figure 6.1: Block Diagram: I/O Card

7 Servo Control Card

The Servo Control Card (SCC) serves two primary functions:

- Provide signals that control the Flow Rate and Power Drive circuits
- Read and interpret information from the head, to control injection Flow Rate and Pressure [limit].

Refer to Figure 7.1 for a block diagram of the Servo Control Card.

Bus Buffers

The control bus is buffered by U12, and the address bus is buffered by U11. The bi-directional data bus is buffered and controlled by U10, with direction control coming from direction logic.

Direction Logic

Gates U7-U9 control the direction line of U10, controlling the flow of data to and from the card.

A/D Converter

Analog-to-digital (A/D) converter U1 inputs a multiplexed analog signal, and converts it into a digital word. This process is controlled by A/D converter logic (U4, U5) and DAC decoder U14. When requested from the CPU, the converted 10-bit value is gated to the data bus by tri-state buffers U2 and U3.

A/D Converter Logic

Gates U4 and U5 control the A/D converter U1, starting the A/D conversion when the data is ready, and enabling buffers U2 and U3 to transfer the converted word to the data bus.

DAC Decoder

Decoder U14, with U18 and U6, provide enable signals for the DACs (digital-to-analog converters) and the MUX (multiplexer). These enables allow data bus information to be written to the device. The decoder also provides signals for the A/D converter logic, direction logic, and Reset pulses for WATCHDOG 2.

WATCHDOG 2

The DAC decoder sends pulses to WATCHDOG 2 (U15) when the mechanical stop is in position, and “Ready to Inject”. If the Mechanical Stop takes too long to move into position, the pulses from the DAC decoder will stop, resulting in a disarm condition. The Sentinel will then display the message “Mechanical Stop Position Failure”.

PIO3

The inputs to PIO3 (U16) are signals from the Injector Head, Power Drive Circuit, and the analog portion of the SCC. These inputs include: Turret switch position sensor, 60 ml indication, and FWD/REV indication from the Injector Head, Aux Monitor from the PDC, and an Overpressure Limit signal from the SCC. The status of PIO3 inputs are directed to the CPU through data busses. Outputs from

PIO3 include: Flow Control signals, the Safe Relay Enable, and the System Override signal.

System Monitor Flip-Flop

The flip-flop (U17) sends alarm signals to disarm the injector, if any of the following input conditions occur: WATCHDOG 2, OPLIM (over-pressure signal), or AUX MONITOR (power drive failure).

Command, Position, and Signal DACs

When enabled and timed by the DAC decoder U14, one of the DACs (U21-U24) will read a byte of data bus information. The DAC then converts the byte to an analog voltage between zero and 10 VDC. DAC resolution is 40mV per count.

Pressure Limit Command DAC
The output of this DAC is the Pressure Limit Command signal (PSILIM SELECTED). This signal is sent to the Multiplexer, the Primary Pressure Limit circuit, and the Overpressure Limit circuit.

Flow Rate Command DAC
The output of this DAC is the Flow Rate Command signal (FLOW RATE SELECTED). This signal is sent to the Multiplexer, Flow Scale Circuit and Power Drive Card (PDCI).

Mechanical Stop Position DAC
The output of this DAC is the Mechanical Stop Position signal (MSPOSCMD). This signal is sent to the Multiplexer, and through Unity Gain Buffer U26C, to the Mechanical Stop Drive Card.

Velocity Signal DAC
The output of this DAC is a digitized velocity signal, sent to the Imaging System Interface Card. This signal is buffered, becoming the Flow Profile Signal available through J106.

Multiplexer (MUX)

The multiplexer circuit is comprised of multiplexer U19, Quad latch U20, and Unity-Gain buffer U26A. This circuit receives eight inputs, and under timing control connects each input to the circuit output, which is sent to the A/D converter.

TTL/CMOS Converter

U25 converts TTL logic (0/5V) to CMOS logic (0/15V).

10V Reference

Chip U28 develops +10 VDC as a reference voltage for the Plunger and Mechanical Stop position feedback pots in the head. This voltage is also applied to the multiplexer to be monitored by the CPU.

Pot Processor

This circuit, comprised of U27C and associated components, buffers and filters the pot wiper signal. The pot signal is an input to the multiplexer and the error amplifier.

Primary Pressure Limit Circuit

The Primary pressure limit circuit (U26B), compares the pressure limit command to the actual pressure developed during an injection. The output of this circuit is sent to three Pressure Limiting circuits to perform the following functions:

Flow Rate Integrator Circuit U29.
The output of U26B is summed with the Flow Rate command to effectively reduce the input voltage to U29. This action results in the reduction of the Flow Rate command signal, thereby preventing the selected pressure limit from being exceeded.

Inverting amplifier, U27B.
The output of this amplifier is summed with the output of the Main Flow Integrator, to reduce the voltage sent to the error amplifier U27D, thereby decreasing the error signal.

Circuit Q4.
This circuit is driven to cut-off, sending a pressure limit indication signal (PRESLIMIND) to PIO3 (U16), and eventually to the CPU. This PRESLIMIND signal will also send Q12 into a saturation state, which shunts R81 and reduces the gain of the error amplifier, thereby decreasing the error signal.

Overpressure Circuit If the actual pressure exceeds the pressure limit command by greater than 100-150 PSI, the Overpressure Circuit (U26D) forwards an OPLIM signal to stop the injection.

Flow Scale Circuit Using the two flow scale signals, circuits Q5, Q6, and Q11 attenuate the flow rate selected signal during ML/MIN and ML/HR flow scale injections.

Standby Reset Circuit Driven by the INJECT signal, Q8, Q9, and Q10 control the flow rate integrator, U29. During standby, the integrator follows the position pot. The output of the integrator is equal in amplitude, and opposite in polarity to the position pot. When an injection is to occur, this circuit allows U29 to generate the position command.

Flow Rate Integrator The master position command is generated by integrator U29. The output of this circuit is a ramp, with a slope proportional to the input signal (flow rate selected).

Error Amplifier When the plunger is moving at the desired flow rate, the master position command from U29 and the pot wiper signal from U27C are equal but opposite in polarity. The output of error amplifier U27D is the difference between these two signals, or the position error. This error signal is used by the drive circuits to power the motor. If pressure limiting occurs, a signal from U27B reduces the error signal, and the gain of U27D is reduced by Q12.

Feed Forward Circuit This circuit, comprised of Q7 and U27A, provides a boost voltage to the motor to compensate for the internal resistance of the motor. This turning voltage varies with the Flow Rate.

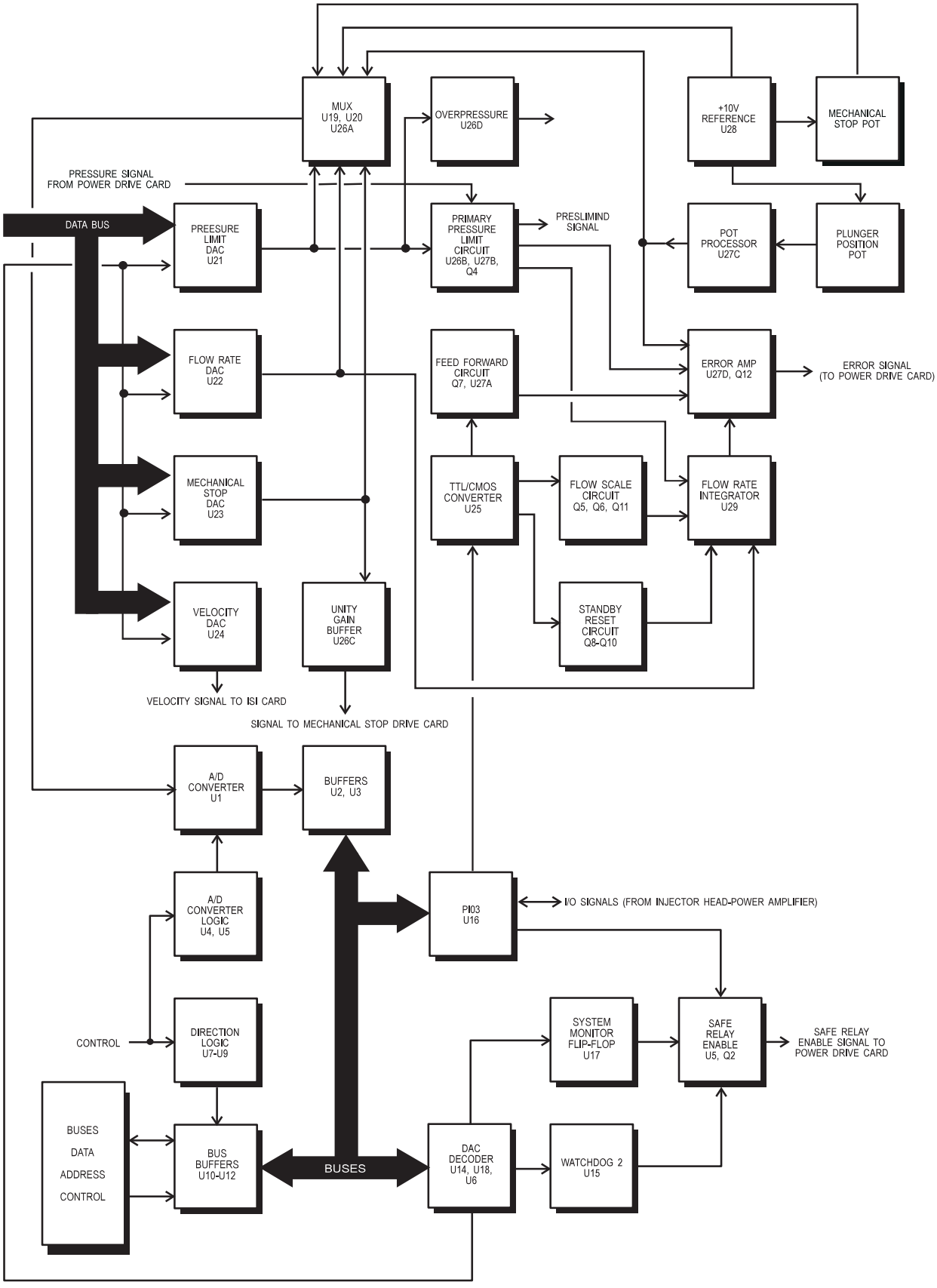


Figure 7.1: Block Diagram: Servo Control Card

8 Pre-Programmed Injection - PPI Card

Bus Buffers

The control bus is buffered by U3, and the address bus is buffered by U1 and U2. The bidirectional data bus is buffered by U4 and U5, with direction defined by one of the lines on the control bus. These data buffers are enabled by the decoder. The data bus for the primary memory chip is controlled by U5; the backup memory chip data bus is controlled by U4.

Decoder

Decoder U6 provides the enable lines for the data bus buffers, the memory chips, and the RS-232C circuit.

PPI Memory

Primary PPI memory is provided by 8K RAM chip U9. Backup PPI memory is provided by U8. The chips are enabled by signals from the decoder, while outputs are enabled by lines from the control bus.

Memory Comparator

The data buses from the primary and backup memory are continuously compared by U7. If the values do not agree, latch U11 sends a signal (MEMERRINT), enabling the CTC on the I/O Card, to interrupt the processor.

Analog Switches

The enable lines for the memory chips are switched through U16. When power is applied, the switches are closed, connecting the enable lines. When power is removed or low, the switches are open, disabling the enable lines to preserve power.

Power-Down and Battery Circuit

When power is removed, or is low, Q1-Q3 disables U16 and opens the analog switches to disable the memory chips to conserve power as they switch over to battery power. The battery provides backup power for the memory chips to preserve the contents when power is removed.

RS-232C Circuit

This circuit consists of Universal Asynchronous Receiver/Transmitter (UART) U13, baud rate clock U12, U19 RS-232 line driver and receiver, and ferrite beads FB1-FB5 added for reduction of conducted noise. With this circuit, the main unit can communicate with the Control Panel using an RS-232C serial interface.

Ferrite Beads

FB1-FB5 are used to suppress noise from the power source.

NOTE: To clear PPI Memory in CRC systems: Remove power, then short pin 2 to pin 1 or 3 of JU1. The shorted state should be maintained for several seconds to ensure complete and proper clearing.

NOTE: To clear PPI Memory in Pedestal systems, remove the rear panel access doors, then depress the PPI Reset button (S1) on the rear of the electronics console. With S1 depressed, remove and reapply unit power.

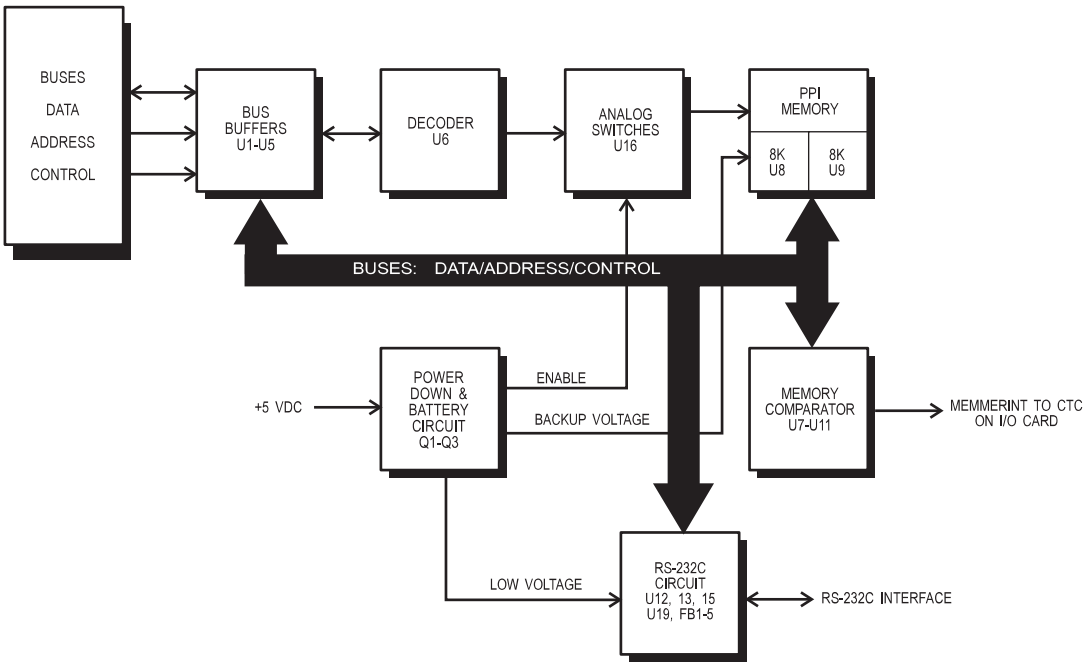


Figure 8.1:Block Diagram: PPI Card

9 Control Panel

The Control Panel is a microprocessor controlled device that serves as the user interface for the injection system, allowing the user to program and monitor the system. The Control Panel consists primarily of an interconnected Display Card and Controller Card. The following sections detail operation of the two boards.

Keyboard Overlay

The keyboard overlay contains snap-action membrane keys, interconnected in a matrix of four columns and eight rows. This matrix is connected to the Display Card.

Display Card

The Display Card contains the alphanumeric displays and LEDs that show through the keyboard overlay. These devices convey messages and operating status to the operator. The Display Card contains the Sentinel display, numeric displays, and LED displays.

Sentinel Display

The Sentinel is made up of eight, 4-character display units (DS1 through DS8), creating a 32-character read-out. These devices receive data and control information from the Controller Card.

Numeric Display Drivers and Numeric Displays

Three display groups are used to display injection parameters on the Control panel. Each display group consists of a display driver (U1, U2, or U4), and numeric display units. Display drivers also receive the data and control line information from the Controller Card. Group designations are as follows:

Display Driver U1, displays Volume (DS23 - DS26), Flow Rate (DS11, DS12), and Rise/Fall (DS9, DS10).

Display Driver U2, displays Pressure [limit] (DS27 - DS30) and Injection Duration (DS13-DS15).

Display Driver U4, displays Program Number (DS16, DS17), Total Levels (DS18), Level (DS22),and Delay (DS19-DS21).

LED Driver, LEDs, and Transistor Driver

The remainder of the Display Card circuit controls and drives LEDs used as backlights of various indicators on the Control panel. Display driver U3 controls all LEDs, and receives data and control information from the I/O Card. Each LED group contains drivers such as Q5 and Q6, or IC U5. These three columns of LEDs are enabled by Q20 through Q22, and driven by Display Driver U3.

Controller Card

Through a cable, the Control Panel connects to J22 on the rear connector panel, which provides power to the Control Panel, and allows two-way serial communication between devices.

The communication protocol is RS-232C, with automatic retries and error checking. During power-up or recovery from System Monitor faults, the Controller Card and console try to establish error-free communications. If communication errors occur, an error message will be displayed on the Sentinel.

The microprocessor, memory chips, interface logic, and power supply are contained on the Controller Card, and described in detail in this section.

The Controller Card consists of two major sections:

Digital Logic
Power Converter

Digital Logic

The digital logic portion on the Controller Card is comprised of the microprocessor, memory chips, and interface logic.

CPU

The CPU (U13) is supported by 64 Kbytes of EPROM / PROM (program memory), and 8 Kbytes of RAM. The processor interfaces with the remaining logic through an 8-bit data bus, 16-bit address bus, and 5-line control bus.

Clock

Crystal Y2 (8.0 MHz), with U8 and U6, generates a clock signal of 4 MHz for the CPU and associated peripherals. UART U10 is supplied with a 3.6864 mHz (Y1) crystal oscillator clock.

Memory

Processor memory is comprised of three chips: U15 and U16, each providing 16 Kbytes of program memory (EPROM); U14, providing 8 Kbytes of data memory (RAM).

Memory / I/O Decoder

Memory / I/O decoder U12 receives the CPU address, data and control busses, and decodes and activates the peripheral chips.

PIO

Programmable Input/Output chip U2 provides the processor with 17 I/O lines: Twelve of these lines (A0-A3, B0-B7) scan the panel keyboard; One output line (A7) drives buzzer BZ1; One line (A6) is the remote handswitch input; One output, A5, drives the Arm light of an armed indicating handswitch.

For additional information on Keypad inputs, see the I/O Card Description on page 6 - 1.

CTC Counter-timer chip U5 provides several functions for the processor. Counters in the CTC let the processor time internal events. The CTC receives interrupt requests from UART U10, and controls interrupts to the processor.

UART Universal Asynchronous Receiver Transmitter (UART) U10, serially communicates with the Main Unit. The UART converts parallel data bus information into serial information. Data sent from the Control Panel to the console is formatted and transmitted by the UART. Data from the main unit is received by the UART, is converted to parallel format, and interrupts the CPU to signal that data is present in the receive holding register.

Line Drivers Level converting driver U20 changes the UART 0 and 5 VDC transmission signals into ±10 VDC. These signals are then compatible with the RS-232C communication standard.

Line Receivers Level converting receivers in U20 change incoming RS-232C signals (±10 VDC) into 0 and 5 VDC signals, respectively. These signals are then compatible with the UART, and can be assembled for the processor.

Display Decoder Display driver U4 interfaces with the Display Card. U4 receives the address and control buses from the processor, an enable line from decoder U12, and provides enable strobes to the 4 display drivers on the Display Card.

Bus Buffers Bus signals transmitted from the processor to the Display Card are buffered by U3 and U7.

PIO Output Buffer Logic inverter U1 buffers the A5-A7 PIO outputs.

Ferrite Beads Ferrite Beads FB1-FB11 are used to suppress noise transmitted from the power source. The beads are also used on transmit receive lines for U20.

Wait State Controller Cards utilize the Intel D82C284-8 clock generator, which will not support wait state, and new generation MAXIM and HARRIS display drivers which do not require wait-state support.

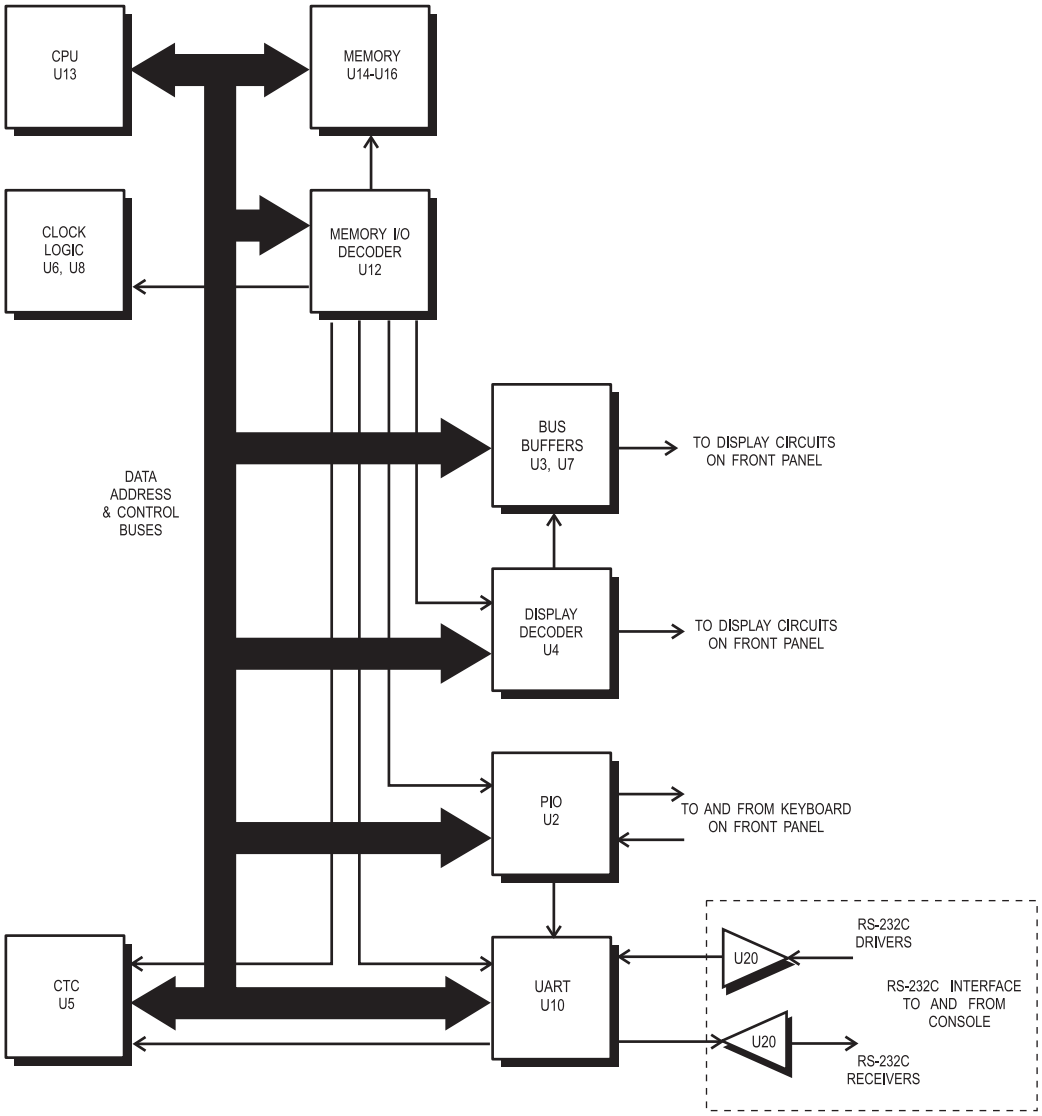


Figure 9.1: Block Diagram: Control Panel Digital Logic

DC to DC Converter

Refer to Figure 9.2.

The DC to DC converter is responsible for converting +26 volt (supplied through the interconnect cable) to a regulated +5 volts, in order to power the digital circuitry. The method of regulating the +5 volts supply is like that used on the Power Supply Card.

+5 Volt Regulator Circuit

The +26 volt supply is filtered and regulated to +5 volts using Pulse Width Modulator (PWM IC) U17, switching the +26 volt supply through FET Q4. Pins 11 and 14 of U17, will pulse low then high, at a frequency determined by R30, R31, and C38 (approximately 150 KHz). The pulses are ORed through D5 and D8, and applied to Q5 and Q6, which pulse the gate of FET Q4. Zener diode D9 protects Q4 by limiting the gate to source voltage to a maximum 15 volts. The output of Q4 is filtered by inductor L1, capacitors C26 and C52, and load resistor R12.

Regulation of the +5 volt supply is through the PWM and support circuitry. Resistor R32 and R33 establish reference at U17 pin 2. +5 volts is coupled back to U17 pin 1, through a voltage divider network of R28 and R34. Voltages are compared to determine pulse width at U17 pins 11 and 14. If voltage is low, pulse width is lengthened to increase voltage; if voltage is high, pulse width is shortened to decrease voltage.

+5 Volt Overcurrent Protection

The +5 volt supply has overcurrent protection circuitry which will shut down the PWM IC (and the +5 volts) if current exceeds 2-4 amperes. If voltage across sampling resistor R13 exceeds a certain value, Q2 and Q3 conduct, sending +10 to +12 volts through Q3, to U17 pin 10 (Shut Down), which stops pulses at pins 11 and 14. The PWM IC will restore the +5 volts if the overcurrent condition is eliminated.

+5 Volt Overvoltage Protection

+5 volts overvoltage protection is provided by 6.2 volt zener diode D8, and 3 amp picofuse F1. If supply rises above +5 volts, D8 conducts, drawing current. If voltage continues to rise, D8 will breakdown, shorting the +5 volts supply to ground. The combination of voltage and current drawn when D8 shorts, will cause F1 to open, removing +26 volts from the PWM IC.

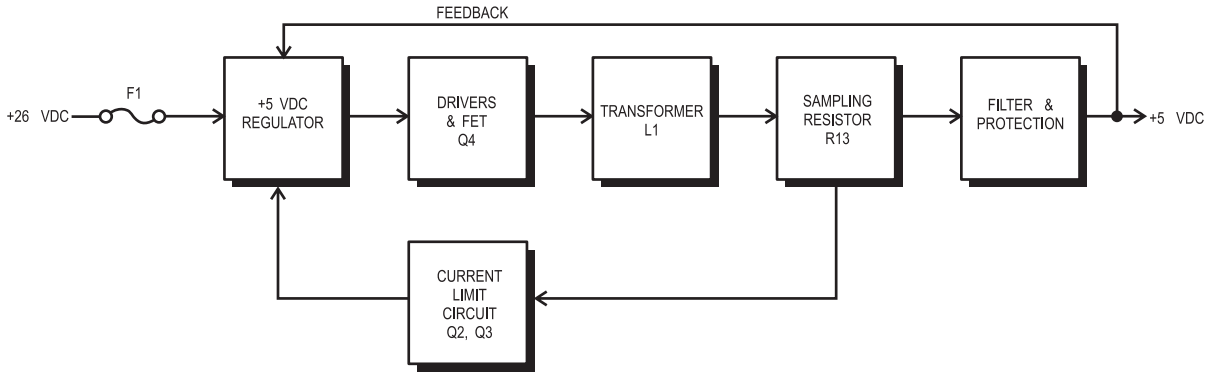


Figure 9.2: Block Diagram: Control Panel: DC to DC Converter

10 Power Drive Circuit

The Power Drive Circuit supplies, and controls power to the Injector Head Plunger Motor.

The Power Drive Circuit is located primarily on the Power Drive Card. The Safe relay, Reverse relay, and selected output stage components are located elsewhere in the unit. The filter choke is mounted on the chassis frame.

PDCI

Refer to Figures 10.1 and 10.2 for block diagrams of the PDCI.

Brake Circuit Q1, Q2, Q3

The Brake Circuit is used to stop the plunger motor at the end of an injection, or if an error condition occurs during the injection. This process is called Dynamic Braking. When the Safe Relay opens, the motor will continue to turn, thereby acting as a generator producing voltage. When the brake is activated, the motor winding is connected across two .75 ohm, 5 watt resistors, stopping the motor. At the end of an injection, the error signal (ERRSIG, a command from the Servo Control Card) goes negative (-1V), activating the Brake Sensing Circuit Q1 - Q3, thus stopping the motor. Zener diode D1 protects Q1 by limiting gate to source voltage to 15 volts. A SYSTEM OVERRIDE, AUX MONITOR, or overrate condition can also activate the brake.

Overcurrent Shutdown U1A, DRC Q1

The Overcurrent Shutdown Circuit opens the plunger motor voltage path if excessive current is flowing through the motor circuit. Sampling Resistor R4 (on DRCI) is in series with the motor, and voltage across it is directly proportional to the current through the motor. This voltage is an input to Motor Current Amplifier U1D, the output of which is applied to the non-inverting input of Overcurrent Shutdown comparator U1A. The inverting input to U1A is connected to a voltage divider, establishing an Overcurrent Shutdown reference. When output of U1D rises above reference voltage at U1A, the output of U1A switches to negative saturation. This negative voltage is applied to the gate of Overcurrent Shutdown FET Q1 on the DRCI, forcing it into cutoff, and opening the motor voltage path.

Safe Relay / Safe Relay Enable K1, Q7

Safe Relay K1 completes the motor voltage path between the SCR Bridge stage, and the Plunger Motor. K1 also provides an additional pair of normally-closed contacts to allow the Mechanical Stop Motor to run while the injector is disarmed, yet prevent the Plunger motor from running. K1 is enabled by either a Forward or Reverse load command from the injector head, or when the injector is armed (Safe Relay Enable [SAFRELEN] from the SCC). In both cases, theses signals cause Q5 to conduct, providing a ground path to energize K1 (SAFRELO). This action disables the Mechanical Stop Motor by breaking connections to the motor, and allowing power to flow to the Plunger motor. The Safe Relay is disabled by a SYSTEM OVERRIDE/ AUX MONITOR from the PDCI, or a loss of the SAFRELEN from the SCC.

Single Button Disarm from Injector Head - When the injector is armed, and the SAFRELEN in the active high state, Q12 conducts, shunting R56. This process allows “Single Button” disarming of the injector head. When the injector is armed, if any single button on the injector

head is pressed, the signal will go through either D15 or D16, then R59 and Q12, making Q13 conduct. This produces an active low FWD/REV IND (to the SCC Card), which prompts the system to withdraw the SAFRELEN.

Reverse Relay Enable Circuits K2, Q10, Q11

When Reverse loading, both Safe Relay K1 and Reverse Relay K2 must be energized. K2 reverses the polarity of the plunger. When REVERSE load is pressed, Q11 and Q10 conduct, applying +26 volts through on-board jumper JU1, energizing K2. JU1 must be set in position “1-2”.

System Override

The SYSTEM OVERRIDE shuts down the PDCI if the system detects the presence of a “System Monitor’ type condition (Overpressure, Overvolume, or Overrate [via Aux Monitor]). When the SYSTEM OVERRIDE signal from U16 (PIO3) on the SCC goes high, Q4 and Q5 (PDCI) conduct, allowing +15 volts to: Disable the Safe Relay circuit (Q6), activate the brake (D2 and Q1), and disable pulses to the SCR bridge controller (Q9). SYSTEM OVERRIDE and AUX MONITOR are OR’ed on the PDCI to form a redundant shut-down circuit.

Zero Crossing Detector U4A, U4D

The Zero Crossing Detector circuit establishes a timing reference for triggering of the SCR bridge. This is done by producing a positive pulse (-10v to +10v) which resets Ramp Generator U5C when the input sine-wave passes through zero. These pulses are also applied to Full Error Trigger Q9, through D6 and R30, to fire the SCR bridge when needed.

Input to this circuit is the added, positive half-waves, from the 36 VAC created by a circuit on the Motherboard (MBRI), forming a full-wave input to U4A. U4A, an inverting amplifier with a gain of 2.06, together with D30 and C15, form a peak detector which produces an output voltage proportional to the incoming line voltage. This voltage sets the input reference for “Window Detector” U4D, which produces a positive output pulse when the input sine-wave is below the reference established by U4A (sine-wave passes through zero). All other times, the output of U4D is negative saturation. The positive pulse, applied to the gate of Q16, resets the Ramp Generator. The pulse width is approximately 1.2 mS @ 60 Hz, and 1.5 mS @ 50 Hz, and is clamped to +/- 10 volts by zener diodes D28 and D29 in the feedback loop of U4D.

Ramp Generator U5C, Q16

Integrator U5C generates 2 volt (-2 to 0 volt) ramp waveforms between each zero crossing that are used to establish a reference level for Trigger Comparator U5B. DC level and amplitude of the ramps are adjusted by R90 and R112, respectively. The integrator is reset when the sine-wave passes through zero (U4D applies a positive pulse to the gate of Q16).

Trigger Comparator, SCR Controller U5B, Q8

Trigger Comparator U5B uses the summed Error, or load profile, signal and ramp wave-form to determine at what point in the sine-wave the SCR bridge is fired. In standby, input to U5B is a negative voltage (-2 to 0 volt integration from U5C), thus output of U2D is negative saturation, and Q8 is off.

During injection, or when forward or reverse loading, the DC signal raises the ramp wave-form input to U5B above zero volts, causing output of U5B to enter positive saturation, making Q8 conduct. Q8 provides a ground path for +26 volts (through R27, R28, and Q8), which creates a positive to negative transition on the primary of pulse transformer T1. The pulse transformer is connected, to invert the polarity of the secondary, creating a negative to positive pulse to fire the SCR bridge. The duration of the pulse is determined by C4, R28, and the primary of T1.

Full Error Trigger Q9

The Full Error Trigger will fire the SCR bridge if a large, instantaneous Error signal does not allow U5B to trigger the SCR bridge. In order for Trigger Comparator U5B and the SCR Controller to fire the SCR bridge, input to U5B must be allowed to go below zero. If the Error signal is too large, input of U5B stays above zero, consequently, output is held in positive saturation. When this occurs, positive pulses from Zero Crossing Detector U4D will make Q9 conduct. This transition momentarily resets SCR Controller Q8, to enable the next positive output from U5B to fire the SCR bridge. Pulses will continue to reset the SCR controller until the Error signal drops to a value which allows U5B to take over.

Transistor Q9 is used to ground trigger pulses (remove base voltage to Q8) if a SYSTEM OVERRIDE (D8 and D9), AUX MONITOR (D10 and D9), or overrate injection (D11 and D9) occurs.

Delinearizing Network

The circuit comprised of R75, R87, R88, R107-110, D26, D27 and C10, increases drive circuitry sensitivity to small error signals, and decreases sensitivity to larger error signals.

Power Output Stage

AC power from the power transformer is applied to SCR bridge Z1. The output of the bridge, controlled by gate pulses from the SCR controller, is filtered by C3 (on DRCI). The SCR bridge is protected by an internal MOV across the AC input. SCR Bridge output is spike protected by MOV Z2, while direction of motor rotation is controlled by Reverse Relay K2. Motor current is sampled for the pressure circuits and the Overcurrent Shutdown circuit by Sampling Resistor R4 on the DRCI.

Pressure Signal Filter U1C

U1C is a non-inverting, low-pass filter that eliminates 50 and 60 Hz oscillations from the Motor Current signal.

Pressure Amplifier U1B

The filtered motor current signal is amplified by U1B. Output is the actual pressure signal PRESSIG, sent to the multiplexer and pressure limit circuitry on the SCC Card. This signal is also used on-card by the Loading Pressure limit. Pressure Amp U1B, a non-inverting amplifier, allows calibration of the Pressure signal. Low pressure is calibrated by R83, which adjusts the input offset to U1B, while high pressure adjustment is calibrated by R17, which adjusts the gain of U1B.

Loading Pressure Limit Control Circuit Q15, Q17, U5D

If the output of U1B indicates pressure in excess of 200 PSI, Q15 and Q17 conduct, summing a positive voltage with the negative load profile voltage (from U4C) to reduce the input to U5D. The lower input reduces the error signal to U5B, thus limiting load rate and pressure.

Motor Current Amplifier U1D

U1D amplifies and inverts the motor current signal from the sampling resistor, which is in series with the motor. Output of U1D is a negative voltage, proportional to motor current. This signal is used by Velocity Amplifier U2B, Auxiliary Monitor U2C, and Overcurrent Shutdown circuit U1A.

Velocity Amplifier U2B

Inputs to velocity amplifier U2B are motor voltage, and current signal from the motor current amplifier U1D; these two signals are opposite in polarity, and added to obtain an analog derivative of actual velocity. The output of U2B is negative, used by Overrate Detectors U2A and U2D. Output is also used to control the speed of the motor when loading (U5D).

Overrate Detector U2A

Overrate Detector U2A compares the actual velocity signal to the FLOW SELECTED input, and will shut down the PDCI if velocity exceeds the flow command. When this occurs, output of U2A nullifies input to Trigger Comparator U5B, stopping trigger pulses to the SCR bridge.

Brake Comparator U2D

The output of U2A is also sent to Brake Comparator U2D. If Overrate Detector U2A cannot adequately control the overate condition, U2D will activate the Brake (Q1), trigger an Aux Monitor (U2C), and short any remaining SCR bridge pulses to ground.

Auxiliary Monitor U2C

The AUX MONITOR circuit will shut down the PDCI if either of the following conditions exist: Excessive current flowing through the motor; Actual motor speed is greater than the selected flow rate. U2C, with diode D14 in the feedback loop, acts as a latch circuit. When either above stated conditions occurs, output of U2C goes positive, forward biasing D14, and feeding positive voltage to the non-inverting input (latching U2C positive). An AUX MONITOR will: Disable pulses to the SCR bridge through D8, D9, and D10; Disable the Safe Relay Enable (SAFRELEN) through Q6; Activate the brake through D8 and D2; Send a signal to U16 (PIO3) on the SCC to interrupt the CPU and terminate the injection.

Excessive Motor Current:
The inverting input of U2C receives the motor current signal from Motor Current Amplifier U1D. Normally, this input is used to decrease the sensitivity of U2C at the beginning of an injection, thus preventing false Aux Monitor indications caused by initial motor voltage and current requirements at the beginning of an injection. As motor current increases, the inverting input goes negative (eventually to the point at which U2C output becomes positive). When this occurs, U2C will latch, shutting down the PDCI, sending a signal to U16 (PIO3) on the SCC (prompting the system to terminate the injection).

Excessive Motor Voltage:
The non-inverting input to U2C receives the output of Brake Comparator U2D. Input to U2D is Overrate Detector U2A which senses if motor speed is greater than the selected Flow Rate. If an overrate is detected by U2A, U2D will send +15 volts to the non-inverting input of U2C, making its output positive. When this occurs, U2C will latch, shutting down the PDCI, sending a signal to U16 (PIO3) on the SCC (prompting the system to terminate the injection).

Forward/Reverse Loading Circuit U3, U4B, U4C, U5D

The Forward/Reverse Loading circuit develops a load profile voltage which is summed with the output of Ramp Generator U5C, to trigger the SCR bridge and produce a drive voltage for the plunger motor. Plunger pressure and velocity when loading are controlled by Error Amplifier U5D.

Forward or Reverse loading sends a voltage that ranges from +7.9-12.9 volts (slow to fast). This voltage is sent to U4C (clamping by D20 not required), generating a negative load profile (-1.5 to -6.5) which is inverted by Error Amplifier U5D to produce an error signal. This signal is summed with the Ramp Generator output to trigger the SCR bridge. Ten Volt Regulator U3 and Inverter U4B supply -10 volts to the input of U4C. The summation of -10 volts and the load rate command voltage at U4C, produce a 0 volt velocity command voltage in standby mode, or when only one button is depressed on the injector head.

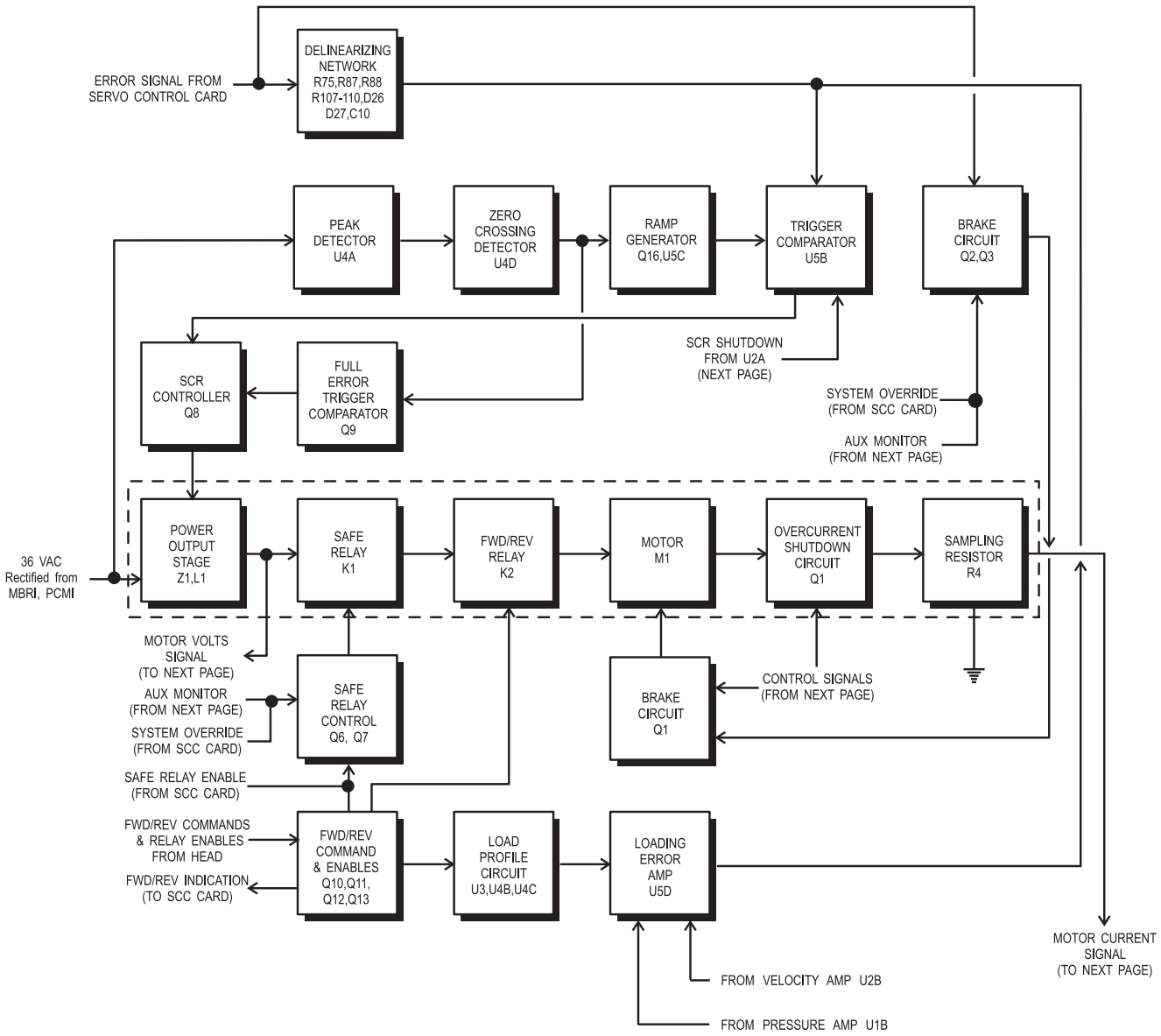
Fwd/Rev Loading Error Amplifier U5D

Error Amplifier U5D controls the plunger velocity and pressure limit when forward or reverse loading. Below are descriptions of velocity and pressure limit control.

Velocity Control:
U5D controls motor velocity by increasing or decreasing the error signal, based upon comparisons of the Load Profile (U4C), and inverted Velocity signal (U2B and U5A). U4C produces a load profile voltage that indicates the desired speed of the motor, while Velocity Amplifier U2C produces an output voltage that represents the actual speed of the motor. The Velocity signal is inverted by U5A, and summed with the Load Profile at the inverting input to U5D.

If there is a negative difference (actual plunger rate is below the desired plunger rate), U5D will increase the error signal, firing the SCR bridge earlier in the sine-wave, producing more power for the motor. Likewise, if there is a positive difference (actual plunger rate is above the desired plunger rate), U5D will decrease the error signal, firing the SCR bridge later in the sine-wave, producing less power for the motor.

Pressure Limit Control:
If the output of U1B indicates pressure in excess of 200 PSI, Q15 and Q17 conduct, summing a positive voltage with the negative load profile voltage (from U4C) to reduce the input to U5D. The lower input reduces the error signal from U5B, thus limiting load rate and pressure.



**NOTE: Blocks that appear within the dotted lines are not located on the PDCI.*

Figure 10.1: Block Diagram: Power Drive Card International (PDCI) and Associated Circuitry (sheet 1 of 2)

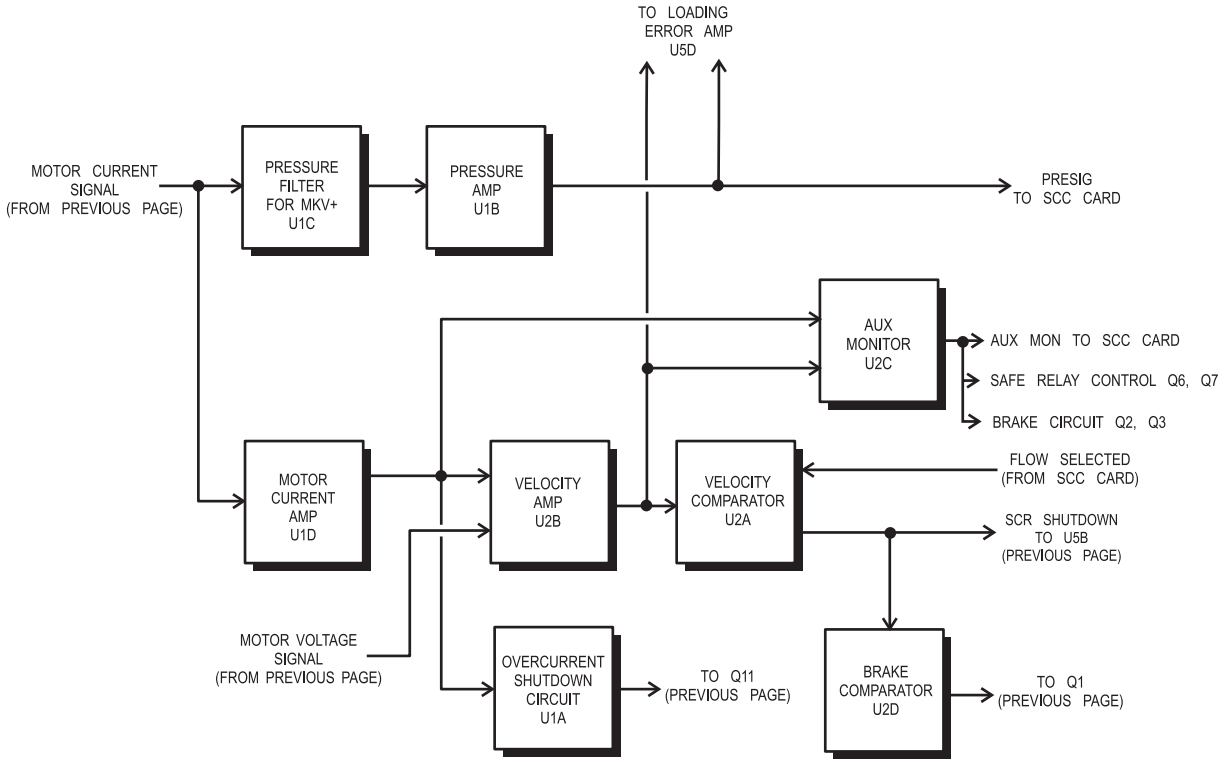


Figure 10.2: Block Diagram:
Power Drive Card International (PDCI)
and Associated Circuitry (sheet 2 of 2)

NOTES:

11 Mechanical Stop Drive Card

Refer to Figure 11.1 for a block diagram of the Mechanical Stop Drive Card.

Differential Amplifier

The inputs to differential amp U2A are: Mechanical Stop Position Command (BMSPOSCMD) and the Mechanical Stop signal (MSPOS) from the Mechanical Stop Pot in the Injector Head. BMSPOSCMD input represents the desired position of the Mechanical Stop. MSPOS input represents actual position of the Mechanical Stop. The output of U2A will be near zero volts when the Mechanical Stop is in position, and will swing positive or negative when there is a difference between BMSPOSCMD and MSPOS.

Absolute Value Amplifier

Regardless of the polarity of the signal from U2A, the absolute value circuit surrounding U2B provides a positive “error” signal to comparator U2C.

Comparator

One input to comparator U2C is a triangular waveform (generated by U2D), the other, an error signal from U2B. U2C compares these inputs, generating a pulse train which actuates drive transistor Q4. The width of the pulses, which determine the duty cycle for Q4, vary proportionally to the amplitude of the error signal from U2B.

Drive Transistor

Motor power is controlled by Q4, through the contacts of relay K1.

Direction Relay Control Circuit

(Card revision D and below)
Relay K1 determines the polarity of the voltage applied to the motor. If output of differential amplifier U2A is negative (meaning that the stop should move back), Q7 energizes K1 and reverses motor direction.

Direction Relay Control Circuit

(Card Revision E and above)
Relay K1 determines the polarity of the voltage applied to the motor. The output of U2A is sent to the non-inverting input of U3, a high gain comparator circuit. A comparator will switch between positive and negative saturation, depending upon the polarity at the input. A hysteresis circuit provides positive feedback through R37 to prevent the output of U3 from switching when the input is near 0 volts.

The output of U3 is then sent to Q7, a 2N3906 transistor that determines the directional control for the Mechanical Stop motor by switching K1 on the MSD card. When Q7 is OFF (output of U3 is at positive saturation), the Mechanical Stop will move toward the rear of the injector head (when the injector is armed). When Q7 is ON (output of

U3 is at negative saturation), the Mechanical Stop will move toward the front of the injector head (when the injection is complete).

Triangular Ramp Generator

A triangular waveform is generated on the U2D non-inverting input.

Overcurrent Shutdown Circuit

If excessive current flows through sampling resistor R32, the voltage developed activates Q5 and Q6, triggering one-shot U1, and disabling ramp generator U2D.

Switched -26 VDC

A pair of normally-closed contacts on the Safe Relay complete the path for -26 VDC to the Mechanical Stop Drive Card, which enables the motor to run while the injector is disarmed. When the injector is armed and the system has determined that the Mechanical Stop is in position, the Safe Relay is energized and the contacts are opened to the MSD Card, removing -26 VDC, which disables the motor.

Injector Head Indicators

The armed light (L1) on the head is controlled by Q1. Syringe size indicators are controlled by Q2 and Q3. Control signals for these indicators originate at the 150/200 Enable on the I/O Card.

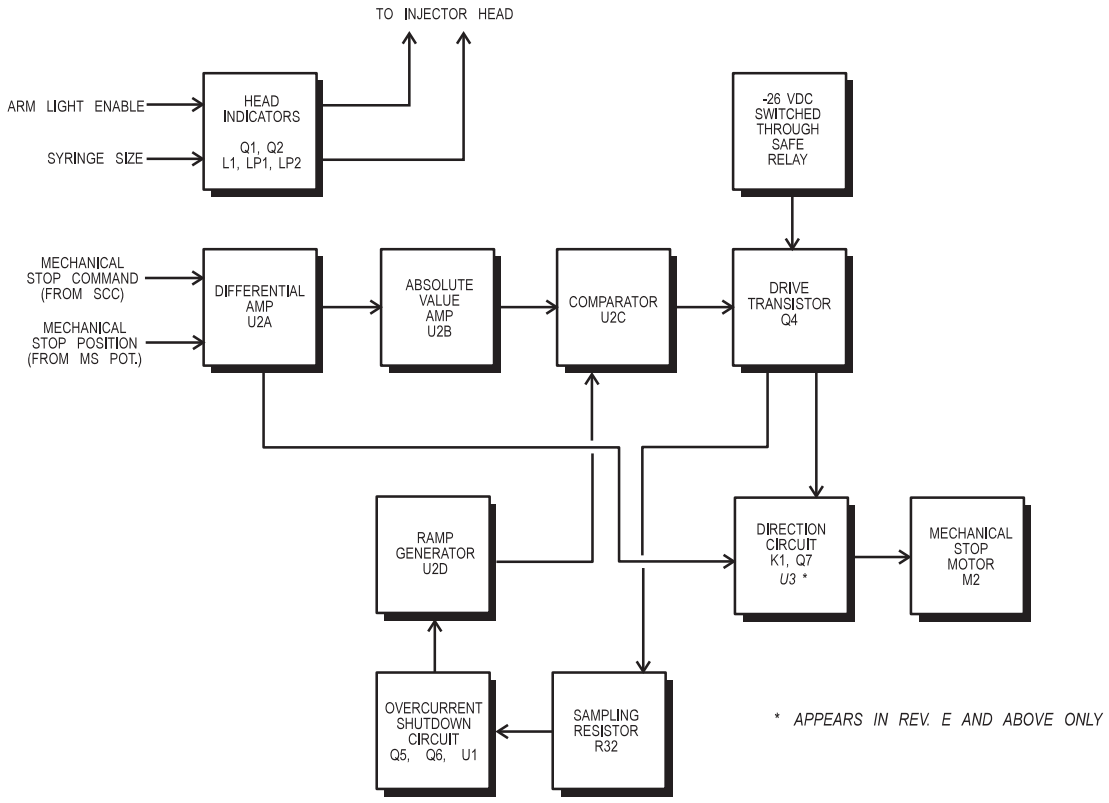


Figure 11.1: Block Diagram: Mechanical Stop Drive Card

12 Power Supply Card

The Power Supply Card supplies all low voltage power (26V and below) to the injector system.

Refer to Figure 12.1 for a block diagram of the Power Supply Card.

+26 VDC and -26 VDC Supply

One winding on the power transformer supplies fused 36 VAC to bridge rectifier Z1. The center tap of the 36 VAC winding is ground. Bipolar bridge output is filtered for +26 VDC, while outputs from Z1 are +26 VDC and -26 VDC.

+15 VDC and -15 VDC Supply

The +26 VDC supply is regulated to +15 VDC by U2, voltage is filtered by C12. The -26 VDC supply is regulated to -15 VDC by U3, voltage is filtered by C15.

+5 VDC Regulator Circuit

The +26 VDC supply is filtered then regulated to +5 VDC using Pulse Width Modulator (PWM) U1 to switch a portion of the +26 VDC supply through FET Q4. Pins 11 and 14 of U1, will pulse low then high, at a frequency determined by R13, R14, and C8 (approximately 330 KHz). The pulses are ORed through D3 and D4, and applied to Q3 and Q5, which will pulse the gate of FET Q4. Zener diode D2 protects Q4 by limiting the gate to source voltage to a maximum of 15 volts. The output of Q4 is filtered by inductor L1, capacitors C1 - C3, and load resistor R1.

Regulation of the +5 VDC supply is through the PWM IC and support circuitry. Resistors R19 and R20 set up reference at U1 pin 2. The +5 VDC is coupled back to U1 pin 1, through a voltage divider network of R16 and R18. The two voltages are compared to determine pulse width at U1 pins 11 and 14. If the voltage is low, pulse width is lengthened to increase voltage; if voltage is high, pulse width is shortened to decrease voltage.

+5 VDC Overcurrent Protection

The +5 VDC supply has overcurrent protection circuitry will shut down the PWM IC (and +5 VDC circuit) if current exceeds 6-8 amperes. If voltage across sampling resistor R2 exceeds a certain value, Q1 and Q2 conduct, switching power to U1 pin 10 (Shut Down), which stops pulses at pins 11 and 14. The PWM IC will restart and restore +5 VDC if the overcurrent condition is eliminated.

+5 VDC Overvoltage Protection

+5 VDC overvoltage protection is provided by 6.2 VDC zener diode D6, and 3.15 amp fuse F6. If the supply rises above +5 VDC, D6 begins to conduct and draw current. If voltage continues to rise, D6 will breakdown and short the +5 VDC supply to ground. The combination of voltage and current drawn when D6 shorts, will trigger F6 to open, removing the +26 VDC from the PWM.

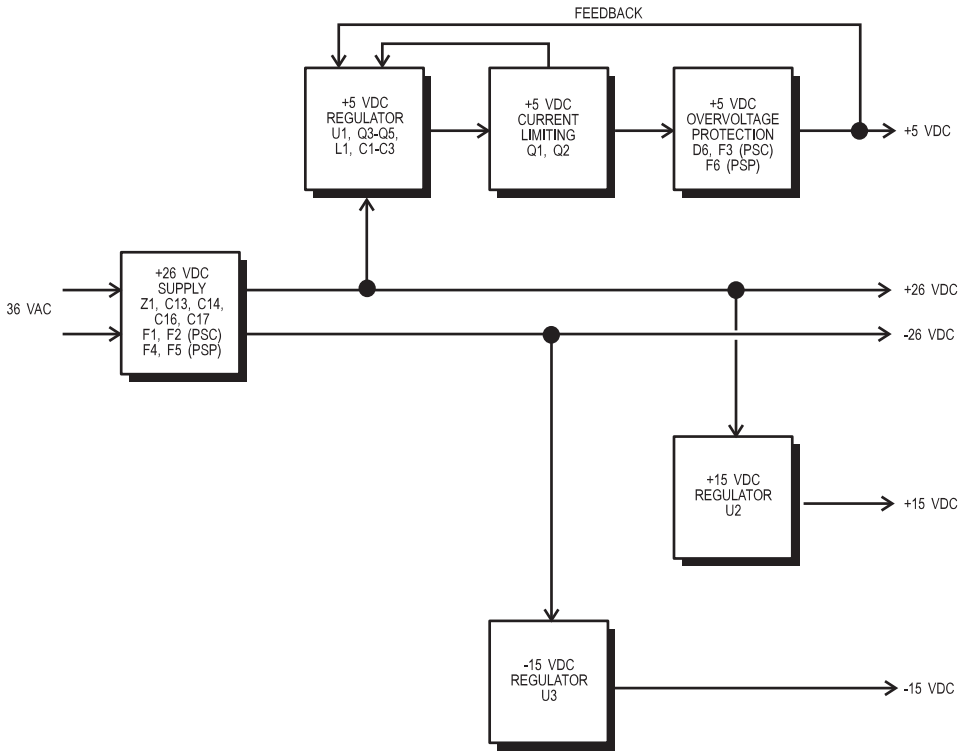


Figure 12.1: Block Diagram: Power Supply Card

13 Injector Head

This section describes the components and circuitry in the Injector Head. The following is a summary of the primary injector head components:

Injector Head Body
Houses the drive and feedback systems for the syringe piston and automatic mechanical stop.

Syringe Heat Maintainer
Fits on pressure jacket; Maintains syringe fluid temperature at approximately 98.6° F (37° C).

Injector Head Scale Overlay/Plate
Contains the forward and reverse load controls and indicators that show armed status, selected syringe size, piston position / Volume Remaining, and Mechanical Stop position/status.

Turret Sensing Circuit and Limit Switches
Provide indication signals to the console if the turret is out of position, or the Mechanical Stop is in contact with the Ball Nut Plate.

Head Cable
Connects to the rear of the Main Unit through a screw-on ring type connector at J21. The Head Cable carries the drive voltages and other signals which control Injector Head functions. Internal connector(s) aid in cable replacement.

Drive Systems

There are two motors and drive systems in the injector head: The Syringe piston, and Automatic Mechanical Stop. The piston motor (M1), is larger than the Mechanical Stop motor (M2). Both motors incorporate belt drives for smooth, quiet operation.

Rotary motion of the piston motor (M1) is converted to linear motion by a ballscrew. The Mechanical Stop Motor (M2), drives two acme screws, one on each side of the piston. These acme screws move the Mechanical Stop Plate between the ball nut plate and the front of the head. The function of this drive system is to position the Mechanical Stop as an over-volume prevention backup.

Feedback Pots

There are two independent feedback pots in the injector head which share a common reference voltage. R1 monitors plunger position, and R2 monitors Mechanical Stop position.

- The wiper voltage from R1 is sent to the SCC, then buffered and filtered to derive the plunger position signal. This signal represents the actual plunger position.
- The wiper voltage from R2 is sent to the Mechanical Stop Drive Card and the SCC, representing the actual Mechanical Stop position.

Syringe Heat Maintainer

The syringe heat maintainer is used to maintain the temperature of contrast media in the syringe. Syringe temperature is maintained through thermostats, and an over-temperature sensor/indicator in the pod. Supply voltage (+26 VDC) comes from the power supply. A 2-pin connector allows quick replacement.

Forward/Reverse/ Enable Circuit

This circuit provides variable forward and reverse load speed control, using a “soft pot” which varies voltage applied to the PDCI load circuit. A “soft pot” is a flat, membrane-type potentiometer, that alters resistance according to what point on the potentiometer is pressed. The ENABLE button is a safeguard against accidental loading if either the forward or reverse load button should fail in the closed position.

Forward/Reverse Loading:
When ENABLE is pressed, +15 volts is supplied to one side of the soft pot; the other is connected to a voltage divider (referenced at 8.5 volts) through Q2. When both FORWARD and ENABLE are pressed, soft pot wiper voltage is sent to RN1, then to transistor Q3. Q3 functions as a emitter follower, to buffer the forward load command, before it is sent to the PDCI. When REVERSE and ENABLE are pressed, soft pot wiper voltage is sent to RN1, then to transistor Q5. Q5 also functions as a emitter follower, buffering the reverse load (REV) command before it is sent to the PDCI. The voltage range of the Forward or Reverse load command is +9.1 to 15 volts (slow to fast). If both Forward and Reverse load are pressed, there is no piston movement.

The non-inverting inputs of U2A and U2D are referenced at +7 volts by voltage dividers R1, R4, and R3. The outputs are positive, and do not effect normal loading. When both load buttons are pressed (assuming Enable is also pressed), both inverting inputs (of U2A and U2D) will have a greater positive value than the reference voltage (+9.1 volts minimum), causing outputs to go to zero. This makes Z2 and Z6 (5.1 volt zener diodes) conduct, clamping the load voltage sent to the PDCI (junctions of Z2/Q3 and Z6/Q5) at +5.1 volts. This low amplitude is not sufficient to drive the piston motor, and will therefore disarm the injector.

Timed Enable Button:
Timed Enable is designed to allow the operator to move the plunger piston forward or reverse by using the Forward/Reverse softpots only after the ENABLE button is depressed. In a no load condition, the Enable input is at +5V. Zener diode Z1 keeps the Enable LED off until the ENABLE button is pressed.

When the ENABLE button is pressed, the Enable input (J71, pin 8) goes to +15V at the junction of Z1 and C3. This input provides two functions. First, the Enable LED Indicator receives positive voltage through Z1 and R8, causing it to illuminate. Second, +15V is applied to the junction of C3 and RN1/RN2, producing a positive pulse. The positive pulse is applied to the inverting input of U2A pin 6, switching the output to negative. This negative output is applied to the trigger input of U1 pin 2, producing a positive pulse for U2B. Pulse duration is approximately 5 seconds. This pulse, applied to U2B pin 4, causes the output of U2B to switch negative. Q1 conducts and passes +15V to hold the Enable line input positive. The action continues throughout the duration of the pulse.

When the FWD or REV button button is pressed, +8V to +14V is applied to the inverting input of U2D through RN1/D1 (FWD) or RN1/D2 (REV). R1 and C6 provide a 100 mS delay when the load button is pressed. When a U2D inverting input votage is greater than +5.5V, the output of U2D will switch the output negative. This negative voltage discharges capacitor C5, and prevents U1 from resetting.

NOTE: If the load button is released, the Timed Enable circuit will remain active for approximately 5 seconds. One button loading is still available during this time.

If FWD or REV is pressed prior to, or simultaneously with, the ENABLE button, the Timed Enable circuit is disabled, and the injector head will function without the Timed Enable feature. This occurs when the inverting input to U2C (pin 10) goes more positive than the non-inverting input (pin 11 referenced at +1.9V). The output of U2C switches to negative, grounding the inverting input to U2A. If the ENABLE switch is pressed, the pulse developed by C3 and RN1/RN2 is grounded, and the Timed Enable circuit is not activated.

Single Button Disarm:
Pressing any button, or combination of buttons on the Injector Head, will disarm the injector. Approximately 2-5 volts is required to disable the Safe Relay and disarm the injector. If Forward or Reverse load are pressed, +5 volts supplies the soft pots through D4, and follows the same path as normal loading. If Enable is pressed, +15 volts goes through the switch, R11, D3 and D5, and Q3 and Q5 to the PDCI. In either case, the voltage is sensed as a disarm.

Forward/Reverse Clamping Circuit

This circuit protects the piston motor and ballscrew from high speed collisions by clamping the load command at the slow speed value when the piston is approximately 0.25” (0.635 cm) from forward or reverse limits. At fast speed, approximately +14 volts is applied to the drive circuit on the PDCI. As the piston approaches front or rear limits, the load command is clamped to +9.1 volts (slow speed).

Forward Load Clamp - U1B/Z1:
The non-inverting input of U1B is referenced at +9.0 volts by a voltage divider consisting of R8, R9, R7, and R17. The inverting input is a buffered plunger position voltage (U3A), while output of U1B is in positive saturation if the plunger position is below the reference. As the piston moves forward, plunger position voltage increases. When the reference input is reached, U1B goes to zero, making Z1 (9.1 volts zener diode) conduct, clamping the forward load command (base of Q3) to +9.1 volts, driving the motor at slow speed.

Reverse Load Clamp - (U2B/Z5):
The inverting input of U2B is referenced at +0.66 volts by a voltage divider consisting of R8, R9, R7, and R17. The non-inverting input is a buffered plunger position voltage (U3A), while output of U2B is in positive saturation if plunger position is above the reference. As the piston moves in reverse, plunger position voltage decreases. When voltage drops below the reference input, U2B goes to zero, making Z5 (9.1 volts zener diode) conduct; thus clamping the reverse load command (base of Q5) to +9.1 volts, driving the motor at slow speed.

Volume Remaining Display

The Volume Remaining Display provides a 3 digit display of the amount of contrast media remaining in the syringe. DVM IC U4 uses the buffered plunger position from U2A to derive the Volume Remaining Display (seven segment LED output). The plunger position is inverted and offset by U2C and sent to the scale switching voltage divider network R23, R4, R6, R14, R16, Q5, and Q6. The output of the divider is sent to the input of U4.

PAL’s U8 and U9 buffer the LED outputs and drive the seven segment LED’s directly (non-multiplexed). The PAL’s are also responsible for all leading zero blanking, and displaying “200”.

U5 is a supply IC that produces the -5V supply required by U4.

Turret Sensing Circuit

The Turret Sensing circuit detects if the turret is in position for an injection or loading without the use of mechanical limit switches.

Turret Detection:
When the turret is in position, +26 volts follows a series path from the Injector Head to the PDCI and SCC. When the turret is in position, +26 volts is switched through transistor Q7. Q7 is enabled by either U8E/D8 or U4C/D9, depending upon turret position. Next, the voltage is sent through the normally open contacts of the Mechanical Stop Limit switch; then, to energize Safe Relay K1 (PDCI) and U16 (PIO 3 on the SCC), alerting the system that the injector head is ready for injection. To determine if the turret is in position, an optical sensing circuit is used. Two optical sensors, mounted on a PC Card in the Injector Head, are set-up as “active high”, meaning that the transistor portion of the sensor is ON (or active), when infrared light passes from the LED to the base of the transistor. The slotted drum, mounted on the turret shaft, rotates with the turret, and permits activation of the sensor that corresponds to turret position.

Mechanical Stop Position / Arm Light Enable Circuit

This circuit provides a visual indication that the Mechanical Stop is in position, and that the injector is armed. When the injector is armed, the software sends a position command to the Mechanical Stop DAC, producing an analog command voltage for the MSD Card, which drives the Mechanical Stop motor. Mechanical Stop position is tracked by the Mechanical Stop Position Feedback Potentiometer. When the position feedback voltage indicates that the Mechanical Stop is correctly positioned (through software comparison with the Mechanical Stop Position Command), the system sends an ARMED indication through the I/O and MSD cards, which lights the Mechanical Stop Set LED, and makes the Arm Light Bar flash.

Mechanical Stop in Position:
In standby, the non-inverting input of U1A is +5 volts (charging of C8 through R14), and inverting input is +3.4 volts (voltage divider R21/R26), making the output of U1A positive saturation. When the injector is armed, and the system has determined that the Mechanical Stop is correctly positioned, ARMLTDR alternates low then high, momentarily discharging C8 through D1, dropping the non-inverting input to zero. Positive 3.4 volts on the inverting input causes the output to go to zero, which makes Q1 conduct, supplying ground to light Mechanical Stop Set LED DS1. The narrow width of the ARMLTDR pulses, coupled with the large value of R14, prevents C8 from charging, keeping output of U1A at zero, and the LED lit continuously until the injector is disarmed.

Arm Light Bar Enable:
When the injector is armed, ARMLTDR alternates low then high, causing the Arm Light Bar to flash. When the handswitch is pressed to initiate the injection, ARMLTDR stays low, keeping the Arm Light Bar lit continuously throughout the injection. When the injection is complete, ARMLTDR will either alternate low then high (MULTI Arm), or remain high (SINGLE Arm).

Mechanical Stop Motor Disable

This circuit disables the Mechanical Stop motor M2 if the piston is in the full forward position when power is applied. This prevents the Mechanical Stop and piston plates from colliding during Self Test. The voltage path for M2 goes through the normally-closed contacts of relay K1 (located on the Injector Head Card), which is controlled by U2C. U2C compares the plunger position with a set reference to energize K1. The non-inverting input of U2C (pin 9), is fixed at +9.35 volts by a voltage divider network (R7,R8,R9,R17), while the inverting input (pin 8), receives the buffer plunger position voltage from U3A. When the piston is not at full forward limit, voltage at pin 9 is greater than that at pin 8, making the output of U2C (pin 14) positive saturation, de-energizing K1. As the piston moves forward, voltage at pin 8 increases. When the voltage at pin 8 exceeds that at pin 9, U2C switches to zero, making Q4 conduct, and energizing K1. The normally-closed contacts of K1 open, breaking the Mechanical Stop motor voltage path.

SIP Switches

The injector head Display Card contains several SIP type switches for proper set-up of the card. The switches must be set according to the type of injector head in which the card is installed. Refer to the chart below:

	SWITCH SETTINGS							
	S1-1	*S1-2*	*S1-3*	*S1-4*	*S2-1*	*S2-2*	*S2-3*	*S2-4*
60/150	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
150/200	ON	OFF	ON	OFF	ON	ON	OFF	OFF

S1 - 1 = 150 ml SCALE SELECTION
S1 - 2 = NOT USED
S1 - 3 = 200 ml SCALE SELECTION
S1 - 3 = NOT USED
S1 - 4 = 63 ml SCALE SELECTION
S2 - 1 = SYRINGE SELECT BAR LAMPS ON/OFF
S2 - 2 = TURRET 60 ml POSITION DISABLE/ENABLE (ON/OFF)
S2 - 3 = TURRET POSITION SENSE DISABLE/ENABLE (ON/OFF)
S2 - 4 = TURRET POSITION SENSE DISABLE/ENABLE (ON/OFF)

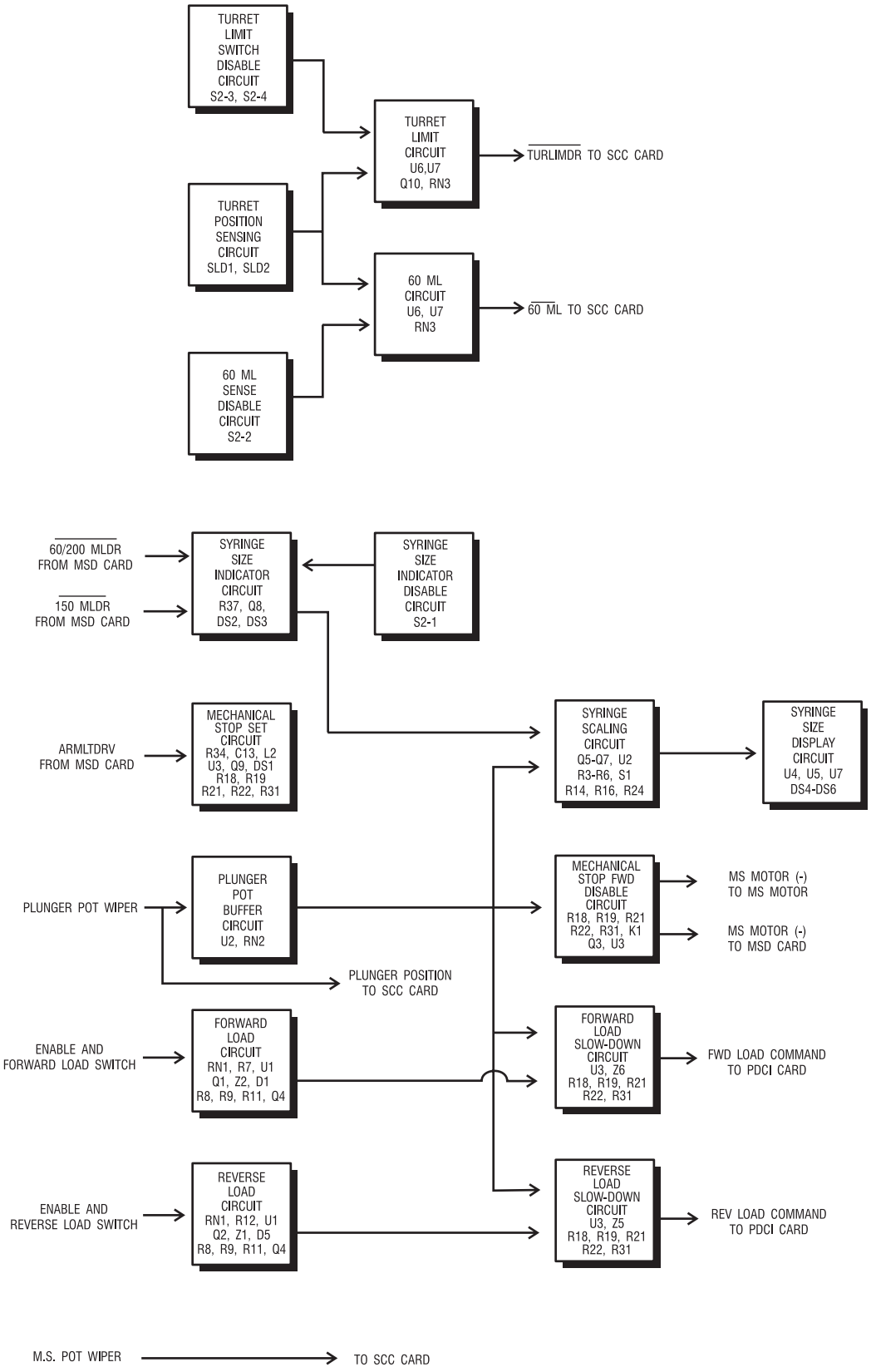


Figure 13.1: Block Diagram: Head Card

NOTES:

14 Imaging System Interface

The Imaging System Interface, ISI 100, is an option that allows the *Mark V ProVis* Injection System to be interfaced with film changer programmers, computer systems, and other digital imaging equipment. This card also provides I/O for control and synchronization of the injection for remote monitoring.

NOTE: When reference is made to input and output, the reference is in respect to the injector.

To achieve control and synchronization, eight inputs and outputs are provided by the Imaging System Interface group (available at J40 on the rear connector panel):

- Disarm control input
- Handswitch disable input
- Injector start input
- Injecting signal output
- Armed / Extended Armed signal output
- X-Ray Trigger Output
- Handswitch Closed

CAUTION: **The Remote Start Signal from the film changer programmer (at pins 7 and 9 of J40), must never contain voltage or AC noise.** Any voltage applied to these pins can damage the injector and void the warranty. Excessive AC noise on these lines may cause intermittent problems of premature, or no injections.

CAUTION: The Remote Start Signal from the film changer programmer must remain closed throughout the duration of the injection. If the start signal is removed before the injection volume limits when armed in the SINGLE mode, the injection will stop, the unit will disarm, and display “PREMATURE TERMINATION” on the Control Panel. If the start signal is removed before the injection volume limits when armed in the MULTIple mode, the injection will stop, the Mechanical Stop will reposition at the selected volume, and the unit will remain armed. If a start signal is received at this time, an additional injection will result at the selected Flow Rate and Volume.

It is recommended that the remote start command remain closed for approximately three additional seconds after the calculated injection duration. This additional time should allow completion of the injection in the event that the actual injection duration is longer than the calculated duration. (When the injector pressure limits, and/or a linear rise factor is programmed, the calculated injection duration will increase accordingly.)

CAUTION: When starting the injection process from a remote location by the use of a relay closure in the film changer programmer, always install a “panic button” in series with the start signal. This function must be provided in the event that the operator must immediately terminate the injection. This button should be installed in a convenient location, properly labeled, and instructions for use provided to all users of the injection system.

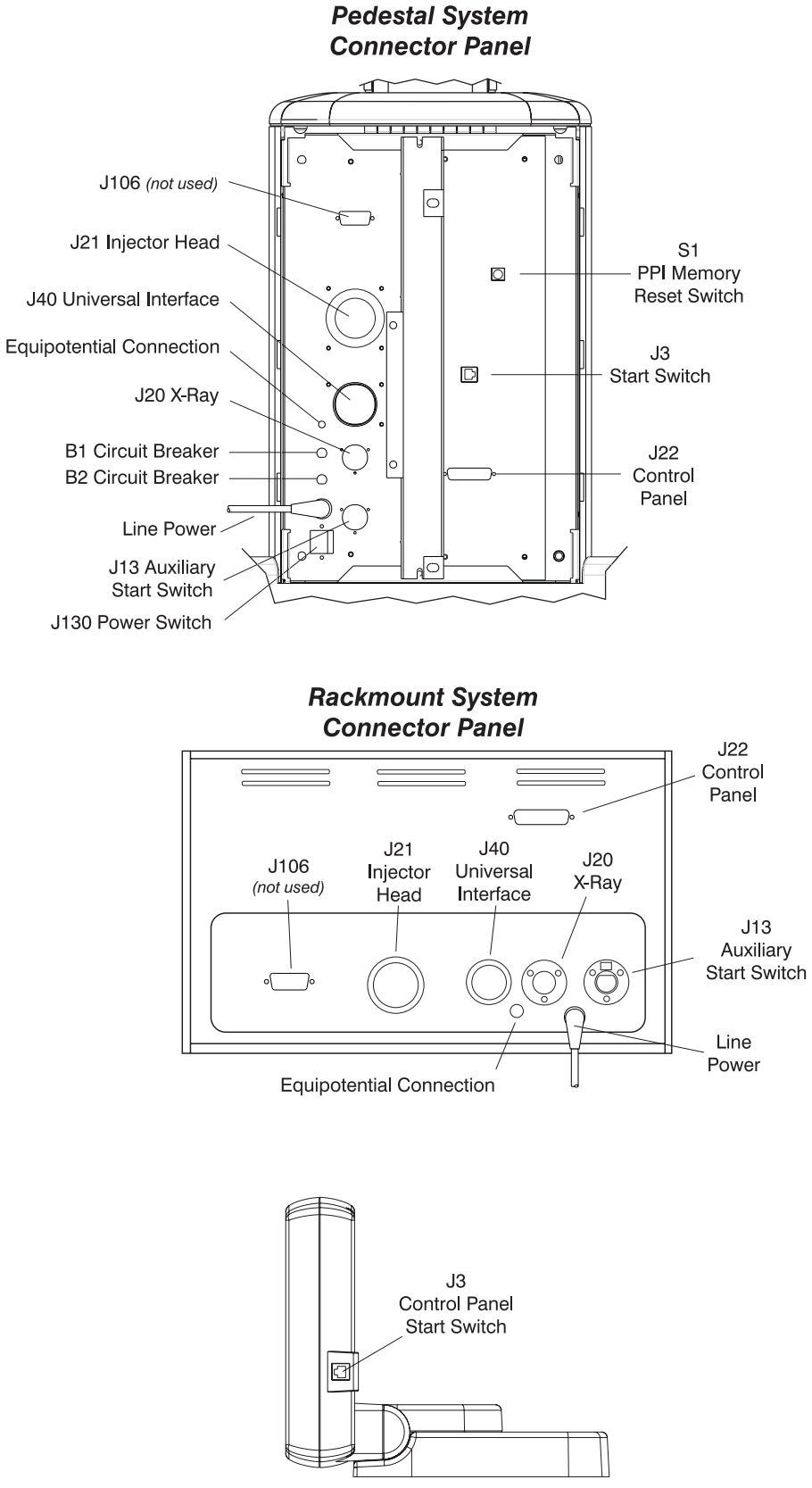


Figure 14.1: Connector Locations

Imaging System Interface Circuits are located on the ISI 100 Option Card. The disarm and handswitch disable inputs are buffered by a separate circuit on the motherboard. For the following description, refer to Figure 14.2.

Disarm Input Circuit

Inverters / buffers U3D and U3E comprise the Remote Disarm Input Circuit. These components are controlled by an external switch closure, connecting J40 pins 6 and 8. When the external switch closes, U3D activates a signal that disarms, or prevents arming of the injector. When the external switch opens, the injector can then be armed.

CAUTION: **Do not apply voltage to J40 pins 6 or 8.** Equipment damage or malfunction may result.

Handswitch Disable Input Circuit

Inverter U3A and relay K3 comprise the Handswitch Disable Input Circuit. This circuit is controlled by an external switch closure, connecting J40 pins 5 and 6. This circuit can disable the injector handswitch, making the start of an injection possible only from a remote start control. This disabling is useful in the prevention of miscued starts by the operator when connected to an imaging system. When the external switch closes, relay K3 energizes and disables the handswitch circuit. When the external switch opens, the handswitch circuit again functions normally.

NOTE: This input disables the RJ Start Switch at J1 on Rackmount systems, and J3 on Pedestal systems.

NOTE: When using this input, the injector can still be started from the Control Panel (if the jumper on the the Controller Card is connecting pins 1 and 2), J20, or J40.

CAUTION: **Do not apply voltage to J40 pins 5 or 6.** Equipment damage or malfunction may result.

Handswitch Operated Output

This circuit provides an indication that the handswitch is closed when the Handswitch Disable circuit is active, through relay K2 and transistor Q4. When J40 pins 5 and 6 are shorted, the Handswitch Disable circuit is enabled, and the normal ground path of the handswitch is opened. When the handswitch is depressed, Q4 will activate, supplying ground to energize K2. This provides a relay closure at J40 pins 14 and 15, thus supplying the external device with an indication then the handswitch is depressed. When the Handswitch Disable circuit is disabled, J40 pins 5 and 6 are open, and K2 is disabled. Relay contacts at J40 pins 14 and 15 are rated for 28 VDC at 1 amp.

Injector Start Input

This input, at J40 pins 7 and 9, is used to start the injector from the Imaging System. This connection is the same as other hard-wired start switches. To start the injector after it has been armed, provide a switch or a pair of normally open, isolated relay contacts. The contacts must remain closed during the entire injection. Opening these contacts during the injection will result in the termination of the injection.

CAUTION: **Do not apply voltage to J40 pins 7 or 9.** Equipment damage or malfunction may result.

Injecting Output Circuit

The purpose of this output signal is very similar to that of the Injection Duration Output. The Injection Duration output is a voltage to an external monitor, while the injecting output is a relay closure to an Imaging System.

Inverter U3B and relay K2, comprise the Injecting Output Circuit. This “injecting” output from the injector, indicates when an injection is occurring, and is useful for timing, synchronization, and as a status indicator. Relay contacts of J40 pins 1 and 2, are open during standby, including when the injector is armed but not injecting. The contacts are closed during an injection, and open when the volume limit is reached, or the start switch is opened. Relay contact rating is 28 VDC, at 1 amp.

Armed Output Signals

J40 pins 3 and 4, provide an Armed output signal, or an Extended Armed Output signal as detailed below. At installation, switch S3 or jumper JU2A is used to select the appropriate signal: The purpose of this signal is to alert the film changer or Imaging System that the injector is armed and ready to inject, before initiating the filming sequence. Switch S3 or jumper JU2A is used to select either the “Armed” or “Extended Armed” output from pins 3 and 4 of J40.

Armed Output Signals
Inverter U3C and relay K1 comprise the armed output circuit. The signal at J40 pins 3 and 4, indicates when the injector is armed. The relay contacts are open when disarmed, or closed when single or multiple armed, regardless of start switch status. The injector must be armed before any injection can start. Relay contact maximum rating is 28 VDC, at 1 amp.

Extended Armed Output
This output uses the Armed Output Signal relay contacts. When the injector is “armed”, the contacts close, giving an indication to the imaging system that the injector is ready to inject. When the injection is complete, and the start switch (or external start lines) remain closed, the Extended Armed relay will remain closed, allowing the imaging system to complete the filming sequence. Although the Extended Armed Output remains active with the start lines closed, the Safe Relay will de-energize when a single bolus injection is complete. Relay contact maximum rating is 28 VDC, at 1 amp.

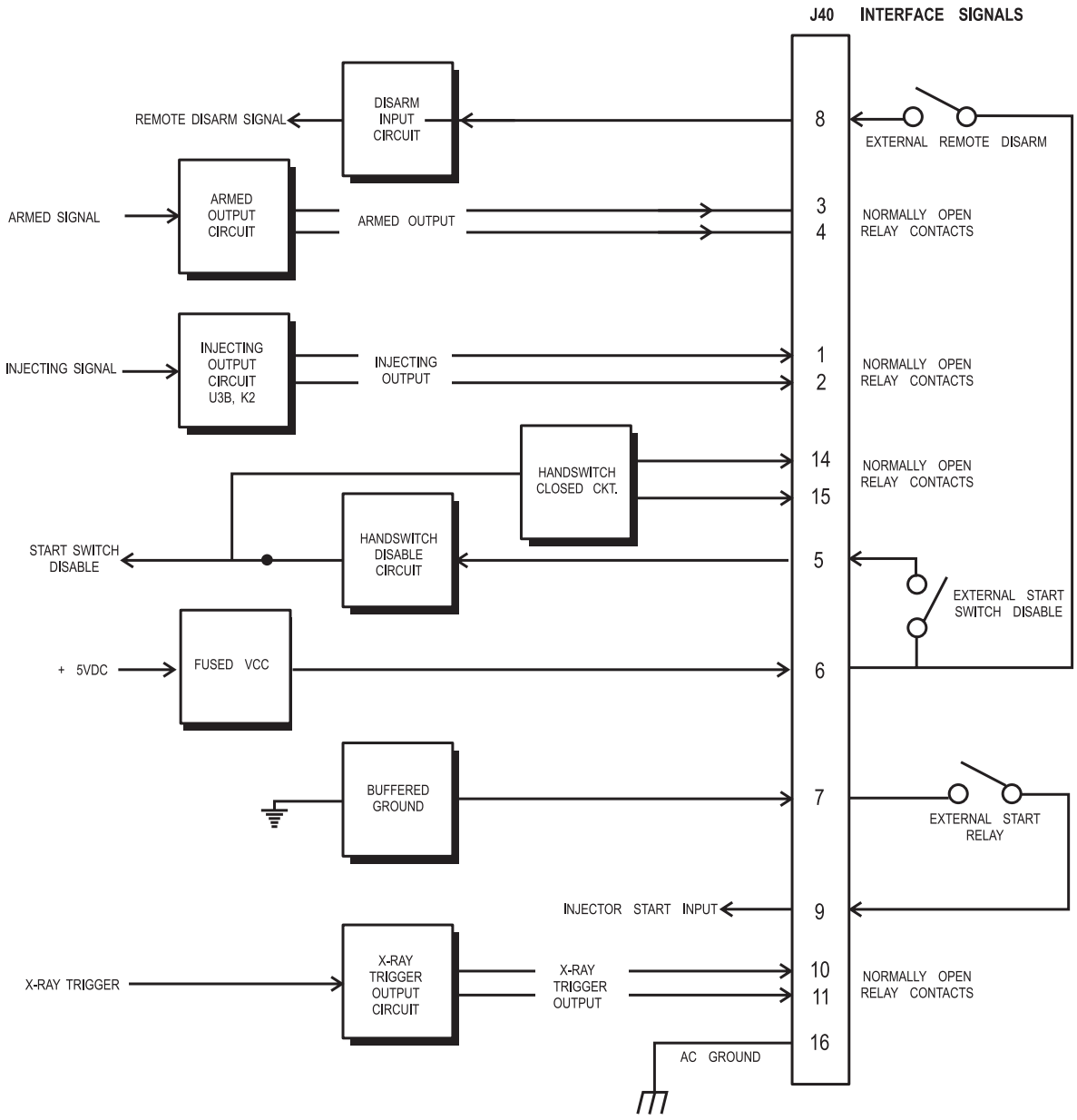


Figure 14.2: Block Diagram: Imaging System Interface

ISI Card *(with Siemens Z5 Option)*

When JU5 is set to the Z5 option (Siemens Interface), card operation is altered as outlined below.

NOTE: The default interface configuration of all *Mark V ProVis* Injection Systems is the Universal Interface Mode.

Injector Arming

When the injector is armed, a high signal (+5V) is supplied to U5D, pins 12 and 13, which produces a low (0V or ground) at pin 11. The low is directly coupled to U4A pin 2, producing a high output at U4A pin 3. The low causes relay K1 to energize, thus supplying +26VDC through connector J40 pin 4, to one side of the coil for relay SR4 in the Siemens equipment interface. The other side of SR4 is connected to Buffered Ground (BGND) through J40 pin 3. When SR4 energizes, +26VDC is supplied to one side of coils of Siemens interface relays SR1, SR2, and SR3.

Injection Initiation

In this interface mode, the injection is initiated by the Siemens imaging equipment. When the Injector Start command is initiated (on the Siemens equipment), relays SR1, SR2, and SR3 energize, supplying +26VDC to the coils of relay K2 on the ISI Card. The other side of the coil is connected to BGND through JU5, pins 5 and 6. When K2 energizes, BGND is supplied to J40 pin 2. Internal to the interface cable (XMC 970, 971, 972, or 973) is a jumper between J40 pin 2 and 9 (J40 pin 9 is the Remote Start), thus when K2 energizes, BGND is supplied to J40 pin 9 through J40 pin 2.

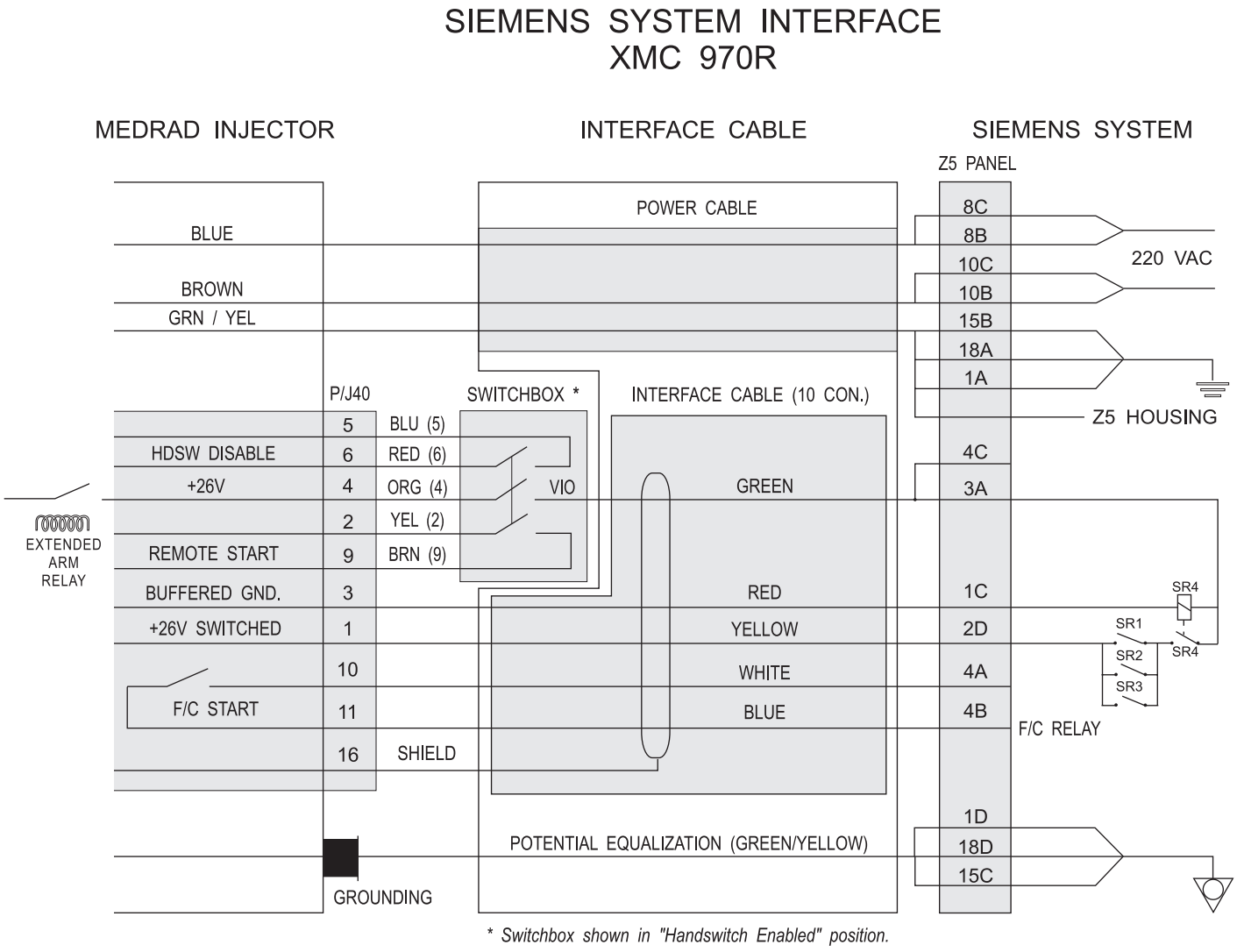


Figure 14.3: Schematic:Siemens Interface (with Switchbox Option)

The Siemens table can be fitted with an adaptor (MEDRAD catalog number SCK 100) which allows the Injector Head to be mounted directly to the table. Contact MEDRAD for availability.

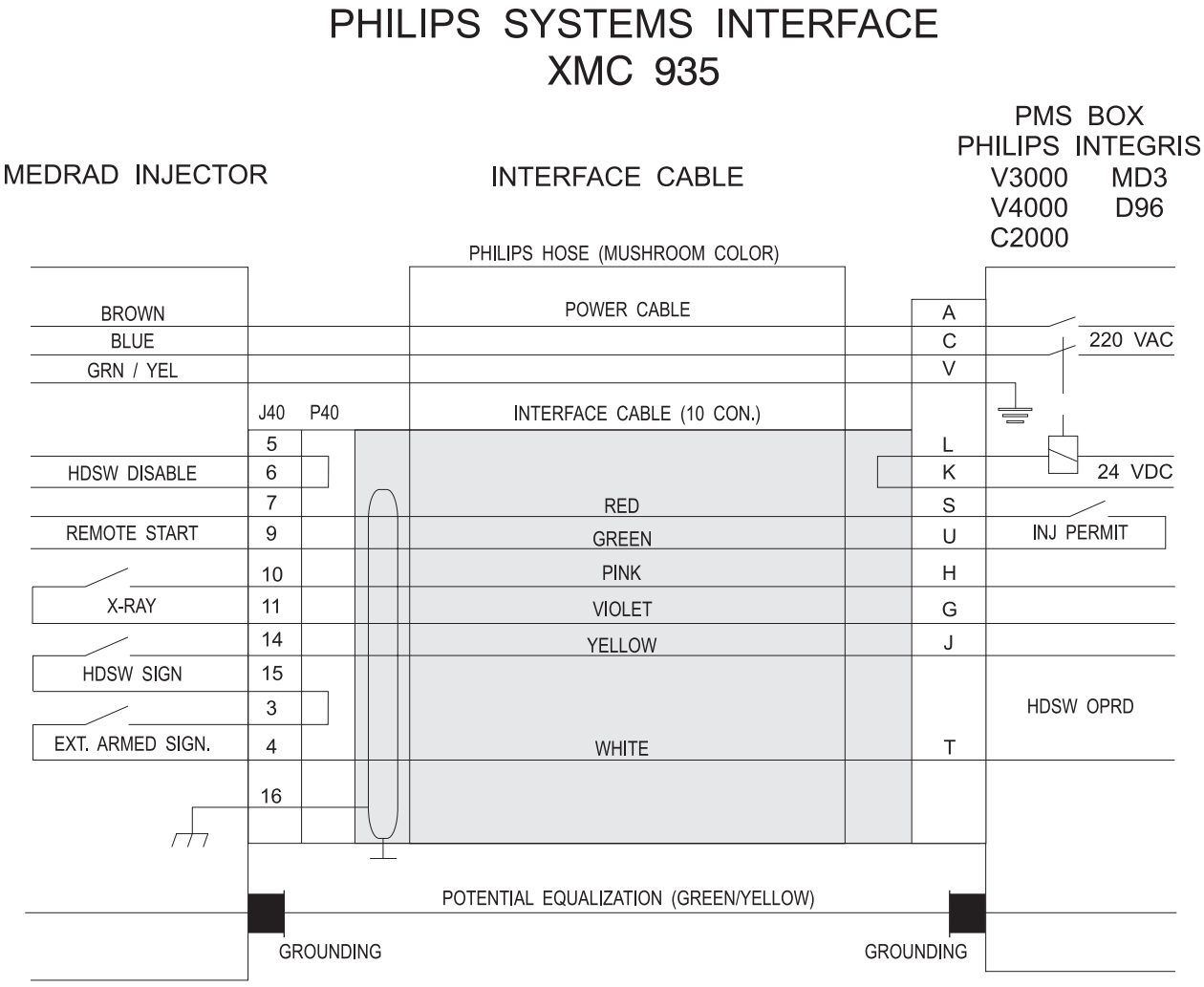


Figure 14.4: Schematic: Phillips Interface XMC 935

The Phillips table can be fitted with an adaptor (MEDRAD catalog number PCK 100) which allows the Injector Head to be mounted directly to the table. Contact MEDRAD for availability.

NOTES:

15 Troubleshooting Guide

The following represents test equipment that may be needed to service a *Mark V ProVis* system, depending on what is being repaired or replaced.

Required Test Equipment

- Digital voltmeter (DVM) (Fluke 87 or True RMS equivalent)
- Oscilloscope (for minor troubleshooting and calibration; not for major repairs) (Tektronix 465 or equivalent)
- Leakage Tester (for checking line leakage)
- Stopwatch or Timer
- KSP 591
    - 25-pin card/cable extender (for PSC and MSC Cards) - MEDRAD part number 78101-01-AC-04
    - 37-pin card/cable extender (for Power Drive Card) - MEDRAD part number 78101-01-AC-05
    - Service Access Card- MEDRAD part number 85106-05-AP-01
    - Portable Digital Timer - MEDRAD part number KSP-141
- Pressure Gauge Assembly - MEDRAD part number KSP-135

Service Access Card

The Service Access Card is inserted in the spare slot on the right side of the Console, providing easy access to test points for troubleshooting and testing. All signals are clearly marked on the card next to the test points.

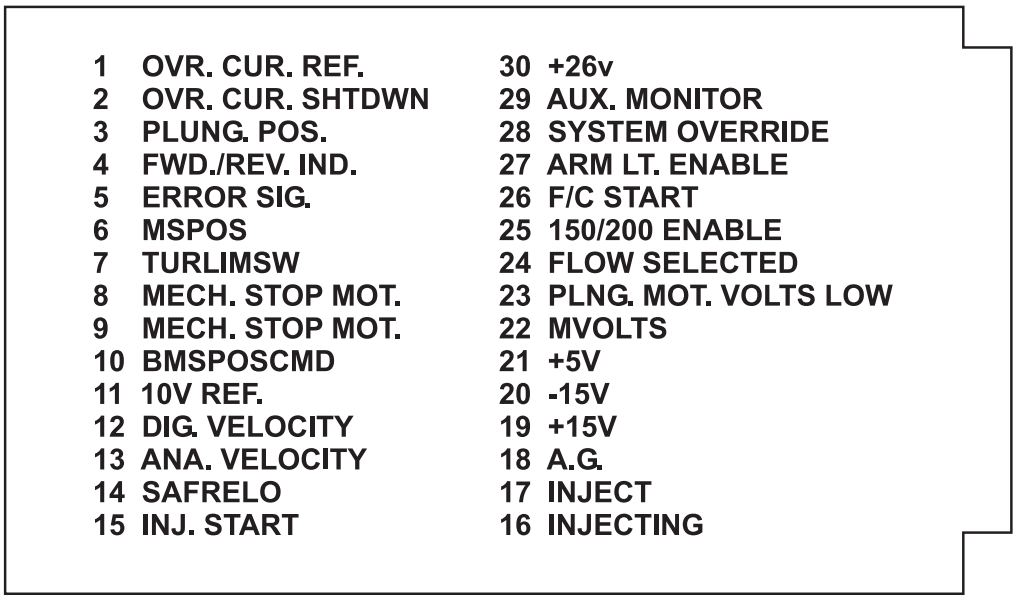


Figure 15.1: Test Points on Service Access Card

SAC Test Points

The following information refers to the test points on the Service Access Card. The measurement should be within 10% of the values given below. Values are with reference to analog ground, test point 18, unless otherwise specified.

	Test Point / Description	***Typical Values***
1	OVR. CUR. REF. *Overcurrent Reference*	-6 VDC at all times.
2	OVR. CUR. SHTDWN *Overcurrent Shutdown*	+14 VDC at any status 14 VDC during overcurrent shutdown, and then only briefly at the onset of a high Flow Rate injection in the 150 ml mode.
3	PLNG. POS. *Buffered Plunger Position*	+0.25 - +9.60 VDC, depending on plunger position.
4	FWD. REV. IND. *Fwd. or Rev. Indications*	Standby = 5 VDC Fwd activated = 0 VDC Rev activated = 0 VDC
5	ERROR SIG. *Error Signal*	Standby/Loading=0 Between zero and +15 VDC during an injection. Less than +6 VDC during most injections.
6	MSPOS *Buffered Mech. Stop Pos*.	+0.25 +/- 9.60 VDC, depending on Mechanical Stop position.
7	TURLIMSW *Turret Limit Switch*	+24 VDC when turret in place and the Mechanical Stop is not engaged. Zero when the turret is out of position or the stop is engaged.
8	MECH. STOP MOT. *Mechanical Stop Motor (+)*	+24 VDC during standby; zero to +24 VDC (switching) when the Mechanical Stop is moving in reverse. Zero when armed, the stop is moving forward, +24 VDC when the stop is positioned.
9	MECH. STOP MOT. *Mechanical Stop motor (-)*	-24 VDC during standby; zero when the Mechanical Stop is moving in reverse; may oscillate as stop is positioned; stays at zero when stop is positioned; -24 VDC when disarmed.

	Test Point / Description	***Typical Values***
10	BMSPOSCMD *Buffered M/S Position CMD*	Measure the same as test point 6 when the Mechanical Stop is not moving.
11	10V REF. *+10 VDC Reference*	+10.0 +0.1 VDC.
12	DIG. VELOCITY *Digital Velocity*	+0.1 VDC/ml (+4.0 VDC at 40 ml/sec).
13	ANA. VELOCITY *Analog Velocity*	+0.15 V/ml (+6.0 VDC at 40 ml/sec).
14	SAFRELO *Safe Relay Low*	+24 VDC when disarmed and not loading; less than +2 VDC when armed, injecting, or loading.
15	INJ. START *Inject Start*	+5 VDC when start switch open; 0 to +0.1 VDC when start switch closed.
16	INJECTING *Injecting*	Zero during standby; +5 VDC when injecting; immediately returns to zero at injection end - no delay.
17	INJECT *Inject*	Zero during standby; +15 VDC when injecting; should stay at +15 VDC for two seconds after the end of the injection, then return to zero. With ECG injections, stays high for one second at end of injection.
18	A.G. *Analog Ground*	Reference for other test point grounds.
19	+15V	+15 +/- 0.5 VDC.
20	-15V	-15 +/- 0.5 VDC.
21	+5V	+5 +/- 0.25 VDC
.		
22	MVOLTS *Motor Volts*	Injecting, 0 - +90 VDC, depending on speed. During forward load, typically measures 7-15 VDC. Reverse load - less than 0 VDC.

	Test Point / Description	***Typical Values***
23	PLNG. MOT. VOLTS LOW *Plunger Motor VDC Low Side*	Less than 1 VDC while injecting or forward load. +1 VDC with 1200 PSI. Reverse load 7-15 VDC.
24	FLOW SELECTED *Flow Selected*	Measure in ml/sec - 60 ml syringe, +0.38 VDC/ml. 150 ml syringe, +0.16 VDC/ml (+6.4 VDC at 40 ml/sec). 200 ml syringe, +0.12 VDC (+4.8 VDC at 40 ml/sec). In ml/min or ml/hr, less than 0.2 VDC.
25	150/200 ENABLE *150/200 Enable*	60 ml = 5 VDC 150 ml = 0 VDC 200 ml = 5 VDC
26	F/C START *Film Changer Start*	F/C Relay Open = 26 VDC F/C Relay Closed = 0 VDC
27	ARM LT. ENABLE *Arm Light Enable*	Light off = 0 VDC Light on = 5 VDC Flashing = Pulses 0 to 5 VDC
28	SYSTEM OVERRIDE *System Override*	Standby = 0 VDC Active state = 5 VDC
29	AUX MONITOR *Aux. Monitor*	Standby = -14 VDC Active state = 13 VDC
30	+26V	+26 VDC

Mark V ProVis Injection System Troubleshooting Guide

This section is a guide in tracking a condition to a board or subassembly. The first segment covers general troubleshooting guidelines, applicable to most conditions.

Most conditions will prompt a message to appear on the Sentinel. Using these messages, the condition can often be identified quickly. The second segment of this Troubleshooting Guide aids the user in determining the source of a condition when a message does appear on the Sentinel.

The last segment of this section is useful in determining the source of a condition when no message appears on the Sentinel.

For disassembly procedures, refer to Section 16, Unit Disassembly and Reassembly.

WARNING: Shock Hazard. Hazardous voltages exist within the injection system that can shock, burn, or cause death. To avoid injury, the system should be opened and serviced by qualified service personnel only. Disconnect the system from line power before cleaning or attempting to perform any maintenance

WARNING: **Immediately disconnect the patient from the injector if any system malfunction occurs.** If a system malfunction message appears, do not attempt to use the system until the source of the condition has been identified and corrected by qualified service personnel. Do not attempt to recreate any fault conditions while connected to a patient.

CAUTION: **Electrostatic Discharge (ESD).** Failure to follow ESD protection practices may result in equipment damage. ESD protection practices must be followed when servicing any component of this system.

Contents of this Section	*Page*

General Guidelines

Consider the following guidelines before troubleshooting any condition. These guidelines may help in resolving the condition quickly: Remember, try the simple things first.

1. Disconnect the injector from external equipment: Disconnect all cables connected to the injector, including those for the film changer, monitor, or external start switch.

2. To verify the existence of a condition, check injector operations before troubleshooting, using the Checkout Procedure located in the *Mark V ProVis* Injection System Operation Manual. Follow the steps that pertain to the major functions of the unit to verify the condition.

3. Remove power for one minute. Allow the unit to reset completely, then reapply power and retry. The condition could be intermittent, or caused by a voltage transient. If the condition persists, continue troubleshooting.

4. Open the Control Unit to remove/re-seat the cards. Remove each circuit card. While the cards are out, ensure that the socketed IC's are fully inserted. Reseat the cards, ensuring that the cards are fully inserted into the connectors on the Mother Board. Replace the card retainers.

5. The injection system is equipped with self-diagnostic software. A combination of safety circuits and software, provide the system with a diagnostic package that detects performance degradation, as well as total failures of portions of the system. Through Sentinel messages, the injector indicates self-diagnosed failures.

6. Any Sentinel message can symbolize a fault within the system. For example, if the Sentinel displays CHECK TURRET, when the turret is properly positioned, there may be a defective limit switch in the head. Watch for messages that contradict the obvious.

7. Some faults can be caused by a noisy electrical environment. For example, a memory error can be caused by a momentary power failure or drop, electrical noise in the power line, or noise in external interfaces.

8. Check power supplies at the Power Supply Card.

9. Always troubleshoot in a logical sequence. Trace a condition along the circuit paths in the unit, isolating the condition to a card or circuit section. This process is shown on the following pages.

10. For assistance in determining the cause of a condition, or in obtaining replacement cards, subassemblies, and parts, contact MEDRAD Factory Service or your local dealer.

12. Check injector operations after repairs to ensure that the condition has been corrected. Follow the Checkout Procedure outlined in the *Mark V ProVis* Injection System Operation Manual.

Suggested Troubleshooting Sequence

When a condition occurs, observe the Sentinel message code or symptom, and determine if the condition is being caused by the Control or Injection group of circuits. Isolate the condition to a board or boards, replace the board(s) or troubleshoot to component level. See Figure 15.2 below.

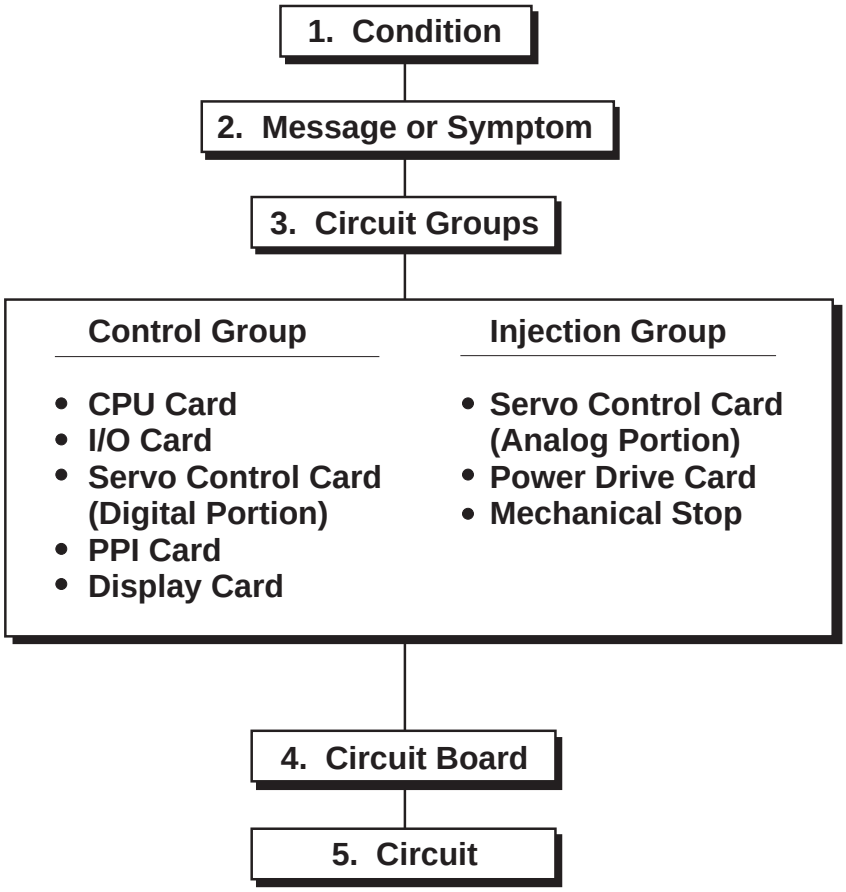


Figure 15.2: Suggested Troubleshooting Sequence

Message Faults

This section is a guide in the interpretation of messages displayed on the Sentinel. An alphabetical listing of all Sentinel messages follows, with a functional explanation and if applicable, possible solutions to the condition.

Messages preceeded by two asterisks (**) are critical faults, which cause the injector to cease functioning until the fault is cleared.

CAUTION: If the SENTINEL displays a system monitor type condition, do not attempt to use the injector until the source of the condition is determined and resolved. Equipment damage or malfunction may result.

The injector performs self diagnostic tests during power-up. If the injector fails any of these tests, an error message will be displayed on the Sentinel containing details of the fault.

Messages

ACTIVATE A FUNCTION
An attempt was made to enter a value without first activating an injector function. Press a Delta button before pressing any number buttons.

ADVANCE TO MAX LEVEL, THEN ARM
An attempt was made to arm at an intermediate level in a multiple-level injection. Advance to the highest level, then arm the unit.

AIR REMOVED FROM XXX SYRINGE?
This message appears when either the SINGLE or MULTIple arm button is pressed to begin the arming sequence.

Procedure:
1. Verify that there is no air in the syringe.
2. If the syringe is free of air bubbles, and the injection compressed, press YES.
3. If the syringe contains any air, press NO.

ALL PPI PROGRAM NUMBERS USED
There are no injection storage positions available in the PPI Memory. Review all stored programs, and delete those seldom or never used.

ARITH OVERFLOW IN FLOW CALC
This could be caused by a software condition or a fault in the system memory. Temporarily remove power from the injector, then reapply power and retry. If the condition persists, replace the CPU Card.

CALL MEDRAD SERVICE
Remove power from the injector for 10 seconds, reapply power, then attempt to operate the unit again.

If the condition persists:

A non-operator correctable system monitor condition has occurred which requires assistance from the MEDRAD Service department.

CAN NOT ROLL THE LEVEL DOWN
The LEVEL DOWN button was pressed with the injector at injection level 1. Press the LEVEL UP button to advance to other injection levels.

CHANGE FLOW SCALE? YES/NO
The Delta 3 button (Flow Scale) has been pressed. Press YES to change the Flow Scale. Press NO to return to present operations.

****CHECK INJ HEAD CABLE MS**
The feedback signal from the Mechanical Stop pot (in the head) is not within allowable limits.

Procedure:

1. Observe the Mechanical Stop position indicator on the injector head:
    - If the indicator is at the extreme forward position (beyond zero), it may be jammed; see step 6 below.
    - If the indicator is against the plunger indicator, the plunger plate may be jammed; see step 6 below.
    - If the indicator is between zero and the plunger position, continue with step 2.
2. Check the injector head cable and connectors for broken or intermittent connections.
3. If the condition persists, check the injector head for broken connections or an open Mechanical Stop pot.
4. If the condition persists, replace the Servo Control Card.
5. Replace the Mechanical Stop card.
6. The Mechanical Stop plate may be jammed. Remove the bottom cover of the head and attempt to move the belt manually.
7. If the condition persists, or if the Mechanical Stop cannot be manually moved, replace the injector head.

****CHECK INJ HEAD CABLE PL**
The feedback signal from the Plunger Position Pot is not within allowable limits.

Procedure:

1. Observe the plunger position indicator on the head Control Panel:
    - If the value displayed is zero, or in extreme reverse position (beyond 63, 150 or 200 ml) the plunger may be jammed; see step 2 below.
    - If the indicator is between the limits of travel, continue with step 3 below.
2. Attempt to move the plunger manually with the motor knob on the back of the head. If the plunger moves, or, the display changes, continue with step 3. If the condition persists, disassemble the head and attempt to manually move the plunger drive gear. The drive may be jammed.
3. Check the injector head cable and connectors for broken or intermittent connections.
4. Check the injector head for broken connections or an open plunger position pot.
5. If the condition persists, replace the Servo Control Card.
6. If the condition persists, replace the injector head.

CHECK TURRET OR MECHANICAL STOP
Turret is not in the proper position for an injection. The turret must be locked into position before the injector is armed. Forward load has been activated while the plunger is at the full forward limit (or the plunger plate is in contact with the mechanical stop plate), or, the turret is out of position.

Reverse the plunger to full reverse position, rotate turret in both directions, then lock turret in proper position.

If the problem persists:

1. Check the injector head cable and connectors for broken or intermittent connections.
2. Check the injector head for broken connections or a defective limit switch.
3. If the condition persists, replace the Servo Control Card.

CLEAR ALL PPI MEMORY - YES OR NO
Clears contents of PPI memory, in response to a RECALL 53. All preset injection programs can be erased. To erase all stored programs, press YES. To keep existing programs and return to normal operation, press NO.

CLEAR ALL VALUES - YES OR NO
Displayed after the CLEAR CUM PATIENT VOLUME - YES/NO message has been answered in the RESET procedure. To clear all currently displayed injection parameters, press YES. To return to normal operation, keeping currently displayed injection parameters, press NO.

CLEAR CUM PATIENT VOLUME - YES/NO
Displayed in response to the pressing of the RESET key. This procedure is used to reset the patient Volume accumulator, which records an accumulating total of the amount injected into each patient. To clear the existing total, (indicating a new patient), and begin accumulating the total Volume injected again, press YES. To protect this total, press NO.

CMD BLOCK NOT PROCESSED
Communication block from the Control Panel has not been properly processed. Remove and reapply power to the injector. If the problem persists, replace the CPU Card.

COMMUNICATIONS ABORTED
Control Panel does not respond, or responds with four consecutive negative acknowledgments. Remove and reapply power, then attempt to operate the unit again.

If the condition persists:

1. Check the Control Panel cable for broken or intermittent connections, focusing particular attention to shield and ground connections, then check continuity of the cable and connections.
2. If the condition persists, call MEDRAD Service.

COMMUNICATIONS ABORTED: NAKCOUNT
The Control Panel has received three consecutive negative acknowledgments from the Main Unit for a transmitted keystroke. Remove and reapply power, then attempt to operate the unit again.

If the condition persists:

1. Check the Control Panel cable for broken or intermittent connections, focusing particular attention to shield and ground connections, then check continuity of the cable and connections.
2. If the condition persists, call MEDRAD Service.

COMMUNICATIONS ABORTED: TIME-OUT
After three attempts to communicate, the Control Panel has not received a response from the Main Unit for a transmitted keystroke. Remove and reapply power, then attempt to operate the unit again.

If the condition persists:

1. Check the Control Panel cable for broken or intermittent connections, focusing particular attention to shield and ground connections, then check continuity of the cable and connections.
2. If the condition persists, call MEDRAD Service.

****CPU RAM CHECKSUM ERROR**
There is a fault in the RAM, located on the CPU Card. Remove and reapply power, then attempt to operate the unit again. If the condition persists, replace the CPU Card.

CPU: ROM CRC
The CPU Card ROM did not pass the Cyclic Redundancy Check. Remove and reapply power, then attempt to operate the unit again.

Procedure:

1. If the ROMs have been replaced as part of a software update procedure, they may have been installed in the wrong slots.
2. If the condition persists, replace the CPU Card with one containing a new set of ROMs.

CPU: SYS RAM
The CPU Card RAM failed a read/write exercise. Remove and reapply power, then attempt to operate the unit again. If the condition persists, replace the CPU Card.

CUMULATIVE PATIENT VOL XXX.X ML
The STATUS button was pressed; the message shows total Volume injected since the accumulator was reset. This keeps track of the total Volume injected into each patient.

DECIMAL NOT ALLOWED
Indicates that the variable must be entered as whole numbers (ex. 1,2,3), not in decimal form (1.2,1.3,1.4).

DUE TO R/F, MIN VOL = XXX.X ML
Selected Volume must be at least the quantity shown to deliver the selected Flow Rate within the specified Rise/Fall time.

ENTER DELAY
The Delta 7 button was pressed. The injector is now ready for an X-RAY or INJECT delay to be entered.

ENTER DURATION
The Delta 5 button was pressed. The injector is now ready for an Injection Duration to be entered.

ENTER FLOW RATE
The Delta 2 button was pressed. The injector is now ready for a Flow Rate value to be entered.

NOTE: Maximum Flow Rate of the 60 ml syringe system is 20.

ENTER PPI NUMBER XX, THEN STORE
The STORE button was pressed; displays the number of the next unused program storage location. Enter the number shown (or any number less than 50), then press STORE.

ENTER PRESSURE
The Delta 6 button was pressed. The injector is now ready for a Pressure Limit to be entered.

ENTER PROGRAM NUMBER THEN RECALL
The RECALL button was pressed. Press the number buttons to enter the program desired, then press the RECALL button again to enter.

ENTER PSI=1,KG=2,KPA=3,ATU=4
Program 51 was recalled to change the Pressure scale. Enter the corresponding number for the scale desired.

ENTER RISE/FALL TIME
Delta 1 was pressed. The injector is ready for the user to enter a rise or fall time.

ENTER SYRINGE SIZE: 60=1, 150=2
Displayed in response to RECALL, 50, in order change the programmed syringe size; or, displayed after the head selection step in the RECALL, 65 procedure. Enter the corresponding number of the syringe to be used in injection procedures.

ENTER SYRINGE SIZE: 150=2, 200=3
Displayed in response to RECALL, 50, in order change the programmed syringe size; or, displayed after the head selection step in the RECALL, 65 procedure. Enter the corresponding number of the syringe to be used in injection procedures.

ENTER THREE CHARACTER PASSWORD
Program 65 has been recalled to change the programmed head configuration. Enter the service access password, then select the proper head configuration.

ENTER TITLE OR STORE
STORE sequence prompt that is displayed after a PPI number has been entered; allows the user to add a title to the stored injection. Procedure: If a title is desired, enter numbers on the keypad or press SHIFT to enter letters. If no title is desired, press STORE again.

ENTER VALUES OR ARMSIZE XXX/TVOL XXX
The unit is in a stand-by condition. The operator may enter new values, or keep the existing values shown or arm by pressing one of the ARM buttons. The alternating message on the right displays the programmed syringe size and the total Volume selected.

ENTER VOLUME
The Delta 4 button was pressed. The injector is now ready for a Volume value to be entered.

ESTABLISHING COMMUNICATIONS
This message is displayed on the Control Panel after power-up or recovery from a system monitor condition. This message implies that the Control Panel is attempting to communicate with the Main Unit, not that a system monitor condition exists. If an error occurs, another message will be prompted to specify the nature of the communications failure.

****EXT START SHORTED**
There is a short in the external start circuit, or the external start switch is closed during the arming procedure.

Procedure:

1. Ensure that the start button is not pressed.
2. Disconnect any auxiliary start connections (footswitch, auxiliary handswitch, etc.), then retry.
3. If the injector now functions properly using an external start switch, check the start switch and cord reel for shorts and improper closure.
4. If the condition remains with the cord reel disconnected, replace the I/O Card.

EXTERNAL DISARM SIGNAL ACTIVE
External disarm input, available through the Imaging System Interface ISI-100, (J40) is active. The injector cannot be armed until this input is open.

****FLOW RATE D/A >0**
Output of the Flow Rate DAC is not zero during standby. Replace the Servo Control Card.

FWD/REV SWITCH DEPRESSED
One of the head load buttons is pressed or shorted while the user is attempting to arm. Press RESET, NO, NO then attempt to ARM again.

Procedure:

1. Check for shorts in the injector head cable, wiring, and Control Panel.
2. If the condition persists, replace the injector head.
3. If the condition persists, replace the Servo Control Card.

****FWD MOTOR MOVEMENT**
The injector was armed, followed by the forward motor movement of 2 ml or more without a forward load command. This message can be triggered by either an electrical malfunction or improper operating technique.

To verify electrical malfunction:

1. Arm the injector, then check the motor knob for plunger movement. If movement occurs, the line frequency may be miscalibrated.
2. Recalibrate or replace the Power Drive Card.
3. If unable to confirm electrical malfunction, this message also appears if the manual knob on the rear of the head is turned after the injector is armed, or during the arming sequence.

****HAND SWITCH SHORTED**
There is a short in the hand start circuit, or the start switch is closed during the ARMing sequence.

Procedure:

1. Ensure that the start button is not pressed.
2. Disconnect any auxiliary start connections (footswitch, auxiliary handswitch, etc.), then retry.
3. If the injector now functions properly using an external start switch, check the start switch and cord reel for shorts and improper closure.
4. If the condition remains with the cord reel disconnected, replace the I/O Card.

ILLEGAL RECALL FUNCTION
The operator attempted to recall a program number above 50 that is not available. Press RECALL, then select the correct program.

ILLEGAL TURRET SIZE SELECTED
The turret selected is not available with the existing injector head configuration. Press RESET, then attempt to select another syringe size.

INCORRECT PASSWORD, TRY AGAIN
An incorrect password was entered in response to the RECALL, 65 procedure of injector head selection. Enter the service access password, then select the proper head configuration.

INJECT DELAY
Displayed when the unit is in an injection delay mode prior to actual fluid delivery.

INJECTING
Injection is in progress.

INJECTION COMPLETE
Injection is finished, the start switch is still closed.

INJECTION NUMBER = XX
A untitled pre-programmed injection has been recalled from memory.

INJECTOR HEAD MALFUNCTION
Actual Flow Rate has exceeded the selected Flow Rate, or, actual Volume delivered has exceeded the selected Volume.

Procedure:

1. Replace the Power Drive Card.
2. If the condition persists, replace the Servo Control Card.
3. If the condition persists, replace the injector head - suspect an intermittently open plunger feedback pot.

INTERRUPT TEST FAILED
There is an error on one of the interrupt lines to the CPU. Remove and reapply power, then attempt to operate the unit again.

Service Procedure:

1. Replace the I/O Card.
2. If the condition persists, replace the CPU Card.
3. If the condition persists, replace the Servo Control Card.
4. If the condition remains, look for an open or grounded interrupt line on the motherboard.

INVALID INJECTION PROGRAM
An attempt was made to store an injection program that has some invalid parameter(s).

Procedure:

1. Review existing parameters, then correct any errors discovered.
2. Store the injection program.

INVALID PPI NUMBER
Number entered cannot be used. The value is either too large, or a decimal.

I/O: PIO1 INOPERATIVE
Input/Output port 1 (PIO1) on the I/O Card is not functioning properly. Replace the I/O Card.

I/O: PIO2 INOPERATIVE
Input/Output port 2 (PIO2) on the I/O Card is not functioning properly. Replace the I/O Card.

LINK ERROR: CAN'T SEND
The Control Panel if it is unable to transmit to the Main Unit. Remove and reapply power.

Service Procedure:

1. Check the Remote Panel cable for broken or intermittent connections.
2. If the condition continues, replace the PPI card in the Main Unit.
3. If the condition persists, call MEDRAD or the local dealer for assistance.

MAX DELAY IS 99.9 SECONDS
A delay above 99.9 was entered. Press RESET, then enter a value no greater than 99.9 seconds.

MAX FLOW IS 59 ML/MIN OR ML/HR
Injector is in the ML/MIN or ML/HR Flow scale, and a Flow Rate above 59 ml/min or ml/hr was entered. Press RESET, then enter a value no greater than 59 ml/min or ml/hr.

MAXIMUM DURATION IS 650 SECONDS
A Duration above 650 seconds was entered. Press RESET, then enter a Duration value no greater than 650 seconds.

MAXIMUM FLOW RATE IS 20
A Flow Rate above 20 was entered while in the 60 ml syringe system. Press RESET, then enter a Flow Rate less than 20.

MAXIMUM FLOW RATE IS 50 ML/SEC
Injector is in the ML/SEC Flow scale, and a Flow Rate above 50 ml/sec was entered. Press RESET, then enter a value no greater than 50 ml/sec.

MAXIMUM RISE/FALL IS 9.9 SECONDS
A Rise/Fall time greater than 9.9 seconds was entered. Press RESET, then enter a value no greater than 9.9 seconds.

MAX PRESSURE IN ML/MIN/HR IS XXXX
A pressure limit was entered that is greater than the maximum allowed in any given flow scale or syringe size. Enter a pressure limit value no greater than the respective maximum.

Minimum and Maximum Pressure Values

	60 ml Syringe					**150 and 200 ml Syringe**				
	psi	*kg/cm²*	*kPa*	*atü*		*psi*	*kg/cm²*	*kPa*	*atü*
	100	7	689	6		100	7	689	6
ml / SEC	1100	77	7584	75	**ml / SEC**	*1200**	*84**	*8274**	*82**
	100	7	689	6		100	7	689	6
ml / MIN / HR	700	49	4826	48	**ml / MIN / HR**	700	49	4826	48

* Values shown are for the 150 ml syringe

ml/SEC values for 200 ml syringe are: 1000 70 6895 68

MAX PRESSURE IN ML/SEC IS XXXX
A pressure limit which exceeds the maximum allowed in the selected syringe system and flow scale. Enter a pressure limit no greater than the respective maximum. (See acceptable pressure value ranges).

MAX PRESSURE IN ML/SEC IS 82
A pressure limit above 82 atü (atmospheres) was entered while using the ml/sec Flow scale. This message appears when using 150 ml syringes and the atü Pressure scale. Press RESET, then enter a value no greater than 82 atü.

MAX PRESSURE IN ML/SEC IS 84
A pressure limit above 84 kg/sq cm was entered while using the ml/sec Flow scale. This message appears when using 150 ml syringes and the kg (kg/sq cm) Pressure scale. Press RESET, then enter a value no greater than 84 kg/sq cm.

MAX PRESSURE IN ML/SEC IS 6895
A pressure limit above 6895 kPa (kilopascals) was entered while using the ml/sec Flow scale. This message appears when using 200 ml syringes and the kPa Pressure scale. Press RESET, then enter a value no greater than 6895 kPa.

MAX PRESSURE IN ML/SEC IS 8274
A pressure limit above 8274 kPa (kilopascals) was entered while using the ml/sec Flow scale. This message appears when using 150 ml syringes and the kPa Pressure scale. Press RESET, then enter a value no greater than 8274 kPa.

MECHANICAL STOP FAILURE
The Mechanical Stop has not positioned itself correctly, or, has taken too long to move into position. Remove and reapply power, then attempt to operate the unit again.

Service Procedure:

1. Remove power from the injector, then remove the injector head covers. Manually move the Mechanical Stop drive belt to ensure freedom of movement; then look for mechanical interference, broken connections, or other damage to the Mechanical Stop motor, drive system, and potentiometers.
2. If the condition persists, replace the Mechanical Stop Drive Card.
3. If the condition persists, replace the Servo Control Card.
4. If the condition persists, replace the injector head.

MIN PRESSURE SELECTABLE IS XXXX
A pressure limit of less than the minimum selectable for a given pressure scale has been entered. Enter a pressure limit value no less than the minimum allowable. (See matrix of acceptable pressure limit value ranges).

MIN VOL ALLOWED FOR 60 ML IS .5
A Volume of less than .5 ml was selected while in the 60 ml syringe system. Enter a Volume value of no less than .5 ml.

MIN VOL ALLOWED IS 1 ML
A Volume of less than 1 ml was selected while in the 150 ml syringe system. Enter a Volume value of no less than 1 ml.

MINIMUM DURATION ENTRY XXX.X SEC
Injection Duration must be at least the value shown in order to deliver the selected Volume at the selected Flow Rate. Set the Injection Duration at any value greater than or equal to that shown, and less than 650.

MINIMUM FLOW RATE IS .3
A Flow Rate value less than .3 was selected. Enter a Flow Rate value of at least .3 ml/sec/min/hr.

MISSING DATA CODE ON RCV
The RS-232C interface (from the Control Panel) is sending an error message.

Procedure:

1. Remove power from the injector for ten seconds, then reapply power and retry. There may have been transient interference on the lines.
2. If the condition persists, replace the PPI card.

MOVE PLUNGER FWD 2 ML, THEN REARM
When power is first applied, this message is displayed if the operator fails to advance the injector head plunger at least 2 ml prior to arming.

To correct:

1. Advance the plunger forward (or reverse) at least 2 ml. Verification is indicated by 5 short beeps.
2. Rearm the injector.

NOTE: If the plunger is in full reverse, pressing reverse load will prompt the Sentinel message PLUNGER POT MECHANICAL FAILURE. To correct, remove injector power, wait 10 seconds, reapply power, then advance the plunger forward.

NOTE: If power is removed and reapplied at any time, the plunger must be advanced forward 2 ml before arming.

****NMI - WATCHDOG 1 FAILED**
Watchdog 1 on the CPU Card is not being triggered, sending an interrupt signal to the CPU.

Procedure:

1. Remove power from the injector for 10 seconds, reapply power and retry.
2. If the condition persists, replace the CPU Card.

NOT ENOUGH VOLUME FOR INJECTION
This message appears during MULTIple injections. Insufficient Volume remains in the syringe for additional injections. Select a lower Volume value, or load additional media into the syringe.

ONE DECIMAL DIGIT ONLY
Entered more than one number after pressing the decimal point. Press RESET, then enter a value with only one decimal digit.

ONE DECIMAL POINT ONLY
Pressed the decimal point button more than once while entering a value. Press RESET, then enter a value with only one decimal point.

PLUNGER POT MECHANICAL FAILURE
The feedback voltage received from the plunger position potentiometer was not within allowable tolerances during the system mechanical Self Test. This message may also be prompted if the reverse load button was pressed in order to verify the head pot, with the plunger in the full reverse position. When power is applied to the injector, the plunger must be advanced forward 2 ml for verification of proper pot operation.

Procedure:

1. Verify proper injector head cable connections.
2. Inspect the physical condition of the plunger pot and associated pot gears.
3. If the condition persists, replace the plunger pot.
4. If the condition persists, replace the injector head.

****POWER DRIVE FAILURE**
A fault occurred in the injector motor drive circuits during standby. Remove power from the injector for 10 seconds, reapply power, and retry.

Service Procedure:

1. If the condition persists, replace the Servo Control Card.
2. If the condition persists, replace the Power Drive Card.

PPI: BACKUP MEMORY
The backup memory on the PPI card failed a read/write exercise. Remove and reapply power, then attempt to operate the unit again.

Service Procedure:

1. Clear the PPI memory by removing power from the injector, then press and hold the Delta 1 and Delta 2 buttons. With these buttons depressed, reapply power to the injector.
2. If the condition persists, replace the PPI Card.

**** PPI MEMORY COMPARE ERROR**
A fault in the PPI memory; the primary memory data does not match backup data. Remove power from the injector for 10 seconds, then turn it on and try again.

NOTE: *(Pedestal systems only) Pressing the PPI Memory Reset Switch will erase all programs in PPI memory.*

Service Procedure:

1. Clear the PPI memory by pressing the PPI Memory Reset Switch (S1) on the rear connector panel, then remove and reapply power to the injector.
2. If the condition occurs repeatedly, replace the PPI card.

PPI MEMORY FILLED
No additional programs can be stored unless an existing program is cleared first. Delete stored programs which are not, or seldom, used.

PPI NUMBER XX NOT USED
Displayed in response to attempting to recall a Pre-Programmed Injection that does not exist at the selected location. Scroll through the programs to search for program desired, or create a new program.

PPI PANEL CHECKSUM ERROR
A fault exists in the PPI memory; the checkless does not match the parameters displayed on the Control Panel. Press RESET to clear the fault. If the message appears again, remove and reapply power.

Service Procedure:

1. Clear the PPI memory by pressing the PPI Reset Switch (S1) on the rear connector panel, then remove and reapply power to the injector.
2. If the condition occurs repeatedly, replace the PPI card.
3. If the condition persists, replace the CPU Card.

PPI: PRIMARY MEMORY
The primary memory on the PPI Card failed a read/write exercise. Remove and reapply power, then attempt to operate the unit again.

NOTE:*Pressing the PPI Memory Reset Switch will erase all programs in PPI memory.*

Service Procedure:

1. Clear the PPI memory by pressing the PPI Memory Reset Switch (S1) on the rear connector panel, then remove and reapply power to the injector.
2. If the condition occurs repeatedly, replace the PPI card.

PPI RECALL CHECKSUM ERROR
The injection program saved in PPI memory does not match the program loaded in the system RAM. Clear the program from PPI memory using RECALL 52, then attempt to reenter the program.

PREMATURE TERMINATION
An injection was interrupted before the selected Volume had been injected. The handswitch or remote start switch was released before the injection completion. Repeat the injection if possible.

Service Procedure:

1. If the condition persists, suspect an intermittent connection in the start circuit, or electrical interference on the start or power lines.
2. If an external start is being used, ensure that it remains closed throughout the injection.

****P.S.I. LIMIT EXCEEDED**
Actual Pressure has exceeded the selected Pressure by at least 100 PSI.

Service Procedure:

1. Replace the Servo Control Card.
2. If the condition persists, replace the Power Drive Card.

****PWR DRIVE FAILURE**
A Fault occurred in the injector motor drive circuits during an injection. Remove power from the injector for 10 seconds, reapply power, and retry.

Service Procedure:

1. If the condition persists, replace the Servo Control Card.
2. If the condition persists, replace the Power Drive Card.
3. If the condition persists, check the injector head cable for broken or intermittent connections. Carefully inspect the plunger motor leads.
4. If the condition persists, replace the injector head.

READY TO INJECT XXX.X VOLUME
Appears when the injector is armed and ready to inject the volume selected. Activate the start switch to begin fluid delivery.

ROTATE TURRET TO 60 ML POSITION *or*
ROTATE TURRET TO 150 ML POSITION
Appears when an attempt is made to arm the unit with the turret in the wrong position. Rotate the turret to the position required for the injection.

REVERSE PLUNGER MOTION DETECTED
The plunger has moved in the reverse direction during an injection.

****REV MOTOR MOVEMENT**
While the injector was armed, the motor moved reverse 2 ml or more without a reverse command. This message can be triggered by an electrical malfunction or improper operating technique.

To verify electrical malfunction:

1. Arm the injector and check the motor knob for plunger movement. If moving, the PDC may be miscalibrated.
2. If there is no plunger movement, replace the Servo Control Card.
3. If unable to confirm electrical malfunction, this message also appears if the motor knob on the rear of the head is turned after the injector is armed, or during the arming sequence.

SCC: +10V REF FAILURE
The +10 V reference supplied by the Servo Control Card, and used by the feed-back pots in the head, is out of specification. Remove and reapply power, then attempt to operate the unit again.

Procedure:

1. Remove power, disconnect the injector head cable, then retry. The message CHECK INJ HEAD CABLE PL should appear. If so, the error condition lies in the injector head, continue with step 4.
2. If the condition persists, check the +15 VDC supply on the servo control board, which powers the +10V reference chip.
3. If the condition persists, replace the Servo Control Card.
4. If the condition persists, check for shorts in the injector head cable, internal wiring, connectors, and feedback pots.

SCC: FLOW DAC FAILURE
Flow Rate DAC output on the Servo Control Card is not within allowable limits. Remove and reapply power, then attempt to operate the unit again. If the condition persists, replace the Servo Control Card.

SCC: MS DAC FAILURE
Mechanical Stop command DAC output on the Servo Control Card is not within allowable limits. Remove and reapply power, then attempt to operate the unit again. If the condition persists, replace the Servo Control Card.

SCC: PIO3 INOPERATIVE
Input/Output port 3 (PIO3) on the Servo Control Card is not functioning properly. Replace the Servo Control Card.

SCC: PSI DAC FAILURE
Pressure limit DAC output on the Servo Control Card is not within allowable limits. Remove and reapply power, then attempt to operate the unit again. If the condition persists, replace the Servo Control Card.

SELECT HEAD: 60/150=1, 150/200=2
Displayed in response to RECALL, 65, after the service access password is properly entered. May also be displayed if unit memory is lost. Enter the corresponding number of the injector head to be used with the system.

SELECT UTILITY FUNCTION
Displayed if unit is powered up with SP1 on the CPU set for the utility mode. Select the Utility Recall function desired.

SELF TEST INDICATES 60 ML TURRET
Displayed only when the turret is in the 60 ml syringe position. RECALL, 65 has been accessed in order to change head configuration to the 150/200 injector head. The system has detected that a 60/150 head is installed, therefore, the 150/200 configuration cannot be used.

SELF TEST IN PROGRESS VER MV XXX
The unit is running a self-test which occurs at power-up. Wait approximately 3-10 seconds for completion of the self-test, then continue with normal operations.

SET LEVEL TO 1 TO CHANGE SCALE
An attempt was made to change the Flow scale at an intermediate level in a multiple-level injection. Go to level 1, then change the Flow Scale

SET VOLUME IS TOO HIGH XXX.X REMAINS
Insufficient Volume remains in the syringe for an injection of the selected Volume. Enter a lower Volume setting or change syringes, replacing with a full syringe.

****STALL TIME EXCEEDED**
The main drive motor (and plunger) has been stalled, indicating either a significant resistance in the fluid path, or physical interference in the plunger or internal workings of the head. Check the syringe, plunger, and fluid path for obstructions.

Service Procedure:

1. If the condition persists, replace the Servo Control Card.
2. If the condition persists, replace the Power Drive Card.

START SIGNAL SHORTED
A short has occurred in the start circuit. The handswitch or external start switch may be closed during standby.

Procedure:

1. Remove power from the injector, disconnect the external start switch, reapply power, and retry
2. If the injector now functions properly using the start switch on the cord reel or front of the CRC, check the external start circuit for shorts and improper closure.
3. If the condition continues with the external start switch disconnected from the injector, disconnect the injector power source, then disconnect the start cord reel, and retry.
4. If the injector now functions properly using an external start switch, check the start switch and cord reel for shorts and improper closure.
5. If the condition continues with the cord reel disconnected, replace the I/O Card.

SYRINGE SYSTEM NOT SELECTED
This message is displayed when the system loses the programmed injector head selection. The system will have to be reconfigured before the injector can be used. Call MEDRAD Service for instructions.

TO CLEAR, ENTER NR, THEN STORE
Displayed when selecting RECALL 52, an injection program can be cleared from PPI memory. Enter the number of the program to be erased, then press STORE.

TOTAL VOLUME EXCEEDED
The total volume of a multi-level injection exceeds the maximum possible volume of the selected syringe size. Change the settings to a lower total Volume, or, select a larger syringe size.

TOTAL VOLUME OF XXX.X DESIRED?
For Multi-Level injections only. Asks for verification that the operator is aware of the total Volume selected for all levels of the injection. “XXX.X” indicates the total injection Volume. Verify that the Volume displayed is the Volume desired, then press YES.

UNIT DISARMED XX
While the unit was armed, a disarm condition occurred. This message is displayed for three seconds. The following is the disarm code reference list which identifies the source of the disarm condition. (For example; if a panel key on the main keyboard is pressed while the unit is armed or injecting, the following message would be displayed:

UNIT DISARMED 01

01 Main keyboard
03 Remote panel keyboard
04 FWD/REV load switch
05 Turret
06 Watch Dog failure while arming
07 0300 only - Injector or Aux start detected while arming or injecting
08 0300 only - X-Ray or ISI released while injecting
09 0300 only - X-Ray or ISI detected during 0300 handswitch start
10 0300 only - Handswitch released (armed or injecting)
11 Remote handswitch released
12 Communication link failure
13 PIO3 Interrupt - type undetermined
14 External Disarm
15 PIO2 or PIO3 Interrupt - type undetermined
16 Start switch debounce error

VACANT INJECTION NUMBER
No program exists at the selected PPI storage number.

VERIFY DURATION
An attempt was made to arm the injector without a Duration value entered or calculated. Enter a Duration value, or, reenter the Flow Rate and Volume parameters.

VERIFY FLOW RATE
An attempt was made to arm the injector without a Flow Rate value entered or calculated. Enter a Flow Rate value, or, reenter the Volume and Injection Duration parameters.

VERIFY PRESSURE
An attempt was made to arm the injector without a Pressure value entered. Press Delta 6, then enter a Pressure limit value.

VERIFY VOLUME
An attempt was made to arm the injector without a Volume value entered or calculated. Enter a Volume value, or reenter the Flow Rate and Injection Duration.

VOLUME GREATER THAN SYRINGE SIZE
A Volume was entered that exceeds the size of the installed syringe. Lower the Volume amount, or change to a larger syringe size.

XX IS USED, CLEAR IT_YES/NO?
A program is already stored in the PPI storage location selected. Press YES to erase the stored program and replace with a new program in the same location. Press NO to save the existing program. Re-enter a different storage location number for the new program.

XXX.X VOLUME REMAINS. ARM? YES/NO
The SINGLE arm key has been pressed in an attempt to arm the injector when insufficient volume remains in the syringe to deliver the program volume. The option is given to the user to either inject the remaining insufficient volume, or to temporarily abandon arming until program volume can be reprogrammed or syringe size can be changed.

Press the YES key to complete the arming sequence
Press the NO key to abandon the arming sequence.

XXX.X VOLUME IS INSUFFICIENT TO ARM
The MULTIple arm key has been pressed in an attempt to arm the injector when insufficient volume remains in the syringe to deliver one bolus of the program volume. This message will be displayed for approximately 3 seconds and indicates to the user that the current remaining volume is insufficient to perform multiple injections according to the program volume selected.

60/150 SYRINGE SYSTEM INSTALLED
The user attempted a size change to a 200 ml syringe from the Recall 50 utility program when the system software/hardware is configured for the 60/150 syringe system. Use Recall 65 to access the 150/200 ml syringe system and select the 200 ml syringe size.

NOTE: The Mark V *ProVis* Injector should not be configured for 200 ml syringe operation.

150/200 SYRINGE SYSTEM INSTALLED
The user attempted a size change to a 60 ml syringe from the Recall 50 utility program when the system software/hardware is configured for the 150/200 syringe system. Use Recall 65 to access the 60/150 syringe system and select the 60 ml syringe size.

NOTE: The *Mark V ProVis* injector should not be configured for 60 ml syringe operation.

SERVICE UTILITY MESSAGES
The following messages are displayed when service utility programs are accessed. Under normal circumstances, an operator of the injector will never see these messages displayed.

CHECK HANDSHAKE LINES

CHECK XMT/RCV LINES

CHECK HANDSHAKE LINES

MOVE PLUNGER TO FULL REVERSE

TESTING INTERFACE - XMIT/RCV=

Non-Message Faults

This section aides in determining the source of a condition when no message (or a garbled message) appears on the Sentinel.

The following non-message faults are covered. Refer to the following pages for possible causes, and the procedure for correcting the condition.

DEAD UNIT

No Control Panel LEDs or backlights are illuminated, the power switch may or may not illuminate.

- *(Pedestal systems only)* Verify that the connection at J130 is secure.
- If the power switch is lit, AC line power is getting to the injector.

  Check the following:

  1. Power Supply Card +5 VDC supply and fuse.
  2. Other Power Supply Card supply lines and fuses.
  3. If any voltages are non-existent, remove injector power, disconnect the injector head, then remove all cards, except the Power Supply Card, from the unit. Reapply power and check for the existence of Power Supply voltages.

  - If Power Supply voltage now exists, one or more of the cards in the unit are not functioning properly. Reinsert each card, checking for the existence of voltage, to determine which card is not functioning properly.
  - If voltage is still nonexistent, replace the Power Supply Card, then insert and check the voltage of the remaining cards, one at a time.

- If the power switch is not lit, the AC line power is not getting into the injector.

  Check the following:

  1. Line power at the outlet.
  2. Power cord and plug for open connections.
  3. Power switch.
  4. Main line circuit breakers.
  5. Line filter and AC line wiring.
  6. Power transformer.

NO DRIVE

The plunger motor does not turn, for loading or injection.

***Symptom**:*

- Injects, but does not load:
    1. Listen for a click when pressing the forward or reverse load switch on the head.
    2. If there is no click, replace the injector head.
    3. If there is a click, replace the DRC Card.
    4. If the condition persists, replace the Power Drive Card

- Loads, but does not inject:

    If the unit does not inject within three seconds after being commanded to do so, this message should appear on the Sentinel: **STALL TIME EXCEEDED

    1. Check for physical interference of the plunger or other mechanical parts of the head.
    2. If the condition continues, replace the Servo Control Card.
    3. If the condition continues, replace the DRC Card.
    4. If the condition persists, replace the Power Drive Card.

- Does not load or inject:
    1. Check AC power (150 VAC) into the SCR bridge on the Power Drive Relay Card.
    2. If the voltage measures correctly:
        a) Replace the Power Drive Card.
        b) If the condition continues, replace the DRC Card - suspect the SCR bridge.
        c) If the condition persists, replace the head - suspect an open plunger motor.

WILL NOT INJECT

The injector appears normal during standby and setup, during Forward and Reverse load, but will not inject.

- The SENTINEL will continue to display, READY TO INJECT.
- Drive circuits are working properly if loading functions normally. The condition is caused by an open start line or defective start circuit.

  Troubleshoot:

  1. Press the SINGLE or MULTiple arm, but not the YES key. Press the hand switch. If there is proper handswitch continuity, the SENTINEL will display: **HAND SWITCH SHORTED. If this message does not appear, check the start switch.
  2. Plug an external start switch into the rear connector panel. Inject with the external start switch.
  3. If there is no injection with the external start switch, replace the I/O Card.
  4. If the condition continues, replace the Servo Control Card.
  5. If the condition persists, replace the Power Drive Card.

GARBLED MESSAGE

The message displayed on the Sentinel is garbled or partial. Suspect the interface between the I/O and Display Card, or suspect the cards themselves.

Troubleshoot:

1. Ensure proper connection of the ribbon cable which connects the Control Panel Control Card and the Display Card by removing and reconnecting.
2. If the condition persists, replace the Control Panel Unit.

NOTES:

16 Disassembly and Reassembly Procedures

This section contains recommended procedures for the disassembly and reassembly of those portions of the injection system that can be readily repaired in the field, along with part numbers and ordering information for field replaceable components. If through troubleshooting and diagnosis, a repair or replacement procedure or component which is not outlined in this section is required, contact MEDRAD Factory Service, or your local MEDRAD Service Representative.

WARNING: Hazardous voltages exist within the *Mark V ProVis* Injection System that can shock, burn, or cause death. To avoid injury, the system should be opened and serviced by qualified service personnel only. Disconnect the system from line power before cleaning or attempting to perform any maintenance or repairs.

WARNING: Immediately disconnect the patient from the injector if any system malfunction occurs. If a system malfunction message appears, do not attempt to use the system until the source of the condition has been identified and corrected by qualified service personnel. Do not attempt to recreate any fault conditions while connected to a patient.

CAUTION: Electrostatic Discharge (ESD). Failure to follow ESD protection practices may result in equipment damage. ESD protection practices must be followed when servicing any component of this system.

Replacement Parts

	Item	***MEDRAD Part Number***
PC Boards	Control Panel Controller Card	3002206
	CPU Card	3003541
	Drive Relay Card	85106-04-AP-03
	Imaging System Interface Card	78101-10-AP-16
	Input/Output Card	78101-10-AP-02
	Keyboard Display Card	3002205
	Mechanical Stop Card	78101-04-AP-05
	Power Drive Card*(Specify 50 or 60 Hz)*	78101-06-AP-10
	Power Supply Card	78101-07-AP-03
	Pre-Programmed Injection Card	3002953
	Servo Control Card	78101-10-AP-03-1 3008759
Assembly	Articulating Arm	3003073
	Caster	3002141
	Fuse, 1/16 A pico	476-0062-000
	Fuse, 1/8 A pico	476-0125-000
	Fuse, 3 A pico	476-0275-003
	Fuse, 10 A pico	476-0275-010
	Fuse, 5x20 5 A	476-2180-005
	Fuse, 5x20 3.15 A	476-2173-150
	Power Switch, 100-125VAC	3002903
	Power Switch, 200-250VAC	3002904
	Start Switch	3002935
	Start Switch, Coiled	3002932
	Start Switch housing*(2 piece)*	3002448 *and* 3002449

Replacement Parts (continued)

	Item		*MEDRAD Part Number*
Injector Head	Cable Assembly, Injector Head -9’		3003478
	Cable Assembly, Injector Head -10’		78101-15-AC-58
	Cable Assembly, Injector Head -15’		78101-15-AC-59
	Cable Bracket		78101-04-SM-41
	Cover, Top		3002433
	Cover, Bottom		3002434
	Ferrite Core (2 per head)		3003744
	Knob, Piston Rotation		3002436
	Lamp, Injector Head Armed Indicator		3002924
	Lens, Injector Head Armed Indicator		3002435
	Lever, Plunger Release		3002437
	Limit Switch kit, Mechanical Stop		78101-04-SK-07
	Overlay, Injector Head, 60/150	*English*	411004551-1
		Gernan	411004551-2
		French	411004551-3
		Spanish	411004551-4
		Dutch	411004551-5
		Italian	411004551-11
		Japanese	411004551-13
	Overlay, Injector Head, 150/200	*English*	411004552-1
		Gernan	411004552-2
		French	411004552-3
		Spanish	411004552-4
		Dutch	411004552-5
		Italian	411004552-11
		Japanese	411004552-13
	Potentiometer, Mechanical Stop Feedback		KSP-514
	Potentiometer, Plunger Feedback		KSP-513
	Pressure Jacket, 200 ml		KMP-778
	Pressure Jacket, 150 ml		KMP-777
	Pressure Jacket, 60 ml		KMP-760
	Syringe Heat Maintainer		3003071
	Turret, 60/150		3002438
	Turret, Dual 150		3003371
	Turret, Dual 200		3003372
	Turret Pin		KSP-105

Replacement Circuitry

The following parts are necessary for proper circuit operation. These parts must be supplied by MEDRAD. Do not make substitutions from other manufacturers due to possible incompatibility with *Mark V ProVis* circuits.

	Designator	*Description*	*MEDRAD Part No.*
CPU Card	U2	Z8581	070-8581-000
	U2	D82C284-8	070-8228-480
	U10	Z80A (CPU)	070-8400-000
	U24	ROM	78101-10-AM-05
	U16	RAM	071-5564-015
	U26	PLA	U26 XXX *(software dependent)*
	U23	PLA	U23 XXX *(software dependent)*
	Y2	8.0 MHz Crystal	180-0080-000
I/O Card (IOC)	U4	Z8430APS (CTC)	070-8430-000
	U5, U6	Z8420APS (PIO)	070-8420-000
	U8	PLA	M5JB8
Servo Control Card (SCC)	U1	AD571 (A/D)	050-0571-000
	U16	Z8420APS (PIO)	070-8420-000
	U21-U24	NE5018 (D/A)	053-5018-000
	U26, U27	4741	060-4741-500
	U29	3527A	050-3527-070
PPI Card	BT1	3.0 V Battery	497-2325-100
	U6	PLA	U6 XXX *(software dependent)*
	U8, U9	TC5564-PL15	071-5564-015
	Y1	3.6864 MHz Crystal	180-0037-000
Power Drive Card (PDCI)	U4, U5	4741	060-4741-500
	U1, U2	LF444	052-0444-000
	U3	REF01	052-4101-000
Mechanical Stop Card (MSD)	U2	LM324	050-0324-050
Power Supply Card (PSP)	L1	39 mH Choke	78101-07-AM-02
	U1	UC3527	050-3527-000

Replacement Circuitry (continued)

	Designator	*Description*	*MEDRAD Part No.*
Control Panel Controller Card	U2	PIO	070-8420-000
	U5	CTC	070-8430-000
	U12	PLA	RP5B12A
	U13	CPU	070-8400-000
	U14	RAM	071-8464-000
	U15/16	ROM	78101-00-SK-03
	U17	3537	050-3527-000
	U6	Clock Generator	070-8228-480
	Y2	8 MHz Crystal	180-0037-000
	L1	47 mH Choke	270-4334-040
	Y1	3.6864 MHz Crystal	180-0080-020

*** NOTE**: ROM chips U15 and U16 should indicate the same software version. For example, RP5B15 and RP5B16 must both indicate the same software versions. Contact MEDRAD Service for information on software version compatibility with Control Unit system software.

Keyboard Display Card	U1-4	7218	072-7218-000
	DS1-8	HDLY 2416	3002805
	DS 9,10,13-22	7 Segment Display	485-7503-000
	DS 11,12,23-26	7 Segment Display	3002806
	LP 3-5	MTLB3150-Y	3002804
	LP 6,7,14-17	HLMP 2350	485-2350-000
	LP 18-21	HLMP 2300	485-2300-000
	LP 1,2,8-11,13	HLMP2450	485-2450-000

How to Order Parts

Order injection system parts from MEDRAD Factory Service:

MEDRAD Factory Service
MEDRAD, INC.
One MEDRAD Drive
Indianola, PA 15051-0780
Phone: (412) 767-2400
1-800-MEDRAD-S
1-800-633-7237
FAX: (412) 767-4126

In Europe:

MEDRAD EUROPE, B.V.
Postbus 205
6190 AE Beek
The Netherlands
Phone: 31 (0) 43 3585601
FAX: 31 (0) 43 3656598

In Japan:

Nihon MEDRAD K.K.
2-4-9, Umdeda, Kita-ku
Osaka 530-0001
Japan
Phone: +81(0)66-133-6250
FAX: 81 (0)66133-2395

When ordering, include the following information:

- **Injector** model and Serial Number
- **Subassembly** the part is used on, Serial Number, and Revision Level
- Circuit designator, **Description** of item, and MEDRAD part number
- **Quantity** desired

Required Tools

The following represents basic tools that may be needed to service a *Mark V ProVis* system, depending on what is being repaired or replaced.

- Medium-blade screwdriver
- Small-blade screwdriver
- 3/8” wrench or pliers
- 1/16” hex wrench
- 5/32” hex wrench
- Pin extractor
- Alignment tool (or very small screwdriver)
- Soldering iron (25 to 60 watts) and solder
- Needle-nose pliers
- Snap-Ring Pliers
- Wire cutters
- Alcohol and swabs
- Cable Ties

Control Unit - ***Electronics Console Access***

Control Unit Disassembly

Pedestal System:

1. Remove AC power, then secure the position of the injector by locking the wheels.
2. Loosen the two captive thumbscrews that secure the right rear access cover to the internal console retaining bar.
3. Loosen the four captive thumbscrews that secure the rear access covers, then remove the covers from the assembly.
3. Loosen the captive screw at the top of the console retaining bar, then remove the bar from the assembly.
4. Disconnect all cables connected to the rear connector panel.
5. Carefully remove the electronics console from the assembly, and position on a flat anti-static surface with the connector panel facing downward.

Rackmount System:

1. Remove power from the injector.
2. Loosen the two screws (either slotted or 9/64” hex key screws) at the top of the front panel.
3. Tilt the front panel downward.

Control Unit Reassembly

Pedestal System:

1. Carefully position the electronic console in the pedestal assembly.
2. Re-establish all cable connections at the rear connector panel.
3. Install and secure the console retaining bar.
3. Install and secure the rear access panels.

Rackmount System:

1. Tilt the front panel upward, and close.
2. Secure the two screws (either slotted or hex key) at the top of the front panel.

Control Unit - ***PC Cards***

PC Card Removal

1. *(Pedestal Systems only)* Remove the twelve screws that secure the electronics console shield, then carefully remove the shield from the assembly.
2. *(Rackmount Systems only)* Remove the chassis shield plate by removing the two thumbscrews, then remove the card retainer brackets from across the edges of the cards.
3. Identify the card to be removed, then lift the inside edge of the ejector tabs to slide the card out.

NOTE: *(Pedestal systems only)* When removing the PPI card, the PPI reset switch must be disconnected at PJ1.

NOTE: *(Pedestal systems only) Do not depress the PPI Memory Reset switch at S1 unless clearing of all injection memory is required.*

PC Card Replacement

1. Identify the proper slot for reinsertion if more than one card was removed.

Card	***Ejector Tab color***
CPU Card	White
I/O Card	Violet
Servo Control Card	Green
PPI Card	Yellow*
ISI Card	Red

NOTE: *(Pedestal Systems only)* Tthe PPI reset switch must connection must be restored at PJ1 when installing the PPI card.

2. Align the card with the proper PC card guides.
3. Insert the card into its respective slot, and align card edge connector fingers with connectors on Motherboard. Push the card firmly to ensure that it is securely seated in the Motherboard.
4. *(Pedestal Systems only)* Install and secure the electronics console shield with the 12 screws previously removed.
5. *(Rackmount Systems only)* Replace the card retainer brackets and chassis shield plate, then secure the shield plate with the two thumbscrews previously removed.

Control Panel - ***Removal and Replacement***

Control Panel Removal

1. Remove power from the injector.
2. Remove the two screws that secure the control panel mounting cover, then remove the cover.
3. Remove the display lock from the assembly by removing the mounting screws.
4. Carefully lift the Control Panel assembly from the pedestal, and extend the interconnect cable to access the connector.
5. Disconnect the interconnect cable by sliding the locking release sleeve back from the connection.

Control Panel Replacement

1. Restore the cable connection at the the base of the Control Panel previously removed.
2. Position the Control Panel assembly in the panel recess of the pedestal assembly.
3. Install and secure the display lock with the screw previously removed.
4. Install and secure the control panel mounting cover with the two screws previously removed.

Control Panel - ***Display Card***

Display Card Removal

1. If applicable, remove the Control Panel assembly from the pedestal.
2. Remove the four screws that secure the rear cover to the Control Panel assembly.
3. Disconnect the interconnect ribbon cable.
4. Remove the four screws that secure the Display card to the inside cover.
5. Disconnect the connectors at P/J10 and P/J11, then remove the card from the assembly.

Display Card Replacement

1. Re-establish the connections at P/J10 and P/J11, then position the replacement Display card in the assembly.
2. Secure the Display card with the four screws previously removed.
3. Re-establish the ribbon cable connection.
4. Install the rear cover on the Control Panel assembly and secure with the four screws previously removed.
5. If applicable, re-install the Control Panel assembly on the pedestal.

Control Panel - ***Controller Card***

Controller Card Removal

1. If applicable, remove the Control Panel assembly from the pedestal.
2. Remove the four screws that secure the rear cover to the Control Panel assembly.
3. Disconnect the interconnect ribbon cable.
4. Remove the four screws that secure the Controller card to the inside cover.
5. Disconnect the ground wire connection and the connector at P/J1, then lift the card from the assembly.

Controller Card Replacement

1. Position the replacement Controller card in the assembly, then re-establish the ground wire connection, and the connection at P/J1.
2. Secure the Controller card with the four screws previously removed.
3. Re-establish the ribbon cable connection.
4. Install the rear cover on the Control Panel assembly and secure with the four screws previously removed.
5. If applicable, re-install the Control Panel assembly on the pedestal.

Injector Head - *Covers*

Cover Removal

1. Before disassembly, fully reverse the plunger, then remove unit power.
2. Remove the injector head from the mounting arm and place on a padded surface.
3. Position the injector head upside down. Remove the four screws retaining the bottom cover, then remove bottom cover.

   NOTE: This point in the procedure is sufficient for syringe heater repair. Proceed with the next step if any other injector head servicing is required.

4. Remove the two hole plugs from the knob and lever on the rear of the injector head.
5. While holding the round piston control knob, loosen the screw inside the knob several turns without removing the screw. When the screw is loose, remove the knob from the shaft.
6. While holding the plunger rotation knob, remove the screw inside, then remove the knob from the shaft.
7. Remove the four screws holding the top cover to the assembly, then remove the top cover.

Cover Replacement

1. Position the top cover face down on the work surface. Place the injector head (upside down) over the top cover and install the four screws which secure the cover to the head assembly.
2. Position the bottom cover on the injector head, then install the four screws previously removed.
3. Install the plunger rotation lever with the screw previously removed.
4. Position the plunger knob on the shaft, then tighten the screw inside.
5. Install the hole caps on the two knobs.

Injector Head - ***Syringe Heat Maintainer***

Syringe Heat Maintainer Removal

1. Remove unit power. Disconnect the injector head from the Injector Unit and place upside down on a suitable work surface.
2. Remove the four bottom cover retainer screws, and remove cover.
3. Disconnect the P29/J29 syringe heat maintainer cable connector.
4. With the pin extractor, remove the white and black wires/pins from the J29 connector. If a pin extractor is not available, use a small blade screwdriver to depress the pin tangs, and pull the pin from the connector. Retain the J29 connector housing for use in reassembly.
5. Note the placement of the following parts for use in reassembly. If there is a ferrite core on the cable, remove and retain for later use. Unscrew and remove the strain relief from the front casting. Remove strain relief from heater cable and retain for use in reassembly. Push on the cable to expose the O-ring, then remove and discard. Remove heater and cable from front casting, and discard.

Syringe Heat Maintainer Replacement

1. Install cable into front casting. Install replacement O-ring and strain relief on cable sheath. Install the strain relief and tighten securely.

   NOTE: The heater cable sheath should protrude 1/8” to 1/4” beyond the strain relief when properly positioned (see Figure 16.1).

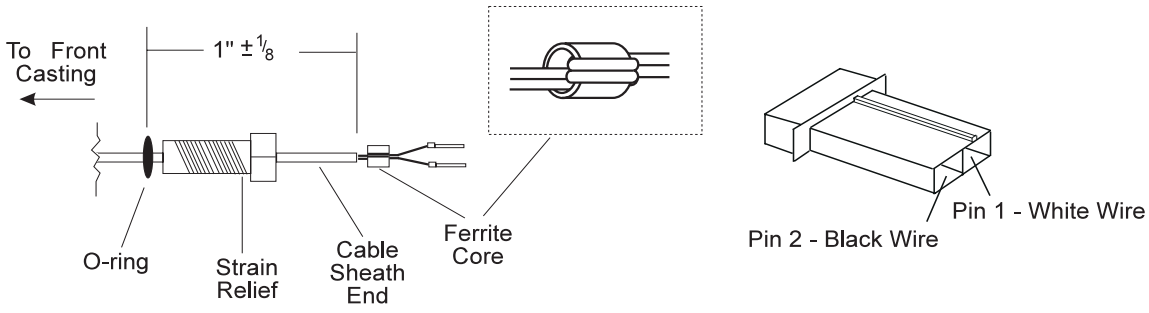


Figure 16.1: Syrige Heat Maintainer Cable and J29 Connector

2. Loop the wires through the ferrite core.

Injector Head - ***Syringe Heat Maintainer*** ***(continued)***

3. Install the wires/pins into the J29 connector housing (white -Pin 1, black -Pin 2). Ensure that the tangs lock into place when inserting pins into the connector housing. After installing the wires/pins, gently tug on each wire to verify that the pins are secured in the connector.
4. Reconnect the P29/J29 connectors and the injector head to the injector unit, and apply unit power. The heater should feel warm within a few minutes. If the over-temperature light illuminates, place the syringe heat maintainer on a pressure jacket; the light should extinguish within a few minutes. If the over temperature light remains lit, the assembly is defective.
5. After verifying correct operation, remove unit power. Reinstall the bottom cover and retainer screws.

Injector Head *- Plunger Position Pot*

The removal and replacement of the Plunger Position Pot requires major disassembly, reassembly, calibration and checkout of the injector head. The procedures for this operation are included here, however, we do not recommend field repair of this item, but suggest that the injector head be returned to MEDRAD Service.

Plunger Pot Removal

1. Apply power to the injector, then ensure that the 150 ml syringe size is selected. If 60 or 200 ml is selected, press RECALL, 50, RECALL, then the appropriate number to select 150 ml. Set the injector parameters as follows:

   Flow Rate 10 ml/sec

   Volume 10 ml

   Pressure 600 psi

2. Reverse the plunger to the rear limit, then remove unit power.
3. Position the injector head (which can remain on the arm or be placed on a padded surface) upside down.
4. Remove the four screws which retain the bottom cover, then remove the bottom cover.
5. Remove the two hole plugs from the plunger knob and plunger rotation lever on the rear of the injector head.
6. While holding the plunger knob, loosen the screw several turns then remove the knob from the shaft.
7. While holding the plunger rotation lever, remove the screw inside, then remove the lever from the shaft.
8. Remove the four screws securing the top cover. Remove the top cover.
9. Position the injector head top side up.
10. Note the position of wires, head cable, and metal clamp. Remove cable ties. Remove the two screws securing the cable bracket.
11. Disconnect the wires from the plunger pot.
12. Remove the two screws securing the pot bracket, then remove the pot assembly. Retain screws and discard the old pot assembly.

Injector Head - ***Plunger Position Pot*** ***(continued)***

Plunger Pot Replacement

1. Hold the pot assembly with the gear facing away from you. Turn the gear counter-clockwise until the gear turns no further. Rotate the gear clockwise 1/4 turn.
2. Install the new pot assembly with the two screws previously removed. The pot assembly cannot be tightened until pot calibration is complete.
3. Carefully reattach the wires and solder (refer to the chart below). Ensure that the wires are positioned away from moving parts.

Terminal / Wire Colors	
1	white/blue
2	white/yellow
3	white/violet

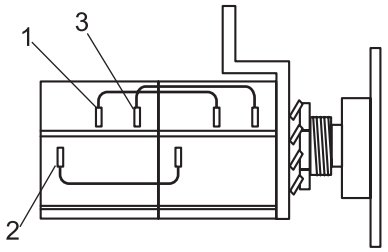


Figure 16.2: Plunger Pot Terminal Identification

4. For the following measurements, connect the DVM ground to terminal 3 on the plunger position pot.
5. Apply power. Disregard any messages that may appear on the Sentinel. Advance the plunger at least 2 ml to satisfy the plunger pot test, *then reverse the plunger to the rear limit .*
6. Measure the wiper voltage on terminal 2 of the plunger position pot. With the pot disengaged, turn the pot shaft gear until the voltage reads 0.250 VDC +0/-0.020 VDC.
7. Reengage the pot gear, maintaining the voltage as measured in the previous step, and tighten the pot screws. Ensure that the gears do not jam.

Injector Head - ***Plunger Position Pot*** ***(continued)***

8. Arm the injector. When the Mechanical Stop is in position, measure the wiper voltage on the white/yellow wire of the mechanical stop pot. The voltage must be 0.860 VDC +/-0.020 VDC. If voltage is within specification, skip to step 14.
9. Disconnect one of the mechanical stop motor leads. Manually move the Mechanical Stop plate forward approximately 1/8 inch (3.2 mm).
10. Advance the plunger until the plunger position pot wiper voltage (terminal 2) is 1.010 VDC.
11. Manually reverse the Mechanical Stop plate into the plunger plate until the mechanical stop microswitch opens (noted by an audible click). The DVM can be used on the microswitch to detect when the microswitch opens.
12. Disengage the Mechanical Stop pot and adjust for 0.860 VDC.
13. Reengage the pot gear, and tighten the pot bracket screws. Reverse plunger to the rear limit. Disconnect DVM from head, then reconnect the Mechanical Stop motor lead.
14. Remove injector power. Ensure that all pot screws are secure, then install the cable bracket on the rear casting.
15. If required, attach the metal clamp and head cable on the cable bracket.
16. Secure the wires and head cable with cable ties.
17. Reassemble the injector head.
18. Ensure that the proper syringe size is selected (look at the indicators on the injector head). If the incorrect syringe size is selected, press RECALL, 50, RECALL, then select the proper syringe size.

Injector Head - ***Mechanical Stop Pot***

Removal and replacement of the Mechanical Stop Pot requires extensive disassembly, reassembly, calibration and checkout. Although the procedures are included here, we do not recommend field repair of this item, and suggest that the injector head be returned to MEDRAD for these repairs.

Pot Removal

1. After removal of the injector head covers, position the injector head (which can remain on the arm or be placed on a padded surface) upside down.
2. Apply power to the injector, then ensure that the 150 ml syringe size is selected. If 60 or 200 ml is selected, press RECALL, 50, RECALL, then the appropriate number to select 150 ml. Set the injection parameters as follows: Flow Rate 10 ml/sec, Volume 10 ml, Pressure 600 psi.
3. Reverse the piston to the rear limit, then remove unit power.
4. Manually reverse the stop plate to the rear limit, then disconnect one of the motor leads.
5. If necessary, remove cable ties in order to avoid cable interference.
6. Carefully remove the wires on the pot.
7. Remove the screws holding the pot bracket, to remove the pot assembly.

Pot Replacement

1. Hold the pot assembly with the gear facing away from you. Rotate the gear counter-clockwise until it stops turning, then rotate the gear 1/4 turn clockwise.
2. Install the new pot assembly with the two screws previously removed. The pot assembly cannot be tightened until pot calibration is complete.
3. Carefully reattach the wires and solder (refer to the chart below). Ensure that the wires are positioned away from moving parts.

Terminal / Wire Colors	
1	white/blue
2	white/green
3	white/violet

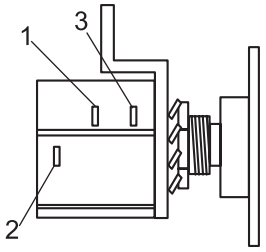


Figure 16.3: Mechanical Stop Pot Terminal Identification.

Injector Head - ***Mechanical Stop Pot*** ***(continued)***

4. For the following measurements, connect the DVM ground to terminal 3 on the *plunger position pot*.
5. Apply power. Disregard any messages that may appear on the Sentinel. Advance moveable stop forward approximately 5/8”. Advance the plunger at least 2 ml to satisfy the plunger pot test, then reverse the plunger to the rear limit.
6. Measure the wiper voltage on terminal 2 of the plunger position pot. This voltage should read 0.250 VDC +0/-0.020 VDC. If the reading is not within specification, loosen the screws securing the plunger pot, then disengage the gear to rotate to the correct setting. Re-engage the pot gear.
7. Advance the plunger until the plunger position pot wiper voltage (terminal 2) is 1.010 VDC.
8. Manually reverse the Mechanical Stop plate into the plunger plate until the mechanical stop microswitch opens (noted by an audible click). The DVM can be used on the microswitch to detect when the microswitch opens.
9. With a DVM, measure the voltage at terminal 2 of the Mechanical Stop pot. Disengage the pot gear, then set pot for a reading of 0.860 +/-0.02 VDC.
10. Reengage pot gear and tighten pot bracket screws, then reverse plunger to the rear limit. *Ensure that the mechanical stop pot gear and the acme screw gear are making positive contact and are not meshed too tightly.*
11. Disconnect the DVM from the head, then reconnect the Mechanical Stop motor lead. Mechanical stop will move forward.
12. Remove injector power.
13. Ensure that all pot screws are secure, then reassemble the injector head.

Injector Head ***- Plunger Motor Drive Belt***

Removal and replacement of the Plunger Motor Drive Belt requires extensive disassembly, reassembly, calibration and checkout. Although the procedures are included here, we do not recommend field repair of this item, and suggest that the injector head be returned to MEDRAD for these repairs.

Drive Belt Removal

1. After disassembly of the injector head, remove the two screws securing the cable bracket on the rear of the injector head, and the two screws securing the limit switch.
2. Remove the belt from the rear of the motor gear by rotating the gear while removing the belt from the large drive pulley.

Drive Belt Replacement

1. Position the replacement belt over the flanged motor gear. Align the belt teeth with the teeth of the large drive pulley, then begin to slide the belt onto the gear.
2. Rotate the gear while pushing the belt onto the large drive pulley. The belt need not be centered on the gear; the belt will become centered as the motor turns.

CAUTION: The drive belt must be tightly secured. If not sufficiently tightened, the belt could jump from the gear teeth at high pressures. Equipment failure or malfunction may result.

NOTE: If it is necessary to tighten the drive belt, loosen the four screws securing the drive motor. Apply tension to the drive belt by prying the motor case with a screw-driver, then tighten the four motor screws. Repeat this process as required until the belt does not slip during a full pressure injection. Refer to Figure 16.4.

Injector Head ***- Plunger Motor Drive Belt (continued)***

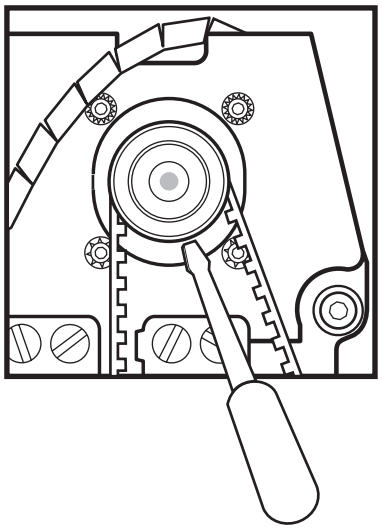


Figure 16.4: Belt Tension Adjustment

Follow these guidelines when applying tension to the drive belt:

- Use a medium blade screwdriver, not longer than 6 inches (15 cm).
- After securing the belt, check the injector at the maximum pressure (1100 psi at 60 ml, 1200 psi at 150 ml or, 1000 psi at 200 ml) to ensure proper operation.
- If the belt is too tight, decreased motor speed may result.

3. Install the cable bracket and limit switch removed in belt removal step 1.
4. Reassemble the injector head. (See the procedure on Page 16 - 13.)

Injector Head - ***Plunger Drive Motor***

Removal and replacement of the Plunger Drive Motor Drive requires extensive disassembly, reassembly, calibration and checkout. Although the procedures are included here, we do not recommend field repair of this item, and suggest that the injector head be returned to MEDRAD for these repairs.

Motor Removal

1. After disassembly of the injector head, remove the drive belt (see Page 16 - 21).
2. Position the injector head with the front plate facing downward.
3. Note the position of the motor leads for re-termination, then carefully pull the connectors from the motor terminals.
4. Remove the four screws, lock washers, and washers securing the motor to the rear casting, then remove the motor, ensuring that the drive belt remains in position.

Motor Replacement

1. Orient the replacement motor in the injector head with the motor spade terminals pointing downward.
2. Install the motor, putting the gear through the drive belt and securing the four screws, lock washers, and washers which hold the motor, but do not tighten. Ensure that the belt is properly seated on the drive pulley.
3. Connect the wires to the motor terminals as follows:

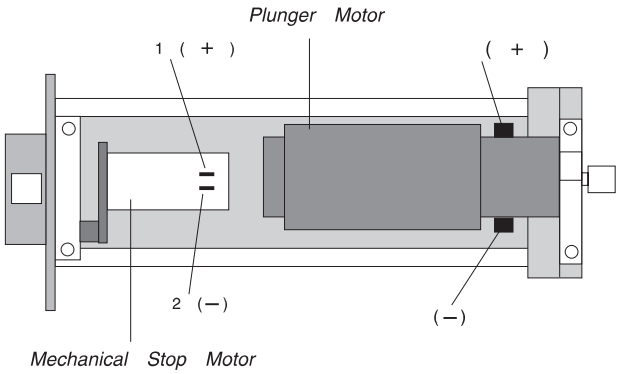


Figure 16.5: Plunger Motor Terminal Orientation

Injector Head ***- Plunger Drive Motor (continued)***

CAUTION: The drive belt must be tightly secured. If not sufficiently tightened, the belt could jump from the gear teeth at high pressures. Equipment failure or malfunction may result.

NOTE: To adjust drive belt tension, apply tension to the belt by prying the motor case with a screwdriver, then tighten the four motor screws. Refer to Figure 16.4.

Follow these guidelines when applying tension to the drive belt:

- Use a medium blade screwdriver, not longer than 6 inches (15 cm).
- After securing the belt, check the injector at the maximum pressure (1100 psi at 60 ml, 1200 psi at 150 ml or, 1000 psi at 200 ml) to ensure proper operation.
- If the belt is too tight, decreased motor speed may result.

4. Reassemble the injector head. (See the procedure on Page 16 - 13.)

Injector Head - ***Mechanical Stop Motor***

Motor Removal

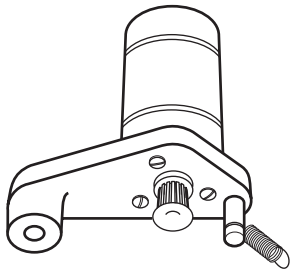
1. After removal of the injector head covers, position the head with the front plate facing down.
2. Carefully pull the connectors from the motor terminals.
3. Disengage the tension spring from the front plate spring post.
4. Remove the E-clip and wave spring. *Note the placement and direction of the wave spring.*
5. Remove the Mechanical Stop belt from the movable stop assembly pulley on the opposite side of the pivot knuckle.
6. Disengage the belt from the Mechanical Stop motor gear.
7. Remove the motor and bracket assembly (in a rotating and lifting motion) from the mounting pin.

   NOTE: Do not move the Mechanical Stop Belt, pulleys or idlers, after removal of the motor and bracket.

8. Remove the three screws securing the motor to the bracket.

Motor Replacement

1. As shown below, install the motor on the motor bracket with the three screws previously removed:



NOTE: Motor Terminals in the above illustration are facing away from the line of sight.

Figure 16.6: Mechanical Stop Motor Mount Configuration

Injector Head - ***Mechanical Stop Motor***

2. Install the motor and bracket assembly on the mounting pin in a rotating and downward motion.
3. Position the belt on the mechanical stop gear.

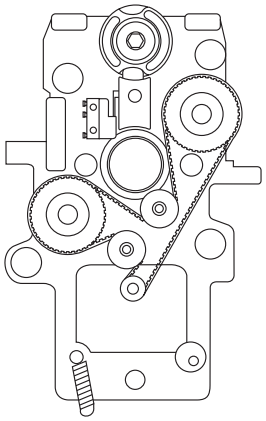


Figure 16.7: Drive Belt Routing

4. Position the belt on the movable stop assembly pulley on the opposite side of the pivot knuckle.
5. Install the previously removed wave spring and E-clip on the mounting post. Ensure that the E-clip is seated in the groove on the post.
6. Reattach the spring to the spring post.
7. Install the wire connectors on the motor terminals as follows:

Violet to Motor (+)	No. 1
Yellow to Motor (-)	No. 2

8. Reassemble the injector head. (See the procedure on Page 16 - 13.)

Injector Head ***- Control Panel***

NOTE: Removal and replacement of the injector head Control Panel requires major disassembly of the injector head. Although the procedures are included here, MEDRAD does not recommended field repair of these items, and suggests that the injector head be returned to MEDRAD Service for these repairs.

Control Panel Removal

1. After disassembly (see Page 16 - 13), place the Injector Head top-side up.
2. Remove the four flat-head screws mounting the Control Panel to the top of the Injector Head.
3. Remove the screw and nut securing the arm lamps to the plate.
4. Remove the head cable connectors, then carefully remove the Control Panel and attached board.
5. Remove the screws mounting the Head Card and card shield to the plate. Disconnect the ribbon cable at the connector.

Control Panel Replacement

1. Reconnect the ribbon cable from the push-button switch to the PC card.
2. Place the top plate and card on a smooth flat surface, top side down.
3. Gently tilt the card upward, placing the card (component side down) on the top plate.

   NOTE: Use extreme caution to avoid creasing of the ribbon cable.

4. Mount the PC card and card shield to the top plate with screws previously removed, ensuring that the ribbon cable is properly positioned, not crimped or pinched.
5. Position the Top Plate on the head, then mount with the four screws previously removed.
6. Attach Head Cable connectors and arm lamps.
7. Connect the Injector Head Cable to the rear connector panel of the injector, then apply power to the system. Ensure that the plunger moves freely in both the forward and reverse directions.
8. Arm the injector. Verify that the head will arm properly.
9. If the Injector Head is functioning properly, reassemble following the procedure on Page 16 - 13.

Injector Head - ***Mechanical Stop Limit Switch***

Mechanical Stop Limit Switch Removal

1. Disassemble the injector head.
2. Desolder the wires from the limit switch.
3. Remove the limit switch and bracket from the injector head.

Mechanical Stop Limit Switch Replacement

1. Assemble the replacement limit switch with bracket and solder wires as shown below:

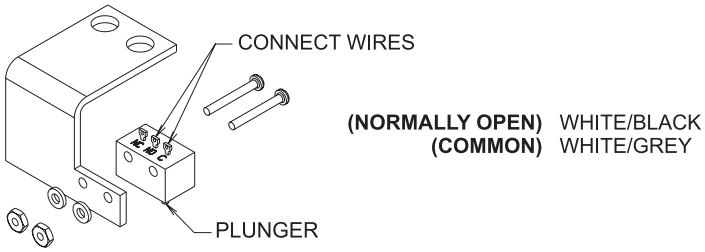


Figure 16.8: Mechanical Stop Limit Switch

2. Install replacement switch with switch plunger positioned over the center of the acme screw ball. Push the switch plunger into the acme screw ball until the switch contacts close (a clicking sound can be heard on switch closure). Secure with the two mounting screws previously removed.
3. Install cable ties as required to keep limit switch wires away from moving parts.
4. Apply power to the system. Install turret (if applicable) and activate forward load. If there is no forward movement, repeat step 2 above. Readjustment of the bracket/switch position may be required.
5. Reverse piston to the rear limit. Enter the following parameters: 5.0ml/sec., 10 ml volume, and 100 psi. Arm the injector. After the mechanical stop plate is in position, disable the mechanical stop motor by disconnecting one of the motor leads. Disarm the injector. Activate forward load until the piston plate makes contact with the mechanical stop plate. When the unit begins beeping, activate reverse load to the rearward limit. Reconnect the lead removed from the mechanical stop motor, allowing stop to return to standby position at 0 ml. Apply Loctite 242 (or equivalent) to limit switch bracket to secure switch.
5. Reassemble the injector head. (See the procedure on Page 16 - 13.)

Injector Head - *Cable*

Head Cable Removal

1. After disassembly of the injector head, note the routing of the cable wires, then remove any cable ties securing the main cable to the cable bracket or any other parts of the injector head.
2. Remove the clamp securing the main cable to the bracket, and set aside until installing the replacement cable.
3. Carefully remove the motor leads (two on each terminal).
4. With a medium-blade screwdriver, remove the screw securing the ground ring terminal to the back casting.
5. Disconnect the connectors from the head card at P/J55 and P/J27.
6. Disconnect the connectors from the TEC Card at P/J71-73, then disconnect the LED by removing Pins 9 (black) and 10 (red) from P71.
7. Carefully lift the cable from the injector head to avoid disturbing other wiring.

Head Cable Replacement

1. Position the replacement cable in the injector head. Route the four wires with push-on connectors (two wires in each connector) to the motor. Refer to Page 20 - 24 for proper connections.
2. Connect the head card connectors at P/J55 and P/J27.
3. Remove the jumper header between P72 and P73. Connect P72 (front) and P73 (rear) to the TEC Card with “THIS SIDE OUT” facing away from the card. Install the BLACK LED wire in Pin 9 and the RED LED wire in Pin 10 of P71.
4. Position the cable on the bracket, then replace and tighten the clamp.
5. Secure the ground wires with the mounting screw previously removed.
6. As necessary to prevent interference with any moving parts, install cable ties securing the cable and other wires to the bracket.
7. Apply power, then check injector head operation.
8. Reassemble the injector head. (See the procedure on Page 16 - 13.)

Injector Head - *Oil Seal*

Oil Seal Removal

1. Remove the plastic plugs from the seal by pushing the edge of the plug with a screwdriver. Remove the screws securing the seal, then remove the seal.
2. Remove the O-ring from the inside of the groove.

Oil Seal Replacement

1. Remove any contrast that may be on the plunger shaft.
2. Lightly lubricate the new O-ring with grease, then insert into groove.

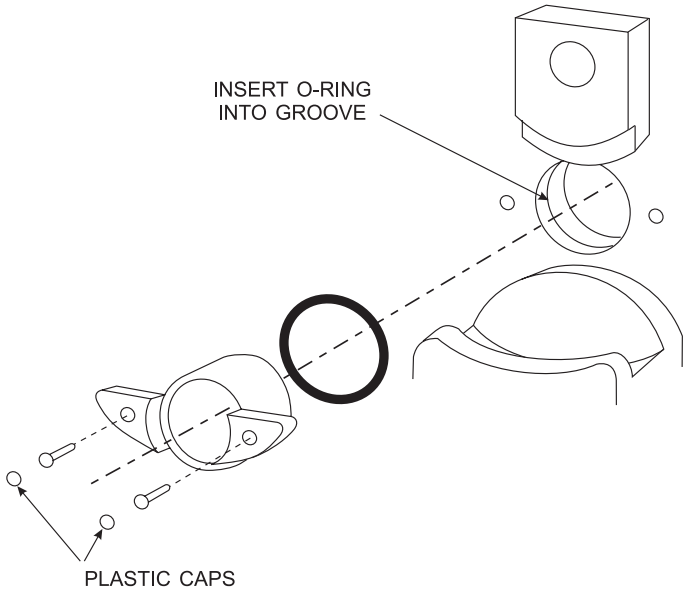


Figure 16.9: O-Ring Installation

3. Install seal cartridge.
4. Lightly lubricate the seal cartridge screws.
5. Install and tighten screws to secure the seal cartridge.
6. Install the plastic plugs over the mounting screws with the rounded boss facing the screws. Use a flat object, such as a coin or the side of a screwdriver, for easier installation.
7. Rotate the piston rotation lever in both directions to ensure unrestricted movement.
8. Install the turret on the head with a pressure jacket and syringe.
9. Apply power to the injector, then verify proper syringe operation with the newly installed seal cartridge.

Injector Head - ***Pivot Knuckle Adjustment***

This procedure is to be performed if the injector head will not stay in the position in which it was set.

Adjustment Procedure

1. Remove the hole plug located on the side of the pivot knuckle.
2. Tighten the nut until the head will remain in the set position.

NOTE: If the pivot knuckle is secured by a bolt, avoid over-tightening of the bolt to prevent stripping of the casting. Stripping will result in slippage of the bolt, causing the injector head to fall.

Power Switch

Power Switch Removal

1. Remove the injector from the power source.
2. Remove the power switch by prying gently with a screwdriver.
3. Disconnect the wires from the switch.

Power Switch Replacement

1 Connect the power switch wires as shown below.

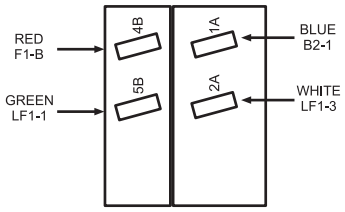


Figure 16.10: Power Switch Terminal Orientations

2. Place the switch in the unit without inserting fully. Connect the injector to a power source, then apply power.
3. If the switch is oriented correctly, the On/Off label will agree with the position of the switch. If this is not the case, remove and reverse the switch. When oriented correctly, fully insert the switch into the case.

Line Voltage Conversion

Adapting the Mark V ProVis Injection System for different line voltage effects the wiring to the transformer only.

WARNING: Hazardous voltages exist within the injection system. To avoid injury, remove the injector from the power source before attempting any line voltage conversion, and remove the line cord from the power source.

Conversion Procedure:

1. *Pedestal Systems:*
   - Remove the rear access panels by removing the four mounting screws.
   - Disconnect all cable connections at the rear connector panel.
   - Remove the bracket that secures the electronics console in the assembly, then remove the console and place on an anti-static surface.
   - Remove the twelve (12) screws that secure the RF shield to the electronics console.

   Rackmount Systems:

   Remove the two screws from the top edge of the front panel, then tilt the panel downward.

Voltage Range	***Line Voltage***	***Breaker***	***Power Switch***
95-105	100 VAC	475-4106-010	3002903
106-120	110 VAC	475-4106-010	3002903
121-125	125 VAC	475-4106-010	3002903
190-210	200 VAC	475-4106-005	3002904
211-239	230 VAC	475-4106-005	3002904
240-250	250 VAC	475-4106-005	3002904

2. Remove the bottom cover of the assembly.

Line Voltage Conversion *(continued)*

3. Locate the power transformer. When changing the configuration, refer to the following table for wiring guidelines. Do not change the wires on the X side.

Line Voltage	***Neutral (blue)***	***Hot (brown)***	***Jumper (white/brown)***
100 VAC	H2 and H6	H1 and H5	n/a
110 VAC	H3 and H7	H1 and H5	n/a
125 VAC	H4 and H8	H1 and H5	n/a
200 VAC	H6 (only)	H1 (only)	H2 to H5
230 VAC	H7 (only)	H1 (only)	H3 to H5
250 VAC	H8 (only)	H1 (only)	H4 to H5

4. Replace the bottom cover of the Control Unit.
5. Mate the harness connectors together.
6. *(Pedestal Systems only)* Replace the RF shield and secure with the twelve (12) screws previously removed.
7. *(Pedestal Systems only):* Position the electronic console in the pedestal assembly and secure with the four mounting screws.
8. Connect the injector head to the rear connector panel.
9. *(Pedestal Systems only):* Re-establish all cable connections at the rear connector panel, then install and secure the rear access panels with the four screws previously removed.
10. *(Rackmount Systems only):* Tilt the Front Panel upward, then secure by tightening the two captive screws.
11. Apply power to the injector, then confirm proper unit operation.

Line Frequency Conversion

The Power Drive Circuit in the *Mark V ProVis* Injector is sensitive to line frequency. When manufactured, the injector is calibrated for either 50 or 60 Hz; marked on a tag on the Power Drive Card, and the system serial number tag on the Control Unit. If the injector is to be used at a line frequency other than as marked, adjustment can be made for proper operation through the following instructions.

Conversion Procedure

NOTE: Disregard any messages that may appear in the SENTINEL throughout this adjustment process.

1. Remove power from the injector, then disconnect from the power source.
2. Access the PC cards inside the electronics console. Refer to the disassembly and reassembly procedures outlined in this section as required.
3. Remove the ISI Card. Position the 50/60 Hz switch on the ISI Card at the line frequency supplied to the injector. Reinstall the ISI Card.
4. Remove the Power Drive Card, then install the card extender between the Power Drive Card and the mating connector in the chassis. Reconnect the cables on the connector plate.
5. Disconnect the white/red AC wires from the SCR bridge, located on the Power Drive Relay Card. Tape or otherwise insulate these wires to avoid an accident.
6. Apply power to the injector.

Line Frequency Checkout

Perform this checkout procedure after adjusting the line frequency according to the procedure on the previous page.

1. Remove power from the injector. Remove the card extender, then insert the Power Drive Card directly into the chassis, and reconnect the AC wires to the SCR bridge. Connect the injector head, then apply power to the injector.
2. Reverse the plunger completely. Activate forward load. The plunger should reach the 0 ml mark +1 ml, within 8-30 seconds.
3. Reverse the plunger completely. Set up an injection of 1 ml/sec for 150 ml. Arm and inject. The injection should be smooth, with no interruptions or error messages.
4. Reverse the plunger completely. Set up an injection of 50 ml/sec for 150 ml. Arm and inject. The injection should be smooth, with no interruptions or error messages.
5. (Pedestal Systems only) Re-assemble the injector following the procedures outlined in this section, as required.
6. (Rackmount Systems only) Tilt the Front Panel upward, then secure by tightening the two captive screws.