



HPC Seismic Simulation Control System

User Manual

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Software Verification and Validation

MTS software is developed using established quality practices in accordance with the requirements detailed in the ISO 9001 standards. Because MTS-authored software is delivered in binary format, it is not user accessible. This software will not change over time. Many releases are written to be backwards compatible, creating another form of verification. The status and validity of the MTS operating software is also checked during system verification and routine calibration of MTS hardware. These controlled calibration processes compare the final test results after statistical analysis against the predicted response of the calibration standards. With these established methods, MTS assures its customers that MTS products meet exacting quality standards when initially installed and will continue to perform as intended over time.

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Technical Support

How to Get Technical Support

Start with your manuals

The manuals supplied by MTS provide most of the information you need to use and maintain your equipment. If your equipment includes software, look for online help and README files that contain additional product information.

Technical support methods

MTS provides a full range of support services after your system is installed. If you have any questions about a system or product, contact Technical Support in one of the following ways.

Web site	www.mts.com > Contact Us (upper-right corner) > In the Subject field, choose To escalate a problem; Problem Submittal Form
E-mail	Worldwide: tech.support@mts.com Europe: techsupport.europe@mts.com
Telephone	Worldwide: 1 800 328 2255 - toll free in U.S.; +1 952 937 4000 - outside U.S. Europe: +800 81002 222, International toll free in Europe

Outside the U.S.

For technical support outside the United States, contact your local sales and service office. For a list of worldwide sales and service locations and contact information, use the Global MTS link at the MTS web site:

www.mts.com > Global Presence > Choose a Region

Before You Contact MTS

MTS can help you more efficiently if you have the following information available when you contact us for support.

Know your site number and system number

The site number contains your company number and identifies your equipment type (such as material testing or simulation). The number is typically written on a label on your equipment before the system leaves MTS. If you do not know your MTS site number, contact your sales engineer.

Example site number: 571167

Technical Support

When you have more than one MTS system, the system job number identifies your system. You can find your job number in your order paperwork.

Example system number: US1.42460

Know information from prior technical assistance

If you have contacted MTS about this problem before, we can recall your file based on the:

- MTS case number
- Name of the person who helped you

Identify the problem

Describe the problem and know the answers to the following questions:

- How long and how often has the problem occurred?
- Can you reproduce the problem?
- Were any hardware or software changes made to the system before the problem started?
- What are the equipment model numbers?
- What is the controller model (if applicable)?
- What is the system configuration?

Know relevant computer information

For a computer problem, have the following information available:

- Manufacturer's name and model number
- Operating software type and service patch information
- Amount of system memory
- Amount of free space on the hard drive where the application resides
- Current status of hard-drive fragmentation
- Connection status to a corporate network

Know relevant software information

For software application problems, have the following information available:

- The software application's name, version number, build number, and (if available) software patch number. This information can typically be found in the About selection in the Help menu.
- The names of other applications on your computer, such as:
 - Anti-virus software
 - Screen savers
 - Keyboard enhancers
 - Print spoolers

— Messaging applications

If You Contact MTS by Phone

A Call Center agent registers your call before connecting you with a technical support specialist. The agent asks you for your:

- Site number
- Email address
- Name
- Company name
- Company address
- Phone number where you can be reached

If your issue has a case number, please provide that number. A new issue will be assigned a unique case number.

Identify system type

To enable the Call Center agent to connect you with the most qualified technical support specialist available, identify your system as one of the following types:

- Electrodynamic material test system
- Electromechanical material test system
- Hydromechanical material test system
- Vehicle test system
- Vehicle component test system
- Aero test system

Be prepared to troubleshoot

Prepare to perform troubleshooting while on the phone:

- Call from a telephone close to the system so that you can implement suggestions made over the phone.
- Have the original operating and application software media available.
- If you are not familiar with all aspects of the equipment operation, have an experienced user nearby to assist you.

Write down relevant information

In case Technical Support must call you:

- Verify the case number.

Technical Support

- Record the name of the person who helped you.
- Write down any specific instructions.

After you call

MTS logs and tracks all calls to ensure that you receive assistance for your problem or request. If you have questions about the status of your problem or have additional information to report, please contact Technical Support again and provide your original case number.

Problem Submittal Form in MTS Manuals

Use the Problem Submittal Form to communicate problems with your software, hardware, manuals, or service that are not resolved to your satisfaction through the technical support process. The form includes check boxes that allow you to indicate the urgency of your problem and your expectation of an acceptable response time. We guarantee a timely response—your feedback is important to us.

You can access the Problem Submittal Form at www.mts.com > Contact Us (upper-right corner) > In the **Subject** field, choose **To escalate a problem; Problem Submittal Form**

Preface

Before You Begin

Safety first!

Before you use your MTS product or system, read and understand the safety information provided with your system. Improper installation, operation, or maintenance can result in hazardous conditions that can cause severe personal injury or death, or damage to your equipment and specimen. Again, read and understand the safety information provided with your system before you continue. It is very important that you remain aware of hazards that apply to your system.

Other MTS manuals

In addition to this manual, you may receive additional manuals in paper or electronic form.

You may also receive an MTS System Documentation CD. It contains an electronic copy of the manuals that pertain to your test system.

Controller and application software manuals are typically included on the software CD distribution disc(s).

Documentation Conventions

The following paragraphs describe some of the conventions that are used in your MTS manuals.

Hazard conventions

Hazard notices may be embedded in this manual. These notices contain safety information that is specific to the activity to be performed. Hazard notices immediately precede the step or procedure that may lead to an associated hazard. Read all hazard notices carefully and follow all directions and recommendations. Three different levels of hazard notices may appear in your manuals. Following are examples of all three levels. (for general safety information, see the safety information provided with your system.)



Danger:

Danger notices indicate the presence of a hazard with a high level of risk which, if ignored, will result in death, severe personal injury, or substantial property damage.



Warning:

Warning notices indicate the presence of a hazard with a medium level of risk which, if ignored, can result in death, severe personal injury, or substantial property damage.



Caution:

Caution notices indicate the presence of a hazard with a low level of risk which, if ignored, could cause moderate or minor personal injury or equipment damage, or could endanger test integrity.

Other special text conventions

**Important:**

Important notices provide information about your system that is essential to its proper function. While not safety-related, if the important information is ignored, test results may not be reliable, or your system may not operate properly.

**Note:**

Notes provide additional information about operating your system or highlight easily overlooked information.

**Recommended:**

Recommended notes provide a suggested way to accomplish a task based on what MTS has found to be most effective.

**Tip:**

Tips provide helpful information or a hint about how to most efficiently accomplish a task.

**Access:**

Access provides the route you should follow to a referenced item in the software.

Examples show specific scenarios relating to your product and appear with a shaded background.

Special terms

The first occurrence of special terms is shown in italics.

Illustrations

Illustrations appear in this manual to clarify text. They are examples only and do not necessarily represent your actual system configuration, test application, or software.

Electronic manual conventions

This manual is available as an electronic document in the Portable Document File (PDF) format. It can be viewed on any computer that has Adobe Acrobat Reader installed.

Hypertext links

The electronic document has many hypertext links displayed in a blue font. All blue words in the body text, along with all contents entries and index page numbers, are hypertext links. When you click a hypertext link, the application jumps to the corresponding topic.

Safety

Topics:

- *Overview.....18*
- *Personnel Qualifications.....19*
- *Hazards.....19*
- *Energy Isolation/Lockout/Tagout.....23*
- *Site Precautions.....25*
- *Guards, Doors, and Covers.....26*
- *Safety Practices.....26*

Overview

Safety Information Overview

MTS systems are designed to generate single-axis or multi-axial motions and forces simultaneously in a controlled environment and impart these motions and forces into a specimen that is secured to the system.

When you prepare to operate the system and during system operation, ensure the following:

- Do not use or allow personnel to operate the system who are not experienced, trained, or educated in the inherent dangers associated with this system and who are not experienced, trained, or educated with regard to the intended operation as it applies to this system.
- Do not disable safety components or features (including limit detectors, light curtains, or proximity switches/detectors).
- Do not attempt to operate the system without appropriate personal safety gear (for example, hearing, head, hand, and eye protection).
- Do not apply energy levels that exceed the maximum energies and velocities for the system design. For these maximum values, refer to the system specifications.
- Do not use a specimen that does not meet the minimum (if applicable) or exceeds the maximum allowable mass. For these values, refer to the system specifications.
- Do not use specimens that are combustible, flammable, pressurized, or explosive.
- Do not use humans as specimens or allow humans to ride in or on the specimen or the system for any purpose unless the system is man-rated and all associated safety conditions are strictly enforced.
- Do not modify the system or replace system components using parts that are not MTS component parts.
- Do not make repairs using parts or components that are not manufactured to MTS specifications.
- Do not operate the system in an explosive atmosphere.
- Do not use the system in an area where uncontrolled access to the system is allowed when the system is in operation.

Personnel Qualifications

Personnel Qualifications

**Warning:**

System installation, maintenance, setup, and operation require specialized training.

Installation, maintenance, setup, and operation of the system by unqualified personnel can expose them, and others, to hazards that can cause death or personal injury and damage to equipment.

Do not allow unqualified personnel to perform any of the system installation, maintenance, setup, or operating procedures. Installation, maintenance, setup, and operating procedures should only be performed by trained personnel.

Hazards

System Hazard Zones

The area around and including the system is considered hazardous. Generally, hazards result from motions that occur during system operation. However, there are latent pressure, overturning, and settling/unexpected movement hazards that can occur prior to or after system operation, during specimen installation, or during maintenance and repair.

The hazard zone includes the entire system and an additional area of at least 2 m (6 ft) around the system perimeter. In addition, the hazard zone should be extended to include the hydraulic power source and any associated hoses, cables, and hard line.

Whenever personnel enter this defined zone they should be outfitted with adequate and appropriate safety attire including hearing protection, safety glasses, hard hat, and safety shoes. Never wear loose-fitting clothing when in the system area. Never enter the system area when hydraulics are on.

Hazard Placard Placement

Hazard placards contain specific safety information and are affixed directly to the system so they are plainly visible.

Each placard describes a system-related hazard. When possible, international symbols (icons) are used to graphically indicate the type of hazard and the placard label indicates its severity. In some instances, the placard may contain text that describes the hazard, the potential result if the hazard is ignored, and general instructions about how to avoid the hazard.

Hazard Warning Icons

Following are hazard warning icons used on MTS products. These icons indicate hazards that can result in personal injury or equipment damage. They are typically placed on or near the area of concern. They are intended to alert the user to possible hazardous conditions or hazardous situations. Warning icons are available in three sizes:

- Large (lg)—96.5 mm dia. (3.80 inches)
- Medium (med)—57.2 mm dia. (2.25 inches)
- Small (sm)—33.0 mm dia. (1.30 inches)

Part Number	Icon	Description
057-230-001 (lg) 057-230-101 (med) 057-230-201 (sm)		General warning. Possible hazard(s) exists in the vicinity where this icon is located. Refer to the manual for additional information.
057-230-002 (lg) 057-230-102 (med) 057-230-202 (sm)		Voltage hazard. High voltage exists in the vicinity where this icon is located. Be aware of possible electrocution when working in areas noted with this icon.
057-230-007 (lg) 057-230-107 (med) 057-230-207 (sm)		Fuse. Circuit is fused. If the fuse blows, troubleshoot and repair the cause. Always replace with a fuse of the same amperage rating.
057-230-009 (lg) 057-230-109 (med) 057-230-209 (sm)		Eye damage hazard. Wear appropriate personal protective equipment. For example, safety goggles.
057-230-035 (lg) 057-230-135 (med) 057-230-235 (sm)		Static sensitivity hazard. Equipment is static sensitive. Handling should only be performed by qualified service technicians or field service engineers familiar with grounding requirements associated with this type of equipment.

Hazard Action Icons

Following are hazard action icons used on MTS products. These icons indicate recommended actions that will minimize the chance of personal injury or equipment damage. They are typically placed on or near the area of concern. They are intended to alert the user to actions that should be taken. Action icons are available in three sizes:

- Large (lg)—76.2 mm dia. (3.00 inches)

- Medium (med)—58.8 mm dia. (2.00 inches)
- Small (sm)—38.1 mm dia. (1.50 inches)

Part Number	Icon	Description
057-237-501 (lg)		Read the manuals.
057-237-601 (med)		
057-237-701 (sm)		
057-237-502 (lg)		Keep locked.
057-237-602 (med)		
057-237-702 (sm)		
057-237-503 (lg)		Lock out electrical power.
057-237-603 (med)		
057-237-703 (sm)		
057-237-504 (lg)		Wear gloves.
057-237-604 (med)		
057-237-704 (sm)		
057-237-505 (lg)		Wear ear protection.
057-237-605 (med)		
057-237-705 (sm)		
057-237-506 (lg)		Wear eye protection.
057-237-606 (med)		
057-237-706 (sm)		
057-237-507 (lg)		Wear ear and eye protection.
057-237-607 (med)		
057-237-707 (sm)		
057-237-508 (lg)		Wear face shield.
057-237-608 (med)		
057-237-708 (sm)		
057-237-509 (lg)		Disconnect from electrical power before servicing.
057-237-609 (med)		
057-237-709 (sm)		

Safety

Part Number	Icon	Description
057-237-510 (lg) 057-237-610 (med) 057-237-710 (sm)		Two person lift.
057-237-511 (lg) 057-237-611 (med) 057-237-711 (sm)		Maintain safe pressure.
057-237-512 (lg) 057-237-612 (med) 057-237-712 (sm)		General action. Refer to the manuals for additional information.
057-237-513 (lg) 057-237-613 (med) 057-237-713 (sm)		Lift point.
057-237-514 (lg) 057-237-614 (med) 057-237-714 (sm)		Lock casters.
057-237-515 (lg) 057-237-615 (med) 057-237-715 (sm)		Wear hard hat.
057-237-516 (lg) 057-237-616 (med) 057-237-716 (sm)		Wear dust mask.

Hazard Prohibition Icons

The following hazard prohibition icons are found on MTS products and indicate actions that should not be performed. Performing any of these actions could cause personal injury or equipment damage. They are typically placed on or near the area of concern. They are intended to alert the user to actions that should not be taken. Prohibition icons are available in three sizes:

- Large (lg)—76.2 mm dia. (3.00 inches)
- Medium (med)—58.8 mm dia. (2.00 inches)
- Small (sm)—38.1 mm dia. (1.50 inches)

Part Number	Icon	Description
057-240-001 (lg) 057-240-101 (med) 057-240-201 (sm)		Do not step here. This is not a step.
057-240-002 (lg) 057-240-102 (med) 057-240-202 (sm)		No standing.
057-240-003 (lg) 057-240-103 (med) 057-240-203 (sm)		Do not operate with guard removed.
057-240-004 (lg) 057-240-104 (med) 057-240-204 (sm)		Stay clear.
057-240-005 (lg) 057-240-105 (med) 057-240-205 (sm)		Do not lift with hook. Not a lift point
057-240-006 (lg) 057-240-106 (med) 057-240-206 (sm)		Do not submerge.
057-240-007 (lg) 057-240-107 (med) 057-240-207 (sm)		No user serviceable parts within.

Energy Isolation/Lockout/Tagout

Identify Lockout/Tagout Points

The customer is responsible for establishing a program of energy control procedures, employee training, and periodic inspections to ensure that, before any employee performs service or maintenance on a machine or component (where unexpected energizing, startup, or release of stored energy could occur and cause injury), the machine or component is isolated from the energy source and rendered inoperative.

using a supply disconnect (energy isolating) device. The purchase, installation, and use of energy isolating, lockout, and tagout devices is a customer responsibility.

Lockout devices utilize a positive means, such as a lock, to hold an energy isolating device in the safe position and prevent energizing a machine or component. Tagout devices consist of a prominent warning device, such as a tag and means of attachment, which can be securely fastened to an energy isolating device in accordance with an established procedure, to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed.

The purpose of energy-isolating, lockout, and tagout devices is to provide a positive and effective means of isolating the test system from the various power sources associated with your system. These power sources can include (but are not limited to) electrical, hydraulic, water, gas, and air supplies. Each device, when installed, should provide a single point in the supply circuit where complete system isolation from supply power or pressure is accomplished when the device is used to interrupt the circuit.

It is important that you are able to isolate the system from its power supplies whenever personnel must work in proximity to the system. Electricity and heated, cooled, or pressurized fluids or gases are all potential hazards and the use of isolating devices, lockout, and tagout valves and switches is recommended. In association with using isolating devices, it is likely that a time interval must be observed to allow latent pressures, heat, or cold to dissipate from components before working with them

Consider the following:

- You should identify a single control point in your primary electrical supply where complete electrical isolation can be accomplished. Also, consider that each uninterruptible power supply (UPS) is potentially an independent (secondary) electrical power source. To determine methods for isolating each UPS as an electrical supply source, see your vendor-supplied UPS documentation. Before you make contact with any system circuit, test the circuit with a properly operating circuit tester to ensure that power is off.
- If your test system is supplied by a hydraulic power unit (HPU) or a facilities hydraulic power unit (FHPU), you must consider that the hydraulic fluid return lines may be pressurized any time that the HPU is operating. To view hydraulic schematic circuit details, see the System Documentation CD. Ensure that you fully understand system supply behavior before you install your lockout/tagout device.
- If your system configuration includes pressure-line accumulators, the lockout/tagout device must be installed downstream from the accumulators and upstream from the hydraulic service manifold (HSM) to be effective. Unless you install the lockout/tagout valve in this way, the charged accumulators will pressurize the line even when the HPU is off and the lockout/tagout valve is closed. Refer to the System Documentation CD to view hydraulic schematic circuit details. Ensure that you fully understand system supply behavior before you install your lockout/tagout device.

Site Precautions

Site Precautions

**Warning:**

The equipment is designed to operate in an environment where precautions have to be taken to minimize hazards to personnel and the equipment.

Ignoring hazards and failing to take necessary precautions can result in injury or death to personnel, and damage to equipment.

Do not install or operate the system equipment in a hazardous environment.

**Warning:**

Hazardous situations or conditions can arise suddenly and without warning at all parts of the system.

If immediate action is not taken to remove the hazard or remove personnel from the hazard, serious injury or death can result.

Do not operate the system unless you have full view of the equipment. If operation of the system takes place in a remote control room (separated from the equipment), it should be designed so that the operator has full and unobstructed view of the system equipment. Make sure that ergonomic issues are considered in the layout of the operating area to limit operator stress and fatigue.

**Warning:**

Working environments that are not designed with appropriate ventilation, lighting, heating and cooling or non-ergonomic equipment, furniture, and equipment/furniture placements can result in operator fatigue and stress.

Operator fatigue and stress can result in operator errors which can result in injury to personnel or damage to the equipment and/or specimen.

Make sure that lighting, heating, cooling, and ergonomic issues are considered in the layout of the operating area to limit operator stress and fatigue.

Guards, Doors, and Covers

Equipment Guards, Doors, and Covers



Warning:

Guards, doors, and covers are designed to protect personnel from moving parts, electrical shock, and pressurized fluid or gas.

If guards, doors, and covers are not installed, potential hazards are exposed that can cause injury or death. Personnel can be struck, crushed, entangled, or drawn into moving parts; hit by flying objects launched with concussive force by the rapid expansion of pressurized gas; sprayed from pressurized fluid that can burn and pierce; and electrocuted by exposed electrical conductors.

Install and close all guards, doors, and covers before applying electrical power and operating the system.

Safety Practices

General Safety Practices

If you have system related responsibilities (that is, if you are an operator, service engineer, or maintenance person), you should study this manual carefully before you attempt to perform any test system procedure.

You should receive training on this system or a similar system to ensure a thorough knowledge of your equipment and the safety issues that are associated with its use. In addition, you should gain an understanding of system functions by studying the other manuals supplied with your test system. Contact MTS for information about the content and dates of training classes that are offered.

It is very important that you study the following safety information to ensure that your facility procedures and the system's operating environment do not contribute to or result in a hazardous situation. Remember, you cannot eliminate all the hazards associated with this system, so you must learn and remain aware of the hazards that apply to your system at all times. Use these safety guidelines to help learn and identify hazards so that you can establish appropriate training and operating procedures and acquire appropriate safety equipment (such as gloves, goggles, and hearing protection).

Each test system operates within a unique environment which includes the following known variables:

- Facility variables (facility variables include the structure, atmosphere, and utilities)
- Unauthorized customer modifications to the equipment
- Operator experience and specialization

- Test specimens

Because of these variables (and the possibility of others), your system can operate under unforeseen circumstances that can result in an operating environment with unknown hazards.

Improper installation, operation, or maintenance of your system can result in hazardous conditions that can cause death, personal injury, or damage to the equipment or to the specimen. Common sense and a thorough knowledge of the system's operating capabilities can help to determine an appropriate and safe approach to its operation.

Observe the prescribed safety practices before and during system operation.

It is the customer's responsibility to take the machine out of service and contact MTS Service if discrepancies in system operation are found.

Safety Practices Before Operating the System

Before you apply power to the test system, review and complete all of the safety practices that are applicable to your system. The goal, by doing this, is to improve the safety awareness of all personnel involved with the system and to maintain, through visual inspections, the integrity of specific system components.

Read all manuals

Study the contents of this manual and the other manuals provided with your system before attempting to perform any system function for the first time. Procedures that seem relatively simple or intuitively obvious can require a complete understanding of system operation to avoid unsafe or dangerous situations.

Locate lockout/tagout points

Know where the lockout/tagout point is for each of the supply energies associated with your system. This includes the hydraulic, pneumatic, electric, and water supplies (as appropriate) for your system to ensure that the system is isolated from these energies when required.

Know facility safe procedures

Most facilities have internal procedures and rules regarding safe practices within the facility. Be aware of these safe practices and incorporate them into your daily operation of the system.

Locate Emergency Stop buttons

Know the location of all the system Emergency Stop buttons so that you can stop the system quickly in an emergency. Ensure that an Emergency Stop button is located within close proximity of the operator at all times.

Know controls

Before you operate the system for the first time, make a trial run through the operating procedures with the power off. Locate all hardware and software controls and know what their functions are and what adjustments they require. If any control function or operating adjustment is not clear, review the applicable information until you understand it thoroughly.

Safety

Have first aid available

Accidents can happen even when you are careful. Arrange your operator schedules so that a properly trained person is always close by to render first aid. In addition, ensure that local emergency contact information is posted clearly and in sight of the system operator.

Know potential crush and pinch points

Be aware of potential crush and pinch points on your system and keep personnel and equipment clear of these areas.

An important consideration for servohydraulic systems is that when power is interrupted, it is likely that stored accumulator pressure will persist for some time within the system. In addition, it is likely that as stored energy dissipates, gravity will cause portions of the system to move.

Be aware of component movement with hydraulics off

For hydraulic systems, be aware that mechanical assemblies can shift or drift due to changes within hydraulic hardware when hydraulics are turned off. This non-commanded movement is because oil can transfer between the pressure and return ports and across internal components of the hydraulic hardware. Be aware that this can happen, and clear the area around the mechanical assemblies when hydraulics are turned off.

Know electrical hazards

When the system electrical power is turned on, minimize the potential for electrical shock hazards. Wear clothing and use tools that are properly insulated for electrical work. Avoid contact with exposed wiring or switch contacts.

Whenever possible, turn off electrical power when you work on or in proximity to any electrical system component. Observe the same precautions as those given for any other high-voltage machinery.

Make sure that all electrical components are adequately grounded. Grounds must remain connected and undisturbed at all times.

Ensure correct cable connection

If a system cable has been disconnected, ensure that you establish the correct cable-to-connector relationship during reconnection. Incorrect cable connections can result in improper servo loop phasing or an open servo loop condition, either of which can cause unstable or unexpected and potentially dangerous system motions. Verify the correct cable-to-connector relationship by observing the cable and connector labeling and the system wiring schematics.

Keep bystanders safely away

Keep bystanders at a safe distance from all equipment. Never allow bystanders to be in close proximity of specimens or equipment while the test is running.

Wear proper clothing

Do not wear neckties, shop aprons, loose clothing or jewelry, or long hair that could get caught in equipment and result in an injury. Remove loose clothing or jewelry and restrain long hair.

Remove flammable fluids

Remove flammable fluids from their containers or from components before you install the container or component. If desired, you can replace the flammable fluid with a non-flammable fluid to maintain the proper proportion of weight and balance.

Know compressed gas hazards

Your system may contain accumulators that require a high-pressure gas precharge (pressures that exceed 138 bar [2000 psi]). High-pressure devices are potentially dangerous because a great amount of energy is available in the event of an uncontrolled expansion or rupture.

Observe the following safety practices when you work with high-pressure air or gases:

- When you charge an accumulator, follow all the charging instructions provided in the appropriate product information manuals. When precharging accumulators, properly identify the type of gas to be used and the type of accumulator to be precharged.
- Use only dry-pumped nitrogen to precharge nitrogen-charged accumulators. (Dry-pumped nitrogen can also be labeled “oil pumped” or “dry water pumped.”) Do not use compressed air or oxygen for precharging: the temperature increase caused by rapid gas compression can result in highly explosive conditions when hydraulic fluid is in the presence of oxygen or compressed air.
- Always follow the recommended bleeding procedures before you remove or disassemble components that contain pressurized gas. When you bleed a gas or remove a fitting, hose, or component that contains a gas, remember that many gases cannot support life. Therefore, as the ratio of released gas to oxygen increases, so does the potential for suffocation.
- Wear appropriate safety devices to protect your hearing. Escaping air or gas can create a noise level that can damage your hearing.
- Ensure that all pressurized air or gas is bled out of a pneumatic or gas-charged device before you start to disassemble it. A thorough understanding of the assembly and its pressurized areas is necessary before you undertake any maintenance. Refer to the appropriate product information for the correct bleeding procedure.

It may not be obvious or intuitive which bolts or fittings are used to restrain a pressurized area. On some assemblies, you must remove a cover plate to gain access to the structural bolts. Sometimes, to protect you from a rapid release of trapped gases, a small port is exposed when you remove this cover plate. Exposing this port ensures that the gas precharge is fully bled before disassembly. However, this is not the recommended procedure for bleeding a pneumatic or gas-charged device, because it can expose you to the dangers of escaping compressed gas and particulates that are expelled from the chamber or around the seals. Do not assume that cover plates and ports are installed in all the critical locations.

Consult MTS when in doubt about the safety or reliability of any system-related procedure or modification that involves devices that contain any type of compressed gas.

Check bolt ratings and torques

To ensure a reliable product, fasteners (such as bolts and tie rods) used in MTS-manufactured systems are torqued to specific requirements. If a fastener is loosened or the configuration of a component within the system is modified, see the system and component assembly drawings (located on the System Documentation CD) to determine the correct fastener, fastener rating, and torque. Over torquing or under torquing a fastener can create a hazardous situation due to the high forces and pressures present in MTS test systems.

Safety

On rare occasions, a fastener can fail even when it is correctly installed. Failure usually occurs during torquing, but it can occur several days later. Failure of a fastener can result in a high velocity projectile. Therefore, it is a good practice to avoid stationing personnel in line with or below assemblies that contain large or long fasteners.

Practice good housekeeping

Keep the floors in the work area clean. Industrial chemicals, such as hydraulic fluid, that are spilled on any type of floor can result in a dangerous, slippery surface. Do not leave tools, fixtures, or other items not specific to the test lying about on the floor, system, or decking.

Protect hoses and cables

Protect electrical cables from spilled fluids and from excessive temperatures that can cause the cables to harden and eventually fail. Ensure that all cables have appropriate strain relief devices installed at the cable and near the connector plug. Do not use the connector plug as a strain relief.

Protect all system hoses and cables from sharp or abrasive objects that can cause the hose or cable to fail. Use a cable cover or cable tray where cables are in traffic locations. Never walk on hoses or cables or move heavy objects over them. Route hoses and cables away from areas that expose them to possible damage.

Provide proper hydraulic fluid filtration

For hydraulic systems equipped with a non-MTS hydraulic power unit, make sure that hydraulic fluid filtration is established to maintain fluid cleanliness standards as stated in the Hydraulic Fluid Care Manual (see the System Documentation CD). Particles present in the hydraulic fluid can cause erratic or poor system response.

Protect accumulators from moving objects

For systems equipped with accumulators, protect accumulators with supports or guards. Do not strike accumulators with moving objects. This could cause the accumulator(s) to separate from the manifold resulting in equipment damage and personal injury.

Record changes

If you change any operating procedure, write the change and the date of the change in the appropriate manual.

Provide test area guards

Use protective guards such as cages, enclosures, and special laboratory layouts when you work with hazardous test specimens (for example, brittle or fragmenting materials or materials that are internally pressurized).

Do not exceed the Maximum Supply Pressure

For hydraulic systems and components, make sure that hydraulic supply pressure is limited to the maximum pressure defined by the system operating limits. Read and review “System Operating Limits” for the system.

Do not disable safety devices

Your system may have active or passive safety devices installed to prevent system operation if the device indicates an unsafe condition. Do not disable such devices as it may result in unexpected system motion.

Use appropriately sized fuses

Whenever you replace fuses for the system or supply, ensure that you use a fuse that is appropriately sized and correctly installed. Undersized or oversized fuses can result in cables that overheat and fuses that explode. Either instance creates a fire hazard.

Provide adequate lighting

Ensure adequate lighting to minimize the chance of operation errors, equipment damage, and personal injury.

Provide adequate ventilation

Make sure work and maintenance areas are adequately ventilated to minimize the risks associated with the collection of hazardous fumes (such as vaporized hydraulic fluid). This is of special concern in confined areas where hydraulic equipment is operating at high pressure in confined areas.

Provide means to access out-of-reach components

Make sure you can access system components that might be out of reach while standing on the floor. For example, ladders or scaffolding might be required to reach load cell connectors on tall load units.

Safety Practices While Operating the System

Wear appropriate personal protection

Wear eye protection when you work with high-pressure hydraulic fluid, high-pressure air pressure, breakable specimens, or when anything characteristic to the specimen could break apart.

Wear ear protection when you work near electric motors, pumps, or other devices that generate high noise levels. This system may create sound pressure levels that exceed 70 dbA during operation.

Wear appropriate protection (gloves, boots, suits, respirators) whenever you work with fluids, chemicals, or powders that may irritate or harm the skin, respiratory system, or eyes.

Provide test area enclosures

Use protective enclosures such as cages or shields, and special laboratory layouts when you work with hazardous test specimens (for example, brittle or fragmenting materials or materials that are internally pressurized).

You must evaluate risks due to ejected parts or materials from the test specimens. If the MTS Test Area Enclosure option is not purchased by the customer, then for protection against ejected parts or materials from test specimens and to control access to the machinery, the Customer must provide a Test Area Enclosure to protect personnel.

Specimen temperature changes

During cyclic testing, the specimen temperature can become hot enough to cause burns. Wear personal protection equipment (gloves) when handling specimens.

Handle chemicals safely

Whenever you use or handle chemicals (for example, hydraulic fluid, batteries, contaminated parts, electrical fluids, and maintenance waste), see the appropriate MSDS documentation for that material and determine

Safety

the appropriate measures and equipment required to handle and use the chemical safely. Ensure that the chemical is disposed of appropriately.

Know servohydraulic system interlocks

Interlock devices should always be used and properly adjusted. Interlock devices are designed to minimize the chance of accidental damage to the test specimen or the equipment. Test all interlock devices for proper operation immediately before a test. Do not disable or bypass any interlock devices as doing so could allow hydraulic pressure to be applied regardless of the true interlock condition. The Reset/Override button is a software function that can be used to temporarily override an interlock while attempting to start the hydraulic power unit and gain control of the system.

Know system limits

Never rely on system limits such as mechanical limits or software limits to protect you or any personnel. System limits are designed to minimize the chance of accidental damage to test specimens or to equipment. Test all limits for proper operation immediately before a test. Always use these limits and adjust them properly.

Do not disturb sensors

Do not bump, wiggle, adjust, disconnect, or otherwise disturb a sensor (such as an accelerometer or extensometer) or its connecting cable when hydraulic pressure is applied.

Ensure secure cables

Ensure that all cable connections (electrical supply, control, feedback, sensor, communications, and so forth) are either locking type, or are secured, to ensure that they cannot be disconnected by a simple act. Do not change any cable connections when electrical power or hydraulic pressure is applied. If you attempt to change a cable connection while the system is in operation, an open control loop condition can result. An open control loop condition can cause a rapid, unexpected system response which can result in severe personal injury, death, or damage to equipment. Also, ensure that all cables are connected after you make any changes in the system configuration.

Stay alert

Avoid long periods of work without adequate rest. In addition, avoid long periods of repetitious, unvarying, or monotonous work because these conditions can contribute to accidents and hazardous situations. If you are too familiar with the work environment, it is easy to overlook potential hazards that exist in that environment.

Contain small leaks

Do not use your fingers or hands to stop small leaks in hydraulic or pneumatic hoses. Substantial pressures can build up, especially if the hole is small. These high pressures may cause the oil or gas to penetrate your skin, causing painful and dangerously infected wounds. Turn off the hydraulic supply and allow the hydraulic pressure to dissipate before you remove and replace the hose or any pressurized component.

Stay clear of moving equipment/avoid crush points

Stay clear of mechanical linkages, connecting cables, and hoses that move because you may get pinched, crushed, tangled, or dragged along with the equipment. High forces generated by the system can pinch, cut, or crush anything in the path of the equipment and cause serious injury. Stay clear of any potential crush points. Most test systems can produce sudden, high-force motion. Never assume that your reactions are fast enough to allow you to escape injury when a system fails.

Know the causes of unexpected actuator motions

The high force and velocity capabilities of MTS actuators can be destructive and dangerous (especially if actuator motion is unexpected). The most likely causes of unexpected actuator response are operator error and equipment failure due to damage or abuse (such as broken, cut, or crushed cables and hoses; shorted wires; overstressed feedback devices; and damaged components within the servocontrol loop). Eliminate any condition that could cause unexpected actuator motion.

Do not use RF transmitters

Keep radio frequency (RF) transmitters away from the workstation computers, remote terminals, and electronics consoles. Intense RF fields can cause erratic operation of the more sensitive circuits in the system.

Overview

Topics:

- *Seismic Test System Introduction.....36*
- *Hydraulic Power Controllers.....36*
- *Digital Hydraulic Power Controller.....37*

Seismic Test System Introduction

The MTS seismic test system is designed to investigate the characteristics of table-mounted specimens undergoing simulated earthquakes generated from a program input.

The test system has been specifically designed to allow the seismic tables to be repositioned in the lab so that a wide variety of structure sizes can be tested on the system.

The tables can be operated individually in a stand-alone mode or operated simultaneously in a synchronized fashion.

Hydraulic Power Controllers

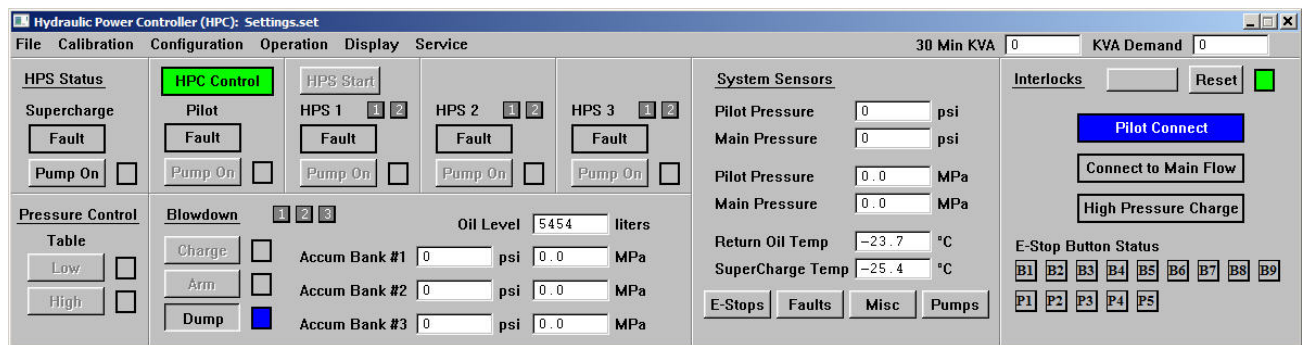
The Hydraulic Power Controllers are real-time, digital controllers that provide the actual control of the system hydraulics, the blowdown system, and the temperature command to the cooling system. The Hydraulic Power Controllers also provide a large number of system inputs and alarms parts of the table system that are not included in the basic control of the seismic table in the 469D Controller. They also provide an operator interface to the real-time hardware. The control hardware architecture is based on Digital Signal Processing technology that optimizes the performance of the embedded control system, and allows for the implementation of control and data filtering operations.

The controller consists of a MTS console assembly, associated cabling and control software. The MTS console assembly has an embedded processors, real-time hardware. The control software consists of the real-time control software and the control panel software. The real-time control software drives the processors to generate and acquire the necessary signals for hydraulic control. The control panel software runs on a PC and has a graphical user interface consisting of interactive, mode less dialogs that are used to interact with the hydraulic power components and input/output signals.

The Hydraulic Power digital control system and software provide the following features:

- Hydraulic Power Supply control and alarm indicators.
- Sequencing of Supercharge, Pilot, and 3 Main Pumps.
- Sequencing of Seismic Table Main Pressure: off, on, low, high.
- Control of the Blowdown Hydraulic System.
- Setting Pilot, Main Low/High, and Blowdown Charge pressure values.
- Monitoring of system inputs for warnings and alarms.
- Temperature control commands to Cooling System.

Digital Hydraulic Power Controller



Access

The main controller panel opens when you start the application.

When to use the panel

Use this panel to access all other panels in the application, define system controls, and run the table control system.

Panel description

The main controller panel allows access to all other parts of the application. It includes both menus and system controls.

System controls on the main controller panel allow you to perform the following tasks:

- Monitor and control hydraulic pumps and blowdown system.
- Monitor and control system fluid pressure and temperature.
- Enable or disable limits.

Overview

- Reset limit/interlock conditions.
- Communicate information to/from the 469D Table Controller.
- Display warnings and system alarms.
- Display details of pump operation and performance.

Control labels that are underlined

A control label that is underlined on the main panel, such as Interlocks, identifies that the control is a shortcut to a menu option.

Application menus

The following menus are provided:

- **File** — allows you to change passwords for access privileges, restore or save settings, convert files from binary to text format or visa versa, and quit the application.
- **Calibration** — allows you to calibrate converters, conditioners, and valve drivers, and save or restore the calibration values.
- **Configuration** — allows you to configure defaults for some panels.
- **Operation** — allows you to setup operations for control of the system.
- **Display** — allows you to set up readout displays.

For More Information

[Function Generators Reference](#) (p. 114)

Panel HPC Reference

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HPC Controller Settings



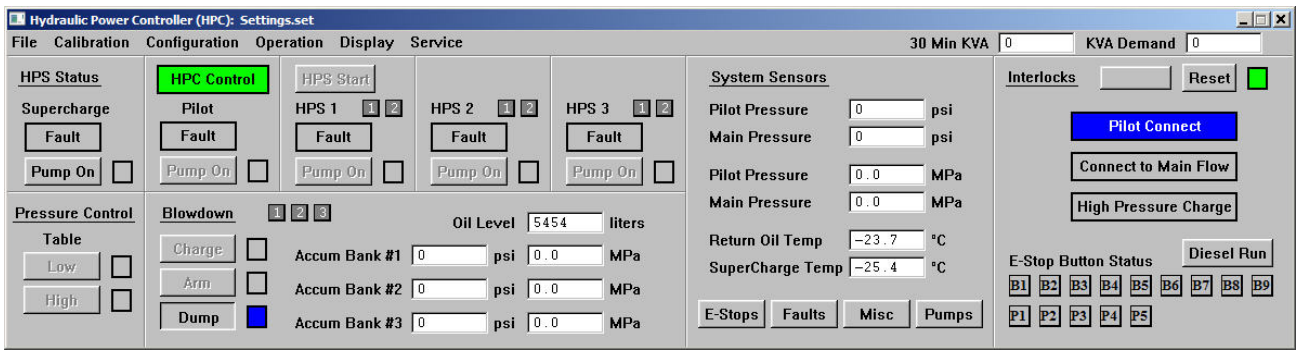
Warning:

When a panel opens it will display the current settings as it applies to the system.

If you change a setting without understanding the effect of the change, unexpected motion can occur in the system. Unexpected system motion can cause personal injury or damage to equipment.

Do not change a setting without knowing what effect the change will have on the system..

Digital HPC Controller



Access

The main controller panel opens when you start the application.

When to use the panel

Use this panel to access all other panels in the application, define system controls, and run the table control system.

Panel description

The main controller panel allows access to all other parts of the application. It includes both menus and system controls.

System controls on the main controller panel allow you to perform the following tasks:

- Monitor and control hydraulic pumps and blowdown system.
- Monitor and control system fluid pressure and temperature.
- Enable or disable limits.

- Reset limit/interlock conditions.
- Communicate information to/from the 469D Table Controller.
- Display warnings and system alarms.
- Display details of pump operation and performance.

Control labels that are underlined

A control label that is underlined on the main panel, such as Interlocks, identifies that the control is a shortcut to a menu option.

Application menus

The following menus are provided:

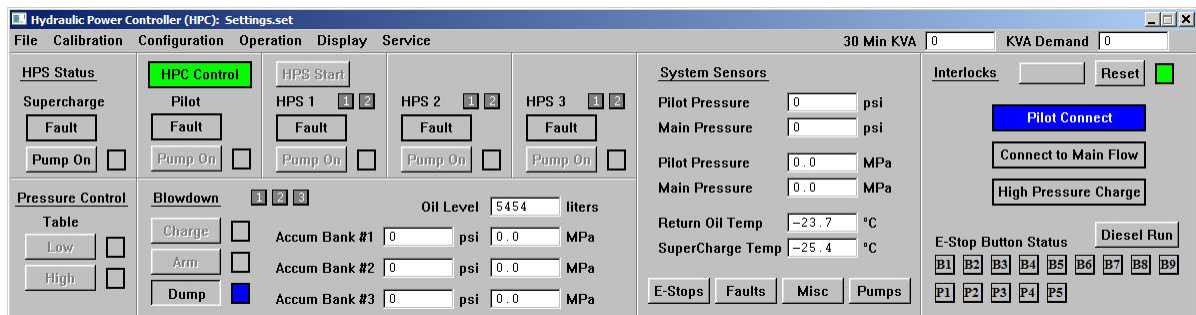
- **File** — allows you to change passwords for access privileges, restore or save settings, convert files from binary to text format or visa versa, and quit the application.
- **Calibration** — allows you to calibrate converters, conditioners, and valve drivers, and save or restore the calibration values.
- **Configuration** — allows you to configure defaults for some panels.
- **Operation** — allows you to setup operations for control of the system.
- **Display** — allows you to set up readout displays.

Digital Hydraulic Power Controller Reference

Basic Pump Controls

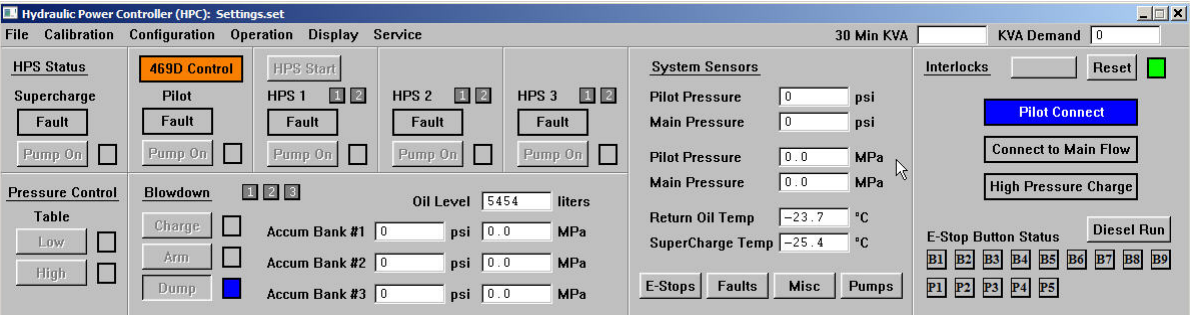
The Hydraulic Power Controller (HPC) controls the start/stop of the Supercharge pump, the Pilot pump, and the 3 Main pumps. There are two basic modes of operation: Control of pumps from the HPC main panel or control from the 469D Table Controller. The 469D controls who has control. On the HPC main panel in the top left 2nd box there is an indicator that shows which mode is currently in use. If the HPC is in control, the indicator shall display: **HPC Control** on a **Green** background or display: **469D Control** on an **Orange** background.

In HPC Control: All hydraulic control is from the HPC Main panel. All of the buttons for Pump On, HPS Start, Table Low Pressure, Table High Pressure, and Blowdown buttons are operational. The 469D ONLY receives status indication signals from the HPC to determine system hydraulic state. Buttons are enabled in sequence when pumps are started and main pressure applied. The blowdown controls also enable buttons as needed.



In 469D Control:

All control buttons for Pumps, Table Main Pressure, and Blowdown are disabled. The 469D controls all of the Pumps, Pressure controls, and Blowdown directly. The HPC only indicates current system hydraulic status. Note that the Supercharge **Pump On** button and the Blowdown **Dump** button are now disabled in this mode versus the HPC Control mode.



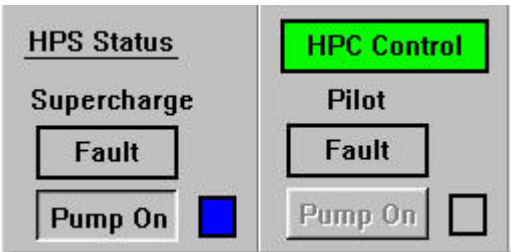
Normal Pump Sequence

The following pump control sequence will be shown using the HPC Control Mode. A later discussion shall indicate the slight differences in the sequence when the 469D is in control.

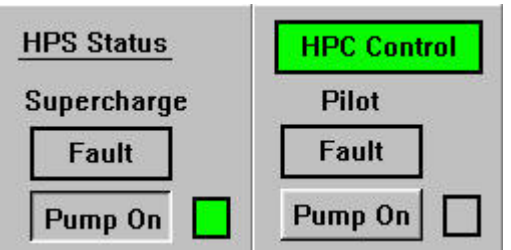
Start the Supercharge pump by pushing the **Pump On** button for the Supercharge. The indicator lamp shall begin blinking **Blue**.

There are 2 conditions where the HPC will not allow the Supercharge to start:

1. Interlocks have NOT been reset
2. UPS Backup power is NOT available.



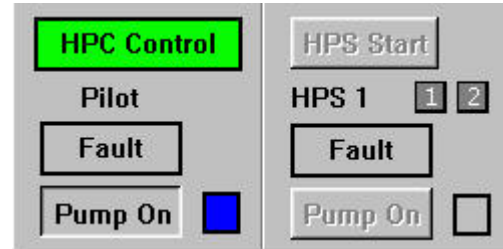
The blinking shall continue until the Supercharge motor is running. This usually takes less than 10-15 seconds. Then, the indicator shall show **Green** and the Pilot **Pump On** button will be activated.



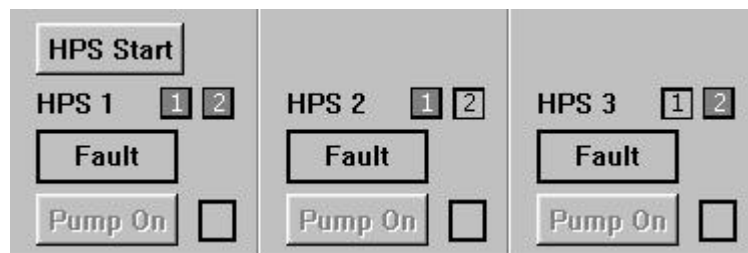
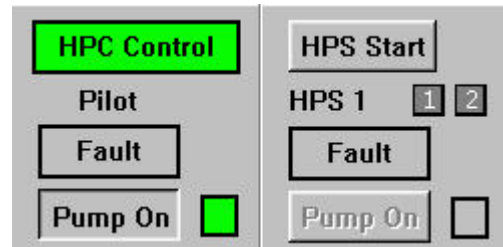
Start the Pilot pump by pushing the **Pump On** button for the Pilot. The indicator lamp shall begin blinking **Blue**.

There are 4 conditions where the HPC will not allow the Pilot to start:

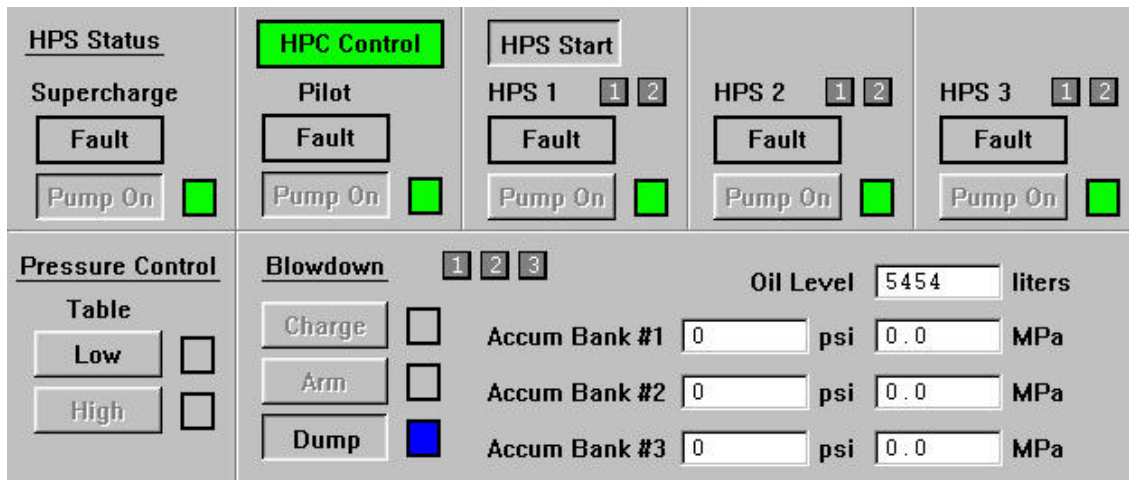
1. Interlocks have NOT been reset
2. UPS Backup power is NOT available.
3. Pilot pump is in Local mode.
4. Pilot pump is already running.



The blinking shall continue until the Pilot motor is running. This usually takes less than 10-15 seconds. Then, the indicator shall show **Green** and the **HPS Start** button will be activated.

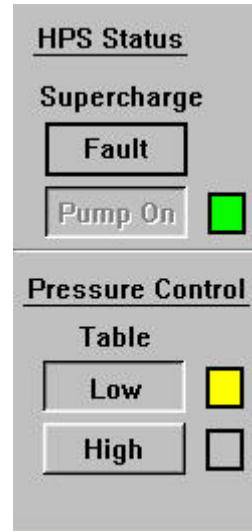


Clicking on the **HPS Start** button automatically starts 0-3 Main pumps depending upon the motor selections on each pump. To the right of the HPS 1, HPS2, and HPS 3 labels are the 2 small motor select buttons. The dark gray state is the positive selection state. HPS 1 has both motors selected and HPS 2 has only motor 1 selected and HPS 3 has only motor 2 selected. If both motors are NOT selected, then that pump shall not start at all. As with the previous pumps, the pump start is indicated by its indicator displaying blinking **Blue**. After all of the selected motors have started, then the indicator turns **Green**. Only one motor at a time is started to minimize maximum current draw on the power system. Turning on all the motors takes about 30 seconds. After all the selected motors have started, the Table Low Pressure button is activated.



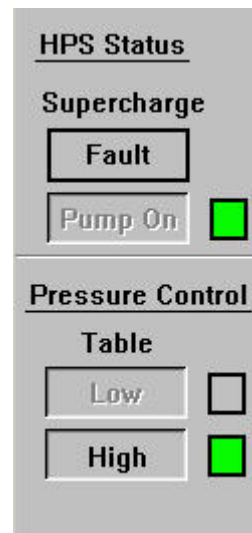
Clicking on the **Low** button starts the Main Pressure Control ramping to the Low Pressure command value. Both of these parameters can be changed on a pump panel described later in this document. The **Low** indicator stays gray until the main pressure gets to within the **Pressure Tolerance**. This value is set on the **Pressure Select** panel shown later.

Once the main pressure gets to the specified Low pressure, the **Low** indicator shall turn **Yellow** and the **High** button is activated.



Clicking on the **High** button starts the Main Pressure Control ramping to the High Pressure command value. Both of these parameters can be changed on a pump panel described later in this document. The **High** indicator stays gray until the main pressure gets to within the **Pressure Tolerance**. This value is set on the **Pressure Select** panel shown later.

Once the main pressure gets to the specified Low pressure, the **High** indicator shall turn **Green**.



To turn all of the pumps off, reverse the process. First, click off the **High** pressure button. The main pressure controller shall start ramping down the pressure. The pressure will go down slowly as the system line accumulators discharge. At about 2000 psi, the pressure reaches the accumulator pre-charge pressure and the main pressure will fall more rapidly to the Low pressure. At that point, the **High** indicator will turn off (gray) and the **Low** indicator shall display **Yellow**.

Note: Be sure to PARK the shaking table BEFORE turning off Low pressure.. Failure to do so shall cause the table to drop rapidly and is dangerous for the table and any mounted specimen.

After Parking the table, turn off the **HPS Start** button and all of the main pumps shall stop at the same time. Monitor the main pressure and after the main pressure has dropped below 200-300 psi, then the Pilot pump may be turned off followed by the Supercharge pump.

NOTE: Do NOT change 469D Settings files before Pilot Pressure is < 200 psi. The servovalves WILL violently crash into their endstops due to this action.

In the **469D Control** mode, ALL of the hydraulic control buttons are disabled. The 469D now has total control of the hydraulic system. The normal on/off sequence of the system hydraulics is quite similar to the HPC mode.

The first difference is that the 469D has only a **Pilot** button and no separate Supercharge button. When the 469D requests the Pilot to start, the HPC shall start the Supercharge pump first. After the Supercharge pump has successfully started, the HPC waits 4 seconds to make sure that supercharge oil pressure has been achieved at the Pilot pump before automatically starting the Pilot pump.

The second difference is when the HPC reports to the 469D that the Pilot sequence is complete. ONLY after the Pilot Pressure has risen to within the **Pressure Tolerance** set in the **Pressure Select Panel** shall the HPC signal the 469D that the Pilot has started. In the **HPC Control** mode, the operator must wait for the Pilot Pressure to rise to a satisfactory level before proceeding.

The Low and High pressure commands from the 469D result in the HPC going through the sequence and reporting success to the 469D when the main pressure is within the **Pressure Tolerance**.

Blowdown Controls

This seismic system has only 3 main pumps to supply oil. This is not adequate to allow the table to reproduce many of the common earthquakes used for seismic testing. In order to obtain more hydraulic power, this system uses a Blowdown system to add extra hydraulic power when required. The blowdown system has 3 main mechanical sections:

1. A large accumulator bank to store the extra charged oil that will be added to the main system pressure lines when needed.
2. Three large poppet valves that can flow a large amount of oil from the accumulator bank to the main pressure line.
3. The Pilot pump can supply 5,000 psi to charge the accumulator bank.

The Pilot pump has the capability of supplying 3000 to 5000 psi of oil. To make it possible to use the Pilot pump at a higher pressure, the Pilot Supply line has a check valve from the Main Supply line. If the Pilot pump is disconnected from the Pilot Supply line, the Main Supply line shall supply oil to the Pilot Pressure Supply line through the check valve. This check valve is also present for safety in case the Pilot pump should totally fail.

The three poppets are controlled by 3-stage closed-loop servocontrols in valve position control. There is a pressure control loop around the 3 poppets to maintain system pressure. Because the pressure control loop will lag any main system pressure drop, the Blowdown Pressure controller uses a flow demand signal from the 469D to use as feed-forward to anticipate the flow demand from the Blowdown system. This Flow Demand signal is calculated by the 469D from the table DOF program time history in real-time and is sent to the HPC via D/A converter to A/D converter. This Flow Demand signal greatly improves the Blowdown control performance.

There are 3 pressure readouts on the main panel for the 3 Blowdown accumulator banks. All 3 banks are commoned, so the 3 transducers display nearly the same pressure. The bank pressure is used for the Blowdown pressure control system. These same pressures are used by the operator to charge the Blowdown to the desired pressure.

The Main Panel has 3 buttons that operate the Blowdown system and several numerical displays to indicate accumulator pressures and reservoir oil level. This section is shown below:

The screenshot shows the 'Blowdown' control panel. At the top left, the word 'Blowdown' is underlined. To its right are three buttons labeled 1, 2, and 3. Further right is the 'Oil Level' display showing '5454' liters. Below these are three rows of controls: 'Charge', 'Arm', and 'Dump', each with an unchecked checkbox. To the right of each checkbox are three numerical displays for 'Accum Bank #1', 'Accum Bank #2', and 'Accum Bank #3'. Each bank display shows '0' psi and '0.0' MPa. A mouse cursor is pointing at the 'Oil Level' display.

The underlined **Blowdown** text at the upper left is a link to display the Blowdown valve control parameters panel. This panel is discussed later in this manual.

The buttons labeled 1, 2, and 3 located to the right of the **Blowdown** label are the selection buttons for which Blowdown control poppet valves are enabled. Unless it is known that less poppets can supply the desired extra flow, all 3 of these buttons should always be selected.

The Charge button starts the accumulator charging process. This button is only active in High Main Pressure because the Pilot Pressure is supplied by Main Pressure while the Pilot pump charges the Blowdown accumulators to a higher pressure. The Charge Indicator flashes Yellow to show that the Blowdown is actually charging. This indicator changes to **Green** when the Blowdown accumulator pressure is within the Pressure Tolerance set on the Pressure Select Panel.

This screenshot shows the 'Blowdown' control panel with the 'Charge' button's indicator flashing yellow. The 'Oil Level' remains at '5454' liters. The 'Accum Bank #1', '#2', and '#3' displays remain at '0' psi and '0.0' MPa. The 'Arm' and 'Dump' buttons remain unchecked.

The Arm button enables the Blowdown poppet valves to supply oil as needed to the main hydraulic supply line. When the Arm button is pushed, the Arm Indicator will flash Yellow until the poppet valves are actually armed. At that time, the Indicator shall show solid **Green**. When the Blowdown is Armed, the Main High Pressure command is automatically raised to 3500 psi. This ensures that all 3 Main pumps will supply maximum flow to the system. After the Arm button is turned off, the Main High Pressure is returned to the setpoint value on the **Pump Panels Page 2**. If for some reason, the Arm button is left on, the Main High Pressure setpoint is restored automatically after 5 minutes.

This screenshot shows the 'Blowdown' control panel with the 'Arm' button's indicator solid green. The 'Oil Level' remains at '5454' liters. The 'Accum Bank #1', '#2', and '#3' displays remain at '0' psi and '0.0' MPa. The 'Charge' and 'Dump' buttons remain unchecked.

The Dump button turns on the 3 dump valves on the accumulator banks. When the button is pushed, the Indicator will flash **Blue** and then turn solid **Blue** when the dump valves have been actually activated.

The screenshot shows a control panel for the Blowdown system. At the top left, the word "Blowdown" is underlined. To its right are three small square buttons labeled 1, 2, and 3. Further right, the "Oil Level" is displayed as a numerical value "5454" followed by the unit "liters". Below these are three rows of controls, each corresponding to an accumulator bank. Each row contains a button ("Charge", "Arm", or "Dump"), a small square indicator light, and two pressure readouts labeled "Accum Bank #1", "Accum Bank #2", and "Accum Bank #3". The "Charge" and "Arm" buttons are grey, while the "Dump" button is blue. The indicator lights for "Charge" and "Arm" are white, while the "Dump" indicator is blue. The pressure readouts show "0" for "psi" and "0.0" for "MPa".

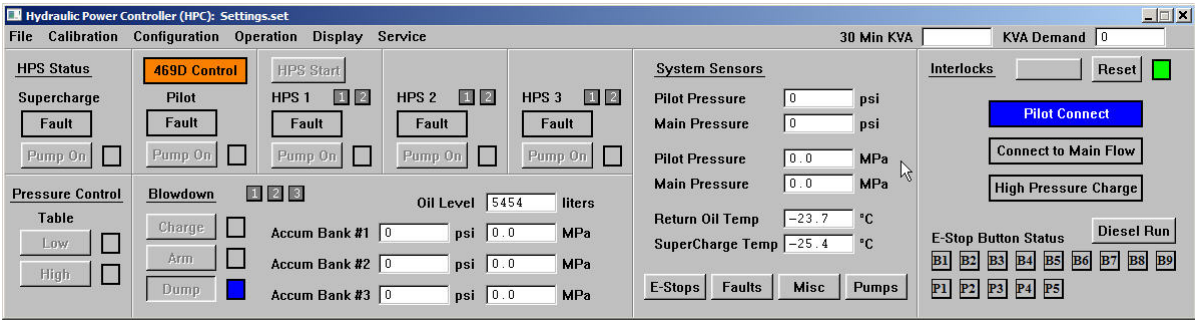
Control	Indicator	Accum Bank #1	Accum Bank #2	Accum Bank #3
Charge	☐	0 psi	0 psi	0 psi
Arm	☐	0.0 MPa	0.0 MPa	0.0 MPa
Dump	☒	0 psi	0 psi	0 psi

The Oil Level display allows the operator to see how much oil is actually being stored in the Blowdown accumulators. The change in Oil Level from start of Charge = Blowdown stored oil.

The accumulator pressure readouts show the actual pressure in each Blowdown accumulator bank. The 3 banks are commoned so all 3 pressures should read about the same. However, Accumulator Bank #1 pressure is used for the Blowdown Main Pressure control loop. Therefore, it is imperative that the Blowdown is not used if the #1 pressure cell is inoperative. There are no control problems if either or both #2 and #3 cells are not working.

In 469D Control:

All control buttons for Pumps, Table Main Pressure, and Blowdown are disabled. The 469D controls all of the Pumps, Pressure controls, and Blowdown directly. The HPC only indicates current system hydraulic status. Note that the Supercharge **Pump On** button and the Blowdown **Dump** button are now disabled in this mode versus the HPC Control mode.



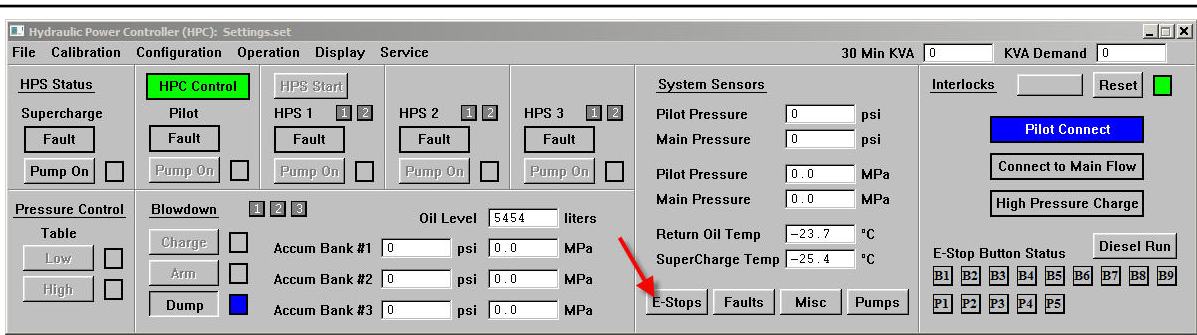
Oil Level Display

Shows how many liters of oil is currently in the pit reservoir. After charging the Blowdown, this number can be subtracted from the start number to compute the total liters in the Blowdown accumulators.

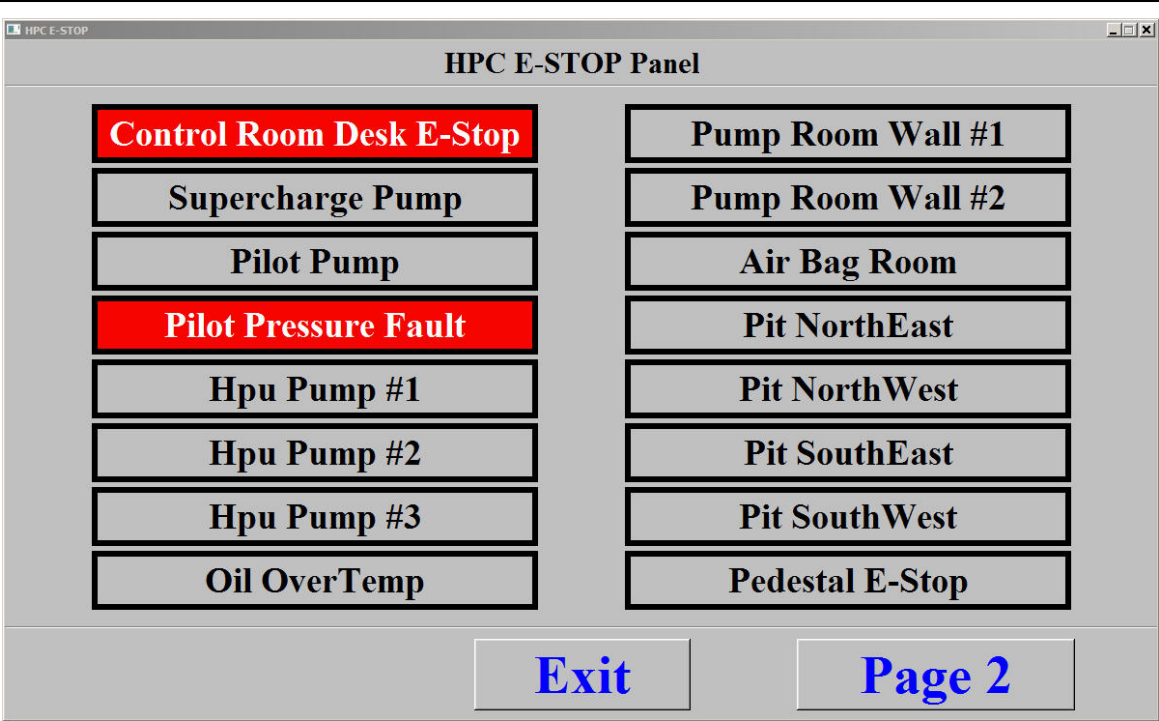
System Sensors

Control	Descriptions
Pilot Pressure	Shows the current Pilot Pressure in psi and MPascals.
Main Pressure	Shows the current Main Pressure in psi and MPascals.
Return Oil Temperature	Shows the Main Return Line Oil Temperature that returns oil to the pit reservoir.
Supercharge Output Oil Temperature	Shows the Supercharge pump output Oil Temperature that supplies oil to the Pilot and Main pumps. This temperature is used as the feedback for the control of the cooling tower water flow to cool the oil.

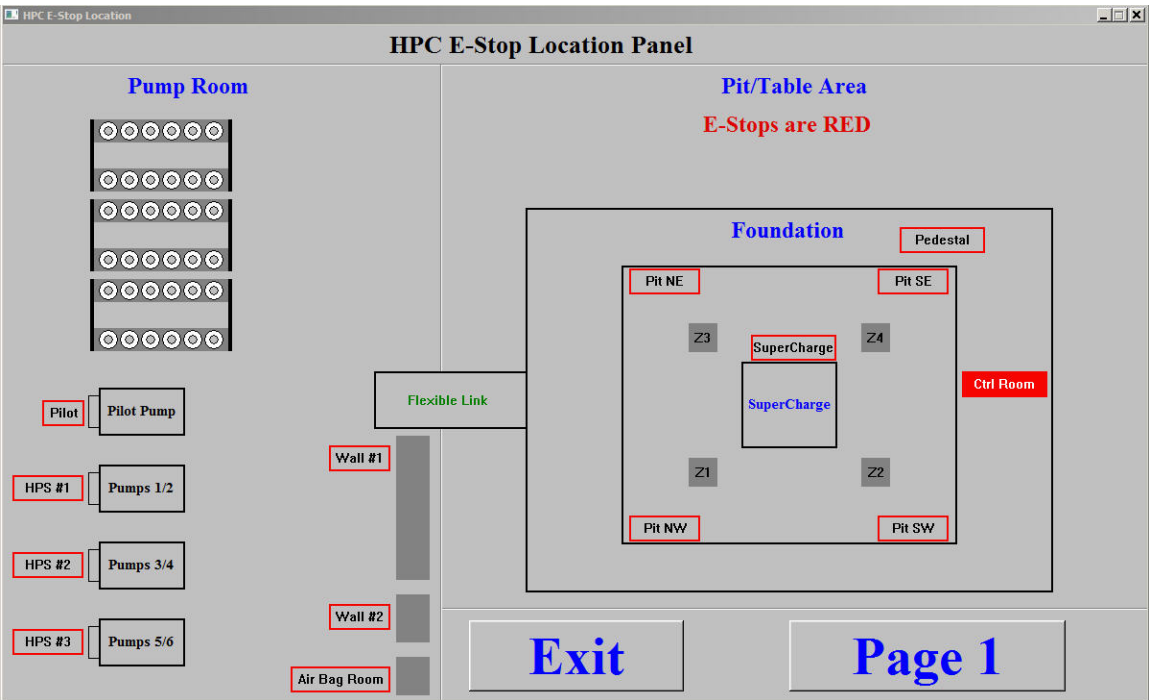
Status Panel Buttons



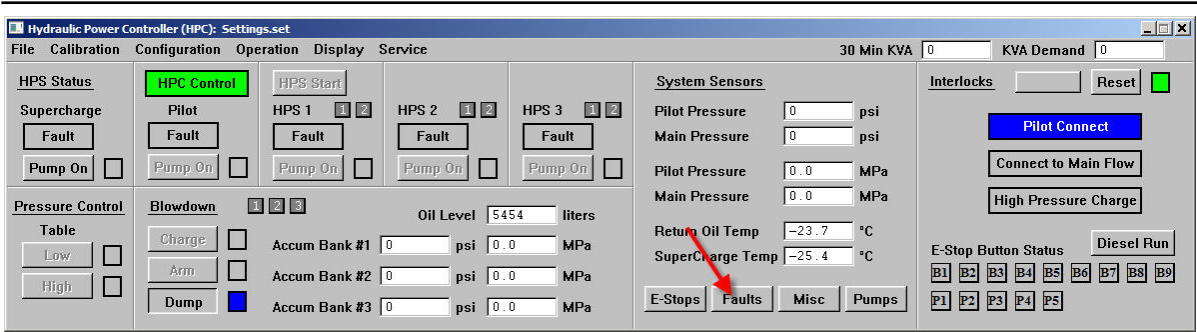
E-Stop status panels show the current status and the location of any pushed E-Stop buttons.



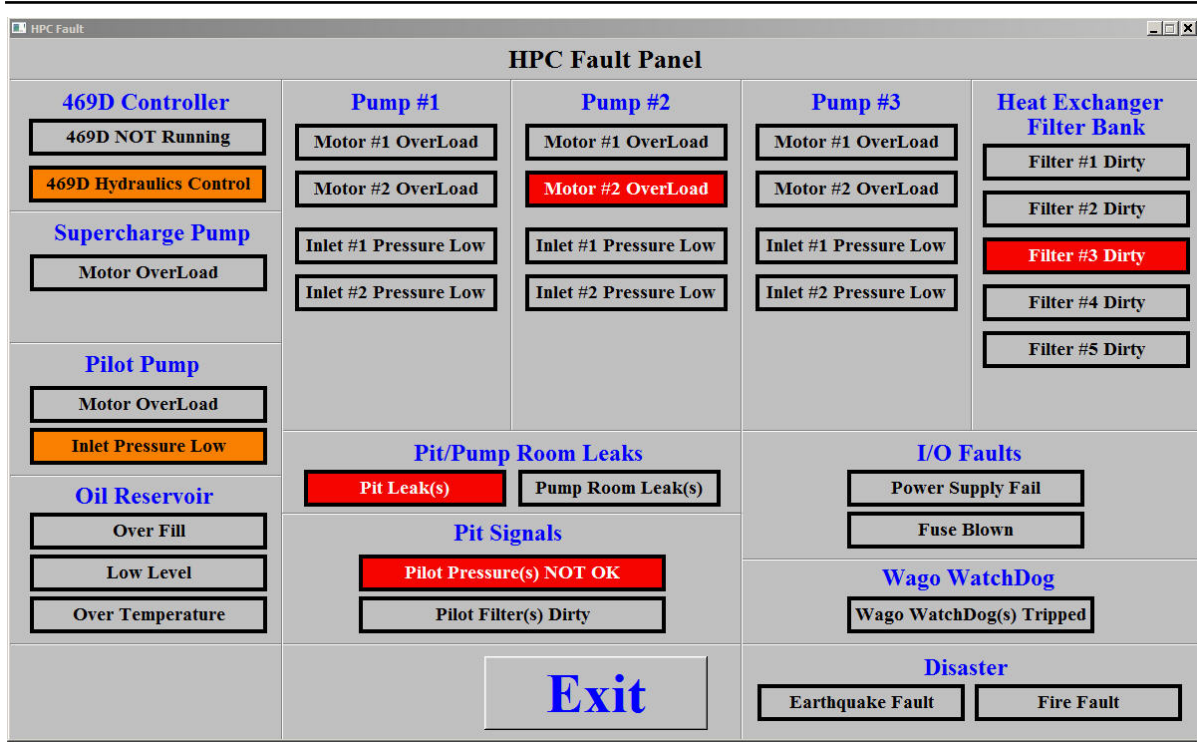
The first E-Stop Status panel shows which E-Stop conditions exist. Clicking the **EXIT** button clears this panel and does not show Page 2. Clicking the **Page 2** button displays the **E-Stop Status Page 2** panel.



The second E-Stop Status panel shows where any physical E-Stop buttons have been pushed. Clicking the **EXIT** button clears both E-Stop panels. Clicking the **Page 1** button re-displays the **E-Stop Status Page 1** panel.



The Faults status panel shows the current system warning and fault status.

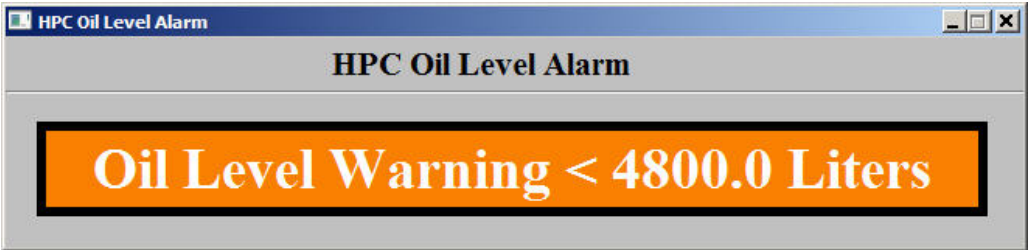


The Faults Status panel shows the warnings in **Orange** and the true Faults in **Red**. Each indicator is described in the following table. Clicking **Exit** erases the panel.

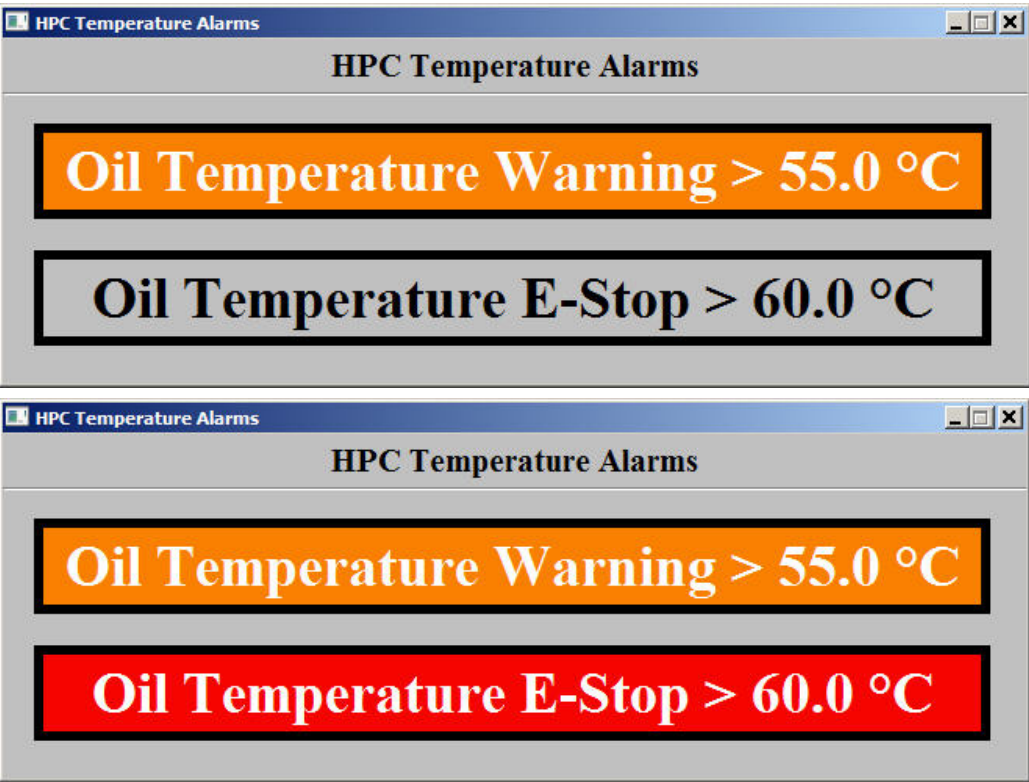
469D NOT Running	Shows that the 469D Controller is NOT running and therefore, ONLY the Supercharge pump may be run. Pilot and Main Pumps are NOT allowed.
469D Hydraulic Control	Shows that the 469D Controller is in control of the pumps and not the HPC. All pump control is then on the 469D main panel.
Supercharge Pump Motor OverLoad	Shows that the Supercharge pump motor has had a current overload and the local control has shut off the pump, forcing an E-Stop condition.
Pilot Pump Motor OverLoad	Shows that the Pilot pump motor has had a current overload and the local control has shut off the pump, forcing an E-Stop condition.
Pilot Pump Inlet Pressure Low	Shows that the Pilot pump has lost supercharge pressure and the local control has shut off the pump, forcing an warning condition.

Oil Over Fill	Shows that the oil reservoir has been over-filled. The oil level transducer is used to determine this condition.
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Oil Low Level	Shows that the oil reservoir has a low level warning. The oil level transducer is used to determine this condition. In addition, there is a Warning display that appears at 4800 liters as shown below.
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Oil Over Temperature	The oil reservoir has an over temperature condition. The Supercharge Output Oil Temperature is the temperature used for this condition. In addition, there is a Warning display that appears at 55 degrees C., and a Fault display that shows at 60 degrees C. and the system will E-Stop. The Warning and Fault displays are shown below.
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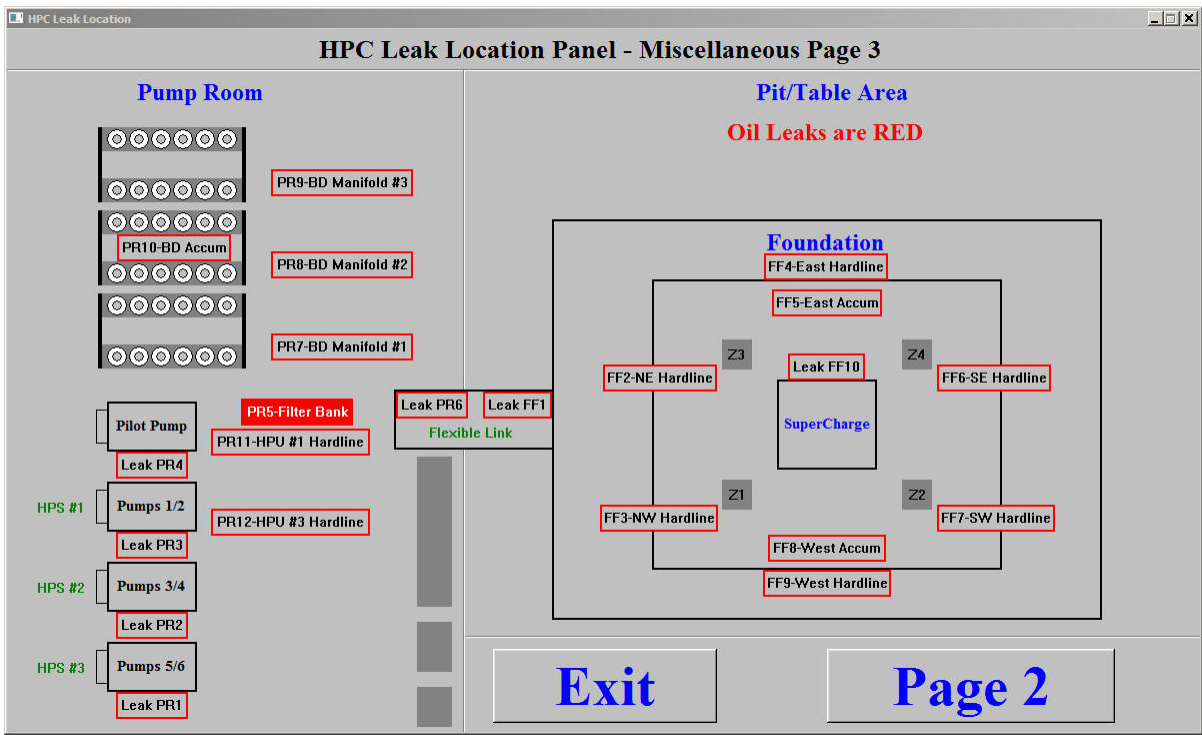
Main Pumps #1, #2, and #3 all have the same Warnings and Faults

Main Pump Motor #1 and #2 OverLoad	Shows that the Main pump motor #1 or #2 has had a current overload and the local control has shut off the pump, forcing an E-Stop condition.
------------------------------------	--

Main Pump #1 and #2 Inlet Pressure Low	Shows that the Main pump #1 or #2 has lost supercharge pressure and the local control has shut off the pump, forcing an Warning condition.
--	--

Pit and Pump Room
Oil Leaks

These two indicators show that there are oil leaks sensed in the Pit or the Pump Room. In addition, a location panel automatically pops up to show the operator where the leak(s) are occurring.



This panel is actually Page 3 of the Miscellaneous Status panels. It automatically appears when an oil leak is detected. The panel shows the basement area of the Pump Room and the Pit. The leak sensors are shown in **RED** if they are sensing an oil leak.

Pit Pilot Pressure
Signals

The first of these two indicators shows the loss of pilot pressure on one or more of the 8 pilot pressure sensors (one on each actuator). The second indicator shows that one or more of the 8 pilot pressure filters are dirty (one on each actuator).

Heat Exchanger
Filter Bank

The 5 Heat Exchanger Filters has a dirty filter output. These outputs are shown here to indicate which filter element is dirty and should be replaced.

I/O Faults Signals

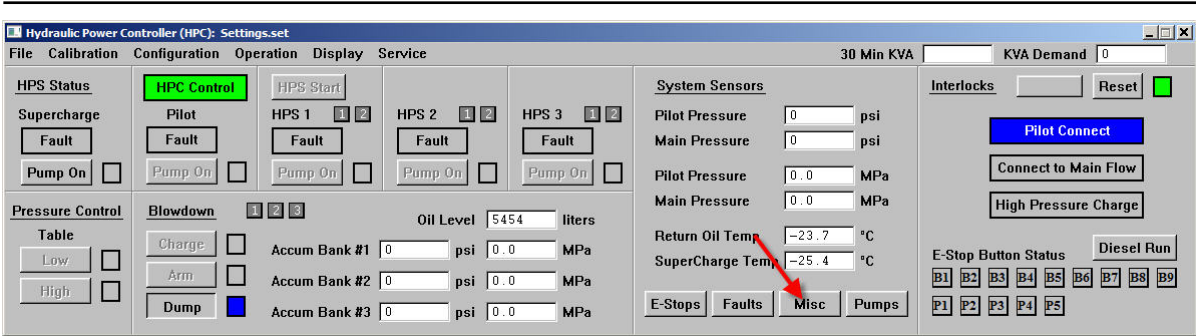
These indicators show the combined status of the 7 Wago PLC Power Supplies and current output Fuses.

Wago Watchdog(s)
Tripped

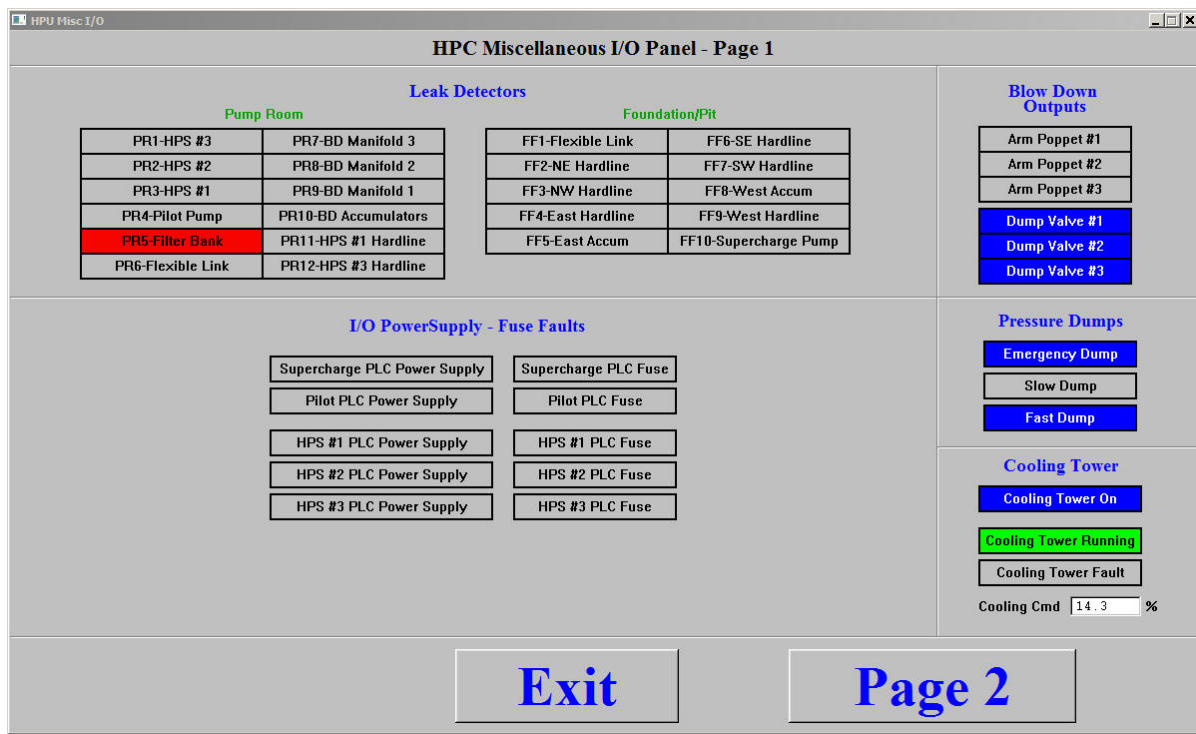
This indicator shows the combined status of the 7 Wago PLC Watchdog signals that indicate a loss of communication.

Disaster Signals

These two indicators show the status of the disaster inputs for Earthquake and/or Fire.



The Misc status panels show the miscellaneous system parameters that are not directly related to Hydraulic Power Control..



Leak Detectors

The two sets of Oil Leak Detectors indicators show if any of the detectors has found an oil leak. **Miscellaneous Panel Page 3** shown above displays the physical location of the leak. Both the Pump Room and the Table Pit areas are indicated in both panels.

I/O Power Supply and Fuse Faults

The I/O PLC hardware can indicate power supply faults and blown fuses. These indicators show which PLCs should be checked for these faults. The I/O on faulted PLCs will not operate properly.

Blow Down Outputs

The Blow Down output solenoids control the operating mode for the Blow Down poppet valves. The Dump Valves dump all of the Blow Down accumulators to near zero pressure. The Arm Valves enable the Blow Down valves to operate. When the Arm Valves are OFF, the Blow Down poppets cannot be opened.

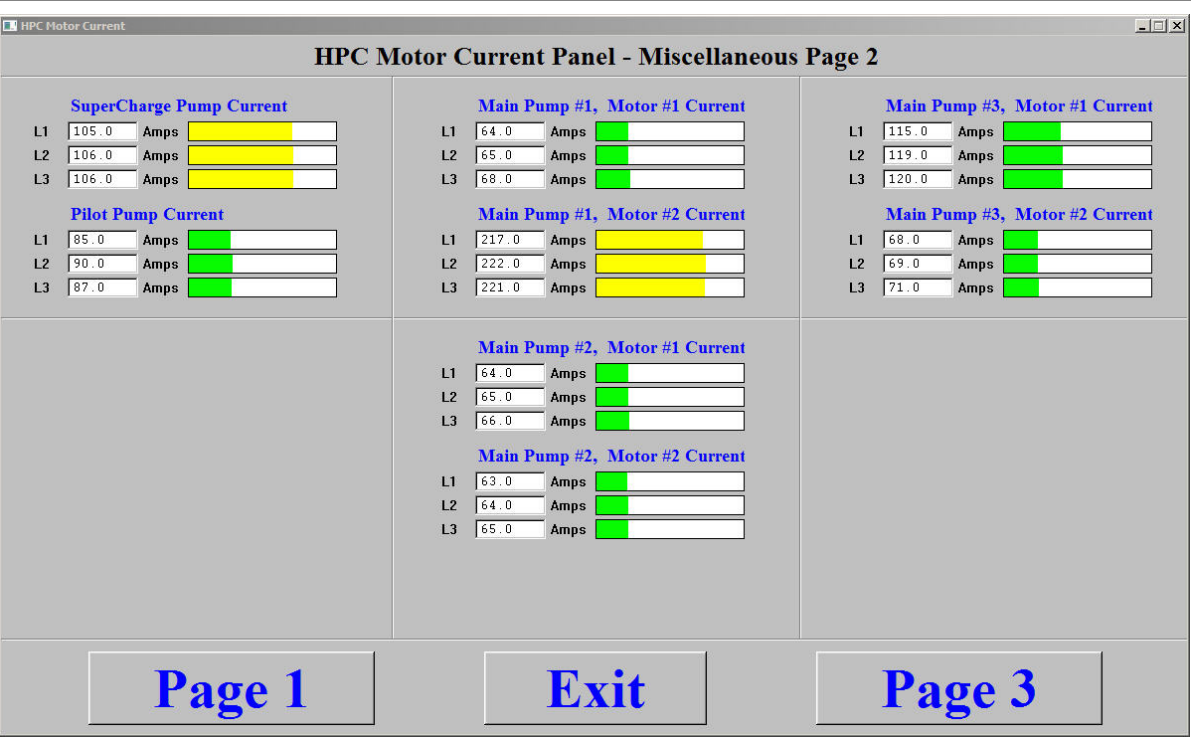
Pressure Dumps

These three indicators show the state of the Pressure Dump Valves. There is an Emergency Dump, Slow Dump, and Fast Dump Valves. The **Slow Dump** is only used to drop pressure from High to Low. The **Fast Dump** is used to drop Pressure when turning off the main pumps. The **Emergency Dump** is for Emergency Stop situations. This valve is always turned on when the pilot pressure is turned off.

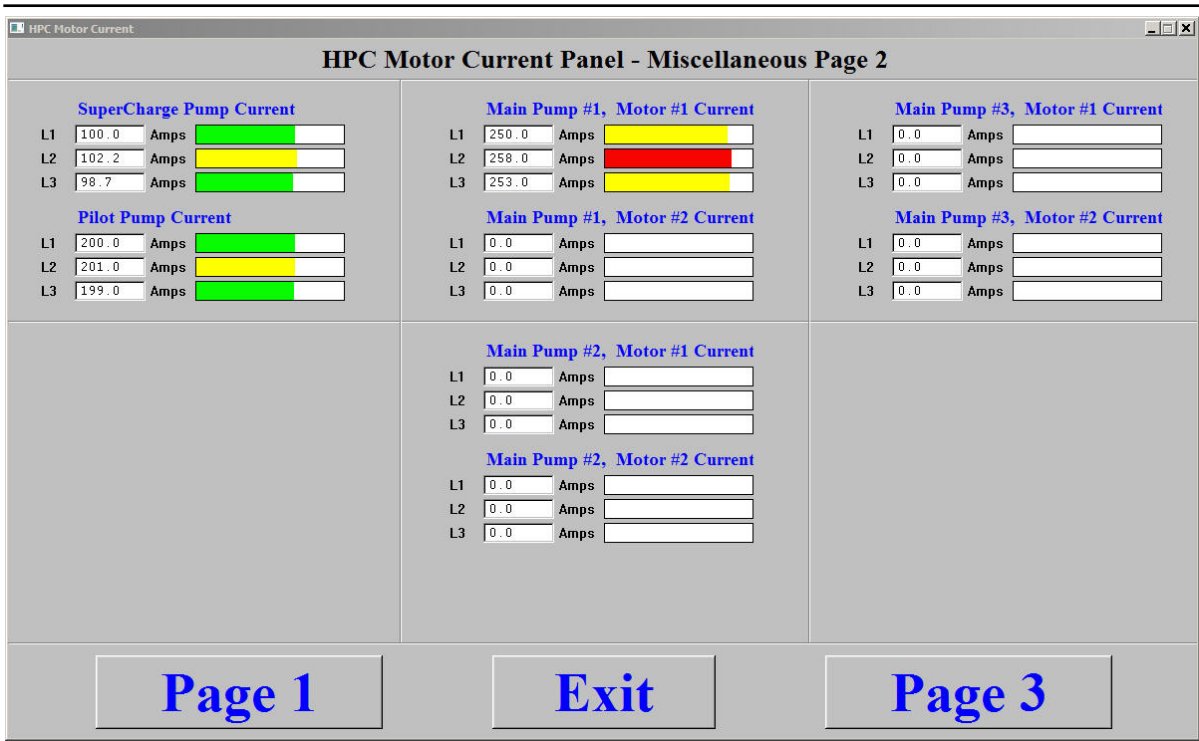
Cooling Tower Indicators

The Cooling Tower On Indicator shows the state of the Cooling Water Solenoid Valve. The ON state means that the Cooling Tower is operating. The Cooling Tower Running Indicator shows **Green** when the Cooling Tower is actually operating. The Cooling Tower Fault Indicator shall show **Red** if there is a Fault preventing the Cooling Tower to operate. The Cooling Cmd signal shows the position of the proportional valve controlling water flow to the Cooling Tower. 0.0 % = Maximum flow and 100.0 % means Zero flow.

Miscellaneous Panel Page 2 (**Motor Current Panel**) shows all of the hydraulic pump currents during operation of the hydraulic power system.



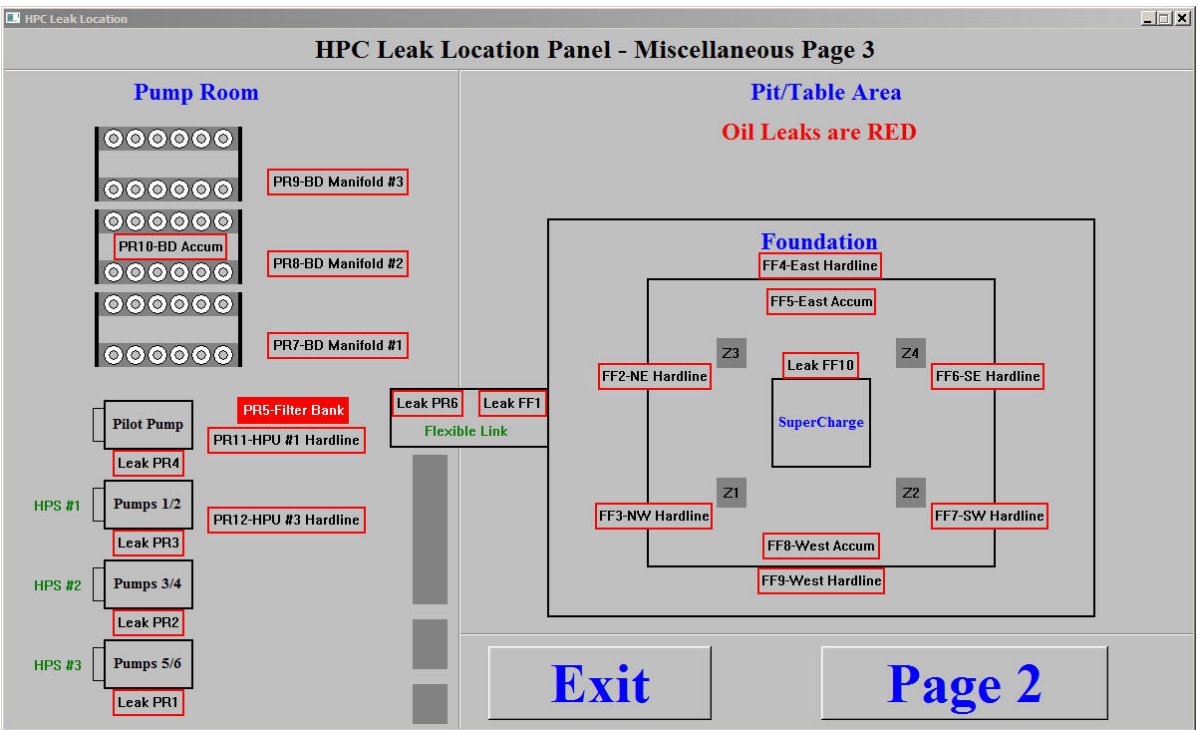
The Motor Current Panel shows a numeric value and a color bar indicator for each power phase of each pump motor. The bar indicators change color to indicate the power zone for that motor. The Supercharge pump has a **Green** zone from 0.0 to 100.0 amps, a **Yellow** zone from 100.1 to 140.0 amps, and a **Red** zone from 140.1 to 150.0 amps. All of the other pumps have a **Green** zone from 0.0 to 200.0 amps, a **Yellow** zone from 200.1 to 255.0 amps, and a **Red** zone from 255.1 to 300.0 amps. The next figure shows typical indicators for the Supercharge, Pilot and Main Pump #1, Motor #1.



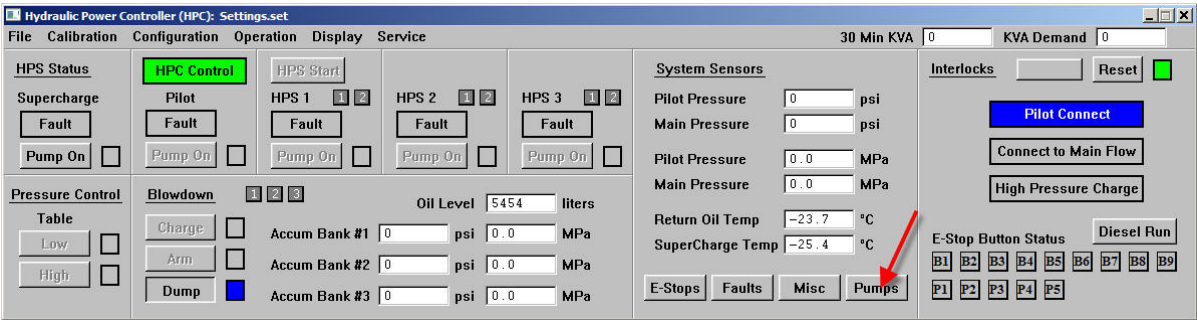
The color zones for the currents are set to indicate general operating conditions. It is not a problem if the zone even turns Red. Yellow indicates that the motors are working hard, but can do so for long periods of time. Red indicates that the motors are near their maximum operating current, but does not indicate an emergency for short periods up to 10-20 minutes.

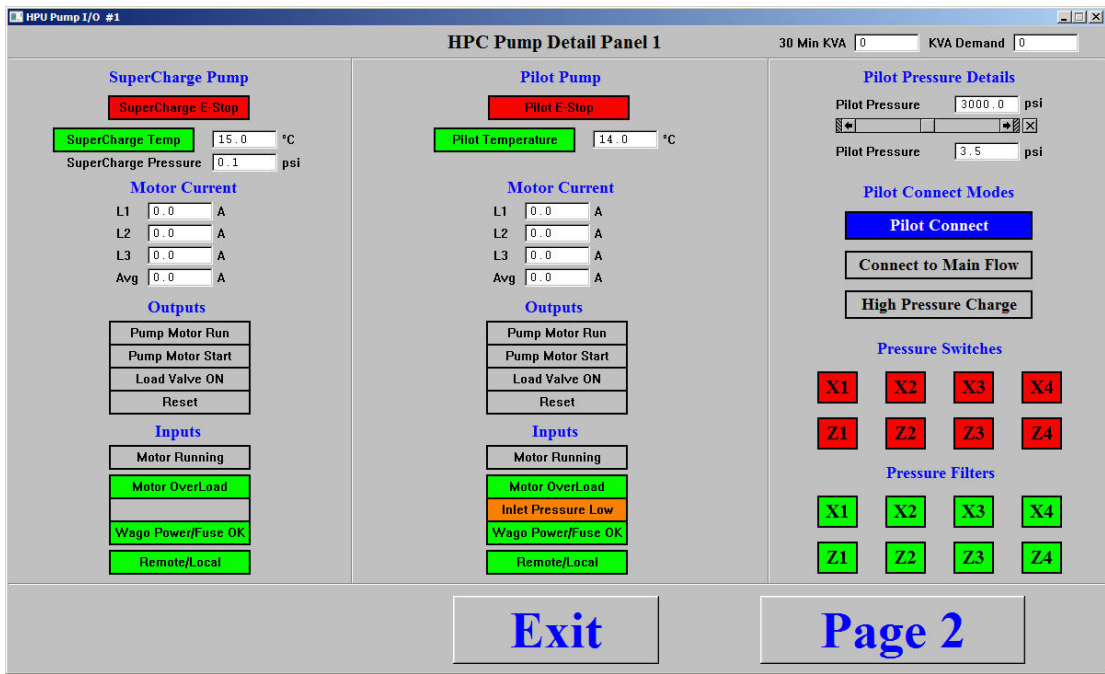
Note that the currents for each winding will vary, but there should NOT be any significant differences between windings. Currents can vary up to 10-20% due to external effects.

Miscellaneous Page 3 is the Oil Leak Detectors Map. This displays the approximate location of each of the 22 oil detectors in the Pump Room and the Table Pit Area. Any oil detector that has sensed oil will turn **RED** on the Leak Map. When an oil sensor turns ON and this page is not visible, the Leak Map shall automatically appear to alert the system operator. There is also an alarm sent to the 469D Table Controller telling the operator there to check the HPC monitor display.



The pump status panels show the details of each hydraulic power supply.





All 3 Pump Status panels have the KVA Demand and KVA 30 Minute Average displays in the upper right hand corner. These are the same displays that are shown on the Main HPC panel.

The left panel shows the status for the Supercharge pump. At the top is the E-Stop status for the pump. **Red** = E-Stop and **GREEN** = No E-Stop condition. This indicator includes the front panel E-Stop button on the pump electronics enclosure in the table pit.

Below the E-Stop Indicator are the Supercharge Output Oil Temperature and the Output Oil Pressure. The Supercharge Oil Temperature is the value used for temperature control and for warning and E-Stop conditions.

Below the Supercharge Oil Temperature and Pressure are the motor phase current displays. The 3 individual phase currents are displayed along with the average current. The individual phase currents are measured directly from measurement toroids, but the average is mathematically computed.

Below the motor phase current displays are the Supercharge pump digital control outputs. If the outputs are ON, the indicator shall appear in Blue with White letters. The following outputs are shown:

Pump Motor Run	Motor Run contactor, must be on for motor to run
Pump Motor Start	Motor Start, turned on for Y-Delta time period
Load Valve ON	Pump is in High Pressure
Reset	Turned on momentarily to clear pump E-Stop interlocks

Below the Supercharge pump digital output indicators are the digital control inputs. The input is normal if **GREEN** and faulted if **RED**. The following inputs are shown:

Motor Running	Motor IS Running = GREEN . Shows Gray if off
Motor OverLoad	Motor current overload = RED , normal = GREEN
Wago Power, Fuse OK	PLC power is normal = GREEN , faulted = RED
Remote/Local	Remote/Local Mode, Remote = GREEN , Local = RED

The middle panel shows the status for the Pilot pump. At the top is the E-Stop status for the pump. **Red** = E-Stop and **GREEN** = No E-Stop condition. This indicator includes the front panel E-Stop button on the pump electronics enclosure in the table pit.

Below the E-Stop Indicator is the Pilot Oil Temperature. The Pilot Oil Temperature is for readout purposes only and is not used for other purposes.

Below the Pilot Oil Temperature are the motor phase current displays. The 3 individual phase currents are displayed along with the average current. The individual phase currents are measured directly from measurement toroids, but the average is mathematically computed.

Below the motor phase current displays are the Pilot pump digital control outputs. If the outputs are **ON**, the indicator shall appear in **Blue** with White letters. The following outputs are shown:

Pump Motor Run	Motor Run contactor, must be on for motor to run
Pump Motor Start	Motor Start, turned on for Y-Delta time period
Load Valve ON	Pump is in High Pressure
Reset	Turned on momentarily to clear pump E-Stop interlocks

Below the Pilot pump digital output indicators are the digital control inputs. The input is normal if **GREEN** and faulted if **RED**. The following inputs are shown:

Motor Running	Motor IS Running = GREEN . Shows Gray if off
Motor OverLoad	Motor current overload = RED , normal = GREEN
Inlet Pressure Low	Pump Inlet pressure is Low. Low = ORANGE fault, OK = Gray
Wago Power, Fuse OK	PLC power is normal and fuse OK = GREEN , faulted = RED
Remote/Local	Remote/Local Mode, Remote = GREEN , Local = RED

The right side panel of the Pump Status Page 1 is the extra details for the Pilot Pump and Pilot Pressure.

At the upper right, there is the Pilot Pressure command knob and the Pilot Pressure readout display. The Pilot Pressure is set by the command slider knob. This data is saved for future use when it is changed. Saving the settings file will save a new Pilot Pressure command value for use when the system re-boots. When the Pilot pump starts, the pressure controls will automatically command the desired Pilot Pressure.

Below the Pilot Pressure knob and display are the 3 indicators for the Pilot pump modes. The Pilot pump can be used for 3 purposes. The Pilot pump can be the sole supplier of Pilot Pressure to all of the system, or another pump added to the main system pressure, or as the charging pump for the Blowdown accumulators. There are 3 solenoid valves mounted on the Pilot pump that can determine the Pilot pump mode. There are 3 combinations of these solenoid valves. Each combination determines the Pilot pump mode. These combinations are:

	Pilot Connect	Connect to Main Flow	High Pressure Charge
SV1	OFF	OFF	OFF
SV2	OFF	OFF	ON
SV3	ON	ON	OFF

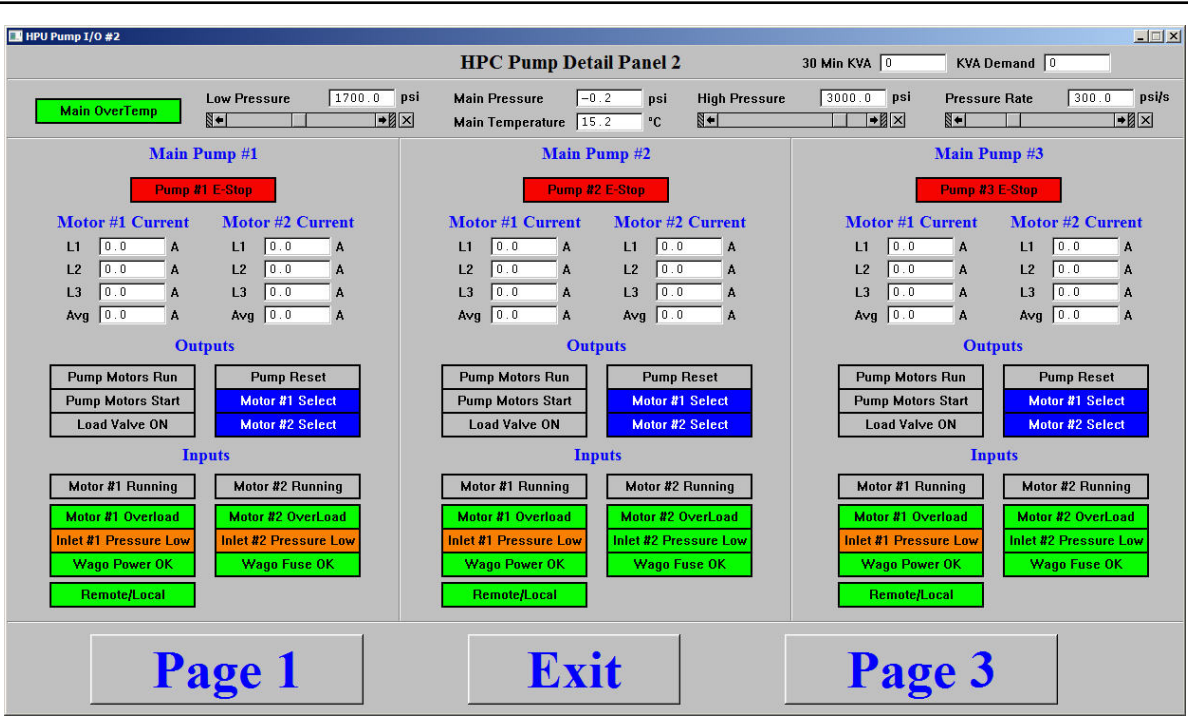
In Connect to Main Flow mode, the system Pilot Pressure is supplied by a check valve from the Main System Pressure. Therefore, the Pilot Pressure will be slightly less than the Main Pressure because of pressure loss across the check valve. The Pilot pump flow is being supplied to the Main Pressure system. In the High Pressure Charge mode, the Pilot Pressure is also supplied by the Main System pressure as the Pilot pump is solely being used to charge the Blowdown accumulators at a pressure higher than system pressure.

Because of the small number of main pumps and the limited size of the Blowdown accumulators, the Connect to Main Flow mode is NOT used on this system. This is done for safety reasons to ensure no loss of Pilot Pressure due to over-demand for flow from the table system during operation. The High Pressure Charge mode has no such restriction because the table is NOT being run during Blowdown charging.

Below the Pilot Pressure mode indicators are the 8 Pilot Pressure Switch Indicators. These switches are mounted on each actuator's servovalve manifold to indicate loss of Pilot Pressure to the two actuator servovalves. The indicators show **RED** when the Pilot Pressure is too low for proper servovalve control of the actuator. They display **GREEN** when the Pilot Pressure is adequate. When the **Main Low Pressure Button** is turned **ON** to ramp the Main Pressure to Low Pressure, any Pilot Pressure Switch fault shall cause an immediate E-Stop condition. This E-Stop sensing shall continue until the **Main Panel Low Pressure Button** is turned **OFF**.

Below the Pilot Pressure Switches are the 8 Pilot Filter Switch Indicators. These switches are mounted on each actuator's servovalve manifold to show the the Pilot Pressure filters are dirty. The indicators show **RED** when the filters are dirty and show **GREEN** for a normal condition. The Dirty Filter fault condition does NOT force a Program ABORT or E-Stop. Any filter fault shall force this panel to appear on the HPC monitor if not already displayed. Also, a message is sent to the 469D Control software to show the operator there that there is a HPC warning. The warning on the 469D is the message log panel popping up with a **RED** flashing border. The message log shall show the **HPC Warning** message.

At the bottom of the Pump Detail Panel 1 are two buttons used to control the exit from this panel. The **EXIT** button erases all Pump Detail panels from the monitor display. The **Page** button shall display the Pump Detail Panel 2 which shows the status of the 3 main pumps.



All 3 Pump Status panels have the KVA Demand and KVA 30 Minute Average displays in the upper right hand corner. These are the same displays that are shown on the Main HPC panel.

The top header area of the Pump Detail Panel 2 has a temperature overtemp indicator and the 2 slider knob controls for the system Low and High Pressure commands and the 2 signal displays for Main Temperature and Pressure.

- Main OverTemp

The OverTemp Indicator on the left shall show **GREEN** for normal Supercharge Oil Output Temperature. This indicator turns **RED** for either the **Warning** or the **Emergency** Temperature faults.
- Low Pressure Slider Knob

This slider knob sets the main system Low Pressure command value. This value is saved when the settings file is saved to the settings.set file that automatically is loaded on HPC program start.
- Main Pressure/Temp Displays

The **Main Pressure Line Pressure** is displayed as the **Main Pressure**. The **Return Line Oil Temperature** is displayed as **Main Temperature**.
- High Pressure Slider Knob

This slider knob sets the main system High Pressure command value. This value is saved when the settings file is saved to the settings.set file that automatically is loaded on HPC program start.
- Pressure Rate Knob

This slider knob sets the main system pressure command ramp rate value. This value is ONLY used for the main system pressure. The pilot pressure command rate is infinite, meaning that the pilot pressure command steps to the command level(s). This value is saved when the settings file is saved to the settings.set file that automatically is loaded on HPC program start.

The Pump Detail Panel 2 central area shows the status of the 3 main pumps. Because each pump's display is common to all the pump displays, only one description fits the definitions within each pump's status display.

Pump E-Stop Indicator	This Indicator shows the E-Stop status of this particular pump. RED indicates that this pump has an E-Stop condition. GREEN indicates no interlocks are set.
Motor #1/#2 Current Displays	Below the Pump E-Stop Indicator, both Motor #1 and Motor #2 for the 2 pumps on this hydraulic power unit each have their measured 3 phase currents displayed along with the computed average current of the 3 measured currents.

Below the two motor phase current displays are the Pilot pump digital control outputs. If the outputs are ON, the indicator shall appear in **Blue** with White letters. The following outputs are shown:

Pump Motor Run	Motor Run contactor, must be on for motor to run
Pump Motor Start	Motor Start, turned on for Y-Delta time period
Load Valve ON	Pump is in High Pressure
Reset	Turned on momentarily to clear pump E-Stop interlocks
Motor #1 Select	Indicates whether or not pump motor #1 should be started on hpu start. Selected on the HPC Main Panel.
Motor #2 Select	Indicates whether or not pump motor #2 should be started on hpu start. Selected on the HPC Main Panel.

Below the main pump digital output indicators are the digital control inputs. The input is normal if **GREEN** and faulted if **RED**. The following inputs are shown:

Motor #1 Running	Motor #1 IS Running = GREEN . Shows Gray if off
Motor #2 Running	Motor #2 IS Running = GREEN . Shows Gray if off
Motor #1 OverLoad	Motor #1 current overload = RED , normal = GREEN
Motor #2 OverLoad	Motor #2 current overload = RED , normal = GREEN
Inlet Pressure #1 Low	Pump Inlet pressure #1 is Low. Low = ORANGE fault, OK = Gray
Inlet Pressure #2 Low	Pump Inlet pressure #2 is Low. Low = ORANGE fault, OK = Gray
Wago Power OK	PLC power is normal = GREEN , faulted = RED
Wago Fuse OK	PLC fuse is OK = GREEN , Blown = RED
Remote/Local	Remote/Local Mode, Remote = GREEN , Local = RED

At the bottom of the Pump Detail Panel 2 are 3 buttons used to control the exit from this panel. The **Page 1** button erases this page and displays Pump Detail Panel #1. The **EXIT** button erases all Pump Detail panels from the monitor display. The **Page 3** button shall display the Pump Detail Panel 3 which shows the voltage/currents and hour meters of the 3 main pumps.

HPU Pump I/O #3

HPC Pump Detail Panel 3

30 Min KVA0KVA Demand0

SuperCharge		Pilot		Main Pump #1		Main Pump #2		Main Pump #3	
				Motor #1		Motor #1		Motor #1	
Hours	225.2	Hours	213.7	Hours	174.8	Hours	147.5	Hours	143.3
L1 Volts	411.0	L1 Volts	412.0	L1 Volts	412.0	L1 Volts	411.0	L1 Volts	411.0
L2 Volts	411.0	L2 Volts	414.0	L2 Volts	411.0	L2 Volts	411.0	L2 Volts	411.0
L3 Volts	413.0	L3 Volts	412.0	L3 Volts	413.0	L3 Volts	413.0	L3 Volts	413.0
L1 Amps	0.0	L1 Amps	0.0	L1 Amps	0.0	L1 Amps	0.0	L1 Amps	0.0
L2 Amps	0.0	L2 Amps	0.0	L2 Amps	0.0	L2 Amps	0.0	L2 Amps	0.0
L3 Amps	0.0	L3 Amps	0.0	L3 Amps	0.0	L3 Amps	0.0	L3 Amps	0.0
Power	0	Power	0	Power	0	Power	0	Power	0
Power Factor	0	Power Factor	0	Power Factor	0	Power Factor	0	Power Factor	0

Motor #2		Motor #2		Motor #2	
Hours	174.1	Hours	147.2	Hours	143.0
L1 Volts	412.0	L1 Volts	411.0	L1 Volts	412.0
L2 Volts	412.0	L2 Volts	411.0	L2 Volts	412.0
L3 Volts	414.0	L3 Volts	413.0	L3 Volts	414.0
L1 Amps	0.0	L1 Amps	0.0	L1 Amps	0.0
L2 Amps	0.0	L2 Amps	0.0	L2 Amps	0.0
L3 Amps	0.0	L3 Amps	0.0	L3 Amps	0.0
Power	0	Power	0	Power	0
Power Factor	0	Power Factor	0	Power Factor	0

Page 1

Exit

Page 2

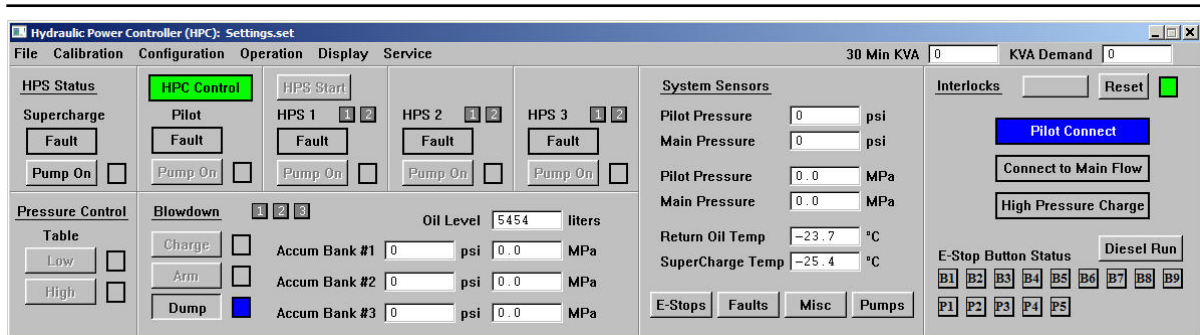
All 3 Pump Status panels have the KVA Demand and KVA 30 Minute Average displays in the upper right hand corner. These are the same displays that are shown on the Main HPC panel.

This panel shows the power information and hour meter for each of the 5 pumps. The data is presented by motor. The Supercharge and Pilot pumps only have one motor while the 3 main pumps have 2 motors each.

Each motor shows the following parameters:

- Total Running Hours
- Three phase voltages (L1,L2,L3)
- Three phase currents (L1,L2,L3)
- Power being Used (KWatts)
- Power Factor (percent)

At the bottom of the Pump Detail Panel 3 are 3 buttons used to control the exit from this panel. The **Page 1** button erases this page and displays Pump Detail Panel #1. The **EXIT** button erases all Pump Detail panels from the monitor display. The **Page** button shall display the Pump Detail Panel 2 which shows the 3 main pumps status.



The last sub-section of the HPC Main Panel is the right-hand section containing the Interlocks and Reset, the Pilot Pressure Mode Outputs, the E-Stop Buttons Status and the Diesel Run button.

The interlocks are normally not used by the HPC. If the operator wishes to use the Interlocks, the Limit Detector Panel needs to be used to enter the information for which input to use to interlock the system. Note that the Program Abort selection for the Limit Detector will NOT work as there are no function generators on the HPC Controller. The 469D would be unaffected by all interlock selections EXCEPT Interlock which is an E-Stop condition. The only signals available on the HPC for interlock are the 32 User A/D inputs, the 4 User DUC (AC/DC conditioners), and Pilot Pressure and Main Pressure.

To the right of the Interlocks status (blank display) is the Reset button for the interlocks and the Interlocks Indicator. Pushing the Reset button will attempt to reset the interlock chain for the HPC AND will send a command to the 469D Controller to reset its interlock chain as well. If both controllers interlock chains reset, the Reset Indicator shall turn **GREEN**. If there is an E-Stop button pushed or the 469D has an E-Stop condition that will not clear, the Reset Indicator shall remain **RED**. The system hydraulics will **NOT** run unless the Reset Indicator is showing **GREEN** = Interlocks OK status.

Below the Interlock area is the 3 Pilot Pump Mode Indicators. These indicators were described in the Pump Detail #1 Panel description. There can be only **ONE** indicator showing **BLUE** with White letters at a time. The Pilot Connect indicator means that the Pilot pump is supplying all of the oil for the Pilot Pressure hydraulics. The Connect to Main Flow indicator means that the Pilot pump is adding its flow to the 3 main pumps and the Pilot hydraulics is being supplied by the system Main Pressure hydraulics via a check valve. This mode is NOT available for this system as this could lead to a loss of pilot pressure if the system is being run too hard. The High Pressure Charge indicator means the the Pilot pump is charging the Blowdown accumulators to a higher than system pressure (usually 5000 psi). In this mode, the Pilot hydraulic flow is also being supplied by the system Main pressure via the check valve. This does NOT pose a danger to the system as there are no programs trying to run the table at this time.

Below the 3 Pilot Pump Mode Indicators and on the right is the Diesel Run button. Pushing this button energizes a HPC relay output that shall start the Shimizu 500KW Diesel Generator to provide extra electrical power as required to run the table system. At this time, there is no indication from the Shimizu interface of a successful diesel generator start or any fault response as well.

At the bottom of this sub-panel section is the E-Stop button status indicators. There are 9 physical E-Stop buttons in the Control Room, Pump Room and the Table Pit Area. There are also 5 pump E-Stop indicators. The pump indicators are set by the pump PLC when the pump stops or when a pump E-Stop button is pushed on the pump front panel. The HPC will reset successfully even if there are pump E-Stops indicated. This is because the E-Stop may only be set by the pump PLC controller and not the front panel button. If the front panel button is pushed, then only that pump cannot be started. All other pumps that have no button pushed can be started. When the pumps are to be started, the HPC shall send a **RESET** command to the pump PLC controller. If the PLC resets its software interlock, then the pump E-Stop indicator will clear. If the pump E-Stop button is pushed, then that pump's E-Stop indicator shall remain **RED**.

If one of the B1 to B9 physical E-Stop buttons are pushed, the exact location of that button can be found by looking at the HPC E-Stop menu. Page 1 has the meaningful names for the buttons and Page 2 shows the physical location of that button on the pump room/pit layout drawing.

For convenience, the following list of Emergency Stop buttons describes actual location:

B1	Control Room Table-Top box with RED button
B2	Pump Room #1 with RED button = Pump Room Wall by Flexible Link
B3	Pump Room #2 with RED button = Pump Room Wall next to Air Bag Room Entry
B4	Air Bag Room Entry with RED button
B5	Pedestal with RED button = Out on Floating Foundation next to Table
B6	SouthEast Pit Wall with RED button
B7	NorthWest Pit Wall with RED button
B8	SouthWest Pit Wall with RED button
B9	NorthEast Pit Wall with RED button
P1	SuperCharge Pump in Table Pit with RED button on control panel
P2	Pilot Pump in Pump Room with RED button on control panel
P3	Main Pump #1 in Pump Room with RED button on control panel
P4	Main Pump #2 in Pump Room with RED button on control panel
P5	Main Pump #3 in Pump Room with RED button on control panel

AC/DC Conditioners

1/04/1/1 Main pressure fbk

Select... Next Previous

Excitation mode **DC**

Excitation ampl **10.0** V

Zero **-0.09838** V

Gain **770.0** V/V

Delta K (+) **1.0** V/V

Filter cutoff **50 Hz**

☐ Invert polarity

Interlocks

☒ Disabled **Reset**

☐ Watchdog timer

☐ Excitation fail

☐ Limit

Upper limit **10.0** V

Lower limit **-10.0** V

Shunt Type **Shunt cal**

8 wire full Neg -FBR

Conditioner output **0.0** V

Access

Main controller panel **Calibration** menu > **AC/DC Conditioners**.

When to use the panel

Use the Conditioners panel to calibrate a conditioner with its associated transducer and to identify and reset hardware interlocks. Whenever a transducer is replaced or moved, the associated conditioner should be calibrated. Hardware limits should be checked and reset before starting a test. In addition, MTS recommends verifying calibration values periodically.

Panel description

The Conditioners panel allows you to perform the following tasks:

- Select a specific conditioner
- Calibrate the conditioner to its associated transducer
- Select polarity of output
- Select filtering option
- Set hardware limits for the conditioner output (feedback)
- Identify whether an interlock has occurred
- Disable and/or reset interlocks

For More Information

- [AC Conditioner Calibration](#) (p. 197)
- [DC Conditioner Delta-P Calibration](#) (p. 198)
- [DC Conditioner Accelerometer Calibration](#) (p. 200)

AC/DC Conditioners Reference

Channel Selection Controls	
Control	Descriptions
text box	Displays the name of the selected channel.
Select...	Selects a channel from a list of channels.
Next	Selects the next channel in the selection panel list.
Previous	Selects the preceding channel in the selection panel list.

AC or DC Conditioner Controls	
Control	Descriptions
Excitation mode pop-up	Displays the type of conditioner as a result of selecting a channel; AC or DC.
Excitation ampl slide bar and text box	Sets the level of the excitation signal sent to the transducer. You can use the slide bar to set a value or you can enter it in the text box.
Zero slide bar and text box	Sets the analog DC offset of the conditioner hardware. You can use the slide bar to set a value or you can enter it in the text box.
Gain slide bar and text box	Sets the total gain of the conditioner. You can use the slide bar to set a value or you can enter it in the text box.
Delta K (+) slide bar and text box	Sets the delta K(+) value for the conditioner. You can use the slide bar to set a value or you can enter it in the text box.
Filter cutoff pop-up	Click the down arrow button to display a list of available cutoff frequencies. Select the desired frequency and click the check mark button to accept the selection and close the list, or click the X button to decline the selection and close the list. To select no cutoff frequency, select None from the list and close the list as described. The predefined cutoff frequencies shown in the list (50 Hz, 100 Hz, 300 Hz, 500 Hz, and 1000 Hz) correlate to the filter selections on the DUC circuit board. The Software cutoff frequency choice bypasses the filter on the DUC circuit board, and allows you to specify any cutoff frequency and specify either a one pole or two pole filter.
Control	Descriptions
Invert Polarity check box	Boxed checked will invert the conditioner signal polarity. Box not checked will not invert the conditioner signal polarity.
Conditioner output text box	Shows the current value of the signal output by the selected conditioner. Not editable.

AC Conditioner Specific Controls

Control	Descriptions
Excitation freq pop-up	Click the down arrow button to display a list of available excitation frequencies. Select the desired frequency and click the check mark button to accept the selection and close the list, or click the X button to decline the selection and close the list. To select no excitation frequency, select None from the list and close the list as described.
Demod. phase slide bar and text box	Sets the demodulator phase of the AC conditioner output. You can use the slide bar to set a value or you can enter it in the text box.

DC Conditioner Specific Controls

Control	Descriptions
Shunt Cal button	Closes the shunt calibration relay to complete a shunt calibration of the conditioner and displays the value in the Conditioner output display.

Interlock Controls

Control	Description
Disabled check box	When checked, disables hardware interlocks for the selected channel.
Reset button	When pressed, resets the hardware interlocks for the selected channel.
Watchdog Timer indicator	Indicates the status of the watchdog timer.
Excitation fail indicator	Shows whether excitation has failed. This detector is always enabled, both in hardware and software. Excitation failure causes a system interlock because it may indicate a broken, defective or missing cable.

User AC/DC Conditioners

AC/DC Conditioners

1/03/3/1

User DUC #1

Select...

Next

Previous

Excitation mode

DC

Excitation ampl

0.0

V

Zero

-0.00046

V

Gain

1.0

V/V

Delta K (+)

1.0

V/V

Filter cutoff

None

☐ Invert polarity

Interlocks

☒ Disabled

Reset

☐ Watchdog timer

☐ Excitation fail

☐ Limit

Upper limit

10.0

V

Lower limit

-10.0

V

Shunt Type

Shunt cal

6 wire full Neg -FB

Engineering Units

+10 volts =

10.0

Volts

-10 volts =

-10.0

Conditioner output

0.0

V

0.0

Volts

Access

Main controller panel **Configuration** menu > **User Conditioners**.

When to use the panel

Use the Users Conditioners panel to calibrate a conditioner with its associated user-supplied transducer and to identify and reset hardware interlocks. Whenever a transducer is replaced or moved, the associated conditioner should be calibrated. Hardware limits should be checked and reset before starting a test. In addition, MTS recommends verifying calibration values periodically.

Panel description

The User Conditioners panel allows you to adjust the calibration parameters for a selected User Conditioner.

User Conditioner Controls

Control	Description
User DUC Name	The User DUC name can be changed by the User to any desired text. This new name shall appear in the channel selection lists in the HPC Controller for displays such as digital meters and oscilloscope.tc.
Engineering Units	The User can edit the full-scale engineering units and the units name to specify how the HPC shall display this DUC's output.

AC/DC Conditioners

1/03/3/1 Specimen Strain #1

Select...NextPrevious

Excitation modeDC

Excitation ampl10.0 V

Zero-0.0448 V

Gain500.0 V/V

Delta K (+)1.0 V/V

Filter cutoff50 Hz

Invert polarity

Interlocks

☒ DisabledReset

☐ Watchdog timer

☒ Excitation fail

☐ Limit

Upper limit10.0 V

Lower limit-10.0 V

Shunt Type

Shunt cal

6 wire full Neg -FB

Engineering Units

+10 volts =5.0mm

-10 volts =-5.0

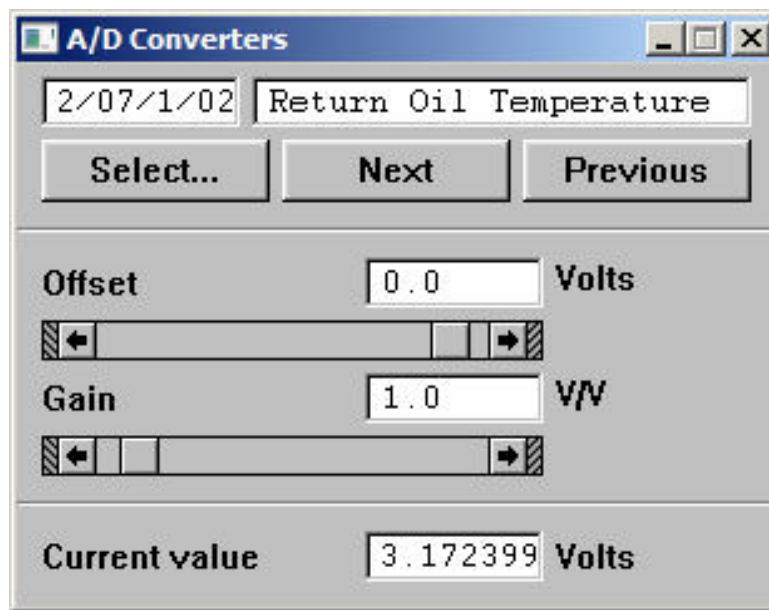
Conditioner output

0.019358 V

0.009845 mm

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A/D Converters



The screenshot shows a software window titled "A/D Converters". At the top, there is a date field containing "2/07/1/02" and a label field containing "Return Oil Temperature". Below these are three buttons: "Select...", "Next", and "Previous". The main area of the panel is divided into two sections. The first section is for "Offset", with a numeric input field set to "0.0" and the unit "Volts" to its right. Below the input field is a horizontal slider with arrows at both ends. The second section is for "Gain", with a numeric input field set to "1.0" and the unit "V/V" to its right. Below the input field is another horizontal slider with arrows at both ends. At the bottom of the panel, there is a label "Current value" followed by a numeric display showing "3.172399" and the unit "Volts".

Access

Main controller panel **Calibration** menu > **A/D Converters**.

When to use the panel

Use this panel during test setup to periodically calibrate the converters in the system to ensure that the input and output voltages are balanced.

Panel description

The A/D Converters panel allows you to adjust the offset and gain for a selected A/D converter.

For More Information[A/D Converter Calibration](#) (p. 196)

A/D Converters Reference

Channel Selection Controls

Control	Descriptions
text box	Displays the name of the selected channel.
Select...	Selects a channel from a list of channels.
Next	Selects the next channel in the selection panel list.
Previous	Selects the preceding channel in the selection panel list.

Signal Adjustment Controls

Control	Descriptions
Offset slide bar and text box	Adjusts the offset of the signal output by the converter. Enter an offset for a Current value of 0.00 V. You can use the slide bar to set a value or you can enter it in the text box. Offset is saved in the Calibration file.
Gain slide bar and text box	Adjusts the gain of the signal output by the converter. Use the Gain adjustment to set the full-scale range of the converter. You can use the slide bar to set a value or you can enter it in the text box. Gain is saved in the Calibration file.

Current Values

Control	Descriptions
Current value display boxes	Displays the current raw (unconverted) and final (converted) values of the selected signal.

User A/D Converters

The screenshot shows a software window titled "User A/D Converters". At the top, there is a list box containing "01/" and a text field containing "User A/D #1". Below these are three buttons: "Select...", "Next", and "Previous". The main area is divided into several sections. The first section has a label "Offset" followed by a text field with "0.0" and the unit "Volts", with a horizontal slider below it. The second section has a label "Gain" followed by a text field with "1.0" and the unit "V/V", with a horizontal slider below it. The third section is titled "Engineering Units" and contains two rows: "+10 volts =" with a text field "10.0" and a unit box "Volts", and "-10 volts =" with a text field "-10.0". The final section has a label "Current value" followed by two text fields, both containing "0.0" and the unit "Volts".

Access

Main controller panel **Configuration** menu > User **A/D Converters**.

When to use the panel

Use this panel during test setup to periodically calibrate the User converters in the system to ensure that the input and output voltages are balanced.

Panel description

This panel allows you to adjust the gain and offset for a selected User A/D Converter. In addition, the User may specify the name for this User A/D Converter that will show up in channel selection lists used by the HPC Controller. The User may also define the full-scale engineering units and units name for this same converter.

User A/D Converters

03/

Specimen Displ. #3

Select...

Next

Previous

Offset

0.0

Volts

←

→

Gain

2.0

V/V

←

→

Engineering Units

+10 volts =

30.0

cm

-10 volts =

-30.0

Current value

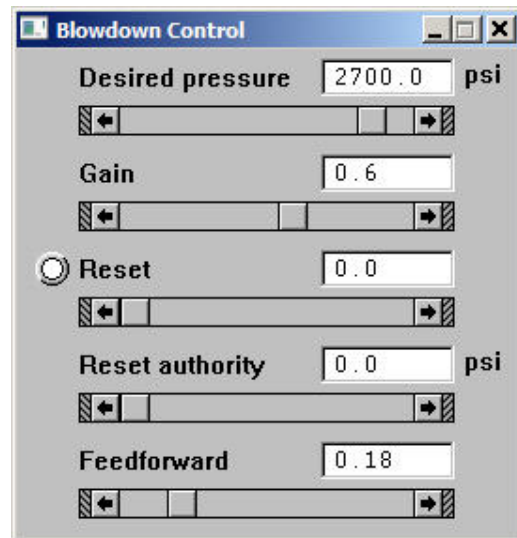
0.002455

Volts

0.007366

cm

Blowdown Valve ControllerI



Access

Main controller panel **Operation** menu > Controllers -> **Blowdown**.

When to use the panel

Use this panel to periodically tune the Blowdown poppets and select the Blowdown operating pressure.

Panel description

The Blowdown panel allows the operator to select the Blowdown operating pressure and the gain, integration gain and authority, and the flow demand feed-forward.

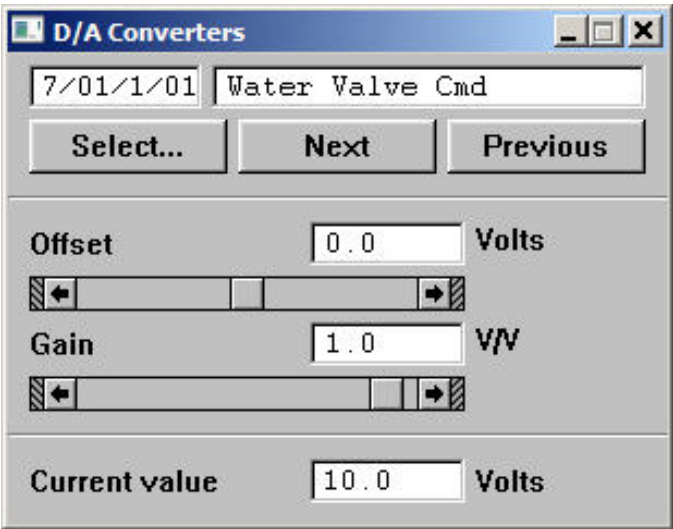
For More Information

[Blowdown Tuning](#) (p. xxx)

Blowdown Controller Reference

Blowdown Controls	
Control	Descriptions
Desired pressure	Displays and allows changing the Blowdown desired pressure setpoint. This pressure is the value to which the main system pressure must drop the Blowdown will add oil flow to hold this pressure.
Gain	Selects the proportional gain of the Blowdown controller.
Reset	Selects the integral gain of the Blowdown controller.
Reset authority	Selects the maximum limit amount of integral reset allowed.
Feedforward	Selects how much of the 469D flow demand is used to help the Blowdown controller to anticipate the main system pressure drop.

D/A Converters



Access

Main controller panel **Calibration** menu > **D/A Converters**.

When to use the panel

Use this panel to periodically calibrate the converters in the system to ensure that the input and output voltages are balanced.

Panel description

The D/A Converters panel allows you to adjust the offset and gain for a selected D/A converter.

For More Information

[D/A Converter Calibration](#) (p. 196)

D/A Converters Reference

Channel Selection Controls

Control	Descriptions
text box	Displays the name of the selected channel.
Select...	Selects a channel from a list of channels.
Next	Selects the next channel in the selection panel list.
Previous	Selects the preceding channel in the selection panel list.

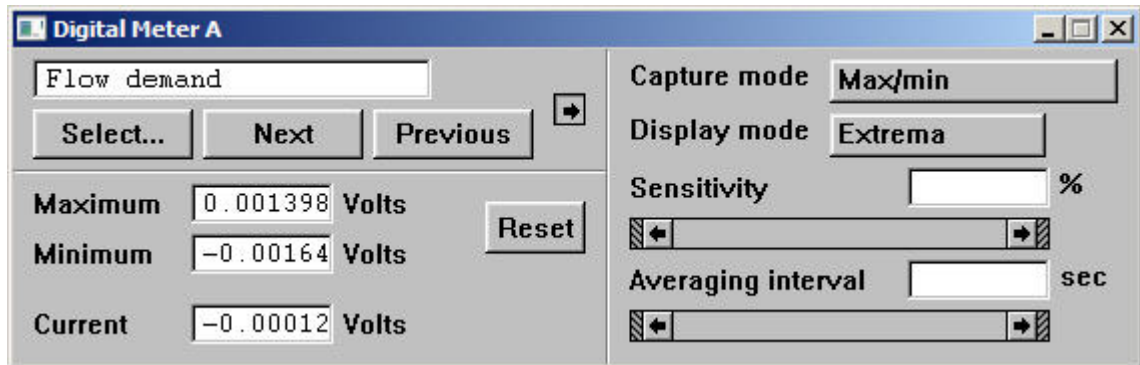
Signal Adjustment Controls

Control	Descriptions
Offset slide bar and text box	Adjusts the offset of the signal output by the converter. Enter an offset for a Current value of 0.00 V. You can use the slide bar to set a value or you can enter it in the text box. Offset is saved in the Calibration file.
Gain slide bar and text box	Adjusts the gain of the signal output by the converter. Use the Gain adjustment to set the full-scale range of the converter. You can use the slide bar to set a value or you can enter it in the text box. Gain is saved in the Calibration file.

Current Values

Control	Descriptions
Current value display boxes	Displays the current raw (unconverted) and final (converted) values of the selected signal.

Digital Meters



Access

Main controller panel **Display** menu > **Digital Meters**.

When to use this panel

Use these panels to read the current value of the selected signal.

Panel description

A Digital Meter panel allows you to monitor a signal.

Background information

The digital meters provide the following signal monitoring modes:

- **Max/min**
Monitors the maximum and minimum signal values since the display session began or the reset button was last selected. Signal values are displayed in the Maximum and Minimum text boxes.
- **Peak/valley (banded)**
Similar to Max/min mode, except the Reset button is automatically pressed after the signal reverses by an amount determined by the sensitivity adjustment. Thus changes in signal peaks and valleys can be continuously monitored. This selection can be used for cyclic and non-cyclic waveforms.
- **Peak/valley (timed)**
Similar to Max/min mode, except the Reset button is automatically pressed after the signal reverses a quarter of a cycle as determined by the signal's current frequency. Thus changes in signal peaks and valleys can be continuously monitored. This selection can be used only for cyclic waveforms.
- **RMS/mean**
Monitors the RMS and mean of a signal since the display session began or the Reset button was last selected. The amount of signal averaging can be adjusted using the Averaging Interval slide bar or text box. This selection can be used for cyclic and non-cyclic waveforms.

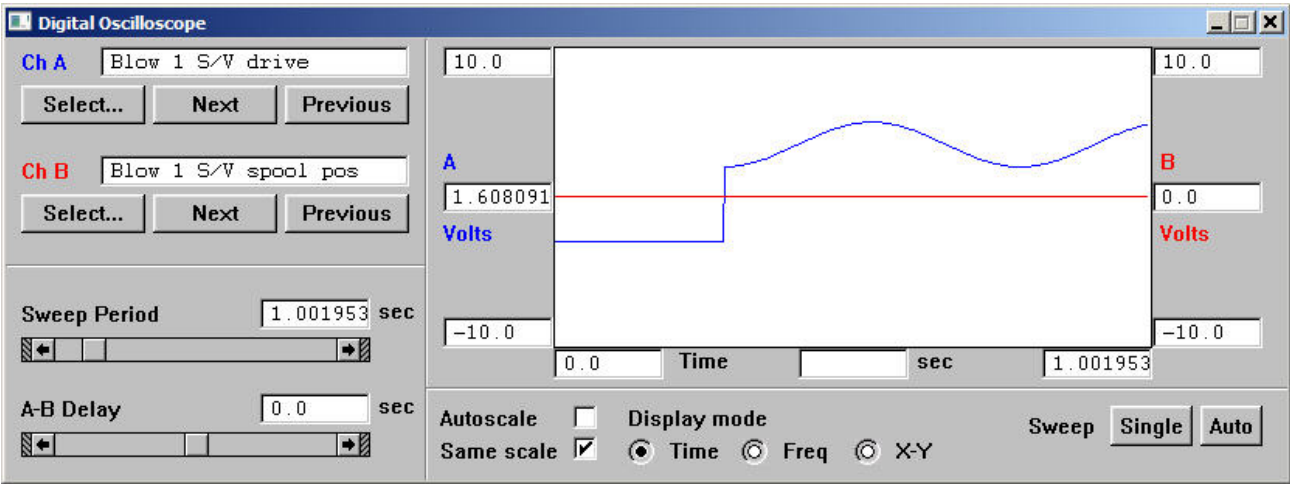
Digital Meters Reference

Signal Selection Controls	
Control	Descriptions
text box	Displays the name of the selected signal.
Select...	Selects a signal from a list of signals.
Next	Selects the next signal in the selection panel list.
Previous	Selects the preceding signal in the selection panel list.
Meter Setup Controls	
Control	Descriptions
Maximum or Peak or RMS or Amplitude text box	Displays the Maximum value for the signal when Capture Mode is Max/Min and Display Mode is Extrema. Displays the Peak value for the signal when Capture Mode is Peak/valley and Display Mode is Extrema. Displays the RMS value for the signal when Capture Mode is RMS/Mean (Display Mode is grayed out).

Control	Descriptions
	Displays the Amplitude of the signal when Capture Mode is Max/Min or Peak/valley and Display Mode is Amplitude/Base .
Minimum or Valley or Mean or Base text box	Displays the Minimum value for the signal when Capture Mode is Max/Min and Display mode is Extrema. Displays the Valley value for the signal when Capture Mode is Peak/valley and Display Mode is Extrema. Displays the Mean value for the signal when Capture Mode is RMS/Mean. (display Mode is grayed out) Displays the Base value of the signal when Capture Mode is Max/Min or Peak/valley and Display Mode is Amplitude/Base.
Current value text box	Displays the current value of the selected signal.
Reset button	Clears the Minimum and Maximum text boxes.
Right arrow	Click to open/close the right side of the display panel, which contains the more options.
Capture Mode pop-up menu	Selects a monitoring mode. The choices are: Max/min: displays the maximum and minimum values of the signal in the Maximum and Minimum boxes. Peak/valley (banded): displays the peak and valley values of a signal determined by reversal outside a specified sensitivity band. Peak/valley (timed): displays the peak and valley values of a signal determined by reversal within an amount of time determined by the signal frequency. RMS/Mean: displays the RMS and mean values of a signal averaged over a specified sliding time interval.
Display mode pop-up menu	Selects a display mode. The choices are: Extrema: displays min/max or peak/valley values. See Capture mode above. Amplitude/Base: is an alternative form of displaying extrema, where: $\text{Amplitude} = \text{max} - \text{min} / 2$ and $\text{Base} = \text{max} + \text{min} / 2$.  Note: Not available in RMS/mean capture mode
Sensitivity slide bar and text box	For peak/valley detection, sets the sensitivity of detection to a percentage of full-scale band. You can use the slide bar to set a value or you can enter it in the text box.

Control	Descriptions
Averaging interval slide bar and text box	For RMS/Mean capture mode, sets the averaging interval. You can use the slide bar to set a value or you can enter it in the text box.

Digital Dual Oscilloscope



Access

Main controller panel **Display** menu > **Dual Scope** or **Oscilloscope**.

When to use the panel

Use this panel at any time to monitor system signals.

Panel description

The Digital Oscilloscope panel shows oscilloscope traces for one or two signals. This panel allows you to perform the following tasks:

- Select one or two signals to be monitored.
- Set the sweep period and delay for the display of the selected signals.
- Select the scaling mode of the selected signals.
- Select the display mode for the monitor.
- Select the sweep mode for the monitor.

Digital Dual Oscilloscope Reference

Signal Selection Controls

Control	Descriptions
text box	Displays the name of the selected signal.
Select...	Selects a signal from a list of signals.
Next	Selects the next signal in the selection panel list.
Previous	Selects the preceding signal in the selection panel list.

Oscilloscope Controls

Control	Descriptions
Sweep Period slide bar and text box	Sets the sweep period in seconds, for a trace on the oscilloscope display. You can use the slide bar to set a value or enter it in the text box.
A–B Delay slide bar and text box	Sets the time by which the Channel B trace follows the Channel A trace. (If the value is negative, B precedes A.) You can use the slide bar to set a value or enter it in the text box.
Autoscale check box	Selects independent autoscaling. In this mode, the two signals are scaled to fill the entire scope display area, regardless of their relation to each other.
Same scale check box	If this box is checked, the same scaling is applied to both signals.
Display mode radio buttons	Select a relation for the A and B traces: Time – time is displayed along the X axis, amplitude along the Y axis Freq – frequency is displayed along the X axis, amplitude along the Y axis X–Y – signal A amplitude is displayed along the X axis, signal B amplitude along the Y axis
Scope display area text boxes	The text boxes surrounding the scope display area show the values of the upper and lower limits currently displayed. If in Time display mode, the top and bottom text boxes on the right and left sides show the minimum and maximum values of the A and B traces (respectively); the right and left text boxes on the bottom of the monitor show time.

Control	Descriptions
	- If in Freq display mode, the top and bottom text boxes on the right and left sides show the minimum and maximum values of the A and B traces (respectively); the right and left text boxes on the bottom of the monitor show frequency. - If in X–Y display mode, values of A and B are shown on the left and bottom (respectively), and nothing is displayed in the text boxes on the right. - If you click on a specific point in the scope display area, a line appears, and the corresponding X and Y values will be shown in the text boxes in the right center, bottom center, and left center.
Sweep, Single and Auto buttons	Select single sweep or automatically updated sweeps for display. - If in Single mode, only one sweep will be displayed. To update the display, use the Single button again. - If in Auto mode, the display will be updated when one sweep period (as set on the Sweep Period slide bar) of new data is available. To return to the single mode from the automatic mode, use either the Single or Auto button.

Digital Readouts

The screenshot shows a software window titled "Digital Readouts" with a blue title bar and standard window controls. The window contains two columns of digital readout (DRO) fields, each with a label, a numerical value, and a unit. To the right of each numerical field is an empty rectangular box for additional information or units.

Label	Value	Unit	Empty Box
Blow 1 S/V drive	-2.99998	Volts	
Blow 2 S/V drive	-2.99998	Volts	
Blow 3 S/V drive	-2.99998	Volts	
Pilot pressure cmd	0.0	psi	
Main pressure cmd	0.0	psi	
Blow 1 S/V spool pos	0.01222	Volts	
Blow 2 S/V spool pos	0.008411	Volts	
Blow 3 S/V spool pos	0.000721	Volts	
Pilot pressure fbk	3.821007	psi	
Main pressure fbk	-0.04069	psi	

Access

Main controller panel **Display** menu > **Digital Readouts**.

When to use the panel

Use this panel to read the present value of a selected signals.

Panel description

The Digital Readouts panel allows you to monitor up to 32 signals.

Channel selection

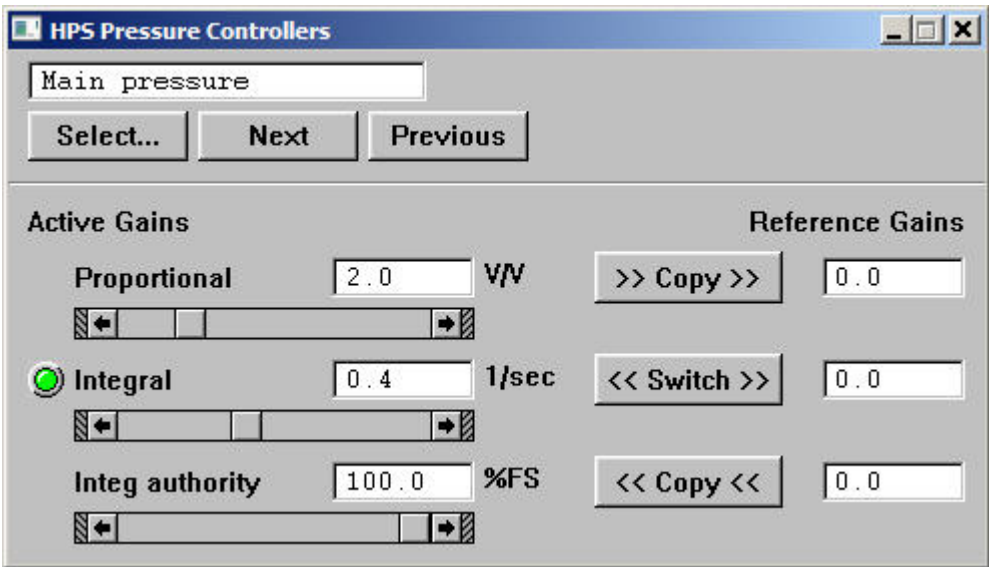
Click on any text box or previously selected channel to display a panel that lists the available channels. Select from the list the desired channel.

Click the **OK** button on the bottom of the list to display the selected signal next to the text box you clicked. The current value for the channel is shown in the text box.

To remove a channel from the panel:

1. Click on the name of the channel you want to remove.
2. From the list of available channels, scroll to the top of the list and select **NONE**.
3. Click **OK**.

HPS Pressure Control Panel



Access

Main controller panel **Operation** menu -> Controllers > **HPS Pressure**

When to use the panel

Use this panel to set the proportional and integral gains and integral authority for the Main Pressure control loop used on the main pumps.

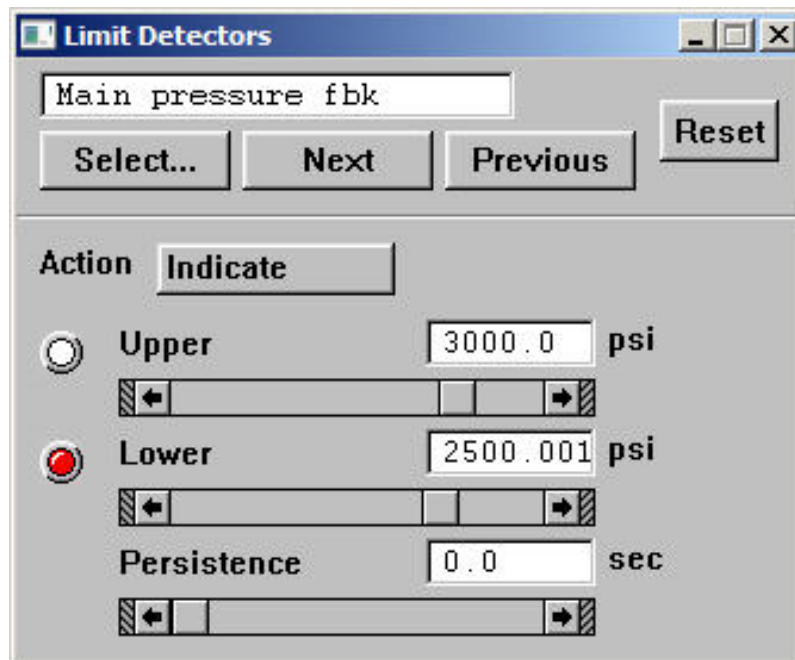
Panel description

Main Pressure control loop parameter select..

HPS Pressure Controls	
Control	Descriptions
Proportional Gain	Specifies the Proportional Gain used for Main Pressure control loop.
Integral Gain	Specifies the Integral Gain used for the Main Pressure control loop.
Integral Authority	Specifies the maximum amount of integral correction that can occur (as a percentage of maximum drive). This operates as a hard +/- value limit.

NOTE: The HPS Pressure Controls also includes a controller for Pilot Pressure. However, this controller no longer operates. The Pilot Pressure command is now set by a direct table lookup.

Limit Detectors



Access

Main controller panel **Operation** menu > **Limit Detectors**.

When to use the panel

Use the panel to set safety limits for the test system.

The limit detectors are enabled and disabled from the main controller panel. If not enabled, they will not set an indicator or interlock.

Panel description

The Limit Detector panel allows you to:

- Select a specific software signal for which a limit can be set
- Choose the action to be taken if a limit is exceeded
- Set an allowable operating range and persistence value for the signal
- Identify if an upper or lower out-of-limit has occurred
- Reset the software limit detector circuit

Background information

A limit event for a particular signal indicates that the signal has exceeded its upper or lower limit. The upper and lower limits establish a range of values that represent a desired system operating range. This band

also represents the range where valid test data can be ensured. The persistence value is a time (in seconds) that an upper or lower out-of-limit condition can persist without causing an interlock.

When an out-of-limit condition occurs, the Message Log panel identifies the specific out-of-limit condition.

Limit Detectors Reference



Warning:

Limit and error detectors are generally used to minimize the chance of accidental damage to the test equipment or test specimen. Limit detectors can also act to maximize the validity of the test data.

Test equipment that is run within acceptable operating limits can still have the potential to cause death or severe injury to personnel.

Do not rely on limit and error detectors to protect personnel from injury.

Signal Selection Controls

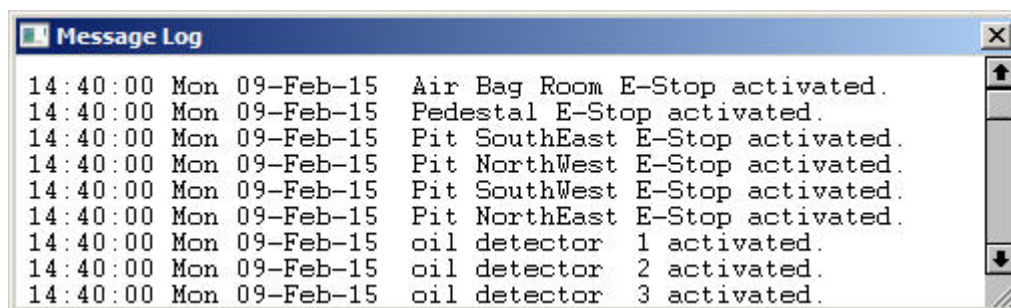
Control	Descriptions
text box	Displays the name of the selected signal.
Select...	Selects a signal from a list of signals.
Next	Selects the next signal in the selection panel list.
Previous	Selects the preceding signal in the selection panel list.

Limit Detector Controls

Control	Description
Reset button	Click to clear the indicators and any software interlocks generated by an out-of-limit condition, if the channel is within limits.
Action pop-up menu	Select the result of an out-of-limit condition. Selections are: • Indicate – This selection causes the indicator to light only while the signal is outside of the limit. When the signal returns inside the limit, the indicator goes out. • Alert – This selection causes the indicator to light and latch. When the signal returns inside the limit, the indicator remains lit until the Reset button is used. The out-of-limit condition will be recorded in the message log.

Control	Description
	• Program Abort– This selection causes the system to trigger a program abort if the signal goes outside the limit where the master span will be ramped to zero at a rate entered in the Ramp Rates panel. The Reset button is required to reset the system. The out-of-limit condition will be recorded in the message log. • Interlock – This selection causes the system to trigger an Emergency Stop if the signal goes outside the limit. The Reset button is required to reset the system. The out-of-limit condition will be recorded in the message log.
Upper slide bar and text box	Sets the upper limit of the selected signal. Note that when you set the upper limit value, the lower limit is automatically set to the negative of the upper limit value. If you desire a different lower limit value, you should change it using the lower slide bar after setting the upper limit.
Upper indicator	Lights when an out-of-limit condition occurs for the upper limit.
Lower slide bar and text box	Sets the lower limit of the selected signal. Setting this value does not affect the upper limit value.
Lower indicator	Lights when an out-of-limit condition occurs for the lower limit.
Persistence slide bar and text box	Sets the time, in seconds, that an upper or lower out-of-limit condition can persist without causing an interlock.

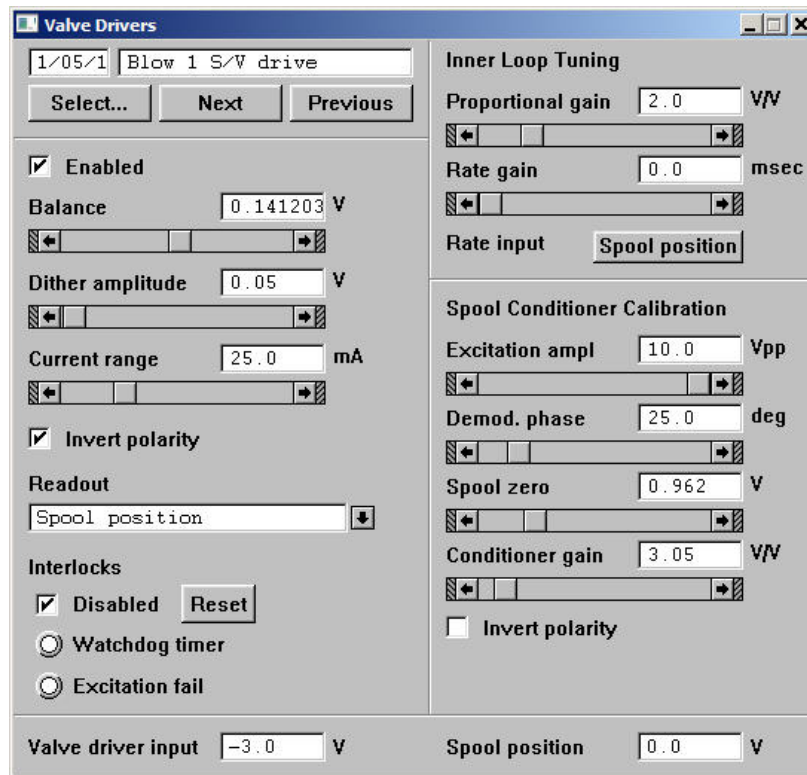
Message Log



Access

Main controller panel **Display** menu > **Message Log**.

Valve Drivers



Access

Main controller panel **Calibration** menu > **Valve Drivers**.

When to use the panel

Use the panel during test setup.

Panel description

The Valve Drivers panel allows you to perform the following tasks:

- Select a specific valve driver channels.
- Adjust the dither amplitude and balance for the selected valve driver channel.
- View the value input to the valve driver by the servo controller.
- Insert the valve phase.
- Disable and/or reset interlocks.
- Monitor interlocks.
- Tune the inner loop.
- Make spool conditioner adjustments.

For More Information

[Spool Conditioner Gain](#) (p. 202)

[Servo Gain Tuning](#) (p. 203)

[Spool Zero Adjustment](#) (p. 203)

Valve Drivers Reference

Channel Selection Controls

Control	Descriptions
text box	Displays the name of the selected channel.
Select...	Selects a channel from a list of channels.
Next	Selects the next channel in the selection panel list.
Previous	Selects the preceding channel in the selection panel list.

Base Valve Driver Controls

Control	Description
Enabled check box	When checked, sets input of valve driver to zero. (For tuning purposes only).
Balance slide bar and text box	Adjusts the electrical balance of the servovalve.
Dither amplitude slide bar and text box	Adjusts the dither applied to the servovalve. You can use the slide bar to set a value or enter it in the text box.
Current range	(Not applicable for this system.) Current range is used to select the control current for 2-stage valves.
Invert polarity check box	Selects inverted or non-inverted valve phasing.
Readout pull-down menu	Selects a function for direct readout. Click the down arrow button to display a list of signals. Select the desired signal and click the check mark button to accept the selection and close the list, or click the X button to decline the selection and close the list.

Interlock Controls

Control	Description
Disabled check box	When checked, disables hardware interlocks for the selected channel.
Reset button	When pressed, resets the hardware interlocks for the selected channel.
Watchdog Timer indicator	Indicates the status of the watchdog timer.
Excitation fail indicator	Shows whether excitation has failed. This detector is always enabled, both in hardware and software. Excitation failure causes a system interlock because it may indicate a broken, defective or missing cable.

Inner Loop Tuning Controls

Control	Description
Proportional gain slide bar and text box	Adjusts the proportional gain for the selected valve driver. You can use the slide bar to set a value or enter it in the text box.
Rate gain slide bar and text box	Adjusts the derivative rate gain for the selected valve driver. You can use the slide bar to set a value or enter it in the text box.
Rate input radio buttons	Sets the signal source for rate input as spool position or spool.

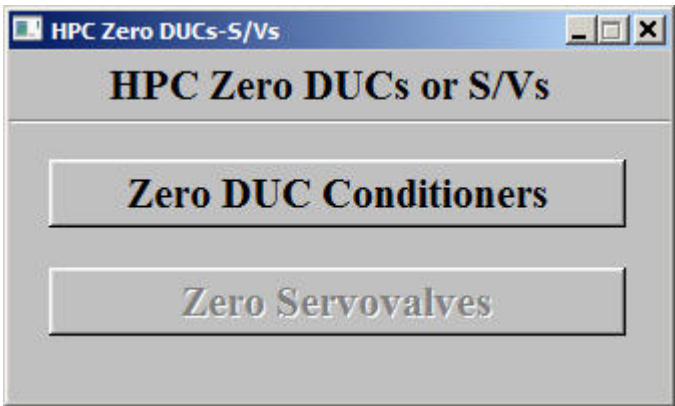
Spool Conditioner Calibration Controls

Control	Description
Excitation amplitude slide bar and text box	Sets the level of the excitation signal sent to the transducer. You can use the slide bar to set a value or enter it in the text box.
Demod. phase slide bar and text box	Sets the demodulator phase of the conditioner output. You can use the slide bar to set a value or enter it in the text box.
Spool zero slide bar and text box	Sets the spool position zero offset. You can use the slide bar to set a value or enter it in the text box.
Conditioner gain slide bar and text box	Adjusts the conditioner gain for the selected valve driver. You can use the slide bar to set a value or enter it in the text box.
Invert polarity check box	Selects inverted or non-inverted spool conditioner polarity.

Valve Driver Readouts

Control	Description
Valve driver input display box	Shows current value input to the valve driver by the servo controller. Not editable.
Spool position display box	Displays the current spool position.

Zero DUCs or Servovalves



Access

Main controller panel **Operation** menu > **Zero DUCs - S/V**

When to use the panel

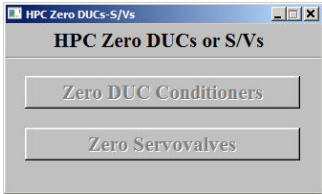
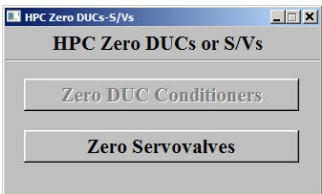
Use the panel to zero the DC Conditioners in the system prior to hydraulic startup or zero the servovalve offsets when only Pilot Pressure is on (NO Main Pressure).

Panel description

The Zero DUCs-S/Vs panel allows you to zero the DC Conditioners or Servovalves.

The buttons on this panel are only active during certain hydraulic on/off states:

- | | |
|------------------|---|
| Zero DUCs | Active ONLY when ALL pumps are OFF (shown above). |
| Zero Servovalves | Active ONLY when Pilot Pressure is ON and Main Pressure is OFF . |



Maintenance

Topics:

- *Maintenance Safety.....154*
- *Maintenance Overview.....155*
- *Summary of Maintenance Procedures.....156*
- *Label Inspection.....157*
- *Control Console.....158*
- *Emergency Stop and Warning Indicators.....158*

Maintenance Safety

Before maintenance is performed, familiarize yourself with procedures in this manual and the maintenance procedures in the applicable product manuals. Make sure that all safety practices are followed. Any system component not specifically discussed in this section or in the other supplied manuals should not be adjusted or tampered with.



Warning:

Maintenance procedures can expose personnel to hazardous situations when working on the system.

Failure to observe the Safety Practices described in this manual prior to attempting maintenance procedures can result in injury to personnel and/or damage to equipment.

The Safety Practices section of this manual contains information that can help maintenance personnel minimize hazards which can be encountered during system maintenance. Ensure that all persons involved in the maintenance of the equipment read the Safety Practices section of this manual.



Warning:

High-pressure fluids can be present in the HPU after shutdown because the HPU accumulator temporarily stores pressure.

High-pressure hydraulic fluid can cause serious injury to personnel.

After you shut down the HPU, check to make sure that the accumulator manifold pressure gauge reads zero before opening system lines or fittings .



Warning:

The HPU motor drive system is fitted with internal discharge resistors.

Internal discharge resistors temporarily store electrical energy after the HPU is disconnected from the electrical supply. Stored electrical energy can cause death or serious injury to personnel.

Wait at least one minute after disconnecting the HPU from the electrical supply before performing maintenance.

**Warning:**

Improper lockout procedures can result in unexpected test rig motion.

Unexpected test rig motion can cause cuts and pinches, or crush personnel or equipment.

Ensure that proper lockout procedures are defined and used whenever personnel are required to work in close proximity to the test system.

**Warning:**

The first time a pump motor is started after electrical service is connected to the HPU, it is possible for the pump motor to rotate in the wrong direction.

A pump motor rotating in the wrong direction at high pressure for longer than 2 seconds can cause severe damage to the HPU.

The first time the HPU is started after connection to electrical service, make sure the pump motor rotates in the correct direction. Use two persons to confirm the direction of rotation - an operator and an observer. The operator should perform a rapid start-then-stop of the HPU while the observer compares the actual direction of the shaft rotation against the direction of rotation labels on the motor and pump. If the direction of rotation is incorrect, change the electrical service connection and re-check the rotation.

Maintenance Overview

Timely completion of scheduled maintenance activities is mandatory during the warranty period. Failure to perform scheduled maintenance activities will void your warranty. In addition, it is highly recommended that you perform all scheduled maintenance activities throughout the system's operating life. Scheduled maintenance can extend the operating life of your test system by using regular inspections and simple procedures, such as filter changes and lubricating bearings, to minimize wear and component failure.

**Important:**

These guidelines can be modified to reflect the operating conditions of your test system. At no time should you be required to stop a test simply to perform a recommended maintenance procedure.

Maintenance information

Refer to the maintenance information in this manual to get started with and to become familiar with the maintenance tasks that are required for the system.

Also refer to the product information manuals for more detailed component information that may not be covered in this manual.

Skilled maintenance personnel

A seismic test system is highly complex and therefore requires skilled personnel to perform the maintenance procedures. Skilled personnel who perform maintenance on the system should have technical education

Maintenance

and training that is related to the job, study the components of the system, and read the manuals included with the system.

Use of rigging

Due to the size and weight of a seismic test system, many repair or maintenance procedures require the use of heavy machine rigging techniques. This manual is not intended to be a primer in this area and assumes a knowledge of such techniques and the use of personnel skilled in rigging.

How to schedule maintenance

Maintenance is recommended based on system operating time. Use running time or calendar time to help you schedule maintenance procedures. As a guideline, for a test system operating eight hours per day, one week will equal approximately 40 hours, and one month will equal 160 hours. For a test system operating up to 24 hours per day, one week will equal approximately 160 hours, and one month will equal 640 hours.

Maintenance procedures that are recommended on a daily or weekly basis generally involve visual checks only and should not interfere with the operation of your test system. These checks will help you assess which procedures must be performed before running the next test. For example, the dirty filter indicator on the Hydraulic Service Manifold signals that it is time to change the disposable filter.

Procedures recommended at monthly or longer intervals may be scheduled as part of your preparations prior to running long-term durability tests.

Additional maintenance

Additional maintenance may be required whenever you notice decreased system performance. An example of this type of maintenance is replacing actuator seals whenever leakage occurs or whenever an actuator has been disassembled. Many of these additional procedures require specialized tools or specific training and should be performed by MTS service personnel. Contact MTS to schedule service.

Summary of Maintenance Procedures

Calendar time	1 Day	1 Week	1 Month	3 months	6 months	1 Year	2.5-3 Years	5 Years
Operating time	8 Hours	40 Hours	160 Hours	500 Hours	1000 Hours	2,000 Hours	5,000 Hours	10,000 Hours
Labels								
Inspect system safety labels			X					
			1					
Control Console								

¹ Symbol denotes services performed by equipment operators or technicians. These checks are also completed by trained field service engineers on each Routine Maintenance visit.

Calendar time	1 Day	1 Week	1 Month	3 months	6 months	1 Year	2.5-3 Years	5 Years
Operating time	8 Hours	40 Hours	160 Hours	500 Hours	1000 Hours	2,000 Hours	5,000 Hours	10,000 Hours
Check console cooling and ventilation	X							
Clean air filter, replace as required			X					
Check condition of all electrical cables and cable connections			X					
Emergency Stop and Warning Indicators								
Check operation (emergency stop/warning lights)		X						

Label Inspection

The labels that are affixed to the system may become illegible or detached from the system due to aging or exposure to sun, heat, chemicals, or contact/wear.

160 Hours

Inspect the labels that are affixed to the system for readability and adhesion. If any label is not readable or if the label is wholly or partially detached from the system, order and replace the label immediately. To determine the appropriate replacement label and order number, refer to the Safety Information section of this manual or to the Label Kit drawing, if provided, on your System Documentation CD (refer to the System Hazard Labels tab).

Control Console



Warning:

Hazardous electrical current can be present in the test system.

Contact with high voltage electrical current can cause death or severe burns and injury.

Ensure that the test system is electrically isolated and that you establish and complete any lockout/tagout safety procedures before you attempt to perform scheduled maintenance procedures on the test system.

The control electronics for your test system require a minimum amount of maintenance. Visually inspect your control electronics components and help to maintain a clean operating environment for them by completing the following maintenance requirements at regular intervals:

- Check the console cooling.
- Clean the fan filter.
- Check the condition of electrical cables.

Emergency Stop and Warning Indicators

Test the operation of the Emergency Stop button(s) and the warning indicators on the various system chassis and controls once every week or after every 40 hours of operation:

1. Press an Emergency Stop button when the system hydraulics are on to ensure that the hydraulic service manifolds shut down when the button is depressed. Reset the button and test each remaining Emergency Stop button until satisfactory operation is verified at all Emergency Stop locations.
2. Test the operation of all indicators and lights on the system. Most indicators and lights have a test mode that can be used to validate the bulb operation. In many cases, this mode is activated when the bulb and bulb housing are depressed and held. If the bulb lights during the test, this verifies that the bulb operates properly.

System Setup and Operation

Topics:

- *Test Startup and Adjustments.....160*
- *Hydraulic Startup.....162*
- *Table Test Execution.....164*
- *Adaptive Control Methods.....165*
- *APC Operation Overview.....166*
- *AHC Operation Overview.....168*
- *AIC Operation Overview.....173*
- *OLI Operation Overview.....189*
- *System Shutdown.....193*
- *Emergency Shutdown 193*

Test Startup and Adjustments

Before applying hydraulic pressure, complete the following tasks.

Specimen Preparation

- Securely mount the test or dummy specimen
- Attach the specimen transducers and cables (if applicable)
- Calibrate the specimen transducers (if required)

Start the Control System

1. Turn on electrical power to the PC.
2. After the PC has completed its startup, turn on the 469D controller.
3. Wait one minute for the 469D controller to fully start up, and then double click on the **469D.exe** icon located on your computer desktop.
4. In the dialog that opens, select the appropriate settings file for the testing you plan to perform.

After the settings file is opened, the main controller panel will open.

Initial Test Settings

After the software is started, you can select to use a different settings file, if you are in the Extended access level. To do this, select **File** menu > **Restore Settings**.

The HSMs must be off before you can you save settings, restore settings, or quit the application. Note that you can perform these functions when the HPS is on.

The following settings are not saved with a settings file:

Parameter	Disposition
Transient values (such as the current value of a program)	Not saved or restored
Display/View menu value (such as oscilloscope or digital meter)	Not saved or restored
Message log	Not saved in Settings file (message log has its own file)
Access privilege	Always set to BASIC

Parameter	Disposition
Displ setpoint	Always set to 0%
Limits	Always disabled
Hydraulics	Always off
Stop /Run button	Always Stop
Adaptive Control	Always disabled

Select the 469D Program Source

Select the **Program Source** on the **469D Digital Seismic Table Controller** panel.

- If **Function Generator** is selected, use the **Function Generators** panel under the **Operation** menu to set up the parameters.
- If **Data Player File** is selected, use the **Data Player** panel under the **Operation** menu to choose the play out file.
- If **Remote Application** is selected, make sure an Ethernet connection exists to the Remote Application (for example: STEX).
- If **External (Analog)** is selected, make sure an external connection is made to a data payout system.
- If **Scramnet** is selected make sure an external connection is made to a data payout system via the scramnet.

Setup and Enable Readout Displays

Setup and enable the desired readout devices for the 469D Table controller using the **Display** menu.

For More Information

[Analog Readouts](#) (p. 95)

Specify Limits

Adjust limit detector levels. Use the **Limit Detectors** panel under the **Operation** menu to set limit detector levels that ensure the safety of the system components.

Disable the limit detectors. Click the **Interlocks Disabled/Enabled** button on the **469D Digital Seismic Table Controller** panel and select **Disabled**.

For More Information

[Limit Detectors](#) (p. 124)

[469D Digital Seismic Table Controller](#) (p. 37)

Hydraulic Startup



Warning:

Hydraulic pressure application can cause high force actuator motion and hardware position changes.

High force actuator motion can cause personal injury or damage to your equipment or specimen.

Ensure that all equipment and personnel are clear of all system fixtures before you apply hydraulic pressure to the system.

Reset Interlocks

Complete these steps to reset interlocks that may have been generated during test setup procedures.

1. Click **Interlocks Reset** on the 469D main controller panel to clear interlock and limit detection indicators.
If the **Interlock** indicator remains red, a hardware interlock or a software limit remains uncleared in the system.
2. If you suspect a hardware interlock:
 - a) Check the **AC Conditioner** and **DC Conditioner** panels to see if a red fault indicator has been set.
Do this by selecting each signal, and look at the interlock indicators (upper and lower limits and excitation). A red indicator indicates there is a fault. If a fault has occurred, move the limits outside of the current signal value, and press the **Reset** button.
 - b) Check all emergency stop buttons in the system (including those on each HPU). Verify that none of the buttons have been pushed and left latched.
 - c) Click **Interlocks Reset** on the 469D main controller panel to clear the interlock indicator.
3. If you suspect a software limit detector is set:
 - a) Open the **Message Log** panel and see if a software limit detector is triggered. The message will identify the limit.
 - b) Open the **Limit Detectors** panel.
 - c) Select the associated signal
 - d) Make a note of the limit value.
 - e) Move the limits outside of the current signal value
 - f) Click **Reset**.
 - g) Click **Interlocks Reset** on the 469D main controller panel to clear the interlock indicators.
 - h) Set the limit detector back to its original value on the **Limit Detectors** panel.
4. Select **Enable** for the **Interlocks** on the 469D main controller panel.

Hydraulic Power Unit Startup

On the main controller panel, select the HPS(s), and then click **HPS On**.

Hydraulic Service Manifold Startup



Warning:

Applying hydraulic pressure to the test station (HSM) can cause the test system to move suddenly and unexpectedly.

Sudden movement of the test system can result in injury to nearby personnel.

Before you apply hydraulic pressure to the test station (HSM), make sure there are no personnel near the test system. The test system should be in a separate protective room and personnel should be restricted from entering that area when hydraulic pressure is applied to the test station.

The following settings are made on the main controller panel.

1. Click **HSM Lo** to apply low hydraulic pressure to the actuators.

The **HSM Lo** indicator will turn yellow.

Allow the system HSM to run at low pressure until the normal hydraulic fluid operating temperature is achieved (at or above 32° C).



Note:

Optimum system response is achieved when the hydraulic fluid is at its normal operating temperature (at or above 32° C).

2. Verify the gain settings for stable system control. Decrease the **Master gain**, if necessary.
3. Set the **Setpoint** to **Parking**.
4. Click **HSM Hi** to apply high hydraulic pressure to the actuators.

The **HSM Hi** indicator will turn green.

Table Test Execution

Verification and Safety Checks



Note:

Optimum system response is achieved when the hydraulic fluid is at its normal operating temperature.

- Ensure that the hydraulic system is at its normal operating temperature (at or above 32° C) before proceeding with testing.
- Check the program input and pre-test adjustments completed in the preceding subsections.
- Clear all personnel from the test area.

Start the Test Program



Caution:

When adjusting the Span and Setpoint controls, ensure that the test program does not exceed 100% of the full-scale limits.

The Span and Setpoint controls can cause the program to exceed 100% of the system full-scale limits.

If the program exceeds 100% of full-scale, the limit detector interlocks will activate causing a program interlock. A program interlock may invalidate the test data because the test will stop abruptly.

1. Verify that the **Desired span** control on the main controller panel is set to a known safe operating level or 0%.
2. Verify the program source selection and parameters.
3. If desired, enable **Adaptive Control**.
- 4.



Warning:

Immediate and unexpected actuator response is possible when a Run command is applied to the system.

Unexpected actuator response can result in personal injury or equipment damage.

Clear all personnel from the test system before running a test.

Press the **Run** button on the main controller panel to begin the test.

For More Information

[469D Digital Seismic Table Controller](#) (p. 37)

[Adaptive Control Methods](#) (p. 165)

Adjustments During a Test

- Make adjustments to the readout devices as desired.
- While constantly checking for system stability, slowly adjust the **Desired Span** control on the 469D main controller panel towards 100%.
- If the system becomes unstable, immediately remove hydraulic pressure by pressing the **EMERGENCY STOP** button. Identify the cause(s) of the instability before attempting the test again.

For More Information

[469D Digital Seismic Table Controller](#) (p. 37)

Adaptive Control Methods

Adaptive control techniques are used to adapt to parameter changes in any system components that affect the control loop feedback of a system.

The choice of which adaptive controller to use is determined by two considerations:

- Type of program waveform.
- Degree of linearity of the entire system, including hydraulics, mechanics and test specimen.

	Sine or Sweep Waveform	Other Waveform
Linear System	Use APC	Use AIC
Non-Linear System	Use APC with AHC	Use AIC with OLI (Online Iteration) or STEX Pro

For More Information

[APC Operation Overview](#) (p. 166)

[AHC Operation Overview](#) (p. 168)

[AIC Operation Overview](#) (p. 173)

[OLI Operation Overview](#) (p. 189)

Adaptive Control Modes

Background information

The **Adaptive Control** mode is selected on the main controller panel.

Adaptive Control Mode	Description
Disabled	Adaptive control is off (disabled).
Frozen	The system continues to use parameters developed during tracking, but the parameters are not updated. In the case of online iteration, a new drive update file is calculated during each pass, but it is not used as the drive file for the next pass.
Tracking	The frequency response of the system is continuously measured and the applied inverse function is continuously modified to suit changing conditions in the system. In the case of online iteration, a new drive update file is calculated during each pass, and this new file becomes the drive file for the next iteration.
Training (AIC and AHC only)	Training mode is used initially to build coefficients without affecting the system operation. A system model is built but the current signal being played out is not modified. These coefficients can then be saved in a settings file.

APC Operation Overview

Amplitude/Phase Control (APC) is a control compensation technique that augments a fixed-gain controller to correct for closed-loop amplitude and phase irregularities in order to improve control fidelity. It measures control system dynamics directly and modifies the control compensation accordingly in real time, making it possible to adapt to changing system dynamics.

APC is optimized to work with sinusoidal command waveforms (both fixed and swept frequency) and predominantly linear systems. If the command waveform is non-sinusoidal, use Adaptive Inverse Control (AIC) instead. If the system has significant nonlinearities, augment APC with Adaptive Harmonic Cancellation (AHC) to reduce harmonic distortion. APC and AHC complement each other: APC enhances the fundamental frequency component of the system response while AHC cancels the harmonics.

APC is very easy to use.

- Select the desired mode from the 469D Digital Seismic Table Controller Panel.
- Select Cyclic, Sine Step, or Sweep on the Function Generators panel.
- Define a sine wave.
- Press the Run button on the 469D Digital Seismic Table Controller Panel.

For More Information

[Adaptive Control Methods](#) (p. 165)

[APC Modifications](#) (p. 167)

[Monitor and Analyze APC Results](#) (p. 167)

APC Modifications

In most cases you will not need to adjust anything on APC Panel. However there are a few situations that may arise where you may want to make modifications:

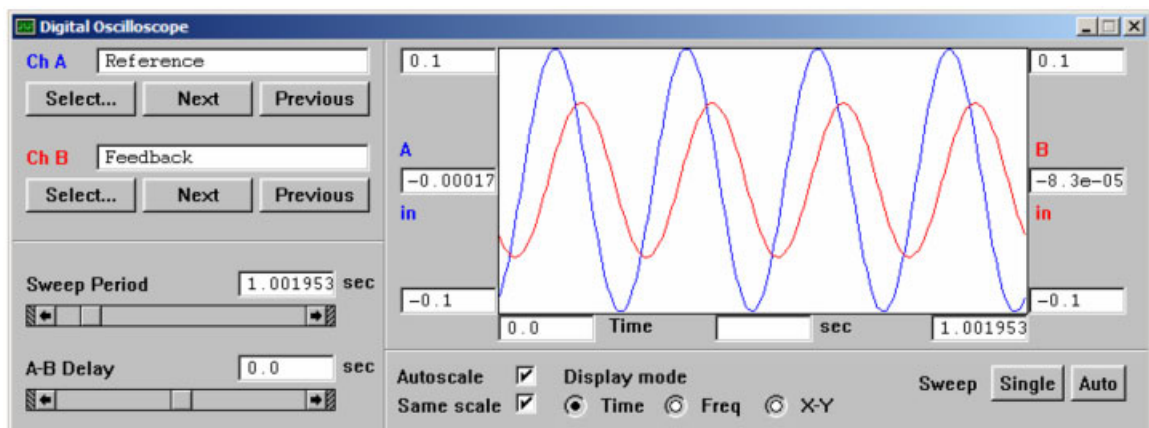
- When operating at a frequency that is close a resonance such as the oil column resonance or a specimen resonance, APC may cause the response amplitude to oscillate. Usually this can be corrected by reducing the Convergence rate.
- When running sine sweeps at a fast sweep rate, you may find that APC is not able to adapt quickly enough to keep up. Try increasing the Convergence rate. However, if you increase the Convergence rate beyond unity, you risk APC instability and the large, potentially damaging motion that will result. You may have to reduce the sweep rate instead.
- For safety purposes you may want to reduce the Max authority value to reduce the danger of damage due to large amplitude motion should APC's adaptation process become.
- If you observe that the response amplitude falls short of the command amplitude, it may be because the amplitude correction that APC needs to apply is beyond the maximum authority limit. You can verify that this is the case because the Ampl correction display value will be nearly equal to the Max authority value. Increase the Max authority in small increments, until the response amplitude matches the command and the Ampl correction falls below the Max authority. If the response amplitude does not increase when Max authority is increased, you may be at a physical limit of the system, in which case there is nothing you can do except reduce the command amplitude or frequency.

Verify that adaptation is occurring by observing the changing Ampl correction and Phase correction values, or by noting that the Tracking indicator is green.

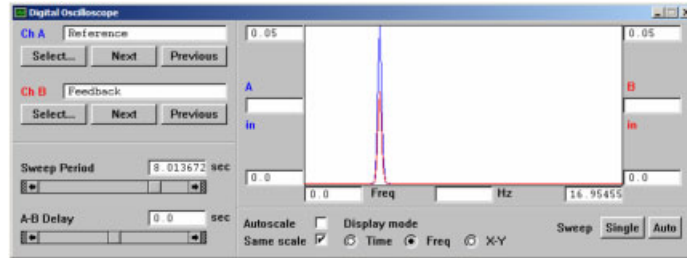
Monitor and Analyze APC Results

You can use the Digital Oscilloscope to monitor command and response waveforms in either the time domain or the frequency domain. In all examples shown below, command is shown on Channel A (blue) and response on Channel B (red).

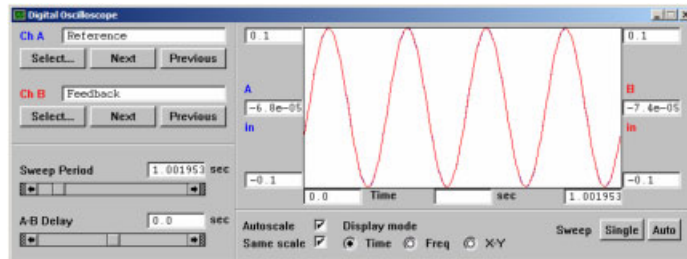
Below is an example showing command and response time domain signals without APC:



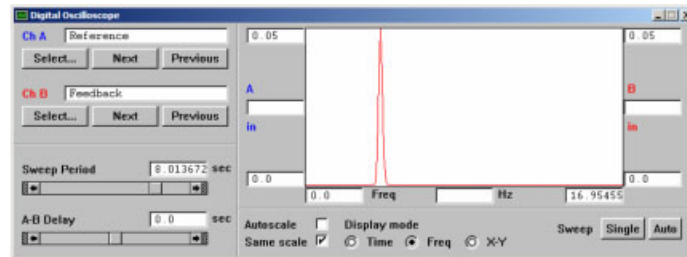
In the frequency domain, the response amplitude obviously falls short of the command amplitude:



With APC, command and response time domain signals are almost perfectly overlaid:



In the frequency domain, the response amplitude matches the command amplitude:



AHC Operation Overview

Adaptive Harmonic Cancellation (AHC) greatly reduces harmonic distortion of the response of a control system driven by a sinusoidal command. It measures the harmonic distortion directly and adapts in real time the cancelling waveform that it applies to the control system input.

AHC is optimized to work with sinusoidal command waveforms (both fixed and swept frequency). To improve the fidelity of the system's response to a sine command, AHC can be augmented with Amplitude/Phase Control (APC). APC and AHC complement each other: APC enhances the fundamental frequency component of the system response while AHC cancels the harmonics.

For More Information

- [Adaptive Control Methods](#) (p. 165)
- [Train the Model with AHC](#) (p. 169)
- [Cancel Harmonics with AHC](#) (p. 170)
- [Cancel Cross-Coupling Disturbance with AHC](#) (p. 171)
- [Monitor and Analyze AHC Results](#) (p. 172)

Train the Model with AHC

Perform the following procedure for every active control channel:

1. Set up the random function generator.

The random function generator consists of a uniform distribution random number generator followed by a bandpass filter. This filter has four parameters that you must enter:

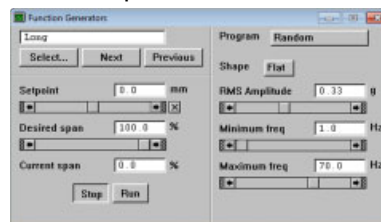
Maximum freq: This is the cutoff frequency of the bandpass filter. Set this according to the highest frequency expected in your test waveform. Due to internal technical considerations, this maximum frequency must not exceed 64 Hz. Also enter this maximum frequency into the Maximum Freq text box in the Adaptive Harmonic Cancellers panel. This tells AHC not to cancel harmonics that exceed the frequency up to which its model has been trained.

Minimum freq: This is the cut-in frequency of the bandpass filter. Set this according to the lowest frequency expected in your command waveform. A minimum frequency of zero is allowed. In seismic controllers in acceleration control mode, this frequency should match the cut-in frequency of the Reference Generator.

RMS Amplitude: Adjust the RMS Amplitude to the minimum value possible to prevent damage to the test specimen. Keep in mind, however, that using too low of an amplitude will result in an inaccurate estimates of the model. If your system is significantly nonlinear, try to use an RMS amplitude similar in amplitude to the test waveform if possible, because in such systems the transfer function is a strong function of signal amplitude. Also, keep in mind that you are setting RMS amplitude, not peak amplitude; peak amplitude will be somewhat higher than RMS amplitude.

Shape: This is the shape of the bandpass filter's magnitude response as a function of frequency between minimum and maximum frequencies. Five shapes are available: $1/F^2$, $1/F$, Flat, F , and F^2 , where " F " denotes frequency. The primary consideration in selecting the shape is to get the most energy into the system across the frequency band of interest without damaging the system by excessive velocity or acceleration. In acceleration control systems, Flat works well, but in displacement control systems, Flat will result in excessive velocity and acceleration at high frequencies; $1/F$ or $1/F^2$ is much gentler on the system in that case. Shapes F and F^2 accentuate acceleration at high frequencies and so should not be used. Note that theoretically a shape of $1/F$ or $1/F^2$ results in a filter magnitude response that tends toward infinity as the frequency tends toward zero. This is neither desirable nor practical, so the filter response is rolled off to zero as the frequency approaches the minimum frequency. In addition, for technical reasons the minimum frequency is not allowed to be less than 1% of the maximum frequency when $1/F$ and $1/F^2$ shapes are selected.

An example random function generator setup is as follows:



2. On the main controller panel select **Training** for the **AHC** mode, and then click **AHC**.

In Training mode, AHC is on but is not canceling. Instead, it passively monitors command and feedback to the plant and updates its model accordingly.

3. Run the random function generator.

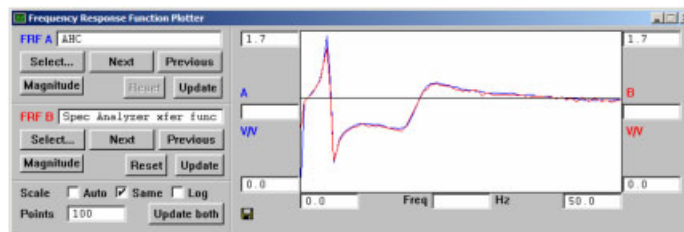
- a) Make sure that the function generators of all other channels are in a stopped state.

System Setup and Operation

- b) Then start the function generator by clicking the Run button.
4. Adapt the coefficients.

When motion has begun, move the Model Convergence rate slider bar away from zero. The coefficients of elements in the training row will begin to change. This can be observed textually in the model coefficient display of the Adaptive Harmonic Cancellers panel, and graphically in the Frequency Response Function Plotter panel and the Impulse Response Function Plotter panel. The Model Tracking indicator on the Adaptive Harmonic Cancellers panel should be green.

While training is in progress, it is a good idea to verify that it is proceeding correctly by comparing the transfer function estimated by AHC with that estimated independently by the Spectrum Analyzer. In the example below, FRF A (blue) on the Frequency Response Function Plotter panel shows the model's transfer function identified by AHC; FRF B (red) shows the same transfer function identified by the Spectrum Analyzer. Note that they are similar, but not the same (especially the phase responses, not shown) because embedded in the AHC transfer function are effects of filters internal to AHC that the Spectrum Analyzer cannot see.



When the coefficients have stopped changing a lot, it is time to begin a process known as “coefficient polishing”. Slowly reduce the Convergence rate in stages, waiting a while between stages to allow time for the coefficients to approach their optimum values. Finally, after the Convergence rate has been reduced to zero, stop the function generator by clicking the Stop button.

5. Save AHC setup and transfer function coefficient values to a settings file
On the main controller panel select **File** menu > **Save Settings**.

Cancel Harmonics with AHC

Perform the following procedure for every active control channel:

1. On the Function Generators panel, set up the sine or sweep program.
2. On the main controller panel select **Training** for the **AHC** mode, and then click **AHC**.

At this point you may also want to turn on APC to improve the fidelity of response to the sine command.

3. Run the sine or sweep function generator.
 - a) Make sure that the function generators of all other channels are in a stopped state.
 - b) Then start the function generator by clicking the Run button.
4. Cancel selected harmonics.

After motion has begun, observe the response using the Digital Oscilloscope panel. It is convenient to view the response in Frequency Display Mode so that individual harmonics are easily discernible. Noting which harmonics have significant amplitude, designate them for cancellation by pressing the corresponding buttons in the Harmonics grid selector on the Adaptive Harmonic Cancellers panel. Then move the Canceller Convergence rate slide bar away from zero. On the Digital Oscilloscope panel, selected harmonics will begin to decrease in amplitude. The Max authority displayed in the Adaptive Harmonic Cancellers panel will increase as the amplitudes of the cancelling signals that AHC

adds to the command are increased. The Canceller Tracking indicator on the Adaptive Harmonic Cancellers panel should be green.

If the authority reaches the maximum authority limit, it is either because the maximum authority is too low, or AHC is unstable at that harmonic. To determine which is the case, increase the Max Authority on the Adaptive Harmonics Cancellers panel by small increments while observing the response harmonics in Digital Oscilloscope panel (using the Frequency Display Mode). If the amplitude of a harmonic keeps increasing with increasing authority, then AHC is unstable at that harmonic. Almost always the cause of this behavior is an inadequately trained model. You may need to go back and retrain or refine it.

Reducing the Max authority to the minimum possible will reduce the danger of damage due to large amplitude motion should AHC's adaptation process become unstable for whatever reason.

When running sine sweeps at a fast sweep rate, you may find that AHC is not able to adapt quickly enough to keep up. Try increasing the Convergence rate. However, if you increase the convergence rate beyond unity, you risk AHC instability and the large, potentially damaging motion that will result. You may have to reduce the Sweep rate on the Function Generators panel instead.

Cancel Cross-Coupling Disturbance with AHC

AHC can be used to cancel the cross-coupling disturbance that sometimes occurs in a multichannel control system when motion on one channel couples into another. Using the term “primary” to refer to the primary motion channel and “secondary” to refer to the channel disturbed by the primary channel, apply the following procedure to the secondary channel:

1. Train the model with AHC.
2. On the Function Generators panel, select **Phased** for the **Program**.
3. Set up the Function Generator.

The **Phased Program** synchronizes itself both frequency- and phase-wise with another channel's function generator (selected with the **Master** button on the Function Generators panel). In this case, designate the primary motion channel's sine generator as the master. Next, specify a very small **Peak amplitude**, small enough that the resultant motion is not noticeable. Even though no motion is desired on the secondary channel, you must drive it with sine command because AHC uses it to drive its internal harmonic generators. The **Peak amplitude** does not have to be large, but it does have to be nonzero.

4. On the main controller panel select **Training** for **AHC**, and then click **AHC**.
5. Click **Run** the Function Generators panel with the **Master** channel selected.

The secondary function generator will start as well because it is linked to the primary function generator.

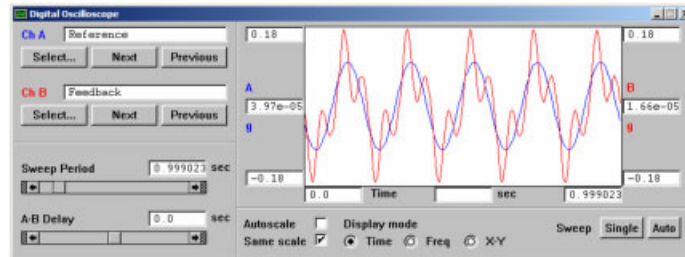
6. Cancel selected harmonics.

When you observe the secondary channel's response in the Digital Oscilloscope panel (in **Frequency Display Mode**), there will probably be a sizeable component of disturbance at the fundamental frequency, that is, the primary function generator's sine frequency. Cancel this “first harmonic” by selecting the “1” button of the **Harmonics** grid selector in the Adaptive Harmonics Cancellers panel. Note that the first harmonic button is used only to cancel cross-coupled disturbance at the fundamental frequency on secondary channels. It is not used for regular cancellation on primary channels.

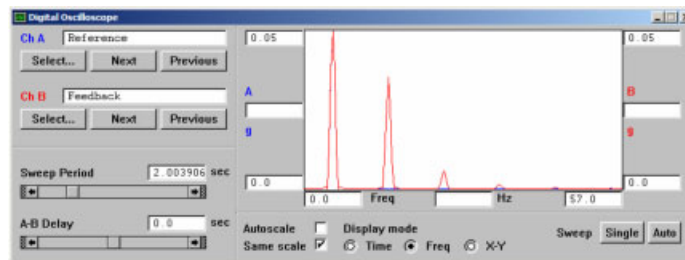
Monitor and Analyze AHC Results

You can use the Digital Oscilloscope panel to monitor command and response waveforms in either the time domain or the frequency domain. In all examples shown below, command is shown on Ch A (blue) and feedback on Ch B (red). APC is enabled in all of these examples.

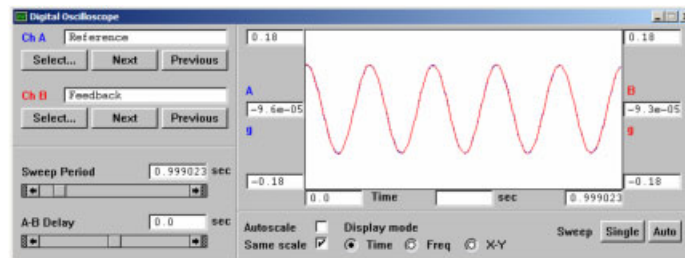
Below is an example showing command and feedback signals in time domain without AHC:



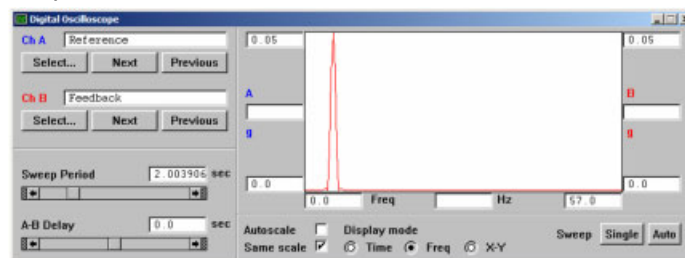
In the frequency domain, harmonics are clearly visible in the feedback:



With AHC, the harmonics are gone and, because of APC, command and feedback time domain signals are almost perfectly overlaid:



In the frequency domain, the harmonics are gone and the feedback amplitude at the fundamental frequency matches the command amplitude:



AIC Operation Overview

Background information

The **Adaptive Control** mode is selected on the main controller panel.

Adaptive Control Mode	Description
Disabled	Adaptive control is off (disabled).
Frozen	AIC is on and controlling, but coefficients are unchanging. This is the mode recommended for running most tests.
Tracking	AIC is on and controlling, and coefficients are changing. This mode is used to refine coefficients during training, as well as adapting to changing plant dynamics during a test.
Training	AIC is on but not controlling. Plant input and output are passively monitored while coefficients are updated. This mode is used to determine initial values of transfer function coefficients prior to running Frozen or Tracking modes.

For More Information

[Adaptive Control Methods](#) (p. 165)

[Prune the Transfer Function Matrix](#) (p. 173)

[Manual Method of Training Forward Transfer Functions for AIC](#) (p. 175)

[Train the Inverse Transfer Functions for AIC](#) (p. 183)

[Save AIC Compensation Settings](#) (p. 185)

[Select AIC Mode and Run Test](#) (p. 186)

[Monitor and Analyze AIC Results](#) (p. 187)

Prune the Transfer Function Matrix

Pruning elements from the matrix is for advanced users and is optional.

AIC has the capability to measure the transfer function between all combinations of input and output. However, in real systems it is not the case that every channel is physically coupled to every other channel. When cross-coupling is weak or nonexistent, removing those elements from the transfer function matrix will speed convergence and improve transfer function accuracy. The process of determining which off-diagonal elements are negligible and then removing those terms is called pruning.

Although pruning can be beneficial, pruning the wrong elements can have detrimental effects that far outweigh the potential benefit. So if you have any doubt about whether or not to prune an element, keep it in the matrix.

To determine which elements can be pruned:

1. Excite a single channel of the forward transfer function matrix.

System Setup and Operation

2. Measure the transfer functions between the command and off-diagonal feedbacks with the Spectrum Analyzer.

If the resultant off-diagonal transfer function is small, prune out the corresponding forward transfer function matrix element by de-selecting its grid element in the Activate Matrix Elements dialog.

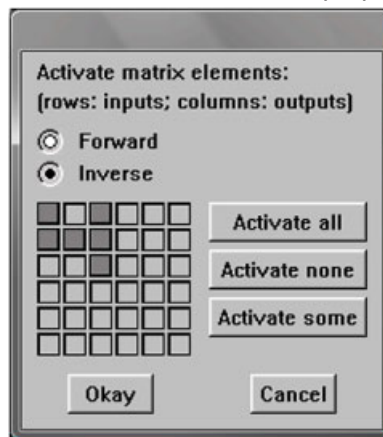
Determining what is a small transfer function depends on its location in the matrix.

- For on-diagonal elements, small means significantly smaller than unity.
- For off-diagonal elements representing translation-to-translational or rotation-to-rotational cross-coupling, small means significantly smaller than unity.
- For off-diagonal elements representing translation-to-rotational or rotational-to-translational cross-coupling, magnitudes are affected by differences in engineering units between input and output, making it difficult by simple inspection to assess what is small.

In these cases it is necessary to normalize the magnitude of the transfer function to a fraction of full scale by multiplying it by full scale input units / full scale output units. If normalized transfer function is significantly less than unity, then it is considered to be small.

- When pruning the forward transfer function matrix, keep in mind that if any element in a row is active, then the diagonal element for that row must be active.
3. After the forward transfer function matrix has been pruned, prune the inverse transfer function matrix.

Because it is difficult to determine the proper pruning of the inverse matrix by inspection, let AIC find it for you. To do this, click **Activate Some** in the Activate Matrix Elements dialog. The software will only select the elements that need be active in order to achieve a proper inverse.



AIC Training Methods

Most users should use the AIC training wizard. The AIC training wizard automates much of the training process. The AIC Training Wizard is accessible from the **Operation** menu > **Controllers** > **Adaptive Inverse** window.

Advanced users can use the "Manual" AIC Training mode, which is accessible on the 469D main controller panel. This mode provides custom control over setting up the forward transfer functions for AIC.

Use AIC Training Wizard

A prerequisite to using the training wizard is to have the HSM at high pressure.

The training wizard will exercise each table axis using user-specified parameters. As a result of the training exercise, the training wizard will calculate coefficients for the forward model.

1. Reset AIC.
 - a) On the **Adaptive Inverse Controller** panel, select the matrix channel that you want to train.
 - b) Click **Reset** Coefficients. Select **Forward**, and then click **Reset**.
2. Set up AIC parameters.
 - a) Set the **Minimum freq** and **Maximum freq** to desired values.
 - b) Set the **Impulse response** to the desired value.
3. Click **Training Wizard**.
4. On the **AIC Training Wizard** panel, specify the **Excitation** (amplitude) for each axis. This can be specified as a nominal value or as a percentage of full scale.
5. Specify the **Training time per channel**.

The **Initial convergence rate** and **Final convergence rate** were set at system commission and should not be changed.



Warning:

Immediate and unexpected actuator response is possible when training starts.
 Unexpected actuator response can result in personal injury or equipment damage.
 Clear all personnel from the test system before training starts (before clicking **Start**).

6. Click **Start**.

The training wizard automatically imports AIC parameters into the function generator, and the function generator runs in the background to train each axis.

Manual Method of Training Forward Transfer Functions for AIC

The following procedure is for advanced users who want custom control over setting up the forward transfer functions for AIC.

1. Prune the forward transfer function matrix.

Pruning the forward transfer function matrix is for advanced users and is optional.



Warning:

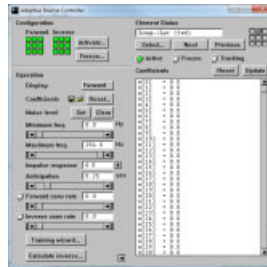
Applying hydraulics can result in sudden actuator motion.
 A moving actuator can injure anyone in its path.
 Always clear the actuator area before applying hydraulics.

System Setup and Operation

2. Set the system to operate with hydraulic pressure on.
3. On the main controller panel, select **Training** for the AIC mode, and disable the other compensation modes.

In Training mode, AIC is on but is not controlling. Instead, it passively monitors command and feedback to the system and updates its transfer function estimates accordingly.

4. On the main controller panel, click **AIC** to open its parameter settings window.



5. Set the **Impulse Response** and **Anticipation** to initial (trial) values.

The impulse response is the amount of time that AIC has to influence the response of the system. To start, choose a long impulse response length.

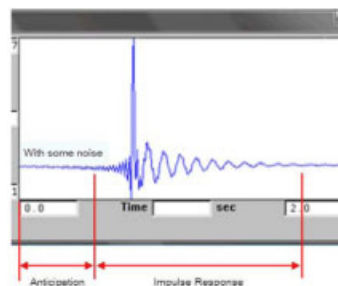
The anticipation delay is amount of time AIC has to prepare the system for a significant motion event. If you know the delay between the input and output plant, set the anticipation to at least that amount of delay. If you do not know the delay, start with 0.25 seconds, or another setting other than zero.

This procedure will help determine the optimal settings for impulse response and anticipation delay through trial and error.

Choosing the optimum amount of impulse response length and anticipation delay is important: too little results in decreased control accuracy; too much results in slower convergence. There is no simple rule for determining the impulse response length. The basic rule for choosing the amount of anticipation delay is that it must be at least as much as the input/output delay of the plant, but how much more is optimum is not easy to determine. So finding optimum values for these quantities is best done by trial and error.

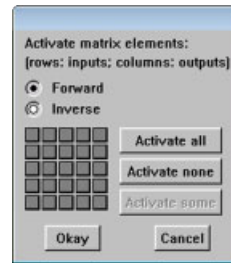
It is better to have too much impulse response length and anticipation delay rather than too little. Too much only slows down convergence a bit. However, too little causes control accuracy to quickly degrade.

Later in this procedure you will use the IRF (Impulse Response Function) Plotter to verify that the impulse response is not too short. A perfectly captured impulse response begins at zero, grows in amplitude, then decays back to zero, without having large intervals of zero amplitude on either side of the main pulse.



6. Select the first matrix channel row for control.
 - a) On the main controller panel, click **Activate**.
 - b) Select **Forward**.

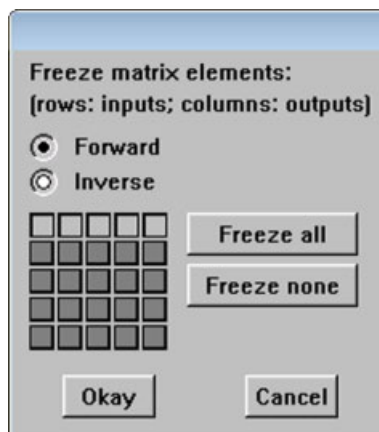
- c) Click **Activate All**.
- d) Click **Okay**.



- e) On the main controller panel, click **Freeze**.
- f) Select **Forward**.
- g) Click **Freeze All** so that all elements in the matrix are selected.
- h) Click to unselect the elements in the first (top) row.

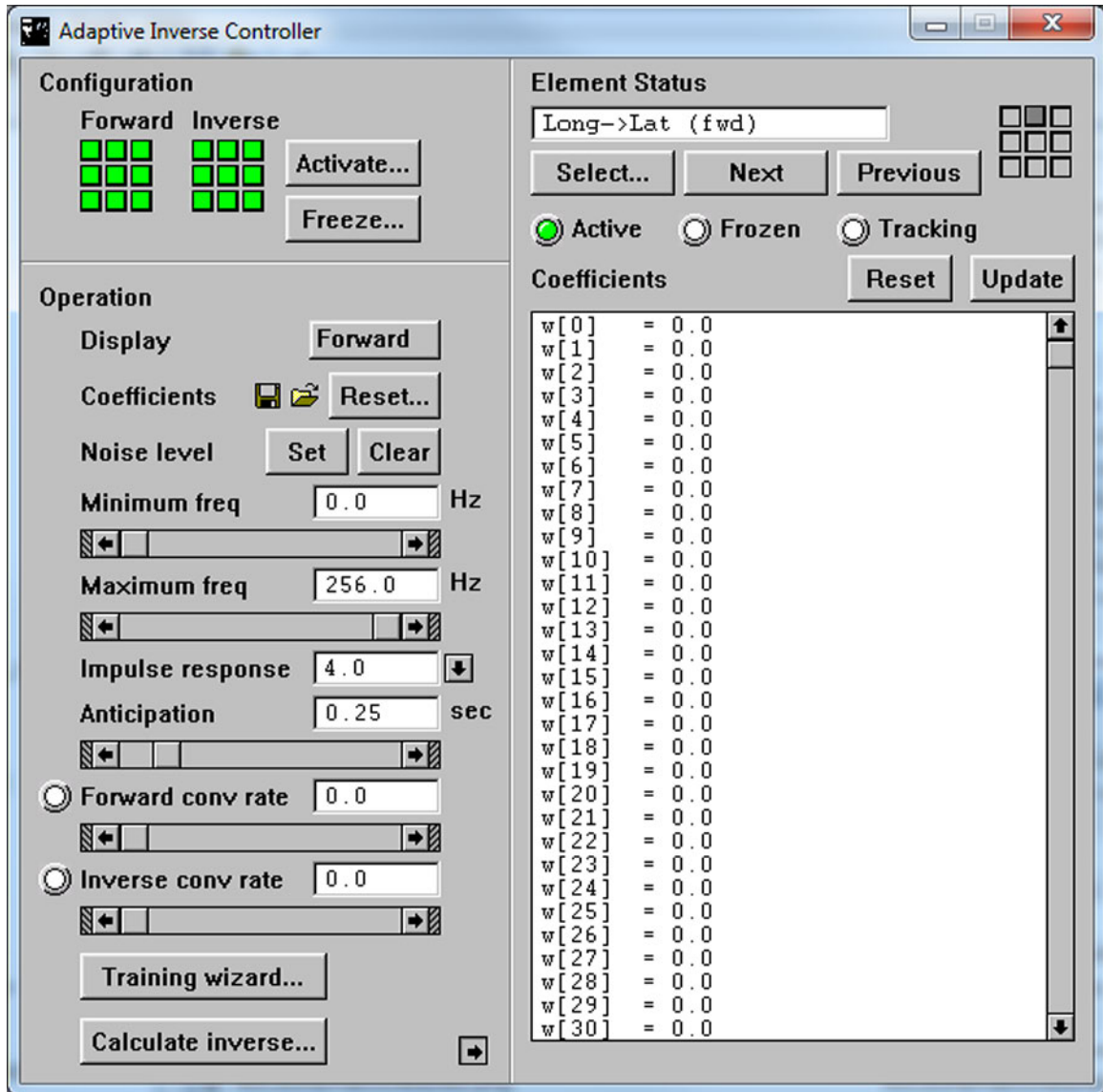
Doing this will unfreeze this input channel row so that it can be controlled by the function generator command.

- i) Click **Okay**.



When all elements are active and just the first row is unfrozen, the element matrix state indicator will look like the following:





7. Optionally, if available, click **Noise Level Set** button.

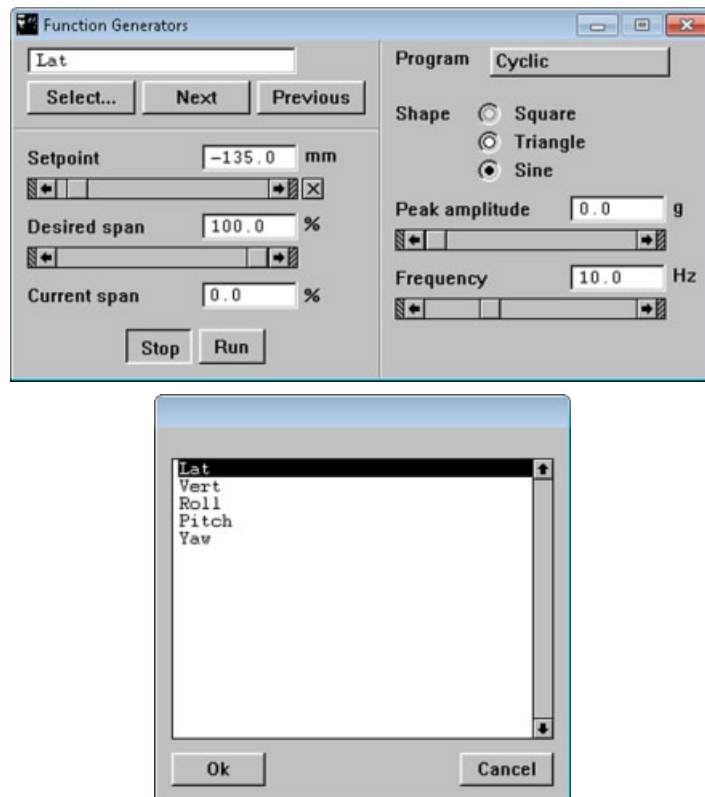
This causes the software to measure its feedback noise level to determine the response threshold below which it will inhibit adaptation. This prevents AIC from adapting to noise when the system is at rest, which can quickly cause the coefficients to become large or infinite in magnitude.

8. On the main controller panel, select **Operation** menu > **Function Generators**.
9. Set up the function generator to run a random waveform on the first input channel, which is currently not frozen.

This procedure will have you run the same random function generator settings on each input channel in a sequential manner. Input (drive) channels are defined by rows and output (response) channels are defined by columns in the matrix. The channels are controlled sequentially by freezing all elements in the matrix, except for the input channel row that is being driven by the function generator. When the random waveform is running on the input channel, the system measures the responses all output channels in the row. The system uses coefficients to factor in cross coupling effects that the input has

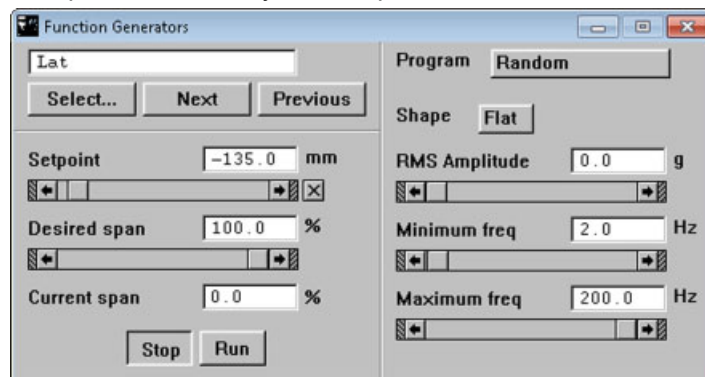
on the other channels. Doing this allows the system to calculate the frequency response of each channel row in the matrix.

- a) In the Function Generator window, click **Select**, and then select the first channel to control.



- b) For **Program**, select **Random**.

This setting consists of a uniform distribution random number generator followed by a band-pass filter. This filter has four parameters that you must provide.



- c) Define the parameters for the Random waveform:

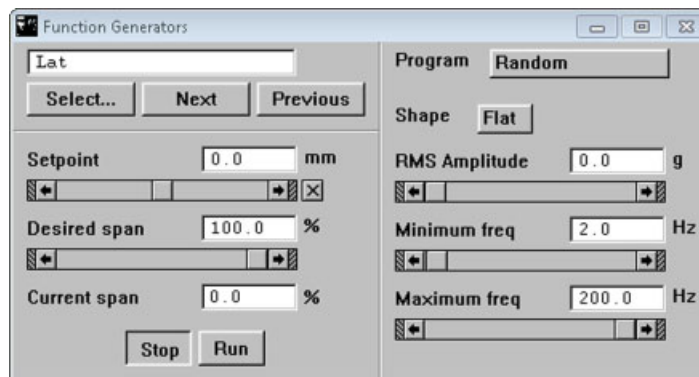
Shape — This is the shape of the band-pass filter's magnitude response as a function of frequency between minimum and maximum frequencies. Five shapes are available: $1/F^2$, $1/F$, Flat, F , and F^2 , where “F” denotes frequency. The primary consideration in selecting the shape is to get the most energy into the system across the frequency band of interest without damaging the system by excessive velocity or acceleration. In acceleration control systems, “Flat” works well, but in displacement control systems, “Flat” will result in excessive velocity and acceleration at high

frequencies; “1/F” or “1/F2” is much gentler on the system in that case. Shapes “F” and “F2” accentuate acceleration at high frequencies and so should not be used. Note that theoretically a shape of “1/F” or “1/F2” results in a filter magnitude response that tends toward infinity as the frequency tends toward zero. This is neither desirable nor practical, so the filter response is rolled off to zero as the frequency approaches the minimum frequency. In addition, for technical reasons the minimum frequency is not allowed to be less than certain small fraction of the maximum frequency or the controller sample frequency when “1/F” and “1/F2” shapes are selected.

RMS Amplitude — Adjust the RMS amplitude to the minimum value possible to prevent damage to the test specimen. Keep in mind, however, that using too low of an amplitude that is within the noise and friction levels of the system will result in inaccurate transfer function estimates. If your system is significantly nonlinear, try to use an RMS amplitude similar in amplitude to the test waveform if possible, because in such systems the transfer function is a strong function of signal amplitude. Also, keep in mind that you are setting RMS amplitude, not peak amplitude; peak amplitude will be higher than RMS amplitude.

Minimum frequency — This is the cut-in frequency of the band-pass filter. Set this according to the lowest frequency expected in your test waveform. A minimum frequency of zero is allowed. In seismic controllers in acceleration control mode, this frequency should match the cut-in frequency of the Reference Generator. Also enter this minimum frequency into the Minimum Frequency slider bar in the AIC Panel. This allows AIC to ignore lower frequencies, resulting in more accurate control in the frequency band of interest.

Maximum frequency — This is the cutoff frequency of the band-pass filter. Set this according to the highest frequency expected in your test waveform. Also enter this maximum frequency into the Maximum Frequency slider bar in the AIC Panel. This allows AIC to ignore higher frequencies, resulting in more accurate control in the frequency band of interest.



Warning:

Clicking the Run button will put actuators in motion.

A moving actuator can injure anyone in its path.

Always clear the test area before pressing the run button.

- d) Click **Run** on the main controller panel, and then click **Run** on the Function Generator panel.
10. Open the FRF and IRF plotters.
 - a) On the Main panel, select **Display** menu > **FRF Plotter**.
 - b) On the Main panel, select **Display** menu > **IRF Plotter**.

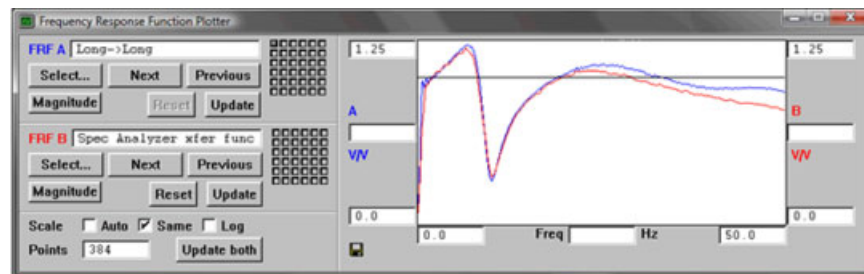
11. After motion has begun, move the **Forward Conv Rate** slider bar away from zero.

The coefficients of elements in the training row begin to change. This can be observed textually in the coefficient display of the AIC Panel, and graphically in the FRF and IRF Plotters.

Another indication of coefficient adaptation is the green color of the tracking indicator next to the **Forward Conv Rate** slider bar.

12. While training is in progress, verify that training is proceeding correctly by comparing the transfer functions estimated by AIC with those estimated independently by the Spectrum Analyzer.

In the following example, Channel A (blue) of the FRF Plotter shown below shows the forward transfer function identified by AIC; Channel B (red) shows the same transfer function identified by the Spectrum Analyzer. Note that they are similar, but not the same (especially the phase responses, not shown) because embedded in the AIC transfer function are effects of filters internal to AIC that the Spectrum Analyzer cannot see



13. After the transfer function has substantially converged, begin a process known as “coefficient polishing.”

Slowly reduce the **Forward Conv Rate** in stages, waiting a while between stages to allow time for the coefficients to approach their optimum values. Visually, the transfer functions will become much more smooth.

After reducing the **Forward Conv Rate** to zero, click Stop on the Function Generator panel.

14. Review the impulse response function in the IRF plotter, and adjust the **Impulse Response** and **Anticipation** settings in the AIC window as necessary.

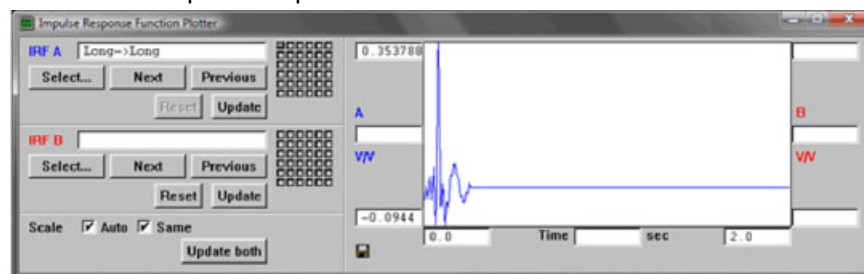


Note:

The impulse response can be changed without having to retrain the forward transfer function, provided that it was not made so short initially as to truncate the forward impulse response.

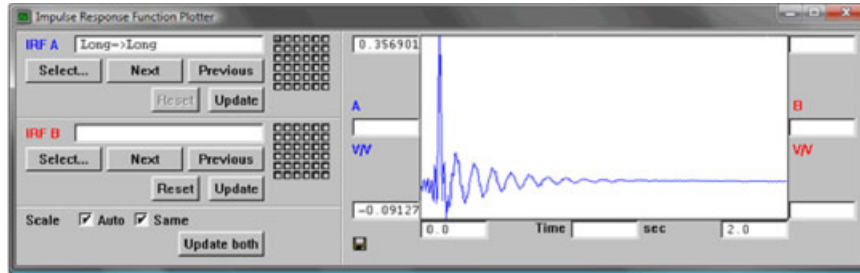
Using the Impulse Response Function (IRF) Plotter, verify that the inverse impulse responses are not too short. A perfectly captured impulse response begins at zero, grows in amplitude, then decays back to zero, without having large intervals of zero amplitude on either side of the main pulse.

An example of a too-short impulse response is:

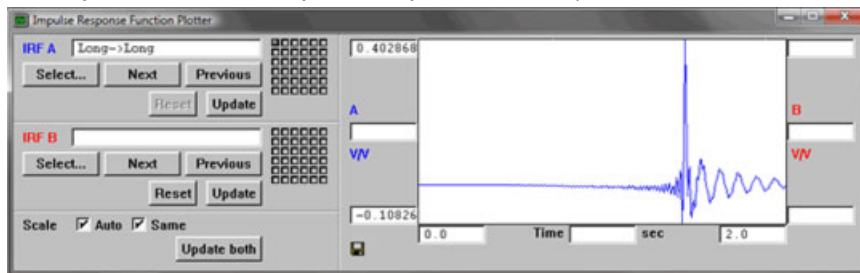


Increase the impulse response length allow the ringing tail end to decay to zero:

System Setup and Operation

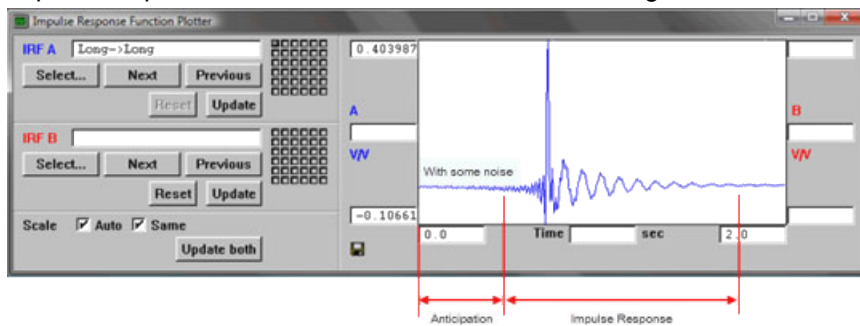


The impulse response now has sufficient length, but has a truncated front end, so the anticipation delay should be increased to shift the impulse to the right (the anticipation delay determines the approximate location of the main pulse within the impulse response interval)



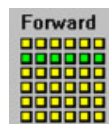
The impulse response now has too many zeros on the front end and truncated tail end, so the anticipation delay should be reduced to shift the impulse to the left.

The following impulse response is correct. It is centered so that it begins and ends near zero:



15. Train subsequent rows of transfer function elements.

Do this by repeating steps 5 through 14 for subsequent matrix channel rows.



Note:

Before you proceed with the next step, you may want to save the coefficients to a file. If you accidentally reset or modify the coefficients of elements already trained, you can easily recover them.

16. Recheck the transfer functions on all rows in another pass, and adjust the Impulse Response and Anticipation if necessary.

Changes That Affect Noise Level Setting

You may have to set the noise level if you change a controller setting that affects the filtering of system feedbacks. Such settings are:

- AIC minimum and maximum frequency.
- Feedback conditioner filter bandwidth.
- Any controller gain setting.

Before setting the noise level, make sure that:

- AIC is in Training mode.
- The convergence rates are set to zero.
- The system should be at rest for a period of time at least twice the impulse response length, plus the anticipation time.

Train the Inverse Transfer Functions for AIC

Before you train the inverse transfer functions, you must train the forward transfer functions. The inverse transfer functions will not converge unless all forward transfer functions are reasonably accurate.

You can use either of these methods to train the inverse transfer functions:

- Automatic method (recommended)
- Manual method

Automatic Adaptation Method

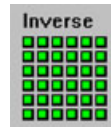
The automatic method is the most convenient and preferred way to calculate the inverse transfer functions.

1. Make sure hydraulic pressure is turned off.

Training the inverse transfer functions using adaptation can be done with hydraulics off because AIC uses only internal forward model feedbacks rather than actual system feedbacks to train the inverse. This is beneficial because your specimen will receive less cumulative damage.

2. On the main controller panel, select **Training** for the AIC mode, and disable the other compensation modes.
3. On the main controller panel, click **AIC** to open its parameter settings window.
4. Activate and unfreeze all inverse transfer function elements.
 - a) Click **Activate**.
 - b) Select **Inverse**.
 - c) Click **Activate All**.
 - d) Click **Okay**.
 - e) Click **Freeze**.
 - f) Select **Inverse**.
 - g) Click **Freeze None**.
 - h) Click **Okay**.

The Inverse configuration grid display should look like this:



5. Click **Calculate Inverse**.

Manual Adaptation Method

1. Make sure hydraulic pressure is turned off.

Training the inverse transfer functions using adaptation can be done with hydraulics off because AIC uses only internal forward model feedbacks rather than actual system feedbacks to train the inverse. This is beneficial because your specimen will receive less cumulative damage.

2. On the main controller panel, select **Training** for the AIC mode, and disable the other compensation modes.

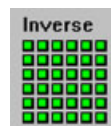
In Training mode, AIC is on but is not controlling. Instead, it passively monitors command and feedback to the system and updates its transfer function estimates accordingly.

3. On the main controller panel, click **AIC** to open its parameter settings window.
4. Activate and unfreeze all inverse transfer function elements.

All active elements of the inverse transfer function matrix should be trained simultaneously.

- a) Click **Activate**.
- b) Select **Inverse**.
- c) Click **Activate All**.
- d) Click **Okay**.
- e) Click **Freeze**.
- f) Select **Inverse**.
- g) Click **Freeze None**.
- h) Click **Okay**.

The Inverse configuration grid display should look like this:



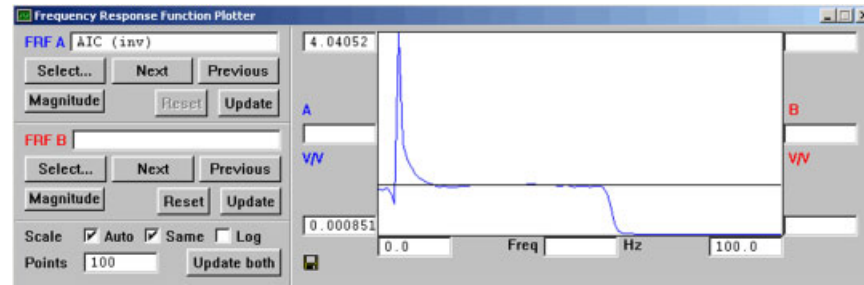
5. Set up the function generator for each input channel.

Use the same random function generator setup that you used to train the forward transfer functions.

6. Click **Run** for each input channel.
7. Move the **Inverse Conv Rate** slider bar away from zero. The coefficients of active elements will begin to change.
 - The coefficient change can be observed textually in the coefficient display of the AIC Panel, and graphically in the FRF and IRF Plotters.
 - Another indication of coefficient adaptation is the green color of the tracking indicator next to the **Inverse Conv Rate** slider bar.

If you find that you need a different anticipation delay, you can change it without having to retrain the forward transfer functions. After making such a change, reset the inverse transfer functions to zero to reduce the retraining time.

8. Verify that training is proceeding correctly by looking at the combined forward-inverse transfer functions using the FRF Plotter. The following is a typical inverse.



9. After training is complete, look at the inverse FRFs.
 - An inverse that is large in magnitude, or appears to be noisy, may be an indication of a problem.
 - Typical on-diagonal inverses vary around unity (shown as a black line in the FRF Plotter. However, it is difficult to determine what “large” is for off-diagonal inverses because their magnitudes are affected by differences in engineering units between input and output.
 - Usually bad inverse transfer functions are due to inadequately trained forward transfer functions. You may need to go back and retrain or refine the forward transfer functions. Then reset the inverses to zero and start over.
10. When the coefficients have converged, polish them by gradually reducing the convergence rate.
 - a) Slowly reduce the **Inverse Conv Rate** in stages, waiting a while between stages to allow time for the coefficients to approach their optimum values. Visually, the transfer functions will become much more smooth.
 - b) After reducing the **Inverse Conv Rate** to zero, click **Stop** on the Function Generator panel.

Save AIC Compensation Settings

Select main controller panel **File** menu > **Save Settings** to save the setup and transfer function coefficient values.

Select AIC Mode and Run Test



Warning:

Due to internal data framing, AIC introduces a large input/output delay to user commands that is equal to twice the impulse response length, plus anticipation delay. Because of this delay, the system will not react to user commands immediately, such as clicking Run or Stop on the 469D Digital Seismic Table Controller panel.

Do not rely on clicking Stop on the 469D Digital Seismic Table Controller panel to stop table motion in critical situations, such as in an emergency, or if the system becomes unstable.

If the table must be stopped quickly, immediately press the **Emergency Stop** button.



Warning:

Selecting an inverse transfer function that is inappropriate for the specimen and test can cause violent system motion.

Violent motion that can damage or destroy your specimen and your test system. Violent system motion may also cause injury to nearby personnel if the specimen is destroyed or if the system becomes damaged.

Before running a test, verify that the selected inverse transfer function is appropriate. Use the FRF Plotter to examine the active inverse transfer function. Do not allow personnel near the seismic table with hydraulic pressure on. The seismic test table should be in a separate protective room from personnel.

Run Test with AIC Frozen Mode

In Frozen mode, AIC actively controls the plant, but the transfer functions it uses are fixed (frozen) and do not adapt. This is the safest mode of operation, because the potential for instability does not exist.

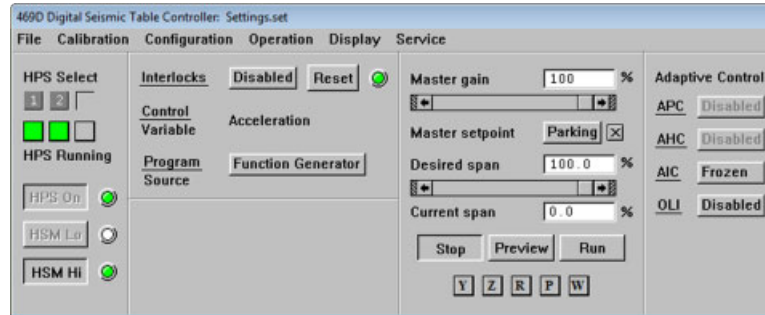


Note:

Frozen mode is the mode recommended for running most tests.

To run a test in frozen mode:

1. Verify that the selected inverse transfer function is appropriate for the test.
2. Select **Frozen** from the popup menu button next to **AIC** on the main controller panel.



3. Clear personnel from the room where the seismic test table is located.
4. Set the system to operate with hydraulic pressure on.
5. Select the appropriate **Program Source** on the main controller panel.
6. Select **Run** on the main controller panel.

Run Test with AIC Tracking Mode

In Tracking mode, the AIC actively controls the plant and also updates the transfer functions it uses based on its estimate of plant dynamics. Because the transfer functions vary according to plant feedback, system control can become unstable.



Warning:

Tracking mode should only be used by experienced users that have been trained by MTS.

Using Tracking mode by an untrained, inexperienced user can result in unstable system control that can damage or destroy the test specimen and the test machine. An unstable system may also cause injury to nearby personnel if the specimen is destroyed or if the system becomes damaged.

Do not use Tracking mode unless you have been trained by MTS on its use for your system configuration. Do not allow personnel near the seismic table with hydraulic pressure on. The seismic test table should be in a separate protective room from personnel.

The decision to use Tracking mode depends on whether you expect plant dynamics to change significantly during the test, and whether the test duration is long enough for AIC tracking to adapt to changing plant dynamics.

If using Tracking mode, the command waveform must have a broad enough bandwidth to excite all dynamic modes of the plant within the frequency range that you specified in the AIC panel. If the command contains only a limited number of frequencies, AIC will adapt only at those frequencies. However, if you change the command's frequency content, large control errors may suddenly arise while AIC tries to adapt.

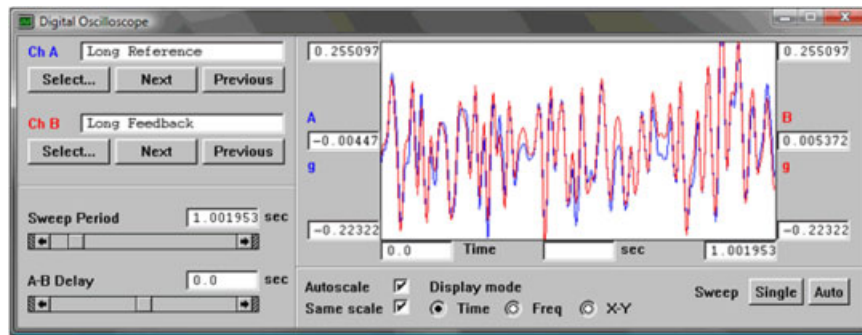
To run a test in tracking mode, follow the procedure that was taught to you during training with MTS personnel.

Monitor and Analyze AIC Results

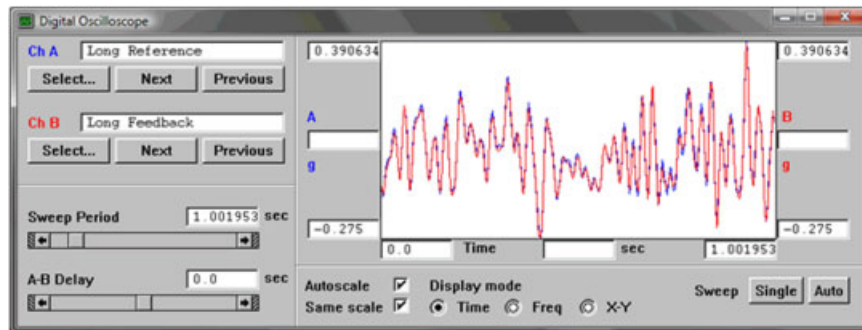
You can use the Digital Oscilloscope to monitor command and response time waveforms, or the Spectrum Analyzer and the FRF Plotter to observe forward, inverse, and combined forward-inverse transfer functions.

System Setup and Operation

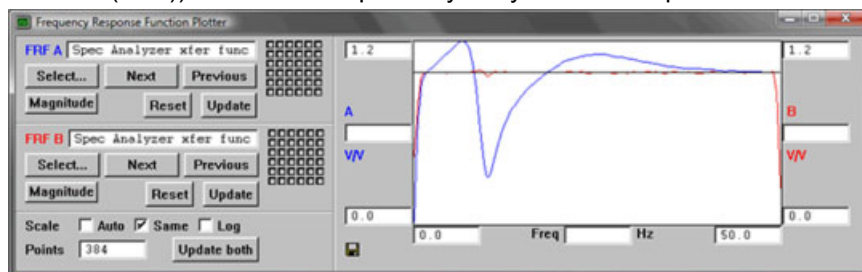
The following figure is an example of Long command and response without AIC:



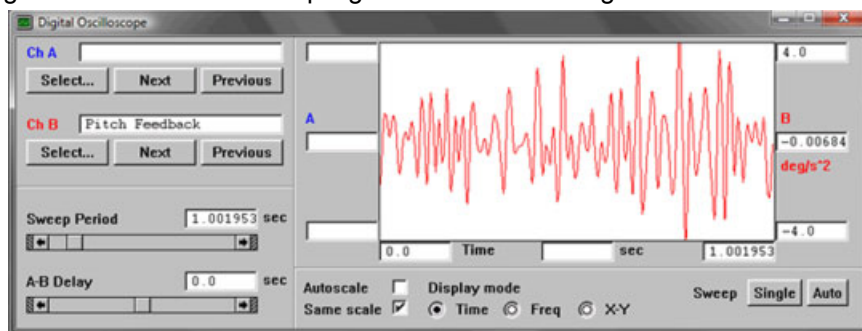
With AIC, Long command and response are almost perfectly overlaid:



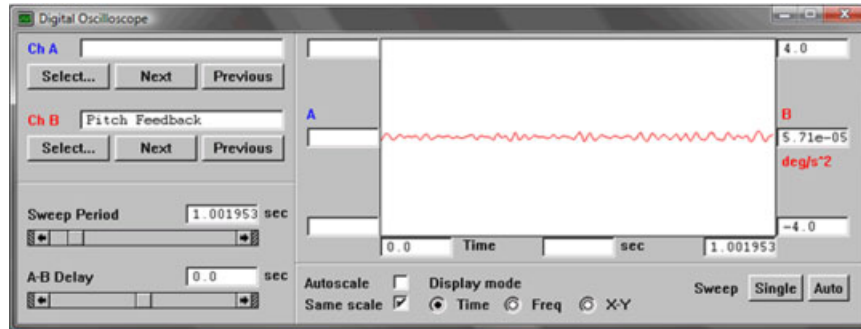
Long->Long frequency response with AIC (Channel B (red)) shows a substantial improvement over that without AIC (Channel A (blue)) and is almost perfectly unity at most frequencies:



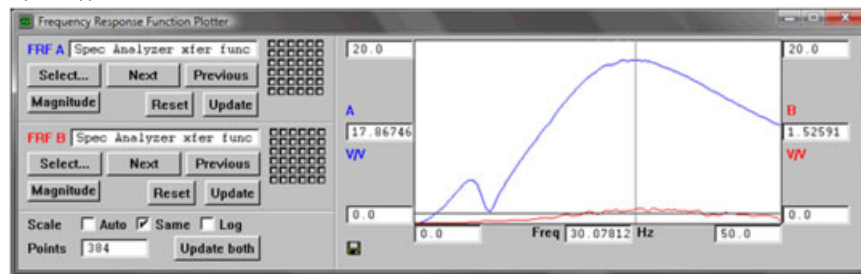
The following figure shows the cross-coupling on Pitch due to Long without AIC:



With AIC, the cross-coupling on Pitch due to Long is greatly reduced:



The cross-coupling on Pitch due to Long (Channel B (red)) shows a factor of ten reduction over that without AIC (Channel A (blue)):



OLI Operation Overview

Online Iteration (OLI) is for advanced experienced users and is optional.

OLI is a control technique that repeatedly modifies the command input to a control system on an individual sample-by-sample basis until the control system response is almost a perfect replica of the original desired command.

OLI is optimized to work with non-sinusoidal command waveforms and significantly nonlinear systems. If the command waveform is a pure sine wave, Adaptive Harmonic Cancellation (AHC) works better and is easier to use. If the system does not have significant nonlinearities, use Adaptive Inverse Control (AIC) instead.

The focus of OLI is two time history files, the Desired file and the Drive file. The desired file is an unchanging file that contains the time history that you want to reproduce on the test system. The drive file is a time history file that is modified every time it is played out in such a way as to cause the system response to eventually match the desired time history. The process of repeatedly playing out the desired and drive files while updating the drive file is called "iteration".

OLI requires knowledge of the inverse transfer function of the model in order to compute a drive correction. This inverse transfer function is provided by the Adaptive Inverse Controller (AIC), appropriately rewired to serve in this role, and is determined by a training process prior to running OLI.

For More Information

[Adaptive Control Methods](#) (p. 165)

[Select OLI Mode and Run Test](#) (p. 190)

[Monitor and Analyze OLI Results](#) (p. 192)

Select OLI Mode and Run Test

1. Train the Adaptive Inverse Controller (AIC).

OLI uses AIC's inverse transfer functions, which must be identified during a training process.

2. Prepare the desired time history file.

MTS's time history files have a proprietary binary format for which MTS provides two file translators. One translator translates a text file that you create using a text editor or a spreadsheet program. The text file must have the sample period on the first line, followed by a column for each data channel. For example:

0.00390625

0.0	0.0	0.0
0.00021	0.00012	0.000867
-0.00033	0.000209	0.000957
-0.00036	0.000359	0.000987
-0.00042	0.000389	0.000389
-0.00036	0.000359	0.00012

After creating this text file, select the translator from the main controller panel by selecting the Translate Text to Binary option under the File menu. You will be prompted for the name of the text file and a name for the binary file. Use the same name as the text file for the binary file but with a different extension. You can use any file extension you wish for desired time history files, but we recommend that you use ".des" for convention.

Another translator is provided for use within MathWorks' Matlab computation environment and translates Matlab arrays directly into binary time history files. The translator is a Matlab script "savebin.m" that you can run from Matlab's command window; type "help savebin" after the command prompt to see how to use it.

When preparing a desired file, there are several restrictions that apply:

- The data in the file must have a sample period of 1/256 second.
 - The number of channels in the file must be equal to the number of control channels.
 - The time histories must begin and end at zero. For best results, you should also append an additional 1-2 seconds of zero samples at both ends.
 - The signal content in the time histories must not exceed 64 Hz.
3. On the main controller panel, click on the **OLI** button and select **Tracking**.
AIC will be automatically turned on in Frozen mode if you have not already done so.
 4. Enter the **Desired span** and click on the **Run** button on the main controller panel.

You can iterate at 100% span, or you can iterate at a reduced level such as 10-20% to minimize damage to your specimen, then after completing the iteration process, run the test at 100% span. Mathematically, linear scaling is not a valid operation in nonlinear systems, but nonetheless this technique often works quite well.

5. Select the desired time history file.

On the **Online Iteration** panel, click the **Desired file Open...** button, in the browser that opens select the desired time history file.

6. Create the first drive time history file.

Click the **Drive File New...** button. Begin a new series of drive files by entering the root name of the drive file series and click **OK**. We recommend that you use the default root name, which is the same as the root name of the Desired file. For example, if the Desired file name is "myfile.des", the default root name is "myfile", and the sequence of drive files created during iteration will be "myfile.d00", "myfile.d01", "myfile.d02", etc. The first drive file in the series "myfile.d00" will be filled with zeros.

Alternatively, you can create your own initial drive file that contains a scaled down version of the desired file rather than just zeros. This may reduce the number of iterations. In this case, use the **Drive file Open...** button instead of the **Drive file New...** button.

7. Enter an iteration gain.

The iteration gain determines how many iterations it takes to converge to the final solution. The ideal case is an iteration gain of 1.0, in which case convergence occurs in a single iteration. However, an iteration gain this high only works with a perfectly linear system; in a nonlinear system iterations would diverge. In general, the more nonlinear a system is, the lower the iteration gain must be for convergence, and therefore the greater the number of iterations that must be performed.

Only by experience will you know what iteration gain is appropriate for your testing situation. If you don't know what iteration gain to use, start with 0.5. Watch the trend of the response errors as iterations progress. If response errors monotonically decrease, it is probably okay to increase the iteration gain. If response errors oscillate up and down from iteration to iteration, you should decrease the iteration gain.

If you find that you are using an iteration gain of nearly one, your system is probably linear enough that you don't have to use OLI. If this is the case, just use AIC.

If you use too high of an iteration gain and cause your iterations to diverge, decrease the iteration gain and go back to a previous drive file using the **Drive file Open...** button.

Lower iteration gain and tighter response error tolerance both increase the number of iterations that you need to perform. A formula for the number of iterations as a function of iteration gain to achieve a given percentage error is: $\# \text{ iteration} = 1n(\text{percent_error}/100)/1n(1-\text{iteration_gain})$. Although this formula is valid only for perfectly linear systems, it is a useful approximation for nonlinear systems as well.

8. Start the iteration.

Click on the **Start** button on the **Online Iteration** panel. If this is Iteration 0 and you had OLI create the initial drive file for you, there will be no motion because the drive file is zero; otherwise motion will begin. We recommend that you watch the desired and response in the **Digital Oscilloscope** panel during the iteration to verify that motion is at acceptable levels. If you don't like what is happening, click on the **Abort** button on the **Online Iteration** panel to immediately terminate the iteration.

9. Examine the results of the iteration.

After each iteration, take time to look at the results of the iteration displayed in the Iteration Log. Verify that errors are decreasing. Iteration is complete when the errors have not significantly decreased for several iterations. Look carefully at max and RMS drive level figures; these tell you how large the motion

System Setup and Operation

will be on the next iteration. If these numbers seem unreasonably large, do not proceed to the next iteration or you may destroy your specimen and damage your machine.

If the errors are increasing from iteration to iteration, the iteration process is diverging. Divergence problems are almost always due to one of two reasons:

- The iteration gain is too high for the level of nonlinearity in the system. Lower the iteration gain, and go back a few iterations in the drive file sequence, especially if the amplitude of the response has built up to a level that exceeds the desired, because OLI has a much easier time scaling up to the desired level rather than scaling down to it. Use the **Drive file Open...** button to call in a previous drive file.
- The inverse transfer function has been inadequately or improperly trained. Go back to AIC and retrain or refine its inverse transfer function.

If the errors are large but neither increasing nor decreasing on average, you may be at a physical velocity or force limit of your test system. There is nothing you can do in this case except accept the errors as they are, or decrease the amplitude of your desired waveform and start over.

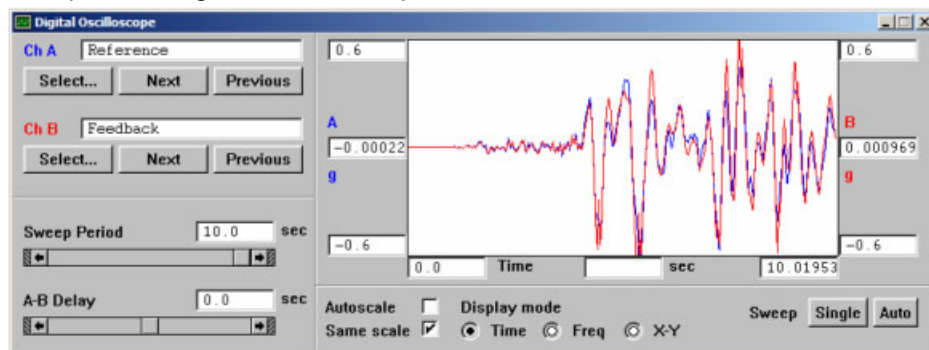
10. Turn off **OLI** (when finished with the final iteration). On the main controller panel, first click the **Stop** button to zero the **Current span**. Then **Disable OLI**. AIC will be automatically disabled as well.

The end product of the iteration process is the final drive file; all other drive files can be discarded. You do not have to use the Online Iteration panel to play this file; the Data Player can be used instead. However, if you want to monitor peak and RMS errors while playing the file, you can use the Online Iteration panel for file payout. In this case, turn on OLI in Frozen mode so that OLI does not advance to the next drive file in the iteration sequence but rather continues to play the selected drive file.

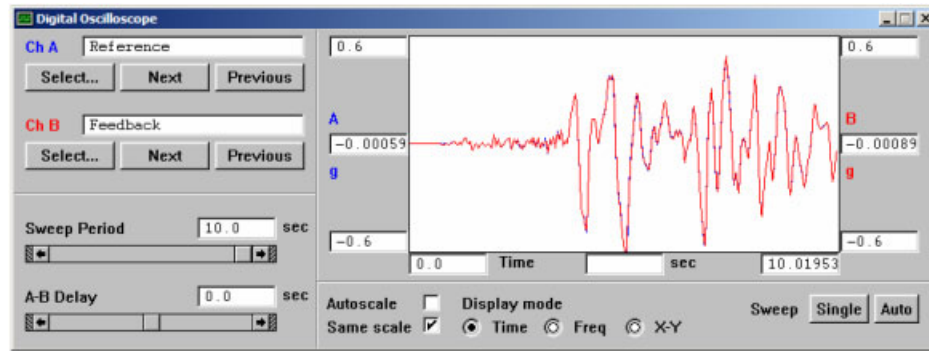
Monitor and Analyze OLI Results

You can use the Digital Oscilloscope panel to monitor desired and response during the iteration process. You can also capture the response to file using the Data Recorder for post-test error analysis.

Below is an example showing desired and response time histories without OLI:



After several iterations of OLI, desired and response are almost perfectly overlaid:



System Shutdown

Perform these steps on the 469D main controller panel.

1. Make sure the test has stopped. If necessary, click **Stop** to stop the test.
2. Put all **Adaptive Control** functions into **Disabled** mode.
3. Set the **Setpoint** to **Parking**.
4. Click **HSM Hi** to set the HSM in low pressure.
5. Click **HSM Lo** to turn off HSM pressure.
6. Click **HPS On** to turn off the hydraulic power supply.

Emergency Shutdown

The following actions should be taken if an emergency arises during operation of the test system.



Note:

If the system electronics senses an exceeded limit or open interlock condition, a system shutdown will be activated automatically.

- If an emergency situation occurs, activate an emergency shutdown by pressing one of the large red **EMERGENCY STOP** (or E-STOP) buttons.
- An interlock (such as an emergency stop) will cause the controller to move the table to Park position. Even if the table does not reach this position, it is commanded to move in that direction while pressure is being removed.
- Correct the condition that caused the emergency shutdown.

Calibrate Converters and Conditioners

Topics:

- *A/D Converter Calibration.....196*
- *D/A Converter Calibration.....196*
- *AC Conditioner Calibration.....197*
- *DC Conditioner Delta-P Calibration.....198*
- *DC Conditioner Accelerometer Calibration.....200*

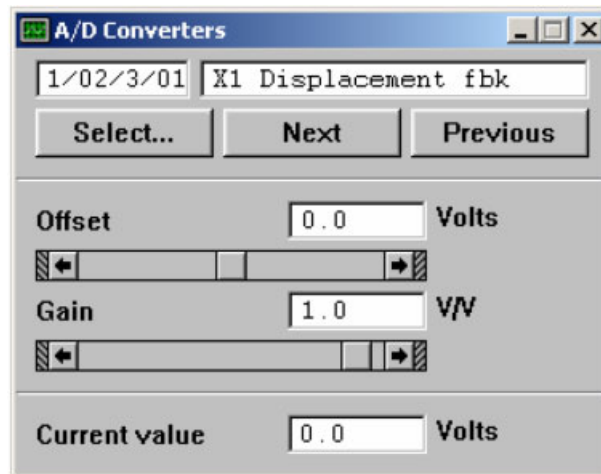
A/D Converter Calibration

Perform the following procedure to calibrate an A/D converter.

Equipment required:

- Calibrated voltage source (such as a DC power supply)

1. On the 469D Digital Seismic Table Controller select the **A/D Converters** from the **Calibration** menu.



2. Using the **Select** or **Next** or **Previous** buttons, select the desired A/D converter.
3. Ground the input signal.
4. Adjust the **Gain** control to +1.00.
5. Adjust the **Offset** control until the **Current value** reads 0.00V.
6. Input a DC signal between 0V and 10V from the calibrated voltage source.
7. Adjust the **Gain** control until the **Current value** displayed matches the value of the signal input from the calibrated voltage source.
8. Remove the calibrated voltage source.
9. Repeat Steps 2 through 8 for the remaining A/D Converters.
10. When the calibration procedures are completed, select **Save calibration** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel to save the new calibration settings.

For More Information

[A/D Converters](#) (p. 78)

D/A Converter Calibration

No D/A calibration procedures should be necessary. Consult MTS Systems Corporation if calibration concerns arise.

For More Information*D/A Converters* (p. 96)

AC Conditioner Calibration

Calibration for a displacement channel means adjusting a known voltage to correspond to a known displacement.

The AC Conditioner uses a reactive type transducer such as a linear variable differential transformer (LVDT). This transducer measures bidirectional displacement from a zero reference position.

Perform the following procedure to calibrate a displacement conditioner.

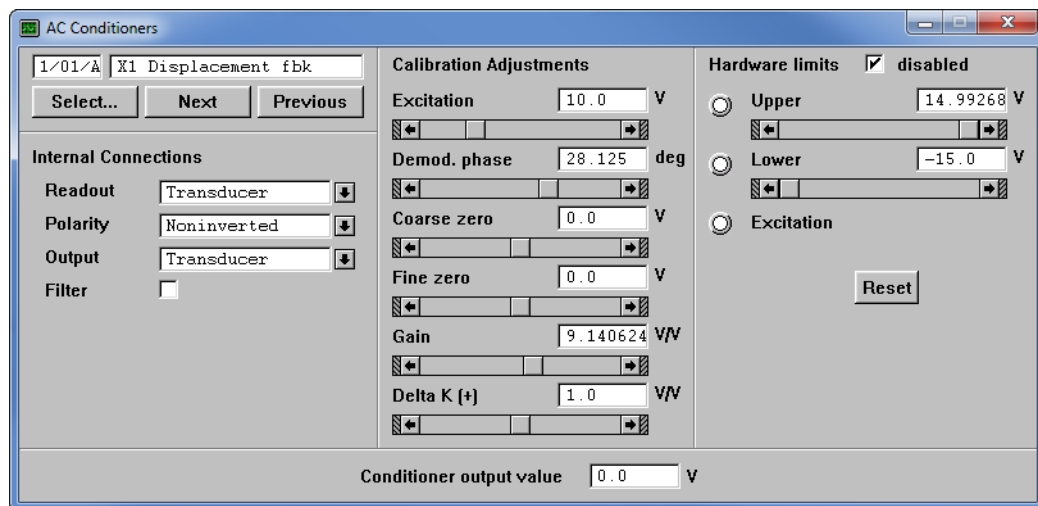
Equipment required:

- Displacement measurement device such as a dial indicator

**Note:**

Turn on the console and allow the modules to warm up properly (approximately 5 minutes) before you make any electrical adjustments.

1. Select **AC Conditioners** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel.



2. Using the **Select** or **Next** or **Previous** buttons, select a displacement conditioner channel.
3. Adjust the **Gain**, **Excitation**, and **Delta K (+)** controls to the respective values listed on the original calibration sheets, or set **Gain** to approximately 3 V/V, **Excitation** to 10.000 Vpp, and **Delta K (+)** to 1.000 V/V (these are the approximate midpoint values for each control).
4. Select **HSM Lo** on the 469D Digital Seismic Table Controller panel to apply low hydraulic pressure to the system.
5. Adjust the **Setpoint** control (on the 469D Digital Seismic Table Controller panel) to fully retract the actuator without positioning it in the end cap.
6. Click **HSM Lo** to remove hydraulic pressure to the system.

7. Adjust the **Demod phase** to maximize the **Conditioner output value** on the AC Conditioner panel.
8. Click **HSM Lo** to reapply hydraulic pressure to the system.
9. Adjust **Setpoint** to obtain a **Conditioner output value** of zero.
10. Connect a displacement measurement device to the actuator rod.
11. Adjust the **Setpoint** control to move the actuator to obtain a **Conditioner output value** of -10.000 V.
12. Adjust the **Gain** until the displacement measurement device reads the correct full-scale displacement.
13. Repeat steps 9 through 11 alternating between zero and negative full scale until the zero and full-scale **Conditioner output** values are within desired tolerance.
14. Adjust **Setpoint** to $+100\%$. The **Conditioner output** value should be 10.000 V.
15. Adjust **Delta K (+)** until the displacement measurement device reads the correct positive full-scale displacement.
16. Plot the actuator linearity by moving the actuator to $\pm 20\%$, $\pm 40\%$, $\pm 60\%$, $\pm 80\%$, and $\pm 100\%$ of full-scale and recording the **Conditioner output** values at each position.

For example, for an actuator with a full scale displacement of ± 75 mm, adjust **Setpoint** for a dial indicator readout of 15 mm ($+20\%$). Record the **Conditioner output** value on your transducer calibration sheet. Repeat this step for $\pm 20\%$, $\pm 40\%$, $\pm 60\%$, $\pm 80\%$, and $\pm 100\%$ of full-scale displacement.

**Note:**

The accuracy tolerance (linearity) should be $\pm 1\%$ of full-scale. Therefore, in the example above, 15 mm should indicate a **Conditioner output** value within the range 1.90 to 2.10 Vdc. If not, return to Step 3.

17. Repeat Steps 2 through 16 for the remaining displacement conditioners.
18. When the calibration of the displacement conditioners is complete, select **Save Calibration** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel to save the new calibration settings.

For More Information

[AC/DC Conditioners](#) (p. 74)

DC Conditioner Delta-P Calibration

The DC Conditioners are used for the force transducers. Force is measured using a differential pressure cell.

Perform the following procedure to calibrate a DC Conditioner used with a differential pressure cell.

Equipment required:

- A calibrated pressure source with a capacity of the differential pressure cell and an accuracy than the differential pressure cell. (MTS recommends using a dead weight pressure tester).

**Note:**

Turn on the console and allow the modules to warm up properly (approximately 5 minutes) before you make any electrical adjustments.

1. Select **DC Conditioners** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel.
2. Using the **Select** or **Next** or **Previous** buttons, select a DC Conditioner with a force feedback.

The screenshot shows the 'DC Conditioners' software interface. It includes sections for 'Internal Connections' (Readout, Input, Output, Filter), 'Shunt Calibration' (Do +, Do -, Update +, Update -), 'Calibration Adjustments' (Excitation, Bridge balance, Offset zero, Gain, Delta K (+)), and 'Hardware limits' (Upper, Lower, Excitation, Reset). The 'Conditioner output value' is displayed as 0.0 V.

3. Disconnect the differential pressure cell from the actuator, being careful to note its orientation.
4. Attach an appropriate, calibrated pressure source to the differential pressure cell input labeled P1. The pressure source must meet the capacity of the differential pressure cell and have a higher accuracy than the differential pressure cell. (MTS recommends using a dead weight pressure tester).
5. If necessary, adjust the **Excitation** and **Gain** controls to the respective values listed on the original calibration sheet.
6. Apply a pressure as close to 100% capacity of the system as possible. Then apply zero pressure and adjust the **Offset zero** value on the DC Conditioner panel until the **Conditioner output** value equals 0V. Repeat step 6 two more times.
7. Apply a known exact pressure at 80% capacity of the system. Calculate the ideal DC conditioner output value for this pressure and compare it with the actual DC Conditioner output value. The actual value should be within the permissible variation of the ideal calculated value. (Refer to the original calibration sheet for the permissible variation). If the actual value is not within the permissible variation, adjust the **Gain** setting on the DC Conditioner panel until it is.
8. Apply pressures equal to 20%, 40%, 60%, and 100% capacity of the system. Monitor the conditioner output values to make sure these values are within specification. (Refer to the original calibration sheet for the permissible variations).
9. Readjust the 80% gain if any values are out of specification by going back to Step 7.
10. Disconnect the pressure source from the differential pressure cell input labeled P1 and connect it to the differential pressure cell input labeled P2.
11. Apply a known exact pressure at -80% capacity of the system. Calculate the ideal DC conditioner output value for this pressure and compare it with the actual DC Conditioner output value. The actual value should be within the permissible variation of the ideal calculated value. (Refer to the original calibration sheet for the permissible variation). If the actual value is not within the permissible variation, balance the error between the two sides of the differential pressure cell (P1 and P2) by readjusting the gain appropriately.

12. If desired, repeat the measurements for $\pm 20\%$, $\pm 40\%$, $\pm 60\%$, $\pm 80\%$, and $\pm 100\%$ of full scale. Record the conditioner output values on your transducer calibration sheet.
13. When the DC Conditioner calibration procedures are completed, select **Save Calibration** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel to save the new calibration settings.
14. When the calibration is complete, disconnect the pressure source from the differential pressure cell, and reconnect the differential pressure cell to the actuator according to its original orientation.

For More Information

[AC/DC Conditioners](#) (p. 74)

DC Conditioner Accelerometer Calibration

Turn on the console and allow the modules to warm up properly (approximately 5 minutes) before you make any electrical adjustments.

To calibrate the DC Conditioner for use with an accelerometer:

1. Select **DC Conditioners** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel.
2. Using the **Select** or **Next** or **Previous** buttons, select a DC Conditioner with a acceleration feedback.
3. Mount a calibration standard or recently calibrated accelerometer to the table in close proximity to the accelerometer which is being calibrated and connect its output to channel 1 of a two channel dynamic signal analyzer or other device that provides narrow band AC voltage measurement capability or, if available, mount the accelerometer to be calibrated onto a portable accelerometer calibration stand with a built-in exciter.
4. Adjust the **Offset zero** value on the DC Conditioner panel until the **Conditioner output** value equals 0V.
5. Apply a known acceleration to the accelerometers.
6. Adjust the gain level on the DC Conditioner board until the peak-to-peak output voltage of the DC Conditioner (channel 2) equals that of the calibration standard accelerometer (channel 1).
7. When the DC Conditioner calibration procedures are completed, select **Save Calibration** from the **Calibration** menu on the 469D Digital Seismic Table Controller panel to save the new calibration settings.
8. Remove the calibration equipment and restore the system to its normal configuration.

For More Information

[AC/DC Conditioners](#) (p. 74)

Tuning

Topics:

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- *Observer Panel Adjustments.....205*
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- *Compensating Payload Resonances Using Notch Filters.....215*
- *Switching Control Modes With Hydraulics On.....217*

3-Stage Valve Driver Inner Loop Tuning

A digital controller controls the position of the third stage pilot valve spool, which in turn controls the flow of hydraulic fluid to the actuator. Valve spool position is measured using a LVDT (linear variable differential transformer). Inner loop tuning consists of setting the LVDT conditioner settings, and tuning the analog controller servo loop gains.

Spool Conditioner Gain

An LVDT is used to measure the position of the third stage pilot spool in a 3-stage servo valve. The 3-stage valve driver card provides excitation and conditioning for this transducer. The first step in inner-loop tuning is setting the spool conditioner adjustments.

1. If necessary, connect a DMV to the tip jacks at the front of the valve driver module in the controller chassis.

Doing this allows the selected **Readout** value to be displayed on the DMV.

2. Turn on the hydraulic power supply.

This provides pilot pressure to the 3-stage servovalves while preventing the actuator from moving.

3. Allow sufficient time for the hydraulic fluid to reach normal operating temperature.
4. On the 469D Digital Seismic Table Controller panel, select **Valve Drivers** on the **Calibration** menu.
5. If a DVM is used for this procedure, select **Spool position** for the **Readout**.
6. Set the **Spool Conditioner Calibration** adjustments to the following initial values:

Excitation ampl	10 Vpp
Demod. phase	22.5 deg
Spool zero	0 V
Conditioner gain	1.0 V/V
Invert polarity	Inverted

7. For **Rate Input**, select **Spool Position**.
8. Set the **Inner Loop Tuning Proportional gain** to zero.

This will allow the third stage pilot spool to float into one of the end caps.

9. Adjust the **Demod. phase** to maximize the **Spool position** value.

If the **Conditioner gain** was initially set too high, you will not be able to read the real demodulator phase value. The conditioner will be saturated.

10. Adjust the **Conditioner gain** so that the **Spool position** value is 10 volts.

The **Spool position** value may be ± 10 volts depending on the mechanical bias of the servovalve.

11. Adjust the **Balance** to drive the servovalve into the other end cap (which will change the sign of the **Spool position** value).

If the **Spool position** feedback exceeds 10 volts, lower the **Conditioner gain** setting until the **Spool position** value reads 10 volts.

For More Information

[Valve Drivers](#) (p. 149)

Servo Gain Tuning

1. Turn on the hydraulic power supply.

This provides pilot pressure to the 3-stage servovalves while preventing the actuator from moving.

2. Allow sufficient time for the hydraulic fluid to reach normal operating temperature.
3. Open the **Digital Dual Oscilloscope** panel.
4. Select to monitor the drive command and valve feedback for the desired channel.
5. Open the **Valve Drivers** panel.
6. Select **Spool position** for the **Rate Input**.
7. Set the **Inner Loop Tuning Proportional gain** to 0.0 and **Rate Gain** to 0.0.
8. Open the **Uniaxial Controller** panel.
9. For **Function Generator** select **Square** for the wave **Shape**.
10. Set the **Frequency** to 1.0 Hz.
11. Set the **Peak amplitude** between 0.5 and 1 volt.
12. On the **Valve Driver** panel, raise the **Proportional gain** until the feedback begins to overshoot.
13. Adjust **Balance** until the overshoot is the same in the positive and negative directions.
14. Raise the **Rate gain** to dampen out the overshoot. Raise the **Proportional gain** to achieve overshoot, then dampening out the overshoot using **Rate gain**. Continue this iterative cycle until the feedback begins showing some sawtooth waveform or instability occurs. Back off the **Proportional gain** and **Rate gain** for a clean rise and the corner moves to horizontal.

For More Information

[Valve Drivers](#) (p. 149)

Spool Zero Adjustment

Ideally, setting the valve drive signal to zero should result in no motion in the system and minimum oil flow. Realistically, all 3-stage servovalves have a little mechanical/electrical bias that must be adjusted out. This is done using the **Spool zero** adjustment and mechanically adjusting the spool LVDT position.

1. Open the **Valve Drivers** panel.
2. Set **Balance** to 0.0.
3. Set **Spool zero** to 0.0.
4. Open a **Digital Meter** panel.
5. Select to monitor the drive command for the desired channel.
6. Turn on **HSM Lo**, and then **HSM High** on the main controller panel.

Tuning



Note:

Do not remove the LVDT adjustment locknut or assembly when adjusting the servovalve LVDT spool position.

If it is removed, hydraulic fluid will spray from the servovalve at full pressure.

Refer to the servovalve product manual to identify the main stage LVDT spool adjustment.

Loosen (but do not remove) the LVDT locknut.

8. Adjust the LVDT in or out of the servovalve until the valve drive signal displayed on the **Digital Meter** panel is zero.
9. Tighten the locknut while holding the LVDT in position.

For More Information

[Valve Drivers](#) (p. 149)

Three-Variable Control (TVC) Tuning

Three-Variable Control (TVC) is what is known in control theory literature as state variable control, with additional special features. The three state variables that TVC can control are displacement, velocity, and acceleration.

During the tuning procedure, you will be making extensive use of the following user interface panels:

- Function Generators panel
- Observer panel
- Three-Variable Controllers panel
- Resonance Compensators panel

A description of these panels will be presented first, followed by basic step-by-step TVC tuning procedures for displacement, velocity, and acceleration control modes. Lastly, some advanced topics such as the tuning of notch filters to combat resonances and anti resonances will be discussed.

It should be emphasized that control tuning is an art. Each control system is different, having its own unique blend of dynamics and peculiarities. Your system may tune differently than the system used to generate the examples presented here. With enough practice you will learn how to modify the procedures presented here to fit your particular case.

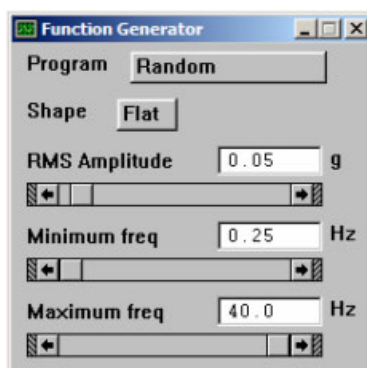
One word of caution: When tuning, do not move a gain slider bar until you first determine its minimum and maximum limits. Otherwise you may inadvertently scroll the gain to a large value, causing instability that could destroy your specimen and damage your test machine. Do not assume that the limits are reasonable values; check them yourself. You can do this by clicking on the striped regions to the left and right of the scrolling arrows as show below.



The minimum or maximum limit is then displayed in the slider bar's value edit display box where you can change it if necessary.

Function Generator Adjustments

Because TVC tuning is done almost exclusively in the frequency domain, the Function Generator using the **Random Program** mode is used to excite the system so that good transfer function estimates can be obtained.



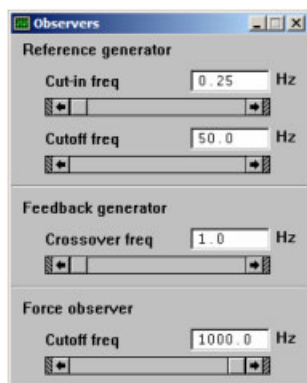
The **Random Program** mode consists of a uniform distribution random number generator followed by a band-pass filter. This filter has four parameters adjustable from the Function Generator panel: shape, RMS amplitude, minimum frequency, and maximum frequency.

For More Information

[Function Generators](#) (p. 113)

Observer Panel Adjustments

The Observers panel is where adjustments for the **Reference Generator**, **Feedback Generator**, and **Force Observer** are made (the term “observer” is control theory terminology for a special-purpose filter that computes a feedback signal).

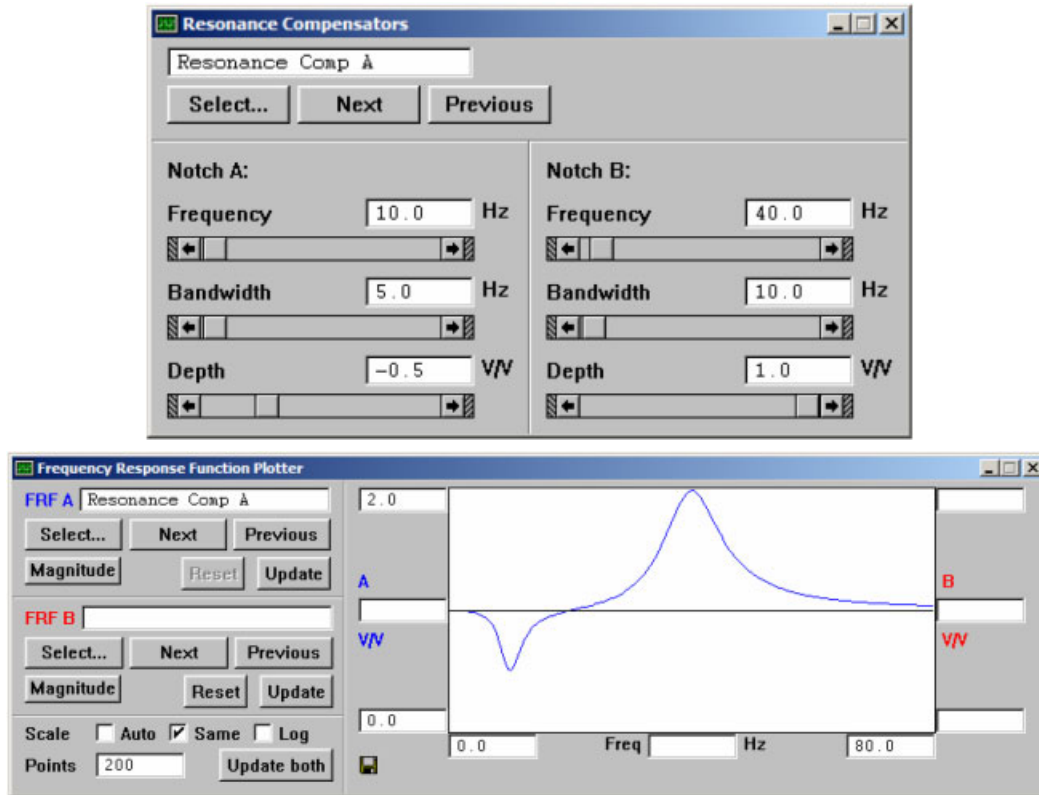


For More Information

[Observers](#) (p. 131)

Resonance Compensator Panel Adjustments

The Resonance Compensator consists of four identical notch filters, grouped into two pairs for user interface purposes because resonances usually come in resonance/anti resonance pairs. Like the TVC notch filter, the frequency response of the Resonance Compensator notch filters can be viewed in the FRF Plotter. For the tuning shown in the panel above, the frequency response looks like the next figure.



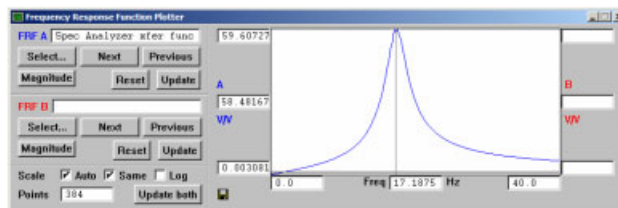
For More Information

[Resonance Compensators](#) (p. 138)

Determining the Oil Column Natural Frequency

Before starting the tuning process, it is useful to know the value of the oil column natural frequency. Certain gains have affect below while others have affect above this frequency; knowing on which side a deficiently-tuned region of frequency response lies suggests which gain adjustment will yield the most improvement. Furthermore, if the oil column natural frequency lies significantly above the maximum frequency of operation, tuning is simplified because some of the tuning steps described in later sections can be omitted.

To measure this frequency, measure the transfer function between the controller output and the force feedback using the Spectrum Analyzer. The oil column natural frequency lies close to the peak of the magnitude response; in the example shown below, this frequency is approximately 17 Hz.



Displacement Control Tuning

While tuning, keep in mind these points, which apply not only to displacement control mode but to all control modes:

As gains are increased, the valve command may become large to the point of saturation at ± 10 volts. When this happens, the frequency response measured by the Spectrum Analyzer can be misleading. Always look at the controller output on the Digital Oscilloscope to verify that the valve command is not saturating. If it is, you may have to either reduce the gain or reduce the reference amplitude.

While tuning you will mostly be looking at the frequency response in the FRF Plotter. As you approach a satisfactory tuning, for example, one that yields a frequency response near unity, you should look at the reference and feedback on the Digital Oscilloscope to verify that they are reasonably similar. This is because it is possible to have a frequency response near unity yet have dissimilar reference and feedback, which can happen if there are nonlinearities at play or if the system has been tuned such that the phase response is nonlinear.

1. Set up the Random Function Generator.

Set the shape to “ $1/F^2$ ” or “ $1/F$ ”, the minimum frequency to zero, and the maximum frequency according to the desired control bandwidth.

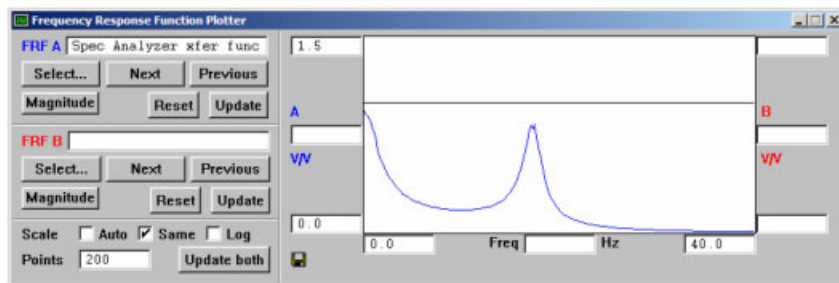
2. Enter initial TVC and Resonance Compensator parameters values:

TVC Parameters	TVC Values
Displacement gain	1.0
Velocity gain	0.0
Acceleration gain	0.0
Feedforward gains	all zero
Input-output delay	0.0
Dynamic force gain	0.0
Dynamic force freq	0.5 Hz

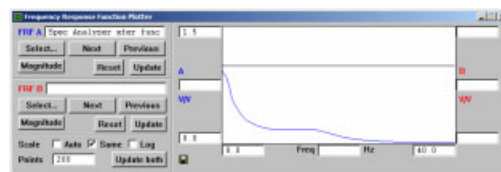
Tuning

Notch frequency	any value
Notch bandwidth	any value
Notch depth	0.0
Reset	0.0
Reset authority	5%
Resonance Compensators A & B Parameters	Resonance Compensators A & B Values
Notch frequency	any value
Notch bandwidth	any value
Notch depth	0.0

- Run the Random Function Generator. Press the **Run** button.
- Increase the displacement gain until the frequency response is adequate at low frequencies, but without causing the oil column resonance to peak above unity magnitude.



- Increase the dynamic force gain until the oil column resonant peak is barely visible.



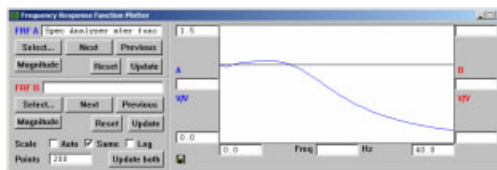
Note:

If the force feedback is phased properly, the dynamic force gain will be negative, and increases in the negative direction result in more oil column resonance suppression (up to a point). It is easy to drive the system into instability by using too much of this gain, so be careful.

In systems without force feedback this gain parameter has no effect. Instead you can use the TVC notch filter to suppress the oil column resonance.

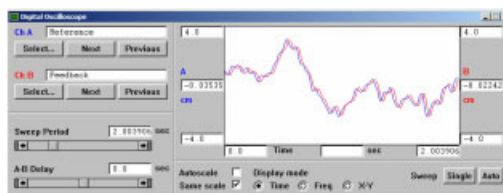
- Increase the velocity lead to boost the frequency response below the oil column natural frequency.

This will also boost the response at the oil column natural frequency, causing it to peak above unity magnitude. Increase the dynamic force gain (or deepen the TVC notch) to bring the response back down. The frequency response then should look like this:



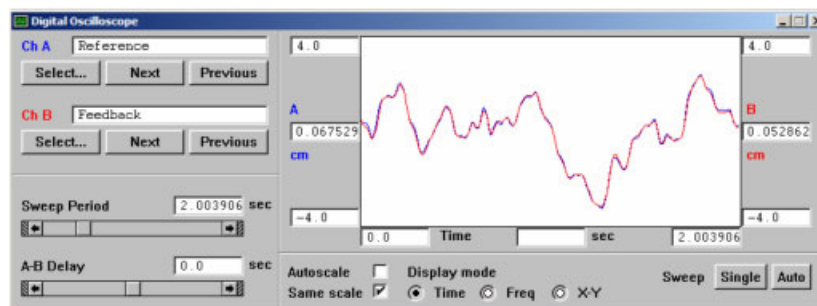
7. Adjust the input-output delay.

Although the controller is now optimally tuned, there is a delay between reference and feedback, as shown in the time response below:



This delay is inherent in all closed-loop control systems. Although the feedback is almost a perfect copy of the reference, the difference between the two waveforms is large solely because of the delay. This difference can be minimized by delaying the reference by an amount of time determined by the input-output delay adjustment so that it is aligned with the feedback for display and error calculation purposes. It has no effect whatsoever on stability or the quality of control.

To adjust the input-output delay, observe the reference and feedback waveforms in the Digital Oscilloscope and increase the delay until they are aligned visually, as shown below:



8. Stop the Random Function Generator.

Press the **Stop** button to bring the system to rest.

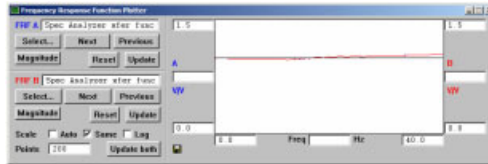
9. Adjust the reset integrator.

Ideally the controller output signal is zero when the system is at rest. This may not be the case if there is a static offset somewhere in the system. To remove a static offset, increase the reset integrator gain and observe the rate at which the controller output signal is driven to zero. More reset gain will result in faster offset removal. Values in the range of 0.1 to 1.0 are typical.

If you observe that Reset Integrator Tracking indicator is glowing red, that means that the correction that reset integrator needs to apply to remove the offset is beyond its authority limit. Increase the Reset Integrator Maximum Authority slider bar in small increments until the indicator glows green. If the indicator is still red after having increased the authority a reasonable amount, it could be that there is a problem with the electrical or mechanical system that you should diagnose before continuing.

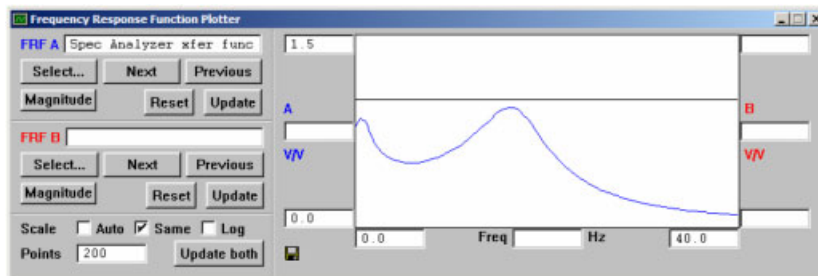
Velocity Control Tuning

Velocity control tuning is done much like acceleration control tuning except for the setup of the Reference Generator and the Random Function Generator. When completed, the frequency response looks like this:



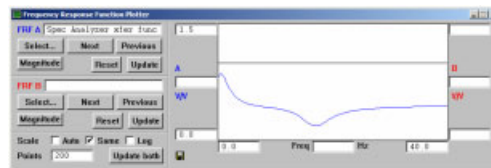
1. Set up the Random Function Generator.
 - Set the shape to "1/F".
 - Set the minimum frequency to match the cut-in frequency of the Reference Generator.
 - Set the maximum frequency according to the desired control bandwidth.
2. Increase the velocity lead to boost the frequency response below the oil column natural frequency.

This will also boost the response at the oil column natural frequency, but don't be concerned about it at this point. The frequency response then should look like this:



3. Increase the jerk lead to boost the frequency response above the oil column natural frequency.

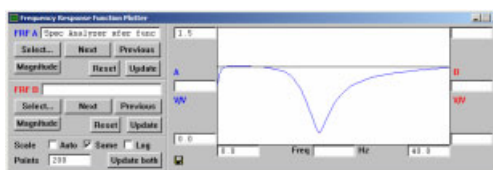
This may cause the peaking response at the oil column natural frequency observed in the previous step to be reduced due phase cancellation. Add only enough jerk lead so that the frequency response is flat overall, as shown below:



4. Continue boosting response below and above the oil column natural frequency.

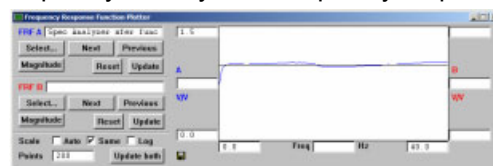
Repeat the previous two steps, increasing velocity lead and jerk lead in small increments. Do not use large increments or else the effect of one lead will wash over into the other lead's frequency region, causing peaks or valleys in the frequency response that make it hard to determine which lead to adjust. In other words, make sure the overall response is reasonably flat at a given level (except near the oil column natural frequency) before boosting it to the next level.

When you have finished boosting the frequency response either side of the oil column natural frequency to unity, it should look like this:



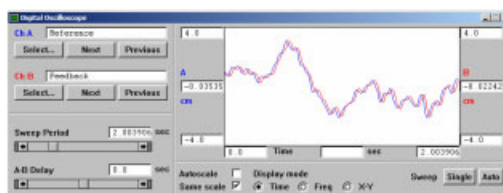
5. Increase the acceleration lead.

Increase the acceleration lead to boost the response near the oil column natural frequency to unity. You may have to make slight adjustments to velocity and jerk leads to keep the response below and above the oil column natural frequency at unity. The frequency response should then look like this:



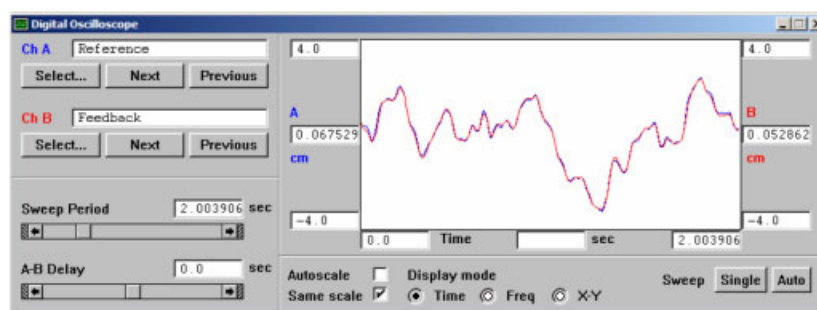
6. Adjust the input-output delay.

Although the controller is now optimally tuned, there is a delay between reference and feedback, as shown in the time response below:



This delay is inherent in all closed-loop control systems. Although the feedback is almost a perfect copy of the reference, the difference between the two waveforms is large solely because of the delay. This difference can be minimized by delaying the reference by an amount of time determined by the input-output delay adjustment so that it is aligned with the feedback for display and error calculation purposes. It has no effect whatsoever on stability or the quality of control.

To adjust the input-output delay, observe the reference and feedback waveforms in the Digital Oscilloscope and increase the delay until they are aligned visually, as shown below:



7. Stop the Random Function Generator.

Press the **Stop** button to bring the system to rest.

8. Adjust the reset integrator.

Tuning

Ideally the controller output signal is zero when the system is at rest. This may not be the case if there is a static offset somewhere in the system. To remove a static offset, increase the reset integrator gain and observe the rate at which the controller output signal is driven to zero. More reset gain will result in faster offset removal. Values in the range of 0.1 to 1.0 are typical.

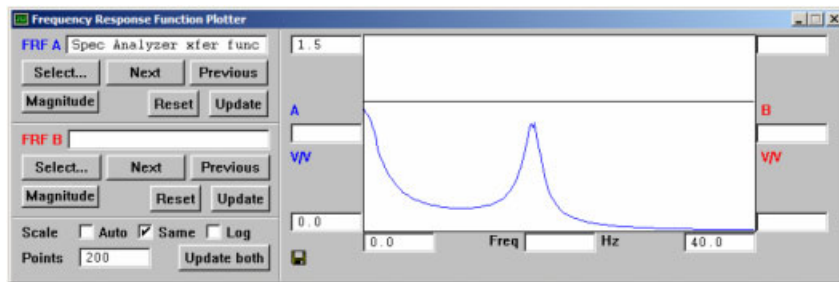
If you observe that Reset Integrator Tracking indicator is glowing red, that means that the correction that reset integrator needs to apply to remove the offset is beyond its authority limit. Increase the Reset Integrator Maximum Authority slider bar in small increments until the indicator glows green. If the indicator is still red after having increased the authority a reasonable amount, it could be that there is a problem with the electrical or mechanical system that you should diagnose before continuing.

Acceleration Control Tuning

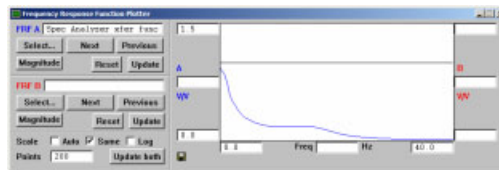
1. Set up the Random Function Generator.

Set the shape to “Flat”, the minimum frequency to match the cut-in frequency of the Reference Generator, and the maximum frequency according to the desired control bandwidth.

2. Run the Random Function Generator. Press the **Run** button.
3. Increase the displacement gain until the frequency response is adequate at low frequencies, but without causing the oil column resonance to peak above unity magnitude.



4. Increase the dynamic force gain until the oil column resonant peak is barely visible.



Note:

If the force feedback is phased properly, the dynamic force gain will be negative, and increases in the negative direction result in more oil column resonance suppression (up to a point). It is easy to drive the system into instability by using too much of this gain, so be careful.

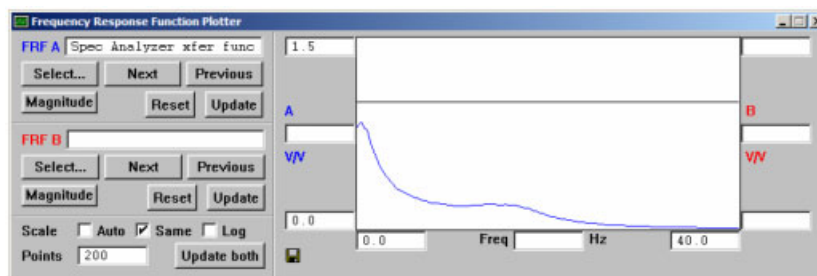
In systems without force feedback this gain parameter has no effect. Instead you can use the TVC notch filter to suppress the oil column resonance.

5. Increase the velocity lead to boost the frequency response below the oil column natural frequency.

This will also boost the response at the oil column natural frequency, causing it to peak above unity magnitude.

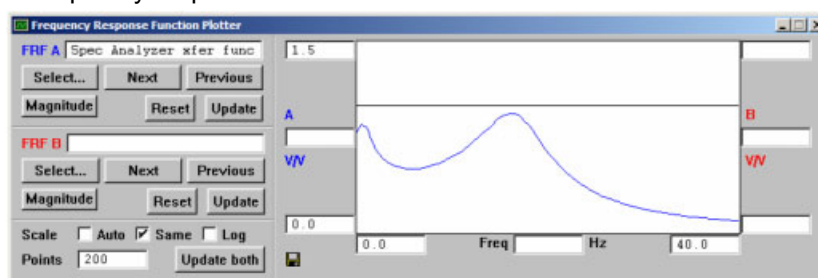
6. Increase the dynamic force gain (or deepen the TVC notch) to bring the response back down.

The frequency response then should look like this:



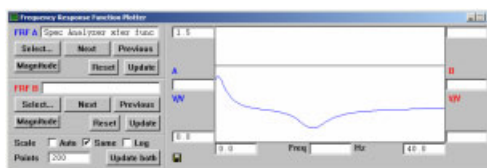
7. Increase the velocity lead to boost the frequency response below the oil column natural frequency.

This will also boost the response at the oil column natural frequency, but don't be concerned about it at this point. The frequency response then should look like this:



8. Increase the jerk lead to boost the frequency response above the oil column natural frequency.

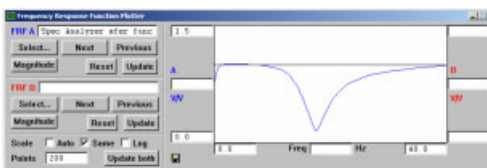
This may cause the peaking response at the oil column natural frequency observed in the previous step to be reduced due phase cancellation. Add only enough jerk lead so that the frequency response is flat overall, as shown below:



9. Continue boosting response below and above the oil column natural frequency.

Repeat the previous two steps, increasing velocity lead and jerk lead in small increments. Do not use large increments or else the effect of one lead will wash over into the other lead's frequency region, causing peaks or valleys in the frequency response that make it hard to determine which lead to adjust. In other words, make sure the overall response is reasonably flat at a given level (except near the oil column natural frequency) before boosting it to the next level.

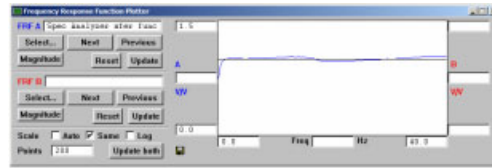
When you have finished boosting the frequency response either side of the oil column natural frequency to unity, it should look like this:



10. Increase the acceleration lead.

Tuning

Increase the acceleration lead to boost the response near the oil column natural frequency to unity. You may have to make slight adjustments to velocity and jerk leads to keep the response below and above the oil column natural frequency at unity. The frequency response should then look like this:



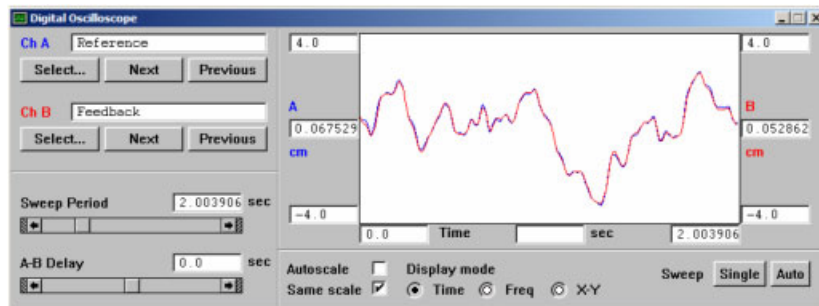
11. Adjust the input-output delay.

Although the controller is now optimally tuned, there is a delay between reference and feedback, as shown in the time response below:



This delay is inherent in all closed-loop control systems. Although the feedback is almost a perfect copy of the reference, the difference between the two waveforms is large solely because of the delay. This difference can be minimized by delaying the reference by an amount of time determined by the input-output delay adjustment so that it is aligned with the feedback for display and error calculation purposes. It has no effect whatsoever on stability or the quality of control.

To adjust the input-output delay, observe the reference and feedback waveforms in the Digital Oscilloscope and increase the delay until they are aligned visually, as shown below:



12. Stop the Random Function Generator.

Press the **Stop** button to bring the system to rest.

13. Adjust the reset integrator.

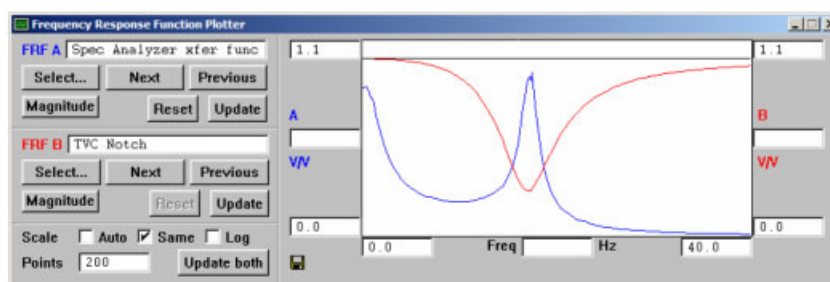
Ideally the controller output signal is zero when the system is at rest. This may not be the case if there is a static offset somewhere in the system. To remove a static offset, increase the reset integrator gain and observe the rate at which the controller output signal is driven to zero. More reset gain will result in faster offset removal. Values in the range of 0.1 to 1.0 are typical.

If you observe that Reset Integrator Tracking indicator is glowing red, that means that the correction that reset integrator needs to apply to remove the offset is beyond its authority limit. Increase the Reset Integrator Maximum Authority slider bar in small increments until the indicator glows green. If the indicator is still red after having increased the authority a reasonable amount, it could be that there is a problem with the electrical or mechanical system that you should diagnose before continuing.

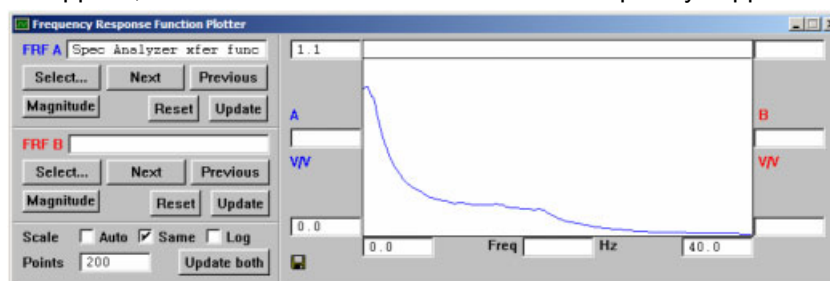
Suppressing Oil Column Resonance Using a Notch Filter

Force feedback is the preferred method of suppressing the oil column resonance because it tracks changes in oil column natural frequency with temperature and actuator displacement. However, if a force sensor is not available, a notch filter can be used instead with similar results.

In the figure below, the frequency response (Channel A (blue)) shows a large peak at the oil column natural frequency. Channel B (red) shows the frequency response of the notch filter that will be applied to eliminate the resonant peak.



With the notch filter applied, the oil column resonance has been completely suppressed:

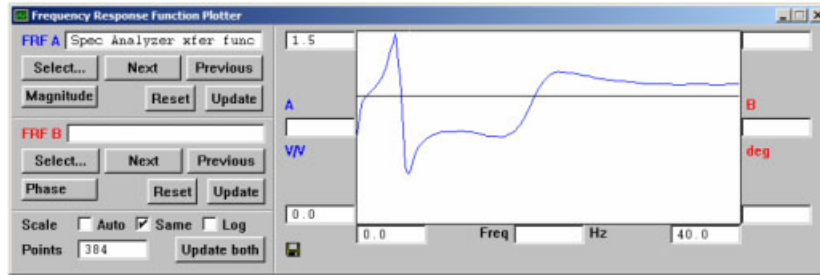


Compensating Payload Resonances Using Notch Filters

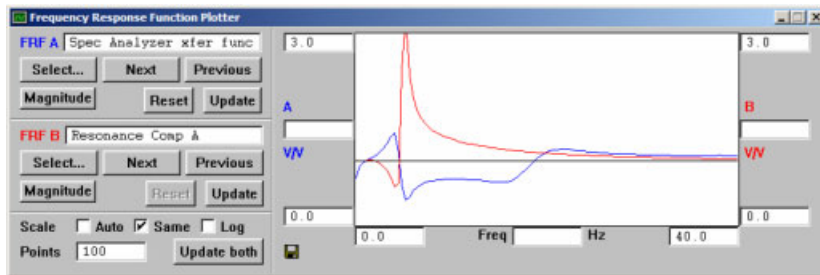
The tuning procedures presented so far assume that the payload is a rigid mass. If instead the payload has resonant modes, the task of tuning becomes more complex. Resonances and anti resonances cause sharp peaks in the frequency response. To deal with these, the notch filters of the Resonance Compensator are employed.

In the following example, a bare seismic table is tuned using the tuning procedures previously discussed. Then a heavy, lightly damped 5 Hz resonant specimen is placed on the table, but the tuning is left unchanged. The resulting frequency response then looks like this:

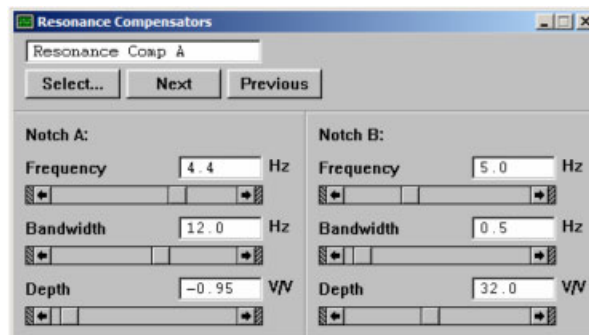
Tuning



There is a resonance at 4 Hz followed by a sharp transition to an anti resonance at 5.4 Hz. Using the Resonance Compensator Panel, a notch is placed on top of the resonance and an anti-notch on top of the anti resonance, as shown in Channel B (red) below:

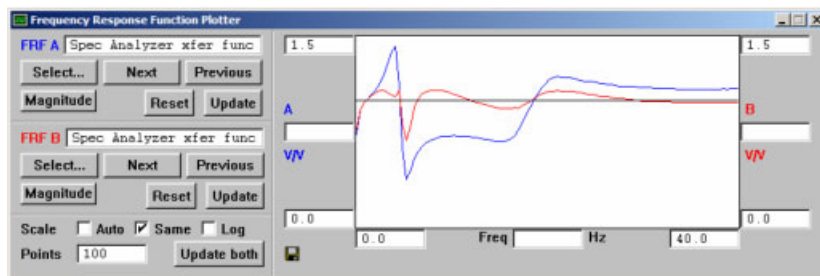


The Resonance Compensator notch filter parameters that achieve this composite notch frequency response are as follows:



Note that the center frequencies of the notch and anti-notch are slightly offset from the measured resonance and anti resonance frequencies; this is almost always the case, so remember to always offset the notch frequencies a little bit for best results.

With the notch and anti-notch filters as above, the system frequency response is that shown in Channel B (red) below superimposed on the original frequency response in Channel A (blue):



The frequency response is far from perfect, but it is still considerably improved.

While tuning the Resonance Compensator notches, you may have to adjust the TVC gains a little. In the above example, the jerk lead was reduced by 13% to reduce peaking caused by the large gain of the antinotch.

Switching Control Modes With Hydraulics On

Most operators like to warm up the system in displacement control, then switch to acceleration control to run the test. Contrary to expectation, switching the control mode is not simply a matter of pressing the Control Mode radio button in the TVC Panel. There are many controller parameters that depend on the control mode and so must be modified to values appropriate for the new mode. Because of the large number of modifications required and the ease of forgetting one, the recommended way of changing modes is to have different settings files for different modes. Before a settings file can be downloaded, the hydraulic power must be turned off because the downloading of new calibration, gains, etc. can cause large controller transients. However, cycling hydraulic power can be very inconvenient and time consuming in some systems, especially if accumulators have to be discharged and recharged. In such systems, it would be convenient start up the system with an acceleration settings file, then change only a minimum necessary number of parameters to allow warm-up in displacement mode, then change back to acceleration mode, with hydraulics on throughout.

To change from acceleration (or velocity) to displacement control for system warm-up purposes, first press the **Save Reference Gains** button to save currently active gain values, and then set all the lead gains to zero. You can now warm up the system with a low frequency sine wave. If you are using any notch filters, you must make sure that the sine wave frequency is well below all notch center frequencies or else large motions may result.

When you are finished with system warm-up, switch back to acceleration (or velocity) control and then restore the lead gains by pressing the **Restore Reference Gains**.



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