Operation Manual

for

MTS Test Systems
Containing a 458.20
MicroConsole™
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## Section 3 Operation

## Section 4 Operation Overview
Section 1
Introduction

This Operation Manual provides operating procedures, installation guidelines, and safety practices for operation of an MTS test system configured with a 458.20 MicroConsole. It also contains a general description of the typical test system and the test system control theory.

An MTS test system can be designed for a wide variety of structural and vibration testing applications. To provide maximum flexibility for operation, the information in this manual is written for the typical system described in Subsection 1.1.

This manual describes local operation of the test system. Local operation uses the front panel switches and adjustments to set up and operate the test system. (The system must be set up locally before remote operation can be initiated.) In remote operation, a computer is used to control the test system, generate the program, and/or control data acquisition. After setting up the test system in local control, refer to the system Software Manual for remote operation information.

In addition to studying this Operation Manual, MTS recommends that you become acquainted with the system by reading the system introduction and the introductory sections of the product manuals supplied in the system Reference or Product Information Manual.

1.1 Typical Test System Configuration

Although specific test systems may contain a wide variety of devices, the operating procedures in this manual presume that the test system contains the following major components:

**Electronic Products**

- a MicroConsole and its associated AC and/or DC Controllers
- a programming device (which may be mounted in the MicroConsole, mounted in another chassis in the console, or externally connected)
- an oscilloscope (which may be mounted in the console or externally connected)

**Servohydraulic Devices**

- one or more hydraulic actuators and the associated servovalves and transducers
- a hydraulic service manifold (HSM)
- a hydraulic power supply (HPS)

These and some of the other devices that may be included in the system are described in Subsections 1.1.1 and 1.1.2.
AC and DC Range Cartridges

One or more range cartridges is provided with each AC and DC Controller. The range cartridges calibrate the Controller for a specific transducer and permit the operator to select a specific gain factor for the system transducers, thereby increasing the system sensitivity. It is important to note that the range cartridges do not reduce the static force capability of the associated actuator, but only increase the sensitivity of the electronic control and readout components.

458.15 Valve Controller

A Valve Controller provides electronic control in systems containing multi-stage servovalves that provide inner-loop feedback. The Valve Controller is used in conjunction with an AC or DC Controller. When a system contains a Valve Controller, the valve driver circuits in the AC or DC Controllers are not functional; the valve driver circuit in the associated Valve Controller is used to generate the servovalve control signal.

458.30 Station Control

The Station Control module contains a cycle counter, a function generator, hydraulic pressure controls, program controls, and station interlocks to control a single test. The Station Control module allows the MicroConsole test system to control more than one test at a time.

458.41/.42/.43 MSP/HSM

The three MSP/HSM modules provide master span, master set point (MSP), and/or hydraulic service manifold (HSM) control. The modules with MSP functions provide system-wide program scaling. The modules with HSM functions control up to four hydraulic service manifolds.

458.05 Hydraulic Interface

The Hydraulic Interface chassis provides the necessary electrical power to operate up to four hydraulic service manifolds. The Hydraulic Interface chassis is required in systems with the 458.30 Station Control module and the 458.41/.43 MSP/HSM modules.

458.01 Expansion MicroConsole

The Expansion MicroConsole expands the functional capabilities of the MicroConsole by allowing additional plug-in modules to be installed in the system. Each Expansion MicroConsole can contain up to eight single-width, plug-in modules. Up to three Expansion MicroConsoles can be connected to any one MicroConsole.

458.90 Function Generator

The Function Generator is a program generation device that provides cyclic sine, square and triangle wave forms. The Function Generator produces wave forms from 0.01 Hz to 1100 Hz.

458.91 MicroProfiler

The MicroProfiler is a digital waveform generator. The MicroProfiler provides three modes of operation: the programmed mode allows 99 programs to be stored, the direct mode allows nine custom programs to be stored for immediate execution, and the remote mode allows a computer to control the MicroProfiler through an RS232 interface.
1.2 Single- and Multiple-Station Applications

A single-station test system provides the hydraulic, program and interlock controls to conduct a single test. A multiple-station test system provides the hydraulic, program, and interlock controls to simultaneously conduct more than one test.

The operating procedure in Section 3 of this manual is written for a 458 test system that controls one or more actuator channels from a single station that does not contain an MSP/HSM module. However, with minor modifications, it can also be used for multiple-station test systems and systems containing an MSP/HSM module.

The following subsections describe various test configurations for single- and multiple-channel and/or single- and multiple-station testing. They also identify the operating procedure modifications that may be required for a specific configuration.

1.2.1 Single-Station, Single-Channel Applications

A single-station, single-channel configuration provides control to one actuator. This configuration will typically contain one MicroConsole and one or more AC and/or DC Controllers.

No modifications to the operating procedure are required for single-station, single-channel operation. Only one AC or one DC Controller will be active during the test.

1.2.2 Single-Station, Multiple-Channel Applications

A single-station, multiple-channel configuration provides simultaneous control to several actuators. This configuration will typically contain one MicroConsole and one or more AC or DC Controllers for each actuator. It may also contain an MSP/HSM module.

Typical Configuration with no MSP/HSM Module

In the typical single-station, multiple-channel application, hydraulic pressure is simultaneously applied to all actuators using the MicroConsole controls. The same program may also be applied to all of the Controllers. This configuration does not contain an MSP/HSM module.

In this typical configuration, no modifications to the operating procedure are required. Each operating procedure step should be completed for each active Controller.
1.3 System Control Theory

1.3.1 Simple Closed-Loop Control

Control of the test system is provided by a "loop" of electronic and servohydraulic components. As shown in Figure 1-1, these components include the programmer, the 458 MicroConsole and its associated Controllers, a servovalve, and an actuator and its associated transducers (in this case, an LVDT and a load cell).

![Diagram of a typical closed-loop system]

Figure 1-1. Typical Closed-Loop System

The configuration of these devices provides a means of comparing a command (programmer output) signal with a feedback (transducer output) signal to generate a signal that controls the servovalve. The servovalve controls hydraulic flow to the actuator which moves the actuator piston rod. The actuator piston rod applies the force required to load or displace the specimen/structure being tested.
1.3.2 Control Modes

The system illustrated in the previous subsection is controlled in the displacement control mode, with an LVDT providing feedback to the system and an AC Controller providing the summing junction, valve driver, and conditioner circuitry.

Another common control mode is load (or force). In the load control mode, a DC Controller would provide the summing junction, valve driver, and conditioner circuits that are being provided by the AC Controller in Figure 1-2. Feedback would be supplied by a load cell.

The operating procedure in this manual describes the displacement and load control modes. However, it can also be modified for use with other control modes. The following paragraphs describe the other control modes that are common in 458 test systems.

**Torque Control**

The torque control mode uses a DC Controller and its associated torque cell to control the static and dynamic torque applied to a specimen.

**Strain Control**

The strain control mode uses a DC Controller and its associated strain gage or extensometer to control the amount of specimen deformation.

**Acceleration Control**

The acceleration control mode uses a DC Controller and its associated accelerometer to control the amount of acceleration of any moving device (for example, specimen, actuator, etc). Only bridge-type accelerometers should be used as acceleration control mode transducers.

**Differential Pressure Control**

The differential pressure (ΔP) control mode uses an AC Controller with the ΔP option to control the difference in pressure across the hydraulic ports of a hydraulic device such as an actuator or servovalve.
Table 1-1. System Interlocks

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cause</th>
<th>Interlock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Stop</td>
<td>Emergency Stop or E-Stop button pressed.</td>
<td>Hydraulic</td>
</tr>
<tr>
<td>Program Aux</td>
<td>Open circuit at the J43 Prog Intlk connector on the MicroConsole backplane.</td>
<td>Program</td>
</tr>
<tr>
<td>Hydraulic event</td>
<td>Fault in the performance of system hydraulic components.</td>
<td>Hydraulic</td>
</tr>
<tr>
<td>Mechanical event</td>
<td>Fault in the performance of system mechanical components.</td>
<td>Hydraulic</td>
</tr>
<tr>
<td>End-of-Count</td>
<td>Completion of a preset number of cycles of the current test program.</td>
<td>Hydraulic or Program</td>
</tr>
<tr>
<td>Underpeak</td>
<td>Selected signal fails to reach a preset minimum or maximum level.</td>
<td>Hydraulic with indicator option*</td>
</tr>
<tr>
<td>Error</td>
<td>Difference between program command signal and transducer feedback signal exceeds a preset maximum level.</td>
<td>Hydraulic with indicator option*</td>
</tr>
<tr>
<td>Upper Limit</td>
<td>Transducer feedback signal exceeds a preset minimum or maximum level.</td>
<td>Hydraulic with indicator option*</td>
</tr>
<tr>
<td>Lower Limit</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These interlocks can be set to indicate only. Refer to the MicroConsole and AC or DC Controller product manuals for further information on configuring these system interlocks.
Section 2
Getting Started

Overview

Before setting up or operating the test system, the hardware component configuration must be defined, control settings (or test parameters) should be calculated, and test setup decisions must be made. This section describes some of the factors to consider when completing these pre-operation procedures.

Record of Setup Adjustments

The Record of Setup Adjustments forms contained in Appendix B of this manual can be used to record the test system component configuration and control setting calculations described in this section. The forms can also be used to record all setup adjustments made during test setup and operation.

Define the Test Configuration

Subsection 2.1 identifies factors to consider when selecting the hardware for a test. It also describes MicroConsole features that can be selected for specific test applications. All of these selections must be made before power is applied to the test system.

Calculate Test Parameters

Subsection 2.2 describes how to determine what range cartridges to use, how to calculate the span and set point control positions, and how to determine the dc error, upper and lower limits, and underpeak detector levels. These test parameters should be calculated before beginning the operating procedure.

Select Test Setup Methods

Subsection 2.3 describes zero suppression, some factors to consider when selecting a control mode for specimen/actuator installation, and the effect of the servo loop adjustments. This information should be reviewed and any necessary setup decisions should be made before beginning the operating procedure.

2.1 Define the Test Configuration

Defining the test configuration involves determining how the mechanical components will be set up, what external equipment will be necessary, and how the MicroConsole features should be configured. The following subsections outline some of the factors to consider when defining the test configuration.
2.1.3 Install the Test Programmer

The MicroConsole and Station Control modules can accept program signals from internal or external programmers. Internal program signals are bussed to all module locations, while external program signals are only bussed to specific module locations. If the MicroConsole chassis contains more than one programmer, one of the two devices will be configured as internal and the other as external. A program signal is defined as internal or external based on the manner in which it is connected to the MicroConsole.

The internal programmer is connected to the MicroConsole either through the backplane (if the programmer is located inside the chassis), or at connector J50 on the rear panel of the MicroConsole or Expansion Chassis. The program signal from an internal programmer is controlled by the MicroConsole Program/Record switches and is bussed to all module locations.

The external programmer is only connected to specific module locations at the JX04 connectors on the rear panel of the MicroConsole or Expansion Chassis. The program signal from an external programmer may not be controlled by the MicroConsole Program/Record switches and is not bussed to any other module locations.

If the test system contains two program sources, both should be installed and/or connected prior to operation. During operation, the test program is selected from either the internal or the external program source.

Refer to the MicroConsole and/or Expansion Chassis product manuals (located in the system Reference or Product Information Manuals) for more information on installing programmers.

2.1.4 Select the Counter Input Signal

An internal, external, or auxiliary source can provide input to the MicroConsole and Station Control module Counters.

The internal input selection is from the internal programmer (installed in Subsection 2.1.3). The external input selection is from an external programmer connected to J51 or to JX04 on the MicroConsole (or Expansion Chassis) backplane. The auxiliary input selection is from J48 on the MicroConsole (or Expansion Chassis) backplane.

The internal, external, or auxiliary input to the MicroConsole Counter is selected by setting two jumpers on the readout/counter circuit card in the MicroConsole. The input to the Station Control Counter is selected by a jumper on the circuit card. Refer to the installation section of the appropriate product manual (located in the system Reference or Product Information Manuals) for additional Counter input selection information.

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2.1.7 Select the Underpeak Detector Input Signal

The MicroConsole underpeak detector senses when a signal fails to reach a specified level. Although any of the signals available for readout on the MicroConsole can be selected as the underpeak detector input, the typical selection is a Controller’s transducer output (feedback) signal. The signal that is input to the underpeak detector should be selected before electrical power is applied to the test system.

When selecting or changing the underpeak detector input, ensure that only one signal is selected as the input. For example, if the displacement AC Controller was selected for underpeak detection and load underpeak detection is now selected, ensure that the displacement Controller is deselected before electrical power is applied. If more than one signal is selected as the input, the underpeak detector will not trigger an interlock unless all of the selected signals are below the specified level.

The input to the underpeak detector is selected by a switch on the appropriate DC or AC Controller circuit card. Refer to the installation section of the appropriate Controller product manual (located in the system Reference or Product Information Manuals) for additional information on the selection of the underpeak detector input signal.

2.1.8 Select the Soft Run/Stop Function

The Station Control and MSP/HSM modules contain soft run/stop circuits. These circuits automatically ramp the program from zero to full-scale when the program is started and vice versa when the program is stopped. The up (program start) and down (program stop) ramp rates can be independently set.

Station Control Module

The soft run/stop feature is optional on the Station Control module. When it is available, a switch on the Station Control module enables or disables the feature. The switch is located under the MicroConsole hinged top cover and must be set with power removed. In addition, a set of switches on the circuit card allow separate ramp up and ramp down rates to be set.

Refer to the Station Control product manual (located in the system Reference or Product Information Manuals) for information on enabling the soft run/stop feature and setting the ramp rates.
Range cartridges are rated for a certain range of values referred to as the "operating range." A typical operating range might be ±100 mm. If a range cartridge has an operating range of ±100 mm, it will scale the feedback signal of its LVDT so that 0 to -10 volts corresponds to 0 to 100 mm of actuator motion in one direction and 0 to +10 volts corresponds to 0 to 100 mm of actuator motion in the other direction. This operating range is usually printed on the range cartridge.

Installing range cartridges whose operating range is close to, but greater than, the testing range will ensure the best use of the ±10 volt resolution of the MicroConsole. For example, consider the following test situations.

<table>
<thead>
<tr>
<th></th>
<th>Example One</th>
<th>Example Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>If</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum test level</td>
<td>= +50 mm</td>
<td>= +15 kN</td>
</tr>
<tr>
<td>Minimum test level</td>
<td>= 0 mm</td>
<td>= −15 kN</td>
</tr>
<tr>
<td>Testing range</td>
<td>= (+50 mm) - (0 mm)</td>
<td>= (+15 kN) - (−15 kN)</td>
</tr>
<tr>
<td></td>
<td>= 50 mm</td>
<td>= 30 kN</td>
</tr>
<tr>
<td>Available range cartridges</td>
<td>range 1 = ±200 mm</td>
<td>range 1 = ±100 kN</td>
</tr>
<tr>
<td></td>
<td>range 2 = ±100 mm</td>
<td>range 2 = ±50 kN</td>
</tr>
<tr>
<td></td>
<td>range 3 = ±40 mm</td>
<td>range 3 = ±25 kN</td>
</tr>
<tr>
<td></td>
<td>range 4 = ±20 mm</td>
<td>range 4 = ±10 kN</td>
</tr>
<tr>
<td>Then</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selected range cartridge</td>
<td>range 2 = ±100 mm</td>
<td>range 3 = ±25 kN</td>
</tr>
</tbody>
</table>

**Example One**

The testing range is confined to the positive signal range of the cartridge, so the selected range cartridge must be able to scale 0 to +50 mm of actuator motion. Which cartridge to select depends on the test program and fixtureing requirements.

If the desired test program mean level cannot be offset, or the test fixtures constrain the actuators to a certain range of motion, then the range 2 cartridge should be selected. If the desired test program signal can be offset so that the range of actuator motion is between -40 mm and +40 mm, and the test fixtures do not interfere, then the range 3 cartridge may be selected. In this example, we will assume that the range 2 cartridge was selected.

**Example Two**

The testing range covers both the positive and negative range of the transducer feedback signal, so the selected range cartridge must be able to scale ±15 kN of load. The best range cartridge selection is the range 3 cartridge because it provides a rating that brackets the expected testing range.
2.2.4 Calculate Span and Set Point Control Settings

The maximum/minimum amplitude of a waveform output by the programmer is ±10 volts, which represents ±100% of the selected operating range. The active Controller's Span and Set Point controls are adjusted to scale this program signal to fit the testing range.

As illustrated in Figure 2-1, adjusting the Span control changes the amplitude of the program command signal. Adjusting the Set Point control changes the program command mean level offset. These adjustments enable the test system to produce the forces or displacements required for a specific test.

![Figure 2-1. Effects of Span and Set Point on Program Command](image)

2.2.4.1 Calculating the Set Point Control Setting

The Set Point control, which adjusts the program mean level offset, is scaled from 000 to 1000. The settings on this control represent the following mean level offsets and actuator positions:

<table>
<thead>
<tr>
<th>Set Point Control Setting</th>
<th>Offset</th>
<th>Actuator Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>-100% offset</td>
<td>full retraction</td>
</tr>
<tr>
<td>500</td>
<td>0% offset</td>
<td>midstroke</td>
</tr>
<tr>
<td>1000</td>
<td>+100% offset</td>
<td>full extension</td>
</tr>
</tbody>
</table>

To calculate the proper Set Point control setting, complete the following equation:

\[
\text{mean level} = \frac{(\text{maximum test level}) + (\text{minimum test level})}{2}
\]
2.2.4.2 Calculating the Span Control Setting

The Span control, which adjusts the amplitude of the program command, is scaled from 000 to 1000 representing 0% to 100% of the program command amplitude. The setting of the Span control is determined by the testing range and the full-scale operating range.

After the testing range and full-scale operating range have been determined (refer to Subsections 2.2.1 and 2.2.3), then the Span control setting can be calculated using the following equation:

\[
\text{Span setting} = \frac{\text{testing range}}{\text{full-scale operating range}} \times 1000
\]

**NOTE** If the testing range is larger than the full-scale operating range, then the Span control setting would not be valid. In such a case, the Set Point control setting and/or the range cartridge should be changed and the Span setting recalculated.

The following table lists the Span control setting calculations completed for two test examples.

<table>
<thead>
<tr>
<th></th>
<th>Example One</th>
<th>Example Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>If</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing range</td>
<td>((+50 \text{ mm}) - (0 \text{ mm})) = 50 mm</td>
<td>((+15 \text{ kN}) - (-5 \text{ kN})) = 30 kN</td>
</tr>
<tr>
<td>Full-scale operating range</td>
<td>100 mm</td>
<td>50 kN</td>
</tr>
<tr>
<td>Then</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span control setting</td>
<td>((50 - 0) \times \frac{100}{500}) = 500</td>
<td>((15 - (-15)) \times \frac{50}{600}) = 600</td>
</tr>
</tbody>
</table>
In the following low-frequency example, the dc error detector can be set to a relatively small level since the feedback tracks the command so closely.

![Diagram showing feedback and program command with largest DC error.]

However, if a higher frequency content were added to the program command, as shown below, the dc error detector would have to be adjusted to a higher level in order to avoid setting the system interlock.

![Diagram showing feedback and program command with larger DC error.]

For static and low frequency testing, the initial error detector levels (adjusted in step 9) can be determined before beginning the operating procedure. The level selected should reflect the response requirements of the specific test. For example, if the test can tolerate up to 25% deviation from the program signal, the dc error detector level may be set to 25%.

The dc error level can also be adjusted during testing (in step 28 of the operating procedure) if desired. Operator experience is the best guide for adjusting the error detectors for high frequency testing.
Determining Limits from Known Test Forces or Displacements

If the test forces or displacement values are known, the limit detectors levels can be determined before setup and adjusted to the required levels in step 17 of the operating procedure.

The test configuration, test program, and fixturing are all factors to consider when determining the limit detector levels. For example, consider the following test situation:

- the test will run in displacement control
- the actuator has a full-scale displacement of 6 inches (±3 inches)
- the actuator is at midstroke after the specimen is installed
- there is a 2-inch clearance between the fixtures and the specimen after the specimen is installed
- the program is a cyclic command of ±0.5 inch

With these conditions, the following displacement limit detector levels can be set on the AC Controller:

- Upper Limit: +0.75 inch (+25% of full-scale operating range)
- Lower Limit: -0.75 inch (-25% of full-scale operating range)

and the limit detector interlock can be enabled. When enabled, the limit detectors will stop actuator rod displacement when the specimen fails, shutting down the system and helping to protect the fixtures.

Setting Limits if Test Forces or Displacements are not Known

As previously discussed, the upper and lower limits cannot always be determined before testing. For example, the load applied to a specimen from a given displacement probably cannot be determined before testing.

If the maximum and minimum test force or displacement values are not known and cannot be determined before testing, the limit detectors should be adjusted to avoid unwanted system shutdown in step 17 of the operating procedure. Then, they should be properly adjusted while the test is running (in step 29 of the operating procedure).

Determining Limits for Actuator/Specimen Installation

The upper and lower limit detector levels used for testing may prohibit specimen/actuator installation. For example, displacement limits may prevent piston rod extension or retraction when installing the actuator. Therefore, limit detector levels should also be determined for actuator/specimen installation. These limit detector levels are set in step 10 of the operating procedure.
To calculate the underpeak detector levels, the maximum and minimum test forces or displacements must be known. If the test forces or displacements are known, the underpeak detectors should be adjusted to the required levels in step 11 of the operating procedure.

As with the limit detectors, the test configuration, test program, and fixturing are all factors to consider when determining the underpeak detector levels. For example, consider the following test situation:

- the test will run in displacement control
- the input to the underpeak detector is the transducer feedback signal from a load cell with a full-scale operating range of ±25 kN
- there is zero load after the specimen is installed
- specimen failure is defined as a 20% drop in load (in respect to a +20 kN initial force at the programmed maximum and minimum displacements)

With these conditions, the following underpeak detector levels can be set:

- Maximum Underpeak: +16 kN (+64% full-scale load)
- Minimum Underpeak: −16 kN (−64% full-scale load)

and the underpeak detector interlock can be enabled. When enabled, the underpeak detector will stop the test when the specimen fails, shutting down the system and minimizing the chance of equipment or specimen damage.

The maximum underpeak level will typically be set at a level 5% to 10% less positive (more negative) than the peak level of the selected input signal. The minimum underpeak level will typically be set at a level 5% to 10% less negative (more positive) than the valley level of the selected signal.

If the desired underpeak values are not known, the underpeak detector should be adjusted to prevent damage to the test system and avoid undesired system shutdown in step 11 of the operating procedure. Then, they should be adjusted while the system is operating (as described in step 30 of the operating procedure).
Consider the following test situation where it may be desirable to zero suppress the transducer output:

- set point level is +7.2 volts (+72% of full-scale operating range)
- program signal is ±0.5 volts (±5% of full-scale operating range)

If zero suppression is used in this testing situation, a zero reference would make it easier for you to determine the proper limit detector settings. Because the testing range does not exceed 100% of the actuator limits, zero suppression can be used.

### 2.3.2 Actuator/Specimen Installation Control Mode

The actuators/specimen can be installed in either the displacement or load control mode. The type of specimen, the actuator configuration, and additional fixturing are all factors to consider when selecting the installation control mode.

When installing a specimen or actuator, the Controller Set Point control is used to move and position the actuator rod. The following paragraphs describe the effect of Set Point control adjustments in the two control modes:

- In displacement control, the actuator rod will move to and stop at a position that corresponds to the Set Point control setting. Displacement control is a closed-loop control mode, because the LVDT feedback provides a known actuator position, or reference.

- In load control, the actuator rod will move with a slight Set Point control adjustment and will not stop until the Set Point control is returned to 500 or a load is applied to the load cell that corresponds to the Set Point control setting. Until a reaction against the load cell exists, the system is in an open loop condition. Therefore, slight actuator rod drift may occur in load control.

When installing an actuator/specimen in load control, consider the amount of load being applied. Because the actuator piston will continue to move until the specified load is achieved, always use the smallest load possible during actuator/specimen installation.

To decrease the possibility of actuator instability when installing a specimen or actuator, the AC or DC Controller's Gain (P), Rate (D), and Reset (I) controls should be decreased to known safe operating levels, as described in step 7 of the operating procedure.

The following examples describe some of the factors to be considered when selecting the actuator/specimen installation control mode.
2.3.3 Servo Loop Adjustments

The servo loop adjustments completed in steps 19 and/or 20 of the operating procedure establish the response and stability of the servo loop. Only the Controllers that have been selected for active control of the test system need to be adjusted for servo loop response and stability.

The required system response (dc error tolerance) and the specimen fragility should be considered when adjusting the servo loop controls. Sensitive specimens that cannot withstand potential actuator oscillation or unstable system operation, require particularly careful consideration. Optional steps are provided in the operating procedure for sensitive specimens.

The following paragraphs explain how the servo loop controls affect the dc error.

Gain (P)

The gain adjustment determines how well the dc error will follow the program. The greater the gain, the more the servovalve opens for a given dc error. As proportional gain is increased, the dc error decreases, indicating closer tracking of the feedback to the command. The following figure shows the program and resulting transducer feedback signal with a small gain.

![Response Time Graph]

Increasing the gain decreases the stability margin of the system, increases the frequency of oscillation, and decreases response time. The following figure shows the effect on the transducer feedback of increasing the gain adjustment.

![Overshoot Graph]

If the gain is set too high, unstable system operation can result. This instability may cause specimen damage. Consequently, gain should be set as high as possible while maintaining stable system operation.
Section 3
Operation

Overview
This section contains a step-by-step operating procedure that will lead the system operator through local test setup and operation. It can also be used as a reference for experienced operators who are using Section 4, Operation Overview.

An illustration of the 458 MicroConsole, configured with one AC Controller and one DC Controller, is provided on even-numbered pages in this procedure. An Operation Overview banner is provided on odd-numbered pages, and identifies what steps are described on the facing pages.

Record of Setup Adjustments
The Record of Setup Adjustments forms contained in Appendix B of this manual can be used to record the setup adjustments made during test setup and operation.

Before Starting the Operating Procedure
The information in Section 2, Getting Started, should be reviewed and fully understood before beginning the operating procedure described in this section. Section 2 contains critical information on the definition and calculation of test parameters that will be used during this procedure. It also contains some guidelines to consider if the operating procedure is modified.

Before operating the system for the first time, make a trial run through the operating procedure by locating the controls involved without actually performing the adjustment. If any operating adjustment seems unclear, review the applicable subsection in Section 2 and/or the operating and adjustment procedures described in the applicable product manual (located in the system Reference or Product Information Manuals).

Modifying the Operating Procedure
This operating procedure describes the adjustments to be performed to accomplish normal operation. It does not cover all possible combinations of system setup and operation. The procedure is designed such that the system operator can gain basic system operating experience. As experienced is gained with the system, the operating procedure can be modified to fit specific system configuration and testing requirements. To ensure the consistency of test results, record any changes or modifications to the operating procedure and use the modified procedure in future testing.

Multiple-Channel Operation
As described in Section 1, this operating procedure is written for single-station, single- and multiple-channel systems. For multiple-channel applications (without an MSP/HSM module), complete each step for each Controller that is to be controlling an actuator during the test. If the system contains a Model 458.41/.42/.43 MSP/HSM module, several steps in this operating procedure will need to be modified. These modifications are described in footnotes to this operating procedure.
• Determine if transducer readouts should be zero suppressed for upper and lower limit detection settings

• Determine the dc error and (if desired) underpeak detection levels

• Calculate the upper and lower limit detection levels to be used during the test

• Select the control mode that will be used during specimen/actuator installation

• Calculate the upper and lower limit detection levels to be used during specimen/actuator installation

• Select the external readout/data acquisition devices to be used during the test

• Select the appropriate data acquisition transducers for the test (strain gages, accelerometers, etc)

• Determine which signals should be monitored during the test

Refer to Section 2, Getting Started, for further information on test parameter calculations and test definition considerations.

2. Set up test components

Set up the mechanical fixturing, data acquisition devices, and MicroConsole as defined in step 1. This setup includes the following:

• Prepare the specimen, data acquisition transducers, actuators, and fixturing

• Ensure that the feedback control cables are properly connected

• Verify that the 458 MicroConsole is correctly configured for the test and for signal monitoring

• Set up the data recording/acquisition devices

3. Turn on electrical power

Electrical power to a console-mounted MicroConsole is typically controlled by the main Power On/switch located on the console lower front panel. Desktop MicroConsole Power On/switches are located on the back panel of the unit.
5. **Install selected range cartridges in appropriate Controllers**

To install the cartridges selected in step 1, complete the following steps.

A. Remove any installed range cartridge by pressing down on the top portion of the cartridge to release the catch and then pulling it straight out of the Controller.

B. Check the model and serial numbers on top of the selected range cartridge to ensure that it matches the transducer in use, and that it is being installed in the proper Controller.

C. Install the range cartridge by pushing it into the Controller to seat the cartridge into the connector.

D. Repeat steps 5A through 5C for each Controller.
C. Using the MicroConsole keypad, enter the transducer full scale value associated with the range cartridge installed in step 5. This value can usually be found on a label on the front of the cartridge.

D. When the correct transducer full scale value is displayed, press the keypad Enter switch to set the transducer full scale value.

E. Repeat steps 6B through 6D for each Controller.

7. **Complete initial servo loop adjustments**

To set the servo loop controls to levels that will ensure actuator stability, complete the following steps.

---

**NOTE** To ensure actuator stability at HPS startup, selection of low proportional gain and stabilization settings is recommended for first-time operation or setup. When using the system for similar tests on similar specimens, this step can be eliminated after the servo loop has been properly adjusted for one test.

---

A. On each DC Controller, set the Gain (P) control to 1, the Rate (D) control to 0, and the Reset (I) control to 1.

B. On each AC Controller, set the Gain (P) control to 1, the Rate (D) control to 0, and the ΔP control to 0.
9. Set error detector levels

To adjust the error detectors to the levels calculated in step 1, complete the following steps.

A. Select Error Detect for readout on the MicroConsole Display using the Display Select switches.

B. Press the Display switch on the active Controller to be adjusted.

C. Adjust the Error control on the active Controller for a display reading equal to the allowable error before system shutdown.

D. Repeat steps 9B and 9C to adjust the Error control on each active Controller.

E. Enable the error detector interlock by pressing the MicroConsole Error Disable/Enable switch to light the associated Enab indicator.

**WARNING**

Unexpected component failure or operator error can cause the testing system to exceed limit detector levels.

Relying on system limit detectors for protection can result in serious injury to personnel.

Under no circumstances should the limit detectors be relied on to protect personnel.

10. Set limit detector levels for specimen/actuator installation

To adjust the limit detectors to the levels calculated in step 1 for specimen/actuator installation, complete the following steps.

A. Select Upper Limit Detect for readout on the MicroConsole Display using the MicroConsole Display Select switches.

B. Press the Display switch on the Controller to be adjusted.

---

1 Error detector levels are only set for those Controllers that will be active during the test.
11. **Set underpeak detector levels**

If underpeak detection will be used during the test, complete steps 11A through 11E. If underpeak detection is not desired, proceed to step 11E.

A. Select Underpeak Max for readout on the MicroConsole Display using the Display Select switches.

B. Adjust the MicroConsole Underpeak Max control for a display reading equal to the desired most positive (least negative) transducer feedback signal level calculated in step 1.

C. Select Underpeak Min for readout on the MicroConsole Display using the Display Select switches.

D. Adjust the MicroConsole Underpeak Min control for a display reading equal to the desired most negative (least positive) transducer feedback signal level calculated in step 1.

E. Disable the underpeak detector interlock by pressing the MicroConsole Underpeak Disable/Enable switch to light the associated Disab indicator. If underpeak detection will be used during the test, the underpeak detector interlock will be enabled in step 30.

---

1 This procedure assumes that a transducer conditioner output (feedback) signal has been selected as input to the underpeak detector.
C. Complete steps 12A and 12B for each Controller that will be active during specimen/actuator installation. Only one Controller will be active for each actuator.

⚠️ WARNING

Uncontrolled actuator movement can result from applying hydraulic pressure to the system when the servovalve command (dc error) has not been zeroed.

If the servovalve command (dc error) does not equal zero when hydraulic pressure is applied to the system, equipment damage and/or personal injury can result.

Always ensure that the servovalve command is zero (complete step 13) before applying hydraulic pressure to the system.

13. Zero servovalve command

To zero the servovalve command(s) and prevent abrupt actuator rod movement when hydraulic pressure is applied, complete the following steps.

A. Press the Display switch on the active Controller.

B. Select DC Error for readout on the MicroConsole Display using the MicroConsole Display Select switches.

C. Note the directional indicators above the Controller's Set Point control and turn the Set Point control in the indicated direction for a display reading of 00.00.

✓ D. Complete steps 13A through 13C for each Controller that will be active during specimen/actuator installation.
**WARNING**

Uncontrolled actuator movement can result from applying hydraulic pressure to the system when the servovalve command (dc error) has not been zeroed.

If the servovalve command (dc error) does not equal zero when hydraulic pressure is applied to the system, equipment damage and/or personal injury can result.

Always ensure that the servovalve command is zero (complete step 13) before applying hydraulic pressure to the system.

---

**15. Apply low and then high system hydraulic pressure**

To apply hydraulic pressure and prevent sudden system pressurization, complete the following steps.¹

A.² Press the Hydraulic Pressure Low switch to start the HPS and apply low hydraulic pressure to the actuators (the Off indicator will extinguish and the Low indicator will light).

B. Observe the actuators for any movement caused by hydraulic fluid pressurizing the system. Ensure that the actuators stabilize before proceeding.

C. If the specimen/actuator installation process does not require high hydraulic pressure, installation may be completed under low hydraulic pressure. If high hydraulic pressure is not necessary, proceed to step 16.

D. Press the Hydraulic Pressure High switch to apply high hydraulic pressure to the actuators (the Low indicator will extinguish and the High indicator will light).

---

¹ The MicroConsole Low switch can be configured for special applications. Refer to the MicroConsole product manual and the system configuration drawings in the system Reference, Product Information or Assembly Drawings Manuals for more information on the configuration of the MicroConsole hydraulic pressure controls.

² If the testing system is configured with a Model 458.41 MSP/HSM or Model 458.43 HSM module, press the appropriate HSM Channel switches to apply low pressure to the actuators, ensure actuator stability, and then press the same switches to apply high pressure to the actuators. Proceed to step 16.
16. **Install specimen or actuators**

**NOTE** If possible, install a dummy specimen at this time. Use of a dummy specimen will help avoid potential damage to the test specimen when establishing the servo loop response and stability. The dummy specimen should be a representative model of the test specimen.

When installing a specimen or actuator, the Controller Set Point control determines the movement and position of the actuator rod. This is done by adjusting the Set Point control from 500 toward 1000 or from 500 toward 000 to cause actuator movement. The direction of movement caused by the Set Point control adjustment is determined by system phasing.

In displacement control, the actuator rod will move to and stop at a position corresponding to the Set Point control setting.

**WARNING**

When installing a specimen/actuator in load control, the actuator piston will continue to move until the specified load is achieved.

Use of large load levels during specimen/actuator installation can result in equipment damage and/or personal injury.

If possible, use a small load level when installing an actuator/specimen in load control.

In load control, the actuator rod will move with a slight Set Point control adjustment and will not stop until the Set Point control is returned to 500 (or a load is applied to the load cell corresponding to the Set Point control setting). However, because the system is in load control, until a reaction against the load cell exists, the open loop condition can cause slight actuator rod drift (in proportion to the Set Point offset from 500).

The method used to install the specimen/actuators depends on the type of specimen to be tested, the system configuration, the selected control mode, and the type of test to be performed. Because of the wide variety of possibilities an exact installation procedure is not provided here. Refer to Subsection 2.3.2 for more information on specimen/actuator installation. **Observe all safety precautions outlined in Section 5 and on the component placards.**

Q: How to adjust dist. between upper/lower groups without influencing set point? Is AC/DC independent?

Operation 3-17
H. Repeat steps 17C through 17G for the U Lim and L Lim controls on each Controller.

I. Enable the limit detectors by pressing the MicroConsole Upper Limit-Lower Limit Disable/Enable switch to light the Enab indicators.

Adjust Servo Loop

18. **Select test control mode**

If the test control mode is already selected (correct Act indicators are lit), proceed to step 19. Complete the following steps to select a different control mode for testing.

A. Press the Display switch on the active Controller.

B. Using the MicroConsole Display Select switches, select DC Error for readout on the MicroConsole Display.

C. Record the value displayed on the MicroConsole Display.

D. Simultaneously press the MicroConsole Control Transfer Enable switch and the desired Controller’s Control switch to light the Next indicator.

E. Press the Display switch on the selected next Controller. The dc error associated with the selected next Controller will be displayed on the MicroConsole Display.

⚠️ **CAUTION**

When a mode switch occurs, the Set Point control on the selected next Controller will have a dynamic effect on actuator rod movement.

Unexpected actuator movement can cause personal or equipment damage.

In the next step, as the dc error of the selected next Controller approaches that recorded in step 18C, turn the Set Point control more slowly.

F. Note the Set Point direction indicators on the Controller and adjust the Set Point control in the appropriate direction to extinguish the indicator. As soon as the indicator goes out, the mode switch occurs and the Act indicator lights.

G. Complete steps 18A through 18F for each Controller that will be active during specimen/actuator installation. Only one Controller can be active for each actuator.
C. Set up the selected programmer (refer to Appendix A) to output a low-frequency (1 Hz to 2 Hz) waveform. In most test situations, a square wave can be used. It will provide the most broad-band, informative response.

When setting up the test system for a sensitive specimen, use a ramp or triangle waveform. A ramp or triangle waveform should contain sufficient frequency and provide sufficient response to optimize tuning without damaging the specimen.

D. Press the MicroConsole Program/Record Run switch to start the program.

E. Press the Display switch on the AC Controller to be adjusted. Using the Display Select switches, select Command for readout on the MicroConsole Display.

F. Slowly adjust the AC Controller Span control for a small percentage (5% to 10%) of the maximum amplitude of the test program defined in step 1.

⚠️ CAUTION

Steps 19G through 19K may cause actuator oscillation and unstable system operation.

In some systems, actuator oscillation and unstable system operation can cause specimen and/or equipment damage.

If sustained oscillation is not acceptable, perform the following steps instead of steps 19G through 19K.

a. Increase Gain (P) to get an overshoot without ringing.

b. While watching the rate of decay oscillation, add Rate (D) and then readjust Gain (P) and Rate (D) iteratively.

c. Verify the system response at different amplitude levels (refer to step 19K). Readjust the servo loop controls as necessary.

When Gain (P) is added after Rate (D) in step b, the gain increase will be more sensitive than it was before adding rate.
Adjust the Rate (D) and/or ΔP controls to stabilize the waveform and eliminate the ringing without excessive overshoot (waveform l). Excessive rate can cause ringing.

J. Repeat steps 19H and 19I to achieve the desired response.

K. Verify the system response at different amplitude levels by increasing the Span control setting. These amplitudes should represent at least 10% of the maximum test program amplitude. Readjust the servo loop controls as necessary (steps 19H through 19J).

L. Press the MicroConsole Program/Record Stop switch to stop the program.

M. Repeat steps 19A through 19L for each AC Controller selected for test control.

---

20. **Adjust DC Controller Gain (P), Rate (D) and Reset (I) controls**

Complete the following steps for each DC Controller that is to be used for test control. If only AC Controllers were selected and step 19 was completed, proceed to step 21.

---

**NOTE**

The following steps are provided as a guide to the servo loop adjustments. Adjustment of these controls will vary depending on the test specimen and the components of the test system (for example, test fixtures, type of feedback, hydraulic components). As operator experience is gained, the steps can be modified to achieve the desired response.

---

A. Set the Span control on the DC Controller to be adjusted to 000.

B. Connect an oscilloscope to the DC Controller Output test jack. Make the appropriate adjustments for amplitude and time base on the oscilloscope.
F. Slowly adjust the DC Controller Span control for a small percentage (5% to 10%) of the maximum amplitude of the test program defined in step 1.

⚠️ CAUTION

Steps 20G through 20P may cause actuator oscillation and unstable system operation.

In some systems actuator oscillation and unstable system operation can cause specimen and/or equipment damage.

If sustained oscillation is not acceptable, perform the following steps instead of steps 20G through 20P.

a. Increase Gain (P) to get an overshoot without ringing.

b. While watching the rate of decay oscillation, add Rate (D) and then readjust Gain (P) and Rate (D) iteratively.

c. Verify the system response at different amplitude levels (refer to step 20N). Readjust the servo loop controls as necessary.

When Gain (P) is added after Rate (D) in step b, the gain increase will be more sensitive than it was before adding rate.

G. The waveform displayed should resemble waveform G1. Increase the Gain (P) adjustment to resemble waveform G2.¹

![Waveform Diagram]

1 A square wave is shown in the figures because it provides the maximum response of the servohydraulic system. The actual waveforms observed can appear different and are dependent on the test system and type of waveform.

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**Operation Overview**

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L. Adjust the Rate (D) control clockwise to eliminate any overshoot. Excessive rate can cause ringing.

M. Repeat steps 20H through 20L to achieve the desired response.

N. Verify the system response at different amplitude levels by increasing the Span control setting. These amplitudes should represent at least 10% of the maximum test program amplitude. Readjust the servo loop controls as necessary (steps 20H through 20M).

O. Press the Program/Record Stop switch to stop the program.

P. Adjust the Reset (I) control clockwise until the zero reference begins to waver. Readjust the Reset (I) control counterclockwise until the signal stabilizes.

Q. Repeat steps 20A through 20P for each DC Controller selected for test control.

Set Up Program

21. Select program source

Select the program source by simultaneously pressing the Enable switch and the Prog Source switch associated with the program source selected in step 1. The appropriate indicator will light.

22. Set up programmer

To set up the programmer, refer to the operating procedure and local programming instructions contained in Appendix A. Information on computer-controlled setup can be found in the system Software Manual.

---

1 The MicroConsole Prog Source Int and Ext switches allow the MicroConsole to select one of two programmers for the program command. The Int switch typically selects the internal program that is bussed to all Controller locations. The Ext switch selects the program BNC connectors (JX04) on the backplane associated with a specific Controller location.
24. If desired, set up Counter

When the MicroConsole Counter is on (the Counter On indicator is lit), the MicroConsole monitors the number of cycles of the program. The Counter can be set to stop the test after a preset count is reached or to count the number of cycles completed in a test.\(^1\)

To zero the counter and set the preset count value, complete the following steps.

A. Use the MicroConsole Display Select switches to light the Current Count indicator and to display the current count value.

B. Press and hold the MicroConsole Enable switch and then press the Counter Reset switch to reset the counter to 0 cycles.

C. Press the Display Select switches to light the Preset Count indicator and to display the existing preset count value.

D. Press the keypad Clear switch to reset the display to 0 cycles.

**NOTE** If a preset count of 0 cycles is entered, the program cannot be started if the Counter is on. The Counter can be used to count cycles without causing any end-of-count function by entering a number higher than the expected number of test cycles.

E. Enter the desired preset count using the MicroConsole keypad switches. Entry mistakes can be cleared by pressing the keypad Clear switch.

F. With the desired preset count value displayed, press the keypad Enter switch to set the preset count.

G. If cycles are to be counted during the test, enable cycle counting by simultaneously pressing the Enable switch and the Counter On switch. (If desired, the Counter can be enabled while the test is running.)

H. If desired, monitor the cycle count on the MicroConsole Display during the test by using the Display Select switches to light the Current Count indicator.

---

\(^1\) The function of the preset count feature is determined during installation or MicroConsole configuration. Functions of the preset count are an interlock at end-of-count and a rollover pulse at end-of-count. Refer to Section 2 of this manual and the 458 MicroConsole product manual for further information on the MicroConsole count feature.
C. Press the Display switch on the Controller to be scaled.

D. Adjust the active Controller Span and/or Set Point controls for the desired results.\(^1\)

E. Repeat steps 27B through 27D for each active Controller.

28. **Check error detector levels**

To check the error detector level for each active Controller and (if necessary)\(^2\) adjust them to the exact levels required for the test, complete the following steps.

A. Press the Display switch on the active Controller to be adjusted (Act indicator lit).

B. Select DC Error for readout on the MicroConsole Display using the Display Select switches.

C. If necessary, press the Peak switch to light the Peak indicator and select the peak mode of display.

D. Monitor the display and note the greatest dc error peak level.

E.\(^3\) If the dc error level set in step 9 is sufficient for the test, proceed to step 28G.

If it is necessary to change the error detector level, disable the error detector interlock by pressing the MicroConsole Error Disable/Enable switch to light the associated Disab indicator.

F. Select Error Detect for readout on the MicroConsole Display. Adjust the Controller Error control to the desired tolerance above the greatest peak dc error noted in step 28D.

G. Repeat steps 28A through 28F for each active Controller.

H. Enable the error detector interlock by pressing the MicroConsole Error Disable/Enable switch to light the associated Enab indicator.

---

\(^1\) If the testing system is configured with a Model 458.41 MSP/HSM or Model 458.42 MSP module, the Master Span % FS control scales the program to all active Controllers. The Span control on each Controller scales the program amplitude for that Controller.

\(^2\) As command frequency increases, the error level increases proportionally. Consequently, the error detector may have to be adjusted to higher levels. Operator experience is the best guide for adjusting the error detector for higher command frequencies.

\(^3\) If the dc error exceeds the test requirements, return to steps 19 or 20 to adjust the servo loop controls for optimum system response.
G. Adjust the Controller U Lim control for the desired operating margin above the upper peak noted in step 29D.

H. Select Lower Limit Detect for readout on the MicroConsole Display using the Display Select switches.

I. Adjust the Controller L Lim control for the desired operating margin below the lower peak noted in step 29D.

J. Repeat steps 29A through 29I for each Controller.

K. Enable the limit detectors by pressing the MicroConsole Upper Limit-Lower Limit Disable/Enable switch to light the associated Enab indicators.

30. Check underpeak detector levels

To check the underpeak detector levels, adjust them to the exact levels required for the test (if necessary), and enable the detector interlock, complete the following steps. If the underpeak detector is not to be used during the test, proceed to step 31.

A. Press the Display switch on the Controller selected as the input to the underpeak detector.

B. Select Transducer Output for readout on the MicroConsole Display using the Display Select switches.

C. Press the Peak switch to light the Peak indicator and select the peak mode of display.

D. Monitor the display and note the upper and lower peaks of the transducer output.

E. Select Underpeak Max for readout on the MicroConsole Display using the MicroConsole Display Select switches.

F. Adjust the MicroConsole Underpeak Max control for the desired maximum underpeak tolerance level.

G. Select Underpeak Min for readout on the MicroConsole Display using the MicroConsole Display Select switches.

H. Adjust the MicroConsole Underpeak Min control for the desired minimum underpeak tolerance level.

I. Press the MicroConsole Underpeak Disable/Enable switch to light the associated Enab indicator.

---

1 The procedures in this step assume that a transducer conditioner output (feedback) signal has been selected as input to the underpeak detector.
Section 4
Operation Overview

This section contains an overview of the system operating procedure detailed in Section 3. This overview should be used only after you are familiar with all of the operating characteristics of the test system and have thoroughly reviewed the safety practices outlined in Section 5 of this manual.

Two copies of the overview are provided. The second copy is on heavier paper and can be removed from this manual if desired.

### Initial Setup
1. Define test
2. Set up test components
3. Turn on electrical power
4. Observe self test indications on MicroConsole Display
5. Install selected range cartridges in appropriate Controllers
6. Set transducer full-scale values
7. Complete initial servo loop adjustments

### Adjust Servo Loop
18. Select test control mode
19. For displacement control, adjust AC Controller Gain (P), Rate (D), and ΔP controls
20. For load control, adjust DC Controller Gain (P), Rate (D), and Reset (I) controls

### Set Up Program
21. Select program source
22. Set up programmer
23. Adjust Span and Set Point controls for desired program scaling
24. If desired, set up Counter
25. Set up and/or start data acquisition devices

### Perform Test
26. Start test program
27. Check program scaling
28. Check error detector levels
29. Check limit detector levels
30. Check underpeak detector levels
31. Continue test to completion
Section 5
Safety Practices

Overview

Reliable operation of the test system is dependent on proper system setup, a safe operating environment, and an operator who has a thorough knowledge of the system operating characteristics.

This section contains lists of safety practices that were prepared for operators of the test system to minimize hazards that may be encountered during system operation. These safety practices were compiled from known hazardous situations that can result from operator error or negligence and other hazards of high-pressure hydraulic systems. Because of the unknown and potentially uncontrolled use of the system, the lists do not contain all precautions or safety hazards concerning system operation. If additional precautions and/or hazardous situations are discovered, the lists should be updated.

Common sense and a thorough knowledge of the system's operating capabilities will usually suggest the appropriate approach to system operation. In addition to studying the following guidelines, system operators and maintenance personnel should read all supplied manuals. Anyone working with the system should also have had prior schooling and training on similar systems.

5.1 Before Operating the Test System

Read All Provided Manuals

System operators should gain an understanding of the system functions by studying the documents and drawings supplied in the system Reference, Product Information and/or Assembly Drawings Manuals. The documents in the Reference or Product Information Manual provide a good background for the operating principles involved with MTS equipment. The drawings in the Reference or Assembly Drawings Manual show the interconnection of electronic and mechanical components in the system.

Review Operating Procedure

Before operating the system for the first time, make a trial run through the operating procedure by locating the controls involved without actually performing the adjustment. If any operating adjustment seems unclear, review the operating and adjustment procedures listed in the applicable product manual (located in the system Reference or Product Information Manual).

Update Operating Procedure

If the operating procedure for the system is changed due to component modifications, mark the procedure to reflect both the correct operating procedure and the date the modification is effective. This will keep the Operation Manual current with system use, minimizing improper or hazardous system operation.
Inspect all cables for cuts, exposed wires or other types of possible damage. Cable connectors must be securely plugged into their respective receptacles. Inspect each cable where it enters the cable connector for signs of excessive flexing (broken insulation) or exposed wires.

Check for visible signs of oil leaks.

Check the fluid level in the hydraulic reservoir.

Ensure that the cooling water to the hydraulic power supplies is turned on.

Check the accumulators for the proper nitrogen precharge.

Ensure that electric power is applied to the hydraulic power supply.

Ensure that all hoses and cables are securely connected and have not been left unattached after a maintenance operation.

Check all hoses and cables for freedom of travel to ensure that they will not be hooked or pinched during operation.

Check all hoses and cables for possible abrasion or wear.

Thoroughly inspect hoses for blisters, cuts or other possible damage.

Check piping and tubing for bends or breaks.

Check all mounting bolts to ensure that vibration has not caused loosening.

Check that the test specimen and its transducers are securely mounted.

Remove tools and any other loose items from the test area.

Check that the power is applied to all control room electronics.

Clear the test area of all personnel before starting the test system.
Do Not Use RF Transmitters Around Equipment

Keep RF transmitters away from the analog control console and the instrumentation conduit. Radio transmissions should be made from outside the control room. Intense RF fields within the room may cause erratic operation of the more sensitive circuits in the system.

Avoid High Voltage Areas

Many electronic control modules (and the HPS) have auxiliary switches attached to printed circuit board subpanels or inside the component chassis. These switches are occasionally used to expand or alter system operating capabilities. Note that line voltage potential will probably be present inside the control console at the Power O/I (OFF/ON) switch. To minimize potential electrical shock hazards while the system electrical power is turned on, avoid touching exposed wiring or switch contacts. Keep all chassis covers securely in place except as required for service.

Be Careful During Specimen/Actuator Installation

During specimen/actuator installation, the operator is very close to or in contact with the system force train. At this time, exercise great caution to avoid crush points. Refer to Subsection 5.2.3 for further information on specimen/actuator installation.

Be Careful Around Control Transducers

Do not touch, bump, wiggle, adjust, or otherwise disturb any transducer while the system is operating.

Equipment Checks During Operation

While the system is operating, inspect all hoses and cables to ensure that there is no excessive thrashing, bending or chafing that could cause cable or hose damage.

Do not shut off control console electrical power during system operation.

Do not disconnect any hoses or cables during operation of the test system.

Check the HPS, actuator, and hoses/hardline for signs of oil or water leaks.

Check for unusual sounds such as squeaking or rumbling.
Loss of Servo Valve Control Signal

An open control loop results if the cable from the console to the servo valve is disconnected or broken while hydraulic pressure is applied. The actuator response will depend on several factors, such as the piston rod position at the time of the break and the type of servo valve being used. In any event, actuator behavior can be violent.

The same precautions recommended for transducer cables apply to servo valve cables. On certain systems or for certain types of tests, it is possible to adjust error detectors to detect this loss of control. Refer to the appropriate AC or DC Controller product manual.

Program Signal Interrupt and Step Functions

The composite command signal for the servo control loop usually consists of several inputs (for example, program input from programmer, Span control setting). If one of these inputs is inadvertently removed or suddenly changed while pressure is applied, the servo control loop will sense a large instantaneous dc error and the actuator will respond accordingly. An example would be changing the input command signal without first reducing the AC or DC Controller Span control setting.

Ensure that you fully understand the effects of program input and program scaling control adjustments before making any changes to the program.

Applying Hydraulic Pressure with Large Servo Valve Command Present

When hydraulic pressure is turned off, the actuator piston can drift down to its lower cushion unless it is restrained by the specimen or by the internal friction of the actuator. If hydraulic pressure is applied without zeroing the servo valve command, the actuator will quickly return to its previous position.

To prevent sudden actuator movement when hydraulic pressure is applied, always adjust the active Controller Set Point control to zero the servo valve command (dc error) before starting the HPS and applying pressure.

In some testing systems, balancing the servo control loop is a function of the system computer. Systems can also be designed to tolerate severe start-up transients. In such cases, the operator is specifically instructed not to zero the servo valve command.

Electrical Power Failure or Shutoff

The failure or shutoff of electrical power to the test system when hydraulic pressure is applied can cause considerable and unpredictable actuator reaction. When hydraulic pressure is applied to the test system, loss of electrical power will generally cause the actuator to stroke at maximum velocity in either direction or, if a specimen is attached, to apply full force (that is, positive or negative acceleration) to the specimen.

Many systems contain hydraulic accumulators that store enough energy to temporarily operate the actuator at full force capacity even when the hydraulic pressure is shut off. For this reason, the usual interlock devices will not prevent hazardous actuator stroking. MTS can design special interlock devices to meet specific customer requirements.
5.2.3 Specimen/Actuator Installation

Specimen/actuator installation can be the most hazardous part of system operation. The following paragraphs outline some basic safety practices to observe during specimen/actuator installation.

**Clear Work Area**

Clear the work area, especially near system crush points.

**Zero the Servovalve Command**

Balance the servo control loop (reduce dc error to zero), turn on low hydraulic pressure, and ensure that the servo control is properly phased and stable. Be particularly alert for phase or control reversal if the system setup has been modified since previous operation.

**Set Gain Controls to Known Safe Levels**

If operating the system in force control, adjust the active Gain (P) control to a value known by experience to be stable for the particular component in use. Otherwise, the possibility of violent instability must be anticipated when mechanical contact between the component and the system force reaction point is made.

**Use Lifting Equipment to Move Crosshead**

To move the crosshead on load reaction structures or load frames not equipped with hydraulic lifts, support the crosshead using an overhead crane with a capacity equal to or greater than the crosshead weight (listed in the product manual) and any fixtures, grips, etc. Remove any slack from the crane cable or chain before unlocking the crosshead.

**Use Lifting Equipment to Move Specimen and Actuators**

Use extreme caution when handling or supporting the specimen/actuator. So that fingers, hands, etc, are never exposed to potential crush points during specimen/actuator mounting, MTS recommends using appropriate lifting devices or fixtures to handle the test specimen and actuators.

**Be Careful Around Control Transducers**

Do not touch, bump, wiggle, adjust, or otherwise disturb any transducer while the system is operating.
Section 6
System Installation

The MTS test system should be installed using the instructions in this manual, and the detailed system drawings and documents located in the system Reference, Product Information and/or Assembly Drawings Manuals. This section provides as much common or typical installation information as possible.

The difference in test setup and laboratory layouts will influence the final layout of the testing system components. These and other customer-specific requirements must be considered prior to installing the system.

6.1 Facility Preparation

To get the maximum intended use of the system, careful consideration should be given to planning its installation and the necessary support services required as part of the total system installation. This includes the types of testing that will be performed as well as the building facilities, contract services and support personnel that may be required during system installation. Each test application has its own requirements in addition to the test system requirements. Therefore, MTS recommends that overall planning be considered before uncrating the system.

To identify different installation considerations that are unique to the many setup configurations available with the system, read the following paragraphs thoroughly.

Space Requirements

Consideration must be given to planning for the space requirements around the equipment to allow for specimen installation and the proper maintenance of the equipment. Additional space may also be required, during installation of the equipment, to facilitate moving the various system components into place.

Consideration should also be given to handling components, storage of test data, and storage of fixtureing and the associated tools necessary for use and service of the system. If hazardous test components (such as fragmentizing materials or internally pressurized materials) are used in the test, protective enclosures and special laboratory layouts are recommended.

When the final layout for the test area has been designed, the dimensional and weight information (located in the specification tables found in the various product manuals) should be supplied to the building facility personnel to ensure that proper building loading and vibration considerations have been evaluated.
Temperature

Room air heating and cooling outlets should be directed so that they spread air uniformly throughout the room. This will help to prevent changes in specimen characteristics and test data associated with varying temperatures.

The operating temperature range of the electronic equipment is 10 to 50°C (50 to 122°F). This includes most temperature-sensitive equipment, such as disk drives which are dependent on cooler air to maintain the proper height of their read/write heads.

The operating temperature range of the HPS is 10 to 40°C (50 to 104°F). Care must be taken to ensure that it is not placed in a location subject to freezing when water cooling is used. Reservoir heaters and oil-to-air coolers are available from MTS.

Relative Humidity

The recommended control for relative humidity in the test room is a range of 10% to 85% (non-condensing). The risk of static discharge, which easily damages logic components and causes loss of data in memory devices, is increased by low humidity. Excessive humidity can result in electrical leakage currents or component failure.

Acoustics

Some types of testing can produce excessive noise that can cause hearing loss. The use of hearing protection is recommended for personnel involved in long-term testing in a noisy testing environment.

Acoustical treatment of walls and ceiling may be necessary to prevent harm to personnel. If disk drives are included in the system, acoustical materials used should not be of the type that generates or collects dust. In addition, it is recommended that the hydraulic power supply be located in a room separate from the test system, if possible, to reduce noise in the test area.

Mechanical Shock/Vibration

In testing situations where impact testing is performed or in higher speed fatigue testing, cyclic loads and simple shock pulses can be introduced into the laboratory floor. Adequate isolation is often possible with vibration isolators. However, in some cases, an air bag isolation device may be required. Contact an MTS representative for additional details.

Radiated Emissions

Operation of the system can be affected by sources of electromagnetic interference (EMI) that are near the system controls, computer, and related peripheral equipment. Common sources of EMI are thunderstorms, broadcast systems, high voltage power lines, power tools, mobile communications, radar, vehicle ignition systems, static electricity, induction heaters, and fluorescent lights.

The effects of EMI are unpredictable; additional grounding and shielding may be necessary. Techniques such as using screen cages or other metal surfaces around the system, along with good grounding practices and proper storage of magnetic memory medium, are recommended.
6.3 Grounding Requirements

Each system has its own internal grounding network, which is common grounded through the green wire in the power cable and must also return to ground, through the conduit of the electrical distribution system. Note that the green wire must not be a current-carrying conductor or a neutral conductor.

Where electrical power is of poor quality (noise spikes, poorly regulated, etc) or the ground system in the facility contains electrical noise, attach a 4 AWG wire directly to the steel structure of the building, or attach a 3 m × 3 m (10 ft × 10 ft) steel plate in contact with masonry and a 4 AWG wire for the ground system.

6.4 Console Requirements

Moving or Lifting the Console

For large stand-up consoles, lifting and moving instructions are attached to the unit. The console has casters for easy movement on smooth, level surfaces. When moving the unit using the casters, be sure that the leveling pads are screwed into the base of the cabinet.

Due to the high center of gravity of the console, two people are required to roll the console if the floor has obstructions or bumps; use one person on each side of the console to watch for obstructions. Move the unit with the front panel controls away from the direction of travel to minimize the damage that could occur if the console tipped over.

Routing Cables

The cable exit from the console is at the rear, through a slot below the rear door. Therefore, location of the cable trays and routing should be considered from this point. Adequate clearance must be provided for rear console access to permit cable attachment, fuse replacement, and component maintenance.

Cooling Fan

Stand-up consoles have a cooling fan on top of the cabinet. Do not block, obstruct, or in any way reduce the air flow from the fan. An air filter is located above the fan; it removes dust that could enter the unit.

Leveling System

The stand-up consoles have leveling feet that allow the cabinet to be leveled as necessary. Disk storage drives require proper leveling of the equipment to minimize wear on the read/write heads and fan bearings.

Computer Console

Peripheral components (such as disk drives) that are susceptible to dust contamination should be placed away from obvious sources of contamination, and the room should be slightly positively pressurized to prevent migration of dust and dirt into the room.
**Cable Connections**

MTS categorizes cables as either console cables or system cables. Console cables provide internal connections between console components and products (for example, between the 458 MicroConsole plug-in modules and an access panel). These cables are connected at the factory and only need to be checked for secure connection during installation of the system (that is, check that they did not come loose during shipment).

If provided, refer to the system assembly and/or console assembly drawings (located in the system Reference or Assembly Drawings Manual) for specific information regarding connector numbers and point-to-point connections.

### 6.8 System Start Up

Before system startup, you should be familiar with the test fixtures, electrical console, computer console, hydraulic power supply, and other system components. This includes reading all of the sections in this Operation Manual and the various documents contained in the system Reference or Product Information Manual. If applicable, also read the vendor manuals supplied with the system. Observe all safety practices and operating procedures to ensure knowledgeable and proper use of the system.

**Control Console**

The console power can be turned on after verifying that the following installation procedures have been completed:

- all connections are made and secured with proper strain relief,
- the power source is ready,
- the components are properly grounded, and
- the hydraulic power supply is shut off.

**Computer Console**

The cabling between the electronic console and the computer console should be checked for proper routing and secured using attachment screws where necessary. It is important that the physical integrity of these connections be maintained to ensure safe and accurate operation of the system. When turning on power to the computer console, be sure that auxiliary equipment is also turned on at the appropriate time. Refer to the installation section of the MicroConsole product manual for information regarding the rear panel connectors provided for computer-controlled operation.

Booting the computer is described in the system Software Manual or vendor manual and must be completed in the proper sequence.

**Hydraulic Power Supply**

Ensure that electrical power is supplied to the HPS. Then turn on the HPS in low pressure and check for leakage or improper operation. The cooling water supply should also be checked for leakage or improper operation.
5. Apply hydraulic pressure by completing the following steps:

A. Press the Hydraulic Pressure Low switch to start the HPS and apply low hydraulic pressure to the actuator (the Off indicator will extinguish and the Low indicator will light).

B. Observe the actuator for any movement caused by hydraulic fluid pressurizing the system. Ensure that the actuator stabilizes before proceeding.

C. Press the Hydraulic Pressure High switch to apply high hydraulic pressure to the actuator (the Low indicator will extinguish and the High indicator will light).

6. Slowly adjust the Set Point control on the AC Controller and observe piston movement. The direction and response should be appropriate for the system configuration.

---

1 If the testing system is configured with a Model 458.41 MSP/HSM or Model 458.43 HSM module, press the appropriate HSM Channel switches to apply low pressure to the actuators, ensure actuator stability, and then press the same switches to apply high pressure to the actuators.
Appendix A
Programming

This appendix contains operation procedures and setup information for the MTS programmers that were purchased with the test system. If no MTS programmers were purchased with the test system, please refer to the appropriate vendor documentation.
Appendix B
Record of Setup Adjustments

The following Record of Setup Adjustments can be reproduced and used to record test configuration and control settings.

The record was designed for use with single- and multiple-channel test systems. The first page of the record contains test configuration information, and the second page contains records for one actuator channel. Copy the second page as needed for multiple-channel systems.
Record of Setup Adjustments

Test Description

Specimen Description

Test Configuration

Actuator, Specimen, and Fixturing Configuration (Illustration):

Number of Actuator Channels:

Data Acquisition Equipment:

Test Programmer:

Test Program:

MicroConsole and/or Station Control module:

Station Control and/or MSP/HSM module:

Other test configuration information:
**Record of Setup Adjustments, page ____ of ____**  

**Actuator Channel Setup, channel number ____**  

**Test Control Mode:**  

**Actuator/Specimen Installation Control Mode:**  

**Expected Testing Range:**  

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<thead>
<tr>
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<th>Maximum</th>
<th>Minimum</th>
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<tbody>
<tr>
<td><strong>Controller</strong></td>
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<td><strong>Range Cartridges:</strong></td>
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<tr>
<td><strong>Controller</strong></td>
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<tr>
<td><strong>MicroConsole Display values:</strong></td>
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<td>(percent full scale or engineering scale)</td>
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<td><strong>Initial servo loop control settings:</strong></td>
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<tr>
<td>Gain (P)</td>
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<td></td>
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<tr>
<td>Rate (D)</td>
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<td></td>
</tr>
<tr>
<td>Reset (I)</td>
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<td>(if DC Controller)</td>
</tr>
<tr>
<td>ΔP</td>
<td></td>
<td>(if AC Controller)</td>
</tr>
<tr>
<td><strong>Transducer readouts (step 8):</strong></td>
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<td>Load cell</td>
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<tr>
<td>Torque cell</td>
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<td>LVDT</td>
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<td>Strain gage</td>
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<td>Accelerometer</td>
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<td>Other</td>
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<td><strong>Error detector levels:</strong></td>
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<td>Controller</td>
<td>Level</td>
<td>Enabled?</td>
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<td><strong>Limit detector levels for specimen/actuator installation:</strong></td>
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<tr>
<td>Controller</td>
<td>Levels: max.</td>
<td>min.</td>
</tr>
<tr>
<td>Controller</td>
<td>Levels: max.</td>
<td>min.</td>
</tr>
<tr>
<td><strong>Underpeak detector levels:</strong></td>
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<td></td>
</tr>
<tr>
<td>Maximum Level</td>
<td>Enabled?</td>
<td></td>
</tr>
<tr>
<td>Minimum Level</td>
<td>Enabled?</td>
<td></td>
</tr>
<tr>
<td><strong>Limit detector levels for testing:</strong></td>
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<td></td>
</tr>
<tr>
<td>Controller</td>
<td>Levels: max.</td>
<td>min.</td>
</tr>
<tr>
<td>Controller</td>
<td>Levels: max.</td>
<td>min.</td>
</tr>
<tr>
<td><strong>Servo loop control settings for testing:</strong></td>
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</tr>
<tr>
<td>Gain (P)</td>
<td></td>
<td></td>
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<tr>
<td>Rate (D)</td>
<td></td>
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</tr>
<tr>
<td>Reset (I)</td>
<td></td>
<td>(if DC Controller)</td>
</tr>
<tr>
<td>ΔP</td>
<td></td>
<td>(if AC Controller)</td>
</tr>
<tr>
<td><strong>Program scaling:</strong></td>
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<tr>
<td>Span</td>
<td>Set Point</td>
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<td><strong>MicroConsole Counter settings:</strong></td>
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<td>Preset Count</td>
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<td></td>
</tr>
<tr>
<td><strong>Other actuator channel information:</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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**Appendix A**  Hydraulic Fluid and Hydraulic System Care

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Section 1
Introduction

All servohydraulic test system components demand periodic, routine maintenance and/or calibration to continue to provide optimum system performance. This manual contains preventive maintenance and calibration information for MTS test system components.

Only experienced, qualified service personnel who are familiar with MTS equipment should perform any of the installation, modification, maintenance, or calibration procedures described in this manual. If experienced personnel are not available, consult the MTS Technical Support Department.

1.1 Maintenance

Section 2 contains safety practices that service personnel should follow when maintaining the hydromechanical system components. It also contains a system maintenance log that can be used to track maintenance tasks and intervals.

1.2 Calibration

Section 3 contains safety practices that service personnel should follow when calibrating the system.

1.3 Installation and Modification Considerations

Section 4 of this manual provides a summary of design considerations that should be reviewed before the system components are installed or modified.

1.4 Appendices

The appendices to this manual contain information on the following maintenance issues:

- Hydraulic Fluid and Hydraulic System Care
- Bolt Ratings and Torquing Requirements
- Console Air Filter Cleaning
- Contacting the MTS Technical Support Department

These appendices contain information that is critical to the safety, performance, and maintenance of the system components.
Section 2
Maintenance

Proper maintenance is important to the operating safety and reliability of system components. Without good maintenance practices, component reliability and safety can degrade to a point where potential hazards become extreme dangers.

To help ensure proper maintenance, this section contains safety precautions that service personnel should follow when completing maintenance procedures. It also contains a maintenance log that can be used to record maintenance.

2.1 Maintenance Procedures

The maintenance procedures for each component are fully described in the standard product manuals contained in the Reference Manual. Maintenance personnel should review these manuals thoroughly and record all of the applicable maintenance procedures and intervals on the system maintenance log.

The system maintenance log is a tool to use in recording maintenance. Service personnel should fill in the procedure and recommended interval columns as they review the standard product manuals. The maintenance interval/date of maintenance entries should be made when the maintenance is actually performed. An example maintenance log is illustrated below.

---

Figure 2-1. Example System Maintenance Log
Fire-Resistant Hydraulic Fluids

Most MTS servohydraulic components can be designed for use with fire-resistant fluids. These types of fluids are usually toxic and can present a serious health hazard if fluid is absorbed through the skin. Avoid breathing the vapor or mist from fire-resistant fluids and do not eat or smoke while working with these fluids. Practice absolute personal cleanliness. If fire-resistant fluids contact skin or clothing, wash with soap and water and change into dry clothing as soon as possible.

Do not mix fire-resistant fluids with petroleum-based fluids or add fire-resistant fluids to systems incompatible with these types of fluids. Doing so can destroy seals and severely damage the equipment.

Small Leak Containment

Do not use fingers or hands to stop small hydraulic or pneumatic leaks. Substantial pressures can build up, especially if the hole is small. These high pressures may cause the oil or gas to penetrate the skin, causing painful and dangerously infected wounds.

Compressed Gas Hazards

Virtually all servohydraulic systems contain accumulators that require high-pressure gas (over 100 psi/1 MPa) precharging. In addition, some systems contain devices, such as static supports, that are operated with high-pressure gas. High-pressure pneumatics are potentially very dangerous because great amounts of energy are available in the event of an uncontrolled expansion or rupture.

Observe the following precautions when working with high pressure gases:

- Properly identify the type of gas to be used and the type of accumulator to be precharged. Follow all charging instructions provided in the product manuals.

- When precharging accumulators, use only dry-pumped nitrogen. (Dry nitrogen can be labeled "oil pumped" or "dry water pumped.") Do not use oxygen or compressed air for precharging. The increase in temperature caused by rapid gas compression can present a highly explosive condition when hydraulic fluid, which has low autoignition temperatures, is in the presence of oxygen or compressed air.

- All precharge gas must be bled out of pneumatic devices before any disassembly is attempted. On some devices, the area where the precharge gas is contained may be restrained by bolts and/or fittings that are not located in the immediate vicinity of the component being disassembled. For example, on some MTS tandem actuators (Series 206 or 207), the upper end cap (nearest the exposed piston rod) may seem to receive only oil pressure internally. However, if the lower side of the actuator is charged with nitrogen and the upper end cap is removed, the piston rod will be violently propelled out of the upper end cap: when the upper end cap bolts are loosened, internal pressure will cause the remaining bolts to fail.
SYSTEM MAINTENANCE LOG

System ____________
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Instructions: When maintenance is performed, fill in date, operating hours (from running time meter), and/or other appropriate maintenance interval.

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<th>RECOMMENDED INTERVAL</th>
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© MTS System Corp. 1986   118329-00-776   0786
## SYSTEM MAINTENANCE LOG

Instructions: When maintenance is performed, fill in date, operating hours (from running time meter), and/or other appropriate maintenance interval.

<table>
<thead>
<tr>
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<th>MAINTENANCE INTERVAL</th>
<th>DATE OF MAINTENANCE</th>
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</table>

Instructions: When maintenance is performed, fill in date, operating hours (if running time meter), and/or other appropriate maintenance interval.
Section 3
Calibration

Calibration consists of electronic adjustments that must be performed in a specific sequence. The calibration procedures for each component are fully described in the standard product manuals supplied in the Reference Manual. Service personnel should review the product manuals thoroughly and develop a sequence for calibration. In addition, the following safety practices should be thoroughly reviewed and consistently followed.

Preparation and Procedures for Calibration

Study all product manuals contained in the Reference Manual before attempting to perform any calibration procedure. When calibrating a component, re-read any procedure that seems unclear. Procedures that seem relatively simple or intuitively obvious may require a complete understanding of system operation to avoid unsafe or dangerous situations.

Main Power Service Connection

Whenever possible, turn the electrical power switch to OFF (or O) when working with any part of the system. Calibration of the system components requires observation of the same precautions as those given to any other high-voltage machinery.

Handling Electronic Components

To complete some of the calibration procedures for the electronic products supplied by MTS, the module or component must be removed from the chassis or console to provide access to the adjustment or signal to be measured. Because certain plug-in modules contain components which are listed by manufacturers as being static sensitive, care should be exercised with all plug-in modules to prevent circuit card and/or component damage. The following precautions are suggested:

- Do not install or remove a module while power is applied to the control console.
- Touch the console or other ground point before removing or installing a module.
- When handling printed circuit cards, avoid making physical contact with any components or circuitry on the card. Grasp the card by its noncontact sides.
- Maintain the same electrical potential between the printed circuit card and the equipment or surfaces it will contact by touching the surfaces first.
- Handle integrated chips by their edges; always avoid touching the integrated circuit chip leads.
- Circuit card repairs should be made at a static-free work station by personnel familiar with repairing such devices.
Section 4
Installation and Modification Considerations

Most test systems will undergo setup changes and modifications to accommodate test facilities and specialized applications. The following installation and modification guidelines contain design practices and modified system setup considerations that should be observed to minimize operating hazards.

A competent engineer should be responsible for any system installation or modification. The engineer must consider how changes to an existing system might affect the safety and reliability of the system. Installation/modification design analysis must include both of these factors.

The following subsections discuss some of the common items that should be given special consideration.

4.1 Installation Safety Considerations

Testing equipment often operates for extended periods of time with no supervision and may attract spectators. This combination of circumstances requires that any test laboratory setup provide adequate protection for bystanders as well as for system operators. Make it immediately obvious to anyone how to stop the system. Ensure that anyone who is allowed access to the test system area knows the dangers involved and knows how to stop the system in an emergency.

4.2 System Power Disconnect and Emergency Stop Switches

The National Electrical Code requires that a disconnect switch be provided within view of each motor controller. Be sure that the system power disconnect switch or an emergency stop switch is easily identifiable in the system setup. Eliminate any unusual combination of switches, multiple power sources, or other configurations that may cause someone unfamiliar with the system to assume that the power is off when it is actually on.

Ensure that all system components are grounded properly. Hydraulic lines and hoses cannot be depended upon to provide any electrical grounding functions.
4.4 Hydraulic Hoses

Pressure and return line hoses for normal hydraulic service should have a burst pressure at least four times greater than the operating pressure. For example, a 12,000 psi (80 MPa) burst pressure is required for 3000 psi (20 MPa) operation.

The strength of a hose assembly can be expected to deteriorate with age and fatigue. Hoses have two modes of failure: the hose can split randomly, or, more commonly, a complete tensile failure can occur in which the hose pulls out of its end fitting. A tensile hose failure can be extremely hazardous until the system is shut down.

Short hoses or large hoses fed only from a small pump present little hazard from whipping. However, the combination of a large pump and a small or intermediate-sized pressure hose presents a greater possibility of thrashing after a tensile failure. Therefore, the consequences of hose failure should be considered at installation. If necessary, the hydraulic pressure hoses should be anchored to the ground or tied to a corresponding return line within 2 feet (60 cm) of the flow outlet end. As an alternative, hoses can be run in trenches or other protected areas.

Random split hose failures caused by ply separation will generally appear as blisters on the hose. Usually, the blister-type failure develops only a small leak or fine spray. However, any weakening of the wire wrapping or reinforcement should be considered cause for hose replacement.

4.5 Pneumatic Fittings and Hoses

Fittings used in pneumatic circuits must be rated for operating pressures in accordance with the National Fluid Power Association standards (NFPA, 3333 North Mayfair Road, Milwaukee, Wisconsin 53222). Pneumatic fittings must be installed in a manner that does not mechanically strain the component but still properly anchors them to prevent thrashing in the event of a rupture.

Hoses used in pneumatic systems also must be rated for operating pressures in accordance with the National Fluid Power Association standards. Hoses must be installed in a manner that properly anchors them to prevent thrashing in the event of a rupture but does not mechanically strain the component. Large-diameter flexible hoses are particularly dangerous when thrashing about, so they must be very securely tied down.

Any hose of substantial length (over approximately 3 feet (90 cm)) that carries high-pressure gas should be restrained near its end fittings to prevent whipping.

The same hose failure/replacement guidelines used for hydraulic hoses should be used for pneumatic hoses.
Appendix A

Hydraulic Fluid and Hydraulic System Care

A.1 Recommended Hydraulic Fluids
A.2 Hydraulic Fluid Analysis
A.3 Hydraulic Fluid Checks
A.4 Hydraulic Fluid and Hydraulic System Maintenance
   A.4.1 Cleaning Hydraulic Fluid
   A.4.2 Replacing Hydraulic Fluid
   A.4.3 Flushing the System after Hydraulic Component Replacement or Configuration Changes
   A.4.4 Flushing the System when Using a Solvent to Clean the Reservoir
A.5 Hydraulic Fluid Disposal
A.6 HPS Filter Element Cleaning or Replacement
A.7 HPS Startup in Special Circumstances
   After Two-Week Shutdown
   Fluid Temperature Below 50°F
Appendix A

Hydraulic Fluid and
Hydraulic System Care

The performance of MTS servovalves, bearings, and actuators is
dependent on the quality of the hydraulic fluid used in the associated
hydraulic power supply (HPS). Therefore, MTS Systems Corporation
strongly recommends periodic hydraulic fluid sampling and preventive
maintenance to reduce hydraulic system down time and increase system
life.

This appendix provides guidelines on the care of hydraulic fluid and a
basic understanding of hydraulic system care. It also contains several
procedures for cleaning/flushing the hydraulic system and care of the
HPS.

Hydraulic fluid deterioration and contamination are normal con-
sequences for most hydraulic systems. Failure to adequately remove
contaminants, or change hydraulic fluid before severe fluid breakdown
occurs, will lead to poor system performance and costly system clean-
ups. Therefore, it is important to maintain a clean hydraulic system.
This is done by regularly testing samples of the fluid and performing
the appropriate maintenance procedures.

A.1 Recommended Hydraulic Fluids

MTS servohydraulic systems require a hydraulic fluid that can operate
at high pressure (typically 3000 psi (20 MPa)) for hundreds of hours
while experiencing high shear forces from the servovalve. The fluid
must have excellent wear, antifoam, and water-resistance additives
while providing lubricity for the moving parts.

The petroleum industry does not have a standard for the contents of
hydraulic fluid base stock or additives; therefore, the composition of
the fluid can vary. MTS has used Mobil DTE 25 for years and has veri-
ﬁed it to be consistent in composition. Where Mobil DTE 25 is not
available, MTS recommends Shell Tellus 46. To prevent problems with
inconsistent and inferior fluids, MTS recommends only Mobil DTE 25 or
Shell Tellus 46 to our customers.

After a fluid has been selected, the same brand and type of fluid should
always be used. Mixing different brands of hydraulic fluid can create
contaminants that will damage the hydraulic system.
**Water Content**

Water is highly undesirable in hydraulic systems. Its presence may result in the formation of emulsions and contribute to the corrosion of metal surfaces. More than a trace of water may indicate a faulty mechanical condition, such as a leak in the heat exchanger or ingestion of water through the reservoir breather filter. If contamination exists, identify the source of water contamination, correct the problem and replace the hydraulic fluid.

During system operation, excessive water contamination of hydraulic fluid can be visually detected: the hydraulic fluid will have a milky appearance. If the system is not in operation, contamination can usually be detected by sampling the fluid at the bottom of the reservoir, because hydraulic fluid and water readily separate, with water settling to the bottom of the reservoir.

**Iron, Silicon, and Copper Content**

These analyses are considered valuable, particularly as an aid to troubleshooting. A high iron reading may indicate wear of pump parts. High silicon readings may be due to ingestion of dirt or may be caused by silicon-containing compounds (i.e., sealing compounds or defoamants). High copper readings may indicate pump wear, faulty lines and fittings and/or faulty heat exchangers.

If any excessive iron, silicon, or copper content is identified during fluid analysis, the fluid must be cleaned or replaced.

**Chemical Breakdown**

A marked change in the smell of the hydraulic fluid can indicate a chemical breakdown. Fluid breakdown is typically caused by operation at high temperatures: a hydraulic system should not be operated at reservoir temperatures higher than 140°F (60°C). Standard MTS hydraulic power supplies are provided with heat exchangers, temperature controls and over-temperature interlocks. These features help maintain the hydraulic fluid at the proper operating temperature of 100-125°F (38-52°C).

Chemical breakdown can also be caused by other chemicals that have entered the hydraulic system. For example, some seal materials used on water systems are not compatible with hydraulic fluid and can cause a chemical breakdown.

If a chemical breakdown does occur, the situation that allowed the over-temperature condition should be corrected and the fluid should be replaced.

**Appearance**

Hydraulic fluid is amber in color. A milky, dark, or otherwise abnormal color may indicate the presence of one or more contaminants. If this is the case, fluid analysis should be performed.
At Installation

The following procedures should be completed before installing or operating the hydraulic system.

- Protect the system from contamination when a plug, cap, hose, or hydraulic component is removed. Foreign matter can enter the system through these openings and can eventually cause system failure.

- On larger systems, where stainless steel tubing is used, the system must be flushed and the hydraulic fluid must be "cleaned" by filtering it until cleanliness requirements can be maintained. To clean the hydraulic fluid, refer to the procedure described in Subsection A.4.1.

- Contamination risk is high on complex systems that have distribution systems with welded, carbon steel pipe. A complete system flush is imperative. Refer to the procedure described in Subsection A.4.3 for the specific steps to flush the system. After the system is flushed, sample the fluid for cleanliness. The proper cleanliness level is a particle count of ISO 13/9 or better. If this level has not been attained, clean the fluid (refer to Subsection A.4.1) until the proper cleanliness level is achieved.

- Take a fluid sample after installation. Keep this first test sample to compare it to subsequent samples.

Daily Fluid Checks

The following checks should be performed daily to prevent fluid contamination or breakdown and subsequent component damage.

- Check the fluid level in the sight gage. Verify that the fluid level is correct. A low level can indicate a leak. A high level can indicate water contamination from the heat exchanger.

- Check the fluid color in the sight gage and compare it to the first test sample. A change in color can mean that the fluid is contaminated or that a chemical breakdown has occurred. A visual inspection can determine if the degree of contamination justifies further action.

- Check the smell of the hydraulic fluid. Distinct changes in odor often indicate fluid breakdown.

- Check all HPS filter or fluid change indicators. Perform any required maintenance procedures.

- Watch for system performance changes. These may indicate contaminated fluid, dirty filters, etc.
A.4   Hydraulic Fluid and Hydraulic System Maintenance

**NOTE**  Before completing any of the following cleaning/flushing procedures, any existing contamination sources should be located and corrected.

If the hydraulic fluid does not meet the recommended cleanliness standards, the hydraulic fluid should be cleaned (Subsection A.4.1) or replaced (Subsection A.4.2). In addition, the hydraulic system should be flushed when any of the hydraulic system components have been replaced or its configuration has been changed (Subsection A.4.3). If dirt or sludge is found in the reservoir, the system must be flushed with a solvent (Subsection A.4.4).

**NOTE**  When replacing or adding fluid, it is very important to use a transfer pump that provides 10-micron or better filtration (such as MTS Model 590.01). Most commercial hydraulic fluids exceed the maximum amount of contamination allowable in MTS hydraulic systems.

A.4.1 Cleaning Hydraulic Fluid

If the fluid does not meet an ISO cleanliness level of 13/9 or better, first identify and correct any sources of contamination. Then change the hydraulic system filters and run the HPS for 2 to 4 hours (or more, depending on the size of the hydraulic system) to remove any contaminants. The system filters will collect any solid contaminants of a 3-micron or larger size.

When the HPS has run for the appropriate period of time, check the fluid for cleanliness. The particle count reading should be an ISO cleanliness level of 13/9 or better. If this level has not been achieved, the hydraulic fluid must be replaced (refer to Subsection A.4.2).
A.4.3 Flushing the System after Hydraulic Component Replacement or Configuration Changes

Perform the following hydraulic system flushing procedure after any of the system's hydraulic components (service manifold, hoses, fittings, hard line, etc) has been replaced or its configuration has been changed.

⚠️ WARNING ⚠️

Uncontrolled actuator movement can be caused by removing a servovalve or flushing valve when the hydraulic system is pressurized.

If the hydraulic system is not at zero pressure when a servovalve or flushing valve is removed, injury to personnel and/or damage to equipment could occur.

Ensure that the hydraulic system is at zero pressure before removing any servovalve or flushing valve. If the system pressure cannot be reduced to zero, contact the MTS Technical Support Department.

NOTE
If a system contains more than one servovalve per actuator, remove all servovalves but replace only one servovalve with a flushing valve. Cover the remaining servovalve ports with cover plates.

1. Ensure that the hydraulic system is at zero pressure.

2. Use one of the following methods to remove the servovalve(s) and connect the pressure and return lines together:

   a. If a flushing valve is available, remove the servovalve from its manifold and mount a flushing valve (MTS Model 291.XX) in its place. Cover any exposed servovalve ports with clean servovalve cover plates.

   b. If a flushing valve is not available, remove the pressure and return lines from the servovalve manifold and connect them together with a suitable union. Cover any exposed ports on the manifold with threaded plugs.
A.4.4 Flushing the System when Using a Solvent to Clean the Reservoir

If the HPS reservoir is very dirty or if sludge or varnish are present, the system must be flushed with a flushing compound. A recommended flushing compound is MOBILSOL A, which is a solvent created for flushing and cleaning hydraulic systems of gummy oxidation products and insoluble materials, and is compatible with Mobil DTE 25 hydraulic fluid.

Perform the following hydraulic system flushing procedure if the HPS reservoir needs to be cleaned of sludge and contamination.

⚠️ WARNING

Uncontrolled actuator movement can be caused by removing a servovalve or flushing valve when the hydraulic system is pressurized.

If the hydraulic system is not at zero pressure when a servovalve or flushing valve is removed, injury to personnel and/or damage to equipment could occur.

Ensure that the hydraulic system is at zero pressure before removing any servovalve or flushing valve. If the system pressure cannot be reduced to zero, contact the MTS Technical Support Department.

⚠️ CAUTION

The flushing compound dislodges contaminants that can be harmful to servovalves.

Unless all servovalves are replaced with flushing valves (MTS Model 291.xx) or cover plates before beginning the system flush, the servovalves can be damaged.

Ensure that all servovalves are replaced with flushing valves (MTS Model 291.xx) or cover plates before beginning the system flush.
9. Turn on the HPS and operate it at high pressure for 2 to 4 hours (or more, depending on the size of the hydraulic system).

10. Turn off the HPS and, if necessary, replace the filters.

11. Ensure that the hydraulic system is at zero pressure.

12. Remove the flushing valve (or union) and connect the servo-valve(s) (or hoses) to the manifold(s). If necessary (on larger hydraulic systems) uncap the inline accumulators.

| WARNING |

Uncontrolled actuator movement can result from failing to properly connect the servovalve cables to the manifold.

Failure to properly connect these cables can result in unexpected actuator movement and result in injury to personnel and/or damage to equipment.

Ensure that the servovalve cable(s) is (are) connected before attempting to operate the system.

A.5 Hydraulic Fluid Disposal

Disposal of hydraulic fluid is governed by local, state, federal and international laws. Many areas have businesses that specialize in fluid recovery for little or no cost. Check with the appropriate agency in your area for details on laws and services. Material Safety Data Sheets (MSDS) are available from Mobil Oil Corporation or MTS Systems Corporation. These MSDS sheets detail the fluid contents and in some areas are required by law. (Refer to the Technical Bulletin titled, In-Plant Handling to Control Waste Oils, available from Mobil Oil Corporation.)

A.6 HPS Filter Element Cleaning or Replacement

If the system is located in a highly contaminated area, it is a good practice to shorten the intervals for filter element cleaning or replacement.

Refer to the HPS product literature to determine the maximum recommended intervals for filter replacement.
Appendix B

Bolt Ratings and Torquing Requirements
Most bolts used in MTS-manufactured systems are torqued to specific design requirements to ensure a reliable product. Any time that a bolt is loosened or the configuration of a component within the system is modified, refer to the system assembly drawings (located in the Reference Manual) and/or the tables in this appendix to determine the correct bolt torquing requirement. Over-torquing or under-torquing a bolt may present a hazardous situation due to the high forces and pressures present in most systems.

Slight over-torquing, while not recommended, may be done in certain circumstances if a bolt is not reused and the amount of over-torquing is not excessive. However, excessive over-torquing will cause the bolt or threaded rod to yield and may damage the mating material's threads. The acceptable level of excessive over-torquing is dependent upon several factors, such as material types, bolt size, the number of times the bolt has been reused, and fatigue load experienced. Therefore, a rule specifying the over-torque limit for any bolt is not practically definable. If over-torquing is necessary, expect failures and take appropriate safety precautions.

Under-torquing can also cause premature bolt failures. If a joint connected with threaded fasteners is subjected to cyclic loading, the fasteners must be torqued (preloaded) to a combined force level higher than the cyclic load applied through the joint. If this preload is less than the cyclic load, the joint will separate on each cycle, causing fatigue loads on the fasteners. For example, grade 8 bolts are usually stressed to 90,000 psi (620 MPa) when fully torqued. At that stress level, even a small cyclic strain will cause fatigue failure. If a joint is inadequately preloaded due to fastener under-torquing, the cyclic strain will be substantial and the fasteners will prematurely fail.

Some bolt connection configurations inherently cause prying or flexing loads on the fasteners. Even though the fasteners are torqued properly, fatigue failures can still be expected to occur unless the operating stress is very low.

Long tie rods might be subjected to fatigue loading or to impact loads in some installations. In such systems, friction collars or sheet-metal covers are installed to restrain a failing tie rod from violent movement. These restraining devices should not be removed. If removal is necessary for a maintenance procedure, the restraining devices should be reinstalled and tightened before the tie rods are tightened.

The following tables identify standard bolt rating and torquing requirements. They should be used if no rating/torque specifications are available on the component assembly drawings in the system Reference Manual. When in doubt about bolt torquing requirements, consult MTS Systems Corporation.
### Table B-2. Bolt Ratings and Torquing Requirements – SI Metric Sizes

#### COARSE THREAD SERIES (PREFERRED)

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<tr>
<th>Size</th>
<th>Tensile Area (in.²)</th>
<th>Socket Head Cap Screws¹</th>
<th>Hex Bolts²</th>
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<td>Working Force (kip) (KN)</td>
<td>Torque³ (lb-ft) (N•M)</td>
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<td>M3-5</td>
<td>0.00769</td>
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<td>1.0 (14)</td>
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<td>M4-7</td>
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<td>0.804 (3.58)</td>
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<td>570 (780)</td>
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<td>12000 (16000)</td>
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#### FINE THREAD SERIES

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<tr>
<th>Size</th>
<th>Tensile Area (in.²)</th>
<th>Socket Head Cap Screws¹</th>
<th>Hex Bolts²</th>
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<td></td>
<td>Working Force (kip) (KN)</td>
<td>Torque³ (lb-ft) (N•M)</td>
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<td>M8-1</td>
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<td>3.61 (16)</td>
<td>21 (29)</td>
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<td>1300 (1700)</td>
</tr>
<tr>
<td>M36-3</td>
<td>1.33</td>
<td>79.9 (355)</td>
<td>2100 (2900)</td>
</tr>
<tr>
<td>M42-3</td>
<td>1.86</td>
<td>112 (496)</td>
<td>3500 (4700)</td>
</tr>
<tr>
<td>M48-3</td>
<td>2.47</td>
<td>148 (660)</td>
<td>5300 (7100)</td>
</tr>
<tr>
<td>M56-4</td>
<td>3.3</td>
<td>198 (862)</td>
<td>8200 (11000)</td>
</tr>
<tr>
<td>M64-4</td>
<td>4.4</td>
<td>264 (1170)</td>
<td>12000 (17000)</td>
</tr>
</tbody>
</table>

1 Use Grade 12.9 or threaded rod of equal strength with $S_{ULT} = 1220$ MPa, working stress = 410 MPa
2 Use Grade 8.8 or threaded rod with $S_{ULT} = 860$ MPa, working stress = 310 MPa
3 Torque for clamp equal to 1.5 x working force
Appendix C

Air Filter Cleaning
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Air Filter Cleaning

A foam air filter is mounted on top of the control console. This filter should be cleaned at least monthly, or more often depending on the operating environment, to ensure proper cooling and ventilation.

To remove the filter, open the rear panel and slide the filter out. Clean the filter by vacuuming it from the intake side or washing it in warm water with a mild detergent. Check the filter for deterioration and replace the filter if necessary (MTS p/n 369407-01).
Appendix D

Contacting the
MTS Technical Support Department
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MTS Technical Support Department

If you have any questions about an MTS system or product, contact the MTS corporate service center:

**Address**
MTS Systems Corporation
Service Support Group
Technical Support Department
14000 Technology Drive
Eden Prairie, Minnesota  55344-2290

**Telephone**
In the United States and Canada
HELPLine (800) 328-2255
Outside U.S. and Canada
Contact your local service center

**Telex**
29-0521 MTS SYS ENPE

**Cable**
MTS Systems Corporation
14000 Technology Drive
Eden Prairie, Minnesota  55344

**FAX**
Technical support questions
(612) 937-4766
General questions
(612) 937-4515

Site No. 565328
System No. 325-61

858 Table Top
458 Controller
Notif 85996